Investigating bias in recreational fishing surveys: Fishers listed in public telephone directories fish similarly to their unlisted counterparts.

Daniella Teixeira^{a*}, Mitchell T. Zischke^{a,1} and James A. C. Webley^a

^a Fisheries Queensland, Department of Agriculture and Fisheries, GPO Box 267, Brisbane, Queensland, Australia, 4001.

* Corresponding author: Fisheries Queensland, Department of Agriculture and Fisheries, GPO Box 267, Brisbane, Queensland, Australia, 4001. Tel: +61 7 3255 4213, Email address: daniella.teixeira@daf.qld.gov.au

Abstract

Several recent offsite recreational fishing surveys have used public landline telephone directories as a sampling frame. Sampling biases inherent in this method are recognised, but are assumed to be corrected through demographic data expansion. However, the rising prevalence of mobile-only households has potentially increased these biases by skewing raw samples towards households that maintain relatively high levels of coverage in telephone directories. For biases to be corrected through demographic expansion, both the fishing participation rate and fishing activity must be similar among listed and unlisted fishers within each demographic group. In this study, we tested for a difference in the fishing activity of listed and unlisted fishers within demographic groups by comparing their avidity (number of fishing trips per year), as well as the platform used (boat or shore) and species targeted on their most recent fishing trip. 3062 recreational fishers were interviewed at 34 tackle stores across 12 residential regions of Queensland, Australia. For each fisher, data collected included their fishing avidity, the platform used and species targeted on their most recent trip, their gender, age, residential region, and whether their household had a listed telephone number. Although the most avid fishers were younger and less likely to have a listed phone number, cumulative link models revealed that avidity was not affected by an interaction of phone listing status, age group and residential region ($p > 0.05$). Likewise, binomial generalized linear models revealed that there was no interaction between phone listing, age group and avidity acting on platform ($p > 0.05$), and platform was not affected by an interaction of phone listing status, age group, and residential region ($p > 0.05$). Ordination of target species using Bray-Curtis dissimilarity indices found a significant but irrelevant difference (i.e. small effect size) between listed and unlisted fishers (ANOSIM

¹ Present address: Department of Forestry and Natural Resources, Purdue University, 195 Marsteller St, West Lafayette, Indiana 47907, United States.

$R < 0.05$, $p < 0.05$). These results suggest that, at this time, the fishing activity of listed and unlisted fishers in Queensland is similar within demographic groups. Future research seeking to validate the assumptions of recreational fishing telephone surveys should investigate fishing participation rates of listed and unlisted fishers within demographic groups.

Keywords

Telephone survey, mobile telephone, angler surveys, representativeness, coverage bias.

1. Introduction

The need for robust methods of monitoring recreational fisheries is increasing, as their contribution to global catch faces growing scrutiny (McPhee et al., 2002; Coleman et al., 2004; Cooke and Cowx, 2006). Offsite methods, those that survey the recreational fishing population through offsite sampling frames, are considered the most feasible and cost-effective for fisheries that are diverse and operate over large spatial areas (Hartill et al., 2012). Registries of fishing licence holders are a preferred sampling frame when available, either on their own or, if some population sectors are excluded from licensing, as part of a dual-frame approach (NRC, 2006; ICES, 2010). Licence registries have been utilised in many surveys worldwide, including in Denmark (Sparrevohn and Storr-Paulsen, 2012), Germany (Strehlow et al., 2012), the Basque Country (Zarauz et al., 2015), Canada (Fisheries and Oceans Canada, 2012), and Australia (Lyle, 1999; Melville-Smith and Anderton, 2000; Lyle et al., 2005; Currie et al., 2006; de Lestang et al., 2012; Ryan et al., 2013; Ryan et al., 2015). For unlicensed populations, surveys can use various methods to probabilistically sample recreational fishers. Postal area mail-outs were used in recent surveys in Finland (ICES, 2010) and England (Armstrong et al. 2013), while New Zealand opted for a meshblock door-knocking approach (Wynne-Jones et al., 2014). Other countries, including Denmark (Sparrevohn and Storr-Paulsen, 2012), France (Herfaut et al., 2013; Rocklin et al., 2014), the United States (NOAA Fisheries, 2015a), and Australia (Henry and Lyle, 2003; Lyle et al., 2005; Jones, 2009; Lyle et al., 2009; Taylor et al., 2012; West et al., 2012; Lyle et al., 2014; Webley et al., 2015), have used telephone directories as the sampling frame in recreational fishing surveys.

The choice of sampling frame depends on various factors, with coverage arguably the most important. Unlike licence registries which, generally speaking, provide high levels of coverage of the recreational fishing

population, the coverage provided by alternative frames for unlicensed populations is more problematic. Historically, telephone directories have provided good coverage of populations, but the rising prevalence of mobile-only households has tended to reduce coverage because mobile phone listings are often unavailable, uncommon, or cost-prohibitive (Ehlen and Ehlen, 2007; Link et al., 2007; Lee et al., 2010; Busse and Fuchs, 2012). This has raised valid concerns about ‘coverage bias’, which refers collectively to the biases associated with total coverage rate (i.e. proportion of the population covered by the sampling frame) and differences in the variables of interest between covered and non-covered populations (Blumberg and Luke, 2009; Lee et al., 2010). With regards to coverage rate, Australian telephone users are rapidly shifting towards mobile-only; the number of mobile-only adults (18+ years) increased by 33.2% in the 12 months prior to June 2014, representing 27% of the adult population (ACMA, 2014). In the United States, the coverage rate is even lower, with almost half of all adults serviced only by mobile phones (Blumberg and Luke, 2015). This poor coverage has, in part, initiated the transition of NOAA’s Marine Recreational Information Program away from its long-running Coastal Household Telephone Survey in favour of postal surveys, which are thought to be less subject to coverage bias due to higher response rates (NRC, 2006; Andrews et al., 2014; NOAA Fisheries, 2015b).

An important consideration in coverage bias is that coverage rates differ among socio-demographic groups, giving rise to the distinct traits of covered and non-covered populations (Blumberg and Luke, 2007; Link et al., 2007; Blumberg and Luke, 2009; Shebl et al., 2009; Hu et al., 2011; Busse and Fuchs, 2012). Age is one indicator strongly associated with telephone services, with younger people more likely to be mobile-only. As at June 2014, 51% of Australians aged 25 – 34 years lived in a household without a landline, compared with just 16% of people aged 55-64 years and 7% of people aged 65+ years (ACMA, 2014). Moreover, there is evidence from the state of South Australia that telephone listing is less common in urban areas (Dal Grande and Taylor, 2010). Likewise, mobile-only Europeans are more likely to be young, high earning city dwellers, although coverage biases appear to differ somewhat among countries (Busse and Fuchs, 2012; Mohorko et al., 2013). In the United States, low-income adults are more likely than higher-income adults to be mobile-only (Hu et al., 2011; Blumberg and Luke, 2015), whilst in California specifically, the mobile-only population disproportionately comprises young, single males relative to the landline population (Lee et al., 2010). Evidently, raw samples collected in telephone surveys will be inherently biased towards certain population sectors and their characteristics. Adopting a dual-frame approach (i.e. incorporating both landline and mobile phone listings) is one mechanism to potentially reduce these biases, but its costs and logistics, such as accounting for households that have both landline and mobile phones, have to date made the approach difficult

to implement (Link, 2007; Georgeson et al., 2015). Moreover, mobile phone surveys may have lower response rates, possibly due to call screening, and participants are more likely to be distracted during interview (Hu et al., 2011). It is necessary, therefore, that the biases associated with landline telephone surveys are appropriately recognised and adjusted during data analysis.

As applied in Australia, telephone surveys of recreational fishing typically employ a two phase process, combining estimates of fishing participation rates (phase 1) with quantitative catch data of fishers recruited into the survey (phase 2). Phase 1 sampling is stratified regionally, and households listed in a public directory are telephoned at random and, if eligible (i.e. a household intending to fish during the survey period), recruited into the survey. The operation of phase 2 has seen amendments since the method's inception in New Zealand in the early 1990s (Hartill et al., 2012). Today it involves a telephone-diary method where trained interviewers telephone the recruited fishers regularly to record data. Based on an earlier survey in the Northern Territory, this approach was refined for Australia's first nationwide survey of recreational fishing in 2000-2001 (Lyle et al., 2002). Its major benefits come as a result of frequent interviewer contact, such as improved data precision, lowered recall bias, and higher participant retention rates.

After a telephone survey's completion, data from phases 1 (participation rate) and 2 (fishing activity) are expanded to make population-wide estimates of fishing catch and effort using peer-reviewed statistical techniques (Lumley, 2004; Lyle et al., 2010; Lumley, 2014). This expansion is based on known demographic benchmarks (e.g. national censuses), whereby a weighting is applied to each fisher or fishing household according their demography (age, gender and residential region). Implicit in the validity of the expansion process is that coverage bias is corrected. It is assumed that, within their demographic group, households with a listed phone number (listed fishers) are representative of all households in the population, including those without a listed phone number (unlisted fishers), with regards to the variables of interest, namely recreational fishing participation rate and fishing activity. Testing for a difference in these variables between listed and unlisted fishers is important for ensuring the validity of offsite recreational fishing surveys (Georgeson et al., 2015).

The validity of the assumption about fishing activity was investigated in two onsite (boat ramp) surveys in Australia wherein the fishing activities of listed and unlisted fishers were compared. In the state of Victoria, Ryan et al. (2009) found no difference in the catch rate of snapper (*Pagrus auratus*) among listed and unlisted licenced fishers. Similarly, in Queensland, Taylor et al. (2012) found no difference in recalled fishing avidity

(number of annual fishing trips) between listed and unlisted fishers. These studies did not test the assumption that fishing participation rate was similar among listed and unlisted households, possibly because they sampled at boat ramps which would not provide adequate access to non-fishers. Whilst these studies provide preliminary support for the assumption that fishing activity is similar among listed and unlisted fishers, these results are limited because they focused only on a single species or population sector (i.e. boat-based fishers), and did not compare within demographic groups.

Recreational fisheries in Queensland, Australia have for several years been monitored through telephone surveys that use landline telephone directories as a sampling frame (Henry and Lyle, 2003; McInnes, 2006, 2008; Taylor et al., 2012; Webley et al., 2015). The aim of this study was to test the hypothesis that, within demographic groups, phone listing status has no effect on fishing activity, i.e. that there is no coverage bias. We tested coverage bias by comparing, within demographic groups, the fishing activities of listed and unlisted fishers interviewed at tackle stores across the state of Queensland. Our primary measure of fishing activity was stated (recalled) fishing avidity, in addition to the platform use (boat/kayak or shore) and target species of each fisher's most recent fishing trip.

2. Materials and methods

2.1 Power analysis

A power analysis was performed using R statistical language (R Core Team, 2014) to estimate a target sample size sufficient for detecting a relevant difference in platform use (an indicator of fishing activity) between listed and unlisted fishers. Two datasets representing populations of listed and unlisted fishers were constructed using binomial distributions to represent fishing platform use (i.e. boat/kayak or shore) and the demographics (age and residential region) calculated in Queensland's 2010 Statewide Recreational Fishing Survey (Taylor et al., 2012). Differences of 5%, 10% and 15% in the fishing activity between listed and unlisted fishers were created by adjusting the platform use of the unlisted population. A sample of predetermined size was randomly selected from each population and analysed using a binomial generalized linear model with platform use as the response variable, and phone listing, age group, and residential region as explanatory variables. The entire process was repeated 500 times with a range of predetermined sample sizes, with the proportion of significant results used to indicate experimental power (1- β). This power analysis indicated that a sample size of approximately 2500

would have sufficient power (>80%) to detect a 10% difference in platform use between listed and unlisted fishers and was chosen as the target sample size for the survey.

2.2 Data collection

This survey ran from 1st November 2013 to 31st October 2014, concurrent with Queensland's 2013-2014 Statewide Recreational Fishing Survey (Webley et al., 2015). Recreational fishers were interviewed by trained interviewers at 34 tackle stores across 12 residential regions of Queensland, Australia (Figure 1). Tackle stores were chosen as the survey locations because they are recognised as common aggregation points for fishers of various behaviours and experience (Griffiths et al., 2013; Zischke and Griffiths, 2014), allowing for efficient sampling across demographic sectors at the one physical site. To account for potential differences in fishers between types of tackle stores, three store types were included in the survey: eight stores were independently owned and operated, nine were franchises, and 17 were part of large retail chains. Within these three store types, individual stores were selected based on ease of access, number of potential fishers, and geographic region so as to get a wide spatial coverage of Queensland. Each store was surveyed at least once every two months and, to capture varying degrees of customer flow, each store was assigned four weekend surveys (high flow) and two weekday surveys (low flow). Logistical difficulties meant that some stores were surveyed more or less frequently. Interviewers were stationed outside of their assigned store's entrance so as to avoid interfering with the store's business. Data were recorded either on paper datasheets or via purpose-made electronic forms. Surveys lasted three hours, usually between the hours of 0900-1200 or 1300-1600, with morning or afternoon selected randomly. Twelve surveys were terminated early, usually due to failure of the electronic forms (when the interviewer did not have paper datasheets), the tackle store closing early or poor weather.

Interviewers attempted to approach all tackle store customers that exited the store (except when already underway with an interview). For groups of customers, the interviewer randomly selected one customer to approach initially, but if the group did not fish together on their most recent trip then all willing fishers were interviewed, including those of the same household. Upon approach, the interviewer briefly described the survey and asked the customer if they had fished recreationally in Queensland in the previous 12 months. If they had, they were deemed eligible for the survey and the interviewer proceeded with a short questionnaire (usually less than 2 minutes). Customers that had not fished in Queensland in the previous 12 months were recorded as ineligible, and those that declined to be interviewed were recorded as refusals.

Eligible fishers were asked a variety of demographic and fishing-related questions. Demographic data collected included gender, age, and residential postcode or suburb (classified into one of 15 residential regions; see Figure 1). They were also asked whether their place of residence had a telephone number listed in the Telstra White Pages (the directory used in Australia's recreational fishing surveys). Data collected about fishing activity were the fishers' stated (recalled) avidity over the previous 12 months, the platform used (boat/kayak or shore) and the species targeted, if any, on their most recent fishing trip. Platform and target species were selected as indicators of fishing activity because they were considered less prone to recall bias than other quantitative variables, such as the number of fish caught on the last trip (see Lyle, 1999).

2.3 Data analysis

Data were analysed using R statistical language (R Core Team, 2014). The effect of phone listing status on fishing activity was investigated by separately comparing avidity, platform use and target species between fishers with a telephone number listed in the White Pages (listed fishers) and fishers without a listed telephone number (unlisted fishers). The variables included in each analysis, and their categorical levels, are described in Table 1. A total of 190 interviews were incomplete for one or more questions, therefore some analyses excluded a number of fishers. Fishers who were unsure whether their place of residence had a listed telephone number, or did not provide a response to this question, were excluded from all analyses. Likewise, we excluded all fishers whose place of residence was outside of Queensland. A priori, we intended to include gender as a variable, however we omitted it from analyses because of the relatively low number of females surveyed leading to a highly unbalanced sample and the implications that has on interpreting the results (females $n = 212$; males $n = 2812$).

To investigate avidity, cumulative link models (ordinal logistic regression) were constructed using the Ordinal package in R (Christensen, 2015), with avidity as the response variable (Table 1). Explanatory variables were phone listing, age group and residential region and significance was tested using one-way and multi-way chi-squared ANOVAs, with significance accepted at $p < 0.05$. Platform use was investigated via binomial generalized linear models with platform as the binary response variable (boat/kayak and shore), and phone listing, age group, residential region, tackle store type and avidity as categorical explanatory variables, including some interactions (Table 1). Models were tested using chi-squared ANOVAs. Significant effects were interrogated via a post-hoc Tukey test using the Multcomp package (Hothorn et al., 2008). Models excluded fishers that fished from both a boat/kayak and the shore on the same trip, or were unsure of their platform use.

Target species were classified twice: into a category according to their habitat type, and into a group with similar species (Table 1). Fishers without a specific target species were categorised and grouped as ‘Anything’. Target species category and group (response variables) were analysed for an effect of phone listing, age group, residential region and tackle store type (explanatory variables) via Analyses of Similarity (ANOSIM) constructed from Bray-Curtis dissimilarity indices, as calculated using the Vegan package (Oksanen et al., 2013). These indices were also used to construct non-metric multi-dimensional scaling (nMDS) plots to examine clustering by phone listing of target species category and group.

3. Results

3.1 Eligibility, demographics and phone listing status

A total of 6314 people were intercepted at tackle stores during the survey period, of whom 1738 (27.5%) refused to be interviewed and 1514 (24.0%) had not fished in Queensland in the previous 12 months and were deemed ineligible. Eligibility varied by tackle store type, with 72.7% of customers at independent stores being eligible, compared to 60.7% and 39.6% at franchise and chain stores, respectively. Of the 3062 eligible fishers (48.5%), all but seven provided a response about their household’s phone listing status (yes, no, unsure). Of these, 1378 (45.1%) lived in a household that had a telephone number listed in the Telstra White Pages (Table 2). Percent phone listing increased markedly with age, with the exception of fishers that were less than 15 years old, presumably because they lived in households with older people (Table 2).

3.2 Fishing activity

3.2.1 Avidity

Few fishers (8.5%) reported their avidity to be 30-39 trips/year, however the remaining avidity categories were comparable in their numbers of fishers (Table 2). Our main hypothesis of interest, that avidity does not differ by phone listing status within demographic groups, was tested by the three-way interaction between phone listing, age group and residential region on avidity, because age group and residential region are used to expand data collected in telephone surveys to the population level (gender is also used but was necessarily excluded from analyses due to highly unbalanced sample sizes). We found no significant interaction between these variables ($p > 0.05$) (Table 3), providing support for our hypothesis. Similarly, there were no significant two-way interactions of phone listing with age group or residential region ($p > 0.05$) (Table 3). Avidity did, however,

differ significantly by phone listing status on its own ($p < 0.01$) (Table 3). Although percent phone listing was roughly equal among avidity groups, only 36.0% of fishers whose avidity was 40+ trips/year were listed (Table 2). This result is likely due to this avidity group being dominated by fishers aged 15-29 years and 30-44 years (Figure 2), who had the lowest listing percentage (Table 2), even though the effect of age group on avidity was not significant ($p > 0.05$) (Table 3).

3.2.2 Platform use

Of the eligible fishers, 3029 provided details of the platform used on their most recent fishing trip. Boats (including kayaks and canoes) were used by 62.4% of fishers, while 29.7% of fishers reported fishing from the shore and only 7.7% fished from both the shore and a boat on the same trip. 4 fishers (0.1%) were unsure about the platform used on their most recent trip. Like avidity, the analysis of platform use most relevant to our hypothesis is the effect of the interaction between phone listing, age group, and residential region, which was not significant ($p > 0.05$) (Table 4). This three-way interaction was therefore removed, to provide a more powerful heuristic examination of the higher order interactions. There were no significant two-way interactions between phone listing and age group or phone listing and residential region ($p > 0.05$) (Table 4).

Platform use percentage was similar between listed and unlisted fishers (Figure 3), but their difference was significant ($p < 0.05$) (Table 4). However, this may be due to the confounding effect of different age frequency distributions (and potentially boat ownership and use) within the samples of listed and unlisted fishers. This highlights the importance of examining the correct interaction (as presented above) when testing our hypothesis. Platform use also differed significantly by age group ($p < 0.001$) (Table 4). Post-hoc analysis revealed that platform use by fishers aged 60+ years was significantly different from fishers aged less than 15 years, 15-29 years, and 30-44 years. Of fishers aged 60+ years, 69.7% fished from a boat, whilst on average only 52.3% of fishers aged less than 45 years reported fishing from a boat. Likewise, residential region had a significant effect on platform use ($p < 0.001$) (Table 4), which post-hoc analysis found to be due to the Wide Bay-Burnett region being significantly different from eight other residential regions, namely Brisbane, Darling Downs, Fitzroy Hinterland, Gold Coast, Mackay Whitsunday, Rockhampton, Sunshine Coast and Townsville. Platform use also differed significantly by tackle store type ($p < 0.05$), specifically between independent stores and franchise stores, but there was no interaction with phone listing status ($p > 0.05$) (Table 4).

There was no significant interaction between avidity and phone listing affecting platform use ($p > 0.05$), and there was no significant three-way interaction between phone listing, age group and avidity ($p > 0.05$) (Table 4). Avidity on its own had a significant effect on platform use ($p < 0.001$). Post-hoc comparisons revealed that low avid fishers (less than 10 trips/year) were significantly different to all other avidity groups. Of the low avid fishers, 53.1% fished from a boat and 39.2% fished from the shore, whereas, on average, 65.6% of the fishers in all other avidity groups fished from a boat and 25.6% fished from the shore.

3.2.3 Target species

Of all fishers interviewed, 40.6% had no specific target on their most recent fishing trip (i.e. they were targeting ‘Anything’). Among fishers that reported a specific target species, estuarine species were the most popular category, targeted by 34.3% and 30.4% of listed and unlisted fishers, respectively (Figure 4A). Flathead was the most popular target species group (after ‘Anything’ and ‘Other’), targeted by 7.2% of listed fishers and 7.0% of unlisted fishers (Figure 4B). Non-metric multi-dimensional scaling (nMDS) showed substantial overlap between listed and unlisted fishers’ target species categories (Figure 5A) and groups (Figure 5B). Indeed, ANOSIM detected weak separation among categories and groups (Table 5). Although significant differences were found for both target species category and group ($p < 0.05$) (Table 5), the small R values indicate that these differences are irrelevant and likely due to the high power of the large sample size (Clarke, 1993; Coe, 2002). Since most fishers were targeting ‘Anything’, additional analyses were performed excluding this category and group. A significant difference was still detected for target species group ($p < 0.05$), but no significance was detected for target species category ($p > 0.05$), likely because category had much fewer levels than group (4 cf. 19).

Small effect sizes were found for age group and tackle store type, indicating that compositions of target species category and group are not affected by these variables (even where significant results were detected) (Table 5). Largest effect sizes were found for residential region, particularly for target species group, which is to be expected given the diversity of geographical regions included in this survey (Table 5). After the removal of ‘Anything’ from the analyses, the effect size of target species category decreased from $R = 0.098$ to $R = 0.090$ while that of target species group increased from $R = 0.141$ to $R = 0.188$.

4. Discussion

4.1 Coverage bias in telephone surveys of recreational fishing

Offsite methods are being increasingly used to monitor large and disparate recreational fisheries (Hartill et al., 2012), and a number of recent surveys have utilised public telephone directories to sample fishers in the population, including in Denmark (Sparrevohn and Storr-Paulsen, 2012), France (Herfaut et al., 2013; Rocklin et al., 2014), the United States (NOAA Fisheries, 2015a), and Australia (Henry and Lyle, 2003; Lyle et al., 2005; Jones, 2009; Lyle et al., 2009; Taylor et al., 2012; Lyle et al., 2014; Webley et al., 2015). However, the growing proportion of mobile-only households in most countries has raised valid concerns about the coverage bias associated with this approach (Blumberg and Luke, 2009; Georgeson et al., 2015). In the United States, the decline in coverage rates has instigated the planned abandonment of the Coastal Household Telephone Survey, which has monitored fishing effort on the Atlantic coast and in the Gulf of Mexico since 1979, to be replaced by a postal survey by 2018 (Andrews et al., 2014; NOAA Fisheries, 2015b). Of particular concern, studies have shown that mobile-only populations are distinct for many socio-demographic factors (Shebl et al., 2009; Hu et al., 2011; Busse and Fuchs, 2012; Mohorko et al., 2013; ACMA, 2014; Blumberg and Luke, 2015). In turn, people included in telephone surveys may differ in important ways from the population to which the survey's results are generalised. A potential solution to this problem is to incorporate mobile listings into a dual-frame methodology that covers both mobile and landline listings (Georgeson et al., 2015). However, mobile listings are often unavailable, and even when accessible, the costs and logistics associated with their sampling may be prohibitive (Link et al., 2007). If surveys are to continue to use landline listings only, it is important that discipline-specific investigations of coverage bias are undertaken.

Coverage bias in telephone surveys of recreational fishing can manifest in participation rates or in fishing activity, or both. This study did not investigate bias in participation rates because tackle stores would not provide appropriate access to non-fishers. We investigated fishing activity, and found no evidence for coverage bias due to phone listing status within demographic groups. Specifically, there was no effect on avidity or platform use by the interaction between the variables phone listing, age group, and residential region. These demographic variables are used to expand data in telephone surveys to the population level (gender was not included in our analyses due to the low proportion of female fishers encountered), and a lack of significance suggests that fishing activity is not affected by phone listing status within these demographic groups. These findings corroborate the results of Ryan et al. (2009) who found snapper catch was similar among listed and unlisted fishers, and Taylor et al. (2012) who found no effect of phone listing status on stated (recalled) avidity.

We found that phone listing proportion increased with age, consistent with previous findings in Australia (Dal Grande and Taylor, 2010; ACMA, 2014), and that older fishers were less avid than younger fishers. This suggests that raw data from telephone surveys of recreational fishing are likely to be demographically skewed towards older fishers, in turn over-representing their behaviours, such as lower avidity. However, the lack of an interaction of phone listing, region and age group acting on avidity suggests that avidity is similar between listed and unlisted fishers within regions and age groups. Therefore, our results indicate that the avidity data of over- and under-represented groups in a telephone survey's raw sample will be corrected through demographic data expansion, provided that coverage bias is similarly benign towards fishing participation rates.

Ordination of target species categories and groups by phone listing status had small effect sizes (i.e. small R values in all analyses), suggesting that target species compositions are similar among listed and unlisted fishers. However, p values of these analyses were significant, but this is likely due to the high power of the large sample size (Clarke, 1993; Coe, 2002). For all intents and purposes, the high degree of overlap in the non-metric multi-dimensional scaling (nMDS) plots and the small R values support our conclusions that there was no meaningful difference between listed and unlisted fishers' target species. Likewise, small effect sizes were detected for age group and tackle store type, suggesting that our conclusions are not affected by these variables. We found a relatively large effect size of residential region on both target species category and group, which was expected since Queensland is a large, geographically diverse area. Given the lack of an effect of phone listing, differences among regions are unlikely to bias conclusions about target species in telephone surveys that use telephone directory listings as sampling frames.

4.2 Biases and representativeness of this survey

Tackle stores were chosen as the sampling locations because interviewers could encounter large numbers of fishers of various demographic and fishing-related factors (Griffiths et al., 2010; Zischke and Griffiths, 2014). However, recreational fishers with different behaviours and demography may not be encountered at tackle stores in the same ratios as they occur in the wider population. For example, high avid fishers may visit tackle stores disproportionately more often than low avid fishers. If this is the case, the sample obtained from tackle stores will be skewed towards more avid fishers for every demographic group. Therefore, the data cannot be expanded to the population level using demographic benchmarks. Recognising this, we made no attempt to expand the data from this survey to the level of the population. Nonetheless, comparing within demographic groups is justified because it is unlikely that, within demographic groups, phone listing status would affect the probability

of being encountered at a tackle store. Therefore, it is unlikely that a disproportionate sample of certain fisher types (e.g. more avid fishers) would affect the conclusions drawn when comparing listed and unlisted fishers within demographic and avidity groups. If our results were affected, it implies that by chance the bias worked in such a way to demonstrate no effect of listing status within demographic groups. This is very unlikely given that there are more ways to be different than there are to be the same.

Queensland is a geographically diverse state and recreational fishing varies regionally and throughout the year. Therefore, we surveyed across most Queensland residential regions to capture regional differences, and across three tackle store types (chain, franchise, independent) to capture differences in the types of fishers among these. The survey also spanned 12 months to ensure that temporal changes were included in the data. Previous research at south-east Queensland boat ramps found that 98.9% of fishers visited a tackle store in the previous 12 months, with 83% visiting a store at least once per month (Zischke and Griffiths, 2014). This suggests that our survey probably encountered most types of fishers. We acknowledge that by requiring the recall of fishing data our survey may be subject to bias, because previous research has shown that after two months fishers may significantly over-estimate quantitative catch and effort data (Lyle, 1999). To reduce the effect of this on our results, our survey did not collect catch or effort data, focussing rather on stated avidity, in addition to the platform used and species targeted on each fisher's most recent trip. A recent study found that fishing method and target species were similarly reported between a 12 month recall survey at tackle stores and an onsite access point survey (Zischke and Griffiths, 2014), which suggests that recall bias is unlikely to be an issue for the platform and target species data collected in our survey. Recall bias may have affected stated avidity, but we expect the bias to similarly affect listed and unlisted fishers (Taylor et al. 2012), meaning that it can be treated as a relative, rather than absolute, measure of fishing activity.

This research did not test for differences in recreational fishing participation rates between listed and unlisted fishers. Currently, when relying on expanded estimates from surveys using telephone directories as a sampling frame, this assumption is implied i.e. that a person from a household with a listed telephone is just as likely to be a fisher as a person from a household without a listed telephone. In this research, collecting participation rate data at tackle stores was inappropriate because it would be biased towards people that shop at tackle stores (i.e. fishers). Rather, such data should be collected in a manner that would provide a broader and more representative sample of both fishers and non-fishers of various demographic groups e.g. door-knocking across residential

meshblocks. This should be a focus of future studies investigating the assumptions associated with the expansion of data from telephone surveys of recreational fishing.

5.0 Conclusions

This research indicates that fishing activity does not differ by phone listing status among fishers of the same demographic groups within Queensland, Australia. Specifically, listed and unlisted fishers within age groups and residential regions did not differ in their fishing avidity (recalled trips over the previous year), nor in their platform use (boat/kayak fishing versus shore fishing) or target species (category or group) for their most recent fishing trip. The expansion of data from offsite recreational fishing surveys that sample from telephone directories assumes that coverage bias does not affect fishing participation rates or fishing activity. The results of this study support the latter assumption for telephone surveys of recreational fishing in Queensland. However, coverage bias could affect fishing participation rates and this should be investigated as a priority when attempting to justify expanded estimates from offsite telephone surveys. If both fishing activity and participation rates are similar among listed and unlisted fishers within demographic groups, current data expansion methods are unlikely to be affected by coverage bias. However, as the mobile-only population continues to increase, particularly among younger people, it is important that coverage biases continue to be investigated into the future. It is likely that the socio-demographic disparity between covered and non-covered populations will continue to increase over time, necessitating that alternative sampling frames that sufficiently cover the recreational fishing population are examined. Where telephone surveys continue to be the preferred method for sampling recreational fisheries, dual-frame approaches that cover both landline and mobile listings are likely to be required.

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Figures

Figure 1 The 15 residential regions of Queensland, Australia. Tackle stores were surveyed in 12 regions. The numbers of tackle stores from each region were: Brisbane (8), Darling Downs (2), Far North (3), Fitzroy Hinterland (1), Gladstone (2), Gold Coast (2), Mackay Whitsunday (3), Northern Hinterland (1), Rockhampton (2), Sunshine Coast (4), Townsville (2), Wide Bay-Burnett (4).

Figure 2 Percent of fishers by age group in each avidity category (trips/year). Sample sizes are displayed above columns.

Figure 3 Platform use by listed and unlisted fishers on their most recent fishing trip. 'Boat/Kayak' includes any kind of boat or canoe-like vessel. 'Shore' comprises all fishing other than from a boat. 'Boat/Kayak & Shore' represents fishers that fished from both a boat and the shore on the same trip. Sample sizes are displayed above columns.

Figure 4 Species targeted by fishers on their most recent fishing trip. (A) Percent of species categories targeted by listed and unlisted fishers, and (B) Percent of species groups targeted by listed and unlisted fishers. 'Anything' represents fishers that had no specific target species on their most recent trip. 'Other' represents fishers who targeted species other than those categories and groups reported. Sample sizes are displayed above columns.

Figure 5 Non-metric multi-dimensional scaling (nMDS) plots, constructed from Bray-Curtis dissimilarity indices, of the species targeted by listed and unlisted fishers on their most recent fishing trip. (A) Target species categories, and (B) target species groups. $n = 2898$.

Table 1 Variables and their categorical levels used in cumulative link models (CLM), generalized linear models (GLM) and Analyses of Similarity (ANOSIM). The response variables avidity, platform and target species (category and group) were used as indicators of fishing activity.

Analysis	Variable	No. levels	Levels
CLM response	Fishing avidity (trips/year)	5	< 10, 10-19, 20-29, 30-39, 40+
GLM response	Platform	2	Boat/Kayak, Shore
ANOSIM response	Target species category	5	Anything, Estuary, Freshwater, Offshore, Other
	Target species group	20	Anything, Australian Bass, Barramundi, Bottom fish, Bream, Coral trout, Crab, Estuarine fish, Flathead, Golden perch, Golden snapper, Javelin, Mackerel, Mangrove jack, Snapper, Surface fish, Tailor, Threadfin, Whiting, Other
GLM, CLM and ANOSIM explanatory	Phone listing status	2	Listed, Unlisted
	Age group (years)	5	< 15, 15-29, 30-44, 45-59, 60+
	Residential region	15	Brisbane, CW/NW/SW, Darling Downs, Far North, Fitzroy Hinterland, Gladstone, Gold Coast, Mackay Hinterland, Mackay-Whitsunday, Moreton, Northern Hinterland, Rockhampton, Sunshine Coast, Townsville, Wide Bay-Burnett

GLM and ANOSIM explanatory	Fishing avidity (trips/year)	5	< 10, 10-19, 20-29, 30-39, 40+
	Tackle store type	3	Independent, Chain, Franchise

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Table 2 Percentage of fishers with a listed phone number in total and by age group and avidity. Note that variables do not sum to the total of 3062 fishers interviewed because some interviews were incomplete for one or more questions.

Variable	Levels	<i>n</i> total	<i>n</i> listed	% listed
Phone Listing		3055	1378	45.1
Age group	<15 years	40	21	52.5
	15-29 years	668	172	25.7
	30-44 years	1078	437	40.5
	45-59 years	909	520	57.2
	60+ years	358	226	63.1
Avidity	<10 trips/year	776	357	46.0
	10-19 trips/year	688	349	50.7
	20-29 trips/year	613	301	49.1
	30-39 trips/year	259	111	42.9
	40+ trips/year	722	260	36.0

575 **Table 3** Results of cumulative link models of avidity (ordinal response variable) by phone listing, age group,
 576 gender and residential region (explanatory variables). * indicates a significant result.

Explanatory variables	df	<i>p</i> value
Phone listing	1	0.003*
Age group	4	0.212
Residential region	14	1.987 ^{e-06} *
Phone listing × Age group	4	0.111
Phone listing × Residential region	14	0.252
Phone listing × Age group × Residential region	44	0.942

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Table 4 Results of generalized linear models of platform use (binary response variable: boat/kayak and shore) by phone listing, age group, gender, residential region, tackle store type and avidity (explanatory variables). * indicates a significant result.

Explanatory variables	df	⁵⁸¹ <i>p</i> value
Phone listing	1	0.028 *
Age group	4	4.088 ^{e-04} *
Residential region	14	2.045 ^{e-09} *
Tackle store type	2	0.003 *
Avidity	4	7.872 ^{e-10} *
Phone listing × Age group	4	0.145
Phone listing × Residential region	14	0.174
Phone listing × Tackle store type	2	0.433
Phone listing × Avidity	4	0.444
Phone listing × Age group × Avidity	15	0.878
Phone listing × Age group × Residential region	41	0.056

Table 5 Results of ANOSIM of target species category and target species group (response variables) by phone listing, age group, gender, residential region and tackle store type (explanatory variables) using Bray-Curtis dissimilarity indices. * indicates a significant result.

Explanatory variable	Species Category		Species Group	
	R statistic	<i>p</i> value	R statistic	<i>p</i> value
Phone listing	0.022	0.015*	0.035	0.002*
Age group	0.024	0.002*	0.033	0.002*
Residential region	0.098	0.001*	0.141	0.001*
Tackle store type	0.010	0.127	0.023	0.029*

Figure 1 Map

Figure 2

Figure 3

Figure 4A

Figure 4B

Figure 5A

Figure 5B