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## Review of recreational fishing surveys in Western Australia

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Department of  
**Primary Industries and  
Regional Development**

## **Fisheries Research Report No. 301**

# **Review of recreational fishing surveys in Western Australia**

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## 2 Executive Summary

Recreational fishing has been a popular activity in Western Australia for many years, with an estimated 25% of the population participating in this activity in 2017/18. Recreational fishing surveys have been implemented by the Department of Primary Industries and Regional Development (formally Department of Fisheries) since 1976. Western Australia's extensive coastline stretches approximately 20,781km (including islands). There are ~3,000 fish species in the waters adjacent to this coastline and a variety of ecosystem types from the tropical north to the temperate south (Hutchins and Swainston, 2014). In 2017/18 an estimated 2.82 million fish were caught by boat-based recreational fishers in Western Australia with fishers capturing over 180 different species (Ryan et al. 2019). Species of particular interest to recreational fishers include Blue Swimmer Crab, Western Rock Lobster, School Whiting, Australian Herring, Pink Snapper and Squid. It is important that ongoing monitoring is undertaken to provide estimates of recreational fishing effort and catch for these key species and to observe changes in these indices overtime. This is especially true for fisheries where recreational fishing data is the only reference point for total catch or in instances where the commercial catch equals or exceeds that of the recreational catch. Licences can provide comprehensive lists of fishers that are used as sampling frames for off-site surveys. A licence is required to fish recreationally in Western Australia when fishing from a boat, and in 2017/18 135,384 fishers purchased a Recreational Boat Fishing Licence. Other recreational fishing licence types include Rock Lobster (55,368), Abalone (17,094), netting (15,705), Marron (10,779) and freshwater angling (8,924) (Department of Primary Industry and Regional Development, 2019). Best practice off-site (i.e., mail, phone) and on-site (i.e. access point, roving, aerial) survey designs have been utilised to provide information on fishing effort and catch, as well as fishery and fisher characteristics to help support a range of management strategies for recreational fishing in Western Australia. This report provides a comprehensive overview of 34 recreational fishing surveys which have been published between 1976 and 2019. This will assist researchers, managers and stakeholders to develop an understanding of survey design and recreational fishing activity in Western Australia.



## 3 Introduction

### 3.1 Background

Recreational fishing has been a popular activity in Western Australia for many years, with an estimated 25.6% of the population participating in this activity in 2018/19 (Department of Primary Industry and Regional Development, 2019). Fishing participation rates in Western Australia are consistently among the highest in the country (Henry and Lyle, 2003; Ryan *et al.*, 2017) and an estimated \$338 million is spent on recreational fishing each year (McLeod and Lindner, 2018). Recreational fishing is a diverse activity occurring across many different platforms (e.g. boat, shore) and habitats (e.g. pelagic, nearshore, offshore, estuarine) to target a range of species. Fishers also have a diversity of experience, characteristics and behaviours, ranging from non-avid fishers participating purely for the social benefits to avid fishers who participate frequently and tend to have stronger motives towards reaching their daily bag or boat limits (Henry and Lyle, 2003). The annual recreational catch of each individual fisher may seem quite small; however, the collective recreational catch can be substantial. In 2017/18, the estimated total catch (kept or released) from boat-based recreational fishing in Western Australia included over 1.32 million individual finfish (49% released) and 1.50 million invertebrates (44% released) (Ryan *et al.*, 2019).

Western Australia boasts the longest coastline of all states in Australia extending 20 781 km, including 12 889 km on the mainland and 7 892 km of island coastline (Geoscience Australia, 2019). The broad geographical scope and widely dispersed population make it challenging to collect robust and representative recreational fishing data which is essential to provide managers and decision makers with information to support resource allocation, stock assessments and management plans. Recreational fishing data also contributes towards elements of Ecosystem Based Fisheries Management (EBFM), Marine Stewardship Council (MSC) certification and Integrated Fisheries Management (IFM) which includes allocating resources between sectors (Crowe *et al.*, 2013; Ryan *et al.*, 2016; Newman *et al.*, 2018). Long-term monitoring plans that ensure catch and effort trends are established for fisheries across the state are essential to the sustainable management of these socially and economically important resources.

Recreational fishers are diverse, with considerable ranges of ability, preferences and motivations (Brownscombe *et al.*, 2019). Surveys should therefore be designed to capture data from one or all of these groups. A variety of survey designs can be used to collect data to achieve this aim, each with their own strengths and weaknesses that are linked to specific management objectives (Table 1). These survey designs can be categorised as off-site surveys and on-site surveys. Off-site survey designs are conducted away from fishing sites after the fishing activity has occurred, and fishers are typically randomly selected from a sampling frame (i.e. telephone directories or licence database which provide a list of fishers). These survey designs are best suited where fishing activity is widespread across large geographical areas for long periods of time. Data collection methods for off-site survey designs include mail, angler-diary, telephone and online. On-site survey designs are conducted at, or near to where fishing activity has occurred, with fishers interviewed or observed while engaging in fishing activity or sometime after the fishing activity. These survey designs are best suited where fishers are

more easily located and there are limited access points (boat-ramps or beach access points). On-site survey methods include aerial, access point, roving and remote camera surveys.

Survey designs are selected based on the survey objectives, the spatial and temporal scope of the fishery, and specific constraints, such as the timeframe or resource constraints. A clear understanding of survey objectives assists in selecting the most appropriate method. For example, catch data cannot be obtained from aerial survey designs, while access or roving survey designs involving face-to-face interviews are generally cost-prohibitive when conducted over large areas. Other factors such as environmental variability, fishery characteristics and fisher ability, preference and motivation should also be considered when determining the most suitable method.

Some surveys may also require a complementary design, whereby a number of different methods are implemented concurrently to improve coverage, reduce biases and improve accuracy. These complementary survey designs have grown in popularity in recent years (Henry and Lyle, 2003; Hartill *et al.*, 2015; Ryan *et al.*, 2019). Complementary survey designs include two or more survey methods to assist in the sampling of the fishery (Ryan *et al.*, 2016).

**Table 1 Key elements, strengths and weaknesses for off-site and on-site survey designs (adapted from Pollock *et al.*, 1994; National Research Council, 2006)**

	Off-site				On-site			
Method	Mail	Angler diary	Telephone	Online	Aerial	Access point	Roving	Remote camera
Target population	Large				Small			
Access points	Many, diffuse				Few, defined			
Context	Past (Recall) data				Current data			
Time to survey	Long				Short			
Cost	Low		Medium	Low	High			Medium
Sampling frame	List of people				Spatial-temporal constraints			
Representative	Low		Medium	Low	High			Medium
Data collection	Reported by fisher				By interviewer/data entry officer			
Questionnaire	Long		Simple	Long	Simple			
Response rates	Low		High	Low	High			
Catch estimate	No		Yes	No		Yes		No
Effort estimate	Yes							No
Catch rate estimate	Yes				No	Yes		

The survey design also influences the types of data that are collected and it is therefore closely linked to the survey objectives (Table 1). The most common data obtained during recreational fishing surveys relates to the calculation of fishing effort, catch and catch rate, and may also include questions relating to the current or previous fishing activity (i.e. number of people fishing, gear type used, length of fishing trip, species caught, numbers of fish kept or released). The unit of measurement for each of these metrics often varies (i.e. fishing effort can be measured in fisher days, boat days, fishing events, fisher hours). In addition, as surveys of recreational fishing are sample surveys (i.e., not a census), it is also important to provide measures of uncertainty (e.g. standard error and confidence intervals) in conjunction with estimates of fishing effort and catch.

### **3.2 Recreational fishing in Western Australia**

Western Australia's extensive coastline stretches approximately 20,781km (including islands) (Geoscience Australia, 2019). There are ~3,000 fish species contained in the waters adjacent to this coastline, and a variety of ecosystem types; from the tropical north to the temperate south (Hutchins and Swainston, 2014). There are a number factors influencing these ecosystems including inputs from tributaries and tidal coastal waters and the increasing pressure from anthropogenic activities and developments (Lenanton et al., 1991, Caputi et al. 1996). This is particularly true for the West Coast Bioregion where the majority (73%) of the state's 2.5 million people reside in the capital city of Perth (ABS 2018). With the adoption of an EBFM approach in Western Australia (Fletcher *et al.*, 2012), six broad bioregions were developed (based on common oceanographic or climate/rainfall characteristics) to be used as the basis for assessments and management (Figure 1). Within these bioregions, recreational fisheries are managed using a variety of input and output controls including licences, bag and size limits, boat limits, and area and seasonal closures (Department of Fisheries, 2012, 2017). The majority of recreational fishing effort currently expended in Western Australia occurs in the West Coast Bioregion (74%) around Perth and the regional cities of Bunbury, Busselton and Geraldton (Department of Primary Industry and Regional Development, 2019). The Gascoyne Coast has the second-highest effort (12%), followed by North Coast (8%) and South (6%). Summer (December–February) in the West Coast and South Coast is the peak period for boat-based recreational fishing while in the Gascoyne Coast and North Coast the peak period is during winter months (June–August) (Ryan *et al.*, 2017). Recreational fishers in Western Australia target finfish species using a variety of methods including lines, nets and spears, while invertebrates may be targeted using pots, scoop or drop nets or loops.

Recreational fishers have been recorded as capturing more than 180 fish identified species in Western Australia with an estimated 2.82 million fish caught from boat-based fishers in 2017/18 (Ryan *et al.* 2019). Species of particular interest to recreational fishers include Blue Swimmer Crab, Western Rock Lobster, School Whiting, Australian Herring, Pink Snapper, and Squid. For some species, particularly nearshore indicator species, the boat-based recreational catch almost equals the commercial catch (i.e. Blue swimmer crab in Peel Harvey Estuary) (Gaughan and Santoro, 2018). Moreover, in the past shore-based catches have also exceeded boat-based catches (Henry and Lyle 2003) however, due to lack of ongoing shore-based fishing surveys a time series of catch is unavailable.

Management measures (i.e. size and bag limits) for many species are usually consistent across bioregions or statewide. However, some localised or species-specific management arrangements are required to manage stocks which have been deemed at risk (i.e. Pink Snapper in inner Shark Bay, Australian Herring and Abalone in the West Coast) (Department of Fisheries Western Australia, 2011; Newman *et al.*, 2018). A licence is required to fish recreationally for Rock Lobster (55,368 licences in 2017/18), Abalone (17,094), netting (15,705), Marron (10,779), and freshwater angling (8,924) in Western Australia. Since March 2010, individuals participating in boat-based recreational fishing in Western Australia from a motorised vessel are required to purchase a Recreational Boat Fishing Licence (RBFL). In 2017/18 135,384 fishers purchased a Recreational Boat Fishing Licence. This is a unique licence in Australia in that only one member of a fishing party is required to hold a licence, as long as all fishers on the vessel comply with a single bag limit.

### **3.3 Objective**

The objective of this report is to summarise the recreational fishing surveys conducted in Western Australia by the Department of Primary Industries and Regional Development (DPIRD), formerly the Department of Fisheries, which have been published between 1976 and 2019. This provides a comprehensive and cohesive overview of 41 recreational fishing surveys, the results of which can be utilised by researchers, managers and stakeholders to develop an understanding of survey design and recreational fishing activity in Western Australia. The report is organised by survey method (off-site and on-site) and chronological order to facilitate comparisons between surveys and demonstrate changes in survey designs over time.

## 4 Methods

For the purpose of this review, all historical recreational fishing surveys conducted within Western Australian coastal and inland waters, and published as Fisheries Research Reports and Occasional Publications were identified using the DPIRD library database (Appendix 1). Peer reviewed papers were not included in the review as they often also draw on data utilised in one or more Departmental publications, or combined with data from other jurisdictions. However, in some instances these peer reviewed papers report on survey results that have not been summarised in Fisheries Research Reports and Fisheries Occasional Publications, a full list can be found in Appendix 2. Unpublished data and data reported by external organisations were also excluded from the review. In order to meet the stated objectives, specific criteria were used to evaluate and review each publication and included elements of survey design, sample selection, data constraints, survey dates, and time of the survey.

## 5 Results

### 5.1 Review of publications

There were 42 Fisheries Research Reports or Fisheries Occasional Publications included in this review (Appendix 1). Of these, the majority were either location specific (28) or statewide (14). Of the four marine bioregions, the West Coast Bioregion was subject to the majority of recreational fishing surveys with 17 publications. Six publications focused on the metropolitan region including the Peel Harvey Estuary (Lenanton and Hall, 1976; Malseed and Sumner, 2001a, 2001b; Smallwood *et al.*, 2011a and 2011b, Hart *et al.*, 2013), four focused outside the metropolitan area (Lenanton *et al.*, 1996; Malseed *et al.*, 2000; Bellchambers *et al.*, 2006; Sumner, 2008) and seven covered both metropolitan and surrounding areas (Norton, 1981; Sumner and Williamson, 1999; Sumner and Malseed, 2004; Sumner *et al.*, 2008; Johnson *et al.*, 2014; Harris *et al.*, 2016, and Desfosses *et al.* 2019). There were five publications on recreational fishing in the Gascoyne Coast (Sumner and Steckis, 1999; Sumner *et al.*, 2002; Smallwood and Gaughan, 2013; Taylor *et al.*, 2018 and Taylor *et al.*, 2019), three in the South Coast (Caputi and Lenanton 1977; Heald, 1984; and Smallwood and Sumner, 2007), two publications focused on the Southern Inland (Morrissy and Fellows, 1990; Molony and Bird, 2002), and a single publication in the North Coast (Williamson *et al.*, 2006). Ten publications were prioritised by species: Abalone (*Haliotis* sp.) (Hart *et al.*, 2013), Australian Herring (*Arripis georgianus*) (Lenanton and Hall, 1976), Blue Swimmer Crab (*Portunus armatus*) (Sumner and Malseed, 2004; Bellchambers *et al.*, 2006; Johnston *et al.*, 2014; Harris *et al.*, 2016), Marron (*Cherax cainii*) (Morrissy and Fellows, 1990; Molony and Bird, 2002), Pink Snapper (*Chrysophrys auratus*) (Sumner & Steckis 1999), and Western Rock Lobster (*Panulirus cygnus*) (Norton, 1981; Melville-Smith and Anderton, 2000).

A range of survey designs have been used in these publications. Off-site survey designs have included data collection by mail (Norton, 1981; Morrissy and Fellows, 1990; Melville-Smith and Anderton, 2000); angler diaries (Caputi and Lenanton, 1977; Morrissy and Fellows, 1990; Molony and Bird, 2002; Smallwood and Sumner, 2007; Sumner, 2008); telephone (Molony and Bird, 2002; Baharthah, 2004, 2008a, 2008b, 2008c, 2009; Ryan *et al.*, 2013, 2015, 2017, 2019); and door-to-door (Williamson *et al.*, 2006). On-site survey designs included data collection using: aerial (Sumner, 2008; Smallwood *et al.*, 2011a, 2011b; Smallwood and Gaughan, 2013); access point (including bus route designs) (Lenanton and Hall, 1976; Heald, 1984; Sumner and Williamson, 1999; Malseed *et al.*, 2000; Malseed and Sumner, 2001b, 2001a; Sumner *et al.*, 2002, 2008; Sumner and Malseed, 2004; Williamson *et al.*, 2006; Smallwood and Sumner, 2007; Ryan *et al.*, 2013, 2015, 2017, 2019); roving (Malseed *et al.*, 2000; Malseed and Sumner, 2001a, 2001b; Sumner *et al.*, 2002, 2008; Sumner and Malseed, 2004; Williamson *et al.*, 2006; Smallwood and Sumner, 2007; Smallwood *et al.*, 2011b); and remote cameras (Smallwood *et al.*, 2011a; Ryan *et al.*, 2013, 2015, 2017, 2019; Taylor *et al.*, 2018).

Complementary survey approaches have been used to provide cost-effective estimates of recreational catch and effort (Norton, 1981; Malseed *et al.*, 2000; Malseed and Sumner, 2001b, 2001a; Molony and Bird, 2002; Sumner and Malseed, 2004; Williamson *et al.*, 2006; Smallwood and Sumner, 2007; Sumner, 2008; Smallwood *et al.*, 2011b, 2011a; Ryan *et al.*, 2013, 2015, 2017, 2019; Taylor *et al.*, 2018, Taylor *et al.*, 2019) In some cases this has involved both on-site and off-site methods (Ryan *et al.*, 2019) while in others it has involved multiple on-site methods (Taylor

*et al.*, 2018).Figure 1 Map of Western Australia indicating the four marine and two inland bioregions and key small-scale fisheries where recreational fishing surveys have been conducted from 1976 to 2019.

**Figure 2 Map of Western Australia indicating the four marine and two inland bioregions and key small-scale fisheries where recreational fishing surveys have been conducted from 1976 to 2019.**

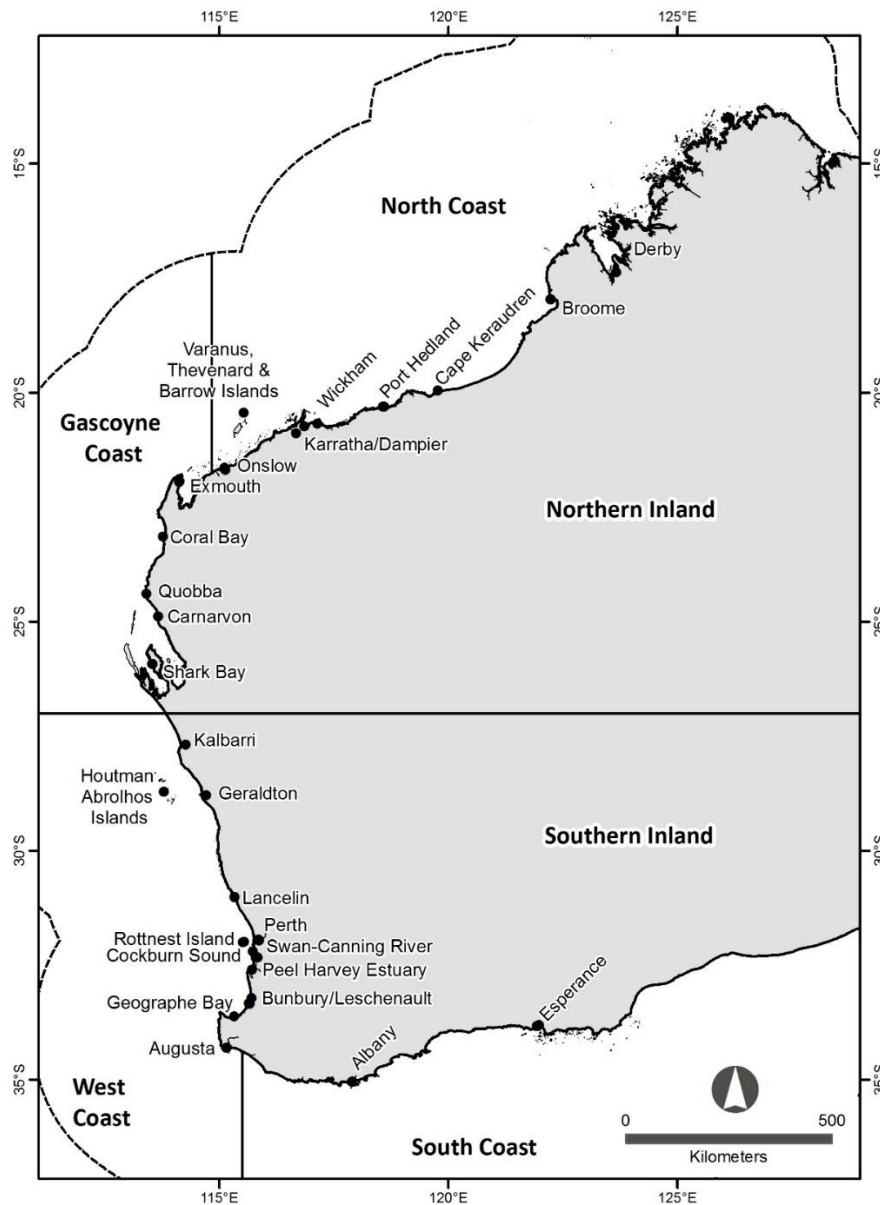
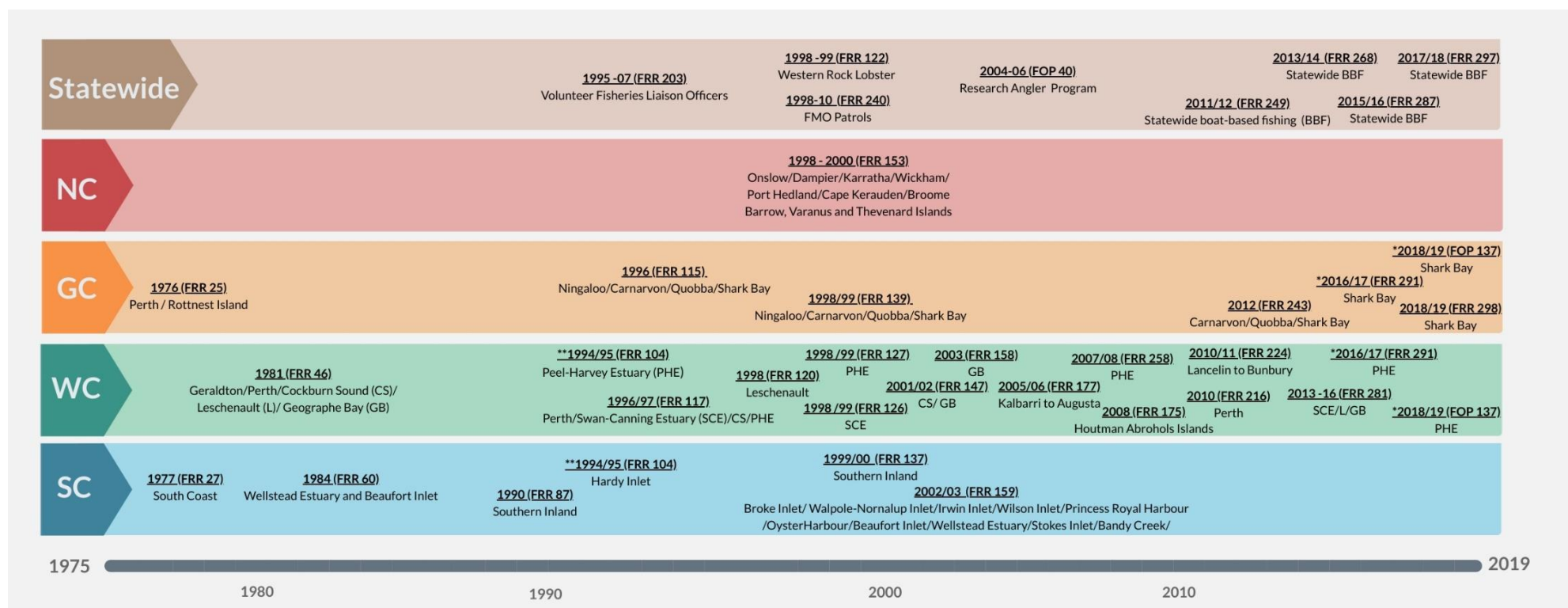


Figure 2. Timeline of recreational fishing surveys in Western Australia from 1976–2019. Excluding statewide community surveys (2002–present)



\*Survey occurs across both Gascoyne and West Coast Bioregions

\*\*Survey occurs across both West and South Coast Bioregions





## **5.2 Off-site surveys**

Mail, angler diary, telephone, and online data collection methods are all off-site survey designs (Table 1). In the majority of these designs, a random sample is drawn from a known list (i.e. licence database) and data are self-reported by the fishers. Off-site survey designs provide a comprehensive and often cost-effective assessment of recreational fishing (including data of fishing effort, catch rate and catch) across a large geographical range. These surveys collect information not only on fishing trips but also on social and economic data. Stratification of samples (i.e. by Regional Development Commissions) are often utilised in these survey designs to increase the precision of results.

### **5.2.1 Mail**

Mail survey designs are a simple approach for collecting recreational fishing data that can easily be applied across large geographical scopes to collect attitudinal and catch and effort data from fishers. Sampling frames for mail survey designs have been obtained from licence databases and by obtaining fishers postal addresses during on-site surveys.

Two mail surveys have been conducted, and both have used the Rock Lobster (RL) licence database as the sampling frame (Table 2) (Norton, 1981; Melville-Smith and Anderton, 2000). Questionnaires and reply paid envelopes were posted to the licensed fishers for their completion and return. In 1976, 22,400 WRL licence holders were contacted, with 3660 returned questionnaires (10 questions). Melville-Smith and Anderton (2000) undertook a census of WRL licence holders (n=32,786) in 1998/99. In the preceding years (1986/87 to 1997/98) a random sample of RL licence holders were sent the survey, however, the sample size for these years were not recorded. This survey continued annually from 1999 with results providing ongoing catch estimates for this fishery, and are currently reported annually in the State of the fisheries report (Gaughan and Santoro, 2018).

### **5.2.2 Angler diary**

Angler diary designs require fishers to report data through diaries, logbooks, questionnaires or catch cards and primarily focus on the collection of catch, effort and socio-economic data. These diaries are often submitted on a voluntary basis, which leads to higher participation by avid fishers. To account for the nonresponse bias, these surveys are often used in conjunction with other survey methods such as a telephone or mail survey in an attempt to sample these non-respondents (Molony and Bird, 2002).

Six angler diary surveys have been conducted in Western Australia since 1977. Two of these surveys were species-specific focusing on the recreational catch of Marron and freshwater species (Morrissey and Fellows, 1990; Molony and Bird, 2002). These surveys have run continuously for 19 (Marron) and 18 years (freshwater) and with annual reports on each fishery presented in the State of the fisheries report (Gaughan and Santoro, 2018). Diaries and questionnaires have also been used to collect data on recreational fishing from holiday resorts along the south coast estuaries

(Caputi and Lenanton, 1977), houseboats in the South Coast (Smallwood and Sumner, 2007), privately-owned vessels in the Houtman Abrolhos Islands (Sumner, 2008), and waterfront properties around the Peel Harvey estuary (Johnston *et al.*, 2014).

Angler diaries can record information from multiple trips over a long period of time (logbooks) or alternatively can be issued to fishers to report their catch information after a single fishing event (catch cards and questionnaires). The method used to obtain a willing participant can also vary. Fisher's can volunteer to participate or are approached by survey officers opportunistically as demonstrated in Morrissy and Fellows (1990), Molony, and Bird (2002) in their recreational Marron *Cherax spp* fishers logbook program.

A Research Angler Program (RAP) has been run by DPIRD since 2004 and requires recreational fishers to provide data on all species caught recreationally across the state. Fishers can opt-in to this program to record fine-scale catch and effort data and record numbers and lengths of their daily catch (Smith *et al.*, 2007). A similar True Blue Swimmer Supporter Initiative has run since 2013 to provide recreational crabbing information on the Swan-Canning estuary, Leschenault Estuary and Geographe Bay. This survey relies on targeted recreational Blue Swimmer Crab fishers completing a logbook (Harris *et al.*, 2016) and provides fishing information that can be used as support for stock assessments. These surveys are representative of fishers in the survey and accurately reports their fishing activity. However, because this survey involves a non-representative sample of Blue Swimmer Crab fishers, it is important that the potential biases are acknowledged when applying these data in subsequent assessments.

### 5.2.3 Telephone

Telephone survey designs have been widely used in fisheries surveys across broad geographic areas (i.e. statewide). Twelve telephone surveys have been conducted in Western Australia since 1999, all either using a special fisher registration list (9) or phone directory frame (3) method. These surveys all collected information at a statewide and bioregional level on effort and catch for boat and shore-based recreational fishers as well as attitudinal information.

Various electronic sampling frames have been used in telephone surveys, including random digit dialling, directory frames and special registration lists (Pollock *et al.*, 1994). Many surveys used a common angler contact method such as the use of a licence database, however, others require more effort to obtain a sample. These include screening households selected from the White Pages® for a phone diary survey to establish a list of stakeholders willing to participate in the survey.

A special registration list is a data frame consisting solely of anglers identified through a licence list or angling club membership resulting in a higher probability of contacting a fisher. Molony and Bird (2002) both the recreational fishing database to establish a sampling frame and then selected all marron and umbrella licence holders (22,430 licences) to conduct a post-season survey of recreational marron fishers and provide estimates of the number of active licences, the number of trips per licence holder, the distribution of effort and the catch. A similar approach was taken by Hart *et al* (2013) for recreational Abalone fishing statewide. A list of Department stakeholders was used to select telephone numbers randomly from each stakeholder group (commercial,

recreational, fish habitat protection and pearling and aquaculture) in biennial telephone surveys. This survey began in 2002 and aimed to sample 150 stakeholders to evaluate the perception of the management of commercial and recreational fishing, pearling and aquaculture (Baharthah, 2003, 2004, 2008c, 2009). Other studies have used the Recreational Boat Fishing Licence (RBFL) database to establish a sampling frame (Ryan *et al.*, 2013, 2015, 2017, 2019), where the primary objectives of these telephone surveys were to estimate fisher participation, effort, and catch for all species.

Directory frame sampling, which samples from a telephone directory confined to a specific geographical area, is less likely to contact fishers as it requires telephoning many non-fishing households in order to locate fishing households. It does not include mobile, private or unlisted numbers. This sampling frame is successful when the intention of the information is to estimate the participation rate or to collect demographic and sociological data. A telephone survey of the Western Australian public conducted annually since 1994 uses the White Pages® like a data frame randomly selecting telephone numbers from metropolitan and regional areas. This ongoing survey was used to determine the community awareness, support and understanding of DPIRD strategies as well as community participation in recreational fishing (Baharthah, 1994-2004 (unpublished), 2008a, 2009).

Table 2. Summary of off-site surveys on recreational fishing in Western Australia.

Attribute↓ Reference →	Caputi & Lenanton 1977 FRR 27	Norton 1981** FRR 46	Morrissy & Fellows 1990 FRR 87
<b>Scope</b>	South Coast Bioregion	West Coast Bioregion	Southern Inland (rivers and dams)
<b>Species in scope</b>	NA	Western Rock Lobster	Marron
<b>Fishing method</b>	Boat and shore-based fishing	Boat and shore-based fishing	Shore-based (scooping, snaring, drop netting)
<b>Data collection method</b>	Logbook	Questionnaire	Logbook
<b>Sampling frame</b>	Holiday resort rentals	Amateur Fishers Licence database	Volunteer Anglers
<b>Sampling design</b>	Random	Census	Opportunistic
<b>Primary sampling unit</b>	People holidaying at selected establishments	22,400 Amateur WRL fishers	74 logbooks issued
<b>Secondary sampling unit</b>	Estimated people days and party days	3,660 returned questionnaires, 1,112 reported fishing for WRL	269 fishing trips detailing 1,059 fishing trips
<b>Sample selection</b>	Logbook left on at reception of holidays resorts where staff would record the activity of holiday maker	WRL licence holders	Anglers volunteered for logbook program
<b>Exclusions</b>			
<b>Survey duration</b>	3 years	9 months	4 months
<b>Survey dates</b>	January 1972–February 1975	15 November 1976–15 August 1977	1971–1987
<b>Temporal coverage</b>	24'hr	24'hr	24'hr
<b>Fishing effort</b>	No	Yes	Yes
<b>Catch rates</b>	No	Yes	No
<b>Total catch</b>	No	Yes (kept only)	No

\*\* Complementary survey design with two survey methods

**Table 2. (Continued) Summary of off-site surveys on recreational fishing in Western Australia**

Attribute↓ Reference →	Baharthah & Sumner 1999–2003 FOP	Melville-Smith & Anderton 2000 FRR 122	Molony & Bird 2002*** FRR 137
<b>Scope</b>	Statewide	Statewide	Southern Inland Bioregion
<b>Species in scope</b>	Community satisfaction survey	Western Rock Lobster	Marron
<b>Fishing method</b>	NA	Boat and shore-based fishing	Shore-based fishing
<b>Data collection method</b>	Interview		Logbook
<b>Sampling frame</b>	White pages	Licence holders	List of volunteer anglers
<b>Sampling design</b>	Random	Census (1998/99), random (1986–97)	Selective
<b>Primary sampling unit</b>	Western Australian residents	32,768 WRL licence holders (1998/99), Unknown 1986/87	130 Logbooks issued
<b>Secondary sampling unit</b>	Interviews 507 (1999), 667 (2000), 707 (2001), 712 (2002), 702 (2002)		110 returned logbooks. Average of 5.75 (1999) and 5.27 (2000) trips per logbook
<b>Sample selection</b>	Individuals randomly selected from white pages	Individuals randomly selected from the licence database. Unknown number	Individuals volunteer to contribute data, opt-in
<b>Exclusions</b>	Individuals under the age of 18 excluded		
<b>Survey duration</b>	1 month	7.5 months	1 month (split to pre and post season)
<b>Survey dates</b>	1999–2003	1986/87–1998/99	1999 & 2000 season
<b>Temporal coverage</b>	24'hr	24'hr	24'hr
<b>Fishing effort</b>	No	Yes	Yes
<b>Catch rates</b>	No	No	Yes
<b>Total catch</b>	No	Yes (kept only)	No

\*\*\* Complementary survey design with three survey methods

**Table 2. (Continued) Summary of off-site surveys on recreational fishing in Western Australia**

Attribute↓ Reference →	Molony & Bird 2002** FRR 137	Baharthah & Sumner 2002 FOP 8	Baharthah 2004 FOP 14
<b>Scope</b>	Southern Inland Bioregion	Statewide	Statewide
<b>Species in scope</b>	Marron	Stakeholder survey	Stakeholder survey
<b>Fishing method</b>	Shore-based fishing	NA	NA
<b>Data collection method</b>	Logbook	Interview	Interview
<b>Sampling frame</b>	Licence database	Management and Industry stakeholder groups	Management and Industry stakeholder groups
<b>Sampling design</b>	Random	Random	Random
<b>Primary sampling unit</b>	800 licence holders selected	Western Australian residents	Western Australian residents
<b>Secondary sampling unit</b>	806 respondents	149 Interviews (40 commercial, 40 recreational, 40 fish and fish habitat, 29 pearling and aquaculture)	145 Interviews (41 commercial, 40 recreational, 38 fish and fish habitat, 26 pearling and aquaculture)
<b>Sample selection</b>	Individuals randomly selected from the licence database	Stakeholder groups randomly selected	Stakeholder groups randomly selected
<b>Exclusions</b>		Individuals under the age of 18 not included	Individuals under the age of 18 excluded
<b>Survey duration</b>	1 month (split to pre and post season)	1 month	1 month
<b>Survey dates</b>	May–August 2000	November 2002	August 2004
<b>Temporal coverage</b>	24'hr	NA	NA
<b>Fishing effort</b>	Yes	No	No
<b>Catch rates</b>	No	No	No
<b>Total catch</b>	Yes	No	No

\*\* Complementary survey design with two survey methods

**Table 2. (Continued) Summary of off-site surveys on recreational fishing in Western Australia**

Attribute↓ Reference →	Williamson <i>et al.</i> 2006 *** FRR 153	Baharthah 2006 FOP 45	Baharthah 2006 FOP 46
<b>Scope</b>	Thevenard, Barrow and Varanus Islands (North Coast Bioregion)	Statewide	Statewide
<b>Species in scope</b>	All Aquatic	Community satisfaction survey	Stakeholder survey
<b>Fishing method</b>	Boat and shore-based fishing	NA	NA
<b>Data collection method</b>	Interview	Interview	Interview
<b>Sampling frame</b>	Area & time	White pages	Management and Industry stakeholder groups
<b>Sampling design</b>	Random	Random	Random
<b>Primary sampling unit</b>	Island Manager conducted interviews at the end of each day (8 months)	Western Australian residents	Western Australian residents
<b>Secondary sampling unit</b>		702 Interviews (422 metropolitan, 279 regional)	137 Interviews (41 commercial, 52 recreational, 22 fish and fish habitat, 22 pearling and aquaculture)
<b>Sample selection</b>	Angler interviews. Catch, effort, attitudinal and demographic information recorded	Individuals randomly selected from white pages	Stakeholder groups randomly selected
<b>Exclusions</b>	Data only collected when time permitted. Not compulsory for staff working on islands to complete a questionnaire	Individuals under the age of 18 not included	Individuals under the age of 18 not included
<b>Survey duration</b>	12 months	1 month	1 month
<b>Survey dates</b>	March 1–October 15 2000	May 2006	August 2006
<b>Temporal coverage</b>	24'hr	NA	NA
<b>Fishing effort</b>	Yes	No	No
<b>Catch rates</b>	No	No	No
<b>Total catch</b>	No	No	No

\*\*\* Complementary survey design with three survey methods



Table 2. (Continued) Summary of off-site surveys on recreational fishing in Western Australia

Attribute\ Reference →	Baharthah 2007 FOP 47	Smith <i>et al</i> 2007 FOP 40	Smallwood & Sumner 2007*** FRR 159
<b>Scope</b>	Statewide	Statewide	Oyster Harbour & Walpole/Nornalup Inlet
<b>Species in scope</b>	Community satisfaction survey	All aquatic	All aquatic
<b>Fishing method</b>	NA	Boat and shore-based fishing	Boat-based fishing
<b>Data collection method</b>	Interview	Logbook	Questionnaire
<b>Sampling frame</b>	White pages	Volunteer fishers	All houseboat rentals
<b>Sampling design</b>	Random	Random	Random
<b>Primary sampling unit</b>	Western Australian residents	193 estuary and 231 ocean logbooks	Houseboat renters
<b>Secondary sampling unit</b>	749 Interviews (444 metropolitan, 304 regional)	Average 40 fishing days per month prior to June 2005, and 150 fishing days per month July-December 2005	132 groups of fishers
<b>Sample selection</b>	Individuals randomly selected from white pages	Anglers volunteered for logbook program	5 question questionnaire left on all houseboat rentals for fishers to complete at the end of their stay
<b>Exclusions</b>	Individuals under the age of 18 not included		Nighttime activity, recreational netting
<b>Survey duration</b>	1 month	2 years	12 months
<b>Survey dates</b>	May 2007	March 2004 – December 2005	December 2002–November 2003
<b>Temporal coverage</b>	NA	24 hour day	24 hour day
<b>Fishing effort</b>	No	Yes	Yes
<b>Catch rates</b>	No	No	No
<b>Total catch</b>	No	No	Yes

\*\*\*Complementary survey design with three survey methods

Table 2. (Continued) Summary of off-site surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Sumner 2008*** FRR 175	Baharthah 2009 FOP 70	Hart <i>et al</i> 2013** FRR 241
<b>Scope</b>	Houtman Abrolhos	Statewide	West and South Coast Bioregions
<b>Species in scope</b>	All aquatic	Stakeholder survey	Abalone
<b>Fishing method</b>	Boat-based fishing	NA	Boat and shore-based fishing
<b>Data collection method</b>	Interview	Interview	Logbook
<b>Sampling frame</b>	Skippers of recreational boats interviewed in the roving survey	Management and Industry stakeholder groups	Licence database
<b>Sampling design</b>	Random	Random	Stratified by licence type (abalone or umbrella) and respondent location (country or Perth metropolitan area)
<b>Primary sampling unit</b>	196 recreational skippers	Western Australian residents	500 licence holders selected
<b>Secondary sampling unit</b>		149 Interviews (39 commercial, 41 recreational, 37 fish and fish habitat, 32 pearling and aquaculture)	
<b>Sample selection</b>	Diary left with skippers to complete for the remainder of their stay	Stakeholder groups randomly selected	Individuals randomly selected from the licence database
<b>Exclusions</b>		Individuals under the age of 18 not included	
<b>Survey duration</b>	12 months	1 month	3 years
<b>Survey dates</b>	April 2006–March 2007	November 2008	2004–2007
<b>Temporal coverage</b>	24 hour day	NA	24'hr
<b>Fishing effort</b>	Yes	No	Yes
<b>Catch rates</b>	No	No	Yes
<b>Total catch</b>	Yes	No	Yes

\*\*\* Complementary survey design with three survey methods

\*\* Complementary survey design with two survey methods

Table 2. (Continued) Summary of off-site surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Ryan <i>et al.</i> 2013*** FRR 249	Johnston <i>et al.</i> 2014*** FRR 258	Ryan <i>et al.</i> 2015*** FRR 268
<b>Scope</b>	Statewide	Peel Harvey Estuary	Statewide
<b>Species in scope</b>	All aquatic	Blue swimmer crab	All aquatic
<b>Fishing method</b>	Boat-based fishing	Boat and shore-based fishing	Boat-based fishing
<b>Data collection method</b>	Interview	Logbook	Interview
<b>Sampling frame</b>	RBFL holders March 2010 to February 2011	Waterfront residents	RBFL holders May 2013 to April 2014
<b>Sampling design</b>	Stratified random	Random	Stratified random
<b>Primary sampling unit</b>	4,635 RBFL holders	2,174 water front residents	3,036 RBFL holders
<b>Secondary sampling unit</b>		920 respondents	
<b>Sample selection</b>	Monthly telephone interview	Logbook sent to residents to complete all fishing activity across 12 month period	Monthly telephone interview
<b>Exclusions</b>	RBFL fishers under 5 were not included	Some residents not contacted	RBFL fishers under 5 were not included
<b>Survey duration</b>	12 months	12 months	12 months
<b>Survey dates</b>	1 March 2011–29 February 2012	November 2007–October 2008	1 May 2013–30 April 2014
<b>Temporal coverage</b>	24 hour day	24 hour day	24 hour day
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	No	No	No
<b>Total catch</b>	Yes	Yes	Yes

\*\*\* Complementary survey design with three survey methods

Table 2. (Continued) Summary of off-site surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Harris <i>et al.</i> 2016 FRR 281	Ryan <i>et al.</i> 2017*** FRR 287	Ryan <i>et al.</i> 2019*** FRR 297
<b>Scope</b>	Swan-Canning Estuary, Leschenault Estuary and Geographe Bay	Statewide	Statewide
<b>Species in scope</b>	Blue swimmer crabs	All aquatic	All aquatic
<b>Fishing method</b>	Boat and shore-based fishing	Boat-based fishing	Boat-based fishing
<b>Data collection method</b>	Logbook	Interview	Interview
<b>Sampling frame</b>	Volunteer fishers	RBFL holders September 2015 to August 2016	RBFL holders September 2017 to August 2019
<b>Sampling design</b>	Random	Stratified random	Stratified random
<b>Primary sampling unit</b>	208 logbooks (103 SCE; 43 LE and 62 GB)	2,931 RBFL holders	2,989 RBFL holders
<b>Secondary sampling unit</b>			
<b>Sample selection</b>	Anglers volunteered for logbook program	Monthly telephone interview	Monthly telephone interview
<b>Exclusions</b>		RBFL fishers under 5 were not included	RBFL fishers under 5 were not included
<b>Survey duration</b>	2 years	12 months	12 months
<b>Survey dates</b>	June 2013–2016	1 September 2015–31 August 2016	1 September 2017–31 August 2018
<b>Temporal coverage</b>	24 hour day	24 hour day	24 hour day
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	No	No
<b>Total catch</b>	No	Yes	Yes

\*\*\* Complementary survey design with three survey methods

### 5.3 On-site surveys

Roving, access point, bus route, aerial and remote camera surveys are all on-site survey methods with some involving interviews with fishers and boat parties and others observing fishers with no direct contact (Table 1). These techniques are useful in collecting data on fishing activity occurring at a medium (bioregion) or small (estuary, island) scale. Unlike off-site surveys, which rely on self-reported data from fishers, in on-site surveys trained staff interview fishers. In many instances, it is possible for the trained staff to inspect, identify and measure the retained catch. Interviews completed during on-site surveys are usually shorter in duration than off-site surveys due to the limited time available of fishers at the completion of their fishing trips and only data from that current fishing trip is generally collected. These methods can provide estimates of fishing effort, catch rate and catch with associated measures of uncertainty whereas, aerial surveys and remote camera surveys have no direct fisher contact and are only able to provide estimations of fishing effort and activity. The majority of these survey methods use elements of randomisation and stratification in their survey design to minimise biases and provide representative and robust estimates. Complementary on-site surveys have also been conducted in Western Australia. For example, in inner Shark Bay, concurrent remote camera and on-site surveys using a bus-route design were combined to provide estimates of recreational fishing effort and Pink Snapper catches in the three inner gulfs. In this instance, the remote cameras provided greater coverage of the spatio-temporal sampling frame (i.e. scheduled and non-scheduled survey days were included) leading to more accurate and precise estimates of Pink Snapper catches.

#### 5.3.1 Aerial

Aerial surveys are a cost-effective method for allowing direct observation of fishing activity from boats and the shore. This survey method is often used to provide a finer-scale mapping of recreational fishing activity and, as there is no direct contact with fishers, only estimates of total effort can be calculated. Aerial surveys are often used to complement access point or roving surveys so that estimates of fishing effort can be combined with interview data to estimate catch for the specified area of interest.

Three aerial surveys of recreational shore-based fishing activity have been conducted in the Gascoyne and West Coast (Table 4). Aerial surveys of shore-based Abalone fishers are also conducted annually (Hancock and Caputi, 2006)

Survey of shore-based recreational fishers have been conducted in Perth The first of the three surveys were conducted in the Perth metropolitan region (Two Rocks to Woodman Point) from April to June 2010 (Smallwood et al, 2011b). This was followed by a wider West Coast survey extending from Lancelin in the North to Bunbury in the south during December 2010 to February 2011 (Smallwood et al, 2011a), and then in Shark Bay and Carnarvon from June to August 2012 (Smallwood & Gaughan, 2013). An aerial survey using both aircraft and drones was also conducted in the Frecynet Estuary 2018/19 (Desfosses *et al.*, 2019).

Aerial surveys in Western Australia have been conducted at a standard height (500 or 1000 ft) using a single engine aircraft with one observer on board. Stratified, random sampling protocols

were implemented to minimise biases and ensure a representative sample has been collected. Depending on the survey site this includes stratification by month, day type (weekday, weekends/public holidays) and time of day (morning, midday, afternoon). Start location and direction of travel are also randomly selected.

### 5.3.2 Access point

Access point surveys are on-site surveys whereby trained interviewers visit sites at which fishers are intercepted at the completion of their fishing trip. A traditional access point design is suited when there are limited sites (i.e., boat ramp) to be surveyed and the interviewer spends their entire shift at this site. A bus route survey is a modified version of an access point survey and is utilised where there are numerous sites within the study area. These surveys require an interviewer to visit a series of boat ramps along a set route with predetermined waiting times at each ramp.

Access point survey designs have been used throughout Western Australia to estimate ramp-based levels of fishing effort and catches for boat-based species, in addition to estimating the average weight of commonly caught boat-based species. Access point surveys have been conducted in the Perth metropolitan area and Rottnest Island (Lenanton and Hall, 1976, Hart *et al.*, 2013), and the wider West Coast for WRL (Norton, 1981), and recreational net fishers (Lenanton *et al.*, 1996 and Heald, 1984). More recently, access point survey designs have been applied to collect boat-based recreational fishing data at key boat ramps across Western Australia; 65 boat ramps statewide in 2011/12 survey (Ryan *et al.*, 2013); 32 boat ramps statewide in 2013/14 (Ryan *et al.*, 2015); 23 boat ramps in the West and South Coast in 2015/16 (Ryan *et al.*, 2017), and 19 boat ramps in the West Coast in 2017/18 (Ryan *et al.*, 2019). Weight-length summaries of the data collected from these surveys have also been reported in Smallwood *et al.* (2018).

Bus route survey designs have been implemented to sample across a large bioregional scale (involving up to 17 bus routes across the broader study area), and have been completed in the North Coast (Williamson *et al.*, 2006), Gascoyne Bioregion (Sumner *et al.*, 2002), West Coast (Sumner and Williamson, 1999; Sumner *et al.*, 2008), and South Coast (Smallwood and Sumner, 2007). More localised bus route surveys (in which a study area can generally be covered using only one or two bus routes) have been completed at; Leschenault Estuary (Malseed *et al.*, 2000), Swan-Canning Estuary (Malseed and Sumner, 2001b), Peel-Harvey Estuary (Malseed and Sumner, 2001a; Johnston *et al.*, 2014), Cockburn Sound and Geographe Bay (Sumner and Malseed, 2004), and Shark Bay (Taylor *et al.*, 2018) (Table 5).

This survey design can also be supplemented by data from other survey designs (i.e. remotely operated cameras) to improve the accuracy and precision of effort estimates (Steffe *et al.*, 2017). All of these surveys required a count of boat parties returning to the boat ramps and interviews were conducted with boat parties encountered. The catch for each trip is identified and counted by the interviewer. Random length measurements may also be obtained. The number of fishers, time spent fishing and a count of the number of trailers at each boat ramp (including launches and retrievals from recreational trailers) is also collected to be utilised in calculating fishing effort. The

catch was estimated by multiplying the average catch rate (estimated from catch and time spent fishing) with an estimate of the total fishing effort.

An access point survey can provide an estimate of fishing effort, catch rate and catch. The key difference between these two methods relates to how estimates are calculated. The bus route method produces estimates for an entire area (i.e. not for individual sites) while an access point design allows estimates to be calculated for each access point surveyed.

### **5.3.3 Roving**

A roving survey is implemented when there are too many access points to accommodate a traditional access point survey. Unlike traditional access point surveys which are used more for boat-based fishing activity at ramps, roving surveys are more often used for assessing shore-based recreational fishing activity (Pollock et al. 1994). Interviewers move around the study area in a pre-determined route conducting counts and/or incomplete trip interviews (i.e. while a fishing trip is still underway) with recreational fishers. Once a fisher has agreed to take part in the interview, their catch is identified, counted and measured for the fishing party. Other data collected during the interview can include the number of fishers, time spent fishing, and fishing location. These data are used to calculate catch by multiplying the average catch rate with total fishing effort.

This report summarises 13 roving surveys which have been completed across all bioregions in Western Australia (Table 8). Surveys in the North Coast were conducted from August 1998–July 1999; in the Gascoyne Coast from April 1998–March 1999; and the South Coast from December 2002–November 2003. The West Coast was surveyed in a number of different regions and years: Houtman Abrolhos (2008), Perth Metropolitan region (April 2010–June 2010), Swan-Canning Estuary (August 1998–July 1999), Cockburn Sound (September 1996–August 1997, September 2001–August 2002 & July 2005–June 2006), Peel-Harvey Estuary (December 1998–April 1999, and November 2007–October 2008), Leschenault Estuary (January 1998–December 1998), Geographe Bay (September 2001–November 2002) (Table 6).

Depending on the survey, stratification could include season (summer, autumn, winter, spring), day type (weekday, weekends/public holidays) and time of day (morning, afternoon). Start location and direction of travel around the roving survey route were also randomly selected. Each survey is completed by one or two interviewers and the length of the survey day varies, depending on the fishery and season, up to a maximum of 8 hours.

### **5.3.4 Remote cameras**

Remote camera surveys are a relatively new method of recreational fishing surveys in Western Australia as the first remote camera was installed at the Hillarys boat ramp in 2005. Remote cameras provide information on the number of vessels launching and/or retrieving at a boat ramp or choke point (e.g. marina entrance). They have also been used to provide information on shore-based recreational fishing activity at choke points (e.g. groynes) and along the foreshore. Five published reports contain data from surveys where remote cameras were used to monitor both recreational boating (Ryan *et al.*, 2013, 2015, 2017, 2019; Taylor *et al.*, 2018) and shore-based recreational fishing activity in the Perth Metropolitan area (Smallwood *et al.*, 2011b) (Table 7).

The set up for each survey is dependent on the survey objective, for example when estimating boat-based fishing effort, cameras are focused on boat ramps or choke points (i.e. entrance to a marine) and counts of vessels retrieving and launching and retrieving (Ryan *et al.*, 2013, 2015, 2017, 2019). Comparatively, when using remote cameras to estimate shore-based fishing effort, choke points can include groynes, jetties or small areas of shoreline (Smallwood *et al.*, 2011b). Remotely operated cameras record count data of boat or fisher movements, however, they do not identify the nature of the fishing activity and so are often used to complement or supplement both on and off-site survey methods to improve estimates. Camera monitoring, when used as a core component of any recreational fishing survey design, will improve the accuracy of fishing effort estimation and provide better information on night-time coverage fishing effort (Smallwood *et al.*, 2011b; Taylor *et al.*, 2018). Remote camera survey can also be used to validate off-site survey estimates of recreational fishing effort. With increasing improvements in satellite technology, the application of remote camera monitoring in recreational fishing surveys is becoming an easier and more cost-effective option.



**Table 3 Summary of aerial surveys on recreational fishing in Western Australia**

Attribute↓ Reference →		Sumner 2008*** FRR 175	Smallwood <i>et al.</i> 2011a*** FRR 216	Smallwood <i>et al.</i> 2011b FRR 224
<b>Scope</b>		Houtman Abrolhos	Perth Metro Area	Lancelin to Bunbury (WCB)
<b>Species in scope</b>		NA	NA	NA
<b>Fishing method</b>		Boat-based fishing	Shore-based fishing	Shore-based fishing
<b>Data collection method</b>		Aerial counts of boats, no direct angler contact	Aerial counts of shore-based fishers, no direct angler contact	Aerial counts of shore-based fishers, no direct angler contact
<b>Sampling frame</b>		Area & time	Area & time	Area & time
<b>Sampling design</b>		Transect covering the entire study area	Stratified by day type and time of day	Stratified by day type and time of day
<b>Primary sampling unit</b>		2 sample days	36 sample days	36 sample days
<b>Secondary sampling unit</b>		2 flights recording number of recreational powerboats and yachts	Flights recording anglers onshore, jetties & small and large groynes at 55 survey locations	Flights recording anglers onshore, jetties & small and large groynes at 97 survey locations
<b>Sample selection</b>		Flights completed on same days as roving survey	1.5hour flight, 60km coastline between Two Rocks and Woodman Point. Flights conducted on same days and same areas as roving survey	3.5hour flight, 300km coastline between Lancelin and Bunbury. The randomisation of survey days, start location and travel direction
<b>Exclusions</b>		Difficult to confirm if actively fishing	Could only identify individual fishers, not fishing party. Difficult to ascertain if people spotted are fishing or not	Could only identify individual fishers, not fishing party. Difficult to ascertain if people spotted are fishing or not
<b>Survey duration</b>		2 days	3 months	3 months
<b>Survey dates</b>		21 and 23 April 2006	April–June 2010	December 2010–February 2011
<b>Temporal coverage</b>		24 hour day	08:00 and 16:00	07:00–10:00, 10:30–14:00, and 15:00–17:30
<b>Fishing effort</b>		Yes	Yes	Yes
<b>Catch rates</b>		No	No	No
<b>Total catch</b>		No	No	No

\*\*\* Complementary survey design with three survey methods

Table 3 (Continued) Summary of on-site, aerial surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Smallwood & Gaughan 2013 FRR 243	Desfosses <i>et al.</i> (in press)** FOP 137	Taylor <i>et al.</i> (in press)*** FRR 298
<b>Scope</b>	Carnarvon & Shark Bay	Freycinet Estuary	Freycinet Estuary
<b>Species in scope</b>	NA	NA	NA
<b>Fishing method</b>	Shore-based fishing	Camps in Freycinet Estuary and shore-based fishing	Boat-based fishing, shore-based fishing and camps in Freycinet Estuary
<b>Data collection method</b>	Aerial counts of the boats with no direct angler contact	Drone counts of fishing camps with no direct angler contact	Aerial counts of boat-based fishers, shore-based fishers and camps with no direct angler contact
<b>Sampling frame</b>	Area & time	Area & time	Area & time
<b>Sampling design</b>	Systematic random and Stratified random day type and time of day	Targeted	Stratified random
<b>Primary sampling unit</b>	27 sample days in Carnarvon & 18 in Shark Bay	7 sample days	28 sample days
<b>Secondary sampling unit</b>	Flights recording shore-based anglers at 9 survey locations (Carnarvon (3), Shark Bay (6))	37 flights recording camps along Freycinet Estuary	Flights recording boat-based fishing in Freycinet Estuary
<b>Sample selection</b>	3hour flight, ~250km coastline (Carnarvon), 4.5hour flight, ~600km coastline (Shark Bay). The randomisation of survey days, start location and travel direction	13minute flight	2hour flight covering 1,360km <sup>2</sup>
<b>Exclusions</b>	Fisher not visible from aircraft No night-time sampling	No night-time sampling	No night-time sampling
<b>Survey duration</b>	3 months	7 days	6 months
<b>Survey dates</b>	June–August 2012	May–June 2018	May–June 2018
<b>Temporal coverage</b>	08:00–11:00, 11:00–14:00 and 14:00–17:00 (Carnarvon); 08:00–12:30 and 12:30–17:00 (Shark Bay)	Random	07:00–17:00 (2hr flight randomly selected from within)
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	No	No	No
<b>Total catch</b>	No	No	No

\*\*Complementary survey design with two survey methods

\*\*\*Complementary survey design with three survey methods

Table 4 Summary of access point surveys of recreational fishing in Western Australia

Attribute↓ Reference →	Lenanton & Hall 1976 FRR 25	Norton 1981** FRR 46	Heald 1984 FRR 60
<b>Scope</b>	Perth metropolitan area and Rottnest Island	West Coast Bioregion	South Coast Bioregion
<b>Species in scope</b>	Australian herring & Western Australian salmon	Western Rock Lobster	Finfish
<b>Fishing method</b>	Boat and shore-based fishing	Boats and shore-based fishing	Shore-based fishing
<b>Data collection method</b>	Face-to-face interview, boat launches and retrievals, counts of shore-fishers	Creel census	Face-to-face interview
<b>Sampling frame</b>	The study divided into two sections: Metropolitan coastal fishery (2 shore locations and 2 boat ramps) and the Rottnest Island fishery (20 shore fishing locations)	WRL fishers in West Coast Bioregion	Net fishers in Wellstead Estuary and Beaufort Inlet
<b>Sampling design</b>	Stratified by Time of day (morning, afternoon) & Weekdays or weekends	19 sample sites from Kalbarri to Augusta	Netters interviewed whilst in the process of retrieving or setting their nets
<b>Primary sampling unit</b>	Sample days	Random sample	Random sample
<b>Secondary sampling unit</b>	Angler interviews	Interviewers conduct interviews with fishers at boat ramps and onshore in the morning hours	Fishing parties at Wellstead estuary (433) and Beaufort Inlet (33)
<b>Sample selection</b>	Survey agents counted shore anglers then conducted random interviews	Survey agents counted anglers then conducted random interviews	Survey agents counted anglers then conducted random interviews
<b>Exclusions</b>	No night-time surveys	No night-time surveys	No night-time surveys
<b>Survey duration</b>	3 months	2 RL seasons (10 months & 8.5 months)	1 month
<b>Survey dates</b>	April 1973–June 1973	1976–1978 (focus on selected Geraldton and Perth beaches for the 1977–1978 season)	January 1981
<b>Temporal coverage</b>	05:00–14:00 and 14:00–00:00	Morning	Daylight hours
<b>Fishing effort</b>	No	Yes	Yes
<b>Catch rates</b>	No	No	Yes
<b>Total catch</b>	Yes	Yes	Yes

\*\*Complementary survey design with two survey methods

Table 4 (Continued) Summary of on-site, access point surveys of recreational fishing in Western Australia

Attribute↓ Reference →	Lenanton <i>et al.</i> 1996 FRR 104	Sumner & Williamson 1999 FRR 117	Malseed <i>et al.</i> 2000 ** FRR 120
<b>Scope</b>	Peel-Harvey Estuary & Hardy Inlet	West Coast Bioregion	Leschenault Estuary
<b>Species in scope</b>	Finfish and Blue swimmer crabs	All Aquatic	Blue swimmer crabs
<b>Fishing method</b>	Netting	Boat-based fishing	Boat-based and shore-based fishing
<b>Data collection method</b>	Field collections	Face-to-face interview collecting catch, effort & biological data, as well as attitudinal questions	Face-to-face interview collecting catch, effort, biological and demographic information
<b>Sampling frame</b>	Netters interviewed whilst in the process of retrieving their nets	A region divided into 12 geographical districts, each containing between 1 and 8 boat ramps	5 public boat ramps
<b>Sampling design</b>	Sample sites adjacent to boat ramps in Peel-Harvey Estuary (9) and Hardy Inlets (4)	Stratified by district, season and weekdays or weekends/public holidays	Stratified by season, time of day and weekdays or weekends
<b>Primary sampling unit</b>	All sites visited on Thursday and Saturday mornings (when nets are set) and Friday and Sunday evenings (when nets retrieved)	Sample days (3–12 days per month)	82 sample days
<b>Secondary sampling unit</b>	Sample days	7,848 angler interviews	933 angler interviews
<b>Sample selection</b>	4 survey days (Wednesday–Saturday)	The randomisation of starting location and travel direction with pre-determined waiting times at each boat ramp	The randomisation of survey day, starting location and travel direction with pre-determined waiting times at each boat ramp.
<b>Exclusions</b>		Survey not appropriate to estimate total fishing and catch effort for non-trailered boats. No night-time surveys	No night-time surveys
<b>Survey duration</b>	18 months	12 months	12 months
<b>Survey dates</b>	January 1994–June 1995	September 1996–August 1997	January–December 1998
<b>Temporal coverage</b>	Thursday and Saturday mornings, Wednesday and Friday evenings	8:00–16:00	07:00–19:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	No	Yes	No
<b>Total catch</b>	Yes	Yes	Yes

\*\*Complementary survey design with two survey methods

Table 4 (Continued) Summary of on-site, access point surveys of recreational fishing in Western Australia

Attribute↓ Reference →	Malseed & Sumner 2001 ** FRR 126	Malseed & Sumner 2001 FRR 127	Sumner <i>et al.</i> 2002 FRR 139
<b>Scope</b>	Swan-Canning Estuary	Peel Harvey Estuary	Gascoyne Bioregion
<b>Species in scope</b>	Finfish and Blue swimmer crabs	Finfish and Blue swimmer crabs	All Aquatic
<b>Fishing method</b>	Boat-based fishing	Boat-based fishing	Boat-based fishing
<b>Data collection method</b>	Face-to-face interview (catch, effort, biological environmental and demographic information)	Face-to-face interview (catch, effort, biological environmental and demographic information)	Face-to-face interview (catch, effort, biological environmental and demographic information)
<b>Sampling frame</b>	8 public boat ramps (5 on 'upper' route & 3 on 'lower' route)	16 boat ramps broken into two routes Eastern (8 ramps) & Western (8 ramps)	Bioregion broke down into 5 districts each with between 1 and 4 boat ramps
<b>Sampling design</b>	Stratified by season, time of day and weekdays or weekends. All boat ramps visited along the designated route (upper or lower) on each sample day	Stratified by season, time of day, weekdays or weekends and area. All boat ramps visited along the designated route (eastern or western) on each sample day	Stratified by district, season and school holiday periods
<b>Primary sampling unit</b>	156 sample days	122 sample days	Sample days (3–12 survey days per district, per month)
<b>Secondary sampling unit</b>	1,302 angler interviews	1,060 angler interviews	1,738 angler interviews
<b>Sample selection</b>	Between 4–11 sample days per month (season dependent) allocated randomly from weekends & weekdays, with two routes and 2 day-time periods. The randomisation of starting location and travel direction	Between 6–16 sample days per month (season dependant) allocated randomly from weekends and weekdays, with two routes and two day-time periods. The randomisation of starting location and travel direction	Between 3–12 survey days per month for each district. The randomisation of starting location and travel direction
<b>Exclusions</b>	No night-time surveys	No night-time surveys	No night-time surveys
<b>Survey duration</b>	12 months	12 months	12 months
<b>Survey dates</b>	August 1998–July 1999	August 1998–July 1999	April 1998–March 1999
<b>Temporal coverage</b>	07:00–19:00	07:00–19:00	11:00–18:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	Yes	Yes
<b>Total catch</b>	Yes	Yes	Yes

\*\* Complementary survey design with two survey methods

Table 4 (Continued) Summary of on-site, access point surveys of recreational fishing in Western Australia

Attribute↓ Reference →	Sumner & Malseed 2004 ** FRR 147	Williamson <i>et al.</i> 2006 *** FRR 153	Bellchambers <i>et al</i> 2006 FRR 158
<b>Scope</b>	Cockburn Sound (CS) and Geographe Bay (GB)	North Coast Bioregion (Pilbara)	Geographe Bay
<b>Species in scope</b>	Blue swimmer crabs	All aquatic	Blue swimmer crabs
<b>Fishing method</b>	Boat-based fishing	Boat-based fishing	Boat-based fishing
<b>Data collection method</b>	Face-to-face interview (catch, effort, biological environmental and demographic information)	Face-to-face interview (catch, effort, biological environmental and demographic information)	Face-to-face interview (catch, effort, biological environmental and demographic information)
<b>Sampling frame</b>	Boat ramps within the survey areas CS (6) & GB (9)	7 districts, each with 1–3 boat ramps	Port Geographe boat ramp
<b>Sampling design</b>	Stratified by season, time of day and weekdays or weekends. All boat ramps visited along a designated route	Stratified by district, season (wet or dry) and day type	Stratified by time of day (morning or afternoon) and weekdays or weekends (public holidays included)
<b>Primary sampling unit</b>	Sample days, CS (63) and GB (96)	56 sample days	64 sample days
<b>Secondary sampling unit</b>	1,235 angler interviews (CS) & 929 (GB)	3,085 angler interviews	375 angler interviews
<b>Sample selection</b>	Between 8 & 14 sample days per month allocated randomly from weekends and weekdays, with two day-time periods (morning & afternoon). The randomisation of starting location and travel direction	8 sample days per district, allocated randomly each season (4 wet, 4 dry) & weekdays (2) and weekends (2). The randomisation of starting location and travel direction	16 sample days per month allocated randomly from weekends and weekdays, with two day-time periods (morning & afternoon).
<b>Exclusions</b>	No night-time surveys	No night-time surveys	No night-time surveys
<b>Survey duration</b>	12 months (CS) & 14 months (GB)	12 months	2 months
<b>Survey dates</b>	September 2001–August 2002 (CS), September 2001–November 2002 (GB)	December 1999–November 2000	July 2003 – October 2003
<b>Temporal coverage</b>	07:00–13:00 and 13:00–19:00	10:00–18:00	07:00–13:00 and 13:00–19:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	Yes	Yes
<b>Total catch</b>	Yes	Yes	Yes

\*\*Complementary survey design with two survey methods

\*\*\* Complementary survey design with three survey method

Table 4 (Continued) Summary of on-site, access point surveys of recreational fishing in Western Australia

Attribute↓ Reference →	Smallwood & Sumner 2007*** FRR 159	Sumner <i>et al.</i> 2008 FRR 177	Hart <i>et al</i> 2013** FRR 241
<b>Scope</b>	South Coast Bioregion	Kalbarri to Augusta (WCB)	Perth metropolitan area
<b>Species in scope</b>	All aquatic	All aquatic	Abalone
<b>Fishing method</b>	Boat-based fishing	Boat-based fishing	Shore-based fishing
<b>Data collection method</b>	Face-to-face interview (catch, effort, biological environmental and demographic information), boat launches and retrievals	Face-to-face interview	Face-to-face interviews and count
<b>Sampling frame</b>	17 estuaries and lakes (7 survey routes each with 1 to 8 boat ramps)	13 districts split into 4 zones (Kalbarri (1), Midwest (4), Metro (5) and South (3)) each with between 1-9 boat ramps	Coastline between Cape Bouvard and Wedge Island
<b>Sampling design</b>	Stratified by season and time of day	Stratified by district and day type	Stratified by high and low usage zones
<b>Primary sampling unit</b>	36 sample days	52 sample days	5 sample days
<b>Secondary sampling unit</b>	534 angler interviews	15,999 angler interviews	1000 angler interviews
<b>Sample selection</b>	6–10 survey days per month (season dependent). The randomisation of starting location and travel direction	61 boat ramps surveyed. The randomisation of starting location and travel direction with pre-determined waiting times	5 survey days per year (1 hour per day)
<b>Excluded</b>	No night-time surveys	Night based survey undertaken in Cockburn Sound only. Did not include catch effort for boats from yacht clubs, canals, private marina's and moorings	
<b>Survey duration</b>	12 months	12 months, 6 months (CS night survey)	5 hours
<b>Survey dates</b>	December 2002–November 2003	1 July 2005–30 June 2006 and 15 Aug 2005–28 February 2006 (CS night survey)	November–March 2007
<b>Temporal coverage</b>	07:00–12:45 and 12:15–18:30	09:00–17:00 and 17:00–22:00 (CS night survey)	07:00–08:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	Yes	No
<b>Total catch</b>	Yes	Yes	Yes

\*\*Complementary survey design with two survey methods

\*\*\*Complementary survey design with three survey methods

Table 4 (Continued) Summary of on-site, access point surveys of recreational fishing in Western Australia

Attribute↓ Reference →	Ryan <i>et al.</i> 2013*** FRR 249	Johnston <i>et al.</i> 2013*** FRR 258	Ryan <i>et al.</i> 2015*** FRR 268
<b>Scope</b>	Statewide	Peel Harvey Estuary	Statewide
<b>Species in scope</b>	All aquatic	Blue swimmer crab	All aquatic
<b>Fishing method</b>	Boat-based fishing	Boat-based fishing	Boat-based fishing
<b>Data collection method</b>	Face-to-face interview	Face-to-face interview	Access point survey
<b>Sampling frame</b>	Recreational fishers retrieving from public boat ramps	Recreational fishers retrieving from public boat ramps	Recreational fishers retrieving from public boat ramps
<b>Sampling design</b>	Targeted design, key boat ramps at time of peak fishing activity	Stratified by season, time of day, day type and area	Targeted design, key boat ramps at time of peak fishing activity
<b>Primary sampling unit</b>	Sample day	240 sample days (96 east route and 144 west route)	Sample day
<b>Secondary sampling unit</b>	Fishing party (5,000 to 10,000 angler interviews)	1555 angler interviews	Fishing party (9,600 angler interviews)
<b>Sample selection</b>	Probability-based sample of key boat ramps (65) throughout Western Australia.	16 boat ramps surveyed. The randomisation of starting location and travel direction with pre-determined waiting times	Probability-based sample of key boat ramps (32) in the West and South Coast Bioregions. Survey officers conduct interviews with fishers upon return to the boat ramp at the end of day
<b>Excluded</b>	No night-time surveys. Does not include moorings or private jetties	No night-time surveys. Does not include moorings or private jetties	No night-time surveys. Does not include moorings or private jetties
<b>Survey duration</b>	12 months	12 months	12 months
<b>Survey dates</b>	1 March 2011–29 February 2012	November 2007–October 2008	June 2013–April 2014
<b>Temporal coverage</b>	06:00-16:30	08:00-13:00	12:00-16:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	Yes	Yes
<b>Total catch</b>	Yes	Yes	Yes

\*\*\* Complementary survey design with three survey methods



Table 4 (Continued) Summary of on-site, access point surveys of recreational fishing in Western Australia

Attribute↓ Reference →	Ryan <i>et al.</i> 2017*** FRR 287	Taylor <i>et al.</i> 2018 FRR 291	Taylor <i>et al.</i> (2019)** FRR 298
<b>Scope</b>	West and South Coast Bioregions	Shark Bay	Shark Bay
<b>Species in scope</b>	All aquatic	All aquatic	All aquatic
<b>Fishing method</b>	Boat-based fishing	Boat-based fishing	Boat-based fishing
<b>Data collection method</b>	Access point survey	Face-to-face Interview	Face-to-face interview
<b>Sampling frame</b>	Recreational fishers retrieving from public boat ramps	Recreational fishers retrieving from public boat ramps	Recreational fishers retrieving from public boat ramps
<b>Sampling design</b>	Targeted design, key boat ramps at time of peak fishing activity	Stratified by months and day types (weekdays and weekend days/public holidays)	Stratified by seasons and day types
<b>Primary sampling unit</b>	Sample day	137 sample days	228 sample days (Denham (90), Monkey Mia (68), and Nanga (70))
<b>Secondary sampling unit</b>	Fishing party (3,068 angler interviews)	Angler interviews	
<b>Sample selection</b>	Probability-based sample of key boat ramps (23) in the West and South Coast Bioregions. Survey officers conduct interviews with fishers upon return to the boat ramp at the end of day	Disproportional sampling for each day type allocation of 6 weekday and 6 weekend days per month	
<b>Excluded</b>	No night-time surveys. Does not include moorings or private jetties	No night-time surveys	No night-time surveys
<b>Survey duration</b>	3.5 months	12 months	12 months
<b>Survey dates</b>	Mid-January 2016–April 2016	March 2016–February 2017	1 March 2018–28 February 2019
<b>Temporal coverage</b>	12:00-16:00	10:00-18:00	10:00–18:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	Yes	Yes
<b>Total catch</b>	Yes	Yes	Yes

\*\* Complementary survey design with three survey methods

Table 5 Summary of roving surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Sumner & Steckis 1999 FRR 115	Malseed <i>et al.</i> 2000 ** FRR 120	Malseed & Sumner 2001 ** FRR 126
<b>Scope</b>	Gascoyne Bioregion	Leschenault Estuary	Swan-Canning Estuary
<b>Species in scope</b>	All Aquatic	Blue swimmer crabs	Finfish and Blue swimmer crabs
<b>Fishing method</b>	Boat and shore-based fishing	Shore-based fishing and crabbing	Shore-based fishing
<b>Data collection method</b>	Face-to-face Interview	Face-to-face Interview	Face-to-face Interview
<b>Sampling frame</b>	Area	Area and Time	Area and Time
<b>Sampling design</b>	Random sample	Stratified by season, time of day (am or pm) and weekdays or weekends.	Stratified by season, time of day and weekdays or weekends
<b>Primary sampling unit</b>	FMO patrols in July 1996 (31 sample days)	82 sample days, additional 3 months shore-based crabbing survey	78 sample days
<b>Secondary sampling unit</b>		117 angler interviews. 84 interviews in shore-based crabbing survey	378 angler interviews
<b>Sample selection</b>	399 fishers interviewed (148 shore-based and 186 boat-based).	The randomisation of survey day, starting location and travel direction. Survey agents counted shore anglers, number of boats, then conducted random interviews in between checkpoints of bus route survey	The randomisation of survey day, starting location and travel direction. Survey agents counted shore anglers, number of boats, then conducted random interviews in between checkpoints of bus route survey
<b>Exclusions</b>	Data only collected when time permitted	No night-time surveys	No night-time surveys
<b>Survey duration</b>	1 month	12 months, 2 months (crabbing survey)	12 months
<b>Survey dates</b>	July 1996	January–December 1998, January–February 1999 (crabbing survey)	August 1998–July 1999
<b>Temporal coverage</b>	No specific survey time	07:00-13:00 and 13:00-19:00	06:00-13:00 and 13:00-19:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	No	Yes	Yes
<b>Total catch</b>	Yes	Yes	Yes

\*\* Complementary survey design with two survey methods

Table 5 (Continued) Summary of on-site, roving surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Malseed & Sumner 2001 ** FRR 127	Sumner <i>et al.</i> 2002 ** FRR 139	Sumner & Malseed 2004 ** FRR 147
<b>Scope</b>	Peel Harvey Estuary	Gascoyne Bioregion	Cockburn Sound (CS) and Geographe Bay (GB)
<b>Species in scope</b>	Finfish and Blue swimmer crabs	All aquatic	Blue swimmer crabs
<b>Fishing method</b>	Shore-based fishing	Boat and shore-based fishing	Shore-based fishing
<b>Data collection method</b>	Face-to-face Interview	Face-to-face Interviews	Face-to-face Interviews
<b>Sampling frame</b>	Area and Time	Area and Time	Area and Time
<b>Sampling design</b>	Stratified by season, time of day, weekdays or weekends and area. Each area was further stratified by ramp	Stratified by season and area	Stratified by season, time of day, weekdays or weekends and area. Each area was further stratified by ramp 16 ramps (CS) & 8 ramps (GB: 4 'eastern', 4 'western' ramps)
<b>Primary sampling unit</b>	122 sample days	35 sample days	63 (CS) & 96 (GB) sample days
<b>Secondary sampling unit</b>	909 angler interviews	1,755 angler interviews (1,060 shore-based & 695 boat-based (beach launches))	619 (CS) & 444 (GB) angler interviews
<b>Sample selection</b>	The randomisation of survey day, starting location and travel direction for each of the 3 zones (Table 4)	The randomisation of starting location and travel direction. Number of shifts per month depended upon the season	4 sample days per month (CS). 8-14 Sample days per month (GB), with randomisation of starting location and travel direction
<b>Exclusions</b>	No night-time surveys	No night-time surveys. Carnarvon Jetty closed due to repair work	No night-time surveys
<b>Survey duration</b>	12 months	12 months	12 months (CS), 14 months (GB)
<b>Survey dates</b>	December 1998–April 1999	April 1998–March 1999	September 2001–August 2002 (CS), September 2001–November 2002 (GB)
<b>Temporal coverage</b>	07:00-13:00 and 13:00-19:00	11.00-18:00	07:00-13:00 and 13:00-19:00
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	Yes	Yes
<b>Total catch</b>	Yes	Yes	Yes

\*\* Complementary survey design with two survey method

Table 5 (Continued) Summary of on-site, roving surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Williamson <i>et al.</i> 2006 *** FRR 153	Smallwood & Sumner 2007*** FRR 159	Sumner 2008*** FRR 175
<b>Spatial scope</b>	North Coast Bioregion (Pilbara)	South Coast Bioregion	Houtman Abrolhos
<b>Species in scope</b>	All aquatic	All aquatic	All aquatic
<b>Fishing method</b>	Shore-based fishing	Shore-based fishing	Boat-based fishing
<b>Data collection method</b>	Face-to-face Interviews	Face-to-face interview	Face-to-face interview
<b>Sampling frame</b>	Area and Time	Area and time	Area and time
<b>Sampling design</b>	Stratified by season and area (Onslow to Dampier, Dampier to Broome)	Stratified by season and time of day	Random sample
<b>Primary sampling unit</b>	28 sample days	32 sample days	45 sample days
<b>Secondary sampling unit</b>	641 angler interviews (569 shore-based & 72 boat-based (beach launches)	927 angler interviews	196 angler interviews
<b>Sample selection</b>	Survey agents counted shore anglers, number of boats then conducted random interviews	The randomisation of starting location and travel direction. A number of shifts per month depended upon the season. Survey agents counted shore anglers, conducted random interviews	
<b>Exclusions</b>	No night-time surveys	No night-time surveys	No night-time surveys
<b>Survey duration</b>	12 months	12 months	3 months (Rock lobster season)
<b>Survey dates</b>	August 1998–July 1999	December 2002–November 2003	April-June 2006 and 2007
<b>Temporal coverage</b>	10:00-18:00	07:0-13:30 and 13:30-20:00	Afternoon
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	Yes	Yes	Yes
<b>Total catch</b>	Yes	Yes	No

\*\*\* Complementay survey design with three survey methods

Table 5 (Continued) Summary of on-site, roving surveys on recreational fishing in Western Australia

Attribute\ Reference →	Smallwood <i>et al.</i> 2010 FRR 203	Smallwood <i>et al.</i> 2011*** FRR 216	Smallwood <i>et al.</i> 2013 FRR 240
<b>Scope</b>	Statewide	Perth Metropolitan Area	Statewide
<b>Species in scope</b>	Finfish and Blue Swimmer crabs	Finfish	All aquatic
<b>Fishing method</b>	Boat and shore-based fishing	Shore-based fishing	Boat and shore-based fishing
<b>Data collection method</b>	Volunteer Patrols	Face-to-face interview	FMO Patrols
<b>Sampling frame</b>	Area	Area and time	Area
<b>Sampling design</b>	Random sample	Stratified random with 42 survey locations, day type and time of day	Opportunistic sample
<b>Primary sampling unit</b>	7,060 patrols	36 sample days	6,629 patrols
<b>Secondary sampling unit</b>	23,816 angler interviews	1,194 angler interviews	47,529 boat-based interviews & 2,237 shore-based interviews
<b>Sample selection</b>	Activities and interactions with recreational fishers were conducted by Volunteer Fisheries Liaison Officers (VFLOs) and recorded onto log sheets	The randomisation of starting location and travel direction. 12 sample days per month randomly allocated from weekdays & weekends	FMOs make contact with fishers at various locations during the course of normal compliance activities
<b>Exclusions</b>	Different methods used by each volunteer may have resulted in inaccuracies. Cannot calculate catch and effort estimates due to unstructured data collection methods	No night-time surveys	Cannot be used to calculate weighted catch and effort estimates
<b>Survey duration</b>	12 years	3 months	12 years
<b>Survey dates</b>	1995–2007	April–June 2010	July 1998–June 2010
<b>Temporal coverage</b>	07:00–09:00 and 17:00–19:00	06:00–13:00 and 13:00–20:00	24 hour day
<b>Fishing effort</b>	No	Yes	No
<b>Catch rates</b>	Yes	Yes	No
<b>Total catch</b>	No	Yes	No

\*\*\*Complementary survey design with three methods

Table 5 (Continued) Summary of on-site, roving surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Johnston <i>et al.</i> 2014*** FRR 258
<b>Scope</b>	Peel Harvey Estuary
<b>Species in scope</b>	Blue swimmer crab
<b>Fishing method</b>	Shore-based fishing
<b>Data collection method</b>	Face-to-face interview
<b>Sampling frame</b>	Area and time
<b>Sampling design</b>	Stratified by month and day type
<b>Primary sampling unit</b>	196 sample days
<b>Secondary sampling unit</b>	506 angler interviews
<b>Sample selection</b>	randomisation of day, starting location and travel direction
<b>Exclusions</b>	Boat-based fishing and private access areas
<b>Survey duration</b>	1 year
<b>Survey dates</b>	November 2007–October 2008
<b>Temporal coverage</b>	09:00–22:30 (bridges and jetties) and 06:00–20:00 (scoop netting)
<b>Fishing effort</b>	Yes
<b>Catch rates</b>	Yes
<b>Total catch</b>	Yes

\*\*\*Complementary survey design with three methods

Table 6 Summary of on-site, remote camera surveys on recreational fishing in Western Australia

Attribute\ Reference →	Smallwood <i>et al.</i> 2011*** FRR 216	Ryan <i>et al.</i> 2013*** FRR 249	Ryan <i>et al.</i> 2015*** FRR 268
<b>Scope</b>	Perth Metropolitan Area	Statewide	Statewide
<b>Species in scope</b>	NA	NA	NA
<b>Fishing method</b>	Shore-based fishing methods	Boat-based fishing	Boat-based fishing
<b>Data collection method</b>	No contact	No contact	No contact
<b>Sampling frame</b>	Remote cameras positioned at 4 high use groynes	Remote cameras positioned at 12 key ramps across the state	Remote cameras positioned at 12 key ramps across the state
<b>Sampling design</b>	Census	Near census (noting that outages occurred at most ramps)	Near census (noting that outages occurred at most ramps)
<b>Primary sampling unit</b>	91 sample days	365 sample days	365 sample days
<b>Secondary sampling unit</b>	Counts of anglers arriving/departing groyne, a record of activity type	Counts of anglers arriving/departing boat ramps	Counts of anglers arriving/departing boat ramps
<b>Sample selection</b>	Activity recorded over 24 hour day	Activity recorded over 24 hour day	Activity recorded over 24 hour day
<b>Exclusions</b>	Outage periods due to poor environmental conditions	Outage periods due to technological failures and poor environmental conditions	Outage periods due to technological failures and poor environmental conditions
<b>Survey duration</b>	3 months	12 months	12 months
<b>Survey dates</b>	April–June 2010	1 March 2011–29 February 2012	1 May 2013–30 April 2014
<b>Temporal coverage</b>	24 hour day	24 hour day	24 hour day
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	No	No	No
<b>Total catch</b>	No	No	No

\*\*\*Complementary survey design with three methods

Table 6 (Continued) Summary of on-site, remote camera surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Ryan <i>et al.</i> 2017 FRR 287	Taylor 2018** FRR 291	Desfosses <i>et al.</i> (in Press) FOP 137
<b>Scope</b>	Statewide	Shark Bay	Peel Harvey Estuary
<b>Species in scope</b>	NA	NA	Blue Swimmer Crab
<b>Fishing method</b>	Boat-based fishing	Boat-based fishing	Shore-based fishing
<b>Data collection method</b>	No contact	No contact	No contact
<b>Sampling frame</b>	Remote cameras positioned at 11 key ramps across the state	Remote cameras positioned at 3 key boat ramps (Monkey Mia, Denham and Nanga)	Remote cameras positioned at 3 key scooping areas
<b>Sampling design</b>	Census	Near census (noting that outages occurred at each ramp)	Census
<b>Primary sampling unit</b>	365 sample days	365 sample days	365 sample days?
<b>Secondary sampling unit</b>	Counts of anglers arriving/departing boat ramps	Counts of anglers arriving/departing boat ramps	Counts of anglers scooping within the field of view
<b>Sample selection</b>	Activity recorded over 24 hour day	Activity recorded over 24 hour day	Activity recorded over 24 hour day
<b>Exclusions</b>	Outage periods due to technological failures and poor environmental conditions	Outage periods due to technological failures and poor environmental conditions	Outage periods due to technological failures and poor environmental conditions
<b>Survey duration</b>	12 months	12 months	12 months
<b>Survey dates</b>	1 September 2015–31 August 2016	March 2016–February 2017	March 2018–April 2019
<b>Temporal coverage</b>	24 hour day	24 hour day	24-hour day
<b>Fishing effort</b>	Yes	Yes	Yes
<b>Catch rates</b>	No	No	No
<b>Total catch</b>	No	No	No

\*\* Complementary survey design with two methods



Table 6 (Continued) Summary of on-site, remote camera surveys on recreational fishing in Western Australia

Attribute↓ Reference →	Taylor <i>et al.</i> (in press)*** FRR 298
<b>Scope</b>	Denham, Monkey Mia and Nanga
<b>Species in scope</b>	NA
<b>Fishing method</b>	Boat-based fishing
<b>Data collection method</b>	No contact
<b>Sampling frame</b>	Remote cameras positioned at 3 key boat ramps (Monkey Mia, Denham and Nanga)
<b>Sampling design</b>	Near census (noting that outages occurred at each ramp)
<b>Primary sampling unit</b>	365 sample days
<b>Secondary sampling unit</b>	Counts of anglers arriving/departing boat ramps
<b>Sample selection</b>	Activity recorded over 24 hour day
<b>Exclusions</b>	Outage periods due to technological failures and poor environmental conditions
<b>Survey duration</b>	12 months
<b>Survey dates</b>	March 2018–February 2019
<b>Temporal coverage</b>	24 hour day
<b>Fishing effort</b>	Yes
<b>Catch rates</b>	No
<b>Total catch</b>	No

\*\*\* Complementary survey design with three methods

## 6 Discussion

Recreational fishing is an important activity that provides social and economic benefits to Western Australia (McLeod and Lindner, 2018). It is therefore essential that representative and robust data is collected for this sector to support informed decision making. This report focuses on published Fisheries Research Reports and Fisheries Occasional Publications, noting findings from these reports have also been disseminated in a number of other publications and forums. For example, in the Status Report of the Fisheries and Aquatic Resources (e.g. Gaughan and Santoro 2018), Annual Report (e.g. Department of Primary Industries and Regional Development 2019), peer-reviewed publications and other media (i.e. newsletters, website).

This report demonstrates the diversity of survey methods used to collect recreational fishing data, which follows best practice and are constantly developing to incorporate new design elements that can improve the precision and accuracy of estimates. Survey methods used in Western Australia have varied over time and improved along with our understanding of recreational fisheries science and the rapid advancement of technology. Ultimately survey methods can be split into two types of surveys; off-site and on-site. Selection of an appropriate survey design depends on the management objectives, available resources, preferred fisher contact method and geographical scale of the fishery. As a result, complementary survey designs have been the most commonly used in Western Australia, whereby fisheries scientists have applied a combination of both off and on-site survey methods to collect data. There is no single survey method that is appropriate for all recreational fisheries. Each survey method has its own set of limitations, advantages and budget requirements confirming the importance of selecting an appropriate survey design to minimise sampling errors and ensure representative data collection and estimates with associated measures of uncertainty. However, the methodology needs to be consistent over time, or differences in survey scope need to be addressed, to enable meaningful temporal comparisons of estimates.

Surveys of recreational fishing involve the collection of information from a sample of fishers (i.e., not a census) and it is therefore important to consider measures of uncertainty (e.g. standard error and confidence intervals) associated with estimates. The chosen survey method influences the types of biases which may be encountered and the strategies applied to minimise any biases (Pollock *et al.* 1994). On-site survey designs (which involve face-to-face interviews) collect data at the time fishing is occurring (or at the end of a boat trip) and may be exposed to sampling, response errors and incomplete coverage (nigh time fishing, boats not launching from a surveyed ramp). These biases can be minimised through the provision of highly trained survey staff that can verify catch data, and reducing the time between the fishing activity and the survey, for fishers to recall information from their fishing trip. Conversely, an off-site survey design (which involves self-reporting by the fisher) can minimise response errors by training of survey staff and through the implementation of diary cards to minimise response errors, such as question misinterpretation and recall bias.

Recent advancements in technologies have paved the way for the application of new survey techniques for recreational fisheries in Australia. Remotely operated cameras are already widely used by DPIRD and are a cost-effective survey tool that improves the coverage of shore- and boat-based activity over a 24-hr period, including nocturnal activity. Taylor *et al.* (2018) used dual-lens thermographic cameras to further improve night-time coverage in shore-based recreational fishing in the Peel Harvey Estuary. The use of camera technologies has the potential to increase as satellite technology advances (Blight and Smallwood 2015).

The recent advancement of unmanned aerial aircraft (drones) has made it affordable to use as a data collection tool in some niche fisheries that have a small spatial extent. This technology has been tested in the Peel Harvey Estuary to collect high-resolution footage of recreational fishers scooping for crabs in areas that are normally inaccessible via a roving survey. This technology was also trialled in Shark Bay to provide estimates of fishing effort from remote camps in the Freycinet Estuary (Desfosses *et al.*, 2019). Both trials were successful and highlight the potential for drones to be used as a tool for collecting effort data in fisheries with a small geographical scope. Investment in funding for larger unmanned aircraft may provide the ability to utilise satellite technology over larger geographic areas (Hodgson *et al.*, 2013).

Incorporating new technologies into recreational fishing surveys via electronic devices is now commonly used and generally thought to be more cost-effective and accurate (Bradley *et al.*, 2019). The application of smartphone technology and ‘Apps’ provides another approach to collecting recreational fishing data. An annual recall survey has occurred for 17 consecutive years to obtain estimates of recreational catch for the south-west Freshwater Angling licensed fishery. In 2017, a screening survey of licence holders was conducted to recruit fishers to a 12-month trial of a smartphone App (Trinnie and Ryan *in prep*). Eligible fishers were sent a link to the App and monthly reminders via text message to remind them to record their fishing information. This trial allowed a randomised and probability based sample of the population to participate, as opposed to approaches where fishers self-select, or opt-in. When using smartphone applications and web-based reporting, it is also important that there are provisions included to ensure valid species identification. However, electronic data collection by trained interviewers may provide more timely data, reduce the potential for data transcription errors, facilitate the implementation of real-time checks of data ranges and corrections at the data-collection stage while also reducing double handling of data and minimise loss of datasheets.

New developments in technologies and survey designs are offering improvements in several areas in terms of efficiency, however, it is essential to allow comparisons between old and new approaches, such as through corroboration studies, to ensure data provided using different survey modes or technologies are accurate. The Department will continue to work proactively to assess and adopt appropriate technologies and surveys designs, and improve the accuracy and precision associated with estimates of effort and catch from recreational fishing, to continue to provide the best available information for sustainable management of fishery resources.

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### **Appendix 3 Theses in collaboration with recreational fishing surveys.**

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