# An investigative analysis of Queensland's statewide recreational fishing surveys

## Identifying bias in self-reported catch and effort data

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This publication has been compiled by Ashley Lawson of Fisheries Queensland, Department of Agriculture and Fisheries.

# Summary

Accurate recreational fishing information is essential to sustainable and effective management strategies. Several statewide recreational fishing surveys have been conducted in Queensland, yet their results have varied widely depending on whether the 'RFish' diary program or the interview-based 'NRIFS' approach was employed. The validity of RFish survey data has since been called into question, with concerns of possible nonresponse and recall biases. Estimates of catch and effort were compared between the two survey methodologies to search for evidence of bias in the RFish data and to explore the possibility of adjusting for any identified biases. Within each RFish survey, the high rate of dropout, gradual sample loss of particular demographics and steady decline in fisher avidity strongly indicates the presence of an attrition-derived avidity bias. The RFish surveys also exhibited an overall inflation of fisher avidity and catch success in addition to varying degrees of catch or effort overestimation for 11 of the 12 investigated taxa. Previous fisheries research would suggest that the likeliest explanation for these results is a recall bias arising from the RFish surveys' considerably longer recall period. However, the true source of these errors is ultimately unknown and other possible explanations include prestige bias, deliberate misreporting, terminal digit preference, species misidentification and nonresponse bias. Regardless of whether the biases in the RFish data can be correctly identified, the significant variation in reporting error between taxa is largely unpredictable and may preclude any reliable adjustments. Re-expanding the raw RFish data to the statewide level using current statistical techniques will prove fruitless unless such adjustments can be made. Although adjustment may not be a viable option, the RFish data may be utilised to assess trends in relative rather than absolute terms. If other options are exhausted, the omission of RFish survey results may be the only way to ensure an accurate time series of statewide catch and effort in Queensland's recreational fisheries.

# 1 Introduction

As the economic, ecological and social impacts of recreational fishers have become increasingly important in fisheries management, estimates of recreational catch and effort and the means by which they are obtained are under growing scrutiny (Coleman *et al.* 2004; McCluskey & Lewison 2008; Ihde *et al.* 2011; Hartill *et al.* 2012). In Australia, the need for reliable recreational fishing data in sustainable fisheries management has driven the development and application of survey techniques over the last 30 years (Hartill *et al.* 2012). The logistical issues of monitoring large areas (states and countries) on annual timeframes mean that many of these survey designs are based on off-site methods (Pollock *et al.* 1994). These include the use of telephone surveys based on directory listings (Henry and Lyle 2003; McInnes 2008; Taylor *et al.* 2012), telephone surveys of recreational fishing licence holders (Lyle 1999; Venema *et al.* 2003; Lyle *et al.* 2005) and mail surveys (Melville-Smith & Anderton 2000) to estimate fishing participation at the population level and recruit fishers into diary programs for more detailed catch and effort information.

The four statewide telephone-diary surveys and subsequent diary programs conducted by Fisheries Queensland between 1997 and 2005 (McInnes 2008), as part of the Recreational Fisheries Information System (RFish) program, were based on the multi-stage sampling method previously conducted in New Zealand (Bradford 1998). These surveys stratified the population into 15 statistical areas, randomly selected people from each area using a telephone directory (Telstra White Pages), determined if they were recreational fishers and then recruited them into a twelve-month diary program. Volunteers were asked to complete a diary of their fishing activities during the following year and submit the information before the end of each quarter. Each survey participant was weighted according to demographic group and the weights were then used to upscale individual catch and effort data to the total recreational fishing population in Queensland (McInnes 2008).

In addition to the RFish surveys, Queensland's recreational catch and effort has also been estimated as part of the National Recreational and Indigenous Fishing Survey (NRIFS) (Henry & Lyle 2003). The NRIFS methodology has since been adopted for statewide recreational surveys in South Australia (Jones 2009), Tasmania (Lyle *et al.* 2009a), the Northern Territory (West *et al.* 2012) and Queensland (Taylor *et al.* 2012; Webley *et al.* 2015). Unlike the RFish surveys, these NRIFS surveys allow direct comparison with other states and are thought to be more accurate due to high rates of participant retention and a survey design tailored to mitigating known sources of bias (Hartill *et al.* 2012). The NRIFS survey methodology contrasts with the quarterly diary approach employed by RFish in two fundamental ways. Firstly, the diary acts as a memory jogger (e.g. includes pictures of common fish species) rather than a conventional logbook. Secondly, data collection is instead facilitated via frequent telephone interviews. With each phone call, respondents are asked when they next intend to fish and are typically called within a few days of each trip. Frequent contact and the use of a memory jogger are thought to reduce recall bias (Lyle 1999; Hartill *et al.* 2012).

This approach also minimizes the burden on the respondents, builds rapport between the interviewer and the fisher and allows the interviewer to interrogate inconsistencies and unclear information, leading to higher participant retention, improved data quality and reduced potential for cognitive and selection biases (Henry & Lyle 2003; Hartill *et al.* 2012).

When estimates of recreational fishing data vary widely among survey methods, as they do between the RFish and NRIFS surveys (appendix a), the validity of the estimates is called into question and indicates that their utility to fisheries managers may be limited (Tarrant *et al.* 1993). These concerns are reinforced by the potential for a recall bias in the RFish estimates, resulting from respondents self-reporting fishing activity up to 3 months prior (McInnes 2008; Hartill & Edwards 2015). This type of cognitive bias arises because of a respondent's inaccurate recollection of events and includes telescoping (attributing a fishing trip to the wrong time period), omission (failing to remember a past event) and other errors in detail (Connelly *et al.* 2000; Osborn & Matlock 2010). Recall bias is recognised as a major threat to the credibility of any study using self-reported information on past events (Hiett & Worral 1977; Chase & Harada 1984; Hassan 2005). Several studies on recreational fishing surveys have demonstrated that recall bias tends to cause a significant overestimation of catch and effort (Chu *et al.* 1992; Tarrant *et al.* 1993; Lyle 1999; Roach *et al.* 1999; Connelly *et al.* 2000; Ellender *et al.* 2010; Connelly & Brown 2011; McCormick *et al.* 2015). Studies have also found that the accuracy of off-site survey results decreases as length of recall period increases (Fisher *et al.* 1991; Connelly & Brown 1995). Specifically, Brown (1977) recommends that the recall period for reporting fishing trips should not exceed 2 months if recall bias is to be mitigated. Other forms of cognitive bias that may impact self-reported fishing data include prestige bias, deliberate misreporting, terminal digit preference and species misidentification (Chu *et al.* 1992; Tarrant & Manfredo 1993; Pollock *et al.* 1994; Vaske *et al.* 1996; Sullivan 2003; Page *et al.* 2012; McCormick *et al.* 2015).

Concerns about the validity of the RFish data are further reinforced by the large dropout rates, with 25-50% of participants failing to complete the year-long surveys compared to a typical dropout rate of 5-10% in NRIFS surveys (Henry & Lyle 2003; McInnes 2008; Taylor *et al.* 2012; Webley *et al.* 2015). The failure of an individual to respond to a survey (nonresponse bias), including the gradual dropout of survey respondents (attrition bias or respondent fatigue), describes a type of selection bias where the survey sample is not representative of the population being analysed (Tarrant *et al.* 1993; Pollock *et al.* 1994). Past research, including the 2000 NRIFS survey, has shown that nonrespondents are less likely to be avid or experienced fishers than respondents, and nonresponse follow-up surveys are routinely conducted to adjust data for this bias (Lowry 1978; Harris & Bergersen 1985; Absher & Collins 1987; Fisher 1996; Connelly *et al.* 2000; Henry & Lyle 2003). The overrepresentation of avid participants in a sample is specifically referred to as avidity bias and may lead to overestimation of recreational catch and effort (Thomson 1991; Tarrant *et al.* 1993; Connelly *et al.* 2000). The overrepresentation of experienced fishers, referred to here as skill bias, may lead to artificially high catch rates and, subsequently, the overestimation of catch.

Uncertainty about the accuracy of the RFish survey results may lead to their underutilisation by fisheries managers, yet their exclusion would effectively halve Queensland's time series of statewide recreational catch and effort. Such a lack of historical data can make it difficult to evaluate stock status, the direction and magnitude of ecological trends and the efficacy of sustainable management strategies (Magurran *et al.* 2010), and may ultimately contribute to the well-known issue of 'shifting baselines' in fisheries management (Pauly 1995; Papworth *et al.* 2009). The aim of this study was to explore the utility of RFish survey data in fisheries management by 1) searching for evidence of cognitive or selection biases and 2) investigating the possibility of adjusting for any identified biases in a scientifically defensible manner.

# 2 Methods

## 2.1 Data

Raw data for this study were obtained from the 1999, 2002, and 2005 RFish and 2000, 2010, and 2013 NRIFS fishing surveys (Henry & Lyle 2003; McInnes 2008; Taylor *et al.* 2012; Webley *et al.* 2015). Due to a number of unknown data adjustments, the 1997 RFish survey data could not be directly compared with other RFish survey results and was not included in this analysis. Additionally, some data groupings were reorganized into broader categories due to differences in taxonomic nomenclature and the categorization of demographic characteristics between the surveys. For example, yellowfin bream (*Acanthopagrus australis*), pikey bream (*A. berda*) and black bream (*A. butcheri*) were grouped as 'black/pikey/yellowfin bream' because these species were not differentiated in the RFish surveys. Similarly, participant age and residential region were reclassified into three age groups (15 – 29; 30 – 59; and 60+ years) and nine residential regions (Brisbane, Moreton, Darling Downs, Central West/South West/North West, Fitzroy, Mackay, Northern, and Far North) (appendix b). Although broader categories provide less resolution, these adjustments allow direct comparison between all surveys.

Twelve taxa with large sample sizes were selected for this study, including Australian bass (*Macquaria novemaculeata*), barramundi (*Lates calcarifer*), blue swimmer crab (*Portunus pelagicus*), black/pikey/yellowfin bream (*Acanthopagrus* spp.), coral trout (family Serranidae), dart (*Trachinotus* spp.), flathead (*Platycephalus* spp.), mud crab (*Scylla* spp.), redthroat emperor (*Lethrinus miniatus*), snapper (*Pagrus auratus*), tailor (*Pomatomous saltatrix*) and trumpeter whiting (*Sillago maculata*).

Removal of outliers was generally avoided, with the exception of one individual who reportedly caught the exact same number of a particular species every day for two months at a rate at least four times greater than any other fisher. No other survey respondent reported such extreme or consistent catches.

## 2.2 Statistical analysis

The statewide estimates of catch and effort reported by the NRIFS surveys excluded all information pertaining to fishers who dropped out of the survey (dropouts). Subsequently, an attrition bias in an NRIFS survey would be in full effect at the start of the survey period rather than appear as a gradual effect across the year. This means that the NRIFS survey estimates can be used as a reference point where temporal patterns in fishing behaviour do not exhibit the gradual effects of attrition bias. In contrast, the RFish surveys were subject to high dropout rates and did not exclude dropout data. An attrition bias in the RFish surveys is likely to appear as a directional trend in catch or effort that coincides with increasing numbers of dropouts, and which cannot be explained by the baseline seasonal patterns observed in the NRIFS surveys. Ideally, the fishing behaviour of dropouts and non-dropouts in the RFish surveys would have been directly compared, but there was no available information that distinguished survey dropouts from participants who simply had not fished.

Catch rate was assessed in terms of catch per unit effort (CPUE) and catch success, following the two-part model recommended for count data with excess zeroes (Heilborn 1994). CPUE was measured in terms of catch per successful fisher day. Catch success was assessed as a binomial variable by dichotomising fisher days into successes (nonzero catch) and failures (zero catch). Due to significant differences in catch size, sample size and seasonality of individual taxa, CPUE was analysed separately for each of the twelve taxa. As a binomial variable, catch success largely avoided these issues and, in addition to providing a taxon-specific measure of catch rates, provided an overall measure of catch rate that was inclusive of all records.

CPUE often involves highly influential outliers, which can lead to overdispersion and difficulty in analysing observed catch rates (Terceiro 2003). A preliminary analysis indicated that models of monthly CPUE were heavily confounded by these extreme outliers, as well as low sample size and high seasonal variability. Using catch success as a response variable produced the most robust models of monthly catch rate. In the absence of an attrition bias, monthly RFish catch success should trend in a direction similar to baseline patterns observed in the NRIFS surveys. Catch rate is also an indirect measure of abundance (McCluskey & Lewison 2008). Therefore, the observation of lower catch rates in the NRIFS surveys could potentially be explained by depleted fish stocks. To determine if differences in catch rate are primarily due to survey methodology rather than a reduction in fish abundance, the three measures of catch rate were compared between the 1999 RFish, 2000 NRIFS, and 2002 RFish surveys. Except in the event of significant changes to the environment (e.g. cyclone Yasi, 2010-2011 Queensland floods, etc.) or fisheries management (e.g. new closures, bag limits, etc.), fish abundance and, by extension, catch rates should trend in a relatively consistent direction across consecutive years (Maunder *et al.* 2006). Operating under this assumption, catch rates reported in the 2000 NRIFS survey would be expected to be intermediary between 1999 and 2002 RFish catch rates in the absence of a cognitive or selection bias. To determine if there was a relationship between reporting accuracy and catch rate, the differences between 1999/2002 RFish and 2000 NRIFS estimates of CPUE were analysed in response to the mean CPUE of each taxon in the 2000 NRIFS survey.

Fishing effort, or fisher avidity, was measured as the number of days spent fishing (fisher days) per fisher. Measuring fishing effort in hours may have been more precise, but records of hours spent fishing were inconsistent and largely unworkable. Evidence for the presence of an avidity or recall bias in the RFish surveys would include clearly inflated estimates of fishing effort compared to NRIFS estimates. Specifically, unbiased estimates of fishing effort in the 2000 NRIFS survey should be intermediary between 1999 and 2002 RFish effort.

Terminal digit preference has been defined as responses favouring digits ending in 0 or 5 (Chase & Harada 1984), and was assessed as a binomial variable by dichotomising catch records into those ending in preferred digits and those that did not.

Logistic regression was employed to model the relationship between fisher demographics and monthly dropout. Fishing effort, catch success, CPUE and terminal digit preference were investigated in response to survey methodology and either month or year. CPUE and fishing effort were modelled using negative binomial and Poisson regression. Both Poisson and negative binomial distributions are particularly appropriate for describing count data such as catch and effort, although the negative binomial regression model confers the additional benefits of accommodating a solution to overdispersion and potentially functioning better for zero-inflated data (Heilbron 1994; Welsh *et al.* 1996; Power & Moser 1999; Barry & Welsh 2002; O'Neill & Faddy 2003; Terceiro 2003; Ver Hoef & Boveng 2007). Frequency distribution plots, dispersion statistics and log-likelihood ratio tests were inspected to evaluate the most appropriate distributional fit to the CPUE and effort data, and to determine if zero-truncation was necessary (Terceiro 2003; Zuur *et al.* 2009; Hilbe 2007). Catch success was modelled using logistic regression, as the probability of nil catch is typically assumed to follow a logistic distribution (Minami *et al.* 2007). Based on statistical methods in medical research (Thavarajah *et al.* 2003; Kim *et al.* 2007; Jie *et al.* 2012), terminal digit preference was also modelled using logistic regression. All models were interrogated for significant effects using log-likelihood ratio tests and were adjusted for demographics factors (sex, age and residential region). Stepwise regression was employed, using the Akaike information criterion (AIC), to eliminate non-significant terms and select the most parsimonious models (Akaike 1974). After adjusting for fisher demographics, CPUE, catch success and fishing effort were also compared between the 1999, 2000 and 2002 surveys using Tukey's honest significant difference (HSD) test. Results of these pairwise comparisons were used to construct a simple linear model of apparent reporting error in response to the typical NRIFS catch rate of each taxon. All analyses were tested at a significance level ($\alpha$) of 0.05 and were conducted within the statistical software package *R* (version 3.1.2; R Core Team 2015).

# 3 Results

## 3.1 Dropout

With the exception of seasonal variability, the number of active respondents in the NRIFS surveys remained relatively stable over the year ($\chi^2$ = 0.86, $p$ = 0.361) (fig. 1). In contrast, there was a clear decline in the number of active respondents as the RFish surveys progressed (fig. 1) ($\chi^2$ = 51.80, $p$ < 0.001).

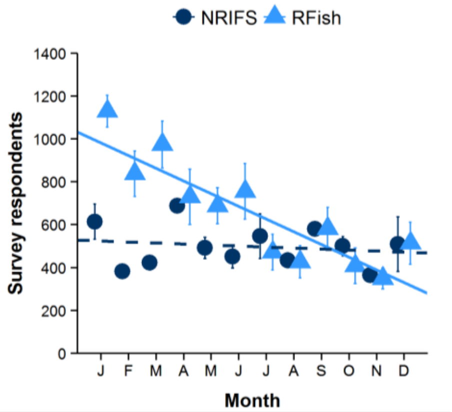


**Figure 1:** Mean number of actively fishing survey respondents ($\text{respondents} \cdot \text{survey}^{-1} \pm \text{SE}$) as a function of month and survey methodology (n = 37579).

The proportion of males and females did not significantly change throughout the year in either group of surveys ($\chi^2$ = 0.26, $p$ = 0.608) (fig. 2). There was no significant change in the proportion of 15-29 year olds ($\chi^2$ = 0.91, $p$ = 0.341), 30-59 year olds ($\chi^2$ = 0.16, $p$ = 0.690) or 60+ year olds ($\chi^2$ = 0.91, $p$ = 0.341) within any of the NRIFS surveys (fig. 2). Similarly, there was no significant change in the proportion of 30-59 year olds in the RFish surveys ($\chi^2$ = 2.72, $p$ = 0.099). However, 15-29 year olds became increasingly underrepresented ($\chi^2$ = 16.78, $p$ < 0.001) and 60+ year olds became increasingly overrepresented ($\chi^2$ = 2.72, $p$ = 0.099) as each RFish survey progressed. As a proportion of all respondents, there were ~22% fewer 15-29 year olds and ~27% more 60+ year olds by the end of each RFish survey. With the exception of Far North Queensland, the proportion of respondents from each residential region did not change over time within any of the RFish or NRIFS surveys (fig. 2) (table 1). By the end of each NRIFS survey, the proportion of respondents from the Far North Queensland region was typically ~26% higher than at the start.

**Table 1:** Results of logistic regression analysis on the relationship between month and the proportion of survey respondents in each residential region. * Statistically significant p-value.

| Survey | Statistic | Residential region | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Brisbane** | **Moreton** | **Wide Bay-Burnett** | **Darling Downs** | **CW/SW/NW** | **Fitzroy** | **Mackay** | **Northern** | **Far North** |
| **RFish** | $\chi^2$ | 2.345 | 0.161 | 1.042 | 0.677 | 0.093 | 0.149 | 0.988 | 0.063 | 1.714 |
| | *p*-value | 0.126 | 0.688 | 0.307 | 0.411 | 0.760 | 0.700 | 0.320 | 0.802 | 0.191 |
| **NRIFS** | $\chi^2$ | 0.937 | 0.314 | 0.344 | 0.886 | 0.303 | 3.108 | 0.581 | 0.468 | 6.395 |
| | *p*-value | 0.333 | 0.575 | 0.558 | 0.347 | 0.582 | 0.078 | 0.446 | 0.494 | 0.011* |

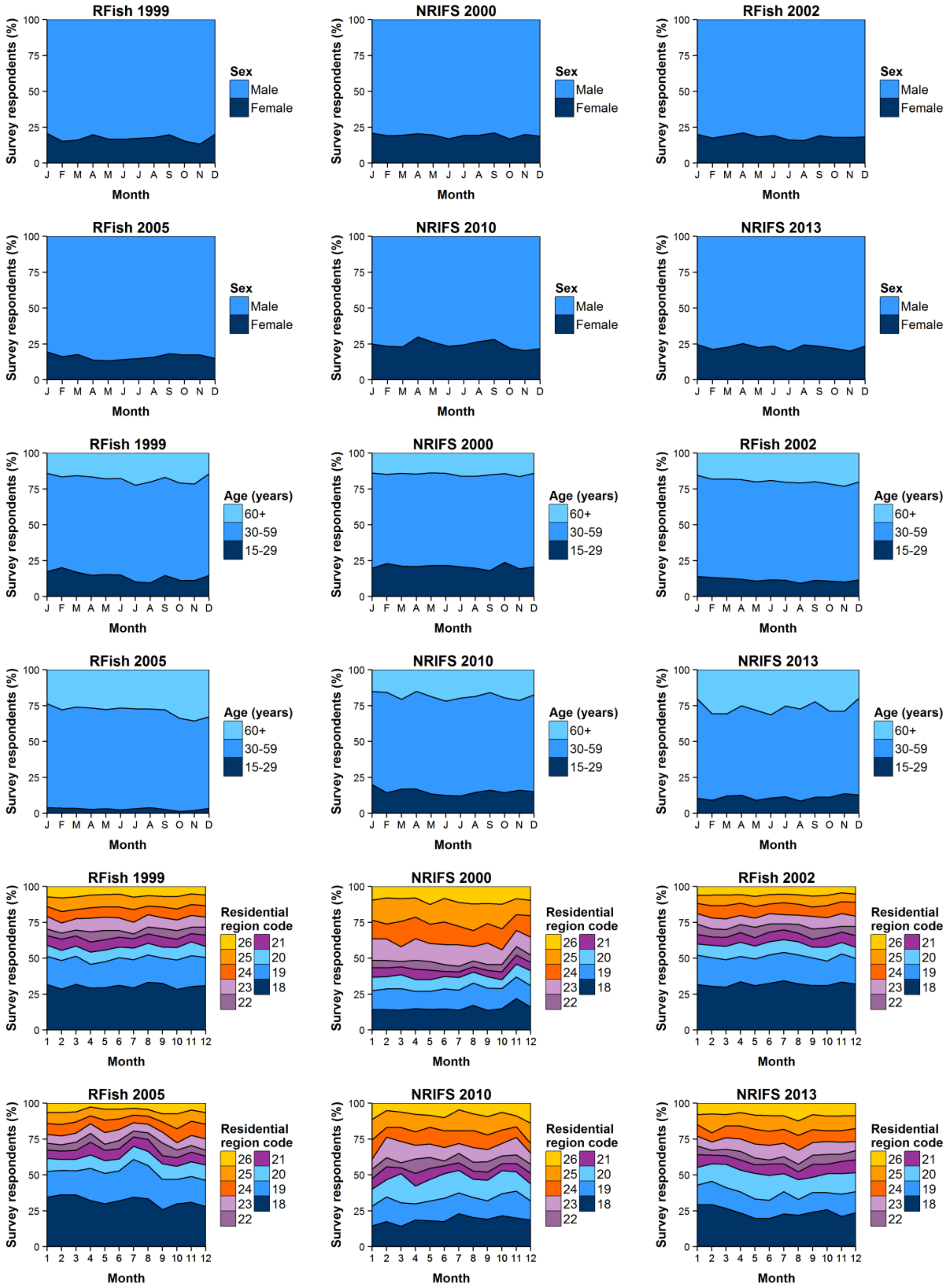


**Figure 2:** Monthly distribution of survey respondents in each category of age, sex and residential region during the RFish (1999, 2002 & 2005) and NRIFS (2000, 2010 & 2013) surveys (n = 38723). Residential region codes represent Brisbane (18), Moreton (19), Wide Bay-Burnett (20), Darling Downs (21), Central West/South West/North West (22), Fitzroy (23), Mackay (24), Northern (25), and Far North (26).

## 3.3 Overall catch success

Catch success did not change over time in either survey methodology ($\chi^2 = 0.13$, $p = 0.719$), but fishers in the 1999 and 2002 RFish surveys were ~20% less likely to report fisher days with zero catch than fishers in the 2000, 2010 and 2013 NRIFS surveys ($\chi^2 = 119.41$, $p < 0.001$) (fig. 3). Additionally, catch success was ~25% lower in 2000 than either of the 1999 ($z = 30.45$, $p < 0.001$) or 2002 RFish surveys ($z = 33.47$, $p < 0.001$) (fig. 4).

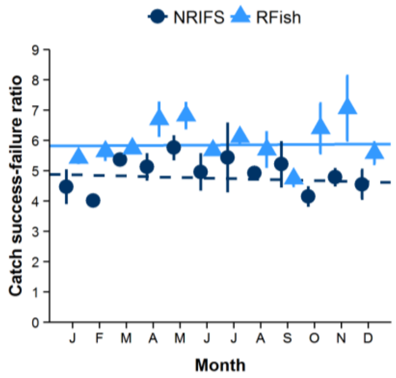


**Figure 3:** Mean catch success-to-failure ratio of fisher days ($\text{successes} \cdot \text{failures}^{-1} \pm SE$) as a function of month and survey methodology (n = 106130).

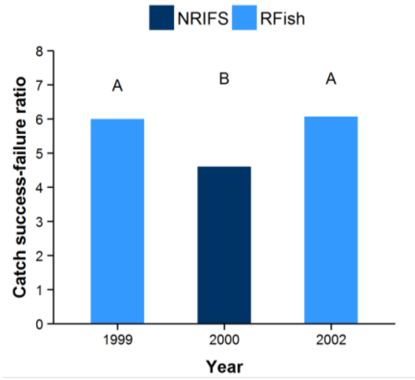


**Figure 4:** Catch success compared between surveys (n = 85009). Ratios with the same letter are not significantly different

## 3.2 Overall fishing effort

RFish survey participants spent ~10% more days fishing per month compared to fishers in the NRIFS surveys ($\chi^2 = 133.85$, $p < 0.001$) (fig. 5). There was also a significant interactive effect between month and survey methodology on fishing effort ($\chi^2 = 13.98$, $p < 0.001$). By the end of the survey period, the average RFish respondent spent ~7.5% fewer days fishing than at the start. In contrast, the average NRIFS fisher spent ~10% more days fishing in the last month than in the first. Compared to 2000, effort was ~17% higher in 1999 ($z = 4.67$, $p < 0.001$) and 34% higher in 2002 ($z = 9.20$, $p < 0.001$) (fig. 6).

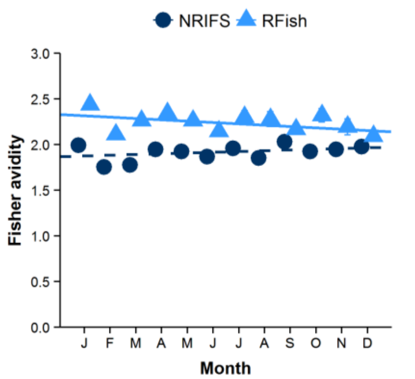


**Figure 5:** Mean recreational fishing effort per fisher ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) as a function of month and survey methodology (n = 38788).

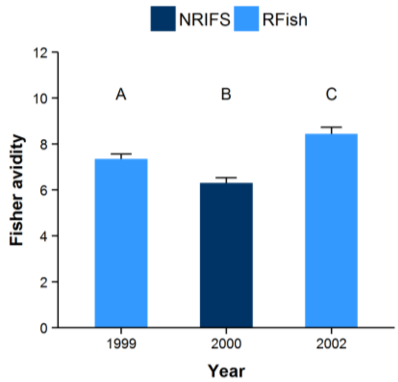


**Figure 6:** Mean recreational fishing effort per fisher ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) compared between surveys (n = 25070). Means with the same letter are not significantly different.

## 3.4 Australian bass

Australian bass CPUE was ~110% higher in 1999 ($z$ = 6.65, $p$ < 0.001) and ~60% higher in 2002 ($z$ = 4.30, $p$ < 0.001) when compared to 2000 NRIFS catch rates (fig. 7). Catch success of Australian bass was 70-150% higher in the 1999 ($z$ = 4.52, $p$ < 0.001) and 2002 RFish surveys ($z$ = 8.44, $p$ < 0.001) when compared to the 2000 NRIFS survey (fig. 8). The average respondent's fishing effort for Australian bass was ~75% higher in 2002 than in 2000 ($z$ = 2.77, $p$ = 0.015), but there was no significant difference between 2000 and 1999 ($z$ = 1.11, $p$ = 0.500) (fig. 9).

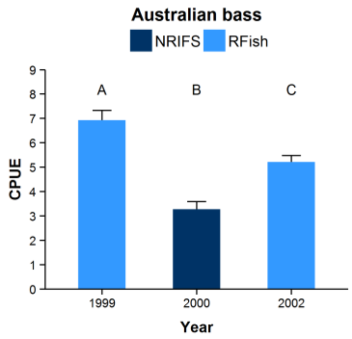


**Figure 7:** Mean recreational CPUE for Australian bass ($\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE}$) compared between surveys (n = 1704). Means with the same letter are not significantly different.

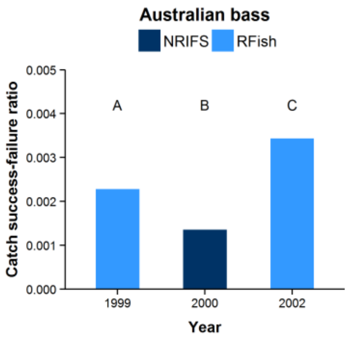


**Figure 8:** Mean recreational catch success for Australian bass compared between surveys (n = 39508). Ratios with the same letter are not significantly different.

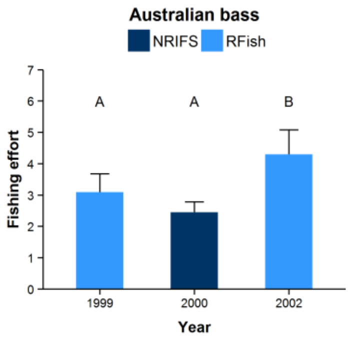


**Figure 9:** Mean recreational fishing effort per fisher for Australian bass ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) compared between surveys (n = 525). Means with the same letter are not significantly different.

## 3.5 Barramundi

Barramundi CPUE was ~55% higher in the 1999 survey compared to the 2000 survey (z = 6.62, p < 0.001), but there was no difference between 2000 and 2002 ($z$ = 1.59, $p$ = 0.248) (fig. 10). Catch success of barramundi was 25-40% higher in the 1999 ($z$ = 4.54, $p$ < 0.001) and 2002 RFish surveys ($z$ = 3.14, $p$ = 0.005) compared to the 2000 NRIFS survey (fig. 11). Barramundi fishing effort per fisher was ~40% higher in 1999 than in 2000 ($z$ = 2.90, $p$ = 0.010), but there was no significant difference between 2000 and 2002 ($z$ = 1.64, $p$ = 0.230) (fig. 12).

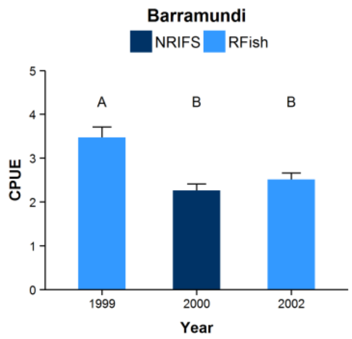


**Figure 10:** Mean recreational CPUE for barramundi ($\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE}$) compared between surveys (n = 2522). Means with the same letter are not significantly different.

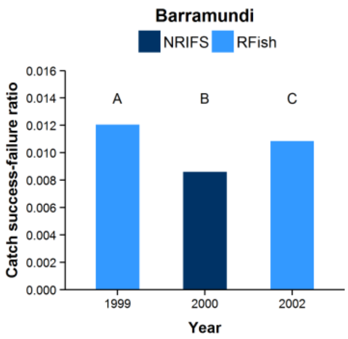


**Figure 11:** Mean recreational catch success for barramundi compared between surveys (n = 39465). Ratios with the same letter are not significantly different.

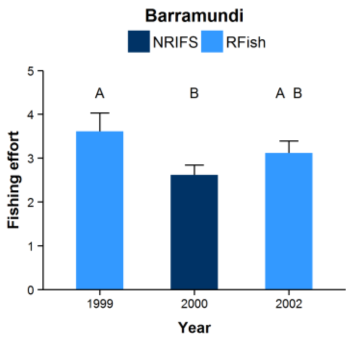


**Figure 12:** Mean recreational fishing effort per fisher for barramundi ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) compared between surveys (n = 936). Means with the same letter are not significantly different.

## 3.6 Black/Pikey/Yellowfin bream

Bream CPUE was significantly higher in the 1999 ($z$ = 11.81, $p$ < 0.001) and 2002 surveys ($z$ = 9.832, $p$ < 0.001) when compared to 2000 (fig. 13), with RFish catch rates exceeding NRIFS catch rates by 30-40%. Bream catch success was 100-115% higher in the 1999 ($z$ = 5.15, $p$ < 0.001) and 2002 RFish surveys ($z$ = 9.05, $p$ < 0.001) when compared to the NRIFS surveys (fig. 14). Similarly, bream fishing effort per fisher was ~25% higher in the 1999 ($z$ = 4.27, $p$ < 0.001) and 2002 RFish surveys ($z$ = 3.86, $p$ <0.001) (fig. 15).

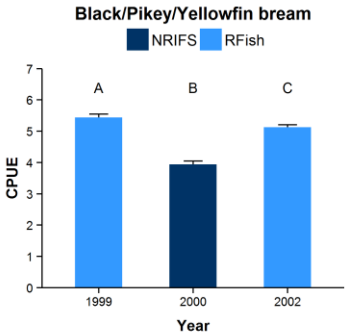


**Figure 13:** Mean recreational CPUE for bream $(\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE})$ compared between surveys (n = 18268). Means with the same letter are not significantly different.

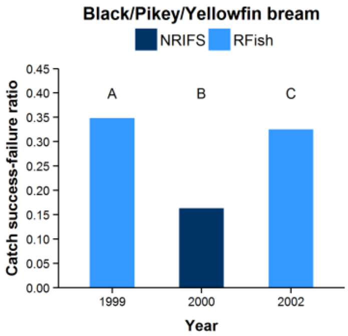


**Figure 14:** Mean recreational catch success for bream compared between surveys (n = 38604). Ratios with the same letter are not significantly different.

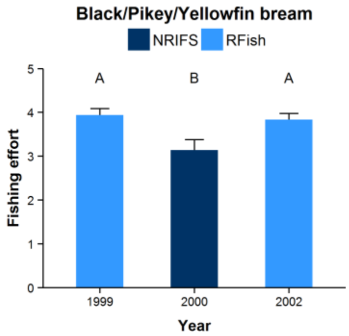


**Figure 15:** Mean recreational fishing effort per fisher for bream $(\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE})$ compared between surveys (n = 5629). Means with the same letter are not significantly different.

## 3.7 Blue swimmer crab

Blue swimmer CPUE was not significantly different between 1999 and 2002 ($z$ = 0.98, $p$ = 0.581) or 2000 and 2002 ($z$ = 2.08, $p$ = 0.088) (fig. 16). In contrast, catch success of blue swimmer crabs was 60-125% higher in the 1999 ($z$ = 3.17, $p$ = 0.004) and 2002 RFish surveys ($z$ = 7.14, $p$ < 0.001) when compared to the NRIFS surveys (fig. 17). The average respondent's fishing effort for blue swimmer crab was ~50% higher in the 1999 ($z$ = 2.78, $p$ = 0.014) and 2002 RFish surveys ($z$ = 3.14, $p$ = 0.005) compared to fishers in the 2000 NRIFS survey (fig. 18).

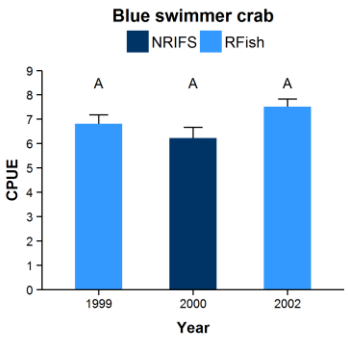


**Figure 16:** Mean recreational CPUE for blue swimmer crab $(\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE})$ compared between surveys (n = 2715). Means with the same letter are not significantly different.

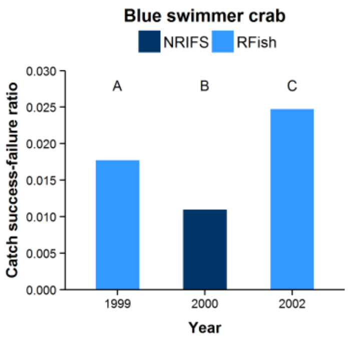


**Figure 17:** Mean recreational catch success for blue swimmer crab compared between surveys (n = 39402). Ratios with the same letter are not significantly different.

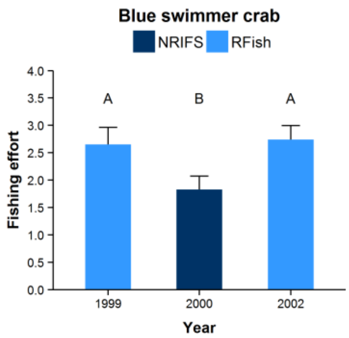


**Figure 18:** Mean recreational fishing effort per fisher for blue swimmer crab $(\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE})$ compared between surveys (n = 1127). Means with the same letter are not significantly different.

## 3.8 Coral trout

Coral trout CPUE was ~25% higher in the 2002 survey compared to the 2000 survey ($z$ = 2.13, $p$ = 0.084), but there was no significant difference between 2000 and 1999 ($z$ = 3.66, $p$ < 0.001) (fig. 19). Coral trout catch success was ~25% higher in 1999 compared to 2000 ($z$ = 2.80, $p$ = 0.014), but there was no significant difference between 2000 and 2002 ($z$ = 0.06, $p$ = 0.998) (fig. 20). There was no significant difference in the typical fisher's coral trout fishing effort between the 2000 NRIFS survey and either of the 1999 ($z$ = 0.46, $p$ = 0.888) or 2002 RFish surveys ($z$ = 0.13, $p$ = 0.991) (fig. 21).

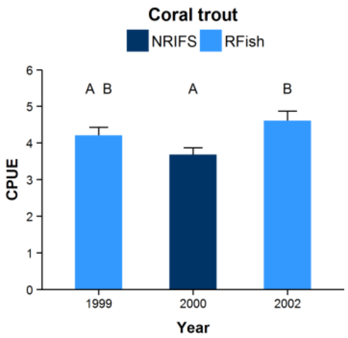


**Figure 19:** Mean recreational CPUE for coral trout $(\mathrm{catch} \cdot \mathrm{fisher\ day}^{-1} \pm \mathrm{SE})$ compared between surveys (n = 2366). Means with the same letter are not significantly different.

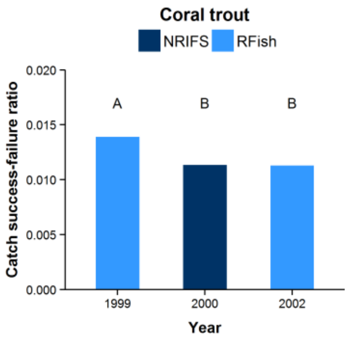


**Figure 20:** Mean recreational catch success for coral trout compared between surveys (n = 39425). Ratios with the same letter are not significantly different.

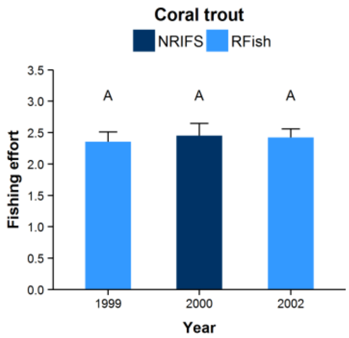


**Figure 21:** Mean recreational fishing effort per fisher for coral trout $(\mathrm{fisher\ days} \cdot \mathrm{fisher}^{-1} \pm \mathrm{SE})$ compared between surveys (n = 1122). Means with the same letter are not significantly different.

## 3.9 Dart

Dart CPUE was significantly higher in the 1999 ($z$ = 6.16, $p$ < 0.001) and 2002 surveys ($z$ = 8.32, $p$ < 0.001) compared to the 2000 survey, with RFish catch rates exceeding NRIFS catch rates by 105-155% (fig. 22). Dart catch success was not significantly different between 1999 and 2000 ($z$ = 1.78, $p$ = 0.174) or 2002 and 2000 ($z$ = 1.70, $p$ = 0.205) (fig. 23). Similarly, dart fishing effort per fisher in the 2000 NRIFS survey was not significantly different to that of the 1999 ($z$ = 0.69, $p$ = 0.764) and 2002 RFish surveys ($z$ = 0.378, $p$ = 0.923) (fig. 24).

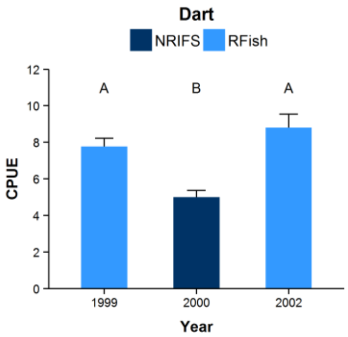


**Figure 22:** Mean recreational CPUE for dart $(\mathrm{catch} \cdot \mathrm{fisher\ day}^{-1} \pm \mathrm{SE})$ compared between surveys (n = 2735). Means with the same letter are not significantly different.

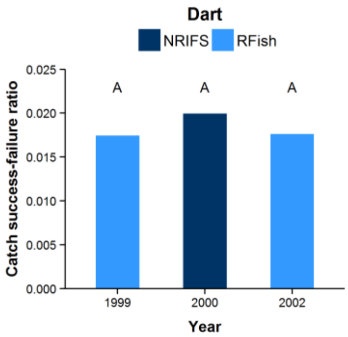


**Figure 23:** Mean recreational catch success for redthroat emperor compared between surveys (n = 39425). Ratios with the same letter are not significantly different.

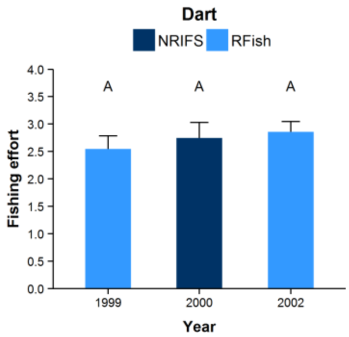


**Figure 24:** Mean recreational fishing effort per fisher for dart $(\mathrm{fisher\ days} \cdot \mathrm{fisher}^{-1} \pm \mathrm{SE})$ compared between surveys (n = 1141). Means with the same letter are not significantly different.

## 3.10 Flathead

Flathead CPUE was significantly higher in the 1999 ($z$ = 3.01, $p$ = 0.006) and 2002 RFish surveys ($z$ = 3.64, $p$ < 0.001) compared to 2000, with RFish catch rates exceeding NRIFS catch rates by ~20% (fig. 25). Flathead catch success was also 100-110% higher in the 1999 ($z$ = 12.49, $p$ < 0.001) and 2002 RFish surveys ($z$ = 13.26, $p$ < 0.001) compared to fishers in the 2000 NRIFS survey (fig. 26). Additionally, flathead fishing effort per fisher was ~30% higher in the 1999 ($z$ = 3.64, $p$ < 0.001) and RFish surveys 2002 ($z$ = 3.71, $p$ < 0.001) compared to the 2000 NRIFS survey (fig. 27).

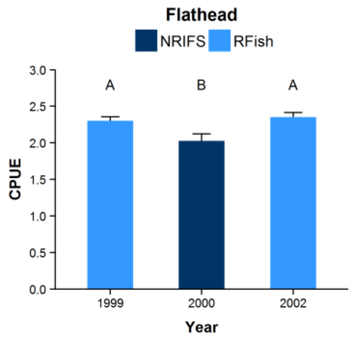


**Figure 25:** Mean recreational CPUE for flathead ($\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE}$) compared between surveys (n = 8410). Means with the same letter are not significantly different.

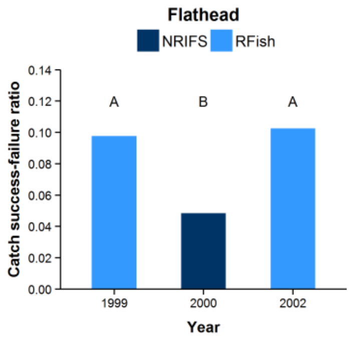


**Figure 26:** Mean recreational catch success for flathead compared between surveys (n = 39079). Ratios with the same letter are not significantly different.

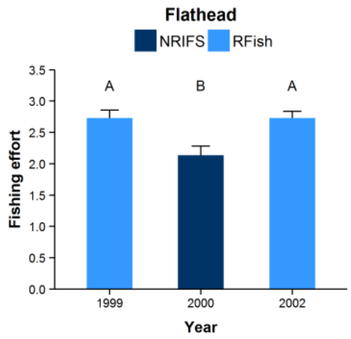


**Figure 27:** Mean recreational fishing effort per fisher for flathead ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) compared between surveys (n = 3560). Means with the same letter are not significantly different.

## 3.11 Mud crab

There was no significant difference in mud crab CPUE between the 2000 NRIFS and 1999 RFish surveys ($z$ = 2.15, $p$ = 0.080), but CPUE was ~20% higher in 2002 than in 2000 ($z$ = 4.70, $p$ < 0.001) (fig. 29). Mud crab catch success was ~30% higher in the 1999 ($z$ = 0.77, $p$ = 0.721) and 2002 RFish surveys ($z$ = 0.64, $p$ < 0.001) compared to the 2000 NRIFS survey ($z$ = 6.00, $p$ < 0.001), but there was no difference between 1999 and 2002 ($z$ = 0.77, $p$ = 0.721) (fig. 30). Mud crab fishing effort per fisher was ~30% higher in the 1999 ($z$ = 5.44, $p$ < 0.001) and 2002 RFish surveys ($z$ = 5.22, $p$ < 0.001) compared to the 2000 NRIFS survey (fig. 30).

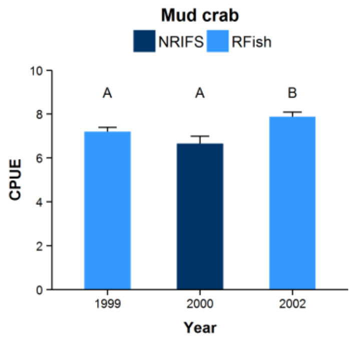


**Figure 28:** Mean recreational CPUE for mud crab ($\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE}$) compared between surveys (n = 8173). Means with the same letter are not significantly different.

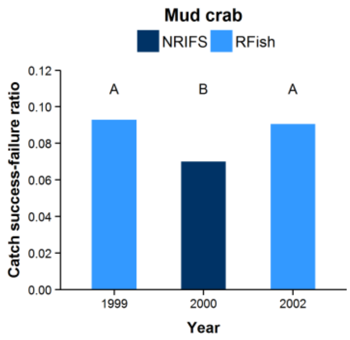


**Figure 29:** Mean recreational catch success for mud crab compared between surveys (n = 39147). Ratios with the same letter are not significantly different.

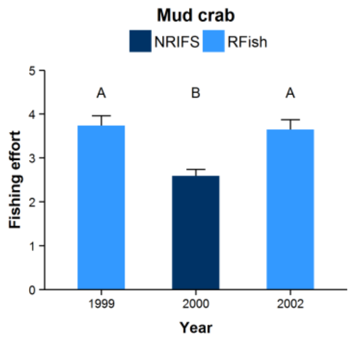


**Figure 31:** Mean recreational fishing effort per fisher for mud crab ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) compared between surveys (n = 2769). Means with the same letter are not significantly different.

## 3.12 Redthroat emperor

Redthroat emperor CPUE was 60-70% higher in the 1999 ($z$ = 4.51, $p$ < 0.001) and 2002 RFish surveys ($z$ = 4.94, $p$ < 0.001) compared to the 2000 NRIFS survey (fig. 31). Catch success of redthroat emperor was 300-480% higher in the 1999 ($z$ = 16.41, $p$ < 0.001) and 2002 RFish surveys ($z$ = 12.70, $p$ < 0.001) compared to the 2000 NRIFS survey (fig. 32). In contrast, the typical respondent's fishing effort for redthroat emperor was not significantly different between the 2000 NRIFS survey and either of the 1999 ($z$ = 1.43, $p$ = 0.315) or 2002 RFish surveys ($z$ = 1.19, $p$ = 0.447) (fig. 33).

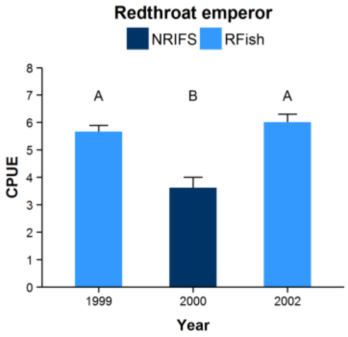


**Figure 31:** Mean recreational CPUE for redthroat emperor ($\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE}$) compared between surveys (n = 1982). Means with the same letter are not significantly different.

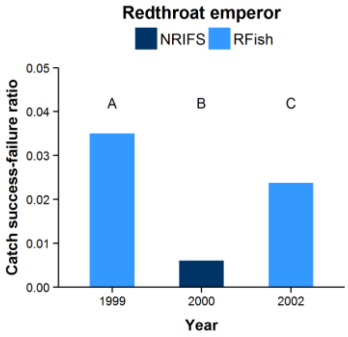


**Figure 32:** Mean recreational catch success for redthroat emperor compared between surveys (n = 39375). Ratios with the same letter are not significantly different.

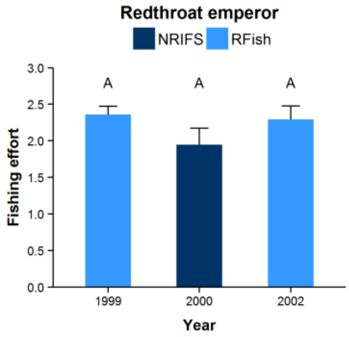


**Figure 33:** Mean recreational fishing effort per fisher for redthroat emperor ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) compared between surveys (n = 958). Means with the same letter are not significantly different.

## 3.13 Snapper

Snapper CPUE was 20-25% higher in the 1999 ($z$ = 3.06, $p$ = 0.006) and 2002 RFish surveys ($z$ = 2.44, $p$ = 0.038) compared to 2002 (fig. 34). Additionally, snapper catch success was 40-80% higher in the 1999 ($z$ = 4.10, $p$ < 0.001) and 2002 RFish surveys ($z$ = 7.14, $p$ < 0.001) compared to fishers in the 2000 NRIFS survey (fig. 35). Snapper fishing effort per fisher was also 30-35% higher in the 1999 ($z$ = 2.38, $p$ = 0.043) and 2002 RFish surveys ($z$ = 2.62, $p$ = 0.023) (fig. 36).

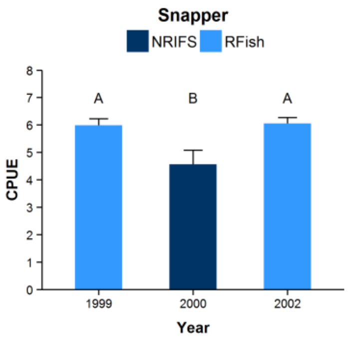


**Figure 34:** Mean recreational CPUE for snapper ($\#\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE}$) compared between surveys (n = 3299). Means with the same letter are not significantly different.

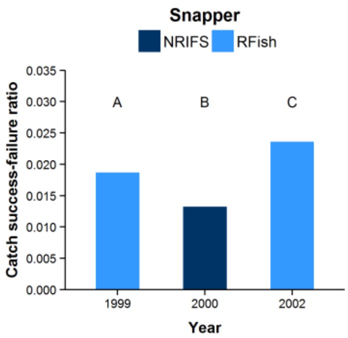


**Figure 35:** Mean recreational catch success for snapper ($\text{snapper fishers} \cdot \text{other fishers}^{-1}$) compared between surveys (n = 39370). Ratios with the same letter are not significantly different.

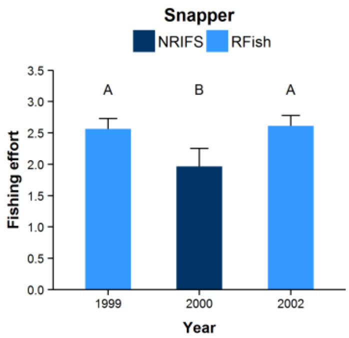


**Figure 36:** Mean recreational fishing effort per fisher for snapper ($\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE}$) compared between surveys (n = 1361). Means with the same letter are not significantly different.

## 3.14 Tailor

There were no statistically significant differences in tailor CPUE between 2000 and 1999 ($z$ = 0.79, $p$ = 0.709) or between 2000 and 2002 ($z$ = 0.56, $p$ = 0.841) (fig. 37). Tailor catch success was 30-55% higher in the 1999 ($z$ = 3.21, $p$ = 0.004) or 2002 RFish surveys ($z$ = 5.69, $p$ < 0.001) compared to the 2000 NRIFS survey (fig. 38). Tailor fishing effort per fisher was not significantly different between the 2000 NRIFS survey and either of the 1999 ($z$ = 0.18, $p$ = 0.982) or 2002 RFish surveys ($z$ = 1.82, $p$ = 0.160) (fig. 39).

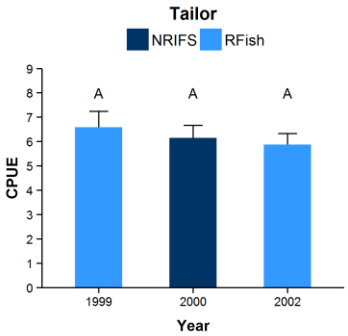


**Figure 37:** Mean recreational CPUE for tailor $(\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE})$ compared between surveys (n = 2542). Means with the same letter are not significantly different.

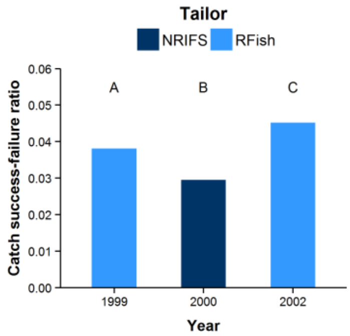


**Figure 38:** Mean recreational catch success for tailor compared between surveys (n = 39446). Ratios with the same letter are not significantly different.

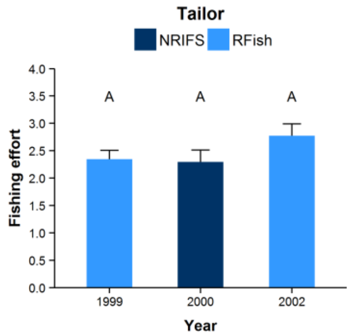


**Figure 39:** Mean recreational fishing effort per fisher for tailor $(\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE})$ compared between surveys (n = 1136). Means with the same letter are not significantly different.

## 3.15 Trumpeter whiting

Trumpeter whiting CPUE was significantly higher in the 1999 ($z$ = 12.81, $p$ < 0.001) and 2002 surveys ($z$ = 11.38, $p$ < 0.001) when compared to 2000, with RFish catch rates exceeding NRIFS catch rates by 145-190% (fig. 40). Catch success of trumpeter whiting was 10-25% higher in 1999 ($z$ = 2.37, $p$ = 0.047) and 2002 surveys ($z$ = 6.49, $p$ < 0.001) compared to 2000 (fig. 41). Similarly, the average respondent's fishing effort for trumpeter whiting was 45-60% higher in the 1999 ($z$ = 3.72, $p$ < 0.001) and 2002 RFish surveys ($z$ = 3.12, $p$ = 0.005) (fig. 42).

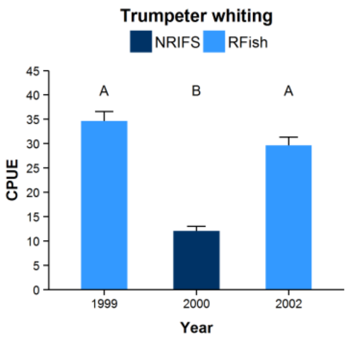


**Figure 40:** Mean recreational CPUE for trumpeter whiting $(\text{catch} \cdot \text{fisher day}^{-1} \pm \text{SE})$ compared between surveys (n = 8410). Means with the same letter are not significantly different.

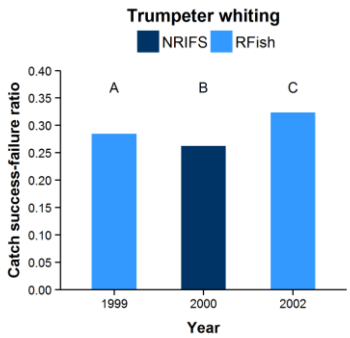


**Figure 41:** Mean recreational catch success for whiting compared between surveys (n = 38822). Ratios with the same letter are not significantly different.

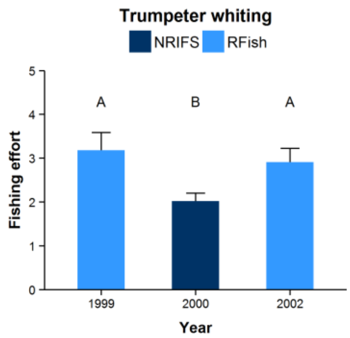


**Figure 42:** Mean recreational fishing effort per fisher for trumpeter whiting $(\text{fisher days} \cdot \text{fisher}^{-1} \pm \text{SE})$ compared between surveys (n = 3560). Means with the same letter are not significantly different.

## 3.16 Taxa summary

For seven out of the twelve investigated taxa, average CPUE in the 2000 RFish survey was not intermediary between 1999 and 2002 RFish averages (table 2). Similarly, average catch success in 2000 was not intermediary between 1999 and 2002 RFish averages for ten of the twelve taxa. Average fishing effort per fisher in 2000 was not intermediary between 1999 and 2002 figures. 2000 NRIFS averages that were not intermediary between 1999 and 2002 were significantly lower than figures from either RFish survey. Only coral trout demonstrated 2000 NRIFS averages that were intermediary between 1999 and 2002 for all three measures of catch rate and fisher avidity.

**Table 2:** Summary of CPUE, catch success and fishing effort per fisher comparisons between the 2000 NRIFS and 1999/2002 RFish surveys.

| Taxa | Inflation of 1999/2002 RFish figures compared to 2000 NRIFS figures? | | |
|---|---|---|---|
| | **CPUE** | **Catch success** | **Fishing effort per fisher** |
| **Australian bass** | ☑ | ☑ | ☐ |
| **Barramundi** | ☐ | ☑ | ☐ |
| **Black/Pikey/Yellowfin bream** | ☑ | ☑ | ☑ |
| **Blue swimmer crab** | ☐ | ☑ | ☑ |
| **Coral trout** | ☐ | ☐ | ☐ |
| **Dart** | ☑ | ☐ | ☐ |
| **Flathead** | ☑ | ☑ | ☑ |
| **Mud crab** | ☐ | ☑ | ☑ |
| **Redthroat emperor** | ☑ | ☑ | ☐ |
| **Snapper** | ☑ | ☑ | ☑ |
| **Tailor** | ☐ | ☑ | ☐ |
| **Trumpeter whiting** | ☑ | ☑ | ☑ |
| **COUNT** | 7/12 | 10/12 | 6/12 |

The level of reporting error in the 1999 and 2002 RFish surveys was typically higher for taxa with higher mean catch rates in the 2000 NRIFS survey ($\chi^2 = 5.18$, $p = 0.046$) (fig. 43), however the relationship was poorly described by a linear model ($R^2 = 0.341$) and was not statistically significant if trumpeter whiting was excluded ($\chi^2 = 0.62$, $p = 0.046$).

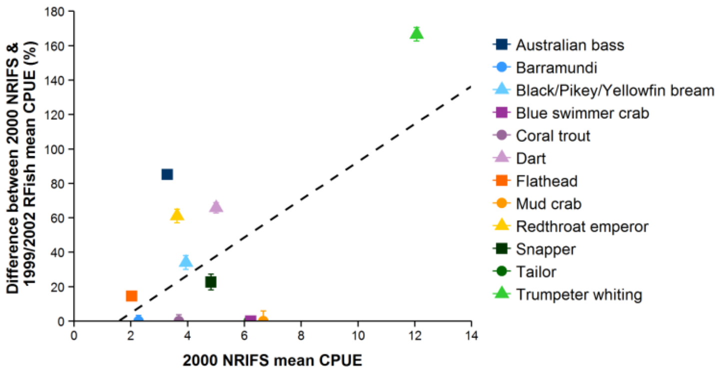


**Figure 43:** Relationship between typical catch size for each taxon (2000 NRIFS mean CPUE) and the apparent overestimation of CPUE in the 1999/2002 RFish surveys (difference between 2000 NRIFS & the combined 1999/2002 RFish mean CPUE).

## 3.17 Terminal digit preference

An examination of the distribution of recreational catch in the NRIFS and RFish surveys shows distinct response peaks at digits ending in 0 or 5, although the magnitude of the peaks was lower for digits ending in 5 (fig. 44). Additionally, NRIFS catches were ~84% more likely to end in 0 ($\chi^2$ = 576.56, $p$ < 0.001) and ~26% more likely to end in 5 ($\chi^2$ = 93.32, $p$ < 0.001) compared to catches in the RFish surveys (fig. 45).

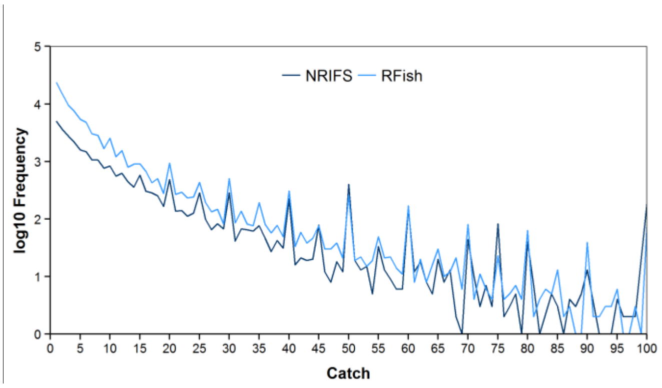


**Figure 44:** Frequency ($log_{10}$) of catches compared between survey methods. Presented data only represents catches less than 100 fish (n = 117079; 99.2% of all records).

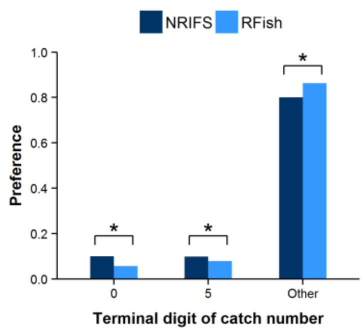


**Figure 45:** Terminal digit preference of catch numbers compared between survey methods (n = 118010). Significant differences denoted by *.

# 4 Discussion

Before reviewing the findings, limitations to this study must first be addressed. First, survey methods were compared under the assumption that, in the absence of significant management changes or extreme weather events, the catch and effort estimates would trend in a relatively consistent direction across consecutive years. Differences between survey methods that did not meet this assumption were concluded to be, at least partially, the effect of survey methodology. However, the precise effect of survey methodology cannot be isolated from yearly variation without comparing surveys that were simultaneously conducted, per the approach taken by Lyle (1999).

A second limitation is that the extent of bias in the RFish survey design was assessed via comparison of survey results with the NRIFS methodology, which, as another off-site survey method reliant on the self-reporting of retrospective information, is likely to have encountered similar biases (Hiett & Worral 1977; Chase & Harada 1984; Hassan 2005). As a result, the true extent of the biases present in the RFish estimates may have been understated in this study. Furthermore, the comparison of survey methods was made under the assumption that the NRIFS survey data was more accurate. While this assumption is generally accepted to be true (Lyle *et al.* 2002; Hartill *et al.* 2012), it is not undisputed and the possibility that the RFish surveys were more accurate should be acknowledged. The ideal approach would have been to compare the RFish survey data with results from a concurrent on-site survey (Roach *et al.* 1999; Hartill & Edwards 2015; McCormick *et al.* 2015) or observer program (Bochenek *et al.* 2012).

Despite these limitations, the presence of an attrition bias in the RFish data was indicated by high levels of dropout and the discovery that dropout was not independent of demographic factors. Although demographic factors are known to be linked with fishing behaviour (Henderson 2004), the RFish and NRIFS surveys adjusted for demographics by assigning individual weightings to each fisher. An attrition bias arising from the disproportionate dropout of particular demographic groups should not affect demographically-weighted estimates of catch and effort. However, fisher avidity in the RFish surveys appeared to decline over time in response to attrition, indicating that a fisher's tendency to drop out was associated with behavioural factors that demographic weightings did not correctly adjust for. Although these findings are indicative of an attrition-derived avidity bias, there were no significant changes in catch success over time in the RFish surveys and, thus, little or no evidence of an attrition-derived skill bias.

The apparent attrition-derived avidity bias in the RFish surveys was characterised by a decline in the average respondent's fishing effort over time. This finding was unexpected given that survey respondents are often found to be more avid fishers than their nonrespondent counterparts (Lowry 1978; Harris & Bergersen 1985; Absher & Collins 1987; Connelly *et al.* 2000; Henry & Lyle 2003). One possible explanation is that respondents report fishing activity with less bias than dropouts. However, this would contradict the findings of a previous study, where nonrespondents in a 1989 survey of recreational fishing effort were less likely to report with recall bias than the respondents (Tarrant *et al.* 1993). Furthermore, there was no significant change in catch success over time in the RFish surveys, indicating that the extent of recall bias did not change as respondents dropped out of the surveys. An alternative explanation is that increased fishing activity equates to more frequent self-reporting, thus placing a greater burden on avid fishers and leading to a higher rate of respondent fatigue. This deduction would imply that, when adjusting for nonresponse bias, a distinction must be made between nonrespondents that immediately refused to participate in the diary program (full nonrespondents) and those that agreed to participate but dropped out before completion of the program (partial nonrespondents or dropouts).

Overall fishing effort per fisher and catch success were found to be inflated in the RFish surveys. Additionally, fishing effort or catch rate was exaggerated in the RFish surveys for 11 of the 12 investigated taxa. These findings demonstrate a well-known phenomenon in fisheries research where survey designs with longer recall periods tend to produce higher estimates of recreational catch and effort than survey methods with immediate or shorter recall periods (Brown 1977; Fisher *et al.* 1991; Chu *et al.* 1992; Tarrant *et al.* 1993; Connelly & Brown 1995; Lyle 1999; Roach *et al.* 1999; Connelly *et al.* 2000; Ellender *et al.* 2010; Connelly & Brown 2011; Hartill & Edwards 2015; McCormick *et al.* 2015). The source of these errors is almost universally agreed to be recall bias. However, differences between the NRIFS and RFish survey designs were not limited to recall period and comparing their results may yield the effects of biases other than recall bias.

An alternative explanation for these findings is prestige bias, where social incentives tend to drive fishers to exaggerate catch rates and fishing activity (Pollock *et al.* 1994; Hartill & Edwards 2015). Prestige reporting is likely to be less prevalent in the NRIFS surveys as, unlike the quarterly diary method employed in the RFish surveys, the interview-based approach allowed interviewers to actively discourage prestige bias by reassuring the diarist that low or nil catches were common (Hartill *et al.* 2012). Non-social incentives may also motivate fishers to deliberately misreport catch and effort (Pollock *et al.* 1994), such as the reluctance of recreational fishers to provide accurate fishing information due to concerns regarding data confidentiality, responsive fishing restrictions or penalties for illegal fishing (Essig & Holliday 1991; Tracey *et al.* 2011; McCormick *et al.* 2013). Unlike commercial fishers, who are often financially incentivised to overreport catch and effort (Hentati-Sundberg *et al.* 2014), the non-social motivations for recreational fishers to misreport fishing information mostly appear to encourage underreporting. Therefore, deliberate misreporting based on non-social incentives is unlikely to have caused the inflation of catch and effort in the RFish surveys.

Another possible explanation is the misidentification of fish species (Pollock *et al.* 2004). Evidence from several studies indicate that angler identification of recreational fish is often unreliable and varies widely depending on the fisher's experience, the availability of educational sources, the species of fish and the fishery (Schmetterling & Long 1999; Lamansky *et al.* 2001; Stelfox *et al.* 2001; Bowlby & Savoie 2011). Page *et al.* (2012) estimated that species misidentification in an Ohio reservoir fishing survey may have inflated catch estimates by up to 386%. In comparison to the RFish survey design, the NRIFS approach employed additional measures to reduce misidentification error, including use of a memory jogger with pictures of common fish species and frequent telephone interviews that allowed interviewers to query suspect information (e.g. fish species occurring outside of their expected distributions). Although species misidentification may explain the varying levels of overreporting observed for different taxa in the RFish surveys, this type of error cannot explain the overall exaggeration of fisher avidity and catch success across all records.

Common causes of exaggerated catch and effort in recreational fishing surveys also include nonresponse bias (Tarrant *et al.* 1993). While this study already indicates the existence of a nonresponse bias in the form of attrition, there was an overall inflation of fisher avidity and catch in the RFish surveys that was independent of survey dropout. This latter finding may instead be explained by the sample loss of full nonrespondents (often referred to simply as nonresponse bias), which is described by the initial response rates of a survey rather than the dropout rates. However, the NRIFS and RFish surveys achieved similarly high initial response rates of 80% to 90% (Henry & Lyle 2003; McInnes 2008; Taylor *et al.* 2012; Webley *et al.* 2015). Given that the magnitude of a nonresponse bias is dependent on the relative size of the nonrespondent stratum (Fisher 1996), these response rates indicate that any effects of nonresponse bias should be relatively equal between survey methodologies. Therefore, it is unlikely that the sample loss of full nonrespondents was a major factor in the large discrepancies between the RFish and NRIFS survey results.

In a study of Illinois anglers, Tarrant and Manfredo (1993) proposed that terminal digit preference may explain errors typically attributed to recall and nonresponse bias. Response peaks for numbers ending in 0 or 5 are characteristic of digit preference (Miller & Anderson 1993) and were prominent in both RFish and NRIFS catch records. However, the extent of digit preference was higher in the NRIFS surveys. This finding appears to contradict several studies that suggest digit preference is more prevalent in surveys with longer recall periods and more avid fishers or hunters (Chu *et al.* 1992; Tarrant & Manfredo 1993; Vaske *et al*. 1996; Miller & Anderson 2002). The studies reported here mainly discuss digit preference as a function of recall error. As such, a lower level of digit preference in the RFish surveys implies that the inflation of RFish catch rates may be unrelated to recall bias. However, it is also likely that digit preference was dependent on the method of data collection and varied between the diary-based RFish and interview-based NRIFS approaches. The findings presented here also imply that the apparent inflation of RFish catch rates may instead be an underestimation of NRIFS catch rates, with fishers tending to round down catch numbers. However, such a conclusion is dubious given that digit preference tends to cause an overall rounding up of catch numbers (Sen 1973). Furthermore, a higher level of terminal digit preference in the NRIFS surveys cannot explain the apparent inflation of catch success and fisher avidity in the RFish surveys.

Irrespective of the causal biases, overall inflation of catch success can only arise from two mechanisms: the overreporting of successful fishing trips, or the underreporting of unsuccessful fishing trips. Extensive underreporting of fishing trips would have led to an apparent reduction in fisher avidity, yet RFish respondents were found to be significantly more avid than NRIFS respondents. This suggests that overreporting, rather than underreporting, was the predominant cause of inflated catch success in the RFish surveys.

Although there was a general overreporting of catch success and fisher avidity in the RFish surveys, the extent of reporting bias was highly variable among taxa. Similar findings were reported by Roach *et al.* (1999), who found that, when comparing recreational catch rates between on-site and off-site surveys in Maine, off-site estimates were variably exaggerated for 28 of 38 species. Previous work suggests that such inconsistencies in reporting bias may arise from a wide range of factors, including: fishing method, gender, age, fisher avidity, bag and size limits, season, water body, species, catch rate, fish length/size, rarity and catch memorability (Pollock *et al.* 1994; Lyle *et al.* 1999; Roach *et al.* 1999; Sullivan 2003; Bochenek *et al.* 2012; Hartill & Edwards 2015). The current study also provided some evidence of a relationship between taxa with higher mean catch rates and increased levels of CPUE overreporting, although the evidence was relatively weak and these results contradict past research that found recreational fishers tended to overreport when catch rates were low (Sullivan 2003; McCormick *et al.* 2015). Nevertheless, any evidence of catch-dependent reporting bias should be acknowledged as it can have serious implications for fisheries management by leading to incorrect conclusions about the trajectory of fish populations (e.g. hyperstability) or the effect of management actions.

The chief purpose of this study was to explore the possibility of adjusting for any biases identified in the RFish surveys. Some researchers have suggested using a correction factor or assuming reporting bias is constant and managing based on trends (Connelly & Brown 1995; Roach *et al.* 1999; Connelly *et al.* 2000). Others have concluded that the use of a correction factor may not be appropriate in circumstances where reporting bias is influenced by a complex range of factors (Lyle *et al.* 1999; McCormick *et al.* 2015). Similarly, the unpredictable and multifaceted nature of the reporting bias observed in the RFish data may preclude any reliable adjustments. Although the catch and effort data from the RFish recreational fishing surveys proved to be unreliable in absolute terms, these data may be useful in assessing relative trends if it is assumed that reporting bias is consistent among the RFish surveys. An alternative approach is to re-run the weighting and upscaling components of the RFish surveys using a recently developed statistical package, known as 'RecSurvey', that was specifically designed to analyse recreational fishing survey data collected through methods similar to NRIFS (Lyle *et al.* 2009b). However, this approach would be unproductive unless the biases in the raw data can be can be adjusted for beforehand. Ultimately, managers will need to evaluate the trade-off between the accuracy and comprehensiveness of Queensland's recreational catch and effort data. If the level of bias indicated in this study is unacceptable, the exclusion of RFish survey results may be the only way to maintain an accurate time series. If, on the other hand, a more comprehensive time series is required, managers must be aware of the existing biases and recognise that RFish and NRIFS survey results cannot be directly compared without some form of adjustment.

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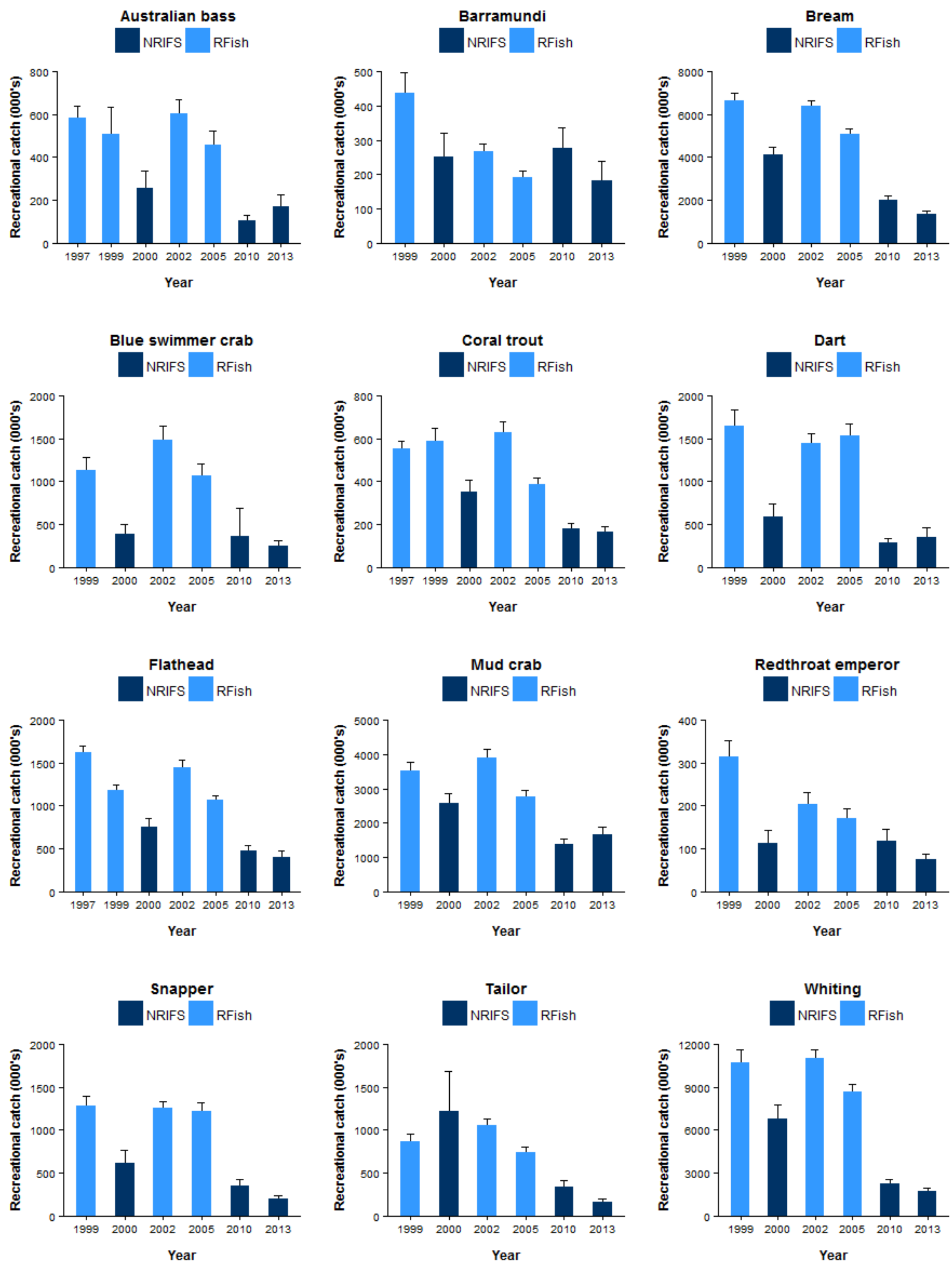
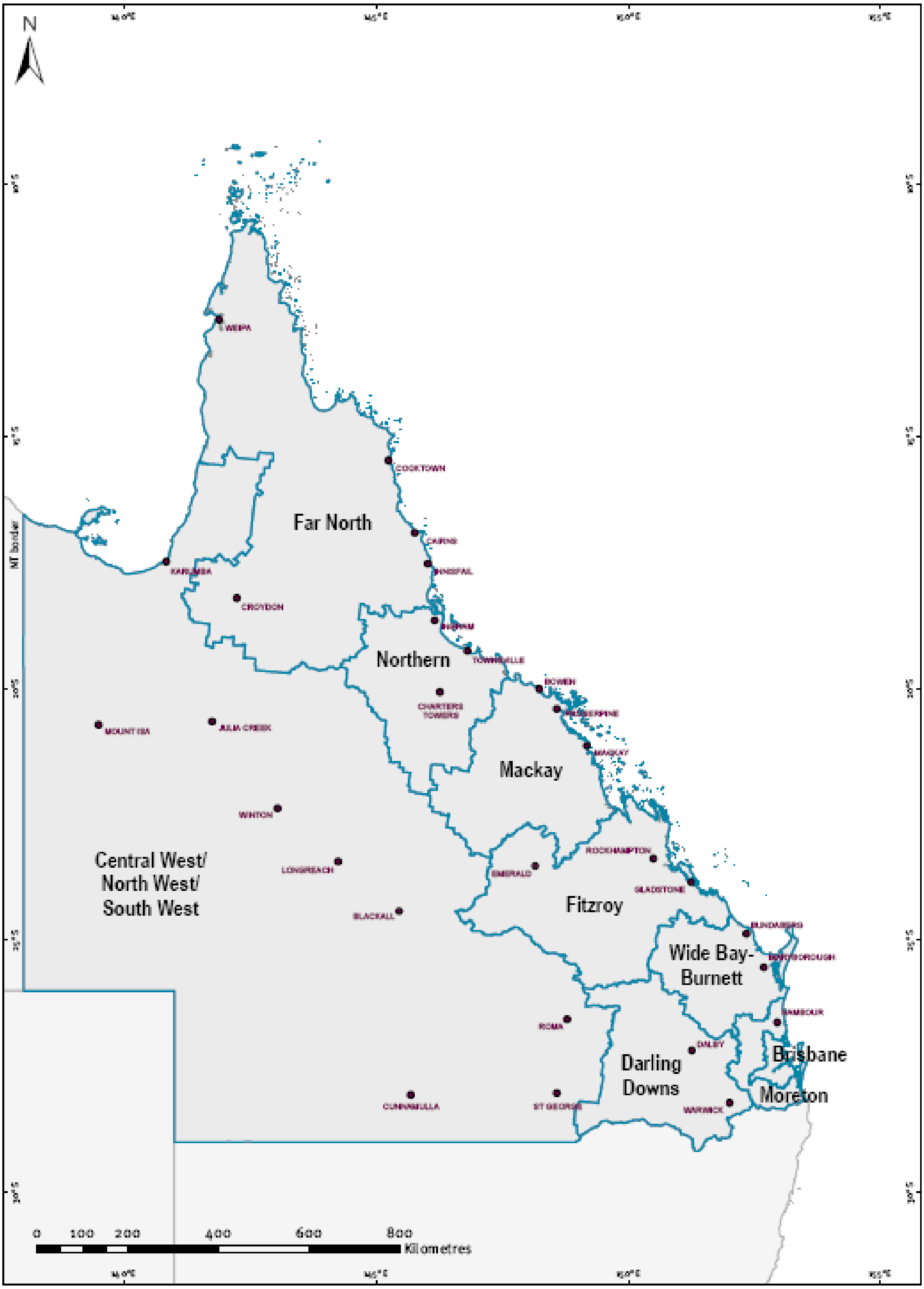
# Appendix




**Appendix a:** Estimates of statewide recreational catch in Queensland provided by the RFish (1999, 2002 & 2005) and NRIFS (2000, 2010 & 2013) recreational fishing surveys.






**Appendix b:** The nine residential regions of Queensland referred to in this study (image source: Taylor *et al.* 2012).