Fisheries

On-site survey of recreational fishing for Pipi in Goolwa, South Australia 2020-21

Durante, L. M., Bailleul, F. and Beckmann, C. L.

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PO Box 120 Henley Beach SA 5022

November 2022

Final Report to PIRSA Fisheries and Aquaculture

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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The South Australian Research and Development Institute respects Aboriginal people as the state's first people and nations. We recognise Aboriginal people as traditional owners and occupants of South Australian land and waters. We pay our respects to Aboriginal cultures and to Elders past, present and emerging.

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South Australian Research and Development Institute (SARDI) acknowledges and appreciates the efforts of the fishers interviewed during the 2020/21 Pipi recreational fishery on-site survey. We thank Drs Sean Tracey and Kate Stark for their advice and insight during survey planning and data analyses, Dr Greg Ferguson and Graham Hooper for providing in-depth knowledge on Pipi biology and fishery, Stephanie Garra, and all the interviewers and FishCare volunteers that contributed to this project. We are grateful to the numerous South Australian Recreational Fishers who gave up their time to participate in the voluntary survey. The project was co-funded by the Fisheries Research and Development Corporation (FRDC) and the South Australian Government under the Adelaide University affiliate agreement as part of FRDC project 2020-056 “Evaluation of a smart-phone application to collect recreational fishing catch estimates, including an assessment against an independent probability-based survey, using South Australia as a case study”. The South Australian Goolwa Pipi Survey has been reviewed and approved by the University of Adelaide Human Research Ethics Committee HREC 2020–238. This report was internally reviewed by Drs Katherine Heldt and Greg Ferguson (SARDI), and formally approved for release by Dr Stephen Mayfield, Science Leader, Fisheries, SARDI Aquatic and Livestock Sciences.

EXECUTIVE SUMMARY

Pipi *(Plebidonax deltoides*) support important commercial and recreational fisheries in South Australia. Pipi or “Kuti” also hold significant cultural and economic importance for the Indigenous People of the Lower River Murray, Lakes and Coorong, known as the Ngarrindjeri. Recreational fishers typically target Pipi on the Sir Richard Peninsula (between the Murray River Mouth and Goolwa) and on the adjacent beaches from Goolwa to Middleton.

Previous estimates of retained catch and effort are available from the 2013/14 on-site survey. State-wide estimates are also available from telephone diary surveys conducted during 2000/01, 2007/08 and 2013/14, however, low sample sizes in those surveys resulted in poor precision. The 2020/21 on-site survey was designed to describe retained catch and effort for the Pipi recreational fishery in the Goolwa region, providing estimates with higher precision than past surveys.

The survey period ran for seven months from November 2020 to May 2021. Data collected during 22 interview days were scaled up to provide a total recreational retained catch and effort estimate for the 2020/21 fishing season. Interviews conducted at the vehicle access point at Goolwa accounted for 91% of the retained catch, with the remainder caught from pedestrian access points. Fisher activities in 2020/21 were characterised by a higher proportion of males. Most of fishers were travelling in vehicles and catching Pipi for bait purposes

Catch rates of Pipi were higher in 2020/21 than 2013/14, with higher values from fishers travelling in vehicles and during school holidays. The estimated total number of Pipi caught across the surveyed area was 4.26 million (± 1.65 million standard error, SE) representing 67.7 t (± 26.2 t SE). This represents a 24% increase of the total number of Pipi caught compared to 2013/14 (3.24 ± 1.09 million SE), and a 51% increase in retained catch weight compared to 2013/14 (33 ± 11 t SE). Pipi caught during 2020/21 were larger than those caught during the 2013/14 survey, explaining the relatively greater increase in catch weight over numbers.

Keywords: Recreational fishery, Pipi, Kuti, Goolwa cockle, resource access, South Australia, beach fishing, bivalve.

1. INTRODUCTION

1.1. Recreational fishing for Pipi in South Australia

Recreational fishing for Pipi is a popular activity in South Australia, attracting thousands of people who catch millions every year (Hall *et al.* 2015). At a wholesale price, the South Australian recreational catch of Pipi can be estimated to be worth more than AU$200,000 in 2013 (Fig. 1A), but the fishery also generates indirect value. Recreational fishing for Pipi provides important benefits to the regional economy of Goolwa through expenditure (e.g. equipment, fuel, meals, and accommodation), and flow-on effects (e.g. wages paid to local workers at tackle shop, service station or motels). The social and cultural aspect of the recreational fishing sector, while difficult to quantify, is also significant for both the Indigenous People, residents, and visitors. Cultural traditions, which can span multiple generations, are important for maintaining social connections and supporting mentally and physically healthy communities.

Historically, Pipi were primarily used as bait in South Australia. They gained popularity for human consumption in the 1990s, after Italian immigrants introduced them into restaurants. While a reduction in commercial catch occurred between 2007/08 and 2008/09, wholesale prices had increased ~1000% by 2019/20 (Fig. 1A) through the transition in use from bait to consumption. The proportion of commercial catches of Pipi for consumption (compared to supplying the bait market) increased from 20% in 2008/09 to 60% in 2013/14 and have remained stable until 2019/20 (Ferguson and Hooper 2021). With the increased volume of imported bivalves into Australia in 2012 (Fig. 1B), Asian cockles have supplemented Pipi as bait, due to lower costs, and recreational catch of Pipi for consumption has gained popularity.

Recreational fishers catch Pipi using cockle rakes (nets), bait spades, bait forks or collect them by hand. The recreational fishery of Pipi is regulated with a closed season (1 June to 31 October), a minimum legal length (3.5 cm), a personal daily bag limit (300) and a possession limit (1,200) (Appendix 1).

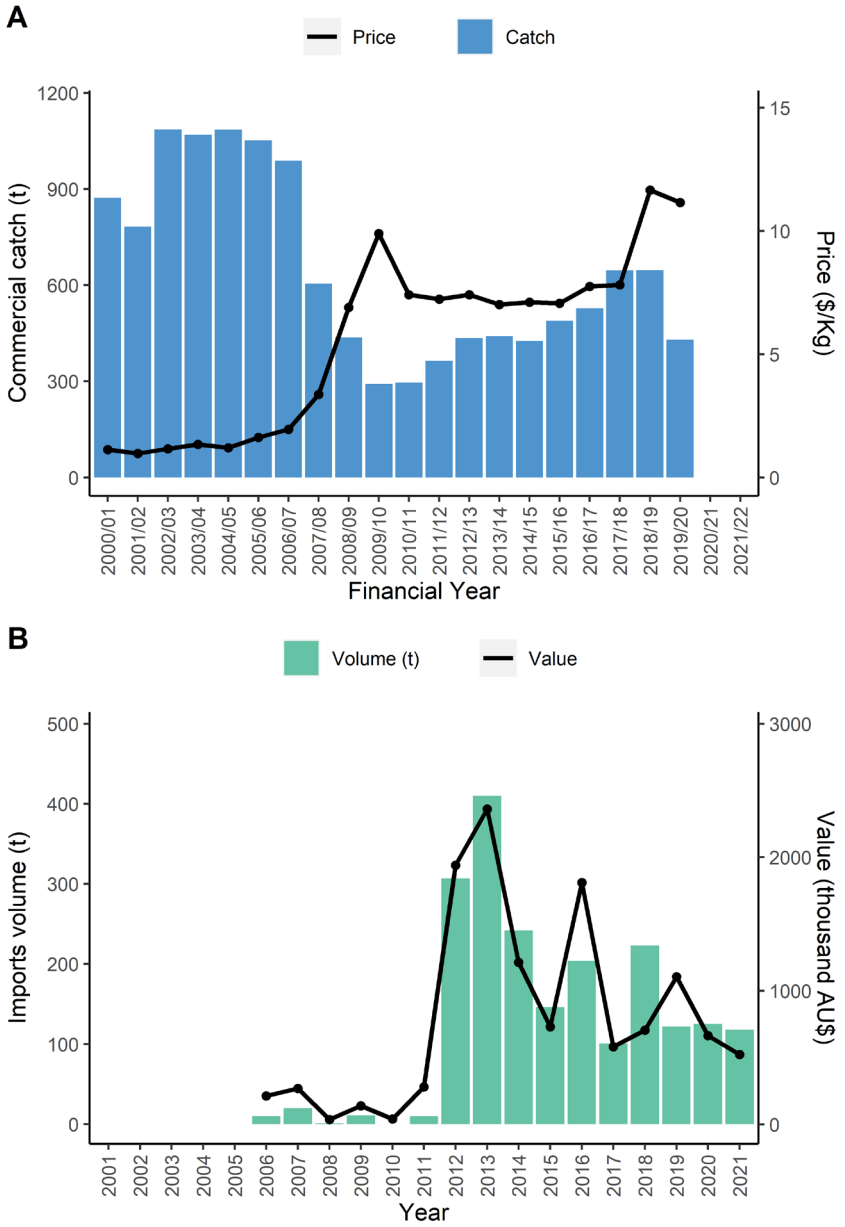

Figure 1. (A) Total commercial harvest and average wholesale price of Pipi in South Australia for each financial year and (B) yearly reported total volume and value of imports of molluscs and aquatic invertebrates (excluding crustaceans, oyster, cuttlefish, octopus, and squid) fresh and chilled from Asia. Source: BDO EconSearch (Dix *et al.* 2021) and Australian Bureau of Statistics (2022).

1.2. Biology, distribution, and ecological importance

Plebidonax deltoides, commonly known as Pipi in South-eastern Australia and as Goolwa Cockle in South Australia, is a small, edible saltwater clam (marine bivalve mollusc) of the family Psammobiidae, endemic to Australia and previously known as *Donax deltoides*. Other names include Coorong cockle, ugari, and eugarie. Pipi are also called “Kuti” by First Nations

Australians, who were the first people to harvest this bivalve and who still rely on these resources (Schnierer 2011).

In South Australia, Pipi are found from the Eyre Peninsula to Kingston (King 1985; McLachlan et al. 1996). Juveniles inhabit the intertidal zone and adults inhabit the subtidal zone where they burrow into the sand to an average depth of 10 cm (King 1976). Pipi require high wave-energy environments as the surf concentrates their primary dietary source (phytoplankton) and increases the oxygen concentration in the water (King 1976). In some areas Pipi can constitute up to 85% of the in-faunal biomass and they play an important role in nutrient cycling through filter feeding (Ansell 1983). The Younghusband Peninsula and Sir Richard Peninsula in South Australia present the ideal environment for the species and this area supports the area of largest abundance of Pipi in Australia (King 1976). In South Australia, Pipi mature at approximately one year of age and they live up to three to five years reaching a maximum size of 61 mm (Ferguson *et al.* 2021). Full maturity and recruitment to the fishable biomass generally occurs at the beginning of their third summer (Ferguson *et al.* 2021).

1.3. Need for information

Data on catch and effort from different fishing sectors are routinely used to ensure species are exploited on a sustainable basis under the *Fisheries Management Act 2007.* While commercial fisheries comprise a limited-entry sector, recreational activities can usually be undertaken by anyone with access to fishing grounds, without the need for licences or data reporting. However, the lack of recreational fisheries data can make management and resource allocation difficult. Reliable fisheries data has become especially relevant due to climate change uncertainties, especially for bivalves inhabiting the intertidal zone (Rullens *et al.* 2022). The loss of intertidal fauna due to droughts, floods and sea level rise would result in ecological, economic, and social impacts, which can be accelerated due to harvesting pressure. Therefore, there is a need for long-term information on stock dynamics and biomass trends from recreational fishing grounds to further support management and increase the resilience of these populations.

Pipi supports increasingly important commercial and recreational fisheries in South Australia (Dix *et al.* 2021; Ferguson and Hooper 2021), with 26% of fishing grounds allocated to recreational activities (PIRSA 2022). Recreational fishers typically target Pipi on the Sir Richard Peninsula (between the Murray River Mouth and Goolwa) and on the adjacent beaches from Goolwa to Middleton (Fig. 2). Key fishing sites are accessible via pedestrian walking tracks connected to carparks, and via a four-wheel drive track which provides access between Goolwa and the Murray Mouth. Anecdotal evidence suggests that most of the fishing activity occurs during daylight hours with the beach being most accessible at low tide.

Obtaining statistically robust recreational catch estimates for species that have a significant land-based access component with a limited geographical distribution, such as Pipi, is challenging. This is principally due to the low fisher sample size in phone-diary surveys used to obtain State-wide estimates of total recreational catch. State-wide phone-diary surveys have previously been conducted in 2000/01, 2007/08 and 2013/14 but resulted in poor precision around estimates of recreational fishing participation, effort, and retained catch of Pipi (Giri and Hall 2015; Hall et al. 2015; Jones *et al.* 2009; Jones and Doonan 2005).

On-site interview-based surveys are a more cost-effective, precise, and statistically robust methodology to measure the land-based recreational catch of species with a limited distribution (i.e. angler surveys, Pollock 1994). Therefore, in 2013/14 an on-site angler interview (creel) survey was undertaken to achieve a statistically robust estimate of recreational catch and effort of Pipi caught from Goolwa Beach and adjacent beaches. The estimated annual retained Pipi catch was 3.24 million (± 1.09 million SE), with a total weight of 33 t (± 11 t SE), and is the most recent estimate for the region (Hall et al. 2015). The creel survey was conducted to supplement estimates generated from the State-wide phone-diary survey conducted over 12 months during 2013/14. Fishery-independent sampling was also undertaken during the 2013/14 fishing season to compare size distributions of the Goolwa Pipi population with those from recreational fishing activities.

1.4. Survey objectives

The primary objective of the 2020/21 survey was to estimate the total recreational effort (fisher days) and catch (by number and by weight) of Pipi from the Goolwa region during the 2020/21 fishing season. Recreational catch indicates the retained catch during recreational fishing activities and will be referred to as catch hereafter for simplicity. Catch data by weight will enable comparisons with data obtained routinely from the commercial sector. An additional objective was to report on the size frequency of the recreational catch and the demographic and behavioural characteristics of recreational fishers targeting Pipi.

2. METHODS

2.1. Recreational fishing surveys

The survey design was based on a stratified random access-point methodology, which improves estimates of total retained catch and effort compared to a non-stratified survey (Pollock et al. 1994). This methodology uses prior knowledge of fishing activities to increase sampling during specific times and at access points with expected high fishing activity.

From previous surveys and advice from Fisheries Compliance Officers and FishCare Volunteers, it is known that the effort in the recreational Pipi fishery is highest around the Murray River Mouth, specifically at the Goolwa Town Beach and adjacent beaches at Middleton and the Sir Richard Peninsula (Hall *et al*. 2015; Jones *et al.* 2009). From the Goolwa Town Beach carpark at Beach Road, access to Sir Richard Peninsula Beach is by four-wheel drive from the Beach Road carpark as well as via walking tracks from the Goolwa Barrage and Beacon 19 carparks, through sand dunes to the beach (Fig. 2). The closed season and the tidal influences on the fishery, along with most of the catch being taken during daylight hours indicate the best times to complete surveys. Therefore, an on-site stratified random access (creel) survey was designed to sample the recreational daytime Pipi fishery during the 2020/21 fishing season.

Sampling days were randomly selected from 1 November 2020 to 31 May 2021 (i.e. the open recreational fishing season for Pipi). Thus, the timeframe consisted of 212 potential calendar days, consisting of 143 weekdays and 69 weekend/public holiday days. Survey days were selected via a combination of spatial and temporal strata with equal probability and without replacement, where only one site was surveyed on any given sample day.

Days were the primary sampling units in each spatial stratum (main and minor sites) and were temporally stratified (day type; weekdays and weekends/public holidays). Due to differences in expected effort, 75% of sampling days were allocated to weekends/public holidays (higher effort) and 25% of sampling days were allocated to weekdays (lower effort). Sampling days were weighted spatially to reflect higher historical levels of effort from the main access point, such that 67% of sampling days were allocated to the main site and 33% of sampling days were allocated to minor sites (Table 1). Based on the random allocation of survey days, surveys were scheduled to commence 21 November 2020 and end 29 May 2021.

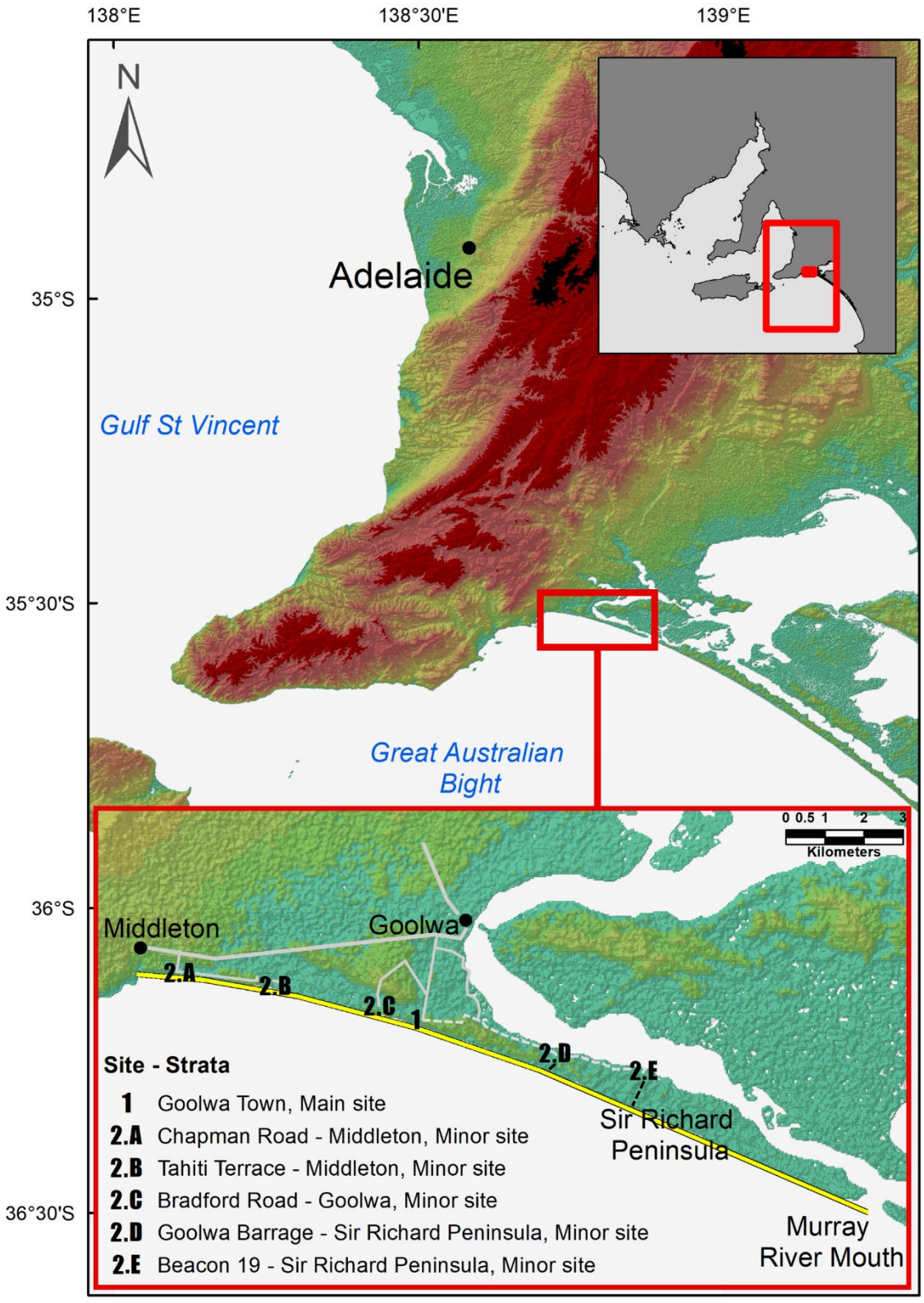

Figure 2. Map of South Australia showing car park locations near on-site access points and their respective survey strata within the survey region between Middleton Beach and the Murray River Mouth (yellow line). Solid grey lines identify major roads and streets, while dotted lines identify four-wheel drive tracks. Black dotted lines identify walking tracks from car parks to beach access points. Topography of the landscape is illustrated with green (red) indicating low (high) elevations.

Table 1. Sampling fractions assigned to spatial strata (main and minor sites) and temporal strata (weekday and weekends/public holiday).

Spatial Strata	Weekdays	Weekends and Public Holidays	All Days
Main Site	17%	50%	67%
Minor Site	8%	25%	33%
All Sites	25%	75%	100%

One sampling day was not completed on the 21 November 2020 due to restrictions in place relating to COVID-19. As a stay-at-home order was in place during this time, it was assumed that no fishing activity took place on this day. The sampling day scheduled for 25 May 2021 was cancelled due to wind speeds forecast at >30 knots, and the sampling day conducted on 24 January 2021 was shortened to four hours due to high temperatures of >38°C. These days were excluded from the analysis, resulting in a total of 22 survey days being analysed, 17 during weekends and public holidays (11 at main and 6 at minor sites) and 5 during weekdays (3 survey days at main and 2 at minor sites).

The survey was designed as a 'daytime' creel survey, with interviews only undertaken within the dawn to dusk period (Hall *et al.* 2015). For the selected sampling days, the 6-hour survey period started three hours before low tide and concluded three hours after low tide. On days of two low tides, two sampling periods were scheduled; one 3-hour period commencing from the first low tide and another 3-hour period prior to the second low tide. When it was not possible to complete three hours of sampling between the second low tide and sunset, a 6-hour sampling period was scheduled from the first low tide.

At minor sites, survey clerks interviewed people at the main pathway adjacent to the beach (Fig. 2, sites 2). To ensure full coverage at the Goolwa Town main site (Fig. 2, site 1) survey clerks were divided into two groups and allocated to either four-wheel or pedestrian paths entering the beach from the car park. Information on catch and effort was obtained by interviewing one member of a Pipi fishing party at the access point (car park) on return from their trip. For each survey period, the total number of vehicles and pedestrians arriving and leaving the beach through the access point were counted and interactions with potential fishers were classified as fishing, not fishing, or unknown (Fig. 3).

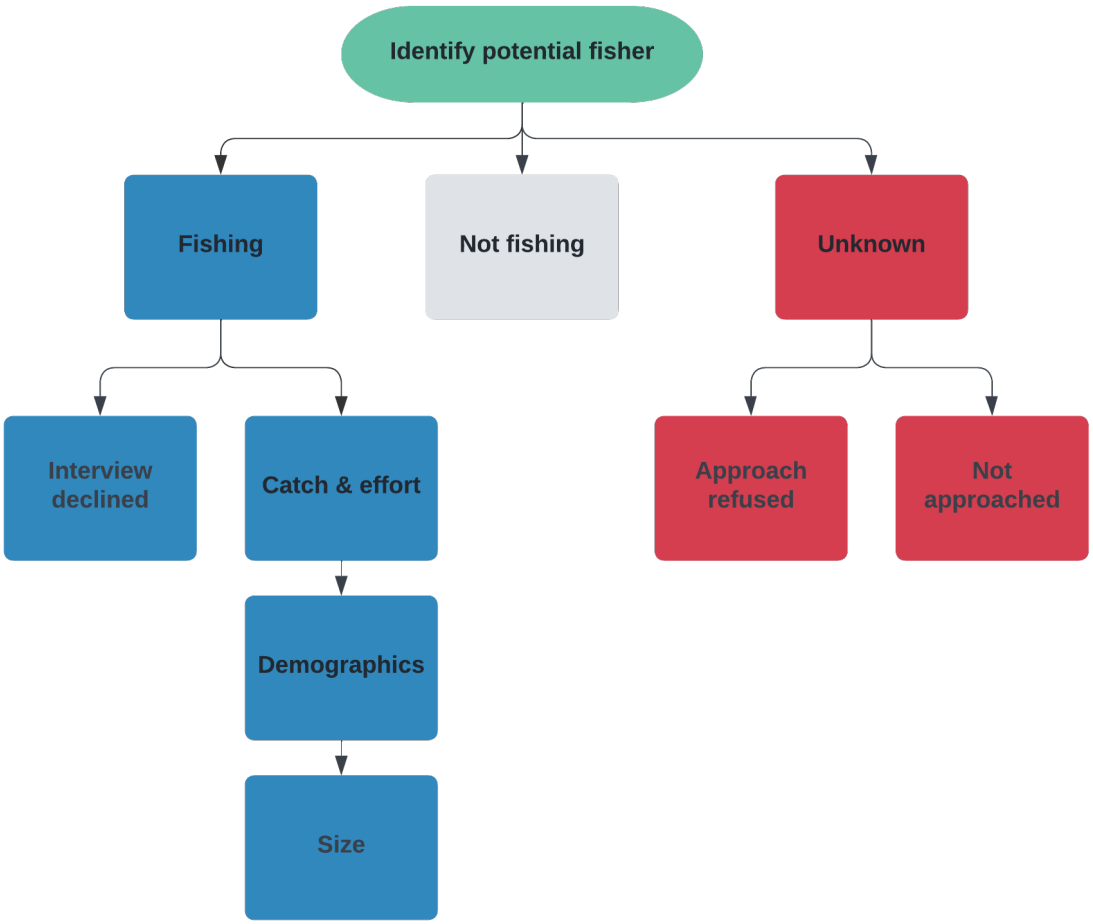

Figure 3. Classification of interactions with potential fishers during creel survey. Total number of fishers was estimated from approached parties (proportion between "Fishing" and "Not fishing"), while total Pipi catch was estimated from interviewed parties ("Catch & effort").

On each survey day, the following were recorded every hour: the number of parties where fishing activity was not able to be identified (i.e. approach refused or not approached), the number of parties where fishing activity was identified but interviews were not completed (i.e. interview declined), and the number of parties that were non-fishers (Fig 3). Where possible, the survey clerk measured the shell length (mm measured across the widest part of the shell) of a randomly chosen sample of approximately ten Pipi from each interviewed party. Where this wasn't possible, the interview was recorded as declined but information collected was used in further analyses. Information was collected on the duration of the fishing trip (start and finish time, minus breaks), the number of Pipi caught, and weight of total catch. Fishing methods were recorded, but during busy periods more emphasis was placed on collecting accurate information on effort and trip activity rather than catch information. All members of the party were asked for the postcode of their principal residence, as well as whether they planned to use their Pipi for bait or for consumption. Gender and travel method during the

fishing activity (i.e. pedestrian or vehicle) was also recorded. Total number of fishers inside each vehicle was recorded, but this was not possible for interviews classified as declined.

Participants were allocated to Statistical Areas Level 4 (SA4) using the ABS correspondence file 'Postcode to SA4' (Australian Statistical Geography Standard Correspondences). SA4 are the largest sub-State geographical areas in the Main Structure of the Australian Statistical Geography Standard (ASGS) and are defined by the Australian Bureau of Statistics. For postcodes that did not map to a single SA4 region, participants were assigned to the most populated region. Postcodes of the interviewed fishers were grouped to determine locations of primary residence of all fishers, and separately of all main fishers.

2.2. Statistical analyses

The raw data were summarised and differences in average hourly catch rate (Pipi/fisher/hour), average number of Pipi caught, and average number of fishers were compared between day type and travel method using Welch two sample t-tests. Interviews were excluded from these analyses when the number of fishers in vehicles and/or total fishing time were not identified (38 interviews). Statistical analyses were undertaken using the R programming language, version 3.6.3 (R Core Team 2020). All errors are presented as one standard error (SE).

Total fishing effort and Pipi catch for the whole fishing season were estimated using the R package *survey* (Lumley 2020). The proportion of fishers present on each survey day (ratio of fishing to non-fishing parties from survey responses) and an average catch rate (Pipi/fisher) was calculated per survey day. The proportion of fishers was then extended to the number of people present each day on the beach (potential fishers) during the survey time to estimate the total number of fishers per day. Number of fishers per day was estimated per day stratum (weekday vs. weekend/public holidays) during sampling days and expanded (multiplied) to the 212 calendar days of the fishing season to obtain a total effort (fisher days) estimate. Total number of Pipi caught was estimated similarly, where daily catch rate was multiplied by the number of cars and pedestrians present each day on the beach and participating in the fishery. In addition, fishing was assumed to occur only during daylight hours, and for estimates of total catch, the sampling period was re-defined to the daylight time over the sampling period. Seasonal variation in daylight hours were accounted for. Calculations were repeated using daily catch rates in weight (kg) to obtain estimates of total weight of Pipi caught. Estimates were calculated separately for each travel method, i.e. vehicle vs. pedestrian, and for the main and minor sites. To produce total estimates of catch and effort that include both vehicle and pedestrian travel methods, the average number of fishers per vehicle was calculated as 2.6 (± 0.1) and were included with pedestrians. Estimates were also produced with the minimum (one) and a maximum (five) number of fishers per car. SE and relative standard error (RSE)

of each estimate were also calculated. Whereas SE displays the absolute uncertainty around the estimates, RSE is calculated as a proportion (SE/estimate) ranging from 0 to 1 and provides a direct comparison between each estimate and their SE. RSE values lower than 0.4 are considered adequate for the type of surveys conducted in the present report.

To identify potential biases in the data analyses that were related to weather conditions and seasonality in fishing effort, the relationships between catch rates and month, average tidal height, and daylight duration were investigated using generalised linear models (GLM).

3. RESULTS

Over 22 days of sampling 1,460 potential fisher parties were approached. Non-fishers comprised 1,016 parties, resulting in 444 fisher parties approached. Of these fisher parties, 351 agreed to be interviewed (860 fishers), from which 283 had Pipi catches to report. A total of 2,009 potential fisher parties were not approached due to time constraints (range of 0 to 463 parties not approached on a given day), and 122 refused to be approached for the interview, resulting in a 92% response rate for all parties (1338 out of 1460) and 79% for fisher parties approached (351 out of 444).

Each party interviewed comprised an average of 2.6 ± 0.1 fishers, catching an average of 216 ± 14.1 Pipi per day, totalling 72,611 Pipi caught from all interviewed fishing parties. Larger number of Pipi were caught by fishers travelling in vehicles (89.3% during weekends/holidays and 9.2% during weekdays) than by pedestrians (1.5% during weekends/holidays and <1.0% during weekdays). Catch rates (Pipi/fisher/hour) were significantly higher for people travelling in vehicles (72.3 ± 3.4 Pipi/fisher/hour) than for pedestrians (8.1 ± 3.3 Pipi/fisher/hour) ($t(217.66) = -8.18$, $p < 0.001$). The average number of Pipi caught by fishers travelling in vehicles was ~2,000% higher (281.5 ± 11.2 Pipi) than that by pedestrians (13.4 ± 4.7 Pipi), but no difference was found in the number of fishers per party between vehicles and pedestrians. Fishing parties were slightly larger on weekends and public holidays (2.7 ± 0.1 fishers) compared to weekdays (2.2 ± 0.2 fishers) ($t(43.20)= -2.59$, $p = 0.013$).

Two school holiday periods occurred during the on-site survey, one dated between 12 December 2020 and 31 January 2021 and the other between 10 April 2021 and 26 April 2021. Although school holidays were included in the weekend/public holiday day strata, the data revealed that catch rates during school holidays (70.7 ± 4.9 Pipi/fisher/hour) were significantly higher compared to other weekends and public holidays (40.7 ± 3.1 Pipi/fisher/hour) ($t(248.3) = 3.19$, $p = 0.002$). The results from the GLMs suggest that tidal height, daylight duration, and month had no effects on daily catch rates (Appendix 2). However, reduced catch rates were observed at the end of the fishing season approaching Winter (Appendix 3).

3.1. Total catch and effort

Estimates of total catch from interviews undertaken at minor sites (<30kg of total weight) were considered negligible for the final estimates of Pipi catch and are not presented in this report.

Both recreational fishing catch and effort of Pipi at the main sites were higher for estimates conducted for vehicles compared to the ones for pedestrians. The total estimated effort from vehicles was three times higher than effort from pedestrians (Table 2), and the total number of Pipi caught estimated from vehicles was 9.6 times higher than the total estimated from

pedestrians (Table 3). The total recreational catch of Pipi at Goolwa in the 2020/21 fishing season was estimated at 4,256,611 ± 1,652,844 Pipi, or 67,722 ± 26,152 kg (91% from fishers on vehicles and 9% from pedestrians) (Tables 3 and 4).

Table 2. Pipi fishing effort (fisher days) during the 2020/21 fishing season, estimated from vehicle and pedestrian travel methods, their standard error and relative standard error (SE/Effort). Estimates are only shown for the main site (Goolwa Town access point). We estimated the average number of fishers per vehicle to be 2.6 fishers (range of 1-5 fishers).

Type	Effort (fisher days)	Standard error (SE)	Relative standard error (RSE)
Vehicle Range	8,388 3,226 – 16,132	462 178 – 888	0.05
Pedestrian	2,782	614	0.22
Total Range	11,170 5,387– 18,293	768 505 – 1006	0.07

Table 3. Estimated number of Pipi caught during the 2020/21 fishing season, estimated from vehicle and pedestrian travel methods, their standard error and relative standard error (SE/Effort). Estimates are only shown for the main site (Goolwa Town access point). We estimated the average number of fishers per vehicle to be 2.6 fishers (range of 1-5 fishers).

Type	Estimated number of Pipi caught	Standard error (SE)	Relative standard error (RSE)
Vehicle Range	3,854,491 1,482,497– 7,412,483	1,643,818 632,238– 3,161,189	0.43
Pedestrian	402,120	172,499	0.43
Total Range	4,256,611 1,884,617 – 7,814,603	1,652,844 655,348 – 3,165,892	0.39

Table 4. Estimated weight (in kg) of Pipi caught during the 2020/21 fishing season, estimated from vehicle and pedestrian travel methods, their standard error and relative standard error (SE/Effort). Estimates are only shown for the main site (Goolwa Town access point). We estimated the average number of fishers per vehicle to be 2.6 fishers (range of 1-5 fishers).

Type	Estimated weight of Pipi caught (kg)	Standard error (SE)	Relative standard error (RSE)
Vehicle Range	61,320 23,584 – 117,922	25,995 9,998 – 49,990	0.42
Pedestrian	6,402	2,858	0.45
Total Range	67,722 29,986 – 124,324	26,152 10,398 – 50,072	0.39

3.2. Demographics, intended use of Pipi and fishing methods

Most fishers interviewed (>60%) were residents of South, North and West Metropolitan Adelaide, 13.3% lived in Central Adelaide (Inner Metro) and the Hills, 11.5% in the Southeast Regions, 5.4% were from interstate, and 0.6% were from overseas (Fig. 4A). The area of primary residency of the main fisher was similar when compared to other party members (Fig. 4B). A higher proportion (67.4%) of males were interviewed than female fishers (Fig. 4C). This proportion was higher when only the main fisher of each party was considered (92% males and 8% females).

When looking at the intended use of Pipi caught in the 2020/21 season, most fishers interviewed intended to use their catch as bait during other recreational fishing activities (58%, Fig. 5A). Only 23.7% of fishers interviewed were planning to use their catch for consumption, with the remaining 18.3% planning to use their catch for consumption as well as bait. Although the intended use of Pipi as bait was prevalent among interviewees, most fishers from Central Adelaide and Hills intended to use Pipi for consumption (Fig. 5B and C). The main fishing method was by hand and feet (72.3%), followed by cockle rakes (10.1%), bait spade (9.8%), bait fork (2.7%), shovel (2.4%) and other methods (2.7%) (Fig. 6).

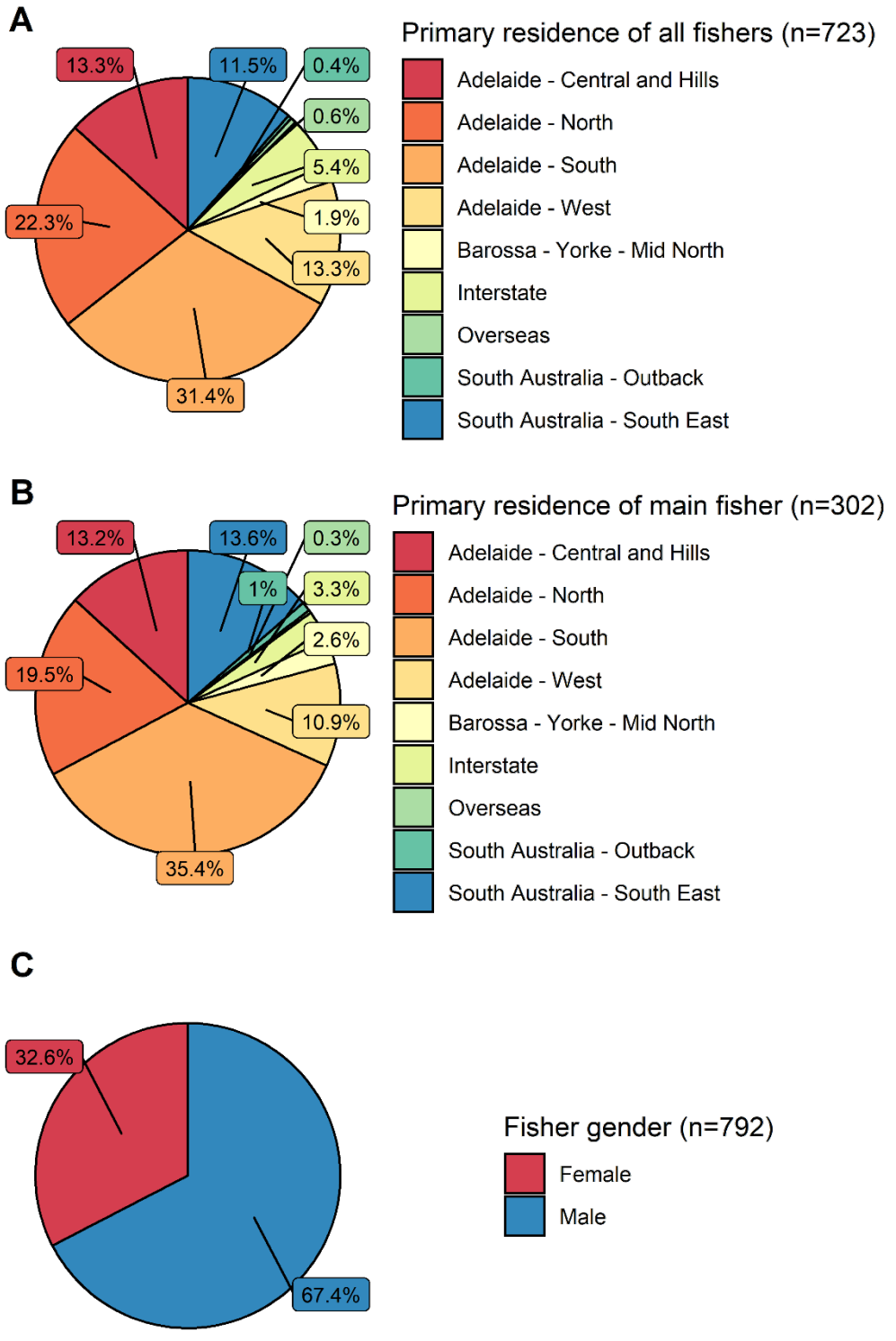

Figure 4. Area of primary residence of (A) all fishers, (B) main fisher and the (C) gender of all fishers interviewed during the 2020/21 recreational Pipi fishery on-site surveys.

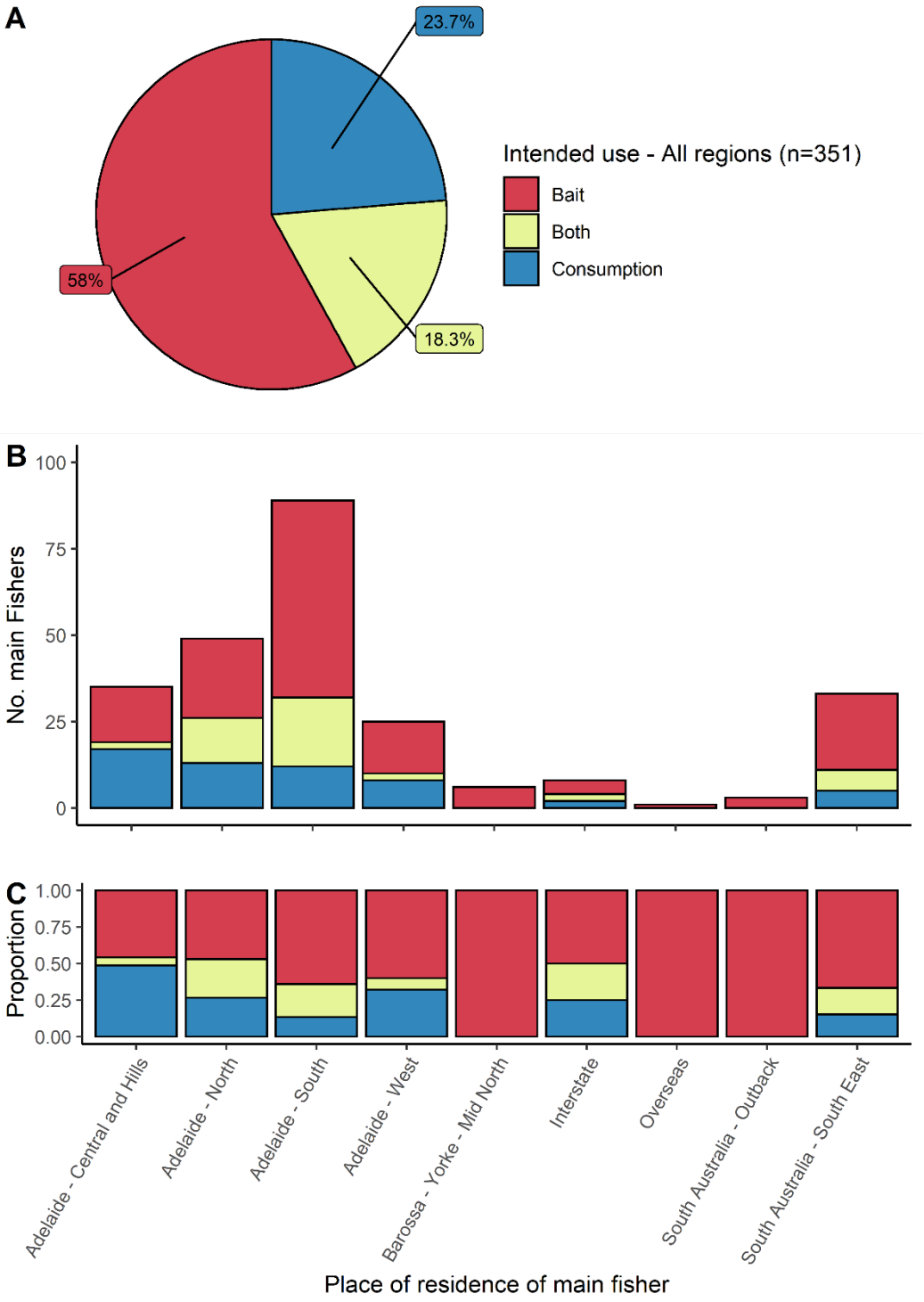

Figure 5. Intended use of Pipi as reported by the main fisher for (A) all regions combined, for (B) each place of residency of main fisher and (C) the proportion of intended use for each place of residency of main fisher.

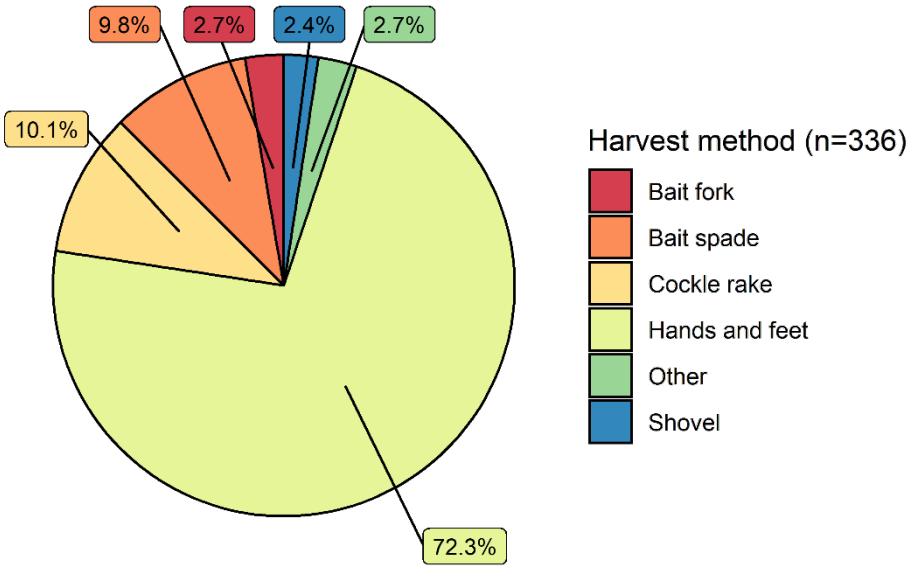

Figure 6. Fishing methods used by fishers during the 2020/21 on-site survey in Goolwa. Methods grouped as "other' include net (2.1%), gardening tools (0.3%) and kids implements (0.3%).

3.3. Pipi size distribution

Pipi caught in 2020/21 measured between 22 and 57 mm, while in 2013/14 the sizes were 10 to 53 mm (Fig. 7). Size distribution was strongly influenced by method of travel (vehicle vs pedestrian) (Fig. 8). Pipi caught by pedestrians displayed a large range of sizes, usually between 34 and 49 mm, compared to catches from fishers travelling in vehicles (41 to 50 mm). The total size range of Pipi caught was 22 to 49 mm for pedestrians and 32 to 57 for fishers travelling in vehicles (Fig. 8).

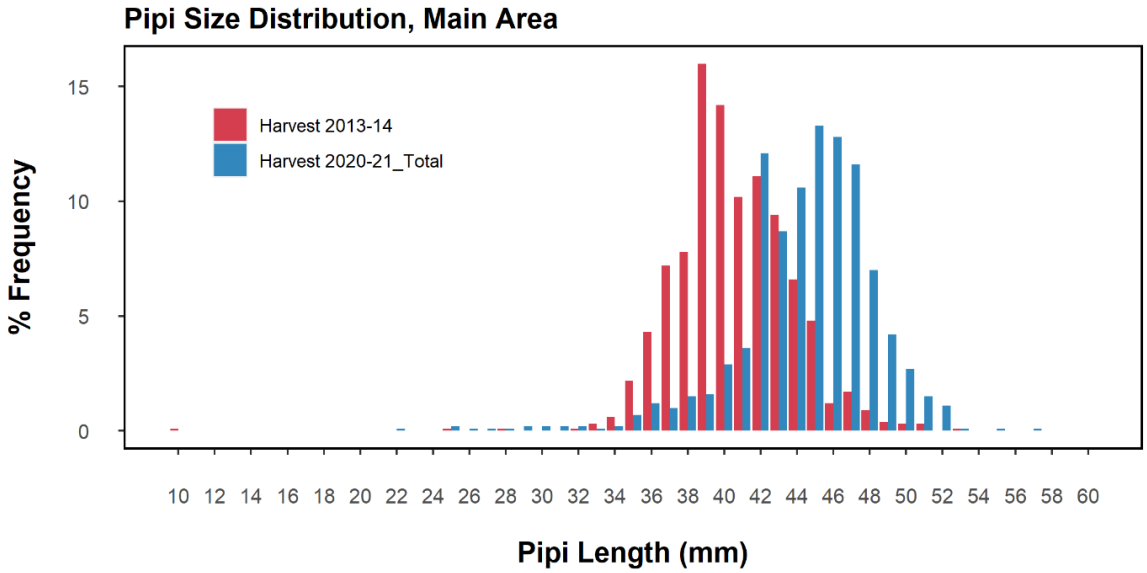

Figure 7. Size distribution of Pipi measured at the main site at Goolwa during on-site surveys in 2013/14 (red) and 2020/21 (blue).

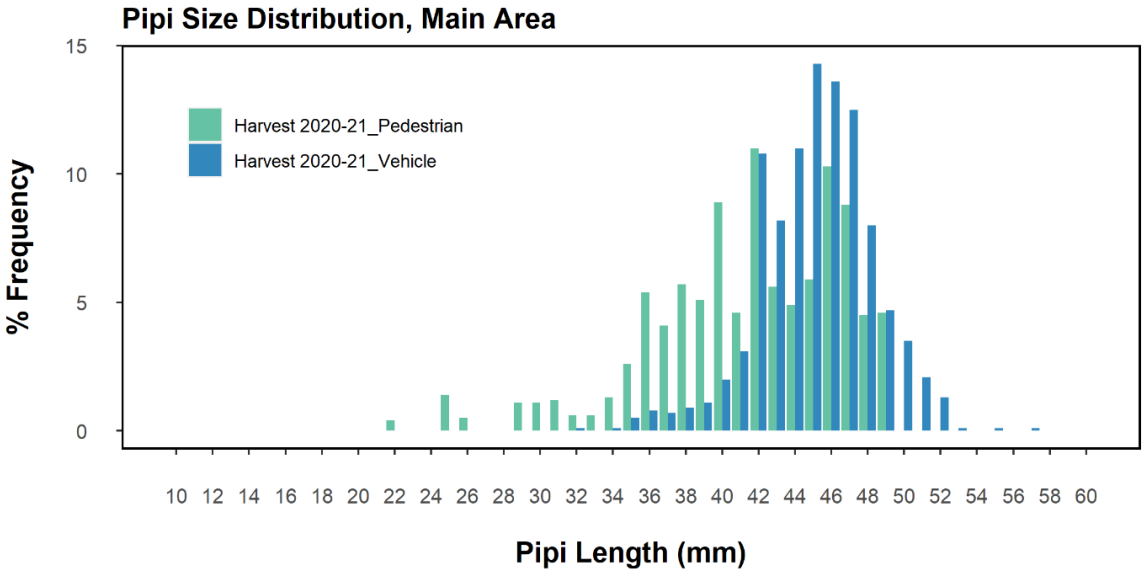

Figure 8. Size distribution of Pipi measured at the main site at Goolwa during on-site surveys in 2020/21 from fishers travelling as pedestrians (green) and by vehicle (blue).

4. DISCUSSION

Historically, information on the recreational catch of Pipi has been obtained from State-wide surveys that were not designed to provide robust estimates for a localised shore-based species (Giri and Hall 2015; Jones *et al.* 2009; Jones and Doonan 2005). Given the large uncertainty around these estimates, due to low sample sizes, it is difficult to interpret trends in catch and effort through time prior to 2013/14. This uncertainty was addressed in a targeted on-site survey conducted in 2013/14 that aimed to provide statistically robust estimates of catch and effort (Hall et al. 2015). The 2013/14 off-site survey catch estimate was 378,158 Pipi (± 237,172; 0.63 RSE) which was considerably lower than the on-site estimate of 3.24 million (± 1.09 million). The on-site surveys also had a smaller RSE (0.33 in 2013/14 and 0.39 in 2020/21), indicating higher precision when estimating recreational catch of Pipi in the region.

Comparison of catch estimates between on-site and off-site (phone-diary) surveys proves difficult as numbers of fishers targeting Pipi in the phone-diary sample were very low (Giri and Hall 2015; Jones *et al.* 2009; Jones and Doonan 2005). These phone-diary surveys also included Pipi catch reports that fell outside the main southern Fleurieu beach site range that were surveyed on-site in 2013/14 and 2020/21. Nevertheless, the Pipi catch estimate from the recent on-site survey (4.26 million ± 1.65) is higher than those estimated during off-site surveys in 2000/01, 2007/08 and 2013/14. Current catch estimates were also higher than estimates from the 2013/14 on-site survey (3.24 million Pipi ± 1.10).

The weight of the total recreational catch of Pipi from Goolwa in 2020/21 was estimated at 67.7 t (± 26.2) and is equivalent to ~16% of the total harvest of Pipi in South Australia (Ferguson and Hooper 2021). The total catch estimate from the on-site survey can be considered an under-estimate of the actual State recreational Pipi catch, due to the scope of the survey excluding recreational catch from other regions of the State and night-time fishing. Night-time fishing that is not assessed during creel surveys can hamper estimates of total catch of popular recreational species (Hall *et al.* 2022). Night-time fishing for Pipi potentially occurs, however more likely to happen on summer evenings with a full moon, and on the lowest (neap) tides, therefore we assume these catches would be comparatively small. Typically, night-time beach fishers only target finfish (sharks, snapper, and mulloway) at the interview sites during summer. Results from GLMs suggest that fishing activities were similar among all months surveyed, among days with different tidal heights, and with contrasting daylight hours. This suggests that recreational fishers tended not to plan their fishing trips to maximize their catches, for example during extremely low tides. Fishing occurred throughout most conditions and periods during interview days.

Small methodological differences, potential changes in fishing behaviour, and the distribution of Pipi hamper the comparison of catch estimates between on-site surveys. For example, catches from vehicles could be underestimated during on-site survey when interviews are not conducted at access points, while harvest weights can vary depending on different weight estimation methods of Pipi catch. The 2020/21 survey was designed to interview fishers (both in vehicles and pedestrians) at access points at the end of fishing events. Surveys conducted from access points provide a better coverage of the total fishery activity, especially when attempting to interview fishers travelling in vehicles. In the 2020/21 survey, weight data was recorded for entire catches, resulting in a robust weight estimate.

Minor sites produced negligible catch estimates in 2020/21 and could suggest differences in the behaviour of fishers and/or Pipi distribution. Pipi distribution, abundance and size are known to display interannual and geographical variation in the region (Ferguson and Hooper 2021), with fishers adapting to the changes. Differences in fishing activity become evident when total estimated fishing effort is compared between surveys. In 2020/21, total effort was estimated at 11,170 ± 768 fisher days, which was comparable to estimated effort from the main site in 2013/14 (10,287 ± 3,784 fisher days). Effort estimates from minor sites totalled 10,830 ± 3,968 fisher days in 2013/14 but were negligible in 2020/21, resulting in higher catch rates in the present survey.

Fishers travelling in vehicles displayed higher catch rates than pedestrians and reflect the importance of interviewing fishing parties accessing sites by car. This result suggests that fishers travelling further from access points in vehicles were more successful catching Pipi than pedestrians. Experienced fishers only visiting the beach to catch Pipi are more likely to be travelling by vehicle than on foot and, consequently, these fishers likely have higher catch rates (Murray-Jones and Steffe 2000; Thurstan *et al.* 2017). In Venus Bay (VIC) recreational fishers tended to select Pipi larger than 30mm (Parry 2013), reducing the abundance of larger Pipi in areas closer than three kilometres from beach access points (Parry 2013, Early *et al.* 2013, Lewis *et al.* 2013). Similar patterns were found in Stockton Beach (NSW), where commercial fishers and fishers catching Pipi for bait selected larger Pipi (larger than 45 mm), compared to fishers catching for consumption (Murray-Jones and Steffe 2000). Comparison of size distributions between on-site and fishery-independent surveys confirmed that active selection of larger Pipi by recreational fishers occurred in Goolwa during 2013/14, likely as a function of daily bag limits. Lower numbers of legal-size Pipi close to the Goolwa Town access point could have reduced the size distribution of Pipi caught by pedestrians, as well as their catch rates. Recreational catches of Pipi in 2020/21 were predominantly recorded from fishers travelling in vehicles, compared to pedestrians in 2013/14, partially explaining the larger sizes present in distributions from the recreational catch of Pipi in 2020/21.

Some features of the SA recreational Pipi fishery have changed significantly over time, with catches in 2013/14 mostly for consumption and the current catches used mostly for bait purposes. This trend can be explained by the recent increase in demand for bait to be used in other recreational fishing activities in SA, coupled with reduced imports of cheaper Asian bivalves since 2013/14, which were previously supplementing bait supplies. Poor Pipi recruitment in Younghusband Peninsula in 2018/19 and supply issues due to increased interstate export following large floods in New South Wales in 2020/21 further reduced the availability of Pipi to bait markets in SA (Ferguson and Hooper 2021).

Communication between fishers prior to fishing activities has become fast and integrative with the increasing use of social media and fishing apps. Fishers can share details of fishing activities with thousands of peers in seconds, including pictures of the catch and precise GPS location (Hall *et al.* 2022). The sharing capabilities of social media can facilitate the access to fishery resources and disseminate their use and consumption. In SA for example, information gathered from one of the largest online recreation fishing groups (with over 24,000 members on the social media platform *Facebook*) has shown an increase in the use of the terms “Pipi” and “cockle” in past years. No mentions of Pipi were posted in the specific group between 2015 and 2016, one in 2017, 14 in 2020 and 23 in 2021. Discussion topics varied between asking for advice on catching and keeping Pipi, as well as reporting its use as bait. The increased access to smartphones, social media use, and the creation of groups focused on discussions of recreational fishing activities, reflects, and might have contributed to a higher proportion of avid fishers catching Pipi for bait purposes in 2020/21.

Although no difference in fishing activity was observed between weekdays and weekend/public holidays, catch rates were significantly higher during school holidays when compared to other weekend/public holidays. The number of fishers in each fishing party was not different between the two groups, but a larger number of fishers were at the beach and were interviewed during school holidays compared to other weekend/public holiday days. This suggests that the number of fishers could be linked to the catch success of Pipi in a specific area. Pipi display patchy distribution throughout their geographical range, therefore catch rates depend on how easily fishers find high density patches. When large numbers of people are catching Pipi, there is a higher chance of high-density areas being identified, drawing fishers to those areas, and increasing catch rates. Therefore, the total number of people on the beach is an important factor when looking at Pipi catch and effort, not just because it is related to the number of fishers, but also the catch rate of each fishing party.

More than 80% of all fishers interviewed had travelled from Adelaide (inner and outer Adelaide), however the trip duration was not recorded, so it is unknown if fishers were

travelling for day trips specifically for fishing or were fishing whilst on holiday. Fishers from Central Adelaide and the Hills also reported higher intended consumption use than bait use. These data may have implications regarding the communication of food safety messages, especially when high levels of diarrhetic shellfish toxins and *Escherichia coli* are detected.

On-site surveys remain the most accurate method for estimation of total recreational catch of species with land-based access and limited geographical distribution. However, the infrequent nature of surveys presents a significant challenge when interpreting interannual trends in recreational catch estimates. Although the present study provides robust estimates of total catch and effort, it also shows that fisher behaviour and Pipi distribution play an important role in shaping fishing pressure. Looking at the behavioural and social aspects of the recreational fishery can provide invaluable tools for future surveys and management decisions. For example, larger catch rates of fishers travelling in vehicles and during school holidays suggest that the total number of vehicles on the beach may be useful as a proxy for fishing activity levels. Applying unmanned methods, like traffic counters in access points, could improve our understanding of the trends in recreational fishing activity and could provide important information to inform fishery management.

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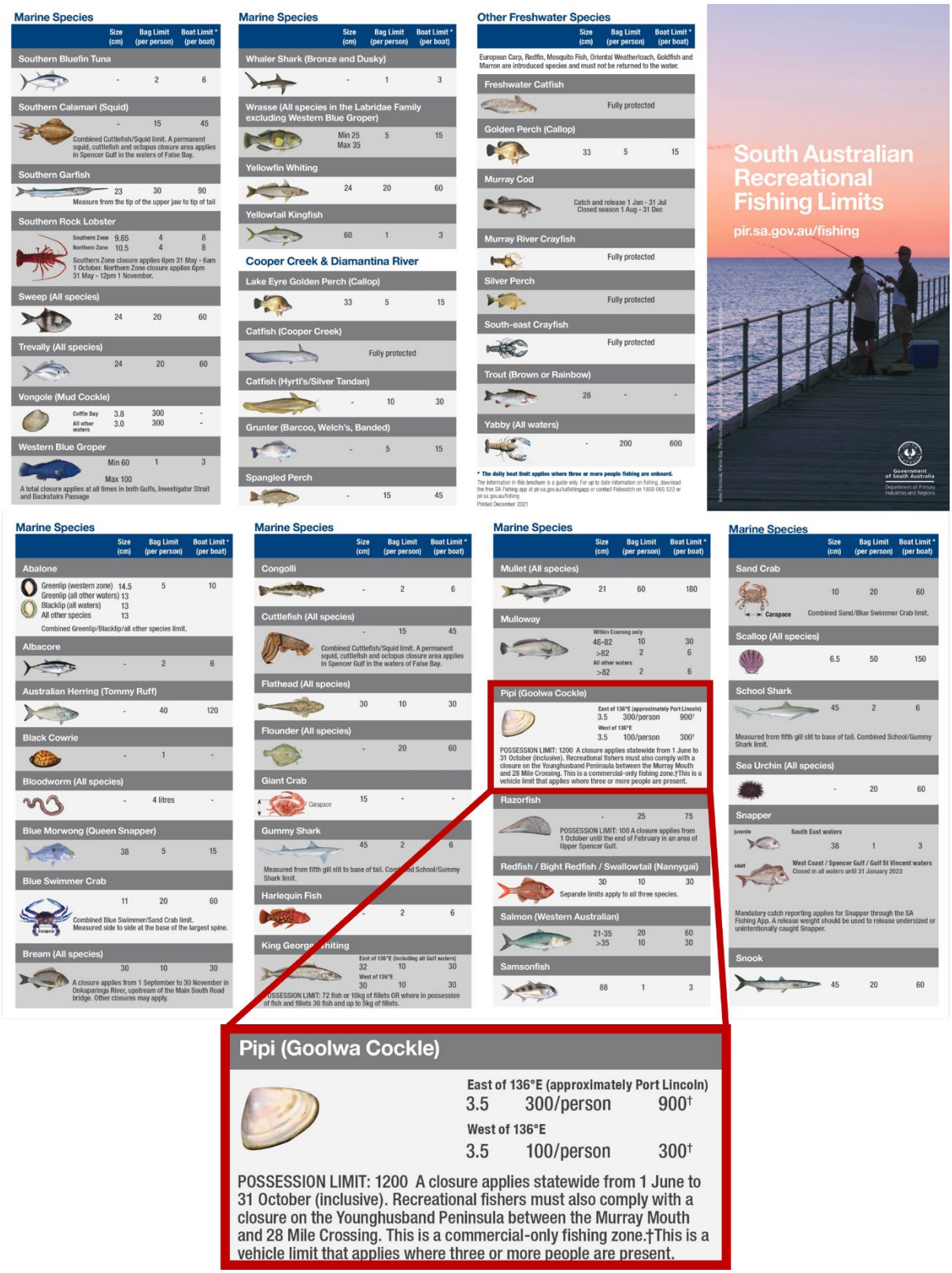
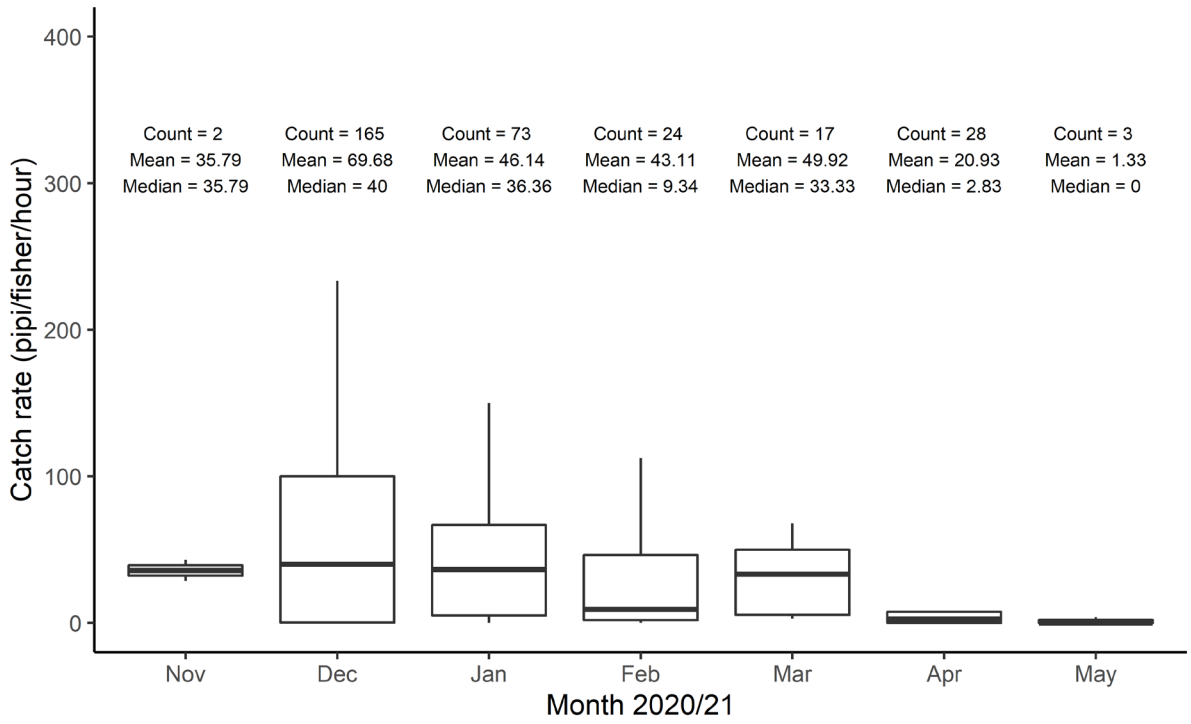
APPENDIX



Appendix 1. South Australian Recreational Fishing Limits Brochures with current legal minimum sizes and bag limits. Detail to Pipi (Goolwa Cockle).

Appendix 2. Estimated regression parameters, standard errors, t-values, and p-values for the generalised linear model with using a default Gaussian family and the following statistical model: Catch Rate ~ factor (Month) + Daylight Hours + Average Tidal Height. Months were analysed as factors (February to December) and compared to Month1 (January). Average tidal height was calculated for during or before the fishing period.

	Estimate	Std. error	t value	p value
Intercept	16.539	24.323	0.680	0.52
Month2	-1.211	1.761	-0.688	0.52
Month3	-3.828	3.054	-1.254	0.26
Month4	-5.831	4.546	-1.283	0.25
Month5	-9.345	6.354	-1.471	0.19
Month11	-2.088	1.951	-1.070	0.33
Month12	1.879	1.165	1.613	0.16
Daylight hours	-1.230	1.620	-0.759	0.48
Average tidal height	6.321	7.973	0.793	0.46



Appendix 3. Boxplot of recreational catch rate (Pipi/fisher/hour) for each month during the 2020/21 Pipi on-site survey. Data from main and minor sites included.