Trawl fisheries onboard camera field trial

Evaluation outcomes

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Summary

Thank you

The Queensland Department of Primary Industries would like to thank all the commercial fishers who generously volunteered their time and expertise during the field trial. The delivery and evaluation of this trial would not have been possible without your hard work, support and ongoing collaboration.

Field trial overview

The trawl fishery onboard camera field trial was a collaborative project funded by the Queensland Department of Primary Industries (DPI) and the Australian Department of Climate Change, Energy, the Environment and Water (DCCEEW). The 18-month trial was undertaken on commercial vessels from the east coast otter trawl fishery (ECOTF) and commercial fin fish trawl fishery (CFFTF), running from June 2023 to December 2024.

Five dedicated electronic monitoring (e-monitoring) systems and one 'off the shelf' CCTV system were tested on board the trawl vessels. The objectives of the trial were to test the performance of onboard camera systems to independently validate threatened, endangered and protected (TEP) species interactions and record bycatch, as well as provide an understanding of installation costs and maintenance requirements.

Onboard cameras were deployed on 11 vessels and tested during fishing operations across the ECOTF, the CFFTF, and several gear types and target species. The vessels were highly diverse in terms of configuration, fishing gear, catch composition and fishing areas/times, allowing the systems to be tested across a range of operational conditions.

Over the course of the trial, 68 hard drives of camera footage were collected, with an additional 7 nights of fishing footage collected using electronic transfer (e-transfer). In total:

- 266 catch-sorting events across 75 fishing nights were reviewed for TEP species interactions
- fishing effort was estimated for 365 trawl shots occurring over 100 nights
- bycatch reviews were completed for 25 catch-sorting events across 11 fishing nights.

Results

The trial provided several key learnings about e-monitoring:

- Systems easily detected interactions with larger TEP species; however, identifying smaller TEP species and their release condition and fate was more challenging
- Robust monitoring of full bycatch composition is only likely to be feasible for vessels with conveyor sorting systems and those sectors of the fishery with low relative diversity and volume of bycatch. However, achieving more targeted bycatch monitoring objectives may be feasible
- The installation of systems must account for the unique layout and fish-handling processes of each individual vessel, and consider the objectives of the e-monitoring program, to determine camera placement options
- The deployment of systems involves a 'bedding-in' period during which systems and processes are established, personnel receive training, and fishers familiarise themselves with the technology
- The review and validation process was enhanced with dedicated systems that included GPS data, winch sensors and customised review software
- The e-transfer of video footage and sensor data significantly reduced program management time and data management tasks for the reviewer, and streamlined the review process. It also limited the amount of footage requiring access, transfer and storage
- Regular cleaning of camera lenses during fishing operations ensured ensure good quality video footage was recorded and available to monitor catch-processing activities.

Recommendations

The trial also provided valuable insights to support the design and establishment of a future e-monitoring program across the ECOTF and CFFTF:

- Objectives of a future program should focus on using e-monitoring systems to monitor and validate TEP species interactions across all sectors of the ECOTF and the CFFTF
- The monitoring of bycatch via e-monitoring systems should be targeted and used in conjunction with other monitoring methods, depending on the fisheries data needs
- A staged rollout of e-monitoring systems should occur across a large fleet of vessels such as the ECOTF, with a risk-based approach taken to identify priority vessels and management regions
- Increased support and resourcing will be required during the ‘bedding-in’ period
- The e-transfer of video footage and sensor data should be prioritised over the physical delivery of hard drives
- Increased uptake of electronic reporting of commercial fishing logbook data by operators should be prioritised to support a monitoring program that is timely and responsive
- While trialling multiple systems proved highly valuable in testing relative strengths and weaknesses, the trial showed that having multiple e-monitoring providers would add layers of complexity in the design, management and larger rollout of a program
- Extensive and ongoing engagement between industry, DPI and e-monitoring providers will be essential to support effective establishment and ongoing delivery of a program.

At the time of publication, no decisions on the final scope of an independent onboard monitoring program across the ECOTF and CFFTF had been made. Further public consultation will be undertaken, including ongoing engagement with the field trial technical focus group, trawl fishery working group and other key stakeholders.

For more information, visit **dpi.engagementhub.com.au**.

Glossary

DCCEEW	Australian Department of Climate Change, Energy the Environment and Water
CCTV	closed circuit television
CFFTF	commercial fin fish trawl fishery
DPI	Queensland Department of Primary Industries
ECOTF	east coast otter trawl fishery
e-monitoring	electronic monitoring
e-transfer	electronic transfer
GPS	global positioning system
TEP	threatened, endangered and protected species

1. Introduction

Improved validation of commercial fishing activities is critical to improving our understanding of threatened, endangered and protected (TEP) species interactions, the ecological risks associated with fishing activities and ensuring accurate information is available to inform evidence-based management decisions.

While Fisheries Queensland have existing processes that support the independent monitoring and validation of commercial fishing data, there remain challenges with the ongoing validation of some commercial fishing data, specifically protected species interactions and the monitoring of non-retained catch (bycatch). This is because protected species and bycatch are discarded while fishing at sea, with no current mechanisms in place to validate or monitor these interactions during a fishing operation.

Independent Onboard Monitoring (IOM) methods, including onboard cameras and fishery observers, are the primary tools available to independently validate commercial fishing interactions with protected species and bycatch. IOM achieves the independent validation of commercial fishing data by comparing data from two different sources – for example, data provided by fishers (e.g. logbook catch and effort records) and data provided by an independent third-party or another sources (e.g. onboard observer records or observation records generated from the review of onboard camera footage captured with an electronic monitoring or 'e-monitoring', system).

The comparison of these 2 data sources provides the ability to assess the accuracy of logbook records. When the 2 data sources align, this provides certainty and confidence that the catch and effort data recorded by commercial fishers is accurate. This independent validation is extremely valuable, as it enhances the ability to detect any errors or biases in the data – ensuring high-quality data is used to underpin fishery management decisions supported by science, as well as provide confidence to regulators and the community that fisheries are sustainably managed.

Independent onboard monitoring programs using e-monitoring exist across commercial trawl and gillnet fisheries on a national and international scale. In Queensland, the gillnet fishery operating within the Great Barrier Reef Marine Park uses e-monitoring to validate interactions with TEP species. The Australian Fisheries Management Authority uses e-monitoring across the eastern and western tuna and billfish fisheries, the midwater trawl sector of the small pelagic fishery and the gillnet, hook and trap sector of the southern and eastern scalefish and shark fishery. New Zealand Fisheries also uses e-monitoring across their long line, inshore trawl and set net fisheries.

While onboard observers have been used previously to collect at-sea catch and effort data and to validate commercial fishing data in Queensland, their use as a fishery validation method has not been ongoing. The use of e-monitoring systems in place of fishery observers has several potential benefits, including:

- reduced labour costs
- establishment of a 24-hour long-term validation program
- improved scalability and monitoring coverage across the fleet
- improved confidence in data accuracy to support fishery assessments, management decisions and address knowledge gaps
- reduced work health safety considerations.

Both the Queensland and Australian governments recognised the importance of an onboard camera field trial to test the performance of e-monitoring systems in Queensland's fisheries, to better understand, and help inform management strategies and actions to reduce the likelihood of interactions with TEP species and other bycatch during commercial fishing activities.

While an e-monitoring program exists for Queensland's NX fishery, the vessels and systems used for this fishery are significantly different to those used in Queensland's east coast otter trawl fishery (ECOTF) and commercial fin fish trawl fishery (CFFTF). Vessels operating in the ECOTF and CFFTF undertake extended trips fishing over several days, while the NX fishery operates on a daily fishing trip basis.

The nature of trawl fishing operations requires e-monitoring systems that are capable of recording and storing camera footage and other data during extended trips – so it was important that systems compatible with these vessels and operations were tested to ensure they are fit for purpose, cost-effective and can improve the validation of commercial fishing data, specifically protected species and bycatch.

1.1 Objectives

The objectives of the field trial were to test the performance of different e-monitoring systems across trawl fishing vessels in the ECOTF and the CFFTF. Specifically, the objectives included:

- Evaluate the footage and data derived from the onboard camera equipment to assess their usefulness, functionality, and reliability for independently monitoring bycatch and TEP species interactions.
- Identify the challenges, opportunities and costs associated with the installation and maintenance of the onboard camera equipment on vessels.
- Compare data collected by independent observers with data derived from camera footage to evaluate the ability of cameras to provide accurate estimates of bycatch.
- Consider how observers could best be used in an independent onboard monitoring program.
- Evaluate different software packages to assess their suitability, functionality, and ease of use for managing video files and reviewing footage of catch sorting/discarding activities.
- Evaluate different methods of transferring footage from vessels.
- Develop and refine protocols for reviewing footage to identify
    - interactions with TEP species
    - the amount and species composition of bycatch.

1.2 Limitations

Due to complex policy issues, onboard observers were not able to be deployed on participating vessels during the trial period. This component was scheduled to be a part of the trial evaluation and facilitate data comparisons collected by independent observers with data derived from camera footage. Subsequently this trial objective was not assessed as part of the report outcomes however, existing observer programs in other jurisdictions may be used to analyse observers as an option for IOM in Queensland.

2. Overview

2.1 Field trial model

The field trial was funded by the Queensland Department of Primary Industries (DPI) and the Australian Department of Climate Change, Energy the Environment and Water (DCCEEW). Camera systems were deployed on board commercial fishing vessels. All costs were covered by DPI and DCCEEW, with participants volunteering their time, vessels and expertise.

DPI were responsible for managing the camera system hardware, including sourcing, installing and troubleshooting. DCCEEW were responsible for coordinating the independent review of camera footage and validation of logbook data – MRAG Asia Pacific were contracted by DCCEEW as the independent reviewer of video footage. Field trial participants were responsible for the operation of the systems during planned fishing operations, camera maintenance (e.g. cleaning) and troubleshooting support in consultation with DPI, MRAG Asia Pacific and system suppliers.

A formal field trial agreement was drafted to support the delivery of the trial. A collection notice explaining how information would be collected and managed as part of the trial was also developed and provided to crew. Key components of the field trial agreement related to the:

- ownership of, and access to, video footage
- use, storage, disclosure and management of video footage and data
- installation and maintenance of equipment.

A technical focus group was established, which included field trial participants and officers from DPI and DCCEEW. This allowed field trial participants to provide feedback and seek troubleshooting advice during the trial. The group met 7 times prior to the publication of this report.

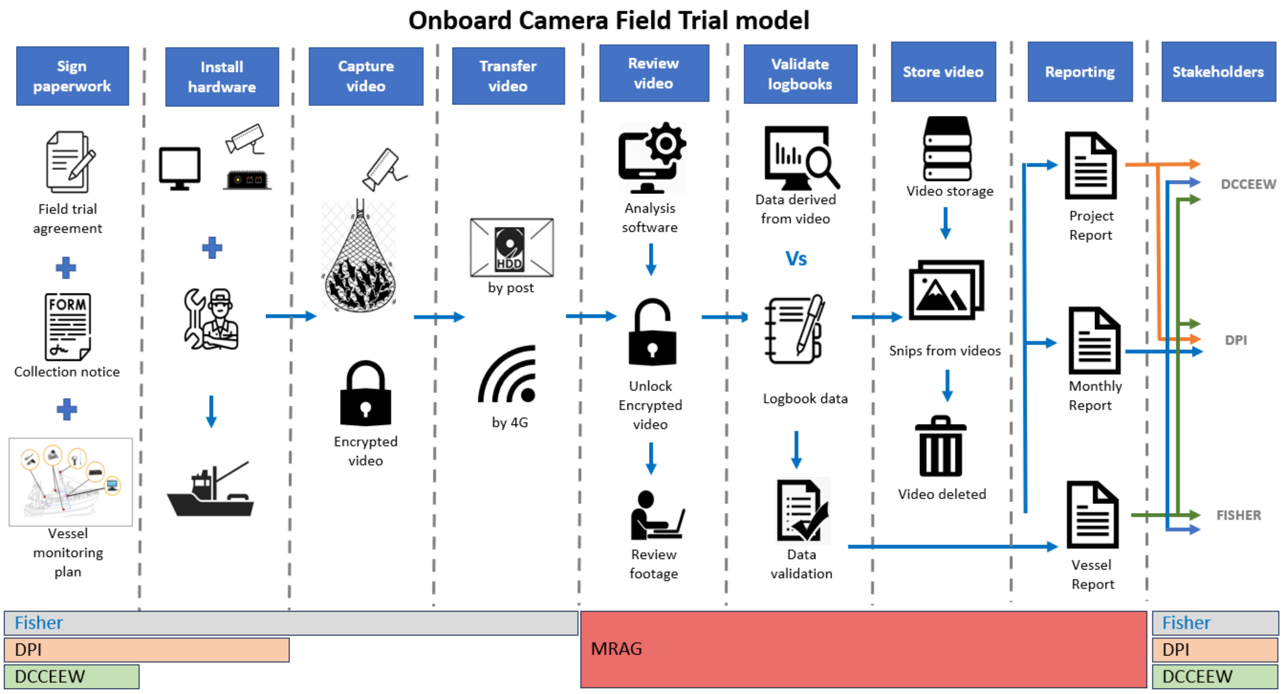

Figure 1: Overview of the field trial model

2.2 Vessels

During the field trial, onboard cameras were deployed across 11 vessels – 10 from the ECOTF and one from the CFFTF.

These systems were tested across each management region of the ECOTF (except Moreton Bay) and across several gear types and target species. The vessels were highly diverse in terms of configuration, fishing gear, catch composition and fishing areas/times, allowing the systems to be tested across a range of operational conditions.

2.3 Camera systems

A total of 6 onboard camera systems were tested during the trial – 5 purpose-built fishery validation e-monitoring systems and one 'off the shelf' CCTV system. Due to complications with one of the purpose-built e-monitoring systems, testing of this system was stopped. See Figure 2 below for the 5 camera systems that were deployed for the duration of the trial and included in the evaluation process.

Anchor Lab

Archipelago

Teem Fish Monitoring

Satlink

CCTV system

Figure 2: Camera systems deployed and evaluated as part of the trial. Note: the purpose-built fishery validation e-monitoring system that experienced complications during testing is not included

Each camera system differed in design and associated components; however, all systems included the following components:

- central control unit
- monitor
- cameras
- GPS aerials
- winch and hydraulic sensors.

Figure 3 shows how the various components were installed on board each vessel (noting each system differed in components and installation locations). Review software and file encryption from 4 of the system providers were also tested during the review and validation process.

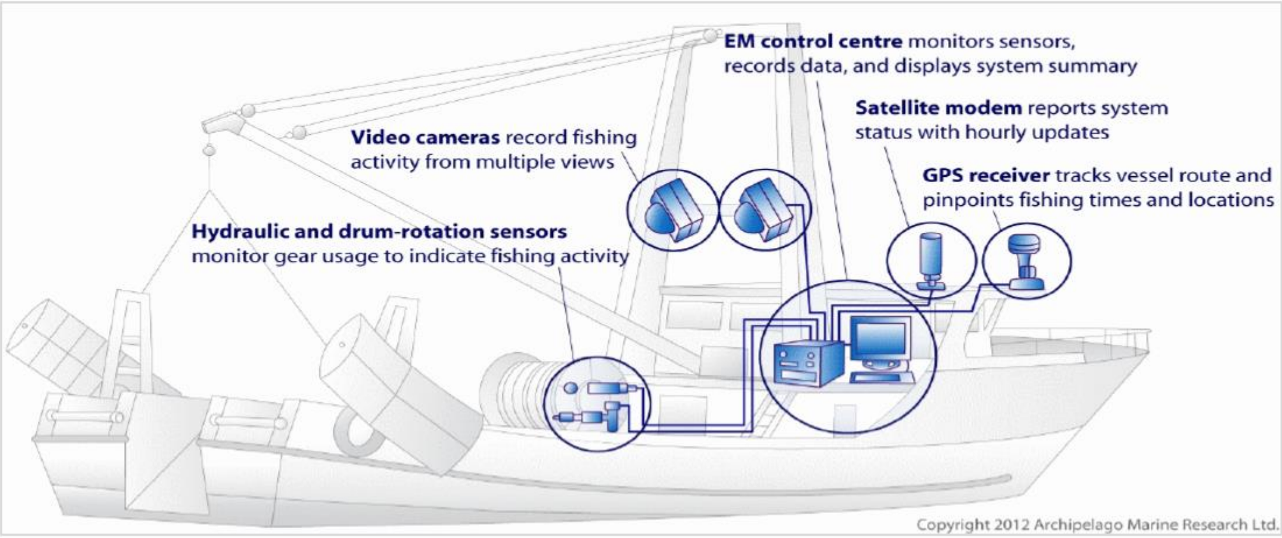

Figure 3: Overview of e-monitoring components installed and tested during the trial

2.4 Review and validation process

Onboard camera footage and sensor data was recorded by e-monitoring systems during at-sea fishing operations and fishers continued to complete catch and effort logbooks and TEP species logbooks (as per the reporting requirements for commercial fishing operations).

The recorded data and corresponding vessel logbook records were provided to the independent reviewer (MRAG Asia Pacific) to support the review of e-monitoring data and comparison of review outcomes against logbook data. The use of hard drives and e-transfer of recorded data were evaluated during the trial.

The following elements of fishing operations were analysed:

- fishing effort – start and stop times, and location of shots
- TEP species interactions – observed interactions with protected species including number and details of interactions (e.g. release condition, fate).

Camera footage of some shots was also reviewed to estimate the composition of bycatch.

Data processing and reporting protocols were developed to guide the review process and associated outputs generated throughout the trial (including reports and information that was recorded). These protocols included an independent selection of the fishing nights to be reviewed, which for the trial was a random 10% of fishing days on each hard drive.

While the fishing days selected for TEP species reviews were mainly chosen at random to cover at least 10% of fishing days on each hard drive, in some cases fishing days were selected to assess the capacity of the camera system to identify TEP species that had been reported in the logbook. During TEP species reviews, all shots occurring during randomly selected fishing days were examined.

Shots selected for bycatch reviews balanced an objective to review at least one full night of fishing for each participating vessel, as well as cover as many different operational sectors of the fishery as possible.

Over the course of the trial, 68 hard drives were collected, with an additional 7 nights of fishing footage collected using e-transfer. In total:

- 266 catch-sorting events across 75 fishing nights were reviewed for TEP species interactions
- fishing effort was estimated for 365 trawl shots occurring over 100 nights
- bycatch reviews were completed for 25 catch-sorting events across 11 fishing nights.

A summary of review outcomes from footage captured on each vessel, including the validation outcomes against the report logbooks, was documented in a Vessel Summary Report that was provided to DPI, DCCEEW and the volunteer fishers.

3. Results

3.1 Threatened, endangered and protected species

3.1.1 Can TEP species interactions be detected?

For the purposes of the trial, a TEP species was defined as a protected animal under the *Nature Conservation Act 1992* (Qld) or an animal that is listed as a threatened species, listed migratory species or listed marine species under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

The camera systems tested across all vessel configurations proved capable of reliably detecting interactions with larger TEP species such as sea snakes (Figure 4A).

However, the independent reviewer was only able to routinely identify smaller TEP species (such as pipefish and seahorses) on vessels with a catch-sorting conveyer, as catch items were sorted serially and cameras placed close to the conveyer (Figure 4B).

On footage from vessels with sorting trays, it was difficult to observe and detect smaller TEP species among piles of other catch.

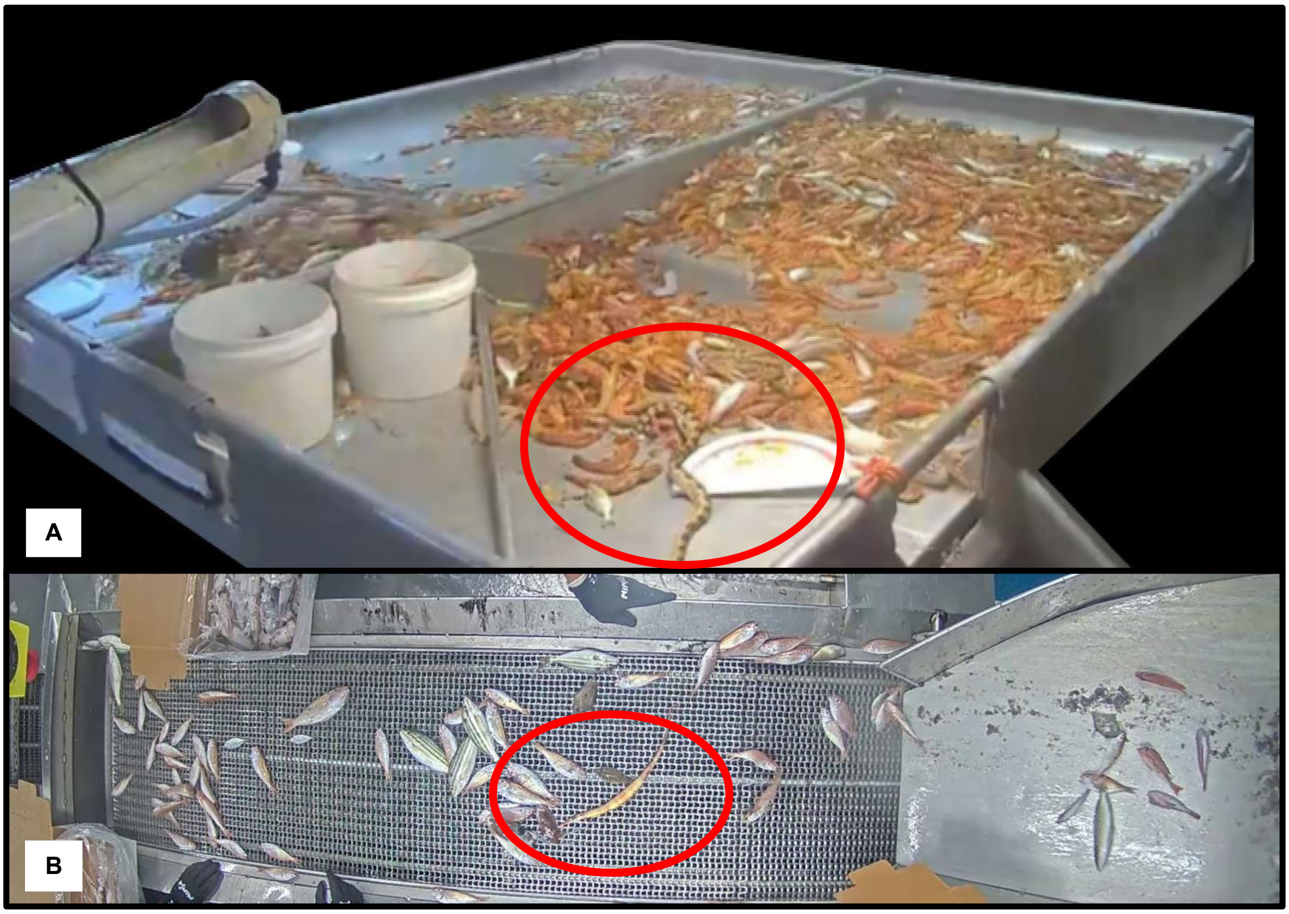

Figure 4: Images of TEP species observed during the field trial – (A) a sea snake on a sorting tray and (B) a pipefish on a conveyor

* Some areas in the images have been blurred and/or modified to exclude identifiable features of the vessel and crew. Note the use of these images has been approved by the relevant authority holders.

On sorting tray vessels, identification of smaller TEP species (e.g. pipefish) could be improved if fishers held these animals up to the camera before release (as some crew did during the trial). Educating and training crew on TEP species handling to support camera observations (such as displaying in camera view prior to release) would be necessary to validate smaller TEP species interactions reported by fishers.

The image quality of most cameras was sufficient to distinguish the taxonomic characteristics of TEP species, allowing for species-level identification of larger animals and between related species with distinct visual characteristics (e.g. difference in stomach shape of pallid and Dunker's pipehorses).

Sea snakes are not reported to species level in logbooks. Although a species expert may be able to identify certain sea snake species with distinct morphometric features, routine species-level identification is challenging during standard fishing operations given safety issues, time constraints and the specialist identification expertise required. However, staged reviews of sea snake interactions could be built into a program to improve species-level identification if required.

In the vast majority of instances, the random review of captured footage validated the fishers' logbook reporting of protected species interactions. In a relatively small number of cases, TEP species observed in footage were not reported in logbooks. In the few cases where a TEP species interaction was reported in the logbook but not observed in the footage, the e-monitoring camera runtime was too short to capture the full net retrieval/sorting event, the vessel's camera was malfunctioning or the fisher advised that the TEP was released out of the field of view or without coming onboard.

3.1.2 Can e-monitoring determine TEP species release condition and fate?

While TEP species interactions could be identified in footage, determining the release condition of captured individuals (alive/dead, injured/uninjured) was more challenging. In many instances, TEP species were only visible on camera for a short period (e.g. before being extracted from the catch pile and released), with limited opportunity to assess condition. In particular, distinguishing between 'alive and uninjured' and 'alive and injured' (categories currently used in the TEP species logbook) was difficult.

To better determine release condition, cameras would require tailored placement to capture release events as well as any areas where TEP species (e.g. sea snakes) are held for recovery prior to release. Importantly, improving the reviewer's ability to assess TEP species release condition would require additional review time (as footage would need to be reviewed for periods after the catch-sorting event ends).

In addition to the challenges associated with determining release condition, considerable difficulties were also experienced in determining if TEP species were retained or released. Most often, this was because the TEP species were removed from the camera's field of view by crew members (presumably for release or to be taken to recovery areas), so the reviewer was unable to observe the animal being returned to the water as the cameras were primarily focused on the locations where catch was being sorted. In other circumstances, TEP species were released while they were in the water beside the vessel, without coming onboard.

To support the improved validation of TEP species release condition, the placement of cameras to capture release areas would be required, as well as reviewing additional footage would be required. When interacting with dangerous TEP species such as sea snakes, fishers already have strategies in place to minimise their risk. If a future IOM program required fishers to modify their behaviour when interacting with these dangerous animals, education and safety strategies would be required.

3.1.3 How did camera position affect TEP species reviews?

Camera position was a key factor influencing the capacity of the reviewer to observe and validate TEP species interactions. Two main camera mounting positions were used in the trial:

- cameras mounted on vessel A-frames
- cameras mounted on vessel awnings over sorting trays or conveyer belts.

A-frame mounted cameras generally captured vision of the nets being shot and retrieved, and provided a wider view of the vessel deck surrounding the sorting tray/hopper. Awning mounted cameras generally provided a close-up view focused primarily on the sorting tray or conveyer system.

On vessels equipped with a sorting tray, at least one angled camera view of catch-sorting operations (ideally mounted underneath the rear awning showing port and starboard gunwales) proved effective for protected species monitoring. Angled views were preferred as they occasionally captured TEP species being released over the gunwales or stern of the vessel, unlike downward views. The underside rear awning mounting location on sorting tray vessels was preferred over A-frame mounting, as TEP species were more easily identified when closer to the camera.

The wider view of A-frame mounted cameras offered the potential to capture TEP species interactions that occur outside the sorting tray/hopper (e.g. animals that drop out of nets or are released beside the vessel). During the trial there were no opportunities to validate in-water interactions between TEP species and trawl gear on vessels equipped with A-frame cameras. Some vessels also had awning cameras installed that focussed on the net hauling area, however due to the angle these awning mounted cameras were unable to validate in-water TEP species interactions. While the EM reviewer did not observe any TEP species interactions on the A-frame cameras, interactions that occur in-water or outside of the sorting table would generally only be visible to EM reviewer through A-frame mounted cameras. These interactions are expected to be harder to see as TEPS species are further away and may be obscured by net mesh.

For vessels fitted with a hopper and conveyor, a minimum of 2 camera angles were required to observe all areas of the fishing operation where catch and TEP species interactions could occur. This includes one view showing the hopper and the other showing the conveyor. This is because some larger TEP species are spilled onto grates positioned over hoppers and then discarded, while other smaller species fall through hopper grates and are later sorted via conveyers.

3.1.4 How long did TEP species reviews take?

The review software allowed the reviewer to adjust the playback speed of video footage from frame-by-frame to 30 times the actual speed, enabling an efficient analysis of the activities on deck. In general, reviews were able to be completed at 3–6 times faster than actual speed. The time taken to review one trawl shot ranged from 4.4 to 35.7 minutes, with a median time of around 13 minutes.

The main factors influencing review times included:

- diversity and volume of catch
- number of camera views
- vessel configuration
- crew sorting practices
- footage quality.

3.2 Bycatch

3.2.1 What methods were trialled to estimate bycatch?

For the purposes of the trial, **bycatch** was defined as all non-target, non-TEP species and any target or byproduct species that were not retained (e.g. because they are too small). To evaluate the capacity of e-monitoring systems to independently monitor bycatch volume and species composition in the fishery, 2 methods were trialled.

Screenshot method

The first method used screenshot images of the footage taken during the catch-sorting operation. The images were used to estimate a ratio of target species to bycatch, as well as determine the number and identity of individual bycatch taxa.

A key challenge with this approach was obtaining representative images of the catch. On vessels with a hopper and conveyer set-up, it proved infeasible to take screenshot images that were representative of total catch composition. On sorting tray vessels, developing a repeatable, scalable screenshot sampling method based on time or the proportion of catch sorted proved difficult due to variations in the configuration of sorting trays across vessels (which influenced catch layering / piling once spilled), as well as differences in catch volumes and sorting rates across vessels and crews. Avoiding double counting of catch items across screenshots was also challenging.

More broadly, estimating the target-to-bycatch ratio was problematic due to the uneven distribution of species when spilled onto sorting trays. Smaller species, such as prawns, tend to settle at the bottom of the catch pile, while larger finfish bycatch often remain on top once the catch is spilled. This uneven catch distribution is likely to distort bycatch ratios when visual estimates are made at specific points in time, with each screenshot receiving equal weighting to the overall ratio.

Given these difficulties, the screenshot method was discontinued and the full monitoring method (below) applied relatively early in the trial.

Full monitoring method

The second method evaluated during the trial, involved the reviewer undertaking a frame-by-frame observation of the catch-sorting event, with each catch item identified to the lowest taxonomic level possible and counted 2 ways:

- An accurate count was used for larger species and species caught relatively infrequently.
- A count range was used for smaller species and/or species with high catch rates – this reflected lower confidence that an accurate count of these animals would be obtained by the reviewer.

3.2.2 Can e-monitoring effectively monitor bycatch?

The capacity to independently estimate the number and composition of bycatch species using e-monitoring varied substantially across the vessels participating in the field trial.

The main factors influencing the ability to estimate bycatch included:

- volume and diversity of bycatch (often influenced by the target species / fishing area)
- operational set-up and sorting practices on the vessel (e.g. conveyor vs sorting table)
- positioning of the camera system and the quality of footage (good vs poor resolution; camera positioned directly above the sorting process vs remote from the sorting process).

Experience from the trial has suggested that a robust estimation of the full composition of bycatch using camera footage is only likely to be feasible for vessels operating in sectors of the fishery that:

- have lower diversity and volume of bycatch (e.g. the deepwater eastern king prawn sector) and/or
- are fitted with conveyor systems (in which catch is sorted serially) with well-maintained cameras mounted directly over the sorting area (see Figure 5).

Using the full monitoring method on the trial vessels that met these operational categories, the reviewer achieved high rates of bycatch species identification to family level, with much of the catch identifiable to genus and species levels.

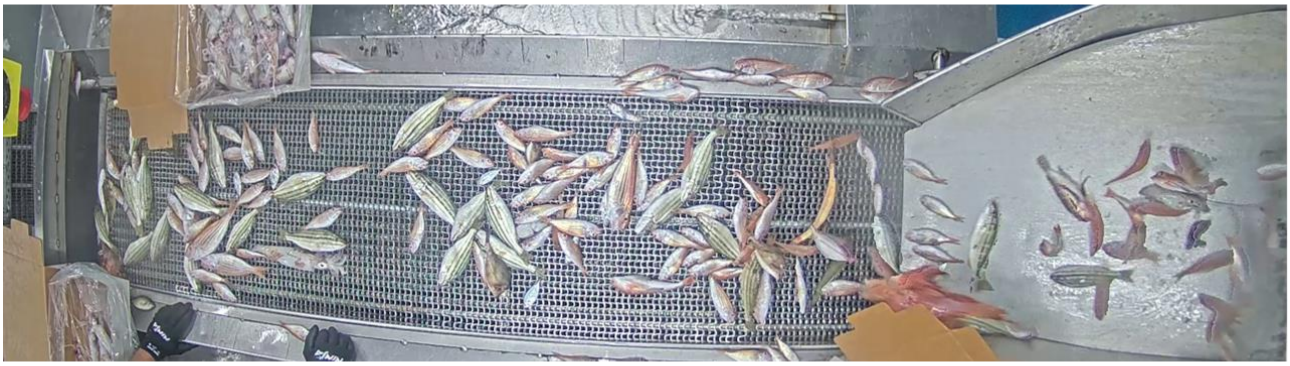

Figure 5: Image of bycatch shown on conveyor system with catch items being sorted serially, improving the ability to count and estimate via camera footage

* Some areas in the image have been blurred and/or modified to exclude identifiable features of the vessel and crew. Note the use of this image has been approved by the relevant authority holder.

For sorting tray vessels operating in sectors of the fishery that have higher relative bycatch volume and species diversity, experience from the trial indicates that effective monitoring of all bycatch during catch processing has limitations and is not practicable. This is primarily because of the nature of the operation which often sees large volumes of catch, including a diverse array of small-bodied bycatch species, spilled onto sorting trays.

This results in a layering of catch, with the majority of catch items concealed from camera view. While crew sequentially sort the catch (identifying and removing permitted species), rapid sweeping of large numbers of bycatch (often remaining in piles) into discard chutes make accurate species counts and identification very difficult. Also, footage of the chutes was often obscured by crew or poor lighting, and sorting tray cameras were more commonly impacted by water droplets, salt spray, poor lighting and glare.

In practice, this meant that reviews of shots on sorting tray vessels with higher volumes and diversity of bycatch had very high rates of uncertainty (e.g. catch ranges more frequently used with a higher proportion of unidentified species). Optimal positioning of the camera directly above the sorting process may resolve some of these challenges, but likely not all. If the objective of bycatch monitoring is to estimate the full volume and composition of bycatch, alternative monitoring measures (e.g. observers, crew sampling) are likely to be more appropriate for these vessels.

However, on sorting tray vessels operating in sectors with higher relative volume and diversity of bycatch, e-monitoring often proved capable of identifying the presence (and often total number) of larger bycatch species, and may be capable of achieving more targeted bycatch monitoring objectives (e.g. detecting larger bycatch species identified as higher risk through ecological risk assessments, or monitoring a smaller number of carefully chosen indicator species).

Importantly, the accuracy of reviewer bycatch estimates could not be evaluated during the trial, as fishers do not report bycatch and no observer trips were conducted on trial vessels with corresponding footage for comparison. If e-monitoring is to be used as part of a future bycatch monitoring strategy, measures to independently validate reviewer species identification will be necessary (e.g. onboard observer programs, or crews collecting samples of bycatch for subsequent identification onshore).

3.2.3 How did camera position affect bycatch monitoring?

As with TEP species reviews, camera position and angle had an important influence on the capacity of reviewers to identify and count bycatch species. However, unlike TEP species reviews where angled views were more effective, a vertical downwards view of catch-sorting operations proved most effective for monitoring bycatch. Capturing the point at which catch was physically sorted by the crew helped to count/identify bycatch species and minimised the risk of double counting.

Cameras with angled views positioned away from the sorting process proved particularly ineffective for estimating bycatch (given lower resolution on zoomed-in footage and large numbers of bycatch items often swept simultaneously into discard chutes).

3.2.4 How long did bycatch reviews take?

Unlike TEP reviews, which could be undertaken at 3–6 times the actual speed, the reviewer could only assess bycatch composition at the actual speed, occasionally reducing video playback to a quarter or half the speed to document rapidly sorted catch items.

Review times for bycatch varied across fishery sectors, reflecting differences in catch-sorting times that occur as a result of variable catch diversity and volume. Other factors influencing bycatch review times, similar to TEP species, included vessel configuration, crew sorting practices and the quality of camera footage.

Overall, review times for bycatch surveys across vessels ranged from 30 to 106 minutes per shot, with a median time of 53 minutes per shot.

3.3 Camera system data – sensors and GPS

In addition to recording footage, the 4 dedicated e-monitoring systems deployed during the trial collected a range of additional data through various sensors and/or GPS aerials installed on board.

All dedicated e-monitoring systems used in the trial collected GPS speed and location, which proved useful for identifying fishing events and estimating fishing effort (specifically trawl start and stop times, and start and end locations). Some vessels were also fitted with inductive rotational sensors, hydraulic pressure transducers, photodiode rotational sensors and/or electrical current sensors to their main winch or codend bag winch.

Fishing effort estimates were most accurate for vessels fitted with a hydraulic sensor on the main winch, as this sensor best indicated when the net hit the bottom and when the net began to be hauled in. Reported fishing effort could be validated for vessels with bag winches, but due to the nature of their use and shorter signals (i.e. bag winches are used momentarily to swing codends over sorting trays), these estimates were less accurate than those for vessels with sensors on the main winch (see Figure 6).

Effort estimates were least accurate for vessels lacking winch sensors, as the reviewers had to interpret trends in GPS speed and net positions in stern-facing camera footage to determine shot timings (which are offset from when nets contact the bottom).

No sensor data accompanied footage from the one CCTV system deployed, and as the CCTV camera was not positioned to capture the shooting or retrieval of nets, it was not possible to independently estimate fishing effort. Moreover, the lack of sensor and speed data meant the reviewer was required to click sequentially through the footage (typically a 12-hour block) to identify the fishing event of interest, which made the review process slightly more time-consuming.

Overall, estimates of fishing effort recorded during the review of e-monitoring data closely reflected fisher logbook reporting in most instances. Some minor discrepancies in effort reporting and instances of non-reporting were also detected, demonstrating the potential of e-monitoring as an effort monitoring and validation tool.

Experience from the trial indicated that sensor and GPS data recorded by e-monitoring systems is valuable both as a standalone dataset (e.g. by providing independent estimates of fishing effort and location that are more precise than currently collected through logbooks) and to optimise the efficiency of the review process (e.g. allowing the reviewer to efficiently identify and navigate to shot start and stop times). By identifying the location and timing of shots during which TEP species and bycatch interactions occurred, e-monitoring data has the potential to greatly enhance our understanding of these interactions, their environmental and operational correlations and, ultimately, the management of interaction risk.

The use of sensors that support the automatic activation of cameras have further benefits, ensuring fishers do not need to manually turn the systems on and off for each fishing operation. Using e-monitoring data to validate reported fishing activities can be used to identify any missed fishing events and address any reporting issues. This improves confidence that all fishing events are being reported and can be validated.

Figure 6: Example of winch in and winch out signals visible to the reviewer from an induction sensor on a bag winch and a hydraulic sensor on the main winch – for a vessel without sensors, only the blue line is available

3.3.1 Sensor configuration

Some vessels in the trial were configured so cameras activated based on winch sensor readings, with cameras recording for a set period of time. The main advantage of this approach was that reviewers could easily identify fishing and catch-sorting events, enabling more efficient reviews, minimising unnecessary footage, and reducing data storage and handling costs.

Establishing a consistent recording rule for each vessel proved challenging due to the seasonality of the fishery, with operators often targeting different species at varying depths throughout the year. Vessel-specific recording triggers set to the lowest level of sensor use (i.e. for the shallowest ground fished) allowed all potential fishing events to be recorded, while limiting ongoing management input.

However, in some cases, variations in volume of the catch, crew sorting practices and vessel configurations led to longer sorting times and the camera run time cut out before catch sorting was finished, preventing a comparison with logbooks. In other instances, the camera's run time significantly exceeded the catch-sorting duration, leading to unnecessary data being captured. Additional exploration of other potential recording rules and sensor configuration options is recommended.

For some of the e-monitoring systems trialled, the ability to remotely configure sensor recording parameters is available and can be accessed from the available review software. This significantly reduces the time and effort required to refine the recording parameters by allowing the reviewer to analyse sensor data and amend configuration simultaneously. However, this remote configuration ability was not activated during the trial because it also requires a live video stream from the vessel, which did not comply with the participant field trial agreements. All remote configuration was completed through DPI requests to e-monitoring providers, which have the ability to remote configure their systems through the ‘back end’ of their software without live video streaming.

3.4 Data transfer

Following the collection of e-monitoring system data (footage, sensor, GPS data) on board fishing vessels, the data was transferred to the reviewer to allow for decryption and review.

The 2 methods of data transfer tested during the trial were:

- physical swapping of exchangeable hard drives
- e-transfer.

3.4.1 Physical hard drive exchange

The primary e-monitoring data transfer method used in the trial involved physically swapping exchangeable hard drives. Once a hard drive was full, or at a convenient time, fishers would send it to the reviewer. Upon receipt, the reviewer decrypted and copied the footage to a secure storage location for review and analysis. Following review, the data was erased from the hard drive and returned to the skipper/owner of the vessel for reuse.

Each of the e-monitoring providers protected the data and formatted the hard drives in different ways. Although all methods ensured a high degree of data security, there was considerable variation between the time required to decrypt footage and, in some cases, to erase data from hard drives before they were returned to fishers. Given the implications for costs and review times, experience from the trial indicates that opting for an e-monitoring system with efficient data decryption and deletion processes is important in terms of maximising operational efficiency.

Decrypting and copying large volumes of data took significant time and incurred significant program management costs, so limiting file sizes and decryption time while maintaining adequate footage quality are recognised as key factors to improve review efficiency.

The CCTV system hard drive contained non-encrypted video files that could be read straight from the drive. While the CCTV footage could potentially be protected with encryption methods, the 4 e-monitoring providers offer superior data security as their systems require non-public and specific decryption software to access the data.

3.4.2 E-transfer

The e-transfer of video footage was tested with one of the e-monitoring systems. E-transfer enables the reviewer to select the specific video footage for review and send a request to the system on the vessel. The requested data is then securely transmitted from the vessel to the reviewer via the 4G data network when the vessel is within range. If vessels are operating outside of 4G range, footage is captured and stored onto the systems internal hard drive, and transmitted from the vessel once it returns within 4G range.

Although e-transfer was only able to be trialled with one system, initial experience indicates this data transfer method provides a range of significant advantages over physical hard drive swaps, including:

- reduced risk of hard drives or associated data being lost, destroyed or intercepted by an unauthorised party
- a significant reduction in the data storage space required for camera footage
- a significant reduction in the volume of data needing decryption, resulting in faster processing time prior to review
- reduced data handling responsibilities for fishers (no need to physically eject, mail and receive new drives in the post)
- no need to erase and return hard drives, resulting in reduced processing and management time post-review
- reduced amount of unnecessary data and video footage available to the reviewer.

An average comparison of the time required for each data transfer method tested is provided in Figure 7.

The time savings identified when testing the e-transfer method suggest this method of video transfer would be significantly more cost-effective when scaled-up across a fishery-wide program. To that end, experience from the trial indicates that priority should be given to e-monitoring systems with efficient e-transfer capability.

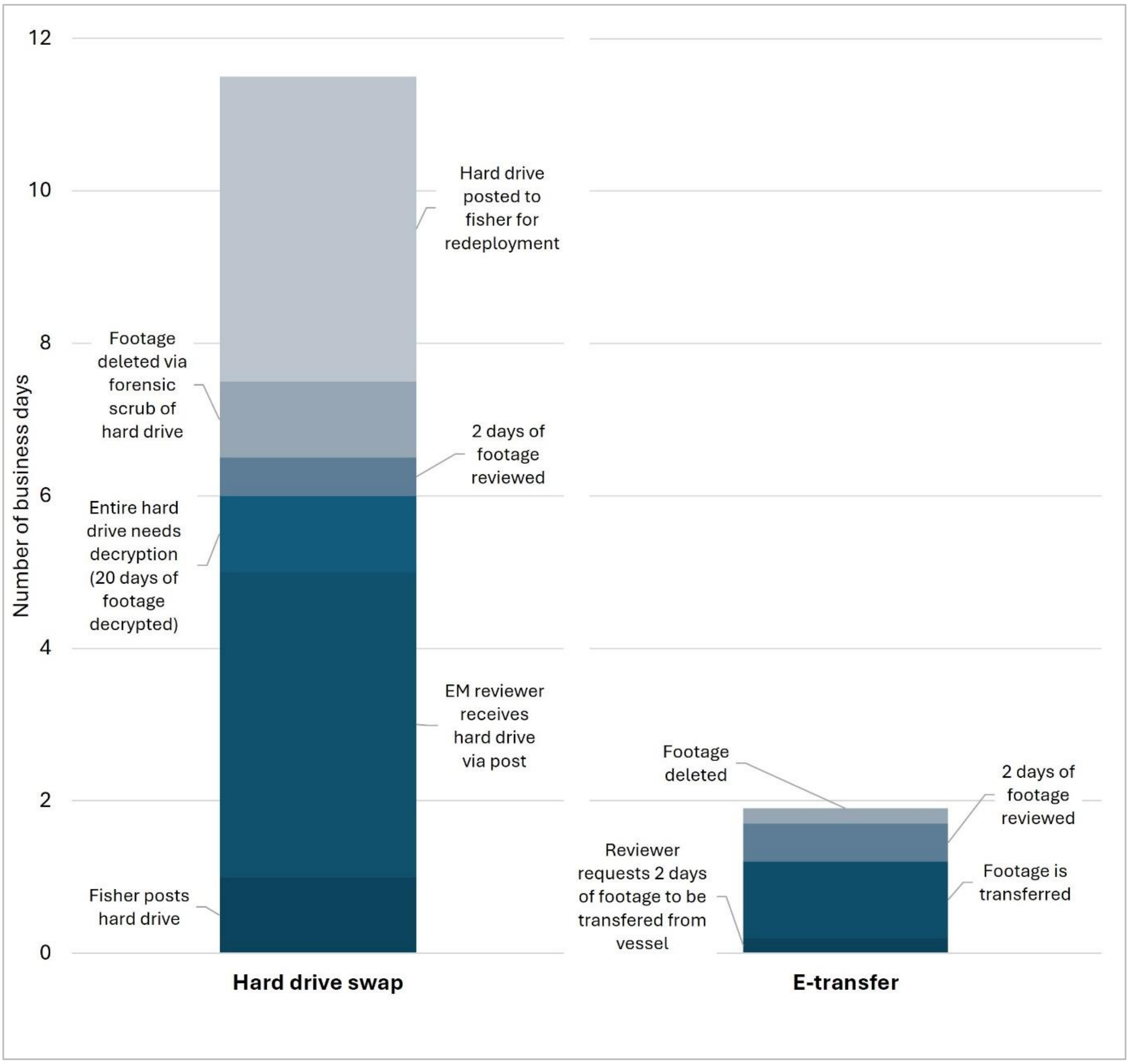

Figure 7: Comparison of average hard drive and e-transfer timelines to review 10% of fishing nights across a 20-day trip

3.5 Review software

Each of the 4 dedicated e-monitoring providers assessed during the trial provided their own purpose-built review software that integrates the multiple data sources (GPS, sensors, time, video, etc.), so that all data recorded by the system can be visualised and analysed together. Each software package had its strengths and weaknesses, but experience from the trial indicates that the following features improve the review process and outcomes:

- a graphic panel that visualises vessel speed and winch sensor readings over time, with the capability for reviewers to zoom in for detailed analysis

- a video panel that allows reviewers to resize camera views and reposition them across computer screens
- a catch quantification module that enables reviewers to record catch items and TEP species interaction details (species, fate, condition and comments), along with the time and location of each record
- frame-by-frame navigation of footage, along with the ability to speed-up playback to 20 times the actual speed
- zoom/video cropping functionality for enhanced focus on specific areas
- the option to assign keyboard shortcuts to streamline review functions
- functions to adjust Coordinated Universal Time to local time
- a system that exports review data in a simple format (e.g. csv file) or can be integrated with a broader database (e.g. through application program interfaces).

By contrast, 'off the shelf' CCTV systems had no dedicated review software, so VLC media player and Microsoft Excel were used. This meant CCTV reviews were more time-consuming and lacked some of the verifiable detail (e.g. vessel location, time) available through the e-monitoring systems.

Reviews using dedicated e-monitoring software were repeatable, efficient and cost-effective, allowing the reviewer to note observed TEP species interactions and catch within the software. This reduced the need for manual data entry (and the risk of errors) and managed reviewer fatigue by optimising the review processes.

3.6 Installation

Installation of system hardware varied considerably across vessels, with optimal camera placement dependent on the system components, vessel layout and existing infrastructure on board.

Some common installation challenges identified during the trial included the:

- availability of fishers in between planned fishing operations, as well as qualified technicians, to complete installations with minimal impact on planned fishing operations and scheduled vessel maintenance activities
- placement of cameras to avoid interference with existing vessel infrastructure (aerials, lighting etc.), ensuring the optimal angle and distance from catch-sorting events, and locations away from water splashback and fishing gear
- availability of skippers and crew to receive training on how to use the system
- installation of the most appropriate sensor type, including the safe placement of equipment and cable runs in working areas.

It was important that the installation technician was familiar with the camera system being installed and understood the onboard practices of the vessel, including where bycatch and TEP species are returned to water, how retained catch is handled and the crew's movements during fishing operations.

The trial has shown how vessel differences, monitoring needs and camera set-ups can influence installation. Future objectives of an e-monitoring program will influence installation challenges and costs (e.g. to achieve accurate monitoring of bycatch, highly refined camera placement locations would be required, introducing installation complications and challenges with increased costs).

3.6.1 Safety

A major consideration at the time of installation was ensuring the system components were installed in locations that did not jeopardise or introduce any risk to crew safety, which was discussed directly with vessel authority holders and skippers prior to installation. Common concerns raised by participants included:

- head height clearance in areas under deck awnings where cameras could pose challenges for crew
- the vessel's reliance on the onboard hydraulic systems and concerns hydraulic sensors could cause a breakdown of the entire system

- cameras in areas where crew could not easily reach and clean while at sea
- placement of cable runs on the vessel deck, particularly with main winch sensors where cables could pose trip hazards
- available space within already crowded wheelhouses to install system control units and monitors.

To address these concerns, the following measures were taken:

- selected installation areas that posed minimal safety risk for crew, through consultation with the operator
- hydraulic technicians inspected vessels and consulted with operators on what could occur in the event of hydraulic sensor malfunction and associated risks, and hydraulic sensors with a t-piece and cap were installed to allow easy sensor removal if required
- consulted with operators about safe and achievable cleaning regimes of cameras in hard-to-reach locations
- installed multiple cameras to provide several options for footage review if operational issues were encountered (e.g. dirty lens)
- rotational sensors on bag winches rather than main winches to avoid cables in areas where crew work hydraulic sensors that could be fully contained within the hydraulic control console and contain cables within the internal cable galleries of the vessel.

3.6.2 Vessel monitoring plans

Individual vessel monitoring plans were developed for each vessel in consultation with each trial participant. The plans were used to document the installation location of cameras and field of view, system configuration settings and information on vessel layout and fish-handling processes.

These plans proved extremely valuable throughout the trial, documenting the proposed locations of cameras and associated equipment prior to installation, which improved installation outcomes and timeframes as well as the participants' understanding of how the installation will occur.

After installation, the plans also supported remote troubleshooting, recording system modifications and errors experienced with equipment.

From the reviewer's perspective, the information within the plans was critical to interpret camera footage and sensor data, in particular:

- mud maps of each vessel provided information on deck layout and the catch-sorting operation, including locations commonly used to release TEP species and bycatch
- system configuration details (including the cameras installed and position on-deck, footage settings and recording rules), and a list of vessel modifications to date (detailing any issues, fixes, or changes to system configurations) – this helped the reviewer determine if any issues identified during the review were pre-existing, configuration-related, operational or new.

While the vessel monitoring plans provided essential information before and after installation, they required a significant amount of work to maintain and update as modifications were made and troubleshooting issues occurred. In future, high level and well-structured templates should be developed that support the installation of cameras and equipment in locations that will achieve program objectives and improve data review and validation processes.

3.6.3 Installation costs

On average, installation of each camera system and its associated components took 18 hours across 2 days. Typically, a vessel pre-installation inspection was also completed, which took an additional 2–4 hours. The vessel inspection was generally completed with the technician and vessel authority holder/skipper present to discuss appropriate installation locations that would achieve optimal views and ensure crew safety.

A qualified electrician had to install the equipment, with some components (such as hydraulic sensors) requiring specialist services. In some cases, a second visit was required to complete the installation.

Factors influencing installation times and costs included the:

- number of cameras and type of camera system being installed
- length of cable to install cameras and required antennae
- position and/or existence of cable entry points into the wheelhouse and/or wiring tunnels
- sensor type being installed
- configuration time and requirements of camera software
- camera system installation training for installation technicians
- availability and capability of supplier support during installation, including remote guidance and camera performance checks at the time of installation
- existing vessel infrastructure and requirements to construct specialist mounting brackets.

On average, technician labour costs to install equipment during the trial ranged between $2,000 and $5,000, including all labour to install the system components, construct brackets for cameras and sensors, run cables and test the system. Key factors that affected installation time and costs were vessel layout, sensor type and additional fabrication works. A summary of the average installation costs for various components during the trial is provided in Table 1.

Table 1: Summary of average installation costs for various components during the trial

Vessel component	Average cost ($)
Camera system, central control unit, GPS and associated cabling	$3,500
Additional camera	$800
Inductive/rotational sensor	$1,000
Hydraulic sensor	$2,000

3.6.4 Technician qualifications

A suitably qualified marine-grade electrician is required to install onboard camera systems. Desirable attributes include:

- working at heights qualifications
- working in confined spaces qualifications
- familiarity with the fishing fleet and onboard infrastructure.

Depending on sensor requirements, additional qualified construction and/or hydraulic tradespeople were also required to complete the installations.

Installation technicians require an understanding of the camera system being installed as well as the program objectives – they must receive training for:

- required software, specialist tools, configuration processes and passwords required to install and configure the system
- placement of antennae to avoid signal interference
- camera placement and angle to minimise the effect of water droplets on the camera dome and interference from existing vessel lighting or water splash
- specialist sealing techniques and processes to appropriately secure camera equipment exposed to harsh environments
- data transfer speed requirements for cabling and connections.

3.7 Maintenance

Ongoing maintenance of systems was required throughout the trial, with much of it undertaken by skippers, and was critical to ensure the systems were functioning properly and issues addressed in a timely manner. This included system checks in port, while at sea and after returning from a fishing trip.

All camera systems deployed during the trial required routine cleaning of the camera lens to ensure good quality camera footage was captured. Figure 8 provides an example of how the quality of an image can degrade throughout a fishing trip. In this example, frequent cleaning of the cameras was also occurring. Common causes of image degradation included water splash from prawn graders or catch on the sorting tray, rain, salt spray and gasses from exhaust stacks.

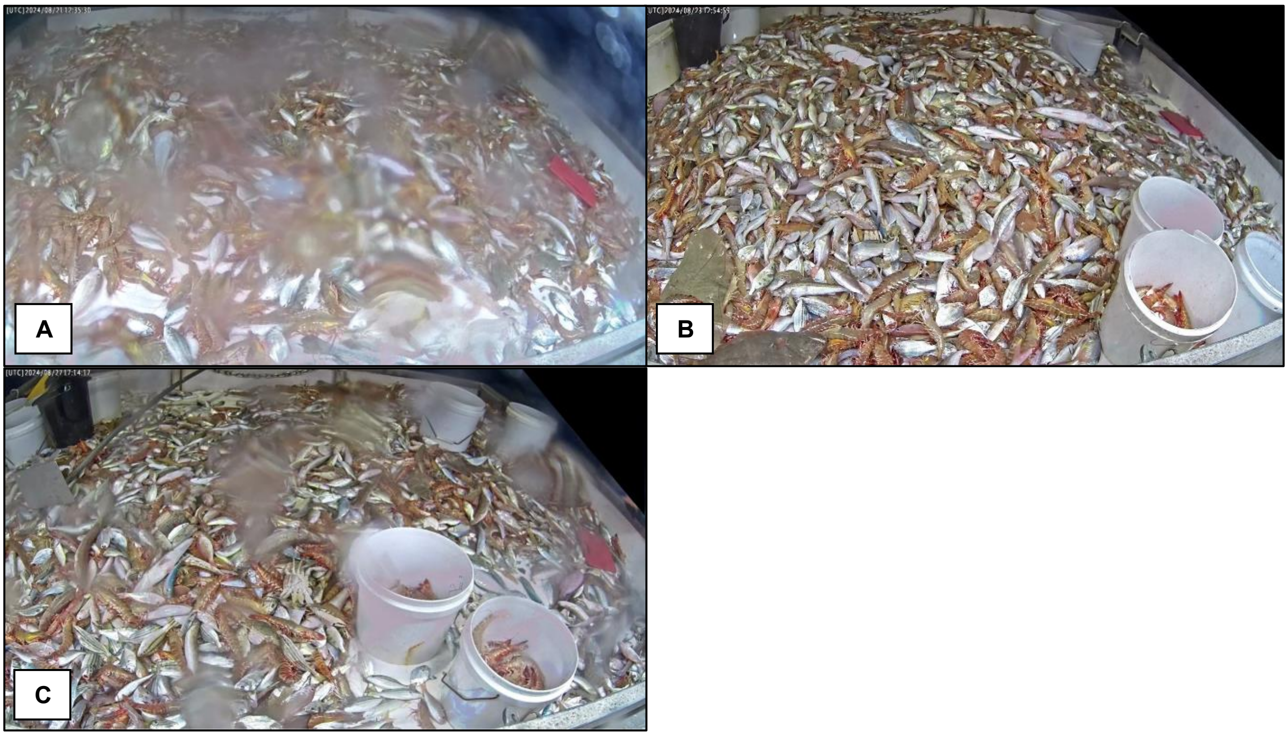

Figure 8: Images from the same onboard camera taken on different days during a continuous fishing trip – (A) camera view is compromised and observations are challenging, (B) 2 days after image A, the camera lens has been cleaned and view is clear, and (C) 5 days after image B, the camera view is degrading again

* Some areas in the images have been blurred and/or modified to exclude identifiable features of the vessel and crew. Note the use of these images has been approved by the relevant authority holder.

Several camera mounting locations were tested throughout the trial to understand if there was an optimal location that avoided the need for continued cleaning while at sea. While the locations available to mount cameras are dependent on the vessel's configuration, it was found that cameras mounted higher on the A-frames were less susceptible to salt and water spray, compared to those mounted over the sorting tray. However, both camera positions required routine cleaning to maintain good quality camera footage.

Regular cleaning of camera lenses within reach of the crew helped ensure good quality footage was maintained, however, this was more challenging for cameras installed high up on A-frames, with cleaning generally undertaken between trips.

With multiple camera locations tested during the trial, there was several factors were identified to optimise cleaning regimes:

- camera placement in areas protected from sources of water splash and/or below exhaust stacks

- where possible fast initial footage review and feedback completion once footage was supplied to the reviewer
- using suitable water repellent products to clean the lenses
- camera placement in areas crew can access safely
- crew education and the completion of pre-start checks, alongside a scheduled cleaning regime at sea and in port
- monitors that provided the skipper with clear views of image quality
- shrouds for cameras in areas that received direct water splash
- angling camera domes so that the lens did not look directly through the bottom of the dome in the area where water droplets accumulate.

While at sea, the skipper was also required to monitor the remaining storage space on memory drives and swap them when space was running low. This was often identified when completing a pre-start system check or by a warning message on the system monitor during a fishing operation.

Factors that reduced memory drive maintenance while at sea included:

- large storage capacity memory drives with clear remaining storage capacities presented on the system monitor
- using systems configured to e-transfer data, which did not require the skipper to monitor and exchange memory drives
- system pre-start checks that contained critical information in simple terms for skippers and crew to understand
- playback functionality on the monitor screen to provide skipper oversight.

When back at port, ongoing maintenance included cleaning A-frame cameras that could not be reached safely by crew while the vessel was at sea. In most cases, this was also when skippers preferred to swap out hard drives of footage of the previous trip and undertake the manual process of posting them to the reviewer.

3.8 Troubleshooting

Most system issues encountered during the trial were identified by the reviewer. Skippers were also able to identify camera malfunctions and frequently reported these to technical staff for troubleshooting assistance – systems with a monitor mounted in the wheelhouse helped skippers identify if the cameras were functioning properly.

The feedback loop between the reviewer, skipper and any technician was critical when addressing troubleshooting issues.

Systems installed during the trial presented a range of operational issues, including several hardware malfunctions. In some cases, the performance of some of the systems was inconsistent, requiring ongoing resources to troubleshoot and rectify issues.

Other than refining sensor configurations, some common issues included:

- faulty or corrupt central control units requiring replacement or repair by system suppliers
- leaking camera housings
- faulty winch sensors
- monitor malfunctions
- system power supply issues with faulty uninterruptible power supply devices.

When issues were identified and reported by the skipper, technical staff supported them to troubleshoot at sea. If issues could not be resolved, they were escalated to the system suppliers for technical assistance and addressed either through remote intervention or when the vessel was in port.

The ability for some systems to integrate with other 'off the shelf' components was a significant benefit and considerably improved troubleshooting outcomes when components required replacing. One system operated with products that could only be purchased from that supplier, which was a distinct disadvantage of that system and contributed to delays to rectify issues.

The refinement of sensor configuration accounted for the majority of the overall troubleshooting interventions required during the trial. This was because the recording configuration parameters are, to a degree, unique to each vessel dependent on the sensor type, winch specifications and fishing practices. In most cases, if the sensor configuration was not triggering recording at all, operators were able to identify and report these issues. Sensor configuration issues that resulted in missed footage were identified by the reviewer.

As sensor configuration was refined over time for each vessel, and feedback times between footage collection and review became quicker, the required intervention rate for each vessel reduced significantly. From the reviewer's perspective, the absence of sensor data restricted the ability to troubleshoot system performance issues.

A frequent cause of software malfunctions was due to formatting requirements of exchangeable hard drives or USB drives associated with one system. This too was easily identifiable by skippers monitoring the remaining hard drive capacity via the monitor and pre-start checks. However, unlike memory malfunctions that were experienced on some internal hard drives, the impact of these issues could not be understood until the data analysis was completed by the reviewer.

Table 2 provides a summary of the elements of key system components that improved troubleshooting ability and overall camera performance during the trial, and those that did not.

Table 2: Summary of system components elements that improved troubleshooting ability and overall camera performance during the trial, and those that did not

System component	Improved troubleshooting ability and camera performance	Did not support troubleshooting and camera performance
Software capabilities	Systems that: • provided skipper oversight through pre-trip checks, video playback and monitors • included review software that provided system health oversight • could be configured to send automated health status updates back to the reviewer and/or control authority while the vessel was at sea • can connect via multiple methods (4G, Starlink or traditional satellite) and could be configured remotely • are compatible with, or can be configured to, new 'off the shelf' components • did not require specialist configuration software and included clear, step-by-step configuration instructions independent of the camera supplier	Systems that: • had limited remote connectivity ability or did not provide the reviewer direct health status oversight • didn't display relevant, interpretable data on monitors for skippers • required multiple remote configuration passwords for different components within the same system • required specialist software for technician access
Hardware components	• Variable focus length cameras • IP66/IK10–rated cameras designed for specific outdoor use • Robust camera mounts designed to mount on multiple surfaces, including poles or bar work with different diameters • Monitors that were large enough for skippers to view and interpret information • High-quality and proven motherboard components	• Camera housings or brackets made of poor quality materials that became damaged or vibrated while vessel was underway • Tablet monitors too small for some skippers to view information • Monitor HDMI connections with locking mechanisms that could break while troubleshooting if the skipper was unaware • Monitors with detachable keyboards caused system errors through improper stowage and lack of awareness • Prototype configurations and motherboard components
Data storage and transfer capabilities	Systems that: • did not require the operator to follow ejection or reformatting processes when swapping exchangeable memory drives • included hard drive formatting processes that could be applied independently of the skipper prior to supply • permitted e-transfer of data and footage, accommodating for times when the vessel had poor reception at sea • had large exchange drive storage capacities limiting skipper intervention • presented clear remaining data capacity warnings for the skipper	Systems that: • had unclear guidelines and processes for hard drive formatting, or that could not be completed independently of the camera supplier • required hard drive formatting specific to the installed onboard system rather than standardised system-wide processes • didn't incorporate bandwidth management processes for e-transfer • were only compatible with USB drives with limited data storage capacity, which resulted in higher frequencies of skipper maintenance
Sensors and recording rules	• Sensors with limited variance in configuration requirements, resulting in reduced refinement effort (hydraulic main winch sensors) • Recording rules that did not rely on winch direction; however, could isolate this by design (hydraulic winch sensors). • Systems that recorded data 24/7	• Sensors that required configuration specific to winch rotational speed, drum diameter and distance tolerances, resulting in higher frequencies of troubleshooting (inductive winch sensors) • Recording rules that did not accommodate for the minimum time of winch movement while vessel was fishing at different depths

3.9 Privacy and data security

Privacy and data security regarding access, use and disclosure of camera footage captured during the trial was a critical consideration in the design and operation of the field trial. Concerns regarding ownership of, and access to, footage was a primary concern of the participants. DPI and DCCEEW also have obligations under the *Information Privacy Act 2009* (Qld) and the *Privacy Act 1988* (Cth) respectively, regarding the collection, management, use and disclosure of personal information.

The field trial agreement was used to outline many of the steps and processes implemented during the trial to appropriately manage footage ownership and the use, access and disclosure of footage and information generated during the trial.

The development of data review and processing procedures was also important, including clear timeframes in which captured video footage was stored and deleted after it was reviewed. Data management procedures outlining data access and storage will be required to support any future program.

Although the camera systems were primarily aimed at the locations where catch, bycatch and TEP species were handled, most cameras inadvertently captured personal information of the skippers and crew in the form of images of their face or other features (e.g. tattoos) that could be used to identify them. During the trial, this capture of personal information was outlined in a collection notice that the participant provided to their skipper and crew. The unintentional capture of this personal information could not always be avoided as the cameras were required to record catch-handling practices.

Several measures were implemented during the trial to safeguard the confidential nature of the footage, sensor data and any unintentionally captured personal information, including:

- encrypted footage that could only be accessed by specific software/personnel with access/authority
- secure storage of footage and data by the reviewer
- clear guidelines for data use, access and retention
- adjusting camera angles to minimise capture of crew where possible
- using software applications such as privacy shields
- using sensor-triggered recording or on-demand e-transfer methods to manage the data collected as accurately as possible and only collect what was necessary to achieve the objective of the trial.

The access, use and disclosure arrangements of camera footage and data will need to be carefully considered under any future program, to ensure key considerations under the *Information Privacy Act 2009* are addressed and the personal information of skippers and crew onboard the vessels is managed appropriately. This includes data transfer and storage on cloud-based servers, and ensuring the review software is compatible with government security standards.

3.10 Reporting

3.10.1 Logbooks

Commercial fishers can currently report logbook information via 2 methods:

- paper logbooks
- electronic reporting using the Qld eFisher app.

Field trial participants reported via both methods, enabling a comparison of the benefits and limitations of each reporting method and its compatibility with a future e-monitoring program. Experience from the trial suggests that any future program should include the electronic reporting of commercial fishing data to ensure timely access to commercial fishing data and reduce data entry errors.

Timely access to commercial fishing data

The submission of paper logbooks does not occur immediately after the completion of a fishing trip. This impacted the ability to provide timely validation of any interactions. Under current reporting requirements, fishers must submit logbook records via mail within 7 days of the fishing operation concluding, and they must be received by the DPI by the 15th day of the following month.

When the Qld eFisher app is used for reporting, the commercial data is received instantly at the conclusion of a fishing operation, or as soon as the vessel comes back into 4G/cellular connectivity. During the trial, this ensured the logbook records were instantly available for review, enabling timely feedback on the camera performance and validation outcomes of submitted records.

Reduced data entry errors

Occasional errors were identified during the trial when review outcomes were compared to database records. Additional checks identified errors often occurred at the time of manual entry of logbook records into the database, as well as logbook entry errors submitted by operators with incomplete fields or illegible handwriting. Reporting via the Qld eFisher app minimises the scope for data entry errors (with fishers unable to submit incomplete fields) and the data is automatically uploaded into the database, limiting the risk of errors.

While reporting via the Qld eFisher app improved validation outcomes, the trial also identified occasions when app reporting was incorrect. For example, participant comments made on the app where not appearing initially within the vessel summary reports they received. In addition, if participants were using a device set to an incorrect time zone, adjusted shot times were submitted with the incorrect time.

3.10.2 Vessel summary reports and review sessions

Following the review of footage and comparison with corresponding logbook data, the reviewer drafted a vessel summary report that was sent to DCCEEW, DPI and the relevant field trial participants – it included:

- a system performance overview for the hard drive date range and a performance issue summary
- a summary of the fishing dates reviewed
- logbook validation results
- recommendations to improve system performance and validation outcomes.

The reports proved extremely valuable for the participants, DCCEEW and DPI in understanding system operation, performance and maintenance requirements – supporting the feedback loop between the reviewer and skippers/authority holders, and improving the overall performance of systems on board each vessel.

Although valuable and a recommendation as part of any future program, the reports generated for the trial were manually drafted and extremely detailed. Reports developed as part of a future program should be automated as much as possible to reduce drafting times and overall costs associated with this important aspect of the review process.

One-on-one review sessions with the participants and reviewer were also provided during the trial to demonstrate how the review software worked and the nature and quality of the footage being captured. These sessions were beneficial for reviewers to better understand operational practices on board each vessel (e.g. crew sorting practices, arrangements for returning TEP species to the water) and helped the reviewer improve efficiency. It is recommended that these one-on-one review sessions are provided as part of an educational induction with any future program, so industry better understand how the footage and data is being used and reviewers understand how the fishery operates and vessel-specific catch processing activities.

4. Field trial participant feedback

Throughout the trial, feedback from participants was sought directly during maintenance and troubleshooting events, and scheduled meetings of the technical focus group. As the trial entered the evaluation phase, participants were sent a list of survey questions to collate a summary of their experiences and key learnings. Some participants also provided feedback via phone calls. Feeback and recommendations requested were within the scope of the field trial objectives and did not include high level policy or program design recommendations.

Several high-level themes were included in the survey questions and discussed with participants, including what they thought was successful and unsuccessful, and what they believe to be the key program components and considerations for any future program. A summary of the feedback is provided in the following sections.

Installation

Participants were asked if they considered the installation process to be challenging or difficult. Overall, they were satisfied with the processes undertaken, including works carried out by engaged marine technicians. While most installations ran smoothly, participants still identified several challenges including:

- camera positioning –some systems had bulky cameras that posed some challenges, while for other systems, selecting positions protected from water splash and collision with fishing gear was challenging
- compatibility with existing vessel power – challenges were experienced operating some systems with the existing power sources on board (any future systems should be compatible with existing vessel power suppliers or include the components required to support operation on vessels with unstable power supplies)
- vessel layout and configuration – impacted installation times with wiring placement as each vessel was different (having only one camera could limit this challenge)
- temporary installation – improvements to the installation processes would be required for any future program that required placement of permanent cameras
- vessel monitoring plans – drafting vessel monitoring plans was challenging and time-consuming for some participants
- time requirements – making their vessel available to DPI and installation technicians, and being present during installation, was time-consuming for some participants.

Operation and maintenance

Participants were asked if they found the systems impacted their fishing operations in any way, and if they were difficult to use, operate and/or maintain during the trial. The majority of participants found the systems did not physically impact on their fishing operations. Some participants suggested that the additional monitor/screen within the wheelhouse took some getting used to, but was valuable to ensure the system was operating properly. The following general comments were received about:

- large components – some operators raised concerns with large and bulky components associated with one of the systems, regarding to crew safety and the lack of safe locations to mount them
- camera cleaning – some participants raised issues about the need to clean the camera lenses during fishing operations and safety concerns about cleaning cameras out of the crew's reach – consistently cleaning cameras is another task that must be completed
- troubleshooting – significant time and effort was required to work with DPI, MRAG Asia Pacific and suppliers to ensure systems were operating properly and troubleshooting issues were resolved, with some issues required temporary work-arounds that were challenging for participants (e.g. manually turning systems on and off)
- system breakdowns – some participants advised that system breakdowns did not impact their fishing operations as they could continue fishing; however, noted that it may have a considerable impact under any future program.

Other than initial embedding issues experienced during the installation process, the following feedback regarding the use and operation of the systems was provided:

- Some systems were simple to use with pre-trip checks easy to perform.
- An interface displayed on the monitor that provides more understanding of issues when they occur, shows how data and information can be interpreted to signal alerts for system checks, and provides the ability to interact with the system for troubleshooting purposes would be desirable.
- Some issues relied too heavily on the suppliers' technical support, including system malfunctions due to formatting or internal operating temperature malfunctions.
- Issues with 4G connectivity for remote troubleshooting were experienced and troubleshooting while at sea was difficult, while more could be done when the vessel was back in port.
- Some tablets were too small for them to interpret and read the displayed data in the wheelhouse.
- Formatting issues were experienced with USB drives, and small issues such as keyboard usage/batteries going flat may be difficult for operators to readily identify while at sea.
- Some cameras vibrated and moved, and operating systems were problematic for themselves and the technician to work on.

System functionality and performance

Participants were asked about system components and operating standards they considered to be the most important, and identified the following capabilities:

- systems that are cost-effective, including cost of components and ability to manage the amount of captured data
- automatic operation (automatic recording) and live views, including playback functionality in the wheelhouse (this functionality allowed skippers to monitor views, camera performance and identify when cameras required cleaning)
- camera systems that provide adequate resolution and field of view, and are also installed in locations that support the reviewer to observe and validate components of a fishing operation that align with future program objectives (noting challenges with camera placement to observe all interactions)
- components that are durable, fit for purpose and can endure the marine environment and temperatures experienced throughout Queensland
- the ability to e-transfer was noted by some participants, which would reduce the time it took for data to get to the reviewer as well as remove workload on operators who would otherwise have to physically send and receive hard drives in the mail
- the importance of future AI capabilities for the system was noted by some participants, which could potentially reduce footage review and reporting workloads.

Troubleshooting support

Participants were asked about supporting information they think will be required to help skippers and crew confidently operate systems, and provided the following feedback:

- Some participants suggested that a fully automatic operating system was preferred, also noting the importance of a system that provides alert messages when errors occur.
- Some expressed the need for troubleshooting support to be available 24/7 or during hours that allowed skippers to make contact while at sea (early morning, night and late afternoon).
- Different methods of technical support were suggested, including online/electronically available troubleshooting material/manuals and recorded troubleshooting tutorial videos in conjunction with hard copy manuals to keep as reference on the vessel.
- Participants recommended that access to program support should be directly to personnel who have technical expertise on the system as opposed to a generic call centre, and expressed the desire to have a 'face-to-face' talk via phone or online video.
- The ability to monitor live view and training on how to resolve issues, including the ability to fix camera angles, was desirable to make the most of this support.
- A training course with follow-up to check their progress and assess any additional needs to operate the system was suggested (to support industry and help them gain experience using the system before cameras are installed).

Privacy

Participants reconfirmed their initial privacy concerns (as summarised in Section 3.9) and were asked if they had additional concerns for skipper and crew privacy following the trial. The following feedback was provided:

- Even with strategic camera placement that may avoid the capture of images of crew, identifying features of people (including tattoos) and vessels may still be captured within the footage collected.
- In the event that footage was deliberately leaked in any way, it would become a privacy concern.
- Limitations to footage access and release is important to manage the risk of footage being used for purposes other than the objectives of the program.

Additional comments

The majority of participants suggested that the trial was too short and should have been extended to support more testing of the systems. Most participants did, however, indicate that their participation in the trial has improved their understanding of how the systems and footage review process work.

Participants advised that the following aspects of the trial worked well:

- quick response time from some suppliers and DPI to resolve technical issues
- geofencing boundaries applied and timed recording rules worked well to ensure the camera did not record when it wasn't needed
- protecting cameras underneath rear deck awning resulted in less risk of damage and fewer components that could potentially break.

Most participants advised that within the initial stages of installation and testing, most systems experienced consistent issues and considerable time was required to troubleshoot them.

Participants also provided the following general comments about the trial:

- There were concerns about future compliance actions towards commercial fishers if they misreport TEP species interactions, with recommendations for improved handling training and awareness for crew.
- The e-monitoring systems trialled are costly and they would prefer an 'off the shelf' CCTV system.
- One participant felt camera systems had limited use for data validation with the exception of shot times. However, they may have future value in quantifying discards, improving our understanding of catch composition and addressing data deficiencies for at-risk species.
- Some participants preferred e-transfer, as long as the server and transfer of footage was secure.
- There were concerns with hydraulic sensors causing breakdowns in the hydraulics system.

5. Summary of key findings

This trial evaluated the capacity of onboard camera systems to independently monitor interactions with TEP species in the ECOTF and CFFTF, as well as estimate the composition of bycatch. Importantly, the vessels participating in the trial were highly diverse in terms of vessel layout and catch-processing methods, trawl gear configurations, target species, catch compositions and fishing areas/times – meaning the effectiveness of the systems was tested across a range of operational conditions across the fisheries.

Overall system performance

The overall performance of systems deployed throughout the trial was variable. Some systems consistently delivered high-quality footage and complete data, while others were less reliable and presented a range of operational issues. Overall, the vast majority (approximately 88%) of camera footage randomly selected for review was either of 'good' or 'acceptable' image quality, with sufficient resolution to enable species-level identification of catch by the reviewer (at least for larger species). The most common reason for 'poor' quality footage was the presence of salt spray on camera lenses, which was resolved in many instances by crew maintenance.

Technical problems experienced by some systems meant that a smaller proportion of hard drives contained complete footage and sensor data. While reviews were often still possible on incomplete hard drives, the interpretation of fishing activity was less reliable (e.g. it was difficult to confirm that no fishing events were missing from the data record).

TEP species

The camera systems tested proved capable of reliably detecting interactions with larger TEP species where interactions occurred within the camera's field of view. Detecting and identifying interactions with smaller TEP species, such as pipehorses, was more challenging and probably only reliable for vessels fitted with a catch-sorting conveyer.

Identifying the condition (alive or dead) and fate (released or retained) of TEP species was difficult under normal fishing operations. Working with crews to develop more standardised catch-handling practices could improve the capacity of the systems to monitor interactions with small TEP species.

Bycatch

The capacity to independently estimate the number and composition of bycatch varied significantly across the shots reviewed. The main factors influencing the ability to estimate bycatch include the:

- volume and diversity of bycatch (often influenced by the target species/sector)
- operational set-up and sorting practices of the vessel (e.g. conveyor or sorting tray)
- positioning of the camera system and the quality of footage (close to, or remote from, the sorting process, good or poor resolution).

In practice, experience from the trial suggests that robust monitoring of full bycatch composition via e-monitoring is only likely to be feasible for vessels with conveyor sorting systems and for those sectors of the fishery with low relative diversity and volume of bycatch.

For other sectors (e.g. sorting tray vessels operating in sectors with higher relative volume and diversity of bycatch), monitoring of bycatch using e-monitoring is not likely to be feasible if the objective is to estimate the full volume and species composition. For these vessels, alternative bycatch monitoring measures (e.g. observers, crew sampling) are likely to be more appropriate. The bycatch monitoring objectives for the trial were also broad, and more detailed considerations and improved objectives would be beneficial to support further testing of capabilities.

E-monitoring may still be useful in achieving more targeted bycatch monitoring objectives (e.g. monitoring interactions with larger bycatch species identified as higher risk through ecological risk assessments or a smaller number of carefully selected indicator species, or monitor specific regions of the fishery). Should e-monitoring be used to undertake bycatch-related data collection, some process of validating and refining the accuracy of estimates through the collection of onboard samples (e.g. by an observer or crew) would be required.

E-monitoring system sensor data

The sensor and GPS data generated by e-monitoring systems are highly valuable, both as a standalone dataset and to optimise the efficiency of the footage review process. For example, estimates of fishing effort (e.g. shot start/stop times, GPS locations) generated through sensors are more precise than those currently collected through logbooks, and open up opportunities to improve tracking/analysis of key metrics that can improve management outcomes (e.g. calculations of swept area, timing and location of TEP species interactions).

The availability of speed and sensor data also allowed reviewers to easily identify and navigate to fishing events of interest, supporting an efficient review process and associated cost savings – particularly when processes are scaled-up across a large number of vessels. Experience from the trial indicated that estimates of fishing effort were most accurate for vessels equipped with a hydraulic sensor on the main winch.

E-monitoring review software

Dedicated review software enabled reviews that were repeatable, efficient, and cost-effective. While each system provider's software has its own strengths and weaknesses, they share several common advantages:

- **Integration of multiple data sources (GPS, sensors, time, video)** enables comprehensive visualisation and analysis, providing a full picture of fishing operations.
- **User-friendly interfaces** simplify data review and analysis, making the process accessible to both experienced users and those new to e-monitoring.
- **Standardised workflows** ensure consistent review and interpretation of data across different users and scenarios.
- **Customisable data fields** allow data collection to adapt to monitoring requirements.
- **Efficient review processes** streamline workflows, reducing review times and associated costs.

These shared features make dedicated review software an essential component for any future program.

E-monitoring review time

Review time varied according to the nature of the review. TEP species reviews were able to be completed in shorter timeframes than bycatch reviews, with a median review time of 12.5 minutes per shot (Figure 8). Bycatch reviews were highly variable, with a median review time of 52.5 minutes per shot, but ranging from 30 to 106 minutes.

Both TEP species and bycatch review times were influenced by a range of operational factors including:

- diversity and volume of catch
- number of camera views
- vessel configuration
- crew sorting practices
- footage quality.

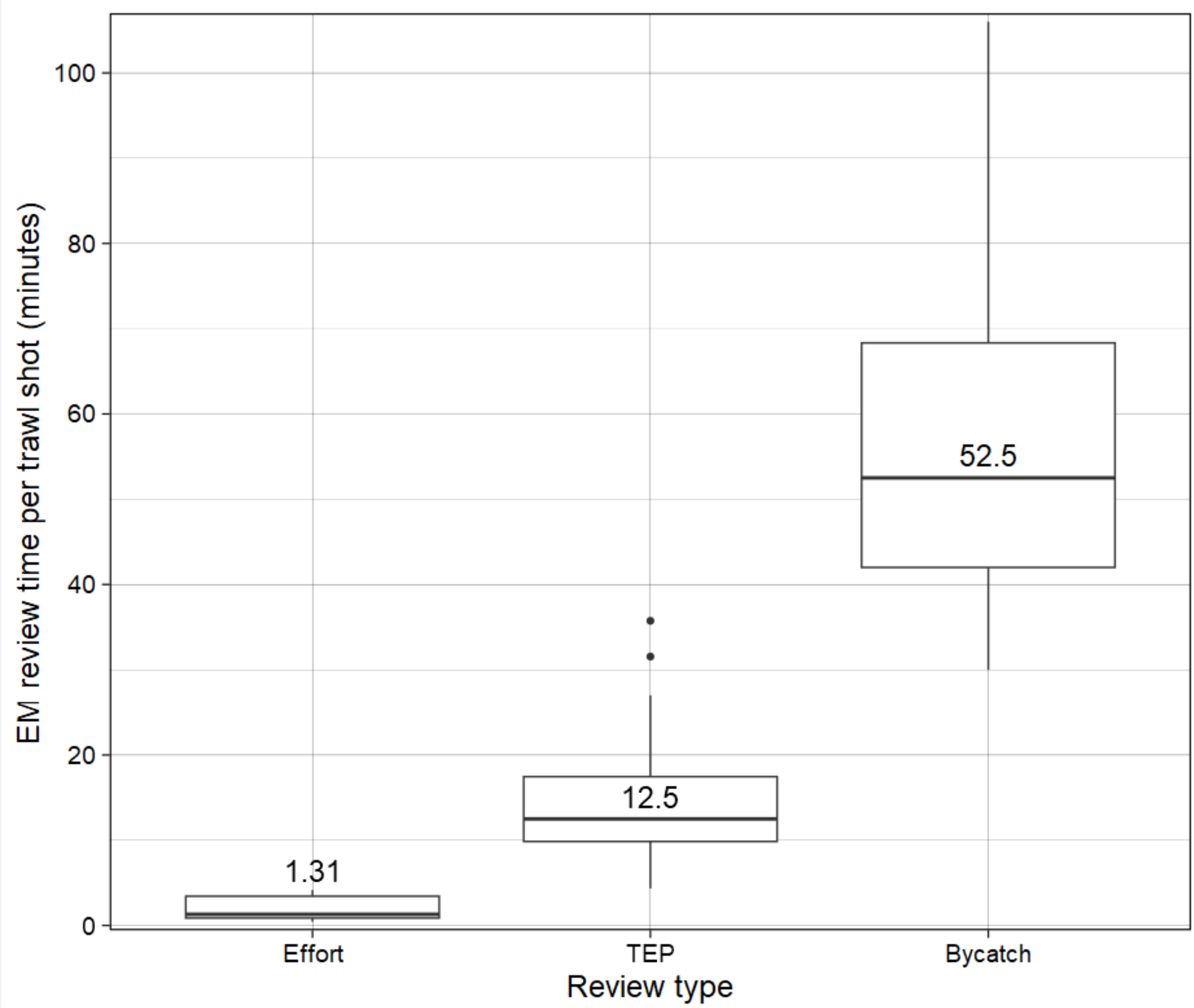

Figure 8: Boxplot illustrating review time across EM review types – the box represents the interquartile range, with the median labelled and indicated by the horizontal line inside the box; and whiskers extend to the minimum and maximum values within 1.5 times the interquartile range, and points outside this range are considered outliers

Lessons learned

E-monitoring systems require ‘bedding in’

An initial ‘bedding-in’ period is required, during which systems and processes are established, personnel receive training and fishers familiarise themselves with the technology. Experience from the trial identified that the bedding-in period was substantial and, while challenges encountered were addressed as the trial progressed, issues were often due to the type of system or the specific vessel.

Facilitating fixes and troubleshooting issues often involved significant coordination between the independent reviewer, DPI, system providers, service technicians and field trial participants. These troubleshooting processes were often more complicated when providers were located in different time zones.

While the trial proved valuable to assess the relative strengths and weaknesses of multiple systems, limiting any future rollout to a smaller number of system providers that offer timely support is likely to be more practical.

Importance of industry engagement

Experience during the trial indicated that maintaining an active feedback loop with skippers was important to the successful performance of systems. While some providers had systems in place for remote monitoring, it was often the skippers who identified and reported issues. Being aware of system malfunctions, sensor failures, impending hard drive capacity limits and other issues resulted in improved data quality, enhanced service response times and reduced service costs.

Skippers also enabled more efficient and accurate reviews by maintaining cameras, sharing details of catch-sorting practices and providing feedback on vessel summary reports (which subsequently informed the modification of camera views, settings, sensors etc.).

Ensuring a high degree of industry engagement will be an essential component of any future program.

Improving review accuracy and efficiency

During the trial, the reviewer received several materials to enhance reporting accuracy and review efficiency, including software manuals, support and training on use of the review software platforms, and commercial fishing logbooks with completion instructions.

The reviewer was provided with configuration details for each vessel in the trial, including camera types, deck positioning, footage settings and mud maps outlining deck layout and catch-sorting operations. One-on-one sessions with skippers and vessel owners further helped the reviewer clarify onboard practices, including TEP return protocols.

Reviewers of any future programs should receive similar materials, as well as species identification guides and/or training. While not provided to the reviewer for the trial, this would be a valuable addition for future reviews and could ideally include images taken of TEP species during the trial.

Identification guides could also be distributed to fishers to enhance reporting accuracy and improve the efficiency of camera footage and logbook comparisons, as discrepancies between the reviewer and trial participants often required time-consuming investigation.

6. Recommendations

Clear objectives

Future IOM program objectives should focus on using e-monitoring systems to monitor and validate TEP species interactions across all sectors of the ECOTF and the CFFTF. The monitoring of bycatch using e-monitoring systems should be targeted and used in conjunction with other monitoring methods, depending on the fisheries data needs.

Program objectives that clearly define the scope of what e-monitoring systems will be used to validate or monitor are required to support the design and roll-out of a future IOM program. These objectives will inform the nature and number of vessels to be fitted with e-monitoring systems, the number and position of cameras on each vessel, the type of reviews undertaken, the proportion of footage to be reviewed, as well as the number of reviewers and associated training required. Objectives for a future IOM (and e-monitoring) program should be developed in consultation with industry and other stakeholders, with close engagement on program design, system operational requirements, the nature of footage to be collected and review processes.

The trial demonstrated that e-monitoring systems can accurately monitor and validate larger-bodied TEP interactions across all vessel types and sectors of the trawl fisheries. For this reason, it is recommended that the future objectives of an IOM program include the monitoring and validation of TEP species interactions via e-monitoring.

The trial also demonstrated that the effective e-monitoring of full bycatch composition was possible on CFFTF and ECOTF vessels with hopper and conveyor catch sorting systems, and sorting table vessels operating in ECOTF sectors with lower diversity and volume of bycatch. To that end, consideration should be given to using e-monitoring to meet bycatch data collection objectives in sectors where the trial demonstrates it's feasible, and e-monitoring is likely to be more cost-effective than alternative approaches (e.g. deployment of a physical observer). Noting that fishery observers were unable to be deployed during the field trial, additional testing which compares observer data (and/or crew sampling) with e-monitoring data should be undertaken to validate the accuracy of species identification from camera footage.

For sorting tray vessels operating in sectors with higher bycatch diversity and volume, where e-monitoring proved less accurate at monitoring bycatch species, alternative bycatch monitoring methods such as fishery observers or crew sampling programs are likely to be more practical.

Future IOM program objectives will have a significant impact on how a program is established and the time and resources required for its ongoing management. The trial demonstrated that TEP species reviews are much faster than full bycatch reviews and therefore, an e-monitoring program that monitors bycatch and TEP species interactions will either be more costly than a program focussed solely on TEP species or have more limited coverage. When considering the scale and design of an IOM program on a fleet as large and diverse as the ECOTF, the fishery's assessment and data needs will need to be balanced against the costs of program management.

For this reason, program objectives should be set based on the management and information needs for the fishery and take into account practical and logistical constraints associated with the program design and roll-out phase. Following commencement of an IOM program, ongoing cost evaluations and data quality assessments will be necessary to maximise the uses of e-monitoring systems and facilitate the adoption of efficient data processing and reporting methods.

Risk-based staged rollout

A staged rollout of e-monitoring systems should occur across a large fleet of vessels such as the ECOTF, with a risk-based approach taken to identify priority vessels and management regions.

The trial has indicated that the installation and optimisation of e-monitoring systems requires a considerable ‘bedding-in’ period for each vessel. During this initial period, a high level of individual care and resourcing is required to troubleshoot any teething problems, optimise performance (adjust camera angles, resolution, etc.), educate skippers and respond to technical issues. Additionally, to effectively review footage, a ramp-up of reviewer capacity is required, with reviewers trained in the efficient use of review software, crew fishing practises and relevant species identification.

The trial has also identified that large quantities of e-monitoring systems are not available for rapid deployment, and lead-time is needed to build and procure the many systems needed to install across the trawl fleet.

For these reasons, a rapid, fleet wide rollout of e-monitoring systems across Queensland’s trawl fisheries appears impractical and would require significant resources to oversee program coordination and management.

Instead, the staged rollout of e-monitoring systems across a large fleet such as the ECOTF is recommended. A staged rollout should commence with only a small number of vessels in the first year and increase though time. This ‘ramp up’ in the rollout of e-monitoring systems across vessels not only affords time for e-monitoring systems to be constructed by suppliers, but provides time to adapt and refine the installation and system establishment processes (e.g. create vessel monitoring plans and train skippers), and increase the number and experience of EM reviewers. Ongoing refinement of the installation and establishment processes will significantly improve the programs management efficiencies and reduce the resourcing needs of a program during the rollout phase.

To support the staged rollout, a risk-based approach should be applied to identify priority vessels and management regions where establishment should commence. This risk-based assessment should prioritise vessels and management regions that pose the greatest and/or most uncertain risk to TEP and bycatch species, and support the ecological values of the Great Barrier Reef World Heritage Area (GBRWHA). A future rollout should also ensure that fleet coverage is representative and all high-risk vessels or management regions across the fishery are captured in the staged approach.

This future rollout should also be consistent with the level of resourcing available, with emphasis on the bedding-in and education period immediately following installation. The practical details of any rollout should be discussed between fishery managers, industry and other stakeholders (e.g. e-monitoring providers).

Education and Engagement

Effective industry engagement and education is essential to support the effective rollout and ongoing operation of any future e-monitoring program.

The trial has shown how collaborations with skippers and crew are critical to support operational needs of an e-monitoring system. In the initial stages of installation and footage review, tight feedback loops are required as technical issues are addressed and system performance is optimised. In the longer term, skippers and crew play an important role in monitoring camera performance and undertaking system maintenance (e.g. routine camera cleaning).

Close interaction between reviewers and skippers allowed for a better understanding of vessel layouts and crew sorting practices, which in turn helped the efficiency and quality of reviews. While this close interaction and feedback loop was extremely valuable during the trial, there was significant time and resources required.

Education on the use and operation of systems is critical at the time of installation and authority holders and skippers should be appropriately educated at the time of installation with technical support available to support the initial ‘bedding in’ period of the systems. Extensive educational material and resources should be made available to support skippers use, operation, understanding and adoption of these new technologies. This education should not only focus on the technical operation of e-monitoring systems but also their TEP species and other logbook reporting obligations. Resources should be designed in consultation with industry to ensure they are fit for purpose and address the operational needs and requirement of industry.

Dedicated e-monitoring system

When considering what system is the most appropriate to be used as a monitoring and validation tool, it is important to consider the fishery for which the program is being designed.

In the ECOTF, there are hundreds of active vessels operating across a large area – there are 148 vessels within the Great Barrier Reef alone. Experience from the trial indicates that the use of a dedicated e-monitoring system offers considerable advantages over a standalone CCTV system, as it can support efficient validation outcomes and reduce ongoing management costs of a program compatible with the scale of the ECOTF.

Key components that a dedicated e-monitoring system provides include the collection of sensor and GPS data to record fishing effort and location, which improves the review process and the data that can be validated. These systems also allow the secure and selective e-transfer of video footage that can significantly reduce data storage and transfer needs of a future program. Finally, they provide for these processes in an automated nature, with reduced operation and input required by vessel owners/skippers and improved efficiencies at the time of review and validation.

It is recommended that a dedicated e-monitoring system is used in any future program (this does not suggest that CCTV systems implemented in other fisheries or under other operational conditions are not appropriate to deliver an independent validation program).

The question then is what approach to take when choosing an e-monitoring provider. While a standards-based approach (under which any system could be used as long as it meets minimum standards) could be used, experience from the trial cautions against deploying multiple systems with specific operational needs that cannot operate with other systems at the same time.

In practice, each system has its own hardware and bespoke review software, and the associated need for technical support, troubleshooting and training. While trialling multiple e-monitoring systems proved highly valuable in testing relative strengths and weaknesses, the outcomes suggest that having a large number of providers involved would complicate any larger rollout.

The field trial outcomes have highlighted that camera system components supporting data integration and review are essential to maximise efficiencies for key aspects of a future program.

Key considerations for camera systems and program design elements include:

- capacity of hardware service providers to supply robust cameras of high quality (good durability, good image quality, easily maintainable)
- integration with sensors that provide data helpful for management purposes, and facilitate efficient review
- review software that incorporates the key features outlined in section 3.5
- capacity for wireless transfer of video footage and data
- efficient data decryption processes
- demonstrated history of providing responsive and competent technical support and troubleshooting (experience from the trial indicates this feature is essential to the effective function of any broader program).

Optimise review arrangements

Careful consideration should be given to the likely implications for review resourcing in any program design, as well as optimising the efficiency of reviews where practical.

Experience from the trial (and other e-monitoring programs) is that the footage/data review components can be resource intensive and account for a significant proportion of overall program cost.

Key considerations include:

- optimising the volume of footage to be reviewed to meet program objectives
- providing high-quality training to reviewers on the efficient use of e-monitoring software
- providing training on species identification (consistent with program objectives) and developing practical image libraries to assist with identification
- ensuring sufficient computing power to allow footage to be processed and reviewed at efficient speeds
- choosing an e-monitoring provider that offer efficient data transfer (e.g. e-transfer) and decryption
- developing scripts to automate comparisons between footage and logbook data.

Integrate e-monitoring data into fisheries management

As e-monitoring data accumulates over time, it is important to consider its suitability for integration into scientific assessment (e.g. stock assessments and ecological risk assessments) and determine the best approach to do so.

The potential for e-monitoring to support alternative management arrangements (e.g. individual accountability approaches rather than fleet-wide measures) and generate cost savings in other areas of fisheries management (e.g. additional data collection or compliance monitoring) should also be evaluated.

The fishing industry could also benefit from mechanisms like accurate reporting / early adoption of e-monitoring technology via access to the data, which could support efforts to demonstrate social licence and pursue fishery-wide environmental performance assessments and certifications.