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**S. Twiname, J.M. Lyle, R. Pearn, S.R. Tracey, K. Hartmann & N.C. Krueck**

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# Abbreviations

| | |
|---|---|
| App | Smartphone application |
| CPUE | Catch Per Unit Effort |
| DPIPWE | Department of Primary Industries, Parks, Water and Environment |
| ECSRS | East Coast Stock Rebuilding Strategy |
| ECSRZ | East Coast Stock Rebuilding Zone |
| IMAS | Institute for Marine and Antarctic Studies |
| ISL | Individual Season Limit |
| RecFAC | Recreational Fishery Advisory Committee |
| RLCMT | Rock Lobster Catch Monitoring Trial (smartphone application) |
| SMRCA | Sustainable Marine Research Collaboration Agreement |
| TAC | Total Allowable Catch |
| TACC | Total Allowable Commercial Catch |
| TARC | Total Allowable Recreational Catch |

# Executive Summary


**Background**

Southern Rock Lobster is an important fishery species in Tasmania, with the commercial sector harvesting approximately 1000 t per year to a landed value of approximately $90 million. The recreational sector, with more than 18,000 licensees, harvested more than 80 t in the 2020/21 season. Lobsters are also taken as part of Indigenous cultural activities and by Indigenous individuals – thought to be represented by more than 1000 participants. Due to concerns about declining stocks in the late 2000s and a record low estimate of stock status in 2011/12 (Hartmann et al. 2013), a formal stock rebuilding strategy was implemented in 2013 for the east coast of Tasmania (DPIPWE 2013). The East Coast Stock Rebuilding Strategy aims to limit the total catch of both the commercial and recreational sectors in the East Coast Stock Rebuilding Zone (ECSRZ), which spans three stock assessment areas in this region. The catch limit was further formalised into a non-legislated catch sharing arrangement for the two sectors based on historical usage, where, of the catch for the zone, 79% was allocated to the commercial sector and 21% was allocated to the recreational sector. The catch share arrangement does not apply to the Indigenous sector.

Since this arrangement has been in place, the recreational sector has exceeded its notional limit four times, including an over-catch of 46% in the COVID impacted season of 2020/21 (Lyle et al. 2021). Repeated over-catches indicate that the current management measures in place are not adequately restricting recreational catch in the ECSRZ for the given share. This project was initiated to investigate alternative options to effectively monitor and constrain the recreational rock lobster catch, particularly in the ECSRZ.

**Objectives**

The specific objectives for the project were to:

- Conduct a global literature review to identify alternative monitoring and management options.
- Develop a feasibility assessment of the identified alternative management systems.
- Create a business case for the preferred option, via the implementation of trial of the chosen alternative monitoring and management option.

**Methodology**

A global literature review of published and grey literature was conducted to identify potential alternative monitoring and management practices implemented in other fisheries, in Australia and worldwide (Objective 1). We further contacted local and international fisheries managers to discuss management options implemented in their respective fisheries.

Multiple plausible options for monitoring and management for implementation in Tasmania were selected to be contrasted in the feasibility assessment (Objective 2). For this, we developed a simple but flexible quantitative framework to measure feasibility according to a cost-benefit analysis. Our framework integrated multiple previously identified objectives for both catch monitoring and regulation, and it balanced considerations of implementation costs, effectiveness (in terms of data quality for monitoring, and potential catch savings for management), and acceptability to the recreational fishing sector.

Responding to COVID induced delays and priorities by the partnering management agency, Objective 3 was modified to the fast-tracked development and trial of a smartphone application (app) intended to allow for the potential implementation of an Individual Season Limit (ISL). Trial participants were recruited by contacting recreational rock lobster licence holders, collecting information to determine fishing behaviours, opinions on alternative management options, and to assess eligibility to participate in the trial. Eligible survey respondents were invited to participate in a one-month trial period from 30 March to 30

April 2021. During this period, fishers were encouraged to enter their recreational rock lobster trip data into a newly developed smartphone app, which included pre-trip reporting of the intention to fish, information on the catch location and fishing method, as well as on the actual catch (numbers of lobsters released and kept). A proportion of the fishers participating in the trial were asked to use catch tags in addition to the smartphone app. Once the trial was complete, a feedback survey was sent to participants, collecting feedback on the use of the app and catch tags. Additional questions on alternative monitoring and management methods for the fishery were included in this trial feedback survey as well as the larger 2020/21 recreational rock lobster and abalone survey.

**Key findings**

The literature review identified various alternative options to monitor and regulate recreational catch. However, only some of these were deemed suitable for implementation, specifically considering quantitative results from the feasibility assessment. Self-reporting methods for catch reporting ranked highly due to their potential for real-time monitoring, but to ensure high quality data such methods will likely require substantial additional investments in education, compliance control and data verification, including the continuation of offsite surveys of annual recreational catch that are already in place. To effectively constrain catch in the ECSRZ, a shorter fishing season was identified as highly cost-effective but widely unacceptable. Rel-time monitoring coupled with fishery closure was identified as the only option to rigorously prevent over-catches. However, neither of the above-mentioned options provided for equitable access to the fishery for all fishers. If equitable access to the fishery is a major consideration, the implementation of an ISL could be desirable. However, an ISL required to constrain catch to the notional limit in the ECSRZ might be lower than acceptable for most fishers.

Feedback from the trial found support for both a smartphone app and catch tags. Most users found the app and tags easy to use, with only a small proportion finding them difficult to use. The feedback helped to identify aspects of the app requiring further improvement, as well as issues perceived by fishers about the use of smartphone apps as a general tool for recreational catch data collection. These issues were listed, varying from simple (i.e. concerns around mobile service) to requiring careful consideration before any potential implementation (i.e. privacy concerns). In addition to feedback sought about the use of smartphone apps and catch tags as catch reporting methods, participants were also asked about their opinions about ISLs. Again, the survey found general support for this catch management measure.

**Implications & Recommendations**

This project was developed and conducted in consideration of the existing 79% commercial and 21% recreational catch share arrangement. Since the project commenced the Tasmanian Government has committed not to adjust the daily bag limit or recreational season for the east coast for the 2021/22 recreational fishing season and to work towards a goal of increased share arrangements for the recreational sector. At the conclusion of this project the amount of share for the recreational sector was not redefined.

Independent of associated outcomes, a new management system is needed to ensure that the recreational catch of rock lobsters, specifically in the ECSRZ, is sustainable into the future. Our study provides a qualitative and quantitative assessment of plausible options for monitoring and management to achieve this overarching management goal. Outcomes from this study include the provision of a simple but flexible decision support tool for use by managers to balance multiple and potentially conflicting considerations (costs, effectiveness, and acceptability) to achieve clearly specified management objectives. Our study showed that both the key management objective as well as the relative importance of costs, effectiveness, and acceptability need to be clarified to identify the most suitable option for monitoring and constraining catch in a given management context.

The currently supported option of an ISL, which ranked highly in providing for equitable access, but which may need to be set to unacceptably low levels for effectively constraining catch, requires near real-time

monitoring of individual fishing activities. Our project provides a smartphone app that can be used for this purpose, and which should be tested more rigorously. Positive perceptions about the smartphone app from this study have incentivised a voluntary roll out of the smartphone app for the 2021/22 recreational rock lobster season by the DPIPWE.

***Keywords***

Catch limits, catch tags, *Jasus edwardsii*, recreational fisheries management, recreational fisheries monitoring, smartphone applications, Southern Rock Lobster

# Introduction

Southern Rock Lobster (*Jasus edwardsii*) is a highly valued commercial, recreational and Indigenous species in Tasmania. The commercial sector currently operates under an Individual Transferable Quota (ITQ) system, with 312 licences issued to commercial operators that collectively caught 990 tonnes (t) in the 2020/21 season (DPIPWE 2021a, b). The recreational sector in the same season had approximately 18,500 licenced participants that collectively caught about 82 t state-wide (Lyle et al. 2021). The Indigenous sector has approximately 1000 participants based on the number of Unique Identification Codes (UICs) for lobster pots and rings issued by DPIPWE. However, there is no catch information available for this sector. All three sectors are subject to a range of fisheries management controls, common amongst them being minimum size limits and seasonal closures to protect spawning stocks in certain areas.

**Commercial fishery**

Southern Rock Lobster is one of Australia's most valuable commercial fisheries species. Total commercial harvest in Tasmania amounts to approximately 1000 t and a value of $90 million per year (Lyle et al. 2020b). The commercial sector is managed using a combination of input and output controls, including a quota management system that was introduced in 1998 (Hartmann et al. 2019). The quota management system was introduced following the observation of peak catches in 1985 and a continuous subsequent decline in catch per unit effort (CPUE) in the following years (Figure 1, Hartmann et al. 2019). The quota management system was aimed at stock rebuilding (Ford 2002), which appeared to occur in all assessment zones after it was implemented. The Total Allowable Commercial Catch (TACC) was not substantially altered from 1502.5 t from 1998/99 to 2009. In the late 2000s, stock levels declined dramatically, presumably due to poor recruitment years (Linnane et al. 2010). This resulted in the TACC being lowered to 1470.98 t in 2009/10, 1323.9 t in 2010/11 and 1103.24 t in 2011/12 (Hartmann et al. 2019). In 2014, the TACC was further lowered to 1050.7 t, where it has remained to the current year. The reduction in commercial catch has led to stock rebuilding, resulting in an increase in CPUE over recent years (Hartmann et al. 2019, Lyle et al. 2020b). In addition to the ITQ system and the TACC, the fishery is subject to minimum size limits and seasonal closures.

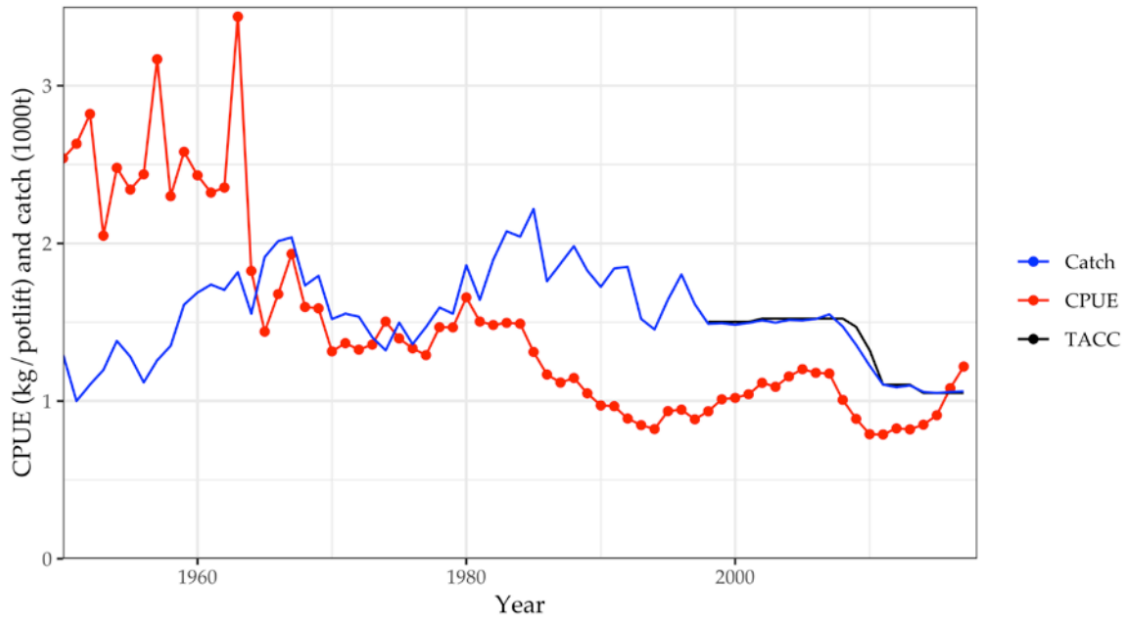


Figure 1. Commercial rock lobster catch, Catch Per Unit of Effort (CPUE), and Total Allowable Commercial Catch (TACC), from Hartmann et al. (2019).

**Recreational fishery**

Tasmania's recreational rock lobster fishery is a licenced fishery with more than 18,000 participants in the 2020/21 season (Lyle et al. 2021). Licences are issued based on the method of fishing, with most fishers purchasing pot licences, followed by dive and ring licences (15,300, 8690, and 4290 licences, respectively, Lyle et al. 2021). The fishery is currently managed using a combination of size limits, daily bag, boat and possession limits, gear restrictions and season closures. The fishery is also subject to a Total Allowable Recreational Catch (TARC) which is equal to 10% of the Total Allowable Catch (TAC) or 170 t, whichever is higher.

The fishery has seen many changes in its management over the years. Licences were first introduced in the late 1970s and consisted of a pot licence and general dive licence that allowed other species (e.g. scallops and abalone) to also be taken. In 1995, the licencing system was changed to reflect the method of fishing, with species specific pot and dive licences issued, later followed by ring licences. From the time this new system was introduced in the 1995/96 season, licence holder numbers have more than doubled from 8,500 to an average of approximately 20,000 licence holders. Licence numbers increased until 2007/08 and have fluctuated since, reflecting, for example, environmental disturbance events, such as toxic algal blooms and COVID-19 (Lyle et al. 2020b, Lyle et al. 2021), with significant impacts on fishing behaviour.

The recreational fishery has been monitored since 2000, with bi-annual surveys occurring from the 2000/01 to 2014/15 seasons and annual surveys since then. Information collected from the recreational sector, including catch and effort data, is used to estimate the recreational take relative to the TARC, and to inform the rock lobster stock assessment (Hartmann et al. 2019, Lyle et al. 2021). The information collected also informs managers on fisheries performance and the effectiveness, or need, of management measures. The current monitoring consists of a telephone diary survey run from the beginning of the season until April, coinciding with the closure of the east coast fishery. Trained interviewers keep in touch with fishers to collect data on their fishing effort, catch and general opinion of the current management environment.

**Indigenous fishery**

Similar to abalone, rock lobster are culturally important to the Indigenous community and have been traditionally harvested for thousands of years. Rock lobsters continue to be taken for Indigenous cultural activities and by individuals for personal consumption.

Indigenous fishers do not require a fishing licence to take non-commercial fish in Tasmania, making estimates of participation and catch difficult as the annual rock lobster survey draws its respondents from the recreational licence database. The number of unique identification codes (UIC) required for marking gear issued to the Indigenous sector assists to provide a rough indicator of participation. The DPIPWE estimates that over 1000 Indigenous persons participate in rock lobster fishing using pots, rings, and diving per year.

Cultural fisheries in Tasmania is a neglected area for policy planning and management effectiveness, one that Lee (2019) suggests cannot be improved without baseline data. Although out of scope for this project, the mechanisms identified in this project may be adapted for use by the Indigenous community to collect rock lobster catch data, provided data ownership and usage issues are worked through.

**East Coast Stock Rebuilding Strategy**

In the late 2000's, concerns over rock lobster stock depletion on the east coast became significant. Intense fishing and several years of poor recruitment resulted in east coast rock lobster stock depletion to historically low levels (Hartmann et al. 2013). As a result, in 2013, the East Coast Stock Rebuilding

Strategy (ECSRS) was implemented for the east coast of Tasmania. The strategy aimed to rebuild the stocks in the East Coast Stock Rebuilding Zone (ECSRZ, Figure 2) back from an estimated 8.5-16% to at least 20% of the unfished biomass by 2023 (DPIPWE 2013, 2018).

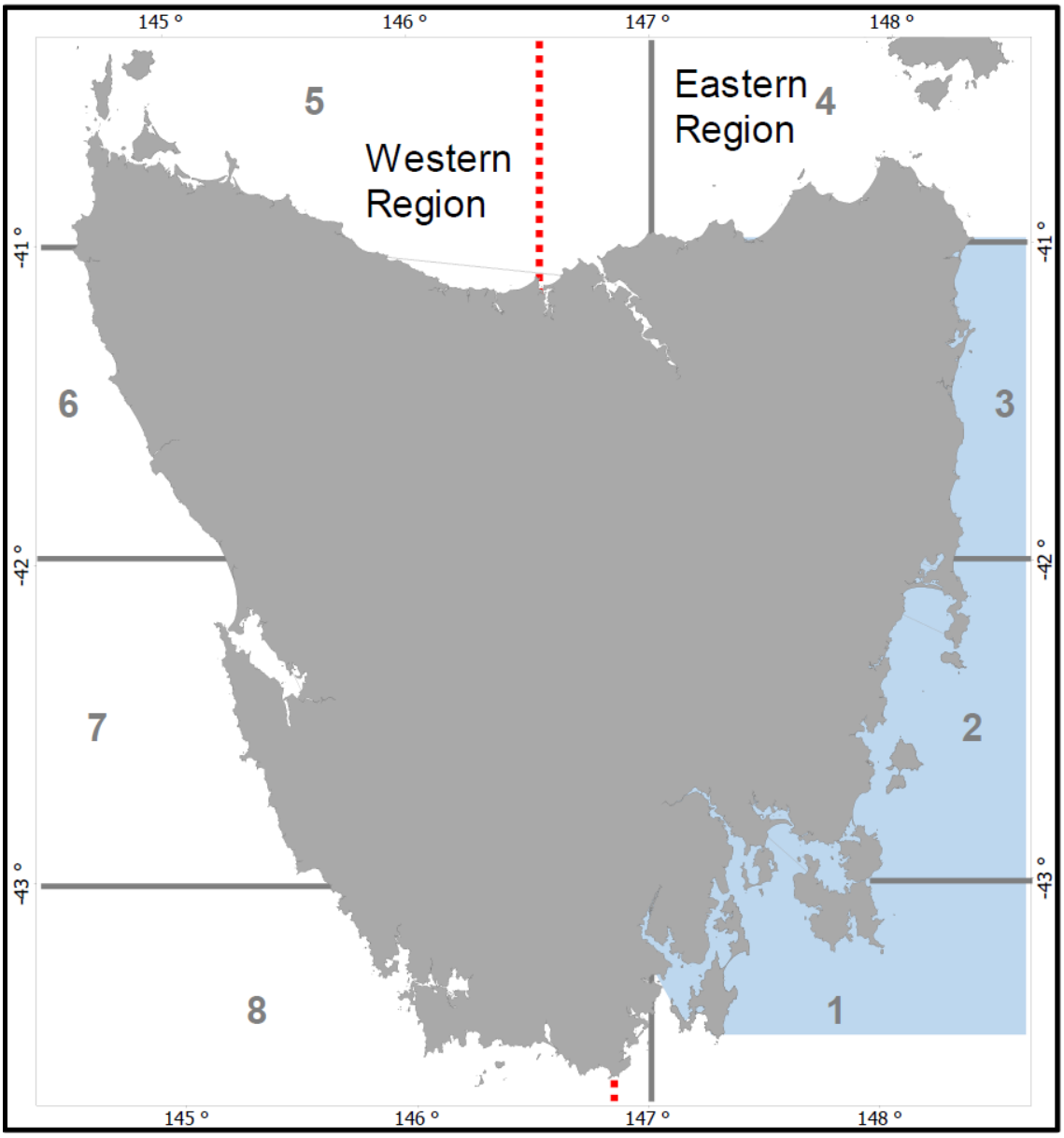


Figure 2. Map of Tasmania showing assessment areas (numbered) and the East Coast Stock Rebuilding Zone (ECSRZ, shaded) implemented in 2017/18. The Eastern and Western Region boundary is marked by the red dotted lines. From Lyle et al. (2020b).

The ECSRZ, spanning the three assessment areas (Zones 1-3, Figure 2), introduced multiple new management tools to restrict catch. Among these, an initial notional total catch of 200 t was of central importance. In 2016, the Minister determined that the catch would be divided between the sectors in a catch-sharing agreement, with 79% allocated to the commercial sector, and 21% to the recreational sector, reflecting the historical usage of the resource. A commercial catch cap was to be set annually and monitored using documentation associated with the quota monitoring system. For the recreational sector, the initial allocation was 42 t across all three recreational assessment zones representing the ECSRZ. In 2018/19, the ECSRZ southern boundary was amended by removing waters south of Bruny Island (DPIPWE 2018, Lyle et al. 2021).

In addition to the commercial catch cap and associated catch share agreement, a number of other management tools were put in place to limit recreational catch in the rebuilding zone, including a reduced bag limit (from five to three lobsters in 2011/12, to two lobsters in 2015/16), stricter possession limits (10 to six to four lobsters), the introduction of a boat limit (15 in 2011/12 reduced further to 10 in 2015/16), and a shorter open season compared to the fishery in the rest of the state (Table 1).

Table 1. Current management restrictions by sector in place for the East Coast Stock Rebuilding Zone. Table adapted from Lyle et al. (2020b).

| Management in place | Commercial | Recreational | Indigenous |
|---|---|---|---|
| **Entry requirements** | Limited entry fishery | Licence required | No licence required, however Unique Identifying Codes (UICs) required for pots and rings |
| **Output controls** | Explicit control through a commercial catch cap for defined area. State-wide Individual Transferrable Quotas (ITQs) | Non-explicit control through daily bag (2), possession (4) and boat (10) limits | Same as recreational controls. Permits are issued for cultural activities. |
| **Catch sharing agreement** | 79% share of the annual catch amount | 21% share of the annual catch amount | Unlimited catch in addition to the calculated catch share. |
| **Minimum size limits** | Females: 105 mm<br>Males: 110 mm | Females: 105 mm<br>Males: 110 mm | Same as recreational limits. |
| **Fishery closures** | October – mid-December or when commercial catch cap triggered. | May – early December | Same as recreational closures. |

Despite the implementation of the catch cap and further restrictions, the recreational sector has exceeded its notional catch allocation in most years since the inception of the rebuilding plan, including an over-catch of 46% in the 2020/21 season (Lyle et al. 2021). This situation highlights the need for management to introduce additional measures that can help ensure that the catch limit allocated to the sector is not exceeded and stock rebuilding targets can be achieved. One key problem is that, as stocks recover, catch rates tend to increase, which in turn results in increased participation and fishing effort of the recreational sector (Figure 3). Therefore, stock rebuilding and the associated increase in CPUE may extend the time required to achieve stock rebuilding targets unless recreational catches are regulated more closely.

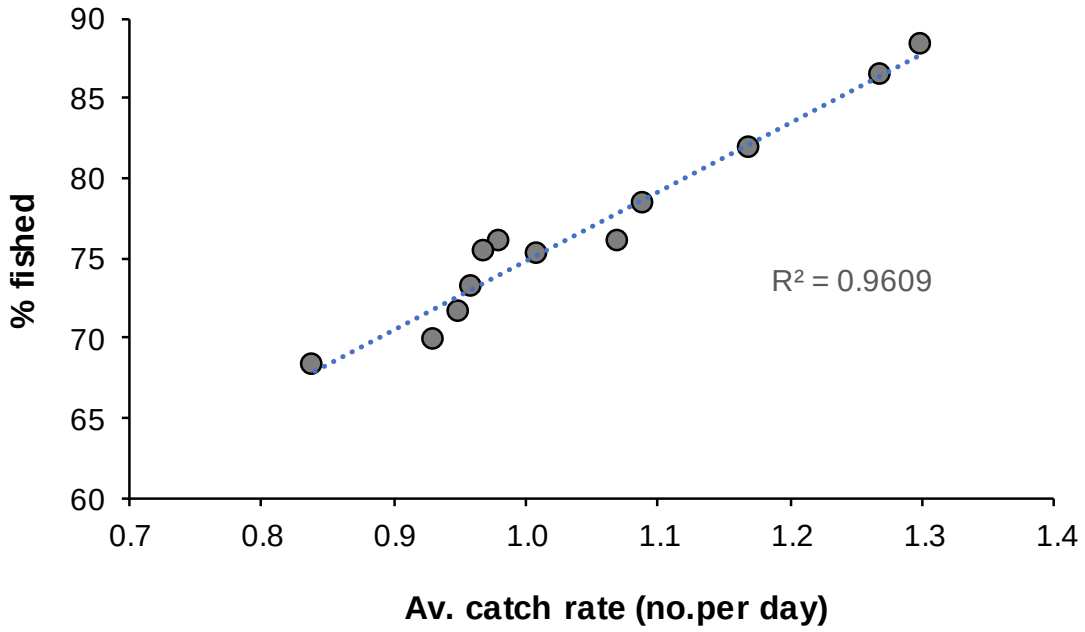


Figure 3. Relationship between the average daily catch in a fishing season and the proportion of active recreational licence-holders, indicating an increase in participation as catch rates increase. From Lyle et al. (2020b).

One novel approach supported by stakeholders to achieve the stock recovery target by constraining the recreational catch to its notional catch limit is the introduction of an Individual Season Limit (ISL) which would restrict the maximum number of rock lobster that an individual could harvest within the season. However, there are many practical issues to be considered in implementing this or any alternative management system, including how they could be monitored. This project aimed to combine an in-depth global review of existing recreational management systems with a feasibility analysis of alternative options to effectively monitor and regulate recreational rock lobster catches in a practical and cost-effective manner.

One possible delivery system for the monitoring of an ISL are smartphone applications (apps), which have become more prevalent in fisheries management worldwide as a means to collect significant amounts of data quickly and cost-effectively. Collaborators at DPIPWE have expressed a strong interest in the use of an app for the monitoring of recreational rock lobster catch, which has therefore become a focus of this project, including the initial development of suitable software and the identification of practical challenges with its application for rock lobster monitoring in the context of a short trial.

# Objectives

**Review of existing monitoring and management systems**

*Objective 1: In-depth review of existing management systems to monitor and constrain recreational harvest*

The first objective for this project was to undertake a global review of management systems implemented to monitor and regulate recreational harvest. The focus of this review was to identify practical challenges, including costs and compliance issues and complications with implementation experienced by management agencies. While direct contact with management agencies was focused on Australia, we also connected with international colleagues responsible for similar fisheries. In this regard, our review was aimed at going beyond a mere collation of information from the literature by engaging directly with relevant management authorities.

**Feasibility assessment based on a decision support tool**

*Objective 2: Assess the practical feasibility of implementing alternative management systems to regulate and monitor the recreational rock lobster catch*

The second aim for this project included the development of a broadly useful decision support tool that could be used by the DPIPWE to identify the most suitable management system for monitoring and constraining recreational catch with a particular focus on the Tasmanian rock lobster fishery. The framework was designed to be flexible in assessing the feasibility of alternative monitoring and management options under explicit consideration of the practicality of implementation, compliance and enforcement, management costs, stakeholder acceptance and effectiveness. Potential options for implementation were selected from the literature review as well as recommendations from previous research (FRDC Project 2017/013, Lyle et al. 2020b).

**Trial of the preferred monitoring system**

*Objective 3: Develop a business case and implementation plan for a preferred catch management system for the Tasmania recreational rock lobster fishery.*

In response to COVID19-induced delays and the associated decrease in project duration and budget, the final objective of the initial project proposal (develop a business case for preferred management option) was revised to the fast-tracked development and trial of a smartphone application (app) for recreational rock lobster catch monitoring. Development of an app for catch monitoring in real-time had received ministerial support and was identified as a key priority by the DPIPWE. In response, the development of a smartphone app and an associated trial were run in parallel to the development of the decision support tool (Objective 2). Notably, the decision to fast-track the app development and the trial was made to test a system that would allow for the introduction of an Individual Seasonal Limit (ISL), which was perceived by the DPIPWE and RecFAC members to have wider support from the recreational fishing community in Tasmania, specifically if its introduction could help relax other restrictions (e.g. on season length).

# Methods

## Review of existing monitoring and management systems

To complete a review of existing management systems, a search of published and grey literature was conducted. The aim of the literature search was to identify possible monitoring and management methods currently or historically implemented in recreational fisheries worldwide. Web of Science and Google Scholar were used to search for terms including: “recreational catch” OR “recreational harvest” AND “monitoring”, “fishery reporting”, “fishing survey”, “survey methods”, “fishery management”, and “recreational fishery regulations”. While Web of Science provided a strong base of peer-reviewed articles, Google Scholar was used to identify other forms of information, such as fisheries assessment reports and technical papers. Once a relevant fisheries report was found, a search was done of the publishing Department’s website for further useful reports or related information. Published research articles provided an overview of different management actions, while the grey literature, including management body websites, report and policy documents, provided important details on the local fisheries management context, rules, and policies. In addition to searching the literature, the project team contacted other fisheries managers in Australia and internationally to gain perspectives on practical experiences with management applications. Specifically, the project team contacted the Victorian Fisheries Authority to learn more about their current Rock Lobster Tagging project, and the Californian Department of Fish and Wildlife to discuss how the monitoring and management of their historically important lobster and abalone fisheries. The review was structured by focusing separately on approaches used to monitor recreational fisheries catch and approaches used to constrain recreational fisheries catch. Several examples of particular relevance to the Tasmanian rock lobster fishery were highlighted.

## Feasibility assessment based on a decision support tool

A decision support tool was developed to measure the feasibility of alternative options for monitoring and constraining recreational catch according to a cost-benefit analysis. Decision support tool development was initiated by firstly clarifying the management objectives for the recreational rock lobster fishery in Tasmania. We then formulated a simple quantitative framework that integrated considerations of costs, effectiveness, and acceptability to measure the relative value of all alternative monitoring and catch regulation options deemed feasible to achieve these objectives. The decision support tool was implemented in Excel to enable broad accessibility and provides flexibility for extension, for example by including additional indicators of effectiveness. The parameterization and results presented here were informed largely by expert opinion of project team members, and would thus benefit from rigorous empirical validation, including comprehensive stakeholder surveys.

**Management objectives**

Discussions among the project team and stakeholders resulted in the identification of three broad objectives to monitor and constrain catch at variable levels, which could be broadly applicable to key recreational species, including but not limited to Southern Rock Lobster.

For monitoring, these included:

- Quantify total catch (requiring an estimate of annual catch)
- Monitor total catch (requiring an estimate of catch at intervals)
- Monitor total catch in near-real time (requiring estimates of total catch at any point in time)

Quantifying total catch refers to a total harvest estimate at the end of the fishing season, as is currently implemented in the Tasmanian recreational rock lobster fishery. Monitoring catch refers to obtaining an up-to-date estimate of harvest prior to the end of the season, either at intervals or in near-real time. From here on, for convenience, we refer to near-real-time monitoring as real-time monitoring.

For constraining catch, objectives included:

- Constrain catch (i.e. constrain catch to some extent using any management option)
- Constrain catch to a notional target (i.e. maintain catch around a specified level, such as specified by the catch sharing arrangement)
- Constrain catch to a hard limit (i.e. no over-catch beyond the specified catch limit)

One additional consideration beyond these three key alternative objectives for monitoring and constraining catch were options to enable equity of access across the recreational sector.

**Options for monitoring and regulating catch**

In the next step, we used findings from our review to select suitable fisheries monitoring and management systems for potential implementation in Tasmania.

Options for catch monitoring included:

- Onsite creel surveys
- Offsite interviewer surveys
- Combined onsite and offsite surveys
- Voluntary reporting system – without verification
- Voluntary reporting system – without verification, with catch tags
- Voluntary reporting system – with verification
- Voluntary reporting system – with verification, with catch tags
- Mandatory reporting system – without verification
- Mandatory reporting system – without verification, with catch tags
- Mandatory reporting system – with verification
- Mandatory reporting system – with verification, with catch tags

Here, voluntary and mandatory reporting systems are used as umbrella terms to describe multiple underlying data collection methods, including the use of smartphone apps, catch cards, online reporting, and telephone reporting. These reporting systems are subdivided according to participation type (voluntary or mandatory), data verification based on another survey method, and whether the monitoring method is used in conjunction with catch tags. We note that for the purpose of this framework, the verification method was assumed to be based on offsite surveys (as currently conducted in the Tasmanian Rock Lobster Fishery).

While monitoring options were broadly defined and intended to represent various species, options to constrain catch were specific to the recreational rock lobster fishery, particularly within the ECSRZ.

Options to constrain catch included:

- Decrease the daily bag limit to one
- Decrease the season length to four months
- Decrease the season length to one month
- Increase the minimum size limit by 10 mm

- Individual season limit of 20 lobsters
- Individual season limit of 15 lobsters
- Individual season limit of 10 lobsters
- Individual season limit of five lobsters
- Limit participation
- Close the fishery when notional catch limit reached

**Parameterization of costs, effectiveness, acceptability, and equitable access to the fishery**

To link objectives to specific monitoring and management options, we started by estimating the likely costs and effectiveness of alternative management options to achieve the defined objectives, as well as their likely acceptability to the recreational sector. Parameterization was based on a combination of local knowledge, expert opinion by scientists and fisheries managers (the project team), existing data, and information from the literature (see Tables 2-4). Rather than providing robust estimates in absolute terms, the stated values were intended to allow for a comparison of the relative costs and benefits of alternative monitoring and management options that can easily be improved by updating values in the decision support tool as soon as new empirical data becomes available.

***Costs***

For self-reporting systems, costs were separated into set-up (initial one-off costs) and running costs (yearly costs, Table 2). The cost estimate for onsite surveys was obtained from Wise and Fletcher (2013) based on simulations of the costs for a similar wide-spread onsite survey for the Tasmanian rock lobster fishery with many access points. The offsite survey estimate was based on the approximate cost of the annual recreational rock lobster and abalone telephone-diary survey currently run by IMAS. The combined onsite and offsite survey cost simply summed the previous two survey cost estimates.

Table 2. Estimated costs of alternative monitoring methods.

| Survey type | Set-up cost estimate | Running cost estimate |
|---|---|---|
| **Onsite surveys** | NA | $550,000 |
| **Offsite surveys** | NA | $125,000 |
| **Combined onsite & offsite surveys** | NA | $675,000 |
| **Voluntary self-reporting of recreational catch** | $90,000 | $136,000 |
| **Mandatory self-reporting of recreational catch** | $140,000 | $136,000 |
| **Survey verification cost for voluntary and mandatory self-reporting methods** | NA | $90,000 |
| **Catch tag cost** | NA | $55,000 |

Set-up and running costs for self-reporting systems were estimated based on multiple possible reporting options, including smartphone apps, catch cards, online reporting, and telephone reporting (Table 3). The decision to capture multiple reporting options assumed that selections of a single option to be used across the entire fishery was considered unlikely, amongst others because not every fisher is likely to be able or willing to use a smartphone. However, set-up costs for any given option are considered in the decision support tool only if they are selected by the user (yes or no, Table 3). If any of these options are used in the framework, the cost is applied in the cost calculation. If the option was not selected to be used, then the cost would be nil. In addition to the set-up and running costs associated with each selected reporting option, we included an estimate of the costs associated with database development (based on recent quotes for databases developed for various similar projects at IMAS for voluntary reporting, and approximate costs of integration with the existing DPIPWE

database for mandatory reporting), administration (salary costs to employ a person to manage the project), data analysis (costs to employ a person to perform statistical data analyses, including a catch estimate) and the associated reporting of results. These additional costs applied regardless of the selected reporting option(s).

Table 3. Breakdown of cost estimates of self-reporting methods. Additional costs applied regardless of the selected reporting option are marked with a *.

| Self-reporting of recreational catch | Method used? | Set-up cost estimate | Running cost estimate |
|---|---|---|---|
| **Smartphone application** | Yes | $25,000 | $5000 |
| **Catch cards** | Yes | $10,000 | $5000 |
| **Online reporting** | Yes | $25,000 | $5000 |
| **Telephone reporting** | Yes | $5000 | $10,000 |
| **Database development – voluntary reporting*** | - | $25,000.00 | $5000 |
| **Database development – mandatory reporting*** | - | $75,000.00 | $5000 |
| **Administration*** | - | - | $90,000 |
| **Analysis (data aspects incl. QA/QC)*** | - | - | $11,000 |
| **Reporting*** | - | - | $20,000 |

Following the order of cost estimates specified in Table 2, the next considerations were costs associated with the verification of catch reporting and the use of catch tags. Survey-based verification costs refer to an alternative survey method used to specify the accuracy and quality of the self-reported data and associated catch estimates. Verification was assumed to be implemented using an offsite telephone-diary survey run alongside self-reporting methods. Thus, the cost estimate was the same as specified for standalone offsite surveys with a monetary saving due to shared administration costs for data management ($35,000, Table 2). The catch tag cost estimate was based on the cost of purchase of tags for this trial (approximately $500 for 3000 tags, i.e. approximately $15,000 for >73,000 lobsters caught in the ECSRZ per year) and expert opinion on the cost of administering those tags, including postage of the tags to fishers, while also accounting for monetary savings due to shared administration costs.

Rough estimates of costs for management options were provided by the DPIPWE on a Likert scale from 1-3, where 1 represents a low cost of implementation and 3 represents a high cost of implementation.

***Effectiveness***

We then quantified the likely effectiveness of alternative options for monitoring and regulating catch. For monitoring, effectiveness was scored based on the assumed quality of data available, assigning a minimum score of 1 and a maximum score of 10 (Table 4). Effectiveness scoring was based on the assumption that annual estimates of catch (i.e. once all data had been collected and analysed, including surveys of non-intending fishers) will generate the most reliable data. This assumption acknowledges that estimating catch in intervals or in real-time might require additional verification effort (e.g. coupled with multiple off-site surveys), given that periodic estimates are likely to be more imprecise and require correction, because some fishers might not have been catching as much or more than projected at any given stage. To capture this plausible complication, our decision support tool incorporated penalty factors that could be used to reduce the assumed data quality estimated here for interval and real-time monitoring. The decision support tool further incorporated penalty factors to increase the estimated costs to verify interval and real-time estimates of catch, given that data collection and analysis would have to be completed multiple times rather than just once. However,

with a lack of access to empirical data or robust expert advice, this functionality of the decision support tool was not used to produce results considered in this report.

Table 4. Input parameters for the feasibility assessment of alternative monitoring options including estimated set-up and running costs (in AUD), effectiveness (score out of 10), and acceptability (score out of 3).

| **Monitoring catch** | **Set-up cost** | **Running cost** | **Quality of annual total catch estimate** | **Acceptability to recreational sector** |
|---|---|---|---|---|
| **Onsite creel surveys** | NA | $550,000 | 7 | 3 |
| **Offsite interviewer surveys** | NA | $125,000 | 6 | 2 |
| **Combined onsite and offsite surveys** | NA | $675,000 | 8 | 2 |
| **Voluntary reporting system - without verification** | $90,000 | $136,000 | 1 | 3 |
| **Voluntary reporting system - without verification, with catch tags** | $90,000 | $191,000 | 2 | 3 |
| **Voluntary reporting system - with verification** | $90,000 | $226,000 | 3 | 3 |
| **Voluntary reporting system - with verification, with catch tags** | $90,000 | $281,000 | 4 | 3 |
| **Mandatory reporting system - without verification** | $140,000 | $136,000 | 4 | 1 |
| **Mandatory reporting system - without verification, with catch tags** | $140,000 | $191,000 | 5 | 1 |
| **Mandatory reporting system - with verification** | $140,000 | $226,000 | 9 | 1 |
| **Mandatory reporting system - with verification, with catch tags** | $140,000 | $281,000 | 10 | 1 |

Effectiveness in regulating catch was quantified by calculating potential catch savings following the implementation of alternative management options. These calculations were done based on data from recreational rock lobster surveys over the last five seasons (2016/17 to 2020/21) and by assuming constant fisher behaviour (Table 5). While the assumption of constant fisher behaviour is unlikely to hold, additional assumptions about changes in fisher behaviour were likely to be too speculative to be useful. The formulas used to calculate potential catch savings, expressed as a proportion of total catch or business as usual, are specified below (Equation 1).

$$CS_x = \frac{C - C_x}{C} \quad (1)$$

where $CS_x$ is the catch saving estimate from implementing management option *x* (expressed as a proportion of the actual seasonal catch), $C$ is the seasonal catch estimate, and $C_x$ is the catch estimate with the alternative management option in place.

For catch savings resulting from closing the fishery once the catch share target is reached, over-catch estimates were taken from Lyle et al. (2020b).

We note that the data to calculate potential catch savings was restricted to the focal study area on the east coast of Tasmania. Means and standard deviations in catch savings across seasons provided information on the extent to which any given season deviated from average patterns (Table 5). All results presented in the following are based on data for the latest season (2020/21), which closely resembled 5-year averages with the exception of the "catch-share fishery closure" scenario (due likely to COVID impacts on commercial catches).

Table 5. Estimated potential catch savings for the East Coast Stock Rebuilding Zone for the past five annual rock lobster survey years (%), based on the constraining catch scenario, the cost of implementation (score out of 3), ad acceptability (% of fishers).

| Constraining catch scenarios | Potential catch saving 2016/17 | Potential catch saving 2017/18 | Potential catch saving 2018/19 | Potential catch saving 2019/20 | Potential catch saving 2020/21 | 5-year average catch saving (±SD) | Score of cost of implementation | Acceptability to recreational sector |
|---|---|---|---|---|---|---|---|---|
| **Decrease the daily bag limit to 1** | 35% | 35% | 35% | 31% | 37% | 34.6 ± 2.2% | 2 | 29% |
| **Decrease the season length to 4 months** | 22% | 17% | 6% | 5% | 9% | 11.8 ± 7.4% | 1 | 68% |
| **Decrease the season length to 1 month** | 66% | 68% | 59% | 55% | 61% | 61.8 ± 5.3% | 1 | 1% |
| **Increase the minimum size limit by 10mm** | 11% | 39% | 30% | 25% | 24% | 25.8 ± 10.2% | 2 | 55% |
| **Individual Season Limit of 20 lobsters** | 7% | 5% | 6% | 3% | 4% | 5 ± 1.6% | 3 | 62% |
| **Individual Season Limit of 15 lobsters** | 13% | 11% | 10% | 7% | 9% | 10 ± 2.2% | 3 | 33% |
| **Individual Season Limit of 10 lobsters** | 24% | 23% | 20% | 15% | 21% | 20.6 ± 3.5% | 3 | 20% |
| **Individual Season Limit of 5 lobsters** | 46% | 47% | 43% | 37% | 43% | 43.2 ± 3.9% | 3 | 10% |
| **Limit participation** | 34% | 29% | 32% | 40% | 31% | 33.2 ± 4.2% | 2 | 9% |
| **Close the fishery when catch share target reached** | 19% | 0% | 21% | 0% | 46% | 17.2 ± 19.0% | 1 | 5% |

***Acceptability***

Acceptability scores for most management options to constrain recreational catch (expressed as a percentage of fishers supporting the regulation) were derived from a previous project investigating alternative stock rebuilding strategies in the ECSRZ (FRDC Project No. 2017/013, Lyle et al. 2020b). For decreasing the season length and implementing ISLs, acceptability was estimated from recreational survey data responses collected by IMAS (Lyle et al. 2020b). No data was available to parameterize the acceptability of an ISL of five lobsters and of closing the fishery. In consequence, corresponding percentages in Table 5 represent estimates by the project team assumed to align with known data.

Acceptability of the alternative monitoring options was more difficult to parameterize, because empirical data to inform the scoring was largely unavailable. For this reason, we adopted a rough

scoring system based on a Likert scale of one to three, where one signified low assumed acceptability and three signified high assumed acceptability by the recreational sector. Relative scores for survey-based monitoring were informed partly by the response rates of participants (higher for onsite than offsite surveys). In consultation with managers and stakeholders, other scores assumed that mandatory reporting system are least likely to be acceptable while voluntary reporting systems are most likely to be acceptable. Comprehensive surveys of stakeholder perceptions would be recommendable for more robust parameterization in higher resolution.

***Equitable access to the fishery***

One additional consideration of interest to managers was the basic interpretation that any restriction in terms of time (i.e. season length and closure of the fishery once a limit was reached), space (closed or restricted areas) and participation would undermine equal opportunities to access the fishery. In contrast, changes in bag limits, size limits, and the introduction of an ISL were deemed to affect all fishers equally. A more comprehensive representation of this complex issue would require consideration of equality (rather than just equity) by considering individual fishing activities and how fisher satisfaction would likely be impacted by any given change in management arrangements.

**Ranking of options for monitoring and management**

To calculate a final score representing the overall suitability of alternative monitoring and management options to achieve stated objectives, we used the following equation:

$$S = \left(1 - (C \times w_C)\right) + E \times w_E + A \times w_A \qquad (3)$$

where $S$ is the final score of the monitoring or management option given the specified objectives, $C$ is the cost, $E$ is the effectiveness, $A$ is the acceptability, and $w_C$, $w_E$, and $w_A$ are associated weights of importance (0-1) as specified by the user. We note that the cost was integrated as specified to ensure that higher costs result in a lower score. We further note that values for $C$, $E$ and $A$ included in equation 1 were normalised (initial values divided by maxima) to allow for representative weighting according to $w_C$, $w_E$, and $w_A$. If weights were set to values of 0, the corresponding values for costs, effectiveness or acceptability were not considered.

The final scores were then ranked for simple visualization of the best options to achieve the stated objective(s).

## Trial of the preferred monitoring system

### Smartphone application for monitoring

Responding to the DPIPWE's request for a fast-tracked trial of the preferred monitoring system to implement and manage an Individual Seasonal Limit (ISL), we developed and trialled a smartphone application that could be used to monitor recreational catch in the Tasmanian rock lobster fishery, as well as monitor and manage an ISL. The app was developed to include an ISL number that would be automatically adjusted as the user recorded catch, and a section to record a catch tag number if applicable. The Rock Lobster Catch Monitoring Trial (RLCMT) was run over the course of several months, from March to May 2021. Multiple key features for the RLCMT smartphone app had been identified from the literature review and direct experiences by the project team and collaborators before the development was started. These features included:

- Overall simplicity
- A maximum of seven questions
- Focus on minimum data requirements for stock assessments
- Integration of 'pre-trip' reporting

In combination, these features were expected to minimize the burden on participants while ensuring that the data collected would be of sufficient quality to be used for stock assessment purposes (FRDC Project No. 2019/075).

The app specifications were developed by the project team with further enhancements made through collaboration with the software developer, Geometry Pty Ltd, in Hobart. Initial stages of software developed were tested by members of the project team and successively revised. Basic functions were then presented to the DPIPWE and RecFAC for feedback. Following two sets of consultations and revisions, we agreed to a draft app that was used for the end user trial (Figure 4). Using the RLCMT app was based on three principal steps:

1. Registration (first use) or log in (subsequent uses)
2. Pre-trip reporting
3. Catch reporting

*1. Registration*

Following initial user registration, and (automated) log in thereafter, the app identified individual users, the fishery and season, and a hypothetical catch allocation on the home page (Figure 4b). For the purpose of this trial, the catch allocation was set to an arbitrary number of 50, which was considered to be non-constraining for by far most users.

*2. Pre-trip reporting*

Users could then start a 'New Trip', being asked where and how they intended to fish (Figure 4c-e). This first set of questions comprised the pre-trip reporting component, which could provide a way to remind fishers to report their catch, and also record zero-catch days which are required to get accurate effort estimates for fisheries assessments. Pre-trip reporting was further considered by the DPIPWE and Tasmania Marine Police to aid compliance checks and the validation of reported data.

*3. Catch reporting*

Once the trip was completed, the home page provided the alternative options to either 'cancel' or 'complete' the trip (Figure 4f). The cancellation option was provided so that if a fisher decided not to

fish (e.g. due to weather conditions), they could cancel the trip without having to complete the catch reporting section. In contrast, the 'complete trip' option guided users through a series of additional questions, including confirmation of their catch location (Figure 4g), confirmation of their fishing method (Figure 4h), information on the number of kept and released lobsters (Figure 4i). Finally, users were able to access a summary page (Figure 4j), which allowed them to edit or submit the provided details of their fishing trip (Figure 4k). Once submitted, the app returned to the home page, showing an updated catch quota.

The final RLCMT app was trialled by the project team and colleagues to ensure it worked across devices (Android and Apple) and without obvious issues.

**Catch tags**

In addition to the RLCMT smartphone app, representatives of Tasmanian Marine Police, who were also involved in project planning, encouraged the integration of catch tags into monitoring. Catch tags were considered essential to ensure practical compliance checks if an ISL was implemented. Catch tags were purchased from a commercial company and were intentionally similar to those used by the commercial fishery in Tasmania.

**Recruitment of participants**

The DPIPWE provided recreational rock lobster licence contact details of a representative (age and postcode) sample of fishers from the Departments' Fisheries Licensing and Monitoring System (FILMS) database. An initial sample of 2,000 individuals were selected and contacted by email. Following a lower-than-expected response rate, a staged recruitment strategy was adopted by inviting a total of approximately 6,000 licensed recreational rock lobster fishers to participate in the trial. The recruitment email outlined the project objective and requirements of volunteers to participate. It further provided a link to a SurveyMonkey online survey. This online survey was designed to seek information on fisher demographics, fishing behaviour, opinions on potential trial options and, most importantly, eligibility to participate in the trial (see Appendix 4 for full details). All participants deemed eligible (i.e. adults who had a smartphone less than 10 years old and were likely to go fishing for lobster before the end of the season) were then invited to participate in the trial. Approximately half of these individuals were also invited to trial the use of catch tags in addition to the smartphone app.

**Trial period**

In close consultation with the DPIPWE, who advertised for the engagement of the fishing community through their Fishing News email subscription service, the trial of the RLCMT smartphone app was run from 31 March 2021 to 30 April 2021, which represents the last peak fishing period in the year over Easter. It was highlighted to participants that during the trials logging and tagging recreational catch was voluntary and not a legal requirement. Fishers were encouraged to log their rock lobster catch by using the app for reporting fishing activities. However, some participants noted that due to changed circumstances they were unlikely to go fishing during the trial period and these individuals were instead encouraged to complete a test run by entering hypothetical fishing trip information so that their feedback could still be considered.

**Feedback survey**

Following trial completion, all participants were emailed a link to a SurveyMonkey questionnaire asking for feedback on their experience of using the RLCMT app, and if applicable, the catch tags. Questions referred to the ease of use of both methods, the timing of reported catch, the timing of tag attachment, as well as the perceived reliability, acceptability, and issues in using smartphone apps and catch tags (see Appendix 5 for full details). In addition, and in line with attitudinal questions included in the annual

Rock Lobster and Abalone survey for the 2020/21 season, participants were asked about Individual Season Limits (ISLs), including feedback on acceptability.

**Evaluation**

Once the final survey responses had been collected, the data was analysed by summarising fisher demographics, fishing behaviour, opinions, and feedback. Free text statements specifying issues and concerns about the RLCMT app and smartphone apps as general methods for data collection were compiled and summarised in tables to identify potential solutions according following discussions among the project team. This analysis included a comparison of the response from the project trial survey and those based on the 2020/21 Rock Lobster and Abalone survey (Lyle et al. 2021), which accessed a larger part of the recreational fishing community to seek feedback in specific alignment with objectives for this project.

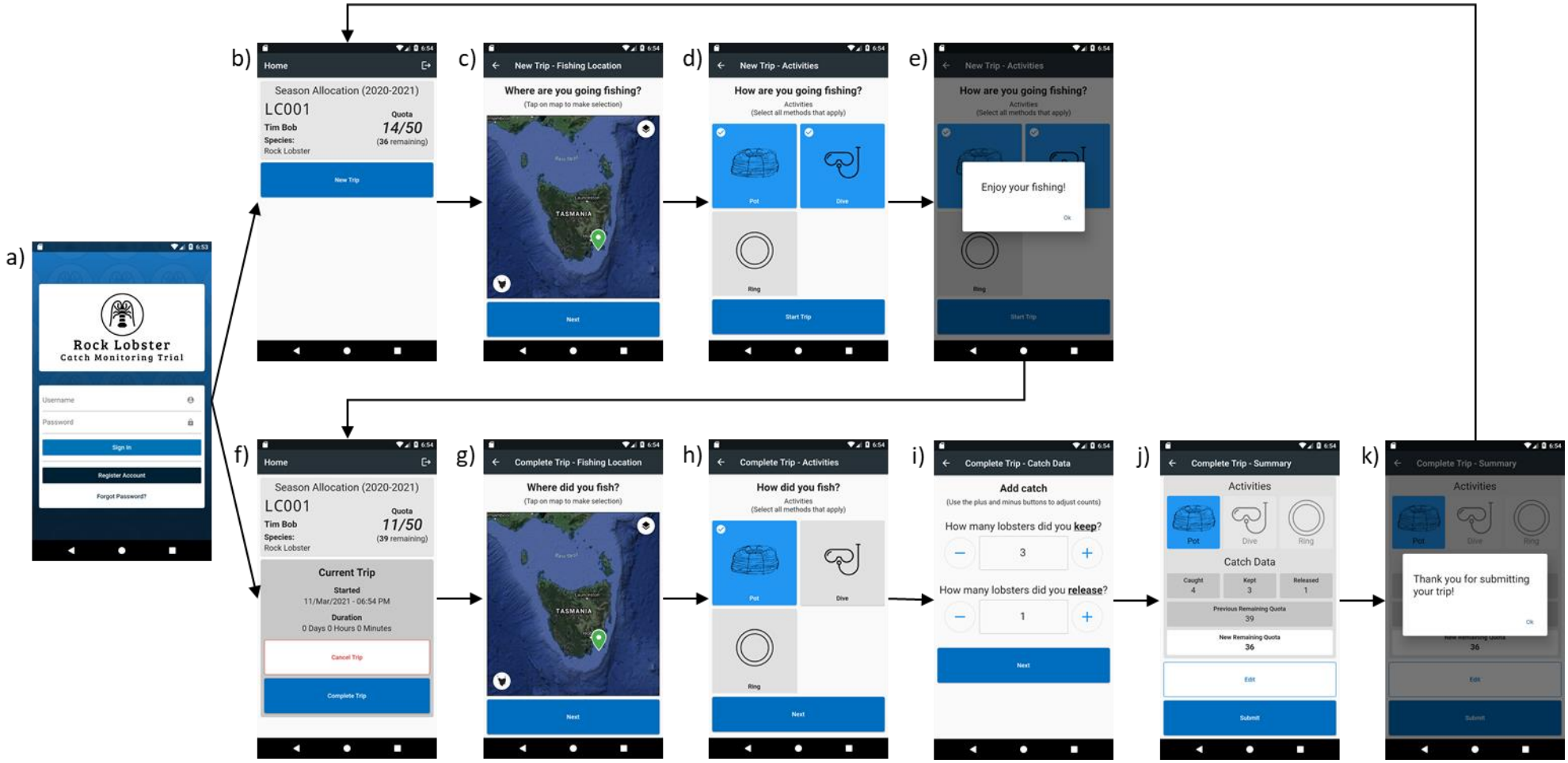


Figure 4. The Rock Lobster Catch Monitoring Trial smartphone application developed to trial recording recreational rock lobster catch in Tasmania. Once a username and password is created, users are able to log on and use the app (a). The home page (b) summarises details on the user, season, and catch allocation. To start a fishing trip, users are guided through pre-trip questions of where (c) and how (d) they intend to fish. Once these details are completed (e), the home page shows the current trip (f). To complete a trip, the user confirms where (g) and how (h) they fished, enter their catch (including kept and released lobsters [i]), and then confirm the summary of their trip details (j) before submitting (k). Users are then taken back to the home page ready for the next trip to be started (b).

# Results

## Review of existing monitoring and management systems

The review of existing monitoring and management systems is presented below in comprehensive stand-alone format for distribution to project partners and stakeholders, including an introduction, information on individual monitoring and management options, case studies and summary tables.

## Options to effectively monitor and regulate recreational catch in the Tasmanian Rock Lobster Fishery

### Introduction

Recreational fishing is an important social and economic activity undertaken around the world. In some countries, participation in recreational fisheries is almost 50%, and while estimates of recreational fishing participation can vary greatly, a global average of 11.5% has been proposed (Cooke & Cowx 2004, Arlinghaus & Cooke 2009). Recreational fishing is an important part of the Australian lifestyle, and in Tasmania, one in four Tasmanians are estimated to participate in some form of recreational fishing each year (Lyle et al. 2019). Recreational fishing has social and economic benefits, both to fishers and local communities through expenditure in fishing activities.

In recent years, there has been a growing recognition of the impacts of recreational fishing on fish stocks and environmental health. While previously thought to have little effect on stocks, it is now clear that some recreational fisheries have harvests exceeding that of commercial fisheries (Cowx 2002, McPhee et al. 2002, Post et al. 2002, Coleman et al. 2004, Cooke & Cowx 2004, Lyle et al. 2019, Tracey et al. 2020b). In addition it is becoming increasingly apparent that traditional management practices may not adequately constrain recreational catches to within sustainable limits (Johnston et al. 2007). While traditional input and output controls (such as bag limits or reduced season lengths) applied to the recreational sector can limit individual catch, they do not control total fishing mortality (Arlinghaus & Cooke 2009).

Tasmania's recreational rock lobster fishery is an economically valuable and socially important fishery for the state. Recreational fishers require a licence to participate and are regulated by daily bag limits, daily boat limits, possession limits, size limits and a closed season (Lyle et al. 2020a). The East Coast Stock Rebuilding Zone (ECSRZ) was implemented in 2013 to rebuild the lobster stocks on the east coast of Tasmania to a more sustainable level (DPIPWE 2018). A key element of the strategy involves limiting the total catch taken from within the rebuilding zone. A catch sharing arrangement based on historical use, whereby 79% total is allocated to commercial and 21% recreational sectors, applies for the duration of the Strategy i.e. 2022 (Lyle et al. 2020b). Despite a number of management changes, including a reduction in daily bag limit and shortening of the recreational season, the recreational fishery has exceeded this notional catch limit allocation in most years since it was implemented. As stocks recover and catch rates are expected to increase, further management intervention will likely be required even if there is an increase in the recreational fishery allocation in the new rebuilding strategy. As current management measures are not adequately constraining recreational catch, a new system is required to monitor and constrain the recreational catch to its notional limit. The following review outlines different management tools for measuring recreational catch, tools for monitoring real-time recreational catch and tools to constrain recreational catch, that have been implemented in Australia, and internationally.

## Measuring recreational catch

The most common approach to quantifying recreational catch is through the use of surveys. Depending on the scale of the fishery and other aspects, decisions can be made on the best type of survey methodology to use (Pollock et al. 1994, Hartill et al. 2012). Below are examples of onsite (i.e. in person creel surveys) and offsite (i.e. telephone, online or logbook) survey methods and their associated strengths and weaknesses. In addition, self-reporting methods (i.e. returned catch cards, online and email return) and some non-traditional methods (i.e. aerial monitoring, video monitoring, and other count survey methods) are explored.

### Onsite surveys

Onsite surveys are generally undertaken using independent observers to interview recreational fishers during or immediately after their fishing trip. These creel surveys are used to estimate harvest by requesting details of the fishers effort and catch and, where possible, take measurements of landed species to allow accurate biomass, and hence harvest, estimates to be calculated. Onsite surveys are generally employed for small spatial scale surveys and as supplemental data collection for larger offsite surveys (Hartill et al. 2012). At small spatial scales, onsite surveys can provide high resolution data of the fishery and can be a cost-effective survey option for measuring harvest (Hartill et al. 2012). Depending on the fishery in question, any, or a combination of, the below onsite survey methods can be used to estimate recreational fisher harvest. Strengths of onsite surveys include high resolution at smaller scales, less bias due to independent observers, high response rates and accurate measurements of catch and fish size for robust harvest estimates (Georgeson et al. 2015).

#### *Access point surveys*

Access point creel surveys are onsite surveys conducted at choke point locations such as boat ramps. Creel clerks attend the ramp(s) in question on survey days, determined by stratified sampling methods. On these days, the creel clerk intercepts fishers returning from their fishing trip and interviews them for trip details such as trip length and fishing location, as well as for catch data, including, where possible, the measurement of any caught species. These surveys provide information on complete fishing trips and most, if not all, fishing parties are interviewed at the location on the sampling day. The benefit of access point creel surveys is they can provide accurate estimates of catch rates for the fishery being investigated. The data are generally considered to have low bias as good sampling design can remove potential biases, as well as due to expert interviewers' ability, and the lack of self-reporting bias. There are also challenges associated with access point creel surveys. As the surveys are conducted at public access points such as boat ramps, other fishing activities are not recorded in the survey, resulting in under coverage of activities that may use alternative launching locations to boat ramps (i.e. marinas, shore launches etc.). Depending on the fishery in question, this may or may not be a problem that requires a secondary survey method to catch these fishers in the survey. Using creel clerks also means that the survey is subject to cancellations via inclement weather, staff sickness or other reasons that may result in an unbalanced sampling design, potentially biasing the results. Using creel clerks also generally limits surveys to daylight hours. These factors can be planned for and overcome but are critical to the accuracy of the data and therefore the harvest estimate.

#### *Roving surveys*

Roving creel surveys are conducted by a creel clerk that travels a predetermined route accessing several access points during a survey day. These surveys are often used to sample shore-based fishing and collecting activities but can be undertaken as on-water surveys. Each access point is sampled for a predetermined time period before the clerk travels to the next access point. This type of creel survey maximises the efficiency of sampling a larger spatial area at a lower cost than access point creel

surveys. However, unlike access point surveys, roving surveys are often sampling incomplete fishing trips, where fishers are interviewed mid-trip rather that at completion, requiring assumptions to be made that may affect the accuracy and precision of the harvest estimates. Bus route surveys are a specific type of roving survey that is used to survey access points, following a similar method of using a predetermined route throughout the day. While bus route surveys collect complete fishing trip details rather than incomplete as with standard roving surveys, the number of interviews completed can be low for this method.

***Aerial surveys***

Aerial surveys are count surveys typically conducted from an aircraft with the ability to increase the spatial coverage of an onsite survey (Hartill et al. 2012, Smallwood et al. 2012). These surveys can count both boats on the water and fishers on the shore, as well as counting the gear fishers use. There are different methods of counting that can be used, depending on the number of flights conducted. Aerial surveys can be a cost-effective method for sampling fishing effort over a medium to large spatial scale. There are inherent challenges with aerial surveys including that they are highly weather dependent which may result in unbalanced sampling and non-random sampling bias. Aerial surveys are used to estimate effort, catch data must be determined from alternative/complementary survey methods.

***Video monitoring***

Video monitoring uses digital cameras to monitor specific locations to estimate fishing effort. Video monitoring has been used in many other applications, including the monitoring of commercial fisheries (Ames 2005). If well designed, it can provide a cost-effective method of monitoring recreational fishing effort over long periods of time (Hartill et al. 2020). In Australia, several states have implemented different forms of video monitoring. In Western Australia, video monitoring has been implemented on a large scale, with time-lapse cameras positioned at boat ramps and groynes over a 3000 km range. These cameras monitor both boat-based and shore-based fishing activities, depending on their locations (Blight & Smallwood 2015). Another example from New South Wales is the use of a long-range video monitoring set up, where fishing effort is monitored on an artificial reef off Sydney (Keller et al. 2016). Unlike many video applications that monitor boat launches/retrievals or passing vessels, this application directly monitors recreational fishing effort on the artificial reef. One of the most useful strengths of video monitoring is the ability to gain a cost-effective census of the number of fishing trips completed at the monitoring site, allowing for the long-term monitoring of recreational fishing effort (Wise & Fletcher 2013, Hartill et al. 2020). This monitoring allows for the long-term collection of data beyond the timescale that many traditional surveys are capable of. Results of these surveys are reproducible due to the nature of the data stored on servers. Data analysis can be relatively low-effort and efficient if a sampling procedure is implemented, with results that can be developed on a fast time scale (Buch et al. 2011). Challenges of the use of video monitoring include the amount of time required to analyse the videos, and the digital space required to store the footage (Hartill et al. 2020). Video monitoring data also does not allow for catch data to be investigated, only indirect measures of activity (effort), which can be problematic if it is not clear whether vessels/persons are fishing or not. On their own, video monitoring data may allow for effort estimates to be made, but without partnered surveys to measure catch rates, there is no way to determine a harvest estimate.

***Camera snapshots***

Camera snapshots of boat ramp car parks can provide information on the number of fishers participating in fishing at any particular time. This method is a cheap count method that can provide proxies for fishing effort. However, due to the lack of catch information provided by this method, it is insufficient by itself as a harvest estimate tool. Combined with a complementary catch data collection

survey, it may be a suitable, cheap method to gain effort data. This data is useful in that it can provide a census of activity at a boat ramp that can be used to monitor recreational fishing effort over longer time periods at low costs. Issues encountered with this system include miscounts of boat trailers due to visibility issues, from both blocking vehicles and weather constraints.

***Traffic counters***

Traffic counters are used to count boat trailers launching at specific boat ramps (Steffe et al. 2008). Tubes attached to a small, waterproofed computer system count pulses as vehicles pass over the tubes, estimating the number of axles passing over the counters. The data is then converted to the number of boats using the ramp and subsequently the number of boating trips. While this supplementary survey measure is relatively cheap, it can be subject to errors. Some of these come from the system itself, where differences in sensitivity and calibration can affect count recordings. It may also be subject to error via noise from non-fisher vehicles creating background noise. Validation of counts are required to determine how suitable the system is for use at the chose ramp for the fishery being investigated. Evidence suggests that they may be suitable for general fishing applications but are less effective for species specific applications (Tracey et al. 2020a).

**Offsite surveys**

Offsite surveys are conducted via sampling recreational fishers and the subsequent reporting of their fishing activities, including catch and/or effort, over a given time period. Unlike onsite surveys, offsite surveys are more cost-effective over larger spatial scales (Hartill et al. 2012) and are useful for sampling fisheries with many access points that would otherwise be difficult to do via an onsite survey. Participants are often selected from a suitable database, such as public telephone listings or more specific fishing licence databases, and then asked to participate in a survey, to provide a representative sample of the target population. However, participants can also be recruited via promotion of the survey using social media and hence participants are self-selected which can result in selection bias. Offsite surveys can be one-off samples of fishing information or can be longitudinal where fishing activities are recorded for a season, or commonly a year, via a logbook or diary. As offsite surveys are dependent on self-reporting by fishers, they are also inherently prone to different forms of bias. Some of these can be rectified using good sampling techniques or the use of skilled interviewers, and some can be accounted for statistically. Often, offsite surveys are supplemented with small-scale onsite surveys to collect additional fishery-independent data on size composition (and weights) to be able to convert harvested numbers to biomass.

One of the key issues with offsite surveys is the lack of appropriate sampling frames (Georgeson et al. 2015). Traditionally, telephone listings were used to contact a broad sample to select fishers for surveys. However, with more people using mobile phones that are not listed in landline telephone directories, this option is becoming less viable for sample selection (Georgeson et al. 2015, Beckmann et al. 2019). Licence databases are available for some recreational fisheries however they are not universal and there are various exemption rules that then do not provide completed coverage of the target population (Georgeson et al. 2015, Griffiths et al. 2017, Beckmann et al. 2019). More recently, commercial data sources, such as 'SamplePages' compiled lists of telephone numbers, are used to identify potential survey participants. It had been suggested numerous times that some form of national (or individual state-wide) recreational fishing database or registry would be the most cost-effective and representative method of identifying participants for recreational fishing surveys (Georgeson et al. 2015, Beckmann et al. 2019).

The two main offsite survey approaches are recall and longitudinal or panel surveys. Recall surveys are typically conducted at the end of a period of interest, such as the end of a fishing season or at the end of a fishing year. These are often conducted via mail, telephone or on-line, and often suffer from recall bias. Longitudinal offsite surveys are run for an extended period of time, often spanning a season

(for individual species fishing surveys) or for a 12-month period with respondents contacted regularly to reduce recall bias. While longitudinal surveys can reduce recall bias and enable greater reporting detail, regular contact with respondents results in higher survey costs. These can be conducted via a range of methods, such as the commonly used telephone-diary survey, or via internet platforms as a way to decrease costs.

***Telephone surveys***

Telephone surveys are implemented using trained interviewers to contact participants and record their fishing activities. Telephone-diary surveys as applied in many Australian jurisdictions and are longitudinal surveys where participants are selected from a relevant population dataset to participate in a survey. Fishing diaries or logbooks are supplied to help fishers remember their fishing details to report back to the interviewers, in the aim of enhancing reporting accuracy and detail. In Australia, species-specific telephone-diary surveys are used for several high value fisheries and are often conducted annual, or biannual, telephone-diary surveys. This includes the high value rock lobster fisheries in multiple states (Tate et al. 2019, Lyle et al. 2021). Benefits to offsite surveys include large spatial scale data at relatively low costs, as well as high quality data for harvest estimates. Telephone surveys can have high response rates compared to other survey methods, up to 85% (Georgeson et al. 2015). Challenges that need to be considered when implementing an offsite survey includes the different types of bias that can arise. These include non-response bias, avidity bias, prestige bias and recall bias. These issues can often be overcome by careful sampling and regular contact with respondents (Hartill et al. 2012). Another significant challenge for many fisheries is the availability of a suitable database from which a sampling frame can be extracted. This is particularly significant for niche fisheries where participation is low and therefore trying to identify participants from a large database, such as telephone number directories, is difficult.

**Self-reporting offsite surveys**

***Respondent-driven surveys***

Respondent-driven surveys are surveys that use self-selection or snowball sampling methods whereby an initial sample of respondents are contacted and they in turn recruit other individuals to participate in the survey (Griffiths et al. 2017). While these survey types may be able to contact hard to reach individuals of interest, there are well-established biases inherent in self-selected survey responses including non-response and avidity bias (Griffiths et al. 2017).

***Mail surveys***

Mail surveys are one method of distributing and collecting survey information. They are easily implemented, can sample large geographic areas, and are often used for a one-off, recall survey that sampled an entire season or year of fishing information. However, mail surveys have a lower response rate than some of the other offsite survey methods and can have highest estimates of catch compared to onsite survey methods due to recall and avidity bias (Wise & Fletcher 2013).

***Internet surveys***

Internet or online surveys have the potential to be a cost-effective survey method due to the very low cost of implementation compared to other survey methods. They have the ability to have large sample sizes and fast response times (Bonnichsen & Olsen 2016) and also provide the ability to collect detailed information from participants as they have the time to consider their responses before submitting (van der Hammen et al. 2015). They also have weaknesses, the foremost the potential for biased sampling. While internet usage is generally high in developed countries, not everyone can use the internet, making sample representativeness difficult. Surveys that do not use a probability-based

sampling also risk self-selection bias. If a sampling frame is available, and probability-based sampling is employed, online panel surveys have the ability to a be a cost-effective representative survey method (van der Hammen et al. 2015).

Online surveys can also be used for one-off recall surveys or for longitudinal surveys. In Canada, the Department of Fisheries and Oceans monitors the sport fishery though various means, one of which is the use of one-off recall online surveys (DFO 2021b). As a condition of the sport fishing license, all licence holders are required to participate in the online reporting programs if requested. The Internet Recreational Effort and Catch (iREC) reporting program is a monthly reporting program that requires randomly selected participants to provide information on their fishing activity, including kept and released species and information on effort such as when fished, location and fishing method. The Internet Annual Recreational Catch (iARC) reporting program is an annual program that collects catch records from sport fishing licences and is used to estimate recreational catches of Halibut, Lingcod, and Chinook Salmon to compare with those form the iREC and creel surveys for better finalised catch estimates (DFO 2021a). Participants are notified at the time of purchase if they have been selected for a survey and which survey they have been selected for. They will only have to participate in one survey, either iREC or iARC annually. These surveys are entirely online with no option to submit catch and effort information via paper records. They can be submitted via computer or smartphone. The Department of Fisheries and Oceans Canada provides an intuitive survey provided with easy steps to prompt fishers to provide their fishing information. Online surveys could provide a comprehensive record of recreational harvest for the species required to be reported. Unfortunately, there is also the problem of low response rates (i.e. iREC response rates averaged 28.6% between 2011-2014, despite being a condition of licencing, Houtman et al. 2015).

Longitudinal online surveys have been run in Europe, where the use of a online panel survey examined the catch of Atlantic Cod and European Seabass in marine waters, and European Eel in freshwater, in the Netherlands (van der Hammen et al. 2015). The survey used a 12-month logbook to estimate catch rate and effort, where participants were contacted monthly online to submit their fishing activities recorded in their logbook. The survey design resulted in the collected of a large data set at a lower-cost than traditional phone-diary surveys (van der Hammen et al. 2015).

***Catch cards***

Catch cards are used to record recreational fisher catch for certain species and are returned to the management agency for catch monitoring. They are a management rather than survey tool for obtaining information about valuable species, and can be a important, fast form of data if returned regularly. Catch cards are used for several high value species in the USA and Canada (FOC 2021, WDFW 2021). In Washington State, catch cards have been implemented for several important recreational species. While initially implemented for monitoring salmon harvest by recreational fishers, the catch card program now includes mandatory reporting for Dungeness Crab, Halibut, Sturgeon and Steelhead, as well as salmon (WDFW 2021). In California, catch cards are used for taking lobster (CDFW 2016). Catch cards are required to be used by everyone catching these species, including minors that do not require any fishing licence to fish. These cards must be carried on the fisher during any fishing activity for the named species. Once a fish has been caught, the fisher must immediately fill out the catch card before fishing can resume. Records can be returned via mail or can be reported online. Dungeness Crab have a slightly different reporting mode than the other fish species, where there are two seasonal catch cards required rather than one for the year. The Dungeness Crab fishery in Puget Sound is separated into a summer fishing season and a winter fishing season, with separate catch cards for these. These two seasons also require two different card return deadlines, each at the end of the respective season. In Canada, salmon conservation catch cards are required, along with a licence, to fish for salmon in the Yukon (FOC 2021). These cards need to be carried with the fisher at all times while fishing and data recorded include the date and location of fishing, species, sex, tags,

adipose fin presence, and gear used while angling. This information is required even if only catch-and-release fishing. Cards are retuned via an online portal, mail or physical drop off. There are also penalties involved for failure to return the cards at the end of the season.

Catch cards have the potential to provide a comprehensive record of recreational catch at a low cost to management agencies. However, due to the self-reporting nature of catch cards, and despite their generally being a requirement for their return, return rates can be low. Providing incentives or penalties may increase the return rates. Catch cards may also be more of a challenge to use in marine offshore conditions on a boat, where weather conditions may not always be conducive to filling out a small form on a wet and rocking boat.

***Online reporting***

An electronic alternative to catch cards is the submission of a form downloaded by fishers from a fisheries management organisation that is used to record catch information and is then submitted via email. This method was implemented for the Snapper fishery in South Australia, which underwent a highly restrictive management change where fishing for Snapper in South Australia was restricted to individuals that received a limited number of harvest tags. These tags were required to be reported upon their use via email to the fisheries management organisation. This fishery has now removed the use of tags but still monitors the catch on the fishery against a total allowable catch (TAC), with catch required to be reported via the SA Fishing App, or via telephone (PIRSA 2021).

***Smartphone applications***

Smartphone applications (apps) are increasingly being looked at as a fisheries monitoring tool. With the prevalence of smartphones and apps used for recording other activities, such as health and fitness activities, they have the ability to provide low cost, broad scale, and real-time data. Apps used to provide information on fishing activities can be either voluntary or mandatory, with data collected varying from app to app. This data can be used to supplement established data collection methods or be a stand-alone method of collection. Real time data availability has the ability to translate to proactive fisheries management (Venturelli et al. 2017). Apps can also facilitate the transfer of information, from fisheries scientists and managers, back to the fisher, promoting informed fishing (Venturelli et al. 2017). This feedback can also encourage accurate reporting as it can benefit fishers themselves via improves catch rates (Venturelli et al. 2017).

Issues arising from the use of apps as a data collection method to inform management include recruitment and retention of participants. Data obtained from self-reported apps can also be problematic, where data may suffer from non-random participation (self-selection), inaccurate reporting (accidental or deliberate), as well as recall, non-response, and avidity biases (Georgeson et al. 2015). The data collected via voluntary reporting is inherently non-probabilistic, meaning scaling up of data to population levels could be problematic if samples are not representative of the general fishing population. Another potential issue flagged is that fishers may underreport zero-catch fishing trips (Skov et al. 2021). Some of these biases can be addressed using modelling techniques. Others can be improved by using mandatory reporting with incentives for use or penalties for non-reporting. While many fishers may indicate initial support for the use of a self-reporting app, in reality participation will likely be low without measures in place to ensure participation. For example, in the Red Snapper fishery in the Gulf of Mexico, a survey on the use of electronic self-reporting methods found that while the majority of respondents already used some form of smartphone app for fishing, and that 80% were also willing to electronically report their catch, only 1% actually used the voluntary app (Midway et al. 2020).

A recent paper on expert opinions of use of smartphone apps for fisheries management indicate that while apps are a growing area of potential fisheries data collection, it is unlikely that they would be

adequate alone, and are likely most effectively used as way to collect supporting data, at least in the short term (Skov et al. 2021).

**Real-time monitoring of recreational catch**

While well designed fisheries surveys can provide the required data to aid in the management of recreational fisheries, they are often time consuming and can take some time before the results are available. Real-time, or near-real-time monitoring of fisheries may be required depending on the management approach or the fisheries objectives. By modifying existing survey methods, or using different approaches, near real-time data capture and analysis is feasible to help proactively manage fisheries, particularly those under significant fishing pressure. Real time monitoring is particularly important for fisheries that have some form of total catch restriction placed on them, such as a Total Allowable Catch (TAC) or total allowable recreational catch (TARC) for the recreational sector.

**Modified survey methods**

Traditional survey methods can be modified to produce nearer to real-time data collection and analysis. This can be done using multiple methods and novel sampling regimes. Many of the survey options listed above can be modified to produce catch estimates faster with traditional methods combined with newer technology and efficient sampling to improve the speed of data collection and analysis, however come options may not be practical or be prohibitively expensive. The method chosen should be carefully considered in the context of the fishery.

One method is the pulse method, where a fishery may be opened in pulses, data is actively collected and analysed after the fishing event has finished and then a decision is made as to whether the fishery can remain open for another pulse event, or it must be closed as the catch limit has been reached. This method is used in the Western Australia Metropolitan Roe's abalone fishery. This is a highly regulated fishery, with the recreational sector requiring a licence to fish, and it subject to a TARC, minimum size limits and daily bag and possession limits. The unique part of this fishery is it is only open for one hour from 0700 to 0800 on a Saturday morning, once a month from December to March (pending no early closure) in the West Coast Zone (DPIRD 2020). During these fishing periods, a complementary survey method is used, where a shore-based access survey collects catch and effort information and an aerial survey is used to estimate effort (DPIRD 2020). This in season monitoring allow for an estimate of catch to be calculated after each fishing pulse, and based on that catch (including any previous pulse fishing events) make a decision on whether the fishery will remain open for the next day, or whether the season will need to be closed (DOF WA 2017). This in season, near-real-time monitoring of the fishery allows for active management to be applied and ensures the management option achieves its objective of ensuring catch does not exceed the TARC.

In the Gulf of Mexico Red Snapper Fishery, video cameras were used to estimate recreational fishing effort by randomly sampling 20% of the days in the season, combined with a creel survey to identify fisher catch and fish weights. Using this combined estimation method, data from the video cameras could be analysed with a 1-2-day delay (Powers & Anson 2016). In the same fishery, an intensive creel survey was used to monitor the short fishing seasons over a three-year period between 2012 and 2014, with the data used to monitor annual catch limits (Sauls et al. 2017).

While not real time, in-season tracking can be achieved using modified survey methods. For example, the recreational Halibut fishery off California, where a monthly catch estimate is provided by the California Recreational Fisheries Survey (CRFS, CDFW 2021b). Due to collecting data from multiple sources, there is a 5–8-week delay in providing the estimates. In the meantime, the CFRS provides a 'preliminary projected catch' estimate based on daily reports from field staff. Once the survey estimate is available, it replaces the projected catch estimate.

**Supplemental methods and validation**

Often, multiple survey types are used to complement or supplement each other. For example, an offsite sampling method is used to estimate effort while and onsite creel survey estimate catch rates, allowing catch and harvest estimates to be calculated. These complemented surveys allow for the benefits of the different survey methods to combine and reduce the negative effects.

As new methods of reporting catch become available, it is important to highlight the need for verification of survey results using an established method. For example, any data collected using self-reporting methods will require verification with an alternative survey method to verify the data quality. Verification of survey results can enhance the scientific credibility and improve stakeholder acceptance (Georgeson et al. 2015).

For a summary of monitoring options, including benefits, costs, response rates and considerations, please see Table 6.

## Constraining recreational catch

There are many traditional methods of management techniques to constrain recreational catch that have been used in many fisheries to differing success (Bochenek et al. 2010, van Poorten et al. 2013, Veinott et al. 2018, Arlinghaus et al. 2019). While these traditional methods are not always effective in constraining catch, new approaches are being developed to better monitor and actively manage valuable recreational fisheries globally.

**Traditional methods**

Altering daily bag limits to constrain recreational catch is a traditional management strategy to reduce the total catch of species of interest. As bag limits only control individual fishers daily catch, they can be ineffective if participation and effort is excessive and are not constrained. As a result, many bag limits are increasingly restrictive to try and constrain catches.

Altering season lengths is another traditional management strategy to indirectly control harvest. By reducing the opportunities to fish, catches can be reduced. However, in some cases, reducing season lengths can result in a race to fish, leading to increased catches, requiring further reductions in the length of the fishing season (Farmer et al. 2019). In the Gulf of Mexico Red Snapper fishery, reductions in the length did not result in corresponding reductions in catch (Powers & Anson 2016).

Introducing more restrictive size limits has been used to both limit catch, and to increase the biomass of spawning stage individuals. This is an indirect approach to reducing catch and one that can have unexpected consequences, especially if fish that have to be released experience some level of post release mortality (Bochenek et al. 2010).

A major challenge with recreational fisheries is the unlimited access nature, where the number of participants are not restricted. In some fisheries, including the Shark Bay Snapper fishery in Western Australia, and more recently the South Australian Snapper fishery have used ballots to reduce the number of participants and limit individual catches to low numbers (Jackson & Moran 2012, Jackson et al. 2016). This in combination with low bag limits and reduced seasons then allow more control of harvest levels.

Recreational management tools are usually very broad and do not explicitly limit the catch. Typically a combination of tools, such as bag limits, boat limits, season and size limits, are used to reduce

recreational catch, rather than implemented any particular one of these tools in isolation. Surveys and catch estimate systems monitor the catch and adjustments are then made to better control the catch.

**Rights-based methods**

Newer methods of constraining recreational catch are increasingly embedded in rights-based management. These types of rights-based management approaches are generally implemented by allocating catch to groups or individuals in an effort to control total catch in the fishery. This is often implemented as a way to decrease the conflict between sectors, as traditional methods often cannot achieve this (Abbott 2015). In Australia, some formalised resource sharing arrangements have been introduced as fisheries management tools (Knuckey et al. 2019, Mazur et al. 2020). These arrangements are also increasingly being defined in policy and legislation, with frameworks available for guiding allocations, reallocations, fairly dividing catch, etc (PIRSA 2011, DOF WA 2012b, a, NSW DPI 2015, NT DPIR 2015, Queensland Government 2018). Rights-based management options may also generally be more flexible than traditional methods. For example, as a TAC is calculated each season, and the subsequent catch amount proportioned for the recreational sector with the permitted number of fishers permitted accordingly. This is in contrast to traditional methods such as bag limits that are often not easy to change from season to season if it is not written into legislation. Two of the types of rights-based management currently being implemented in recreational harvest activities are Total Allowable Recreational Catches (TARCs) and Individual Season Limits (ISLs).

***Total allowable recreational catch***

A TARC is one of the most common formalised sharing arrangements in fisheries management. A TARC is generally an allocated proportion of a seasonal/yearly TAC which is then divided between participating sectors. This proportion is often defined by historical use in the fishery by each sector. A TARC will often require some form of monitoring to determine whether the catches are under the limit, reached or exceeded, and then determine if the fishery can remain open or requires closing for the season. Real time monitoring is important if the TARC is being actively managed and the management in place is a closure of the fishery once the TARC is reached.

***Individual season limit***

An ISL (also referred to as a season catch limit, annual limit, retention limit, or season bag limit) is the allocation of a maximum number of fish from a fishery that can be harvested by an individual during a specified time period (i.e. season). Individual season limits can provide an alternative method to traditional management measures that may not be effective in constraining catch in a fishery. They can also provide a means for the more equitable distribution of catch amongst fishers (Lyle et al. 2020b). Previous surveys in Tasmania have found generally high support for the concept of ISLs because it is perceived as a system in which catches are shared more equitably. However, this acceptability is also linked to the ISL level, where higher ISLs have higher acceptability. A potential issue with ISLs is that they do not directly control catch without some form of fishery entry limitation. They may require some form of access restriction (e.g. limited licences or a ballot system) in conjunction with the ISL to directly contain catch in the recreational fishery, though support for licence restriction is very low and unlikely to be an acceptable management option. ISLs also require some form of compliance monitoring to be an effective management system.

***Catch tags***

In 2016, DPIPWE officers undertook a comprehensive assessment of catch tags, including whether they could be used to monitor an ISL (DPIPWE 2016). The assessment found that catch tags would be costly to implement and administer, and that they would be unlikely to help constrain the recreational rock lobster catch in the Eastern Region.

Harvest tags are a rights-based management tool that is essentially the allocation of a right to take a specified quantity of a resource during a specified time period (Johnston et al. 2007). They allow for the regulation of harvest via the issuing of a certain number of tags and are also used for data collection. Harvest tags have a longer history as a management technique implemented by terrestrial hunting managers, where hunting of large game species requires regulation. Harvest tags have a long history of use in the US, where most large game requires some form of licence/permit as well as allocated harvest tags to allow them to be harvested by hunters (Johnston et al. 2007). Most often, harvest tags are implemented as a management strategy when there is concern over the sustainability of the harvest of certain species. The number of tags issued can be determined to whatever level required to ensure sustainability, whether the number issued is restricted or not. Commonly, these tags are physical tags attached to the harvested game; however, paper documents are also used. Harvest tags have the potential to be a useful management tool in fisheries where traditional management systems may not be adequately constraining catch to levels that promote sustainability. A key element in rights-based management is taking responsibility for your actions to have the right to fish and may also increase the awareness of resource scarcity (Johnston et al 2007).

While the benefits of tags may seem significant, there are also many challenges associated with implementing harvest tags in a fishery. First is the expectations of fishers. While terrestrial hunters are generally more used to restrictions such as short seasons, requirement of licences and tags, recreational fishers are more accustomed to open access of fisheries. As such, recreational fishers may not be willing to pay higher fees to do something they have historically participated in, leading to decreased participation. Allocation of tags is also an issue. How many tags will be issued? Will this be a hard target or can fishers access as many tags as they like? If numbers are restricted, how will the tags be fairly shared between fishers? An unfortunate side effect of introducing a limited tag system is the practice of high grading. This may result in unaccounted mortalities as high grading is difficult to detect (Johnston et al. 2007). Scale of the fishery is an important consideration when assessing whether tags are appropriate. As the number of tags increases, so do administration costs. Fisheries with many participants requires many tags, which cost money, and have detrimental environmental effects at their end of life (Johnston et al. 2007). Alternatives to plastic tags include catch card that can be sent in to management bodies, similar to the NSW Gamefish Tagging Program, where individual cards correspond with an individual tag (DPI 2021). The Victorian Rock Lobster Tagging Program has moved away from physical tags to electronic tags (VFA 2020). This has just been implemented, and if successful would provide the guidance going forward for other states that may be looking to implement some form of tagging program.

For a summary of recreational catch constraining options, including the strengths, weaknesses, costs, and considerations, please see Table 7.

## Fishery case studies

### Australian rock lobster fisheries

Australia has lobster fisheries operating in all states and the Northern Territory (Table 8). These vary in participation rates, monitoring regimes and management tools implemented. In Western Australia, the Department of Fisheries in Western Australia currently have their Western Rock Lobster Fishery managed under an Integrated Fisheries Management (IFM) plan (Crowe et al. 2013). This plan was the first formalised for Western Australia and includes the allocation of total catch between sectors based on historical use with some room for future growth (Integrated Fisheries Allocation Advisory Committee 2007). This explicit resource sharing arrangement then requires each sector to take responsibility for the catch management of its share (Caputi et al. 2018). The management plan also

includes social objectives, where social performance of the fishery is determined using recreational catch and catch rates, and social benefits associated with the commercial sector moving to an ITQ system, such as access for local consumers via a trial of a set quota to be made available to the local market (Caputi et al. 2018). The recreational fishery requires a licence to participate, and implements bag, possession, boat and size limits on both western and tropical rock lobsters caught. Differently from all other states except New South Wales, there is no season closure implemented for rock lobster, however there are restrictions on night fishing and taking berried females.

In Tasmania, a method-specific licence (i.e. pot, dive, or ring) is required to fish for rock lobster in the state. In South Australia (SA), Victoria (Vic) and New South Wales (NSW), no licence is required to fish for rock lobster, but all require some form of registration or payment, where in SA pots are required to be registered, in Vic participants need to register for rock lobster tags before fishing, and in NSW, eligible participants are required to pay the Recreational Fishing Fee.

While fishing regulations vary considerably between states for recreational rock lobster fishing, from no licence required to detailed size limits and area-specific season closures, sustainability is the goal they are trying to achieve, with this particularly obvious in that the single similar feature across all states is the protection of berried female lobsters.

**Victorian Rock Lobster Tagging Program**

In 2017, the Victoria Fisheries Authority (VFA) implemented a three year trial of a recreational rock lobster tagging program (VFA 2020). This program aimed to use catch tags in partnership with a smartphone application for reporting the tag fate to estimate the recreational rock lobster catch for the state. At the end of the season, any unused tags were also reported to determine a more accurate estimate of lobsters caught.

Fishers are required to register for the program via VFA's app, 'VicRLTag', through which they can apply for tags and report their used and unused tags. Fishers were provided with an initial allocation of 20 tags to use while fishing, with more tags available to them once the first allocation have been assigned to catch. The system then uses the number of tags reported as lobsters kept to represent the number of lobsters caught. Information collected when the tags are reported include the date fished, tag number, carapace length, and location. There is an additional 'citizen science' section that allows for the input of extra data including lobster weight, sex, other species caught, fishing method, and fishing duration. Over the three years that the program has run, participation increased slightly (from over 5000 participants in the first season to 5712 in the third season) however the number of lobsters reported as kept decreased from season one to three (7925 to 4395) as well as the percentage of users reporting catch the same day, down from 60.9% in the first season to 43% in the third season. While compliance in terms of attaching the tags was high, there was less compliance with reporting the fate of the tags after fishers were checked by Fisheries Officers (VFA 2020).

While the reporting part of the program is continuing, the physical catch tags are being replaced with a 'digital' tag in 'Phase Two' of the program. This digital tag consists of a generated 'tag' number when the user logs their catch using the app (FRDC Project No. 2019/075), a process which eliminates the need for double handling of the tags and no further requirement to physically attach the tags and then report them afterwards. One key incentive for moving from physical to digital tags was the associated reduction in plastic waste (VFA 2021).

**California spiny lobster**

The California Spiny Lobster fishery is managed using a Fisheries Management Plan (FMP) with a Harvest Control Rule (HCR) that applies to both the commercial and recreational sectors. The FMP with its HCR is an adaptive management tool, allowing fisheries managers to respond to changes in

the fishery and adaptively apply suitable new management options. The primary goal of the FMP is sustainability and to achieve this the HCR defines a set of references points for the fishery and a toolbox of options for decision makers to use in the instance that one (or more) of these reference points are triggered. There are three reference points, one for each of catch, catch per unit effort and spawning potential ratio. If any of these reference points are triggered, there are eight management options available to implement based on the particular situation: change the commercial trap limit, change the recreational bag limit, implement a total allowable catch, change the season length, change the minimum size limit, implement a maximum size limit, or implement a sex-selective fishery restriction. This toolbox of management options is given in no particular order and was developed with the Lobster Advisory Committee, a stakeholder group, meaning all options are likely to be more acceptable to those involved.

The recreational sector is managed by the California Department of Fisheries and Wildlife (CDFW) using daily bag limits, possession limits, size limits and gear restrictions. Historically a majority dive fishery, the main recreational method of fishing is now via hoop nets, with potting by recreational fishers not allowed in California. The fishery also requires participants to purchase and fill out a California spiny lobster report card each season to monitor the recreational catch. The report cards record the fishing date, location (from 92 area codes provided), gear type (conical hoop net, flat hoop net, skin diving, and SCUBA diving), and the number of lobsters kept. There is currently a limited way to measure effort (number of trips) as opposed to the more relevant soak time of nets or time diving for lobsters. These report cards were introduced in 2008 and initially had a low return rate. This has been improved by the introduction of a proactive public education push by the CDFW as well as the introduction of a $20 USD non-return fee in 2013. Due to the still low return rates of reporting cards (a max return rate of 54% was achieved in 2014/15), a survey was completed in 2019 to test the assumptions of those who did not return their catch cards. The survey found that there were differences between the fishing activities of those who returned their cards (e.g. more likely to have fished and be more avid) compared to those who didn't (e.g. more likely to have not fished or be one time participants) (CDFW 2021a). The survey's findings have led to a more accurate catch estimate for the recreational fishery to be developed. It is also noted that this study should be repeated in the future to determine if these patterns change over time, to ensure the calculated estimate is accurate

Table 6. Summary of options to measure and monitoring recreational catch

| Option | Strengths | Weaknesses | Cost | Response rate | Considerations |
|---|---|---|---|---|---|
| **Onsite surveys** | | | | | |
| **Access point creel survey** | • Assesses catch rate.<br>• Accurate harvest estimates.<br>• High resolution at small scales.<br>• Less bias than self-reported surveys.<br>• Consistent data collection. | • Subject to weather.<br>• Generally does not measure night fishing or fishing at low peak times.<br>• Generally does not measure fishing outside of boat ramps.<br>• More likely to encounter avid fishers.<br>• Minor access points missed. | • Low at small spatial scales, high at larger spatial scales. | • High | • Need to consider scale of survey. |
| **Roving creel survey** | • Assesses catch rate.<br>• Cost-effective onsite data collection method.<br>• Can sample beach fishing activities.<br>• Time and effort-efficient survey method. | • Incomplete fishing day data.<br>• Subject to weather.<br>• Generally does not measure night fishing or fishing at low peak times.<br>• Minor access points missed. | • Low at small spatial scales, high at larger spatial scales. | • High | • Need to consider scale of survey. |
| **Aerial surveys** | • Assesses effort.<br>• Cost-effective method for large scale fisheries<br>• Can count boats nearshore and sometimes offshore, and fishers onshore and deployed gear.<br>• Single flight adequate for sampling. | • Subject to weather (non-random sampling).<br>• Limited number of flights due to cost.<br>• Cannot gather any catch information. | • High | • NA | • Good supplementary measure but insufficient for harvest estimates alone. |
| **Video monitoring** | • Assesses effort.<br>• Ability for long-term monitoring of trends.<br>• Census of boat launches and retrievals. | • High data storage requirement.<br>• Images subject to weather.<br>• Image quality affected by a range of factors including | • Low to high, depending on number of video monitoring stations implemented. | • NA | • Need to consider position, location, power, and internet requirements. |

| | | | | | |
|---|---|---|---|---|---|
| | • Reproducible due to data stored on a server. | location, glare, and vandalism.<br>• Cannot distinguish between different boat uses (i.e. fishing or not). | | | |
| **Vehicle counter surveys** | • Assesses effort.<br>• Ability for long-term monitoring of trends.<br>• Census of activity. | • Data clarity affected by non-fisher vehicles/mixed number of axles on boat trailers.<br>• Malfunction (tubes disconnect).<br>• Data extraction issues. | • Low | • NA | • Need to consider location to minimise noise from non-fisher vehicles.<br>• Good supplementary measure but insufficient for harvest estimates alone. |
| **Parking snapshot surveys** | • Assesses effort.<br>• Ability for long-term monitoring of trends.<br>• Census of activity. | • Some boat trailers may not be visible in camera field of view/blocked by other vehicles.<br>• Images weather dependent. | • Low | • NA | • Good supplementary measure but insufficient for harvest estimates alone. |
| **Offsite surveys** | | | | | |
| **Telephone-diary surveys** | • Assesses harvest.<br>• Can sample larger-scale fisheries at low cost.<br>• Ability to obtain good catch and effort data. | • Ineffective at small scales.<br>• Non-response bias.<br>• Recall bias.<br>• Inaccurate reporting. | • Low at larger spatial scales. | • Variable, often low without incentives, but can be high if implemented with skilled interviewers and regular contact. | • Consider scale of survey.<br>• Requires a database for a representative sample to be drawn.<br>• Can provide in-season monitoring of catch, but not real-time monitoring of catch.<br>• Survey fatigue |
| **Panel/internet surveys** | • Assesses harvest.<br>• Can sample large numbers of participants at low cost.<br>• Ability to get detailed information. | • Sampling bias. | • Low | • Variable, often low without incentives, but can be high if implemented with skilled interviewers and regular contact. | • May require a database for a representative sample to be drawn.<br>• Can provide real-time monitoring of catch, though accuracy of estimates will vary based on reporting requirements (i.e. |

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|---|---|---|---|---|---|
| | | | | | voluntary/mandatory) and ability to verify estimates. |
| **Smartphone apps** | • Most people have a smartphone.<br>• Ability to collect supplementary data.<br>• Near real time data. | • Some people do not have a smartphone.<br>• Selection/non-random selection bias.<br>• Avidity bias.<br>• Non-response bias.<br>• Recall bias.<br>• Inaccurate reporting.<br>• Underreporting of zero-catch trips. | • Moderate, high initial cost to set up, low to continue. | • Dependent on voluntary or mandatory use | • Incentives or penalties for app use may be required.<br>• Can provide real-time monitoring of catch, though accuracy of estimates will vary based on reporting requirements (i.e. voluntary/mandatory) and ability to verify estimates. |
| **Catch cards** | • Can provide a comprehensive record of fisher catch and effort. | • Can have low return rates.<br>• Selection/non-random selection bias.<br>• Avidity bias.<br>• Non-response bias.<br>• Recall bias.<br>• Inaccurate reporting.<br>• Difficult to fill on a boat.<br>• Administration cost. Need to physically send out. And management data. | • Low | • Low to moderate | • Incentives or penalties for data return may be required.<br>• Can provide real-time monitoring of catch, though accuracy of estimates will vary based on reporting requirements (i.e. voluntary/mandatory) and ability to verify estimates. |
| **Online reporting** | • Can provide a comprehensive record of fisher catch and effort. | • Low to moderate participation rates.<br>• Selection/non-random selection bias.<br>• Avidity bias.<br>• Non-response bias.<br>• Recall bias.<br>• Inaccurate reporting. | • Low | • Low to moderate | • Incentives or penalties for data return.<br>• Can provide real-time monitoring of catch, though accuracy of estimates will vary based on reporting requirements (i.e. voluntary/mandatory) and ability to verify estimates. |

| | | | | | |
|---|---|---|---|---|---|
| **Telephone reporting** | • Can provide a comprehensive record of fisher catch and effort.<br>• Easy system to use for those who cannot use other technologies. | • Mobile coverage. | • Low | • | • Often used as a complimentary method.<br>• Can provide real-time monitoring of catch, though accuracy of estimates will vary based on reporting requirements (i.e. voluntary/mandatory) and ability to verify estimates. |
| **Complementary/ supplemented surveys** | • Assesses harvest.<br>• Ability to increase usefulness of data while removing some of the negatives of single method surveys. | • Possibility to be more expensive than single method surveys. | • Low to high, depending on methods used. | • High | • Best of both onsite and offsite surveys while reducing the negatives of cost and bias.<br>• Can provide real-time monitoring of catch, though accuracy of estimates will vary based on reporting requirements (i.e. voluntary/mandatory) and ability to verify estimates. |
| **Harvest Tags** | • Assesses harvest.<br>• Tags alone do not provide comprehensive information, | • Administration costs very high.<br>• Just because they are issued it does not mean a lobster is harvested.<br>• Removes ability to instantaneously fish. | • High | • High – needs to be mandatory | • Many barriers to fishing including require physical tags before fishing, loss of tags, plastic pollution. |

Table 7. Summary of management options to constrain recreational catch.

| Option | Strengths | Weaknesses | Cost | Compliance | Considerations |
|---|---|---|---|---|---|
| **Bag limits** | • Can reduce catch. | • Low fisher acceptability depending on limit.<br>• Can result in high grading. | • Moderate | • Due to low acceptability, voluntary compliance may be low. | • Does not inherently constrain catch. |
| **Season lengths** | • Can reduce catch.<br>• Easy enforcement. | • Low fisher acceptability<br>• Can result in race-to-fish, further reducing season. | • Low | • Easy to enforce.<br>• Generally high compliance. However due to low acceptability, voluntary compliance may be low. | • Does not inherently constrain catch. |
| **Minimum and maximum size limits** | • Can reduce catch. | • Can have unintended side effects<br>• Catch and release mortality unaccounted for | • Moderate | • Due to low acceptability, voluntary compliance may be low. | • Does not inherently constrain catch. |
| **Individual Season Limit** | • High fisher acceptability.<br>• System able to be flexible with catch allocations. | • Acceptability depends on number allocated.<br>• System easily gamed. | • Moderate-High | • Unknown, system likely to be gamed by some. | • Does not inherently constrain catch. |
| **Limit participation** | • Due to limiting entry, catch can be constrained to some form of limit. | • Low fisher acceptability. | • High | • Unknown, though due to low acceptability or perceived 'unfairness', compliance may also be low. | • Can constrain catch by restricting effort. |
| **Closing the fishery once TARC reached** | • Can constrain catch to the mandated limit.<br>• Easy to enforce. | • Requires real-time or near-real time monitoring that is mandatory for all participants.<br>• May result in a race to fish. | • Low | • Similar to seasons, however, requires communication resources. Unknown, though easy to enforce. | • Can constrain catch to the required level however requires some form of real-time or near-real time monitoring to determine when closure is required. |

Table 8 Summary of recreational lobster fishery rules in Australian States and California, USA*

| Fishery | Licence required? | Daily bag limit | Possession limit | Boat limit | Size limit (CL) | Gear limit | Season closures | Other rules |
|---|---|---|---|---|---|---|---|---|
| **Tas** | Yes, fishers aged 10+ required to buy separate licences for pot, rig or dive fishing. | Eastern Region = 2<br>Western Region = 5<br>North Bass Straight = 2 | Eastern Region = 4<br>Western Region = 10<br>North Bass Straight = 4 | Eastern Region = 10<br>Western Region = 25<br>North Bass Straight = 10 | North West Zone<br>Male = 110 mm<br>Female = 120 mm<br>Other Waters<br>Male = 110 mm<br>Female = 105 mm | 1 pot per licence holder. Max of 5 pots and 20 rings per vessel | Yes<br>ECSRZ:<br>1 May until first Saturday in Dec<br>Eastern Region outside ECSRZ:<br>1 May until first Saturday in Nov<br>Western Region Males:<br>1 Sept - first Saturday in Nov<br>Western Region Females:<br>1st May until first Saturday in Nov | Berried females protected.<br>Kept lobsters must be tail clipped. |
| **WA** | Yes | 8 (of which no more than 4 may be TRL) | 24 (of which no more than 12 may be TRL) | Dependent on number of fishers:<br>1 fisher = 8<br>2 fishers = 16<br>3+ fishers = 24 | SRL = 98.5 mm<br>WRL = 76 mm<br>TRL = 76 mm | 2 pots per licence holder, to a max of 6 pots per vessel | No, but restriction on night fishing | Berried females protected.<br>Kept lobsters must be tail clipped. |
| **Vic** | No, but fishers must register and be allocated rock lobster tags before fishing | 2 | 4 | No given boat limit? | Male = 110 mm<br>Female = 105 mm | NA | Yes<br>Males:<br>15 Sept-15 Nov<br>Females:<br>1 Jun-15 Nov | Berried females protected.<br>Kept lobsters must be tagged and tail clipped (note tagging will be discontinued next season). |
| **SA** | No, but pot registration is required (fishers aged 15+) | 4 | No given possession limit? | Dependent on number of fishers:<br>1 fisher = 4 | Northern Zone = 105 mm<br>Southern Zone = 98.5 mm | 2 pots OR<br>3 drop nets OR<br>3 hoop nets, per person | Yes<br>Northern Zone:<br>31 May- 1 Nov<br>Southern Zone: | Berried females protected.<br>Kept lobsters must be tail clipped. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 2+ fishers = 8 | | | 31 May- 1 Oct | |
| **NSW** | No, but fishers are required to pay the NSW Recreational Fishing Fee to fish in NSW | 2 | 2 | NA | ERL min = 104 mm<br>ERL max = 180 mm<br>SRL male min = 110 mm<br>SRL female min = 105 mm<br>TRL = NA | 1 lobster trap/pot per fisher.<br>Cannot use hoop or lift nets in ocean waters. | No | Berried females protected. |
| **QLD** | No | NA | 5 | Dependent on number of fishers:<br>1 fisher = 5<br>2+ fishers = 10 | Painted = 90 mm | Maximum of 4 pots or dillies per person. | Yes<br>1 Oct-31 Dec north of 14°S and in the Gulf of Carpentaria | Berried females and males with tar spots protected.<br>Recreational fishers must not possess live tropical rock lobsters. |
| **NT** | No | | 5 | Dependent on number of fishers:<br>1 fisher = 5<br>2 fishers = 10<br>3+ fishers = 15 | | Maximum of five pots or dillies (or combination of) per person to a maximum of 10 per vessel. | | |
| **CA** | Yes, fishers aged 16+ need a sport fishing licence, and all lobster fishers must have purchased a CA spiny lobster report card | | | | 82.6 mm min CL | No pots.<br>7 hoop nets per fisher<br>10 hoop nets per vessel | March-October | Hoop nets must be pulled every 2 hrs.<br>Requires the purchase and return of a CA spiny lobster report card |

*Abbreviations: Tas = Tasmania, WA = Western Australia, Vic = Victoria, SA = South Australia, NSW = New South Wales, QLD = Queensland, NT = Northern Territory, CA = California, CL = carapace length, ECSRZ = East Coast Stock Rebuilding Zone, TRL = Tropical Rock Lobster (*Panulirus ornatus*), SRL = Southern Rock Lobster (*Jasus edwardsii*), WRL = Western Rock Lobster (*Panulirus cygnus*), ERL = Eastern Rock Lobster (*Sagmariasus verreauxi*).

## Feasibility assessment based on a decision support tool

While many alternative monitoring and management options were identified in the literature review, there were certain options that were ranked higher by the feasibility assessment based on our decision support tool due to their ability to achieve certain objectives.

**Monitoring catch**

In the first instance, the decision support tool was used to identify high ranking options for measuring and monitoring catch. This was done separately for each of the three previously defined objectives and by considering effectiveness, costs and acceptability independently (Table 9). Mandatory self-reporting methods were identified as the most effective options to monitor catch if neither costs nor acceptability were considered important. If cost was assumed to be the only consideration, implementation of an offsite interviewer survey was the highest ranked option for quantifying and monitoring catch. This form of monitoring is currently run annually for the Tasmanian recreational rock lobster fishery and is likely to be most economically feasible because of its ability to reach a representative sample of fishers in a widespread geographic area. However, offsite surveys are not feasible for real-time monitoring, which would require some form of self-reporting method (without verification or catch tags for reduced costs and voluntary for increased acceptability). Overall, onsite creel surveys and voluntary reporting methods were the most acceptable monitoring methods for fishers, while onsite surveys were the most expensive option (Wise & Fletcher 2013) and voluntary reporting was least likely to provide accurate catch data due to inherent biases in self-reporting, among others (Venturelli et al. 2017, Skov et al. 2021). Equal consideration of effectiveness, costs and acceptability resulted in mandatory self-reporting methods as the highest ranked options for all objectives.

Table 9. Best ranked monitoring options based on the objective selected and key considerations for monitoring recreational catch.

| | **Objectives** | | |
|---|---|---|---|
| **Considerations** | **Quantify total catch** | **Monitor total catch** | **Monitor catch in real-time** |
| **Effectiveness only** | Mandatory reporting system – with verification, with catch tags | Mandatory reporting system – with verification, with catch tags | Mandatory reporting system – with verification, with catch tags |
| **Cost only** | Offsite interviewer surveys | Offsite interviewer surveys | Voluntary/mandatory reporting system - without verification |
| **Acceptability only** | Onsite creels surveys, and any form of voluntary reporting systems | Onsite creel surveys, and any form of voluntary reporting system | Any form of voluntary reporting system |
| **Equal weighting of considerations** | Mandatory reporting system – with verification, with catch tags | Mandatory reporting system – with verification, with catch tags | Mandatory reporting system – with verification, with catch tags |

**Constraining catch**

To achieve objectives for constraining catches, we analysed the same scenarios as described above for monitoring. Unsurprisingly, the results showed that the best ranked option to constrain catch to a hard limit

is the closure of the fishery once the catch limit is reached. This was true regardless of considerations of costs or acceptability because it represented the only option that can defensibly achieve this objective. If catches were simply aimed to be constrained (but without a specific target or hard limit in place) or maintained around a notional limit, a decrease in the season length to one month would be sufficient and more effective than alternative options. The least costly methods to implement were earlier closures of the fishing season, given that this management action does not require the development, implementation or administration of any additional tools. With respect to acceptability, the best ranked option varied based on the objective, with a season length of four months representing the most acceptable option for any reduction in catch, while decreasing the bag limit represented the most acceptable option to constrain catch to a notional rather than hard limit. Under equal weighting of all three considerations (effectiveness, cost and acceptability), the results mirrored those for acceptability except for objective 2 (constraining to a notional limit), which switched from lowering the bag limit to closing the fishery once a specified catch share target is reached.

Table 10. Best ranked constraining catch options based on the objective selected and key considerations for constraining catch.

| | **Objectives** | | |
|---|---|---|---|
| **Considerations** | **Constrain catch** | **Constrain catch to a notional limit** | **Constrain catch to any hard limit** |
| **Effectiveness only** | Decrease the season length to 1 month | Decrease the season length to 1 month | Close the fishery when catch share target or other limit is reached |
| **Cost only** | Any form of season closure | Decrease the season length to 1 month, or close the fishery when catch share target or other limit is reached | Close the fishery when catch share target or other limit is reached |
| **Acceptability only** | Decrease the season length to 4 months | Decrease the daily bag limit to 1 | Close the fishery when catch share target or other limit is reached |
| **Equal weighting of considerations** | Decrease the season length to 4 months | Close the fishery when catch share target or other limit is reached | Close the fishery when catch share target or other limit is reached |

**Constraining catch while providing equitable access to the fishery**

An additional management objective was to ensure equitable access to the fishery. The best ranked options to achieve this objective based on consideration of effectiveness, costs and acceptability are given in Table 11. Providing equitable access automatically ruled out any shortening of the season or limit in participation. There was also no intuitive option to ensure equitable access while providing for the ability to constrain catch to a hard limit. Considering effectiveness only, an ISL of five lobsters was the best ranked equitable management option to constrain catch. Considering only costs, decreasing the bag limit or increasing the minimum size were the two best options. Considering only acceptability, an ISL of 20 lobsters was the best ranked option for constraining catch, while decreasing the daily bag limit to one was the most acceptable for constraining catch to a notional limit. Under equal weighting of all considerations, increasing the minimum size by 10 mm (constrain catch), or decreasing the bag limit to one lobster (notional limit), were identified as the highest ranked options.

Table 11. Best ranked options to constrain catch while ensuring equitable access to the fishery.

| | **Objectives** | | |
|---|---|---|---|
| **Considerations** | **Constrain catch** | **Constrain catch to a notional limit** | **Constrain catch to a hard limit** |

| | | | |
|---|---|---|---|
| **Effectiveness only** | Individual Season Limit of 5 lobsters | Individual Season Limit of 5 lobsters | No option available |
| **Cost only** | Decrease the daily bag limit to 1 or increase the minimum size limit by 10 mm | Decrease the daily bag limit to 1 | No option available |
| **Acceptability only** | Individual Season Limit of 20 lobsters | Decrease the daily bag limit to 1 | No option available |
| **Equal weighting of considerations** | Increase the minimum size limit by 10 mm | Decrease the daily bag limit to 1 | No option available |

## Trial of the preferred monitoring system

### Recruitment survey

From the approximately 6000 recruitment emails sent to licenced rock lobster fishers, a total of 413 participated in the recruitment survey. Of these, the vast majority were male fishers, similar to previous recreational rock lobster surveys (Figure 7, Lyle et al. 2020b).

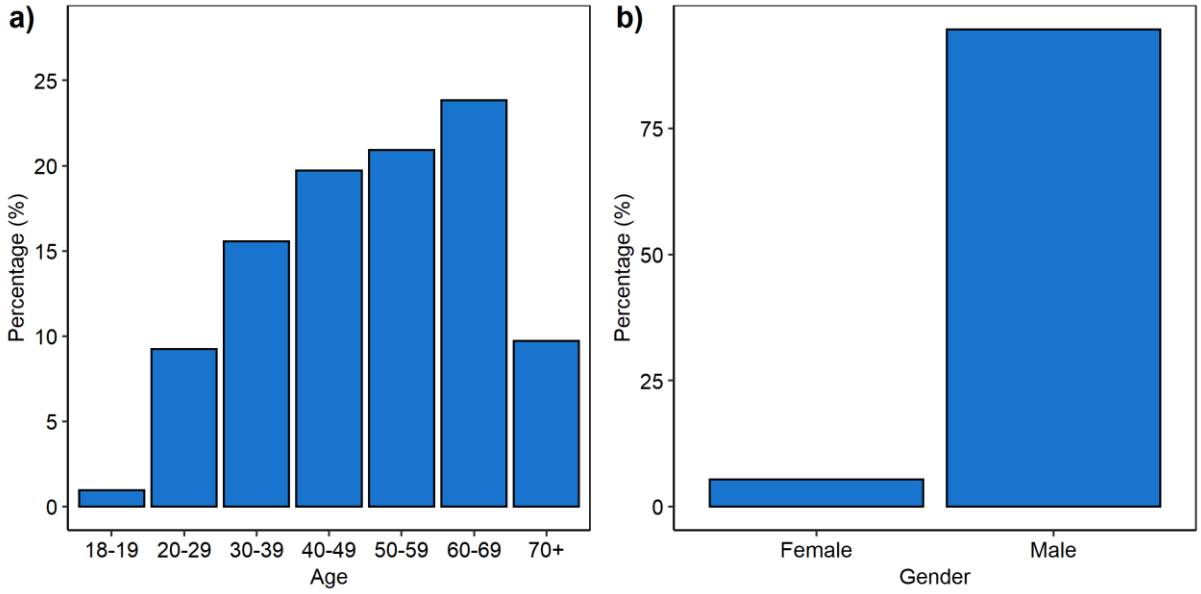


Figure 5. Demographics of the recruitment survey participants (n = 413).

Most fishers that responded have been fishing for a significant amount of time (Figure 6a). For the 2020/21 season, most had fished for fewer than 10 days, but a small percentage were avid fishers who had fished for more than 50 days of the season (Figure 6b). Season catch to date reflected that of general annual surveys, with most fishers catching just a few lobsters, and a small percentage taking more than 40 (Figure 6c). The dominant fishing method for those who participated in the survey was pot fishing, followed by dive and then ring fishing (Figure 6d).

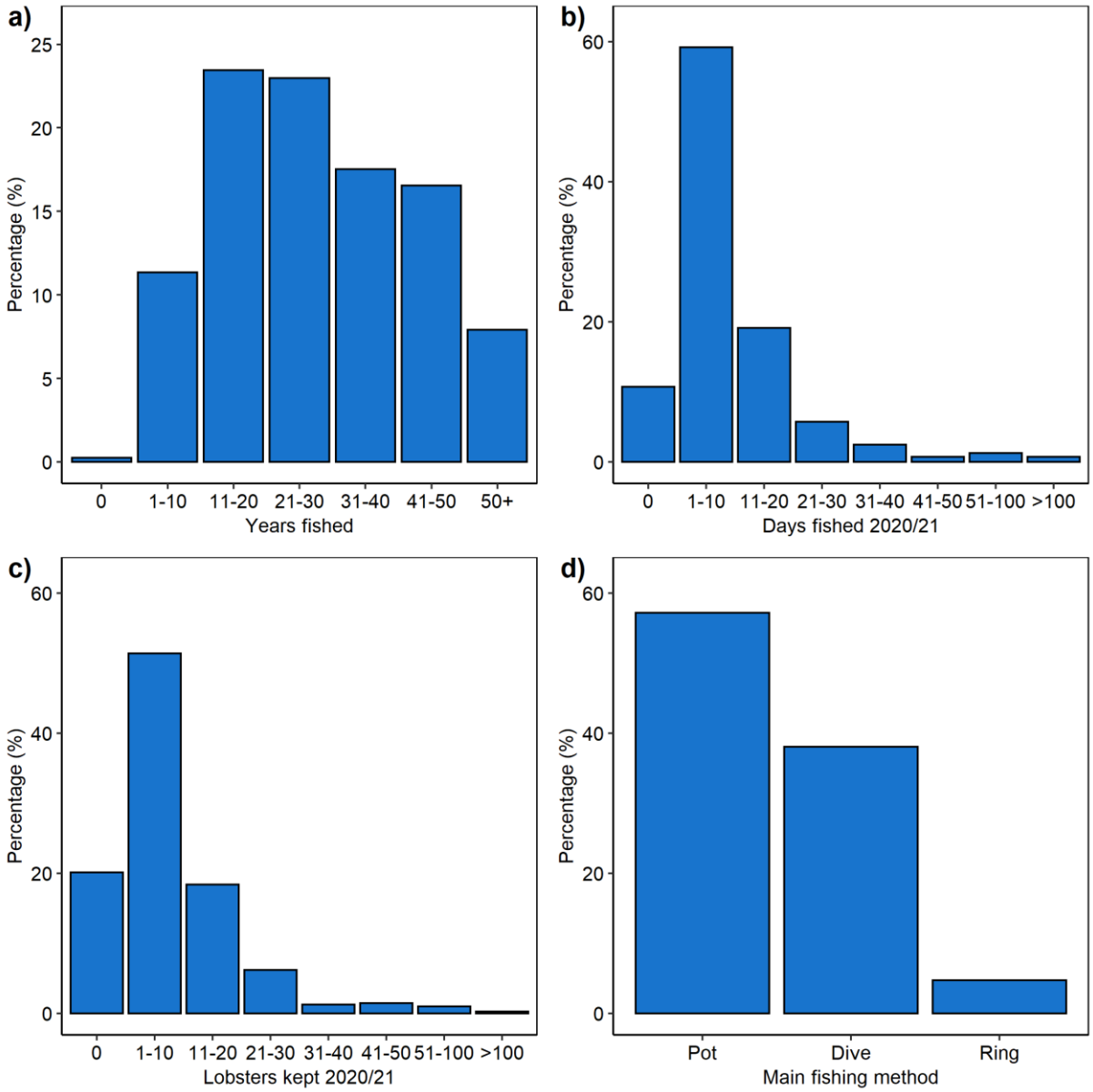


Figure 6. Fishing behaviour of participants in the recruitment survey, where a) is the number of years each participant has fished (n = 405), b) the number of days fished in the 2020/21 season to March 2021 (n = 402), c) the number of lobsters kept so far in the 2020/21 season to March 2021 (n = 403) and d) their main fishing method (n = 465).

In general, the majority of fishers agreed that the use of a smartphone app was a good idea to collect recreational catch data, but interestingly, a high proportion of respondents also thought that other fishers wouldn't be supportive of an app (Figure 7a-b). Similarly, for catch tags, the majority of fishers answered that the use of tags would be a good idea to collect catch data, with again a high proportion thought that other fishers would not be supportive (Figure 7c-d).

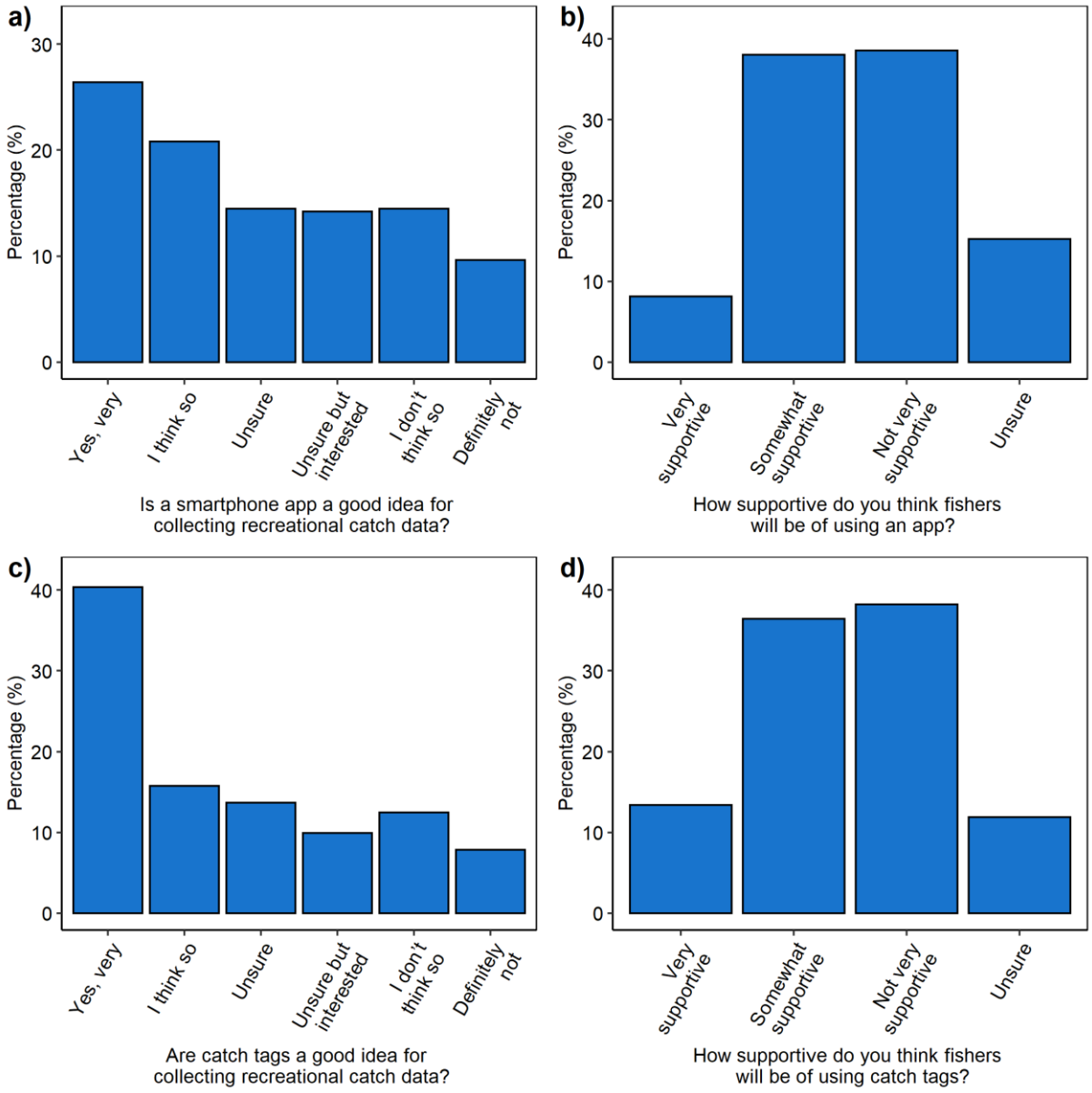


Figure 7. Reponses to the recruitment survey asking about general fisher support of alternative data collection methods, including a-b) smartphone apps and c-d) catch tags.

From the responding sample of 413 fishers, we identified 138 eligible participants to participate in the app trial, i.e. those who answered that they had a smartphone that was less than 10 years old (software requirements), they would be quite or very likely to go fishing before the end of the season, and they were willing to participate in the trial.

**Feedback survey**

Of the 138 fishers invited to participate in the trial, 70 created user accounts for the RLCMT app and submitted a total of 149 trips. A total of 56 participants responded to the feedback survey. Of the 56 responses received, 34 participants fished during the trial with 25 of these using the app to report their catch.

The age of respondents was slightly more skewed towards younger participants than the recruitment survey, with most participants in the 40-49 age bracket. As for the first survey, the participant sample was majority male.

**Smartphone app responses**

Of the 33 respondents that either used the app to report their catch after fishing or trialled the app via inputting dummy data if they were not able to fish, most of the participants found the RLCMT app very easy

to use, and no participants found it very difficult to use (Figure 8a). Most fishers submitted their pre-trip report from home before they went fishing (Figure 8b). For catch reporting, relatively few fishers recorded their catch immediately, with most submitting it when they returned to shore, or at home after the event (Figure 8c).

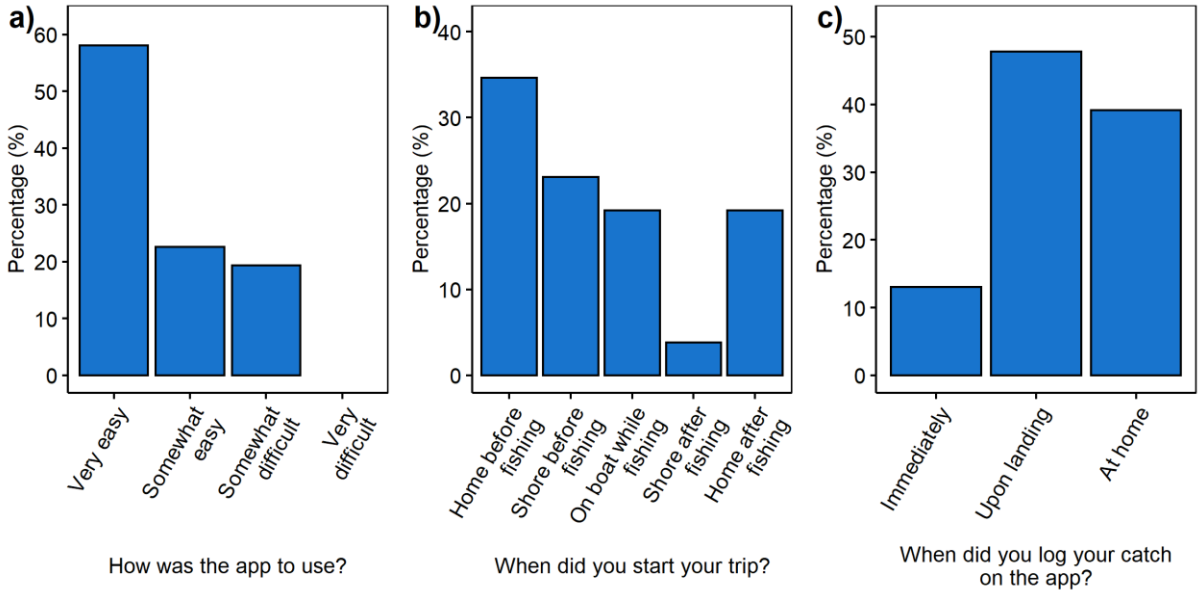


Figure 8. Participant response to a) the ease of use of the smartphone catch reporting application, and where the smartphone application was used to b) start the trip (i.e. pre-trip reporting of intention to fish) and b) log their catch for the trip.

***Smartphone app issues***

The first section of the feedback questionnaire asked respondents if they went fishing and if they used the RLCMT app to record their catch. Approximately 29% of respondents said that they did not use the app to report their catch. The main reason participants did not use the app was that they did not go fishing during the trial period (43%). This was followed by forgetting to use the app (19%) and technical difficulties (19%). The last issue of note that was the app was deemed 'too complicated' (5%).

All participants (including those that did not fish or use the app during the trial) were asked about their thoughts on the use of smartphone apps as a catch data collection method. Questions included whether the respondent thought they would be an accurate data collection method, and if they would be supported by the fishing community. In addition, participants were asked if they perceived any issues with the use of a smartphone as a data collection method, and if yes to provide details about those issues. All stated issues are summarised in Table 12.

Table 12. General issues raised about the use of smartphone applications as a catch data collection method. Percentage indicates the percent of respondents that indicated the issue in the feedback survey.

| General smartphone app issues | Percentage |
|---|---|
| Lack of telephone service | 32% |
| Individuals who do not have/will not use a smartphone or any form of electronic reporting | 29% |
| Use of a device at sea | 21% |
| Compliance | 21% |
| Remembering to use the app | 12% |
| General reluctance for any monitoring measure (perceived to be restrictive) | 12% |
| Inaccurate data entry/issues with data quality | 12% |
| Reporting catch location | 9% |
| Added complexity | 6% |
| Pre-fishing report unnecessary | 3% |

| | |
|---|---|
| Forgotten device | 3% |
| Device battery life | 3% |
| Data privacy | 3% |
| Potting set and retrieval recording | 3% |

**Catch tag responses**

Similar to the smartphone app, the majority of those who trialled the catch tags found them very easy to apply. However, some who them very difficult to use (Figure 9a). Unlike the smartphone app where catch was recorded mostly after the fishing event, most fishers attached their tags immediately after the catch (Figure 9b). Very few attached the tags after the fishing event, with some participants tagging when they got home or not at all because they forgot the tags while fishing or forgot to attach them.

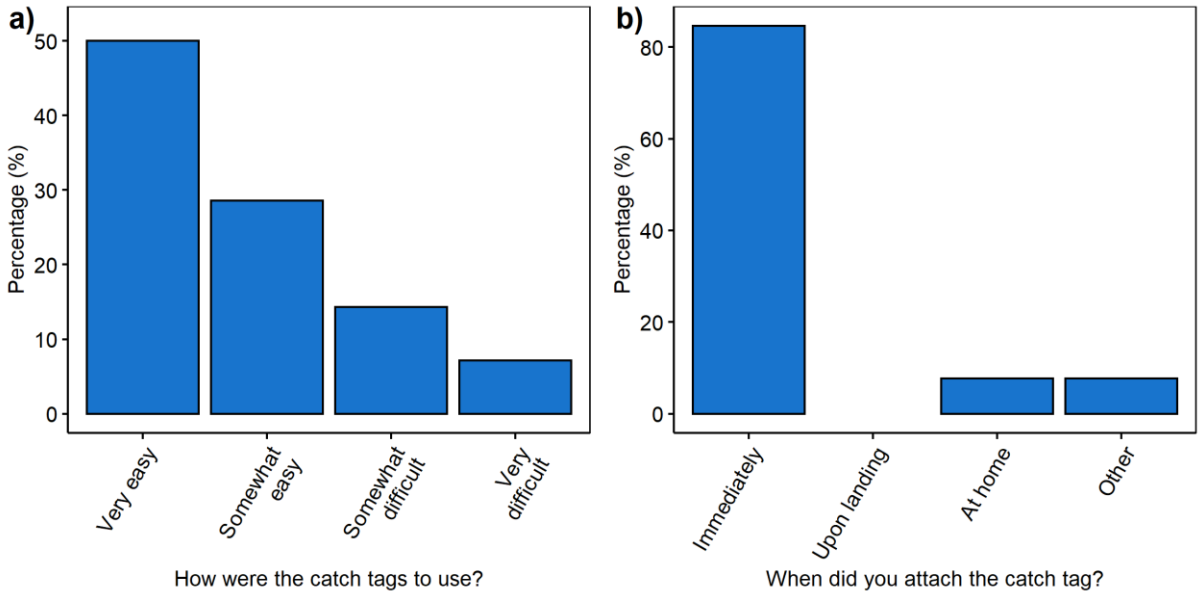


Figure 9. Participant response to a) the ease of use of catch tags and b) when they were attached the catch tag to their lobster catch.

***Catch tag issues***

Similarly to the smartphone app, the main issue with the use of tags during the trial were forgetting to take or attach the tags on the fishing trip (13%), as well as tags being difficult to attach (7%).

There were also issues raised with the use of a catch tags in general. These are summarised in Table 13.

Table 13. General issues with the use of catch tags. Percentage indicates the percent of respondents that indicated the issue in the feedback survey.

| **General tag issues** | **Percentage** |
|---|---|
| Compliance with use of tags, e.g. using them when lobsters are taken, attaching tags correctly, use of the reporting method to report fate of tags, etc. | 71% |
| High cost of tags, e.g. this cost may be passed to licence holders | 18% |
| Unplanned trips, e.g. not having tags with them before going fishing | 13% |
| Plastic waste once tags are used | 13% |
| Tampering with the tags | 13% |
| Complexity of attaching the tags, e.g. on a moving boat with wet hands | 13% |

| | |
|---|---|
| General reluctance for any monitoring measure, e.g. perceived to be a further restriction on their fishing rights | 13% |
| Issues with recording tag numbers for reporting of catch | 6% |

**Opinion comparison with the 2020/21 annual recreational rock lobster survey**

The 2020/21 recreational rock lobster survey participants were asked the same questions about smartphone apps, catch tags and ISLs as those participating in the feedback survey for the smartphone app and catch tag trial (Lyle et al. 2020a, Appendix 5). We compared the responses from both surveys to determine if there were any significant differences between the responses. We found that our sample was likely to be biased towards fishers in favour of smartphone apps and catch tags (Figure 10). This was to be expected as those who participated in the feedback survey had already agreed to participate in the trial. Overall, catch tags had slightly higher support in terms of both reliability and acceptability than smartphone apps. Interestingly, the trial survey revealed generally higher rates of uncertainty about each of the alternative catch reporting options as well as about the use of ISLs than the rock lobster survey. In terms of the ISL levels, the trial survey revealed higher acceptable numbers. Despite these differences, the general results of the two sets of responses were similar, i.e. most individuals were supportive of the proposed reporting and management options (Figure 10).

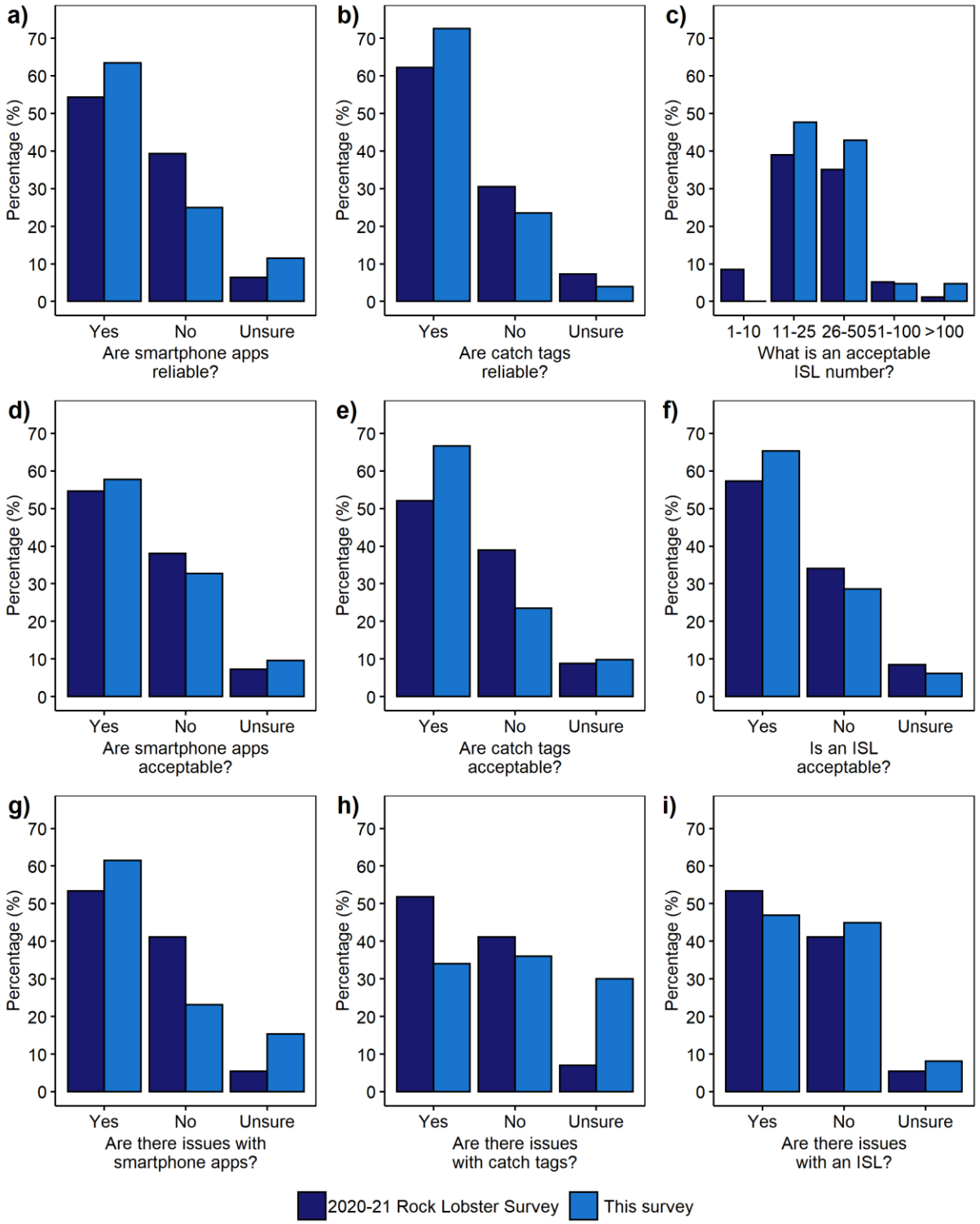


Figure 10. Comparison of opinions of smartphone apps (a, d, g), catch tags (b, e, h), and Individual Seasonal Limits (ISLs, c, f, i) between this study (light blue) and the 2020/21 Rock Lobster Survey that asked the same questions.

**Other issues raised**

In addition to issues about smartphones, catch tags and ISL, there were other issues raised by fishers, which were unrelated to the trial and objectives of our study, including concerns about boat limits, illegal fishing, a lack of policing, and current licencing arrangements.

# Discussion

## Review of existing monitoring and management systems

Our review identified various possible options for monitoring and constraining recreational rock lobster catch in Tasmania. However, some options were unlikely to be suitable. Onsite surveys, for example, would need to capture the high number of access points beyond boat ramps in Tasmania (Wise & Fletcher 2013). Implementing this type of survey would thus be very costly over the spatial scale required, and may still miss crucial components of the rock lobster fishery. Consequently, offsite surveys, such as the current annual Rock Lobster and Abalone survey, represent a more suitable option for such a widely spread fishery, particularly given the availability of a suitable sample frame (e.g. the recreational rock lobster fishery licence database, Lyle et al. 2021). The implementation of self-reporting methods is a new option for recording catch that may be acceptable to many fishers. However, mandatory reporting and verification of reported catch data using another method, as well as compliance monitoring, is likely needed to ensure that the data provides a reliable estimate of catch (Jiorle et al. 2016, Venturelli et al. 2017, Skov et al. 2021).

Constraining catch in the recreational fishing sector using traditional input and output restrictions is currently not effectively limiting catch to the recreational notional catch limit in the ECSRZ. The use of ISLs is assumed to be supported by both the management body and recreational fishers to help ensure the equitable sharing of catch between fishers, and to help reduce catch in the rebuilding zone more effectively. The use of an ISL may also allow a targeted management response to areas of most need, without impacting fishing in other areas. For example, a conservative ISL implemented for the ECSRZ may help constrain catch in this area, and a higher ISL or no ISL could be applied for the rest of the state, where further catch restrictions are not required. The implementation of an ISL may also increase flexibility by enabling the relaxation of other restrictions, such as season length limits, to increase acceptability. However, for ISLs to be effective for stock rebuilding they might be unacceptably low.

## Feasibility assessment based on a decision support tool

The feasibility assessment tested the relative performance of several possible monitoring and catch management options that could be implemented in the Tasmanian recreational rock lobster fishery.

**Monitoring catch**

Mandatory self-reporting methods with verification was consistently ranked highly for catch monitoring. This ranking assumed that compliance and response rates are high, which has not always been the case for previously implemented self-reporting methods (Midway et al. 2020, VFA 2020), but which can be higher than voluntary self-reporting methods (Collier et al. 2019, Skov et al. 2021). As described above, the self-reporting methods include a range of options that could be implemented (e.g. via a smartphone app, catch cards, telephone reporting, or online reporting). However, different combinations of options can be developed to suit the fishery in question.

The Victorian Rock Lobster Tagging Program was rolled out as a mandatory reporting for all rock lobster fishers (VFA 2020). While catch tags are also included in many of the highest ranked monitoring options, they represent a considerable investment. Tags are costly to purchase, take a considerable amount of administration to distribute and will contribute to plastic pollution (Johnston et al. 2007). The Victorian Rock Lobster Tagging Program has moved away from the use of physical tags for the previous three year trial, citing the reduction in the plastic footprint of their method (VFA 2021). It will also reduce the burden on fishers in terms of having to comply with attaching a tag, and then comply with reporting that tag later, instead rolling this into a single step using electronic tagging (VFA 2021).

While the use of a self-reporting method, most significantly via the use of a smartphone app, can assume to collect much data fast, it will still require some form of verification to determine the quality of the data collected (Venturelli et al. 2017, Skov et al. 2021). This feasibility assessment assumed that an offsite survey would be used as the verification method, such as the one currently implemented in the Tasmanian recreational rock lobster fishery (Lyle et al. 2021). While the framework also assumes that this verification is run annually, other jurisdictions have implemented verification surveys at longer intervals, which could reduce costs. For example, the Californian rock lobster fishery is monitored using the return of season catch cards (CDFW 2016). To determine if there was any difference between the fishing behaviour of those who returned their cards compared to those who did not, the CDFW implemented a survey to determine the fishing activities of participants and found that there was a difference in the fishing activity between those who returned their cards compared to those who did not (CDFW 2021a). The survey findings have led to a 'correction' factor for non-response bias applied to the data obtained from the catch cards, resulting in more accurate catch estimates. Managers proposed that this survey be periodically implemented to determine any changes in response patterns over time (J. Hofmeister, pers. comm.). This method may decrease the costs of the verification method but would likely result in lower quality estimates compared to annual verification.

**Constraining catch**

For constraining catch, the best ranked options were those to shorten the season length. These options are cheap to implement, easy to enforce and are effective in reducing the recreational catch depending on the level of restriction (e.g. one versus four month season length). However, these results assumed that there is no change in fisher behaviour, which is unlikely in reality. If the season gets shortened significantly, the catch saving is unlikely to be as high as assumed due to behaviour changes by fishers, including for example the commonly expected "race to fish". That is, if fishers perceive to miss out by not catching their allocation first, this situation might cause heavily concentrated fishing pressure and potential over-catch unless additional measures are in place to prevent it (Powers & Anson 2016, Farmer et al. 2019). Closing the fishery once the catch share target (or a total allowable catch) has been reached is the only option that could achieve the objective of constraining catch to a hard limit. However, this method requires some form of interval or real-time monitoring, which is likely to increase the cost of this otherwise cost-effective management option.

Other management options might have higher potential catch savings than a catch share target (e.g. decreased bag limits), but, again, potential changes in fisher behaviour mean that such measures are not guaranteed to prevent exceeding the notional catch limit. Moreover, further reductions to bag limits do not appear to be feasible for implementation in the ECSRZ. Similarly, changes in fisher behaviour could cause unexpected consequences from altering size limits, including for example the effect of high grading, whereby the smallest caught individuals are gradually replaced by larger ones to adhere to size and bag limits. The associated risk is that replaced and discarded individuals do not survive (due to impacts of handling, predation, or both), which is an effect that cannot generally be quantified with confidence and considered in stock assessments. ISLs, as the last principal option to constrain catches, are considered equitable in terms of access and catch sharing. However, it is unlikely that an acceptable ISL will be sufficient to constrain catch to the limit anticipated for the ECSRZ (Lyle et al. 2020b). Notably though, setting a suitably low ISL would primarily affect very few and avid, rather than the average, fisher.

## Trial of the preferred monitoring system

Smartphone apps are increasing in prevalence in recreational fisheries management. While they provide the potential for quick and cost-effective data collection, there are significant potential challenges to ensure high quality data. The trial of the RLCMT app highlighted a range of perceived issues with the use of smartphones and catch tags as methods to collect recreational catch data. Many of the issues raised have been encountered or pre-empted by other research groups investigating the use of smartphone apps as catch reporting methods. Below, we identify potential solutions to the issues raised, drawing on knowledge from other research groups, fisheries managers and the literature.

**Smartphone app solutions**

For the participants that did not get a chance to use the app during the trial, an extension of the trial via a voluntary roll out would provide an opportunity for more detailed feedback and improvement prior to official implementation. For example, in South Australia, there is currently a smartphone app trial being conducted voluntarily in conjunction with the state-wide fishing survey that will survey participants for a year (FRDC Project No. 2020/056). Participants can trial the smartphone app for a season and the data can be verified using the state-wide survey data. This project could provide an estimate of the quality of data collected via smartphone apps compared to more traditional survey methods. Alternatively, the Victorian Rock Lobster Tagging Program was implemented as a mandatory measure, with all rock lobster fishers required to register and obtain tags through the app or web portal. This trial ran for three years, and based on a recent assessment, will continue as a mandatory catch reporting program for the Victorian recreational rock lobster fishery (VFA 2021).

Remembering to use the app, which was a commonly stated concern, can be aided by using prompts sent by the app to users (Venturelli et al. 2017). For example, if push notifications are enabled on the users device, notifications during peak fishing times, such as Christmas, Easter, and long weekends, can be sent to fishers reminding them to use the app to record their catch if they are going fishing. Similarly, if location services are enabled on the users device, prompts can be sent when the device registers that the user is near, or on, the ocean. Additionally, for users that have started a trip but not cancelled/completed it, a reminder after a certain time period after the trip was started can be sent to the user to remind them to complete their trip details.

Added complexity is going to be the case for any form of catch reporting by fishers, based on the current lack of requirement to report their catch. Keeping the added burden on fishers in mind, the RLCMT app was developed on the basis of being as simple as possible, requiring the minimum amount of data from fishers that could be used in stock assessments (e.g. fishing location, method, and kept and released lobsters). Few participants stated that the pre-fishing report was unnecessary. Previous experiences by research groups implementing smartphone applications in other fisheries have found the implementation of pre-trip reporting essential to gain good quality effort data (FRDC Project No. 2019/075). If fishers are required to report their intention to fish before they go fishing, they are more likely to complete the catch record for zero-catch days. If this is not required, fishers are less likely to report on days they did not catch anything, resulting in underestimated effort measurements (Skov et al. 2021). Communication around why this measure is important may lead to increased reporting of zero catch days. Pre-trip reporting has been implemented in some states in the US for the Gulf of Mexico Red Snapper fishery (FRDC Project No. 2019/075). In Mississippi, fishers are required to register their intention to fish and receive an authorisation number via the 'Tails 'n' Scales' app (Gigli 2020). This information is then validated by dockside surveys. This method generates robust recreational data that is then used as part of NOAA's Marine Recreational Information Program (MRIP) to monitor Red Snapper harvest (NOAA 2018). The process of pre-trip reporting for the RLCMT app can be simplified to ensure it is not a burden on fishers. Its importance should also be emphasized to fishers to ensure their understanding and compliance of the measure.

There will also be fishers who cannot or will not use a smartphone app to report their catch (Skov et al. 2021). Alternative methods as identified in the literature review and assessed using the decision support framework include other types of electronic reporting such as email or online reporting, catch cards, and telephone reporting. The latter option is already implemented by the DPIPWE for some commercial fisheries. Any of these options provides an alternative reporting method, even though it should be noted that these will each have different set-up and running costs which may influence cost-effectiveness.

The concern about lack of telephone service is not considered an issue by the project team. The RLCMT app stores all the information recorded locally on the users device which is then uploaded to the server once the device is in service again. Education would solve this issue.

Another set of issues was related to complications with the use of electronic devices at sea while fishing. These issues included not taking a device to sea at all, the safety of using devices at sea, preserving battery life for emergencies, use of devices with wet hands including the potential for dropping devices into the sea. These issues would need to be considered when providing the policy around when catch data should be recorded. If data is required to be reported immediately upon catching of lobsters, these are concerns that

need to be addressed. However, if there is a requirement to report before leaving the landing site as opposed to before landed, then these issues are not as relevant.

Privacy concerns, such as those around fishing locations and data collection, are common with any form of electronic reporting. These concerns can be addressed with considered and informative messaging about the use of the app, including why the data is required and what will be done with the data collected to ensure trust in the app (Fujita et al. 2018). Another barrier to uptake of any measure of catch reporting is the view that it could be used to further restrict fishers. There were also some participants in the trial that perceived the implementation of a catch reporting mechanism as a further restriction on their fishing rights. This issue can also be corrected with informative messaging as above.

The issue of compliance was raised with concerns that due to the nature of inputting your own data, there would be issues with accidental and deliberate wrong data entered. Data quality checks can be used to pick up accidental data inputs, as well as clear guidelines on how to enter data in the app correctly. The issue of deliberate misreporting may be due to prestige bias (to give the impression they are catching more than they are), distrust of management, or attempting to influence management (Sullivan 2003, McCormick et al. 2013, Venturelli et al. 2017). These issues can be combatted by identifying the cause of the issues (Venturelli et al. 2017), education around the reason for the data is required, and using peer-influence and stewardship by other fishers, to encourage individuals to do the right thing. As a secondary option, increased compliance checks by Marine Police may be required to ensure any catch data collection method was being correctly used. Similar to the submission of commercial catch data compliance, checks would be required to protect the integrity of the system.

One issue that was not resolved before the app trial was conducted was the best way to collect data from fishers whose main method of fishing was potting. Unlike dive and ring fishing methods, where fishing events generally start and finish on the same day, setting pots can happen the day before they are retrieved, and this can affect how effort data is collected, and therefore the CPUE data required to monitor fisheries. Initial drafts of the RLCMT app suggested that fishers input pot set and collection times, however it was later deemed that this introduced too much complexity to the app. Potential solutions may be to include pot set and retrieve times in a 'citizen science' section that would keep the app simple but provide the opportunity to those willing to input the data. This data may also be collected from complementary verification surveys. Careful consideration and interaction with pot fishers may determine a suitable solution for this issue.

There were also suggestions in the feedback survey for what fishers wanted to see in an app developed for catch reporting. These included a trip record with the ability to edit submitted trips in case an error was made, the option to put in addition data such as lobster sex, weight and length, other fishing observations including bycatch, the integration of the current Tas Fish Guide app and the ability to see the real-time catch estimate. Most of these additions would be simple to incorporate into the existing RCMT app, especially as a voluntary component available for submission following the provision of all basic information on catch records e.g. a 'citizen science' component similar to that implemented in the Victorian Rock Lobster Tagging Program app, 'VicRLTag' (VFA 2020). This would keep the app as simple as possible for those wishing just to report their catch while also providing the flexibility for others to provide suggested additional information.

While data quality was not an issue raised by respondents in the feedback survey, it should be noted that it is an integral aspect of determining whether a smartphone app to record catch data is suitable for the fishery. Ensuring the mandatory use of an app for catch reporting is expected to increase participation unless compliance is very low. However, even in situations where catch reporting is mandatory, self-reporting responses rates can be insufficient to ensure accurate catch estimates. To address this issue, incentives and penalties can be implemented alongside increased compliance checks. Education around the importance of data collection and fostering stewardship will be important additional measures to help increase participation.

**Catch tag solutions**

Forgetting to take tags and forgetting to use them were the main issues identified by survey participants. This could be aided in prompting users to keep the tags somewhere easy to remember such as their car (if

shore fishing) or on their boat if potting or dive fishing. Additionally, signs at boat ramps used for lobster fishing could be used to remind fishers to tag their catch. If the tags are used with an app for reporting, similar reminders to those to use the app could be adjusted to remind users to remember to tag their catch if going fishing (Venturelli et al. 2017). Ultimately, if catch tags are implemented in the fishery, it will be up to fishers to remember to take and affix them to their catch, just as they need to take their gear to be able to fish. These above solutions are also relevant for the concerns raised about unplanned trips, if tags are kept with fishing gear, then unplanned trips can still occur if there is a requirement to tag catch.

Some participants also found the tags hard to attach. This related to the tags being one directional and hard to affix to the horn of the lobster. While this trial used standard tamper-proof pull-up seal tags, similar to those used in the Tasmanian commercial fishery and the Victorian Rock Lobster Tagging Program, other tagging options could be explored if required.

Plastic waste is also a considerable issue with the use of catch tags (Johnston et al. 2007). For the Tasmanian recreational rock lobster fishers, in the 2020/21 season more than 13,000 fishers fished. If each of these fishers received 10 tags to use for the season, this adds up to a considerable amount of plastic waste each year from the fishery. While biodegradable options are available, this is still a considerable plastic waste issue that breaks down into microplastics faster. It should also be noted that the Victorian Rock Lobster Tagging Program has recently moved from physical catch tags to digital tags (VFA 2021). These digital tags are a number identifier that is generated when the lobster(s) are recorded as kept and can be checked by compliance officers digitally. This was to save on the amount of plastic generated by the program (VFA 2021) but would also result in considerable cost savings in relation to purchasing and administering the tags to fishers in time for the fishing season (Johnston et al. 2007).

Compliance issues were also raised with catch tags. While they were perceived as easier to police than an app in terms of restrictions such as individual catch, they do not necessarily translate to easy compliance with reporting of those tags. In the Victorian Rock Lobster Tagging Program, high compliance was found in the use of the tags, however reporting of those tags using the smartphone was lower despite it being a mandatory component of the program (VFA 2020). Tampering with the correct way to put on tags was also raised, with participants noting that tags could either not be tightened properly on lobster horns for easy re-use, or for them to be attached to larger lobsters, removed, and then reattached on smaller lobsters. Compliance can be encouraged by educating fishers on the need for the measure, as well as encouraging stewardship to do the right thing. Compliance checks can be run by the Marine Police to ensure that fishers are complying with the regulations.

Complexity of using tags with an additional reporting mechanism is unavoidable. Reporting of tags would require some form of reporting system to report their fate (i.e. used or not) and that would increase complexity. While reporting of tag fate may provide information on harvest, they themselves do not provide information about catch location or discards. Due to the nature of physical catch tags, any reporting would require a two-part system, first where the tags are attached and second where the tags are reported. If some form of tagging system is required, it could be simplified using electronic tags and single-step tagging and reporting, such as recently developed by the Victorian Rock Lobster Tagging Program (VFA 2021). Results from this second phase of the program will determine if electronic tags are a suitable alternative for physical catch tags.

# Conclusions

This project investigated multiple monitoring and management options currently implemented in Australia and internationally. However, not all these options were likely to be applicable for use in the recreational rock lobster fishery in Tasmania. Our decision support analyses highlighted that for monitoring, some form of mandatory self-reporting could provide high quality data on the fishery, if there is a requirement for near real-time monitoring. The most cost-effective option to achieve catch constraints was found to be a shortening of the fishing season, either by shortening it to a fixed period, or by closing the fishery once the recreational catch allocation is reached. However, these options are not necessarily acceptable nor equitable in terms of access, the latter of which was an additional management objective considered to be important by the management agency. If equitable access to the fishery is a requirement, the introduction of an ISL could be suitable. However, an ISL that could achieve catch constraints required for stock rebuilding would likely be lower than acceptable levels stated by recreational fishers (Lyle et al. 2020b).

According to priorities by the DPIPWE, a smartphone app that could be used for real-time monitoring and ISL implementation was developed and trialled. Smartphone apps are increasingly being used as a method to collect a lot of data quickly and easily (Venturelli et al. 2017, Skov et al. 2021), with numerous implementations in fisheries in Australia (e.g. South Australia, FRDC Project No. 2020/056) as well as internationally (e.g. Red Snapper in the USA, FRDC Project No. 2019/075). Our study confirmed that apps are a positively perceived tool for catch reporting, which makes them a potentially valuable tool for recreational catch monitoring in Tasmania. However, for the resulting data to be of sufficient quality for stock assessments, it is likely that reporting needs to be mandatory (Jiorle et al. 2016), and that reported data needs to be verified based on independent additional survey methods (Venturelli et al. 2017, Skov et al. 2021). A feasible option for data verification in the Tasmanian recreational rock lobster fishery would be the continuation of the offsite survey already in place. Importantly, other monitoring options could be equally reliable and more cost-effective (e.g. the currently implemented offsite telephone-diary survey, Lyle et al. 2021) but may not be feasible to support management methods that require real-time monitoring.

Catch tags were also trialled due to support from the recreational sector and Marine Police. While there were largely positive responses on their use by participants in the trial, concerns about compliance was highlighted as a considerable issue by more than 70% of respondents. Previously, the DPIPWE had investigated the use of catch tags in the recreational fishery and deemed them very costly in terms of purchasing and administration, a burden on fishers, unable to provide catch estimates, and difficult in terms of compliance of use, including tampering (DPIPWE 2016). These issues have been raised again in this project, with no further solutions. In addition, the Victorian Rock Lobster Tagging Program has recently removed the use of physical tags from their program, also citing high costs and an excessive plastic waste (VFA 2021).

Based on our findings effective catch constraints in the ECSRZ could be achieved by shortening the season, decreasing the bag limit, or introducing an ISL, with the final choice depending on the relative importance of effectiveness, costs, and acceptability. Our decision support tool provides the flexibility to balance these considerations and explore highly ranked management options in more detail as new data for increasingly robust parameterization becomes available. Current support of an ISL by the DPIPWE is based largely on considerations of acceptability and equitable access, and while this management option has been addressed in various previous reports, practical experience is limited (Lyle et al. 2020a, Lyle et al. 2020b, Lyle et al. 2021). In this study, we were unable to investigate the practical implementation of an ISL, but we provided a tool that can be used to monitor and manage an ISL, the RLCMT app. The RLCMT app provides a means for monitoring ISLs without a need for other measures, such as catch tags. Extended trials of the RLCMT app are needed to better understand compliance and data quality.

Importantly, the implementation of any of the alternative monitoring or management options investigated in this study will not address some fundamental concerns expressed by fishers, including the current resource sharing arrangement in the ECSRZ.

# Implications

A new management system is needed to ensure that the recreational catch of rock lobsters, specifically in the ECSRZ, is sustainable. Our study provides a qualitative and quantitative assessment of plausible options for monitoring and management to achieve this overarching management goal. Outcomes from this study include the provision of a simple but flexible decision support tool for use by managers to balance multiple and potentially conflicting considerations (costs, effectiveness, and acceptability) to achieve clearly specified management objectives. Our study shows that both the key management objective as well as the relative importance of costs, effectiveness, and acceptability need to be clarified to identify the most suitable option for monitoring and constraining catch.

The currently supported option of an ISL, which ranked highly in providing for equitable access, but which may need to be set to unacceptably low levels for effectively constraining catch, requires near real-time monitoring of individual fishing activities. Our project provides a smartphone app that can be used for this purpose, and which should be tested more rigorously. Positive perceptions about the smartphone app from this study have incentivised a voluntary roll out of the smartphone app for the 2021/22 recreational rock lobster season by the DPIPWE.

# Recommendations

The voluntary roll out of the smartphone app over the next fishing season is needed to clarify further issues and desirable improvements prior to any official or mandatory implementation. Importantly, such a voluntary roll out should be used further to educate users and clarify the need for mandatory app use later on, including a comparison of reported catch data to estimates of catch based on the currently implemented offsite survey. Establishing the app and complementary forms of individual reporting (catch cards, online reporting or telephone reporting) is likely to be necessary to provide for regulations of catch around or strictly below the notional limit in ECSRZ. Specifically in this region, where stocks might otherwise not recover according to the rebuilding plan, app reporting might have to be combined with catch tags or differential tail snipping to ensure high compliance. Further investigation of the app as a catch reporting method will be needed to streamline the data collection aspect of fisheries management prior to implementing any form of management change.

This project focused on the collection of recreational fishing data. There is currently no data for the State's Indigenous catch as Indigenous fishers do not require a licence to participate in the fishery and thus are not surveyed as part of the annual rock lobster survey.

## Further development

Based on feedback from this study, several refinements of the app could be completed before a voluntary roll out over the next season. The data collected could then be assessed against the annual recreational rock lobster survey for quality and any potential unforeseen issues.

Research into the compliance rates of use would also need to be completed to determine if the data is of suitable quality for assessments. This can be done by using the current recreational rock lobster fishing survey as a verification method. However, if this verification method is not suitable, Marine Police may be required to ensure compliance with the monitoring method.

# Extension and Adoption

Findings from the literature review in combination with the monitoring and management decision support tool will be used by the DPIPWE to determine changes to current management arrangements over the coming fishing seasons. The Rock Lobster Catch Monitoring Trial smartphone app developed as part of this project is expected to be adopted by the DPIPWE for a voluntary roll out in the 2021/22 recreational rock lobster season. This voluntary roll out to a wide sample of fishers will help ensure that the system meets the objectives of catch monitoring, and that it is acceptable to fishers in terms of practical use as well as additional data provision back to fishers through citizen science programs.

# Appendices

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## Appendix 2: Intellectual Property

The research relating to this project is for the public domain and the report and any resulting publications are intended for broad dissemination and promotion.

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# Appendix 4: Recruitment questionnaire

**Alternative methods for monitoring and managing the recreational rock lobster fishery.**

***Information for participants***

Thank you for considering taking part in this survey. Please note that participants should be 18 years or older.

Southern Rock Lobster is one of Tasmania's most important recreational species. Over the last decade, there have been concerns about stock levels and resource sharing in this fishery and there has been support from the recreational sector to look at new methods to monitor and manage the fishery. A novel approach supported by government and many recreational fishers is the consideration of an individual season limit (ISL), where each fisher would have a maximum allocation that they may take in a season.

There are many practical issues to be considered in implementing this or any alternative management system. As a recreational rock lobster fisher, we are inviting you to participate in a short survey to get your opinions on potential new technology and method options for reporting recreational catches for the fishery, including the use of smartphone applications for catch reporting and catch tags that would be relevant to the introduction of an ISL. Depending on your responses, you may also be asked to consider participating in a brief smartphone application trial.

This survey is being conducted by the Institute for Marine and Antarctic Studies (IMAS), participation is entirely voluntary, and the survey is expected to take 5-10 minutes to complete. The survey is conducted in two parts, first to provide some information about you, then to provide your opinions of alternative management options. The survey will be available until the 31 March 2021.

Please be assured, any personal identifying information that you provide will be treated in the strictest confidence and will be removed from the database at the completion of the study. Other information will be held for five years and then destroyed. Any reports will involve combined information and thus any comments or responses will not be individually identifiable. When available, reports from this study will be promoted through various IMAS media platforms.

This study has been approved by the UTAS Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on (03) 6226 2975 or email ss.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number 24507.

If you have any questions about the study, feel free to contact Samantha Twiname on (03) 6226 8201 or by email at Samantha.Twiname@utas.edu.au.

By submitting your survey response you are providing your consent to participate in this study.

In anticipation, thank you for your co-operation and we look forward to your contribution to this important study.

Dr Nils Krueck, Dr Jeremy Lyle, Mr Rod Pearn, Dr Sean Tracey & Dr Samantha Twiname

(Project Team)

**Part A: Information about you**

***First, we have some questions about you and your general fishing experience.***

What is your age? (Please note respondents must be 18 years or older)

- 18-19
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70+

What is your gender?

- Male
- Female
- Other

What is your postcode?

How many years have you recreationally fished for rock lobster in Tasmania?

How many days have you fished for rock lobster in the current (2020/21) season?

Since the start of this year's season, how many lobsters have you personally caught & kept?

What is the main fishing method you use for rock lobster?

- Pot
- Dive
- Ring

**Part B: Your opinions on alternative catch data collection and management methods**

***In this section, we want you to provide your opinions on the use of alternative catch data collection and management methods, specifically the use of smartphone applications ('apps') and catch tags (physical form of monitoring catch, see image below).***

Do you think the use of smartphone apps for recreational catch reporting would be a good idea?

- Yes, a very good idea
- I think so
- Unsure
- Unsure but I'm interested
- I don't think so
- Definitely not a good idea

Generally, how supportive do you think other recreational fishers will be of catch reporting using a smartphone app?

- Very supportive
- Somewhat supportive
- Not very supportive
- Unsure

Do you think catch tags to regulate individual catches and provide an estimate of overall catch would be a good idea?

- Yes, a very good idea
- I think so
- Unsure
- Unsure but I'm interested
- I don't think so
- Definitely not a good idea

Generally, how supportive do you think other recreational fishers will be of catch reporting and regulation using catch tags?

- Very supportive
- Somewhat supportive
- Not very supportive
- Unsure

If a smartphone app, or catch tags, were introduced for all fishers, and it became compulsory for all recreational rock lobster fishers to report their catch, do you see any major issues of barriers to the implementation and uptake of these methods?

Do you have a smartphone?

- Yes, Android (e.g. Samsung Galaxy, Google Pixel, Motorola, Oppo, Nokia etc.)
- Yes, Apple iPhone
- No

Is your smartphone less than 10 years old?

- Yes
- No
- Unsure

How likely is it you will go fishing for rock lobster between now and the 30th of April 2021?

- Very likely
- Quite likely
- Unlikely

**Part C: Participation in a short trial**

***Thank you for completing the survey.***

***The Institute for Marine and Antarctic Studies (IMAS) is seeking volunteers to participate in a short trial of a new approach to collect recreational catch data. Volunteers must have a recent smartphone and be likely to fish for rock lobsters between now and the end of April.***

***A current study is looking into alternative management and catch monitoring options for the Tasmanian Recreational Rock Lobster fishery. A trial will be conducted in March/April 2021, with a smartphone app and catch tags to monitor rock lobster catch as the methods selected. This trial is focussed on the potential***

***for the implementation and management of an Individual Season Limit (ISL), and will assess the feasibility, functionality, and ease of use of the proposed approach and to seek stakeholder feedback.***

***This trial will be conducted using two groups. The first group of participants will trial the smartphone app alone, and the second group of participants will trial the smartphone app with the use of catch tags. Participation in either of these two groups will be allocated randomly. Participants will be asked to record any lobster catch using the app, with some participants also attaching a tag to their catch, for the duration of the trial. Once the trial is complete, participants will be contacted to provide feedback.***

Are you interested in participating in the trial?

- Yes
- No

Please provide your contact details. If you are eligible and randomly selected to participate in the trial, a member of the survey team will be in touch by email to provide more details and information about the trial, and to confirm that you still wish to participate. If so, we will then provide you with the app download and registration details and arrange delivery of catch tags (if appropriate).

- Name
- Email Address

**Thank you for your participation**

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***Your response is appreciated and will contribute to the discussion around alternative monitoring and management methods for the fishery.***

Would you like to receive a summary of the survey once the project is complete?

- Yes
- No

If yes, please provide your email address (if not previously entered)

# Appendix 5: Feedback questionnaire

**Rock Lobster Catch Monitoring Trial - Feedback Survey.**

***Information for participants***

Thank you for volunteering to participate in the smartphone app and catch tag trial. Now that the trial is complete, we would like your feedback on the smartphone app and, if applicable, the catch tags. The rock lobster fishery in Tasmania is an important recreational fishery. There has been support from the recreational sector for exploring alternative catch data collection methods including smartphone applications and/or catch tags. Therefore, your feedback on these methods will be very important for assessing their suitability for the fishery.

This trial is being conducted by the Institute for Marine and Antarctic Studies (IMAS) and your participation is voluntary. Completing the survey is expected to take 5-10 minutes. The survey will be available until 28 May 2021. Please note:

- Should you wish to withdraw during this trial, any information you have provided will be deleted. There are no negative consequences for withdrawing.
- You can also withdraw your information at any time up until 31 May 2021. To withdraw your information, please advise IMAS researcher Samantha Twiname by email (Samantha.Twiname@utas.edu.au).
- The information you provide as part of this trial will not identify you personally but will be grouped with information from other participants.
- Any personal contact details and fishing information will be removed from the database at the end of the study.
- The de-identified information you provide might be used for future research projects conducted by IMAS.

Reports on this trial will be anonymised, meaning that any information, comments, or responses are not individually identifiable. When available, reports from this study will be promoted through IMAS and the DPIPWE media platforms and publicly accessible.

This study has been approved by the Tasmania Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on (03) 6226 2975 or email ss.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number S0024507.

If you have any questions about the study, feel free to contact Samantha Twiname on (03) 6226 8201 or at Samantha.Twiname@utas.edu.au.

By submitting your survey response you are providing your consent to participate in this study.

Thank you in advance, we look forward to your feedback on this important study.

Dr Nils Krueck, Dr Jeremy Lyle, Mr Rod Pearn, Dr Sean Tracey & Dr Samantha Twiname

(Project Team)

**Part A: Did you fish and use the app?**

Did you do any fishing for rock lobster during April, whether you caught any or not?

- Yes
- No

Did you use the app to record your rock lobster fishing trips and catch?

- Yes – all
- Yes – some
- No

Did you trial the app?

- Yes
- No

What was the main reason you did not use the app?

**Part B: What did you think of the app/catch tags?**

Generally, how easy was the app to use?

- Very easy
- Somewhat easy
- Somewhat difficult
- Very difficult

How were each of the app features to use?

| | Very easy | Somewhat easy | Somewhat difficult | Very difficult | NA |
|---|---|---|---|---|---|
| App download | | | | | |
| User registration | | | | | |
| Reporting a trip | | | | | |
| Reporting your method | | | | | |
| Reporting location (including the map) | | | | | |
| Reporting catch | | | | | |
| Sequence of app questions | | | | | |
| Other (please specify) | | | | | |

Are there any additional features you think should be included in the app?

When did you start your trip by answering questions about your intended fishing location and method?

- Before I left home to go fishing
- At the shore before fishing
- On the boat while fishing

- Once my trip was finished but before going home (i.e. at the boat ramp)
- At home after my trip
- Other (please specify)

When did you log your catch?

- Immediately (i.e. as soon as the lobster was brought onto the boat)
- Upon landing (i.e. at the boat ramp)
- At home
- Other (please specify)

Did you trial catch tags?

- Yes
- No

Generally, how were the tags to use?

- Very easy
- Somewhat easy
- Somewhat difficult
- Very difficult

How were each of the tag features?

| | Very easy | Somewhat easy | Somewhat difficult | Very difficult | NA |
|---|---|---|---|---|---|
| Handling of lobster for tag attachment | | | | | |
| Securing the tag to the horn | | | | | |
| Recording the tag details | | | | | |
| Other (please specify) | | | | | |

When did you tag your catch?

- Immediately (i.e. as soon as the lobster was brought onto the boat)
- Upon landing (i.e. at the boat ramp)
- At home
- Other (please specify)

**Part C: Your thoughts on monitoring and managing the recreational rock lobster fishery**

Do you think compulsory smartphone app reporting would be a reliable way to estimate the size of the recreational catch of the lobster fishery?

- Very reliable
- Somewhat reliable
- Not very reliable
- Not at all reliable
- Unsure

Do you think compulsory smartphone app reporting would be acceptable to most recreational lobster fishers?

- Very acceptable
- Somewhat acceptable
- Not very acceptable
- Not at all acceptable
- Unsure

Do you think there would be any major issues with mandatory smartphone app reporting in Tasmania, including compliance by lobster fishers?

- Yes
- No
- Unsure

What sort of issues?

Do you think the use of catch tags, including their reporting requirements, would be a reliable way to estimate the size of the recreational catch of the lobster fishery?

- Very reliable
- Somewhat reliable
- Not very reliable
- Not at all reliable
- Unsure

Do you think introducing catch tags and their reporting requirements would be acceptable to most recreational lobster fishers?

- Very acceptable
- Somewhat acceptable
- Not very acceptable
- Not at all acceptable
- Unsure

Do you think there would be any major issues with introducing catch tags in Tasmania, including compliance by lobster fishers?

- Yes
- No
- Unsure

What sort of issues?

When do you think fishers should report their catch in the app?

- On marking their catch (i.e. when tail clipping (current requirement))
- On landing their catch (i.e. back at the boat ramp)
- Other (please specify)

When do you think fishers should tag their catch?

- On marking their catch (i.e. when tail clipping (current requirement))

- On landing their catch (i.e. back at the boat ramp)
- Other (please specify)

***DPIPWE are currently investigating the feasibility of individual season catch limits, which if introduced would limit the total number of lobsters each licence-holder could catch in a season. Season limits can lead to more equitable sharing of the catch between recreational fishers and, to some extent, constrain the overall catch within a sustainable level. If introduced, fishers would need to report each lobster caught and the whole process will need to be traceable and enforceable. Tags and/or smartphone apps are options to meet this requirement for catch reporting.***

If it were introduced, how many lobsters do you think would be an acceptable individual season catch limit?

Do you think the concept of an individual season limit and associated reporting requirements would be acceptable to most recreational fishers?

- Very acceptable
- Somewhat acceptable
- Not very acceptable
- Not at all acceptable
- Unsure

Do you think there would be any major issues with introducing an individual season limit to help sustainably manage the recreational lobster fishery?

- Yes
- No
- Unsure

What sort of issues?

Please provide any additional feedback on the trial, smartphone apps, catch tags or individual season catch limits in the comment box below.

**Part D: A bit about you**

What is your age?

- 18-19
- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70+

What is your gender?

- Male
- Female
- Other
- Prefer not to say

What is your postcode?

**Thank you for completing the survey**

***Your feedback is greatly appreciated and will contribute to the evaluation of alternative monitoring and management strategies for the Tasmanian recreational rock lobster fishery.***

If you would like to receive a project summary at the end of the study, please provide your email address below.

Email address

***If you would like to further discuss the project or your feedback, please feel free to get in touch with a member of our team at 03 6226 8201. If you would prefer us to call you, please provide your name and phone number below and a team member will be in contact.***

Name

Phone Number