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Framework for Integration of Data from Remotely Operated Cameras into Recreational Fishery Assessments in Western Australia

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1 Executive summary

Remotely operated cameras can be used for cost-efficient monitoring of recreational fishing activities. This report provides an overview of the current usage of cameras in recreational fishery assessments by the Department of Primary Industries and Regional Development. Since 2006, 32 remotely operated cameras have been installed at 26 locations throughout Western Australia and currently 28 cameras are in use. Monitoring information has great potential for improving the accuracy and precision of estimates of recreational fishing effort and harvest from some on-site survey designs. Also, camera information (when adjusted to account for non-fishing activities) can be used as a "gold standard" benchmark to evaluate the accuracy of estimates of recreational fishing effort from off-site surveys. A framework has been developed to integrate camera monitoring data into recreational fishing survey projects. The framework covers the following broad areas: (1) project description; (2) survey design and sampling strategy; (3) feasibility and logic checks for proposed analyses; (4) survey implementation, data analyses and reporting; and (5) project outputs and project outcomes. An overarching Quality Management Plan is described for all phases of a project to achieve and maintain quality and confidence in the results produced by camera monitoring. The implementation of this framework requires a change in the way surveys are planned and designed. Camera monitoring when used as a core component of any recreational fishing survey design will improve the accuracy and/or precision of fishing effort estimation enabling the provision of better information for management needs.

2 Introduction

Remotely operated cameras have been used in a variety of projects by the Department of Primary Industries and Regional Development (DPIRD) since 2006 (Blight and Smallwood 2015). The utility of cameras has been demonstrated for improving assessments of:

- Shore and boat-based recreational fisheries (e.g. Smallwood et al. 2012, Ryan et al. 2015);
- Night-time coverage in some recreational fisheries (e.g. Smallwood et al. 2012);
- Bycatch issues in commercial fisheries including interactions with threatened species (e.g. Wakefield et al. 2015).

The cost-effectiveness and reliability of data collection using remotely operated cameras has been established (Wise and Fletcher 2013, Blight and Smallwood 2015). These benefits are expected to increase as improvements in camera technologies occur. Thus, the deployment of remotely operated cameras to new locations is also expected to increase in the future.

Blight and Smallwood (2015) provide a detailed description of the setup, hardware, software and network systems used for the remotely operated cameras by DPIRD to monitor shore-based and boat-based recreational fisheries. A summary of the data extraction process is also available in that report.

This report provides an overview of the camera program and its integration with respect to the assessment of recreational fisheries. The cameras also directly assist in numerous Departmental and stakeholder projects relating to compliance, surveillance, research and infrastructure planning. These projects are summarised in Appendix A, but are not considered further in this report.

2.1 Aims

1. Describe the current application of camera data in recreational fishery assessments by DPIRD.

2. Investigate approaches for integration of camera data into recreational fishing surveys.

3. Discuss sampling strategies for camera monitoring and the relative costs associated with the camera program.

4. Describe a Quality Management Plan with Quality Control and Quality Assurance issues to be implemented in the camera program for long-term monitoring success.

5. Develop a framework for planning and implementing projects that use data from remotely operated cameras to enhance recreational fishery assessments in Western Australia.

3 Current application of camera data in recreational fishery assessments

Since 2006, 32 remotely operated cameras have been installed at 26 locations throughout Western Australia (Fig. 1) and currently 28 cameras are in use (refer to Appendix B). There are six types of camera viewpoints being used and each viewpoint captures data that provide very different coverage of the recreational fishery being monitored (Table 1). These camera data are being used to address a variety of different objectives which will be described below with examples of their implementation in some recreational fisheries in Western Australia.

Objective 1 - Initial assessment of the magnitude of recreational fishing effort in a fishery

The most basic use for camera data is to provide an initial assessment of the relative magnitude of recreational fishing effort. The Peel-Harvey estuary is known to have a large recreational fishery for blue swimmer crabs (*Portunus armatus*). This fishery is typically accessed by boat or from the shore by wading in the shallows and using scoop nets to catch crabs (Johnston et al. 2014). The shore-based fishery is characterised by diffuse access across large areas of the estuary and the night-time component of this fishery has not been quantified. Concerns about the magnitude of this night-time wading fishery and the possibility of widespread non-compliance with recreational fishing regulations led to the placement of three thermal imaging cameras at separate fixed locations overlooking areas of shallow subtidal habitats within the estuary. Data from these thermal imaging cameras are being used to show that shore-based crabbing effort is important but highly variable. This information will be used to improve the design of a future survey to quantify effort and catch of the night-time fishery.

Objective 2 - Index of recreational fishing effort

Camera-generated count data that record boat movements (i.e. launches and retrievals) but do not determine the nature of the boating activity (e.g. fishing or non-fishing trips) at an access point can be used to derive an index of recreational fishing effort. The utility of this index can be influenced by many factors but is most reliable when the proportion of vessels undertaking fishing activities is high. Ryan et al. (2015) present plots that summarise power boat launches and retrievals at 13 public boat ramps during 2013/14 from cameras. These summary data have not been adjusted to account for non-fishing trips and are indices of fishing effort because they provide an indirect measure that is correlated to fishing effort. Previous information collected during a 2005/06 survey of recreational boat-based recreational fishing in the West Coast Bioregion, which includes many of the same ramps, found that the proportion of non-fishing trips was greater than 35% during that survey period (Sumner et al. 2008). This indicates that camera data of boat ramp activity may not be reliable metrics for assessing long term trends in boat-based recreational fishing effort unless the proportion of non-fishing trips is estimated reliably.

Objective 3 - Estimate recreational fishing effort

Remotely operated cameras can provide a cost effective way of capturing information that can then be used in the estimation of recreational fishing effort (Smallwood et al. 2012, Hartill et al. 2015, Keller et al. 2016). This is usually the main objective when using camera technologies to monitor a recreational fishery. However, there are many potential sampling, data capture and data interpretation issues that need consideration when using camera-generated information to derive an estimate of fishing effort. The main issue that should be addressed is the need to adjust the camera data to account for non-fishing trips to accurately determine the amount of fishing effort from the camera data.

Objective 4 - Describe patterns of recreational fishing effort that occur at different temporal scales

Remotely operated cameras are useful for capturing high volumes of information across many different temporal scales. Smallwood et al. (2012) used fixed cameras overlooking four groynes to determine the within day (24 hour coverage) distribution of shore-based recreational fishing effort along the Perth coast. The potential value of camera monitoring for providing information on hourly, monthly, seasonal and annual temporal scales is demonstrated by the plots of power boat launches and retrievals at 13 public boat ramps throughout Western Australia during 2013/14 (Ryan et al. 2015). A sound understanding of temporal patterns of fishing effort is important for improving the designs of recreational fishing surveys and sampling programs that seek to maximise contacts with fishing parties. For example, a sampling program that aims to collect length and weight frequency data from the boat-based marine fishery across Western Australia has used camera-based monitoring to determine when most boats return from their fishing trips (Ryan et al. 2015). These peak times within a day are then sampled thereby maximising the number of interviews with fishing parties and increasing the sample sizes of fish that are measured and weighed. The average weights derived from this targeted sampling program are then used to convert estimates of recreational harvest from off-site surveys from units of numbers to units of weight.

Objective 5 - Supplement an existing survey design by increasing coverage for recreational fishing effort of the temporal frame

A supplemented access point survey design (Steffe et al. 2008) is being used to assess the recreational snapper fishery in Shark Bay (Wise et al. 2012). Cameras are being used to monitor vessel movements at the boat ramps covered by a bus route survey. The supplemented access point survey design uses a double sampling approach to improve the accuracy and precision of estimates of recreational fishing effort and harvest. The camera data provide better coverage of the temporal sampling frame than the bus route survey alone and are adjusted for non-fishing trips by using party-based interview information collected during randomly scheduled survey days. Steffe et al. (2008) provide a worked example of the supplemented access point method.

Objective 6 - Expand an existing survey design by including an additional monitoring component that provides coverage of night-time recreational fishing effort

An aerial-roving survey design was used to estimate shore-based recreational fishing along the Perth coast between April and June 2010 (Smallwood et al. 2012). This survey design was expanded to include counts of anglers derived from fixed cameras overlooking four groynes. The camera data were used to provide information about the hourly distribution of fishing effort within days and improve the precision of estimates of total fishing effort and catch (Smallwood et al. 2012).

Objective 7 – Corroborate estimates of recreational fishing effort from another independent survey

Effective fisheries management is based on accurate information. Fisheries resource assessments that inform management processes can use information collected during recreational fishing surveys. However, the off-site and on-site survey methods used to assess recreational fisheries in Western Australia are subject to various potential biases that can affect the accuracy of their results (Pollock et al. 1994). This means that it is important to assess the level of bias in the survey results so that managers and stakeholders can be confident when using the survey information.

The assessment of survey bias can be done by means of a corroboration study or a validation study (Steffe 2015). A corroboration study uses two or more independent methods to estimate some population parameter (e.g. fishing effort or harvest) and none of the methods used can be regarded as a "gold standard" (Steffe 2015). The estimates derived from the different methods are then compared and their similarity is assessed relative to a predefined range of acceptable difference. The main issue with a corroboration study is that it is not possible to definitively conclude that the results of the different studies are unbiased even when there is close agreement in their estimated values. The correlation in the parameter estimates derived by different methods may occur because all methods used have biases in the same direction (Steffe 2015). Further, disagreement between parameter estimates provides no insight regarding which of the methods being compared is most accurate.

A corroboration study can have the following features:

(a) Data can be verified by direct observation and contact with potential fishing parties;

(b) Full or limited spatial coverage of the selected fishery;

(c) Relatively high or low levels of sampling intensity (temporal coverage across Primary Sample Units);

(d) Partial coverage of the Primary Sample Units (PSUs) that are randomly selected. This is usually done by stratifying periods within days or by implementing a survey design that treats periods within days as second stage sample units that can be selected with either equal or non-uniform probabilities. This means that within PSU expansions are necessary prior to estimation of stratum totals thereby potentially introducing a source of sampling error.

The Recreational Fishing from Boat Licence (RFBL) was introduced in 2010 and is the sampling frame for comprehensive biennial state-wide surveys of boat-based recreational fishing in Western Australia (Ryan et al. 2015). This integrated survey includes three complementary components: (a) off-site telephone surveys using the RFBL sampling frame, with an initial screening survey to recruit diarists for a 12 month longitudinal Phone-Diary survey, followed by post-enumeration surveys to detect differences among licence holders (wash-up/attitudinal, non-intending fisher and benchmark surveys); (b) on-site boat ramp surveys to provide biological information (including a state-wide biological survey to collect length/weight information); and (c) remotely operated cameras at key boat ramps to monitor launches and retrievals (24 hour per day coverage) during the 12 month Phone-Diary survey period (Ryan et al. 2015). Currently, camera data are used as ramp-specific indices of fishing effort to corroborate the effort estimates generated by the off-site surveys.

Objective 8 –Validate estimates of recreational fishing effort from another independent survey

A validation study is better than a corroboration study for the assessment of bias. A validation study uses two or more independent methods to estimate some population parameter and one method is used as a "gold standard" (Steffe 2015). The "gold standard" method provides unbiased information that is then used as validated reference point to evaluate potential bias from the other methods being compared. Ideally, a "gold standard" method would provide a census of the population with no measurement error so that the parameter of interest is known exactly. However, this is too costly or logistically impossible to implement in most cases, which is why sampling theory was developed and probability-based sample surveys are used (Cochran 1977, Groves et al. 2009, Thomson 2012). A practical solution is to design and implement a probability-based survey that minimises all sources of potential bias (Steffe 2015). This type of "gold standard" survey has the following features:

(a) Data can be verified by direct observation and contact with potential fishing parties;

(b) Full spatial coverage of the selected fishery;

(c) High level of sampling intensity (temporal coverage across Primary Sample Units);

(d) Full coverage of the Primary Sample Units that are randomly selected.

Steffe (2015) provides a detailed description of corroboration and validation studies and the features of a practical "gold standard" survey for a recreational fishery. To date, there have been no validation studies done for any recreational fishery in Western Australia.

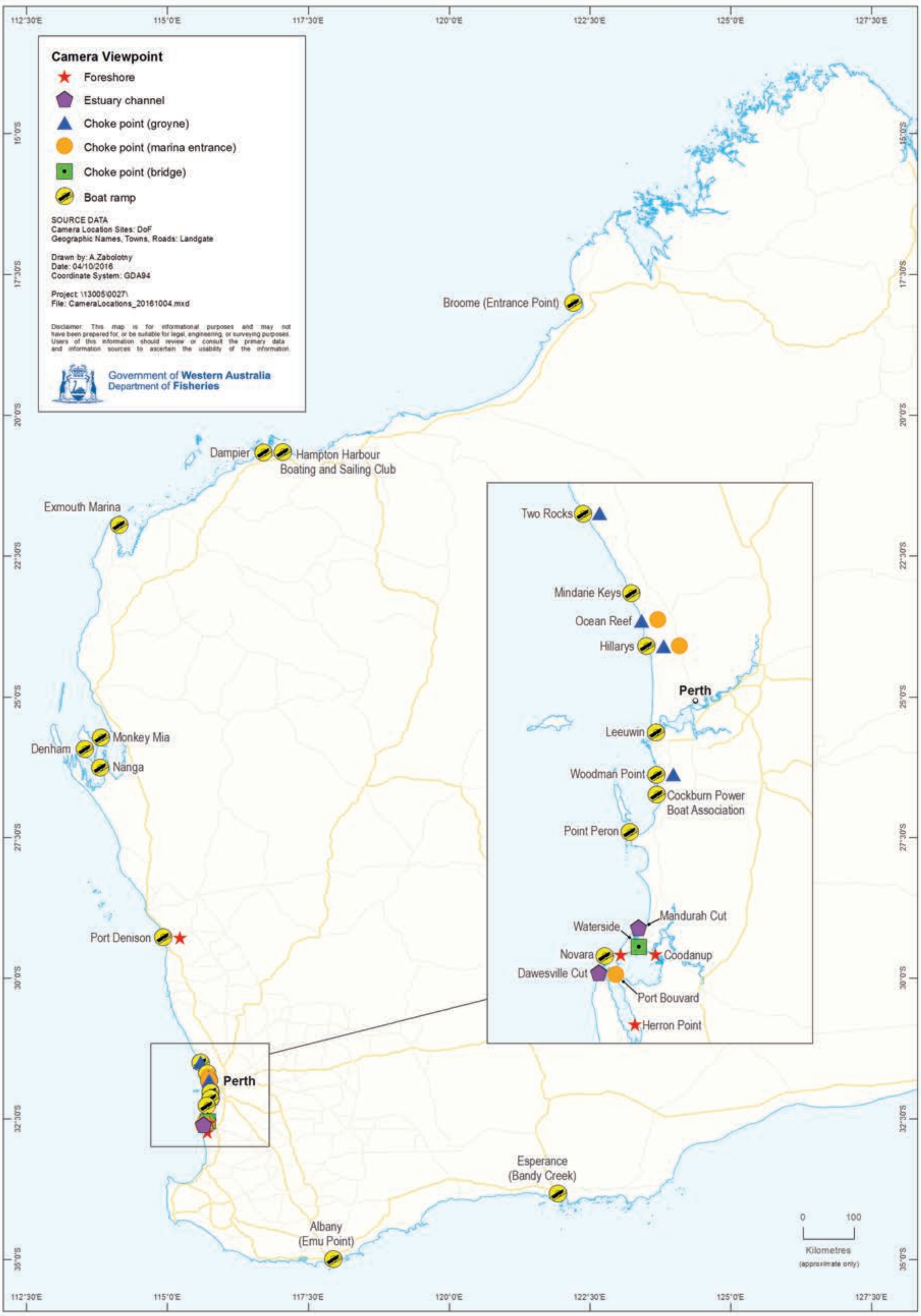

Figure 1. Locations where remotely operated cameras have been used to monitor recreational fishing. The latitude, longitude, and current operational status of each camera is given in Appendix B.

Table 1. Camera viewpoints, monitoring coverage and the recreational fishery being assessed in Western Australia

Camera viewpoint	Monitoring coverage	Recreational fishery
Boat ramp	Recreational vessels (activity unknown) that have been launched or retrieved at a boat ramp (or beach at Broome/Nanga). These cameras mainly monitor public boat ramps that have multiple lanes.	Marine boat-based
Choke point (estuary channel)	Recreational vessels (activity unknown) that have entered into or exited from an estuary via a channel entrance. These cameras monitor private and public vessel movements from ramps, marinas, boat stackers and private waterfront dwellings.	Marine boat-based
Choke point (marina entrance)	Recreational vessels (activity unknown) that have entered into or exited from a marine fishery via a marina entrance. These cameras monitor private and public vessel movements from ramps, marinas, boat stackers and private waterfront dwellings.	Marine boat-based
Choke point (groyne)	People (activity unknown) that pass a specified line to access or leave a groyne area.	Coastal shore-based
Choke point (bridge)	People (activity unknown) that pass a specified line to access or leave a bridge.	Coastal shore-based
Foreshore (Shallow flats & shore)	People (activity unknown) that enter or leave a specified area of shallow water in an estuary.	Estuarine, shallow water crab fishery accessed from shore

4 Approaches for integration of camera information into recreational fishing surveys

Recreational fishing projects within DPIRD mainly use camera data to gain a better understanding of the temporal variability of recreational fishing activities whilst assuming that there is strong correlation between the distribution of general activity patterns and the behaviour of recreational fishers. Camera information usually consists of counts of vessels (i.e. launches, retrievals, direction of travel past a choke point) or counts of people accessing a defined area (i.e. shore-based people accessing a groyne or scooping crabs in shallow estuarine waters). These count data do not positively identify the activity that is in progress and are only indices of fishing effort. Thus, there is a need to adjust these data to account for non-fishing activities. Similarly, when fishing effort information is required for a specific type of fishing activity (e.g. rock lobster fishing) the camera data need to be adjusted to account for non-fishing and other types of recreational fishing (e.g. line fishing). The most important metrics that need to be adjusted for vessel monitoring are the number of boat retrievals (boat ramp viewpoint) and the number of returning vessels (choke point viewpoint) because these represent measures of completed fishing trips and are consistent with data collected during on-site surveys. The shore-based metrics that need adjustment are: (a) the number of people that have completed their fishing trips (choke point viewpoint – groyne and bridge); and (b) the number of people that are actively participating in the recreational fishery within the area being monitored (shallow flats and shore viewpoint – trips in progress).

Adjusted camera data also enable the validation of estimates of recreational fishing effort obtained from different independent surveys. For example, estimates of recreational fishing effort for Perth metropolitan ramps obtained from the off-site state-wide survey of boat-based recreational fishing (Ryan et al. 2015) can be compared against validated estimates of fishing effort derived from a census of adjusted camera data (assuming zero outages and after accounting for non-fishing boating activity). This simple step improves the quality of the camera information to enable the implementation of validation studies rather than corroboration studies.

Better integration of camera information into recreational fishing surveys requires a change in the design approach used when planning surveys. Camera technologies and the data they provide should be core components of a survey. On-site surveys should all be designed with the intent of using adjusted camera data in the estimation of recreational fishing effort. This means that all complementary surveys that use independent methods to estimate catch by combining estimates of catch rates (i.e. obtained from roving, bus route, traditional access point and supplemented designs) and fishing effort (i.e. obtained from adjusted camera data) will have improved levels of accuracy and precision. Also, fishing effort estimates made using camera data that have been adjusted to account for non-fishing boating activity can be used as “gold standard” benchmarks to evaluate the accuracy and potential bias in estimates of fishing effort derived from other survey methods, particularly off-site surveys such as the state-wide survey of boat-based recreational fishing.

The design of on-site surveys of specific recreational fisheries (e.g. rock lobster) can be improved by including sampling that allows camera data to be corrected for non-fishing and other types of recreational fishing that are not targeted at rock lobster. This type of survey design would enable the calculation of rock lobster harvest by combining the estimates of recreational fishing effort for rock lobster (obtained from supplementing on-site sampling with the camera data) and estimates of directed harvest rates (obtained from on-site surveys). Supplemented survey designs have been shown to improve both accuracy and precision of fishing effort and catch estimates (Steffe et al. 2008).

The collection of weight information for estimation of recreational fishing harvest (obtained from off-site surveys) is currently achieved by a targeted sampling program (Smallwood et al. 2017). This sampling program is designed to target peak periods of recreational fishing activity to maximise interviews with fishing parties and hence maximise the collection of weight data. This sampling regime assumes that the weight data collected during peak periods of recreational fishing activity are representative of the entire fishery. The sampling program can use adjusted fishing effort information from camera monitoring to design and implement a non-uniform probability sampling program. This revised sampling regime would still allocate most of the sampling to periods of peak fishing activity whilst providing some limited coverage of other periods. The non-uniform probability sampling regime offers an option that is designed to minimise the potential bias of a fully targeted, non-probability, sampling program whilst providing more data than a simple randomised sampling program.

5 Sampling strategies for camera information

The relative costs of the various components of a camera monitoring are described in Table 2. The largest cost is attributed to the reading and interpretation of video/images (Table 2). If all of the video/images from the 28 currently operational cameras were read (i.e. a census) it would cost in excess of $200K. Cost effective sampling strategies are proposed for the camera program (Table 3).

Sampling strategies are largely dependent on the monitoring objectives (Table 3). Validation studies that compare fishing effort estimates derived from a “gold standard” survey to estimates derived from another independent survey method requires the reading of all available camera data and adjustment for non-fishing trips. Similarly, the best outcome from a supplemented survey design (see Steffe et al. 2008) is achieved when a census of camera data is used. It is still possible to obtain improved accuracy and precision for estimates of recreational fishing effort and harvest derived from a supplemented survey design without using a census of camera data. However, the performance of the supplemented survey design continues to improve as the sampling fraction of camera data is increased. All other monitoring objectives can be adequately addressed by an appropriate probability-based sampling approach, usually a stratified random sampling design (Table 3). The sampling fractions presented in Table 3 are intended to provide broad guidance of the sampling intensity that would be needed to address different monitoring objectives. Cost-benefit analyses (Cochran 1977) should be done on a case-by-case basis to determine optimal sample sizes for different monitoring objectives and budgets.

Public holidays (e.g. Easter and Christmas) have the potential to greatly influence variability within a stratum thus the mandatory reading of public holidays must be done and treated as a fixed cost in any sampling approach. A stratified random sample of days should then be drawn from the revised sampling frame of available days. The entire sample unit (i.e. day) should be read and sampling fractions within each stratum should be greater than 10% to allow use of a finite population correction factor to minimise measures of precision (Cochran 1977, Pollock et al. 1994, Groves et al. 2009). Cost-efficient sampling can also be achieved by considering the adoption of different levels of temporal stratification for different studies. For example, a fishery that is restricted to part of a year may require monthly stratification whereas a larger fishery may only need seasonal stratification.

Table 2. Relative costs of important components in a camera monitoring program

Cost Component	Description	Relative Cost
Purchase and installation of equipment	Camera gear, computers, routers, aerials and setting up the monitoring system	Medium
Maintenance and on-going costs	Internet, routine online checks to ensure cameras are operating, travel for equipment maintenance and responding to equipment failures and vandalism	Medium
Reading video/images and data entry	Interpretation of video/images and data entry	High
Database management and on-going data storage	Cameras generate high volumes of data that need to be secured, accessible for analyses and archived for long-term storage	Medium
Quality management plan	Implementation of quality assurance and quality control. Documentation of metadata.	Low
Data analyses and report writing	Scientists and managers analyse data and document results	Low
Extension of results to stakeholders	Provide data extracts and analysis summaries to internal and external stakeholders	Low

Table 3. Monitoring objectives and recommended sampling strategies for camera data

Monitoring objective	Recommended sampling strategy
1. Initial assessment of the relative magnitude of fishing effort in a data-poor fishery	Small probability-based sample (5-10% coverage of full PSU's)
2. Index of fishing effort	Medium probability-based sample (10-75% coverage of full PSU's)
3. Estimate fishing effort	Medium probability-based sample (10-75% coverage of full PSU's)
4. Describe patterns of fishing effort that occur at different temporal scales	Small to medium probability-based sample (5-75% coverage of full PSU's)
5. Supplement an existing on-site survey design by increasing coverage for fishing effort of the temporal frame	Census preferred but large probability-based sample (75-100% coverage of full PSU's) can be used
6. Expand an existing survey design by including an additional monitoring component that provides coverage of night-time fishing effort	Medium probability-based sample (10-75% coverage of full PSU's)
7. Corroborate estimates of fishing effort from another independent survey	Census preferred but large probability-based sample (75-100% coverage of full PSU's) can be used
8. Validate estimates of fishing effort from another independent survey	Census (100% coverage of full PSU's)

6 Quality management plan

It is important to develop and implement a quality management plan for the camera projects. An effective quality management plan can: (a) increase the success of projects that use camera data; and (b) provide greater levels of stakeholder confidence in the methods, results and outcomes of projects. A quality management plan consists of two main parts: quality assurance (QA) and quality control (QC). Quality assurance provides processes, standards and procedures that are appropriate for different projects and is used to manage and deliver quality data capture, analysis and interpretation from cameras. Quality control provides a series of checks that measure how well the project processes, standards and procedures are implemented and perform. Thus, QC is used to verify the quality of the data capture, analysis and interpretation.

Quality management issues encountered when working with camera data are very similar to those identified by researchers reading otoliths in fish ageing studies. Campana (2001) provides a detailed review of QA/QC as it is applied in fish ageing studies and some aspects of the integrated quality management plan outlined below have been adapted from that work. There are four main parts of an integrated quality management plan for camera imagery and video work. These are: (1) development, justification and documentation of data capture methods; (2) validation of the data that are captured; (3) quality management monitoring; and (4) quality management reporting.

Projects that use camera data will adopt the following QA/QC elements.

(1) Development, justification and documentation of data capture methods;

It is important to develop, justify and document the data capture methods used. Clear articulation of the data capture method used and the reasons for selecting that method will provide the basis for periodic methodological reviews and on-going improvements in long-term monitoring programs. Table 4 provides a brief description of the information (metadata) needed for each project that uses camera data capture.

(2) Validation of the data that are captured;

The scientific credibility of the camera information depends on validation of the data. There are many variables that may influence the coverage and accuracy of camera data. For example, weather conditions (i.e. heavy rain, fog, strong winds, sun glare) can alter visibility of monitoring targets. Uncorrected visibility biases can negate the benefits derived from other quality control procedures (e.g. duplicate video reading will provide a false indication of unbiased consistency). Keller et al. (2016) estimated recreational fishing effort in a nearshore area that had an artificial reef. Data from digital images were corrected for visibility bias by using information from a validation study that covered all types of weather conditions. Keller et al. (2016) found that the visibility bias (if uncorrected) would have led to underestimates of fishing effort of about 7.5%. This example shows that it is vital to validate the data.

(3) Quality management monitoring

Quality management monitoring is needed across all areas of a project and can be divided into four main components: (a) operational issues; (b) office-based data capture and standardised data interpretation; (c) data entry issues; and (d) missing data arising from camera outages.

(a) Operational issues

Ideally, remotely operated cameras operate continuously (24 hours per day over many years). The video/image data collected represent an invaluable collection of historic information that need to be securely stored and archived. Failure to safely store video/image information will seriously undermine the ability to monitor long-term trends in recreational fishing activity. Thus, it is important to implement a secure system that stores the large amounts of information as they are collected. This should be done prior to any video/image inspection and interpretation. This system would provide time for informed decisions to be made regarding whether to census or subsample the video/image data and to organise the long-term archiving of the camera information.

Remotely operated cameras can fail occasionally and these outages can occur for a variety of reasons. Operational quality management is focused on maintaining and upgrading equipment to minimise outages. Long-term monitoring programs need to allocate staff time and resources to implement a periodic field-based maintenance schedule and to regularly monitor the functionality of remotely operated cameras from an office-based computer. It is possible for equipment failures in remote locations to remain undetected for many months and the failure to detect and fix the problem may impact adversely on a project. Regular (weekly) checks to see if camera data are being received are sufficient for most projects. Ideally, cameras should be checked daily whenever used for validation studies or as part of a supplemented survey design that relies on double sampling to improve the accuracy and precision of estimated recreational fishing effort and harvest.

(b) Office-based data capture and standardised data interpretation

It is vital that the capture of data elements from camera videos and images is consistent among different staff and through time. This issue is particularly relevant for any long-term monitoring program that has high volumes of video footage and uses different viewpoints to monitor different fisheries. This issue can be addressed by using a reference set of videos/images for each site that is monitored. The reference set of videos/images can be used to: (a) train new staff; (b) ensure video/image reading consistency among staff and through time; and (c) promote stakeholder confidence in the results of any project that uses camera data.

Reference sets of videos/images for each monitored site should be compiled by a group of experienced video/image readers so that they contain a known, consensus-derived, number of data elements. Reference sets should include examples of different weather conditions and levels of activity. Annotated reference sets can be used to provide feedback to staff regarding interpretations of boat types and other in-scope data elements. Periodic viewing of a randomly drawn subset of the reference set should be encouraged to avoid gradual changes in interpretation through time. Video/image readers should also use the reference sets before starting work on different sites or when returning to work after a substantial break (e.g. annual leave). The regular usage of reference sets to maintain consistent reading/interpretation of data elements has the added cost-saving benefit of removing the need to use duplicate independent readers to verify video/image reading accuracy. It is important to continually update reference sets so that they include new examples to test readers of all experience levels.

(c) Data entry issues

There are two types of data entry issues that need consideration. The first type of data entry into a database occurs when a staff member has completed reading a video. Standard data checks that are routinely used across many different projects can be used to ensure the accuracy of this manual data entry. The second type of data entry occurs when an automated system (e.g. artificial neural network software) identifies an in-scope data element and inputs a record into a database. Verification of the accuracy of the identification of data elements is needed.

(d) Missing data arising from camera outages

Regular camera maintenance and checks will be useful for minimising camera outages (i.e. equipment failures that cause data to be lost). However, unpredicted camera outages will always occur. These missing data can have large impacts on projects, particularly validation studies and studies that use supplemented survey designs. Camera outages vary in duration with different impacts on data quality. The challenge faced by project managers is how to impute values to replace missing data.

In situations where camera data are critical to the success of a project it would be prudent to use two independent cameras (i.e. cameras that are placed on different vantage points and use different power sources) to monitor the fishery. However, this may not be possible at some remote sites. Alternatively, it may be possible to use data from camera monitoring at nearby sites (i.e. clusters of cameras subject to similar weather conditions) to impute values for missing data at the main site of interest. Consideration should be given to ensuring that important sites are not monitored in isolation but also have at least one other camera within that cluster.

The development of a suitable imputation method for camera data used in recreational fishing survey projects in Western Australia has been identified as a priority research objective. There are many different methods that can be used to impute missing values (e.g. Hartill et al. 2015, van Poorten et al. 2015) but all methods are imperfect because they rely on assumptions that often cannot be tested. The preferred imputation method would utilise the correlation in counts taken from adjacent sites within a cluster and possibly account for weather conditions.

(4) Quality management reporting

The final part of a sound quality management plan involves regular evaluation and reporting on program performance and progress. A long-term monitoring program that has multiple monitoring sites would benefit from producing an annual status control report. This report would include annual reports on sites monitored, details of data collected and processed, outages, analyses and imputations done, data available to the public, summary graphs of important monitoring metrics, and brief descriptions of quality management measures undertaken for different projects. Thus, the status control report becomes an important metadata document that demonstrates the utility of the camera program and justifies the expenditure of departmental funds on this program. The annual status control report can also be used to respond to stakeholder requests for information and their concerns regarding the progress of specific projects.

Table 4. Information needed to document details and justify selection of data capture methods

Information needed	Relevance
Viewpoint	Different viewpoints may require different data capture methods.
Monitoring objective	Different monitoring objectives may require different data capture methods.
List of reading options and justification of option choice	Multiple options may be available for capturing data e.g. read whole video, read subsamples of video every x minutes or y hours, automated reading process (i.e. artificial neural network software) vs trained persons. Justification of the option selected provides transparency and allows critical evaluation of methods.
List of data elements that are recorded	Many different data elements may be recorded per image/video e.g. launches, retrievals, boat types (power, kayak, commercial), persons in an area, persons entering or leaving an area.
Rules that define the detection and recording of data elements	Rules that define when a data element is in-scope and should be recorded are important for ensuring consistency among readers.
Measured units for each data element	It is important to avoid unit mismatch problems at the analysis stage. Clear articulation of units is important e.g. angler hours, party hours, trips (activity unknown).
Proposed analysis method	Are the data collected adequate for the proposed analyses? This important question needs to be answered at the start of a project.
Documentation of the data capture protocols for each camera	Important for long-term consistency. Clear documentation provides the basis for methodological review and ongoing improvement.

7 Long-term program planning issues

The success of a long-term monitoring program relies on sound planning that identifies important issues that can adversely impact on the success of projects and implements strategies to mitigate these impacts. Important issues to be considered are the: (a) allocation of appropriate resourcing to the monitoring program – this includes dedicated staff positions and operational budgets (i.e. equipment maintenance, data storage and archiving, travel and staff training); (b) testing and adoption of new technologies (i.e. the utility of thermal imaging cameras is still being explored and methods of thermal image reading and interpretation are still being developed); and (b) succession planning to ensure the agency retains capability and capacity to deliver quality project outcomes.

8 Framework for improving integration of camera information into recreational fishing survey projects

Camera information can be very useful for addressing many different monitoring objectives and has the potential to enhance the success of many different types of recreational fishing surveys. However, there is a common perception that camera monitoring only involves installing some cameras and reading some video/images. This simplistic view is incorrect. A framework for evaluating the utility of camera monitoring programs in meeting project and monitoring objectives and for integrating camera information into recreational fishing surveys is presented in Fig 2. This is done to enable researchers and managers to assess the utility of proposed monitoring before the start of a project and to provide guidance for decision-making throughout all phases of a project.

The framework (Fig. 2) covers the following broad areas: (1) project description; (2) survey design and sampling strategy; (3) feasibility and logic checks for proposed analyses; (4) survey implementation, data analyses and reporting; and (5) listing project outputs and project outcomes. An overarching Quality Management Plan (see section 5) should be used during all phases of a project to achieve and maintain quality and confidence in the results produced by camera monitoring.

(1) Project description

This part of the framework (Fig. 3) focuses on describing the main project and how the camera data are intended to be used within it. Project description requires: (a) that the main project objectives are defined (e.g. the project intends to deliver estimates of recreational fishing effort and catch); (b) clear articulation of the monitoring objective; (c) selection of an appropriate camera viewpoint; (d) statement defining monitoring coverage (in-scope data elements) and exclusions (out-of-scope data elements); and (e) assessments of whether the proposed monitoring coverage can adequately address the stated monitoring objective and, if so, can the proposed monitoring coverage address the stated main project objectives. This process should be completed before the start of a project.

(2) Survey design and sampling strategy

This part of the framework (Fig. 4) documents details of the survey design and sampling strategy to facilitate an assessment of the effectiveness of the proposed work for adequately meeting stated objectives. Clear statements are needed to define: (a) the proposed survey design; (b) the sampling frames (i.e. spatial and temporal units for on-site survey); (c) the sampling units (primary and any other multi-stage units); (d) the levels of stratification; (e) the selection probabilities for sample units; (f) the proposed sample sizes. This information can then be used to assess whether the proposed survey design and sampling strategy can adequately deliver the data needed to address the stated main project objectives. Sampling strategy assessment and decisions should be completed before the start of a project.

(3) Feasibility and logic checks for the proposed analyses

It is important to know that the monitoring data that are to be collected can be integrated into a survey analysis (Fig. 5). It is vital to check that there are no mismatches in the primary sample units in a complemented survey analysis or the reporting units (e.g. fisher hours, party hours, trips) for different survey components. Consideration should also be given to using a dummy dataset to test the feasibility of any proposed survey analysis, particularly with respect to the estimation of appropriate measures of precision (i.e. variances, standard errors and confidence limits). These feasibility and logic checks should be completed before the start of a project.

(4) Survey implementation, data analyses and reporting

This part of the framework covers the data collection, interpretation, analysis and reporting period of the concurrent on-site survey project. There are many published textbooks and guidelines that can be used to assist in this phase of the project (Cochran 1977, Pollock et al. 1994, Groves et al. 2009, Jones and Pollock 2012, Thomson 2012). It is imperative that close attention should be paid to Quality Management issues during this phase of the project and that continual improvements be made to the Quality Management Plan as necessary.

(5) List project outputs and project outcomes

This part of the framework (Fig. 6) is important for evaluating the role of camera data for informing and achieving better management decisions. The documentation of outputs and the evaluation of outcomes are important for increasing internal and external recognition of the value of the camera program and for justifying the Department's investment in this program. The final role of the framework is to facilitate the review of completed survey projects, update the Quality Management Plan, and note potential improvements for future survey projects.

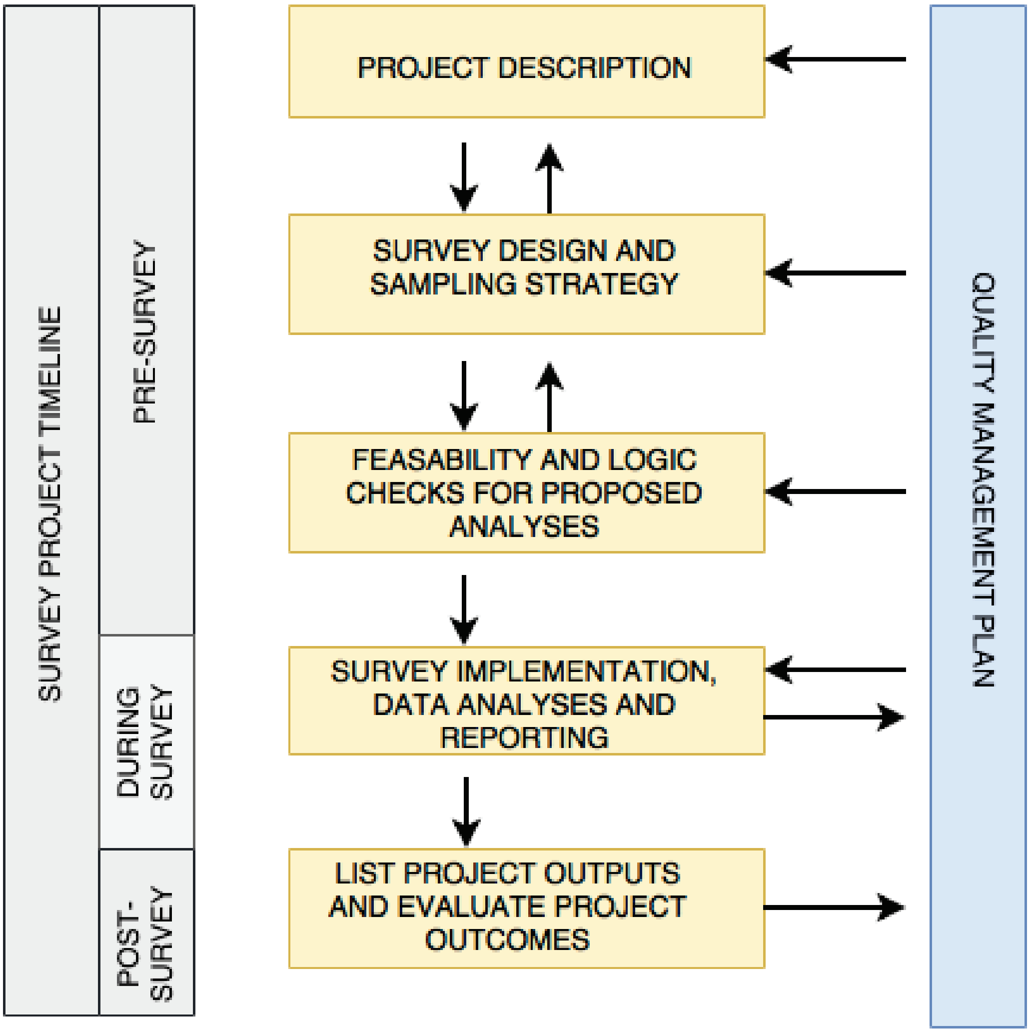

Figure 2. Schematic representation of a framework for improving the integration of camera-derived data into recreational fishing surveys

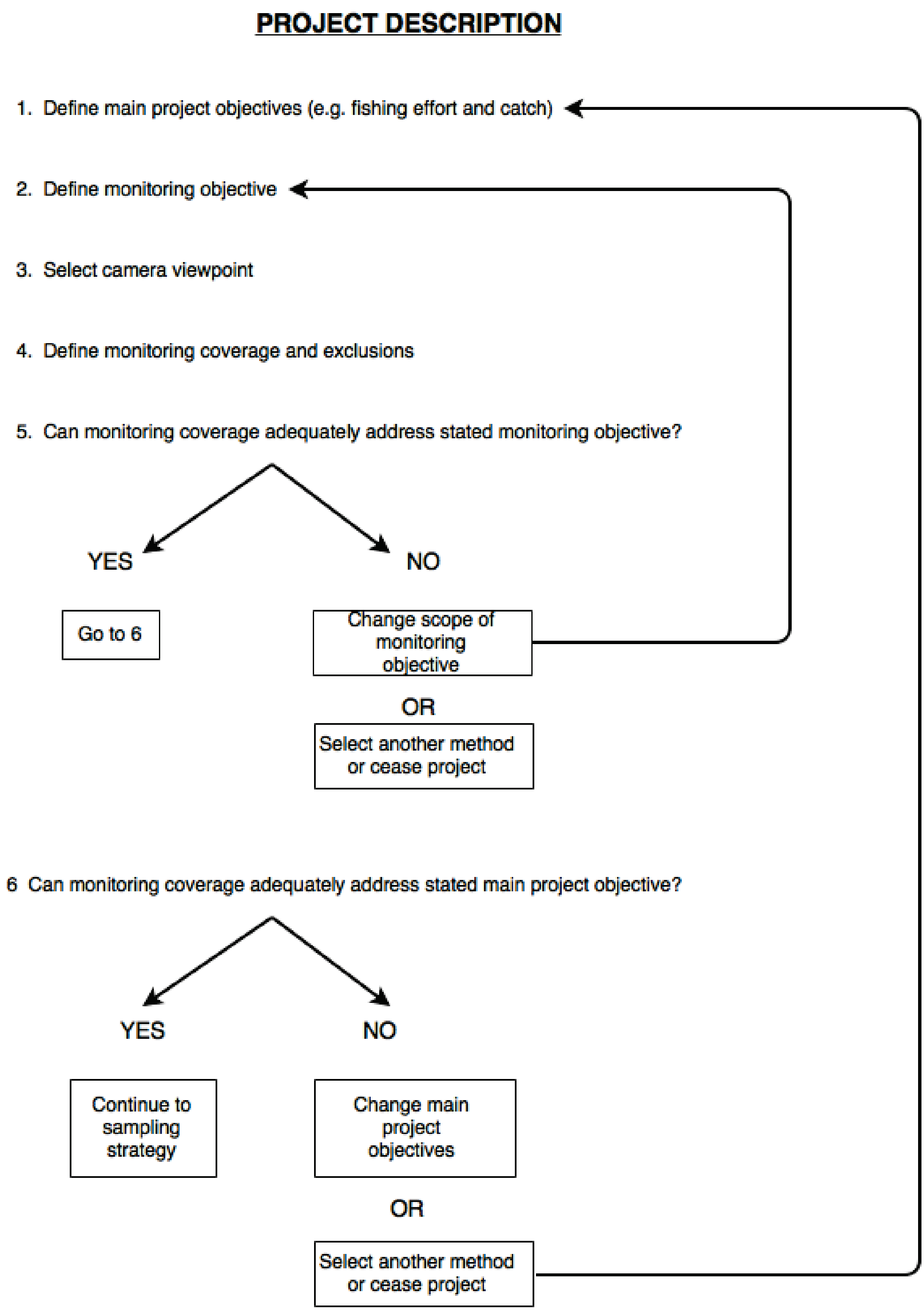

Figure 3. Schematic representation of the project description part of the framework

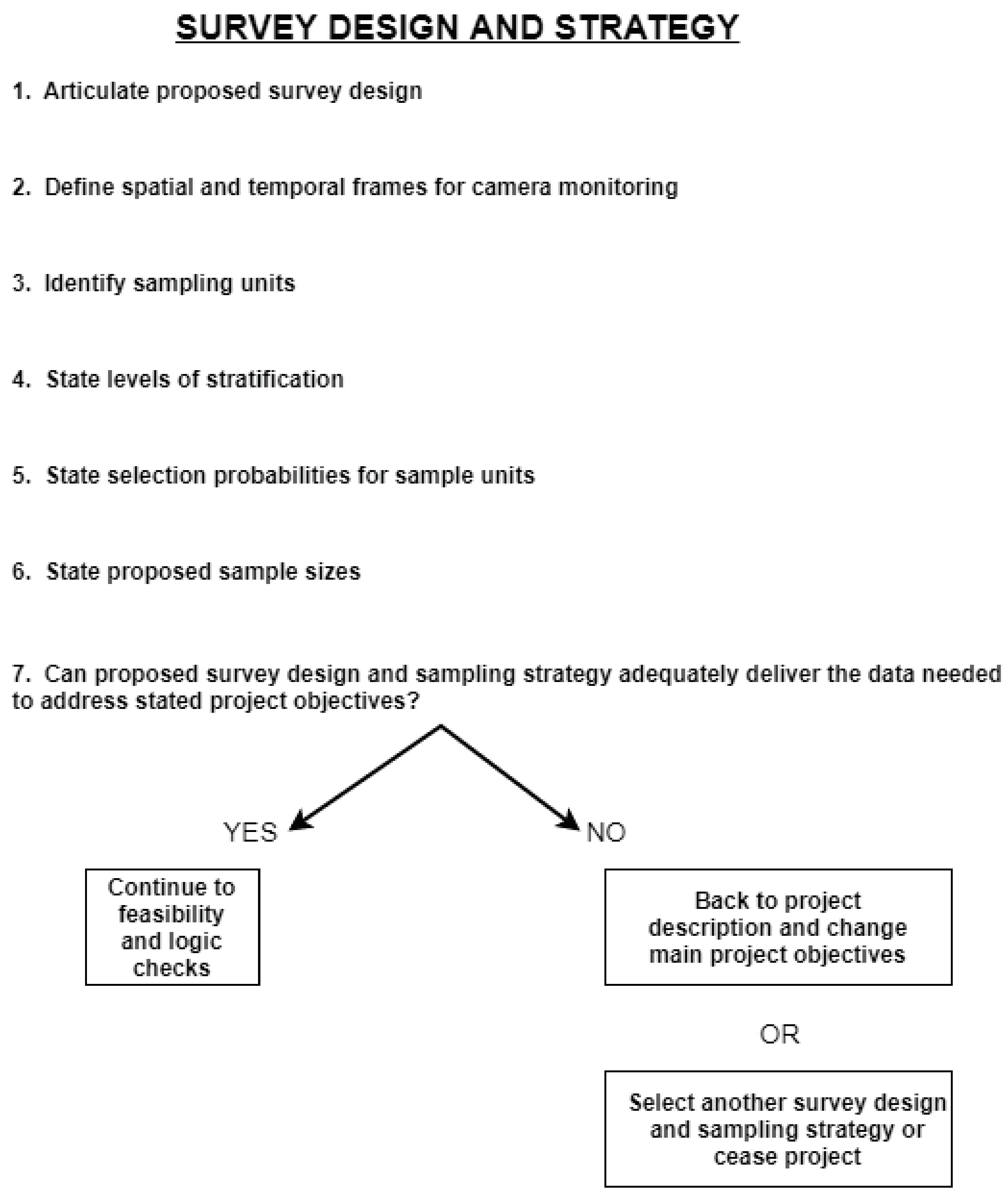

Figure 4. Schematic representation of the survey design and sampling strategy part of the framework.

FEASIBILITY AND LOGIC CHECKS FOR PROPOSED ANALYSES

1. Check for mismatches in PSU's between the different components of the survey contact methods used

2. Check for mismatches in the reporting units used for the metrics derived from the different survey contact methods

3. Test the feasibility of the proposed analyses by using a dummy dataset

4. Can the proposed analyses be done?

5. State selection probabilities for sample units

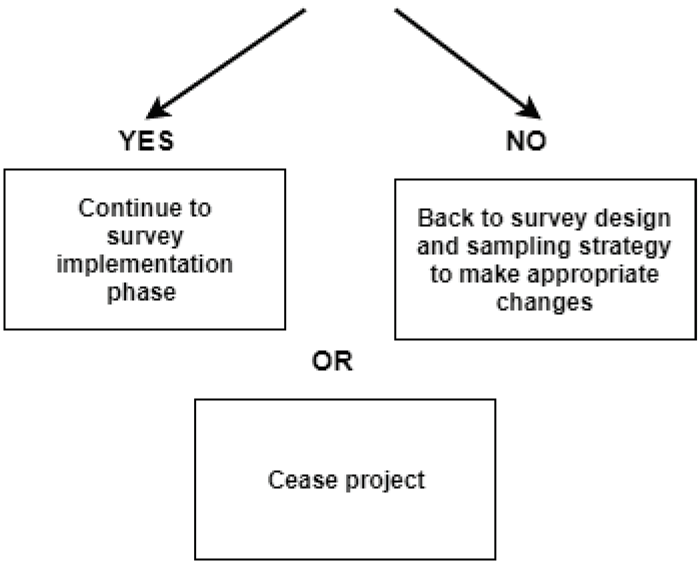

Figure 5. Schematic representation of feasibility and logic checks for proposed analyses.

LIST PROJECT OUTPUTS AND EVALUATE PROJECT OUTCOMES

1. Maintain list of reports and peer-reviewed publications

2. Document stakeholder requests for information

3. Document the management issues that have been addressed with the information from projects that have used camera data

4. Document the role of the management advice arising from the project for achieving management outcomes:

   (a) Was the camera-derived information influential in determining the management action that was adopted?

   (b) Was the management action successful in resolving the management issue?

5. Review survey projects, update the Quality Management Plan, and note potential improvement for future surveys

Figure 6. Schematic outline of project outputs and project outcomes part of the framework.

9 Conclusions

Remotely-operated cameras can be a cost-efficient tool for monitoring recreational fishing activities. Monitoring information has great potential for improving the accuracy and precision of estimates of recreational fishing effort and harvest from some on-site survey designs. Also, camera information (when adjusted to account for non-fishing activities) can be used as a "gold standard" benchmark to evaluate the accuracy of estimates of recreational fishing effort from off-site surveys (such as the state-wide survey of boat-based recreational fishing). This report provides a framework for further integration of camera information into recreational fishing survey projects. The implementation of this framework requires a change in the way surveys are planned and designed. Camera monitoring when used as a core component of any recreational fishing survey design will improve the accuracy and/or precision of fishing effort estimation enabling the provision of better information for management needs.

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12 Appendix A. Other departmental and stakeholder projects that access camera information.

Stakeholder	Used for	Frequency of use
Regional Services (DPIRD)	Investigations, scheduling shifts	Weekly/Monthly*
Department of Transport	Planning/Infrastructure	3-6 months
Sea Search and Rescue	Safety/Investigations	3-6 months
Western Australian Police and Federal Police	Safety/Investigations	3-6 months
Universities	Research	6-12 months
Environmental consultancies	Research	6-12 months
Local Government	Planning/Infrastructure	6-12 months
Department of Parks and Wildlife	Planning/Infrastructure	6-12 months

* Some Regional Services staff access live feeds of the cameras on a weekly basis.

13 Appendix B. Location and viewpoint for cameras installed by the Department of Primary Industries and Regional Development

Camera	Camera Viewpoint	Cluster	Latitude (DD)	Longitude (DD)	Active? Y/N
Broome	Boat ramp	North	-18.007	122.209	Y
Hampton Harbour Boating and Sailing Club	Boat ramp	North	-20.663	116.703	Y
Dampier	Boat ramp	North	-20.656	116.707	Y
Exmouth	Boat ramp	North	-21.956	114.139	Y
Denham	Boat ramp	Shark Bay	-25.928	113.533	Y
Monkey Mia	Boat ramp	Shark Bay	-25.793	113.720	Y
Nanga	Boat ramp	Shark Bay	-26.255	113.805	Y
Port Denison	Boat ramp	Mid-West	-29.275	114.919	Y
Port Denison	Foreshore	Mid-West	-29.275	114.919	Y
Two Rocks	Boat ramp	Metro North	-31.499	115.585	Y
Two Rocks	Choke point (groyne)	Metro North	-31.499	115.585	N
Mindarie	Boat ramp	Metro North	-31.692	115.703	Y
Ocean Reef	Choke point (marina entrance)	Metro North	-31.759	115.728	Y
Ocean Reef	Choke point (groyne)	Metro North	-31.759	115.728	N
Hillarys	Boat ramp	Metro North	-31.821	115.739	Y
Hillarys	Choke point (marina entrance)	Metro North	-31.821	115.739	Y
Hillarys	Choke point (groyne)	Metro North	-31.821	115.739	N
Leeuwin	Boat ramp	Metro South	-32.029	115.763	Y
Woodmans Point	Boat ramp	Metro South	-32.138	115.763	Y
Woodmans Point	Choke point (groyne)	Metro South	-32.138	115.763	N
Cockburn Power Boat Association	Boat ramp	Metro South	-32.138	115.763	Y
Point Peron	Boat ramp	Metro South	-32.271	115.699	Y
Mandurah Cut	Estuary channel	Mandurah	-32.536	115.717	Y
Novara	Boat ramp	Mandurah	-32.573	115.675	Y
Novara	Foreshore	Mandurah	-32.573	115.675	Y
Waterside	Choke point (bridge)	Mandurah	-32.549	115.720	Y
Coodanup	Foreshore	Mandurah	-32.570	115.761	Y
Herron Point	Foreshore	Mandurah	-32.740	115.711	Y
Port Bouvard	Choke point (marina entrance)	Mandurah	-32.612	115.645	Y
Dawesville Cut	Estuary channel	Mandurah	-32.607	115.640	Y
Albany	Boat ramp	South	-34.995	117.944	Y
Bandy Creek	Boat ramp	South	-33.831	121.936	Y