First implementation of an independent observer program for the charter boat industry of NSW: data for industry-driven resource sustainability

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Executive Summary

Overview: This project successfully completed the first observer-based program to assess kept and released catches in the coastal charter boat fishery in New South Wales (NSW), Australia. In doing so it (i) demonstrated the potential value of observer work for obtaining important information for resources assessments and management and (ii) assessed the accuracy of the data collected in the current industry-based logbook program. The project methodologies and results have applicability to other recreational fisheries in Australia and elsewhere.

Background: The recreational charter boat fishery is the single most valuable fishery in NSW providing an estimated annual $50.2 m of output to the economy from operators and their clients. As with any fishery, quantitative data on the diversity and sizes of retained and released catches, biological information on key species such as ages and reproductive capacity, as well as information about the areas and habitats fished, are required for (i) the sustainable management of the fishery and its stocks, and (ii) reporting on the status of these stocks to their public owners. Such data are also needed so that the industry itself can promote its viability and sustainability to its customers and other stakeholder groups.

There currently exists an ongoing logbook program in the NSW recreational charter boat fishery which is supposed to provide some of the above data to inform resource management. However, the data collected have not been independently validated and therefore may lack accuracy, compromising their utility in stock assessments, fisheries management and as a credible source of information for stakeholders. It is well-accepted that the best way to collect such fishery data, and to validate self-reported logbook data, is to use independent fisheries observer programs.

This project examined the feasibility of using an observer program to obtain kept and released catch information about this fishery, demographic data about the key species involved, and to assess the accuracy of the data collected in the current industry-based logbook program. As such, this study delivered the first step to implementing a data collection system in this fishery which will not only deliver scientifically rigorous, cost-effective and quantitative data about the fishery for its management, but also provide ongoing information about the overall status of recreationally harvested fish stocks throughout the state.

A**ims and objectives:** The specific project objectives were:

1. Deliver independent quantitative observer-based information on the diversity, rates of capture and length compositions of species retained and released from coastal charter boats in NSW
2. Obtain quantitative information on the ages and age compositions of catches of key fish species harvested by the coastal charter boat fishery in NSW
3. Provide summaries of analyses across appropriate spatial (e.g. within and among ports and regions) and temporal (e.g. across days, weeks, months, seasons) scales required for future cost-efficient sampling designs of charter boat observer-based monitoring of key recreational fish species for resource sustainability
4. Deliver summary profiles of charter boat cliental to industry
5. Compare on-board observer estimates of species retained and their rates of capture with industry logbooks for validation purposes
6. Assess the value of the above data for inclusion in resource assessments and determine appropriate sampling levels and strata for future resource surveys
7. Provide feedback to industry and management on project objectives (1-5) to inform future decision-making

Methodology: Scientific observers deployed aboard inshore coastal charter boats during standard fishing trips collected independent data on the diversity and composition of catches, and rates and lengths of all kept and released species. Sampling was strategically stratified spatially (two ports in each of three regions) and temporally (five seasons) to test for variability in kept and released catches across the fishery between December 2014 and February 2016. The observer collected data were compared to industry logbook data to assess the utility of the latter in monitoring the fishery and key harvested species.

Results and key findings: The project successfully developed and demonstrated the utility of a standardised observer-based sampling program in providing quantitative data for assessing the numbers and length compositions of kept and released catches across the charter boat fleet. A total of 181 trips were successfully observed, that yielded a total of 126 species of which 88 were kept and 92 released – highlighting the high diversity of catches taken within the fishery. Overall, between 34 and 85% of total individuals were kept depending on the season and region. There was considerable small-scale (among ports and habitats) as well as region-scale (latitudinal) variability in the compositions of catches and rates of catches of key species that need to be considered in deliberations concerning future sampling strategies. Legal length restrictions determined whether many species were kept or released, whereas for species without such restrictions it was dependent on client and operator preferences.

Mean catch rates of total kept individuals and most kept key species did not differ between the observer and industry logbook data sources. But compared to observed data, industry logbooks under-reported the mean diversity of kept catches and rates of catches of several species that included those kept for bait. Industry logbooks could be used as a primary source of monitoring catch rates of key kept species, but requires improved reporting by operators. Nevertheless, the logbooks do not provide data on released catches or the lengths of species either kept or released. Cost-effective monitoring of the fishery could be based on industry logbooks for catch, effort and CPUE information of key kept species and include a periodic (e.g. every 5 years) observer-based sampling strategy to monitor and report on levels of released catches and length (and age) compositions of kept and released organisms and be used to validate logbooks. Risk-assessment techniques would best determine the required periodicity for each type of observer-generated data.

Charter boat clients were predominately adult males (> 77%) across all ports examined. The proportion of private (whole boat) charters ranged from 0 to 95% depending on the port, with fishing clubs accounting for 24 to 44% of such charters. Family/social groups were important components of client groups for both private and public charters.

Implications for relevant stakeholders: This study provided the first quantitative estimates of the compositions and rates of kept and released catches in the NSW charter boat fishery. In doing so it demonstrated the utility and value of a standardised observer program for independently evaluating catches and the current logbook data. These data are valuable to management and industry for inclusion in any environmental assessment of the fishery and most importantly in determining future monitoring and assessment strategies for the fishery and key harvested species. The methods and results reported here have applicability to other recreational fisheries in other management jurisdictions in Australia and elsewhere.

Recommendations: The relevant management authorities need to (1) define the objectives and information requirements for managing the coastal charter boat fishery in NSW, (2) consider the costs, logistics and deliverables of the alternative data sources and sampling strategies, (3) design an appropriate long-term monitoring and assessment program that will deliver the necessary data for managing a sustainable and viable charter boat fishery in NSW.

Keywords: Recreational Fishing; Fishery Assessment; Observer Program; Management Evaluation; Monitoring Strategy; Sampling Design; Exploitation; Sustainable Harvest; Pay-For-Hire; Australia

1. Introduction

1.1. Background and Need

Ever since the time of Justinian the Great and the establishment of the so-called "Public Trust Doctrine" in 540AD, the general public in any society effectively owns the wild fisheries resources up to the point where fish are retained by fishers for sale or personal use. In most places, this has led to governments taking responsibility for these resources on behalf of the public along with those activities expected of anyone who is responsible for someone else's property: i.e. its stewardship, management, monitoring and reporting back to the owners. Yet, despite around 1500 years of this public ownership, it has only been during the last hundred years or so that governments have actively studied fishing activities and the fish stocks on which they depend. The past few decades has seen this work develop to the point where most jurisdictions now undertake monitoring of fisheries and stocks and regularly reporting to the public on their status.

There is also now growing acceptance that governments need to report on the status of bycatches and discards from fishing activities. This is because, while the public own fish right up to the point where they are retained for sale or personal use, for discarded fish, this public ownership is perpetual – i.e. the public own all discarded fish, all the time. So governments are now also expected to monitor, and report on, bycatches and discards to the public owners (see discussions in FAO 2015, Kennelly 2015).

There are many methods that have been used to monitor fisheries catches, bycatches and discards including: scientific surveys using research vessels, Coast Guard inspections, post-trip sampling of landings, post-trip interviews of captains and crews, and getting fishers to self-record data by completing logbooks at sea. But by far the most reliable and accurate way to collect data on actual catches, bycatches and discards in a fishery is through the use of onboard observer programs. These involve scientifically trained staff going on normal fishing operations and recording all relevant data as well as, if required, gathering biological samples of species (such as otoliths for ageing, gonads for studies on reproduction, stomachs for dietary studies, etc.). Many such programs now exist throughout the world and they have become a major, mainstream source of fisheries information for many uses, including the validation of fishers' logbook data.

The recreational charter boat fishery is the single most valuable fishery in New South Wales (NSW) providing an estimated annual $50.2 m of output to the NSW economy from operators and their clients (McIlgorm and Pepperell 2014). This is around twice the value of the most economically important commercial fishery in the state (the oceanic prawn trawl fishery). As with any fishery, quantitative data on the diversity and sizes of retained and discarded catches, biological information on key species such as ages and their reproductive capacity, and information about the areas and habitats fished, are required (i) to sustainably manage the fishery and its stocks and (ii) to report on the status of these stocks to their public owners. Such data are also needed so that the industry itself can promote its viability and sustainability to its customers and other stakeholders.

There currently exists an ongoing logbook program in the NSW recreational charter boat fishery which is supposed to provide the above data to inform resource management. However, the data collected are not independently validated and therefore may lack accuracy, compromising their utility in stock assessments, fisheries management and as a credible source of information for stakeholders. As mentioned above, it is well-accepted that the best way to collect such data, and to validate self-reported logbook data, is to use independent fisheries observer programs.

This present project examines the feasibility of such an observer program to obtain catch and discard information about this fishery, demographic data about the key species involved, and to assess the accuracy of the data collected in the current industry-based logbook program. As such, this study takes the first step to implementing a data collection system in this fishery which will not only deliver scientifically rigorous, cost-effective and quantitative data about the fishery for its management, but also provide ongoing information about the overall status of recreationally harvested fish stocks throughout the state.

2. Objectives

The specific objectives of the project are:

1. Deliver independent quantitative observer-based information on the diversity, rates of capture and length compositions of species retained and released from coastal charter boats in NSW

2. Obtain quantitative information on the ages and age compositions of catches of key fish species harvested by the coastal charter boat fishery in NSW

3. Provide summaries of analyses across appropriate spatial (e.g. within and among ports and regions) and temporal (e.g. across days, weeks, months, seasons) scales required for future cost-efficient sampling designs of charter boat observer-based monitoring of key recreational fish species for resource sustainability

4. Deliver summary profiles of charter boat clientele to industry

5. Compare on-board observer estimates of species retained and their rates of capture with industry logbooks for validation purposes

6. Assess the value of the above data for inclusion in resource assessments and determine appropriate sampling levels and strata for future resource surveys

7. Provide feedback to industry and management on project objectives (1-5) to inform future decision-making

3. Observer-based sampling of the kept and released catches in the NSW charter boat fishery

3.1. Overview

This project component used scientific observers to obtain information about retained and released catches from the coastal charter boat fishery in NSW.

As determined during consultation with NSW DPI Recreational Fisheries Management staff and the two nominated charter boat representatives from the NSW Advisory Council on Recreational Fishing (ACORF), this first observer-based survey focused on the so-called 'traditional' coastal charter boat operations – i.e. the inshore demersal reef and soft substrate fishing operators - not the specialised game fish charter operators, the deep water sea-mount fishing operations nor any newer 'boutique' operators that only take a very small number of clients for specialised fishing experiences. Whilst these latter three charter-fishing sectors are important, it was deemed more appropriate to initially implement and test the methodologies involving observers on the traditional (and far more common) charter operators.

Moreover, the traditional charter operations were considered to occur in a relatively homogenous manner along the coast, and across seasons and years, and thus potentially the fishery could provide a relatively consistent platform to collect relative abundance information (as catch-per-unit-effort) and demographic information on recreational fish species for inclusion in routine resource assessments. The pilot study outlined here was therefore strategically stratified spatially and temporally to test for variability in the diversity and composition of catches and rates and sizes of kept and released catches. Such pilot studies are required prior to the implementation of any large-scale survey that seeks to (in this case) to provide cost-effective options for monitoring key recreational fish species for resource assessment and, ultimately, sustainable fisheries management.

This chapter reports specifically on objectives 1, 2, 3, 6 and 7.

3.2. Methods

3.2.1. Sampling

The sampling of charter boat catches was stratified spatially across three geographic regions and temporally across five seasons between 1 December 2014 and 29 February 2016. Catches from charter boats based in two ports were sampled in each region: these were Wooli and Coffs Harbour in the North Region, Port Jackson and Port Hacking in the Central Region and Kiama and Shoalhaven in the South Region (Figure 3.1). Not all ports were sampled each season due to variable rates of operator participation during the sampling program.

Catch data were collected by scientific observers who accompanied regular charter fishing trips. For each trip, the charter operator was paid the normal per person charter fee for taking the observer. On each trip, the observer identified and counted all kept and released fish and, when possible, measured them for their length (nearest cm). They also collected operational information including the number of clients, fishing times, depth, bottom topography (as determined by the operator), fishing gear, bait types and general weather and sea conditions. This was done for each fishing event throughout each trip.

As requested by NSW DPI, when possible, observers extracted the sagittal otoliths (ear bones) of kept snapper, bluespot flathead, grey morwong and pearl perch for processing for age determination.

Logistic problems hampered some collections – for example, otoliths could only be collected when: (i) fish were cleaned on-board (not all operators clean fish or allow it on their boats), (ii) clients approved (some clients retained whole non-dissected fish, other clients required whole fish as part of a fishing competition), (iii) conditions permitted (available area on boat, rough weather) and (iv) the time and opportunity permitted - as the sampling priority for the observers was the counting and measuring of each organism landed on each boat.

3.2.2. Data Analyses

3.2.2.1. Catch Composition

Two- and three-factor permutational analyses of variance (PERMANOVA; Anderson 2001, Anderson et al 2008) were used to test for differences in the compositional structure of total, kept and released catches among regions, ports and seasons. The catch data for each observed fishing trip were used as the replicate samples in each analysis. One-factor PERMANOVAs were used to test for habitat-related differences in the composition of catches separately for each region, as not all habitats were fished across all regions. Analyses were done on raw and standardised data for the total, kept and released catch components. Theses multivariate analyses were based on the Bray-Curtis dissimilarity measure, and Type III (partial) sums-of-squares were calculated using 9999 unrestricted permutations of the raw data. Where appropriate, separate pair-wise comparisons were subsequently used to determine which levels of each significant factor differed for each level of the other factor using the PERMANOVA routine. The proportion of variation attributable to each factor and interaction term in each model was calculated to aid the interpretation of the results. Similarity percentage analyses (SIMPER) were used to identify individual species that contributed greatest to differences in the compositional structure of catches among regions and seasons. All analyses were done using the Primer 6 and Permanova+ programs (Clarke 1993, Anderson et al 2008).

3.2.2.2. Catch Rates

Two-factor permutational analyses of variance were used to test for differences among regions and seasons in the rates of kept and released catches of total individuals and key species. Catch rates were examined as catch-per-trip, catch-per-hour fished, catch-per-client and catch-per-client/hour fished. Each univariate analysis was based on the Euclidean distance measure (Anderson et al., 2008) and Type III (partial) sums-of-squares were calculated using 9999 unrestricted permutations of the raw data. Where appropriate, separate pair-wise comparisons were subsequently used to determine which levels of each significant factor differed for each level of the other factor using the PERMANOVA routine. The proportion of variation attributable to each factor and interaction term in each model was calculated to aid the interpretation of the results. All analyses were done using the Primer 6 and Permanova+ programs.

3.2.2.3. Length and Age Compositions of Key Species

The lengths for each key species (kept and released) were aggregated across all observed trips for each region and graphically displayed.

Counts of completed opaque zones on sectioned sagittal otoliths were used to estimate the age all four species of fish. One otolith from each sampled fish was embedded in resin and a modified high speed gem cutter was used to obtain four transverse sections (each about 300µm thick). The resulting sections were mounted on glass slides, viewed under transmitted light and total counts and measurement widths of successive opaque zones were made between the primordium and otolith edge for the clearest section of each otolith. Counts were repeated for 25% of samples for quality control and a resulting index of average percentage error (IAPE) value determined (Beamish and Fournier 1981). All readings were done without knowledge of the length, sex or location of capture of each sample. A final age was determined using an algorithm that included assumed birth date (based on published reproductive data) and the month of capture. This ageing work was outsourced to Fish Ageing Services Pty Ltd (Australia).

The length-at-age data for each species were used to develop an age-length key for each species. These keys were applied to the appropriate length compositions of kept catches so to provide corresponding age compositions of kept catches of each species.

3.3. Results

3.3.1. Fishing Methods

The observed vessels ranged in length from 10 to 15 m and were licenced to carry a maximum of 9 to 35 passengers. The fishing gears used by clients were mostly provided by the operators but some clients (particularly those associated with fishing clubs) supplied their own gears that differed slightly to that described below.

Rod and non-electric reels were typically used with a Paternoster hook and sinker rig. Typically, two hooks were used in the central and southern regions, but one vessel used only one hook in the North. Bait usually consisted of a mixture of frozen squid, pilchards and prawns but was often supplemented with fresh fish caught *in-situ* (typically blue mackerel, sergeant baker and yellowtail scad - see below). All observed trips in the central and south regions typically drifted across fishing grounds, but for many fishing events in the northern region, vessels anchored at specific reef locations. Whilst demersal fishing operations were specifically investigated here, the trolling of surface-orientated lures to and from the demersal fishing grounds was observed across all regions, but its practice varied greatly among vessels and clients.

3.3.2. Sampling Coverage

A total of 181charter boat trips were successfully sampled by observers (Table 3.1). The number of sampled trips varied among seasons within each region, ranging from 8 to 17 trips. Inclement weather and variable trip availability caused the variations in the numbers of trips sampled each season. Most sampling was done on weekends, with few weekday trips being sampled outside the summer holiday period.

The mean number of clients per trip varied significantly according to region and season (PERMANOVA, $P < 0.05$), with the pairwise comparisons identifying that, on average the least number of clients occurred in southern region. The average number (across all seasons) of clients on trips was 9.4, 12.1 and 8.6 for trips in the north, central and southern regions, respectively, with the number being partially dependent (range 4 to 23 persons) on the vessels' carrying capacities. The mean number of clients also varied across seasons (Figure 3.2), but the pairwise comparison failed to distinguish logical patterns. Observed fishing time also varied significantly among regions (PERMANOVA, $P < 0.001$) but not season ($P > 0.05$). Average fishing time was less (6.3 hours) in the north compared to 7.7 and 7.3 hours in the central and southern regions (Figure 3.2). Observed trip times ranged from 1.5 to 9.5 hours.

The number of fishing events (i.e. locations/drifts/anchored and not counting trolling for pelagic species) observed per trip varied from 1 to 18, with individual events varying from < 5 to 80 minutes long. Observed fishing occurred in depths ranging from 10 to 130 m, but most took place between 30 and 80 m. Substratum types varied from bare sand to complex reef and reef/gravel habitats and their combinations.

3.3.3. Overall Catch Composition and Diversity

A total of 126 species were observed in catches across the three regions and five seasons, of which 88 and 92 species were kept and released, respectively (Table 3.1). Overall, 70% (range 51-91% among regions and seasons) of species were kept. A similar total number of kept species were observed across the three regions but a greater number of total and released species were observed in catches in the north compared to the central or south regions. Consequently, a greater proportion of total species was released in the north (44%) compared to the other two regions (21 and 10%).

A total of 13357 individuals were sampled in catches during the 181 observed trips (Table 3.1). Overall, 62% (range 42-74% among regions and seasons) of individuals were kept. Similar numbers of total individuals were caught across the three regions, but a greater proportion of these were released in the northern compared to the central and southern regions (Table 3.1).

Snapper and bluespot flathead were key species (kept and released) in all regions, whilst ocean leatherjacket, redfish, grey morwong, ocean perch, eastern blackspot pigfish and maori wrasse were more prominent (particularly in kept catches) in the central and southern regions compared to the north (Table 3.2). Other species prominent in catches across all regions included sweep, sergeant baker and eastern red scorpionfish (Table 3.2).

3.3.4. Spatial and Temporal Variability in Catch Compositions

Spatio-temporal relationships of the composition of total, kept and released catches were complex as they significantly differed among regions and seasons and their interaction, and this was consistent for the raw and standardised data (PERMANOVA, Table 3.3, Figure 3.3). Nevertheless, the pairwise comparisons identified that differences in kept, released and total catch compositions among regions were consistent across seasons ($P < 0.05$ in all cases), but differences among seasons were not consistent among regions. For example, there were no significant ($P > 0.05$) differences in the composition of kept catches between the two sampled summer seasons in central and southern regions, but they significantly ($P < 0.01$) differed in the northern region. Similarly, for released catches, there was no significant ($P > 0.05$) difference in catches between autumn and spring in the central and southern regions, but they significantly ($P < 0.001$) differed in the northern region.

Variability in compositional structure among individual catches (the residual term in the analyses) accounted for approximately 50% of the variation among the terms in each analysis (Table 3.3). Regions contributed greater variation than seasons in all analyses (Table 3.3), highlighting the importance of small- and large-scale geographic variabilities in catch compositions.

The SIMPER analyses identified the species that contributed greatest to characterising catches within each region (Table 3.4). Snapper and bluespot flathead contributed greatest to similarity among catches (kept and released) in the north. Pearl perch and teraglin were also important in distinguishing kept catches in the north. Snapper and bluespot flathead were the most important species in characterising released catches in the central region, but ocean leatherjacket, redfish and grey morwong were more important in characterising kept catches. In the south, grey morwong and snapper contributed greatest to characterising kept catches, and snapper and sergeant baker to the released catches (Table 3.4).

Significant differences in the compositions of kept, released and total catches were also evident between the two sampled ports within each region (Table 3.5). These differences were driven by particular species being caught in different quantities and frequencies across catches. The five species that contributed greatest to the dissimilarities of kept, released and total catches between the two ports within each region are listed in Table 3.6. Some species were important in distinguishing catches across regions and kept and released catches; for example, bluespot flathead were on average caught (kept and released) in greater quantities from Coffs Harbour than Wooli, Sydney than Port Hacking and Shoalhaven than Kiama (Table 3.6).

The habitat fished (substratum type) also played a significant (PERMANOVA, $P < 0.001$ in all six analyses) role in distinguishing the composition of kept and released catches across all regions. In particular, the pairwise tests identified that kept and released catches on sand differed significantly to those taken on reef and reef/gravel locations. The primary species driving such differences was bluespot flathead (Table 3.7), which was most prevalent and contributed greatest to the similarity of kept and released catches from the sand habitat. Differences in kept and released catches between reef, gravel and reef/gravel locations were less obvious and not consistent across regions as the primary species contributing mostly to the similarity of catches were similar across these habitats. Nonetheless, the pairwise test distinguished significant ($P < 0.05$) differences in the composition of kept and released catches among reef and reef/gravel catches in the northern and central regions, but not in the south ($P > 0.05$). Snapper, grey morwong and redfish were important in characterising kept catches along with sergeant baker for released catches across both reef and reef/gravel habitats across regions (Table 3.7).

3.3.5. Catch Rates of All Individuals and Key Species

The catch rates of total individuals and snapper (and other species not shown here for brevity) displayed the same patterns across each of the four data standardisations (i.e. catch per: trip, fished hour, client and client/hour) (Figures 3.4 and 3.5). Consequently, to reduce repetition, all further analyses and results are reported as catch per trip. Nevertheless, these data showed that, on average, each fishing client took home between 2 and 8 individual fish and between 0.1 and 2.2 snapper per trip depending on the region and season. The mean number of the ten most abundant kept species retained per client per trip from each region (pooled across seasons) is provided in Table 3.8.

The mean numbers of total species and individuals caught were significantly influenced by region and such differences were generally consistent across seasons (Table 3.9). The greatest number of kept species was in the south and least in the north, and likewise the mean number of released species was greatest in the north and least in the central region (Figure 3.6).

Geographic region had a significant influence on kept and released catches of all key species (Table 3.9, Figures 3.7-3.10). Notably, mean kept and released catches of snapper were significantly greatest in the north, whereas the opposite was evident for kept and released catches of redfish, ocean perch and kept catches of grey morwong, ocean leatherjacket and sergeant baker. Greatest kept and released catches of sweep and maori wrasse were evident in the south, tiger flathead in the central region, and pearl perch and teraglin in the north (Figures 3.7-3.10).

Season had less of an influence on kept and released catches, significantly influencing kept and released catches of snapper which were generally greatest in Autumn and Winter (Figure 3.7). Kept and released catches of bluespot flathead were more complex, being significantly influenced according to the interactions between region and season. Pairwise comparisons identified that greatest kept and released rates occurred in the spring and winter in the northern region, but no such patterns were evident further south (Figure 3.7).

3.3.6. Length Compositions of Key Species

The length compositions of the kept and released catch components of several key species are shown in Figures 3.11-3.16. Where comparisons could be made, the length compositions of catches of most key species were similar across regions, the notable exceptions being sweep and ocean leatherjacket (Figures 3.11-3.16). For species with a mandated legal length like snapper, pearl perch, bluespot flathead and tiger flathead, the kept versus released split coincided with the legal length restrictions. For several species such as redfish, ocean perch, sergeant baker and eastern red scorpionfish that have no prescribed legal length, the length compositions of the kept and retained catch components were similar, due to personal choices of skippers, crew and clients.

3.3.7. Age Compositions of Key Species

Ages of sampled kept fish ranged between 2-16 years for snapper, 1-8 years for bluespot flathead, 4-18 years for grey morwong and 3-8 years for pearl perch (Figure 3.17). The age compositions of kept catches were dominated primarily by young fish; snapper 3-7 years, bluespot flathead 2-4 years, grey morwong 6-9 years, pearl perch 4-5 years (Figure 3.18). Regional differences in age compositions of kept catches of bluespot flathead and snapper were evident; kept bluespot flathead catches were dominated by 3 and 4 year olds in the north, but 2 and 3 year olds in the central/southern region, and for snapper - 3 to 9 years of age in the north, and 3 to 5 year olds in the central/southern region (Figure 3.18).

3.4. Discussion

3.4.1 Assumptions

In observer studies such the one described here, several assumptions are usually required, including one that observed trips were representative of those done by similar operators and that the fishing locations, times and practices covered were not influenced by the presence of an observer. To try to ensure this, we attempted to select the days and vessels to be observed at random among those available in each region. However, most observed trips were done on weekends and were often clumped due to inclement weather conditions. Further, not all operators within a region participated in this voluntary project even though operators received payment (the normal per-person fee) for hosting an observer. Nevertheless, the times and locations fished were generally similar across all vessels (observed and not observed) from each port. Most importantly, the charter operators had to satisfy their paying clients making it unlikely that they did anything different when an observer was present. Future observer-based programs in this, as well as other recreational charter fisheries would be better served if observer placement was made mandatory and a condition of licences – as is the case in the most successful and professional observer programs done in commercial fisheries worldwide (e.g. papers in McVea and Kennelly 2007, NMFS 2011).

3.4.2. Catch Compositions and Catch Rates

The data presented here revealed several general patterns concerning the composition and rates of catches of coastal demersal charter boat operations throughout NSW. Notably, the composition of catches (both kept and released) was diverse, exceeding the diversity quantified in the co-occurring inshore coastal commercial line fishery (Macbeth and Gray 2016). Nevertheless, the primary species retained (e.g. snapper, bluespot flathead, grey morwong, sweep) were similar across both these fisheries and, in general, mirrored that taken in the coastal recreational trailer boat fishery (Steffe and Murphy 2011). Taken in combination, these studies show that these different fishing sectors compete for the same primary resources, indicating that one needs to consider the impacts of all these harvest sectors in species assessments and consequent management arrangements.

The observed kept catch was more diverse and greater than the released catch in the central and south regions, but the opposite occurred in the north. The reasons for such overall differences are not clear, but probably reflects client and operator preferences, perceived quality, and levels of overall catches - especially those of key species such as snapper and bluespot flathead. Regardless of the reasons, this variation demonstrates that no overall generalisations concerning rates of releasing species can be made across the entire fishery, an important consideration for any environmental assessment of the fishery, and for the development of management arrangements for the fishery.

3.4.2.1 Spatial Patterns

Geographic region (latitude) was a strong driver of the variation in total, kept and released catch composition and corresponds with latitudinal clines of marine fauna distributions along the east Australian coast (Malcolm et al 2007) and that displayed in other regional fisheries (Kennelly et al 1993, Gray and Kennelly 2003, Macbeth and Gray 2016). Specifically, the northern region sampled here borders the convergence zone of tropical and temperate waters (Suthers et al 2013), with catches having more occurrences of warm water ichthyofauna such as venus tusk fish, samsonfish and pearl perch. Whilst catches in the central and southern regions contained more temperate cold water species such as ocean perch, redfish, grey morwong and specifically eastern orange perch and southern maori wrasse. It is therefore likely that the compositions of charter boat catches beyond the regions covered here would also vary as a result of differing latitudes and corresponding environmental conditions.

Smaller-scale geographic differences in catches were also evident as differences between ports within a region, with certain species being more or less frequent and abundant in catches from vessels from one port compared to the other. Such differences were the result of localised and often vessel-specific differences in fishing practices, fishing grounds, the habitats fished and client requirements. For example, in the central region, kept and released catches of bluespot flathead (but none of the other key species) were on average greater on vessels based in Sydney than those based in Port Hacking. The Sydney vessels typically targeted flathead occurring on bare substrata adjacent to the harbour entrance. In contrast, vessels from Port Hacking typically fished a variety of habitats and locations, providing a broader range of fishing conditions, encountering a greater range of species and therefore different types of fishing experiences than the Sydney vessels. Importantly, the primary clientele in each port and their expectations also varied, with the Sydney vessels particularly catering more for tourists and local persons desiring a “Sydney fishing and sightseeing experience”. The Port Hacking clientele were generally more experienced fishers, including regular fishing club members fishing for specific purposes (Appendix 4).

Some port-related differences in catch composition and catch rates were most likely related to local seabed topography and depth along with the targeting practices of individual operators taking consideration of client requirements. For example, in the northern region, the Wooli-based fishing practices often involved anchoring and targeting particular reefs specifically for snapper and did not fish bare substrata, whereas the Coffs Harbour-based practices targeted both reef fish (drifting) and flathead inhabiting sand habitats (hence greater catches of bluespot flathead). Similarly, in the southern region, the catches from Kiama primarily contained reef-associated species, whereas those from the adjacent Shoalhaven contained more flathead, where available sand habitat was more pronounced and fished.

The habitat fished, particularly reef versus bare sand, played a significant role in distinguishing and characterising kept and released catches within each region. Nonetheless, differences in catch compositions among reef, gravel and reef/gravel habitats were less clear as many species were common to all such habitats. Importantly, most vessels drifted whilst fishing and given the general complex spatial heterogeneity of habitats, any particular fishing event could cover a mixture of habitats. This potentially confounded comparisons among the latter habitats as it was not possible to explicitly define in all instances the exact habitat each species was captured within each fishing event, but only the general habitat as defined by the operator.

Depth impacted some catches with observed depths fished varying from 10 to 130 m. Notably, some species such as mado were primarily caught in shallow waters whereas other species such as snapper and grey morwong were caught across all depths. The depth and the habitat fished often changed within each fishing trip, precluding one to identify a “typical” day’s fishing and associated catch characteristics, as it depends on sea/wind conditions and client preferences, particularly for private charters where the entire boat is hired. Nevertheless, some observed trips followed a pattern of targeting reef species first then moving to flathead grounds prior to returning to port.

Given both the considerable small- and large-scale spatial variability in kept and released catches documented here, it is reasonable to assume that charter boat catches across other ports along the east Australian coast would also differ depending on factors such as those discussed above. Any future stratified monitoring survey of catches should account for the small-scale port-to-port variability and the larger-scale regional variability in catch composition and abundances of individual species detected here.

3.4.2.2. Temporal Patterns

Seasonal differences in catch compositions and catch rates of key species were subtle and less influential on characterising catches than spatial differences. This coincides with that observed for reef-associated species along the NSW coast in other studies (e.g. Malcolm et al 2007). Temporal differences in catches were typically region-specific, most likely being influenced by local environmental and fishing conditions such as water temperature, current direction and strength and their effects on the behaviours and catchability of resident and transient species. There was some evidence that species like snapper and grey morwong were more prevalent in winter and others like ocean leatherjacket in summer. However, such trends were not consistent across all regions. Although this study mainly covered ground fishing, seasonal pelagic species such as dolphin fish were observed in summer catches. However, before definitive assessments of the influence of temporal scales on catches can be made, additional years should be examined to determine if the patterns detected here remain consistent over greater periods of time.

3.4.3. Lengths of Fish

Mandated legal length restrictions drove the division of kept and released lengths of several species, notably snapper, bluespot flathead and tiger flathead, with those below the MLL being released. However, for a raft of other species with no prescribed legal length, the choice to keep or release each individual fish was driven by the clients, and to a lesser extent the operators. Some clients kept fish of all lengths, whereas others were more selective - only keeping larger individuals, or releasing all individuals irrespective of their length. For several species such as eastern red scorpionfish, redfish and sergeant baker, the combined length compositions of kept and released components of catches were therefore similar.

Interestingly, several of these secondary (or ‘less desired’) species (e.g. eastern red scorpionfish) were mostly all released in the northern region, whereas a greater proportion of them were kept in the central and southern regions. These differences in release behaviours may reflect regional differences in client preferences and/or the general condition of fish assemblages. Greater quantities of the more desired species such as snapper in the north with catches in central and southern regions containing greater proportions of secondary species. This could potentially be the result of greater overall fishing effort and pressure on resources in the central and southern regions compared to north.

The length compositions identified in this study of kept catches of several species, especially those with prescribed legal lengths, were similar to those documented in the coastal trailer boat fishery (Steffe and Murphy 2011). This was particularly evident for snapper, grey morwong, bluespot flathead and sweep. For species such as snapper, most kept individuals were within 5 cm of the legal length - as observed in the coastal commercial trap and line fishery (Stewart and Hughes 2008). However, the length compositions of kept catches of several species (e.g. snapper, pigfish, southern maori wrasse, grey morwong) differed to those reported for charter boat kept catches measured by the actual charter boat operators between 2001 and 2003 (see graphs in Stewart and Hughes 2008, and Chapter 5). Notably, a greater proportion of longer individuals were evident in the logbook data for all species; the reasons for which are unclear as the data covered different years and potentially regions (see Chapter 5). Thus. the potential of industry-based sampling of fish lengths as a monitoring strategy in this fishery remains to be determined.

An additional, somewhat tangential observation was that some species (e.g. blue mackerel, yellowtail scad and sergeant baker) were kept and used in-situ as bait by the whole boat. Although some clients took some of these species home, mostly they were incorporated into the bait supply for the actual trip or were kept by the operator for bait on a later trip. Actual levels of bait retainment were not quantified, but it is an important component of overall kept catch.

For released fish, no attempt was made here to assess any physical damage or rates of survival upon release as our focus was on recording what was actually captured. Nevertheless, this is an important avenue of research that has recently received considerable attention both regionally (Butcher et al 2012, Broadhurst et al 2012) and internationally (Cooke and Schramm 2007). Although permitted, no release-assistance methods such as the use of release weights or venting of fish were observed during our study.

3.4.4. Ages of Key Species and Age Compositions of Catches

The age compositions of kept catches of snapper were dominated by fish < 6 years of age which is similar to that reported for the commercial fishery in NSW since the MLL was increased to 30 cm TL (Stewart and Hughes 2008). Likewise, kept catches of pearl perch were also dominated by young fish (4 and 5 years), although too few samples were collected here for quantitative comparisons, commercial catches have been reported to be dominated by fish between 3 and 6 years (Stewart and Hughes 2008). In comparison and although sample sizes were low, kept catches of grey morwong sampled here were dominated by fish aged between 6 and 9 years, whereas 2 to 6 year olds have dominated commercial catches (Stewart and Hughes 2008). Notably, the length compositions of kept catches also differed between sectors with smaller sizes being taken in the commercial fishery. Young fish also dominated kept catches of bluespot flathead, which is typical of other flathead species (Gray and Barnes 2015).

There were several logistic issues concerning collecting otoliths in-situ aboard charter boats. For example, some vessels did not permit cleaning of fish onboard, with anglers having to retain whole fish. Moreover, many fishing club events (that dominated observed trips in some regions) required retainment of whole fish for competition weigh-ins. Consequently, observers could not sample otoliths of these fish in-situ. Nevertheless, whilst the observers attempted (and some successfully) to accompany some clients to adjacent cleaning facilities to collect otoliths, the majority left the area immediately following disembarkation. For those clients that observers did accompany, most often only a few otoliths could be collected before the clients completed cleaning their fish and left. Most otoliths were collected at sea when the crew cleaned clients fish, the timing of which varied from immediately upon capture to most often, as bulk lots between and during fishing events. This limited the time available to collect otoliths as observers were concentrating on recording numbers and lengths of kept and released fish as they were captured. Moreover, the often confined, or lack of, bench space combined with vessel movement further limited opportunities to dissect fish and collect otoliths. Success of otolith collection was also dependent on the species, as some species have large and easy to retrieve otoliths (e.g. snapper, flathead), others have very small otoliths that are difficult to locate even in the laboratory, and this was exacerbated on a moving vessel. In some circumstances, the vessel operators did not allow observers to use dissecting items (knife) due to inclement weather conditions.

The collection of otoliths aboard charter boats will remain problematic in many circumstances and will greatly depend on individual vessels, crew and the clients. Moreover, many trips will need to be sampled to collect adequate sample sizes of otoliths for some species. For example, only 69 legal sized pearl perch were encountered (and 53 otoliths collected) across 181 trips.

Importantly, the cost effectiveness of collecting age-based data from charter boat catches for longitudinal monitoring of key species needs to be evaluated comparatively against other collection strategies, such as the voluntary donation of fish frames, sampling otoliths from recreational trailer boat catches and at commercial fisheries cooperatives. Nevertheless, the data are a potential source of recreational fisheries input into stock assessments, which is lacking at present. As encountered here and also identified by industry members, it would be logistically difficult to rely on a dockside otolith collection strategy in this fishery.

3.4.5. Conclusions

This study has provided the first scientific information about important facets of the large charter boat fishery in NSW for the consideration and use by industry, management, scientific and conservation agencies. In particular, these data are valuable for inclusion in any fishery, resource sustainability or environmental impact assessments as well as for promotional material for the sector. Despite the clear value of the work described here, further work that incorporates broader temporal and spatial components is required to make generalisations of catches across different years and places. Moreover, other charter fishing sectors that target different species and habitats require similar investigations. But despite the need for such ongoing research, this study has demonstrated the value and utility of observer work in providing independent information, not only about this fishery, but also about the demographics of the common fish species living off the coast of NSW. As such, the data obtained here will prove invaluable for designing and implementing any ongoing monitoring programs to assess, and report on, the stocks of such species.

Table 3.1. Summary of the total number of trips, species and individuals kept and released across the three regions and five seasons.

	Trips Completed	Species Retained	Species Released	Species Total	Species % Retained	Individuals Retained	Individuals Released	Individuals Total	Individuals % Retained
North									
Summer 1	17	27	42	53	50.9	339	647	986	34.4
Autumn	14	38	36	55	69.1	479	578	1057	45.3
Winter	8	21	25	33	63.6	307	426	733	41.9
Spring	11	17	29	35	48.6	413	572	985	41.9
Summer 2	9	15	23	29	51.7	264	256	520	50.8
Total	59	50	67	89	56.2	1802	2479	4281	42.1
Central									
Summer 1	15	27	23	34	79.4	1017	183	1200	84.8
Autumn	14	31	16	34	91.2	749	189	938	79.9
Winter	13	27	21	31	87.1	430	274	704	61.1
Spring	13	26	19	32	81.3	439	161	600	73.2
Summer 2	8	23	16	30	76.7	533	276	809	65.9
Total	63	49	40	62	79.0	3168	1083	4251	74.5
South									
Summer 1	10	27	16	31	87.1	654	202	856	76.4
Autumn	13	33	27	41	80.5	565	373	938	60.2
Winter	14	27	23	32	84.4	752	277	1029	73.1
Spring	13	30	22	35	85.7	800	329	1129	70.9
Summer 2	9	31	25	35	88.6	593	280	873	67.9
Total	59	53	36	59	89.8	3364	1461	4825	69.7
Overall	181	88	92	126	69.8	8334	5023	13357	62.4

Table 3.2. The total number of each kept and released species caught in each region and the percent kept. (Page 1/3)

	North				Central				South				Total			
Species: Common Name	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**
Snapper	613	830	1443	42.5	135	73	208	64.9	337	182	519	64.9	1085	1085	2170	50.0
Bluespot Flathead	413	399	812	50.9	185	399	584	31.7	193	120	313	61.7	791	918	1709	46.3
Ocean Leatherjacket	9		9	100.0	982	6	988	99.4	175	8	183	95.6	1166	14	1180	98.8
Redfish	1	64	65	1.5	427	76	503	84.9	348	171	519	67.1	776	311	1087	71.4
Grey Morwong	65	7	72	90.3	329	15	344	95.6	468	20	488	95.9	862	42	904	95.4
Sweep	40	166	206	19.4	26	4	30	86.7	359	165	524	68.5	425	335	760	55.9
Sergeant Baker	19	182	201	9.5	109	39	148	73.6	128	159	287	44.6	256	380	636	40.3
Blue Mackerel	20		20	100.0	177	17	194	91.2	327	8	335	97.6	524	25	549	95.4
Tiger Flathead	30	17	47	63.8	177	188	365	48.5	67	23	90	74.4	274	228	502	54.6
Ocean Perch		3	3	0.0	237	86	323	73.4	85	89	174	48.9	322	178	500	64.4
Eastern Red Scorpionfish	5	291	296	1.7	51	16	67	76.1	33	35	68	48.5	89	342	431	20.6
Mado		70	70	0.0	1	16	17	5.9	7	166	173	4.0	8	252	260	3.1
Eastern Blackspot Pigfish	20	4	24	83.3	56		56	100.0	138	5	143	96.5	214	9	223	96.0
Maori Wrasse		10	10	0.0	13	2	15	86.7	168	25	193	87.0	181	37	218	83.0
Yellowtail Scad	83	12	95	87.4	29	2	31	93.5	69	13	82	84.1	181	27	208	87.0
Longfin Perch		2	2	0.0	64	7	71	90.1	96		96	100.0	160	9	169	94.7
Pearl Perch	68	91	159	42.8					1		1	100.0	69	91	160	43.1
Longfin Pike		1	1	0.0	30	10	40	75.0	60	57	117	51.3	90	68	158	57.0
Silver Trevally	59	33	92	64.1	11	2	13	84.6	33	7	40	82.5	103	42	145	71.0
Yellowtail Kingfish	15	96	111	13.5		10	10	0.0	7	13	20	35.0	22	119	141	15.6
Barracouta					12		12	100.0	51	61	112	45.5	63	61	124	50.8
Teraglin	109	7	116	94.0	3		3	100.0	1		1	100.0	113	7	120	94.2
Longspine Flathead	7	8	15	46.7		75	75	0.0		23	23	0.0	7	106	113	6.2
Eastern Orange Perch									53	25	78	67.9	53	25	78	67.9
Southern Fusilier	53	1	54	98.1									53	1	54	98.1
Painted Grinner		46	46	0.0		1	1	0.0						47	47	0.0
Marbled Flathead	11	2	13	84.6	10	4	14	71.4	14	5	19	73.7	35	11	46	76.1
Red Gurnard	1		1	100.0	39	2	41	95.1	4		4	100.0	44	2	46	95.7
Venus Tuskfish	42	3	45	93.3									42	3	45	93.3
Dolphinfish	26	13	39	66.7	1	1	2	50.0	1		1	100.0	28	14	42	66.7
Six Spine Leatherjacket					4		4	100.0	35		35	100.0	39		39	100.0
Samsonfish	23	4	27	85.2					5		5	100.0	28	4	32	87.5
Halfbanded Seaperch		1	1	0.0	6	3	9	66.7	4	16	20	20.0	10	20	30	33.3
Butterfly Perch						1	1	0.0	17	9	26	65.4	17	10	27	63.0
Bonito	1		1	100.0	13	1	14	92.9	11		11	100.0	25	1	26	96.2
Moses Perch	5	3	8	62.5					5	13	18	27.8	10	16	26	38.5
Tarwhine	9	13	22	40.9									9	13	22	40.9
Velvet Leatherjacket					2	2	4	50.0	9	9	18	50.0	11	11	22	50.0
Red Spot Whiting		3	3	0.0	4	2	6	66.7	8	4	12	66.7	12	9	21	57.1
Blackbanded Seaperch		3	3	0.0					1	14	15	6.7	1	17	18	5.6
Crimson Banded Wrasse		9	9	0.0	2		2	100.0	4	1	5	80.0	6	10	16	37.5
Blackspot Goatfish	4	6	10	40.0					4		4	100.0	8	6	14	57.1
Blacktip Rockcod		14	14	0.0										14	14	0.0
Smooth Golden Pufferfish					1	10	11	9.1					1	10	11	9.1
Banded Seaperch					1	1	2	50.0	5	2	7	71.4	6	3	9	66.7

Table 3.2. Continued (2/3).

	North				Central				South				Total			
Species: Common Name	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**
Sharpfin Barracuda	9		9	100.0									9		9	100.0
Yellowfin Bream	1	7	8	12.5									1	7	8	12.5
Amberjack	4		4	100.0					3		3	100.0	7		7	100.0
Jack Mackerel	2		2	100.0	1		1	100.0	3	1	4	75.0	6	1	7	85.7
Latchet									7		7	100.0	7		7	100.0
Tailor					7		7	100.0					7		7	100.0
Bluestriped Goatfish	1	3	4	25.0	1		1	100.0	1		1	100.0	3	3	6	50.0
Gummy Shark		5	5	0.0					1		1	100.0	1	5	6	16.7
Mackerel Tuna	3	1	4	75.0					2		2	100.0	5	1	6	83.3
Banded Rockcod					1		1	100.0		4	4	0.0	1	4	5	20.0
Eastern Fiddler Ray		3	3	0.0		2	2	0.0						5	5	0.0
Giant Cuttlefish					1		1	100.0		4	4	0.0	1	4	5	20.0
Jackass Morwong					1		1	100.0	4		4	100.0	5		5	100.0
Maori Rockcod	3	2	5	60.0									3	2	5	60.0
Rainbow Runner	5		5	100.0									5		5	100.0
Almacojack	4		4	100.0									4		4	100.0
Eastern Wirrah		3	3	0.0	1		1	100.0					1	3	4	25.0
Elegant Wrasse		4	4	0.0										4	4	0.0
Pink Tilefish					4		4	100.0					4		4	100.0
Southern Smiler		4	4	0.0										4	4	0.0
Dogfish					2	1	3	66.7					2	1	3	66.7
Gemfish					1		1	100.0	2		2	100.0	3		3	100.0
Ghost Flathead	1	2	3	33.3									1	2	3	33.3
Green Moray Eel		3	3	0.0										3	3	0.0
Mulloway	2		2	100.0		1	1	0.0					2	1	3	66.7
Skipjack Tuna					2		2	100.0	1		1	100.0	3		3	100.0
Southern Calamari					1		1	100.0	2		2	100.0	3		3	100.0
Splendid Perch									3		3	100.0	3		3	100.0
Unicorn Leatherjacket	2		2	100.0					1		1	100.0	3		3	100.0
Variegated Lizardfish		3	3	0.0										3	3	0.0
Black Cod		2	2	0.0										2	2	0.0
Eastern Striped Trumpeter		2	2	0.0										2	2	0.0
Imposter Trevally	2		2	100.0									2		2	100.0
Moon Wrasse		2	2	0.0										2	2	0.0
Shortfin Mako					2		2	100.0					2		2	100.0
Silver Dory										2	2	0.0		2	2	0.0
Spanish Mackerel	2		2	100.0									2		2	100.0
Three Barred Porcupinefish						2	2	0.0						2	2	0.0
Triggerfish		2	2	0.0										2	2	0.0
Wahoo					2		2	100.0					2		2	100.0
Yellowfin Tuna	2		2	100.0									2		2	100.0
Bartailed Flathead		1	1	0.0										1	1	0.0
Bigeye Barracuda		1	1	0.0										1	1	0.0

Table 3.2. Continued (3/3).

	North				Central				South				Total			
Species: Common Name	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**	**Kept**	**Released**	**Total**	**% Kept**
Blacktail Snapper		1	1	0.0										1	1	0.0
Blotched Saury		1	1	0.0										1	1	0.0
Blue Groper					1		1	100.0					1		1	100.0
Bluespotted Mask Ray		1	1	0.0										1	1	0.0
Cobbler		1	1	0.0										1	1	0.0
Cobia	1		1	100.0									1		1	100.0
Comb Wrasse		1	1	0.0										1	1	0.0
Dogtooth Tuna	1		1	100.0									1		1	100.0
Dusky Flathead						1	1	0.0						1	1	0.0
Eastern Shovelnose Ray						1	1	0.0						1	1	0.0
Fortescue						1	1	0.0						1	1	0.0
Frigate Mackerel					1		1	100.0					1		1	100.0
Golden Trevally		1	1	0.0										1	1	0.0
Goldspotted Sweetlip	1		1	100.0									1		1	100.0
Gunthers Wrasse		1	1	0.0										1	1	0.0
Large Tooth Flounder					1		1	100.0					1		1	100.0
Largetooth Beardie					1		1	100.0					1		1	100.0
Little Conger Eel						1	1	0.0						1	1	0.0
Longnose Trevally	1		1	100.0									1		1	100.0
Longtail Tuna	1		1	100.0									1		1	100.0
Mosaic Leatherjacket									1		1	100.0	1		1	100.0
Mosaic Moray Eel		1	1	0.0										1	1	0.0
Narrow Lined Pufferfish						1	1	0.0						1	1	0.0
Northern Calamari	1		1	100.0									1		1	100.0
Ornate Wobbegong		1	1	0.0										1	1	0.0
Pink Ling									1		1	100.0	1		1	100.0
Pinkbanded Grubfish		1	1	0.0										1	1	0.0
Redthroat Emperor	1		1	100.0									1		1	100.0
Remora		1	1	0.0										1	1	0.0
Rosy Wrasse									1		1	100.0	1		1	100.0
Rough Leatherjacket										1	1	0.0		1	1	0.0
Scalloped Hammerhead Shark		1	1	0.0										1	1	0.0
School Shark		1	1	0.0										1	1	0.0
Smooth Hammerhead Shark										1	1	0.0		1	1	0.0
Spangled Emperor	1		1	100.0									1		1	100.0
Starry Toadfish						1	1	0.0						1	1	0.0
Stripey Snapper		1	1	0.0										1	1	0.0
Whaler Shark		1	1	0.0										1	1	0.0
Grand Total	1802	2479	4281	42.1	3168	1083	4251	74.5	3364	1461	4825	69.7	8334	5023	13357	62.4

Table 3.3. Summary of PERMANOVA analyses comparing the composition of total, kept and released catches across regions and seasons.

		Raw Data					Standardised Data				
	df	MS	Pseudo-F	P(perm)	Unique Perms	% Variation	MS	Pseudo-F	P(perm)	Unique Perms	% Variation
Total Catch											
Region	2	46316	20.404	0.0001	9889	27.92	47980	23.504	0.0001	9892	29.01
Season	4	5341.7	2.3533	0.0001	9868	9.42	5717.2	2.8007	0.0001	9864	10.48
RxS	8	4791.5	2.1109	0.0001	9833	14.70	4324.8	2.1186	0.0001	9817	14.23
Residual	166	2269.9				47.97	2041.4				46.27
Kept Catch											
Region	2	45285	17.404	0.0001	9885	26.10	48594	20.711	0.0001	9889	27.68
Season	4	6692.7	2.5722	0.0001	9841	10.32	6471.5	2.7581	0.0001	9878	10.56
RxS	8	5444.2	2.0923	0.0001	9779	14.82	5027.3	2.1426	0.0001	9813	14.67
Residual	166	2602				48.76	2346.3				47.09
Released Catch											
Region	2	43220	15.078	0.0001	9873	26.65	36267	13.549	0.0001	9900	26.00
Season	4	4622.1	1.6125	0.0061	9861	7.11	4668.1	1.744	0.0034	9865	8.09
RxS	8	4725.7	1.6487	0.0002	9797	12.60	3832.8	1.4319	0.0072	9821	10.62
Residual	165	2866.4				53.64	2676.7				47.08

Table 3.4. Summary of SIMPER analyses identifying the five species that contributed greatest to the similarity of kept, released and total catches in each region.

	Kept Catch				
	Average Abundance	Average Similarity	Similarity/ Std. Devation	Contribribution %	Cumulative Contribution %
North					
Snapper	10.27	16.99	1.12	48.49	48.49
Bluespot Flathead	7	10.73	0.59	30.64	79.12
Pearl Perch	1.15	1.22	0.53	3.48	82.6
Grey Morwong	1.1	1.19	0.43	3.41	86.01
Teraglin	1.85	1.08	0.38	3.07	89.08
Central					
Ocean Leatherjacket	15.59	6.14	0.59	25.78	25.78
Redfish	6.78	3.92	0.67	16.48	42.26
Grey Morwong	5.22	3.57	0.65	14.98	57.25
Bluespot Flathead	2.94	3.03	0.39	12.71	69.96
Snapper	2.14	1.48	0.48	6.22	76.17
South					
Grey Morwong	7.93	9.01	1.16	27.45	27.45
Snapper	5.64	5.94	0.99	18.1	45.54
Sweep	6.08	3.15	0.58	9.61	55.15
Redfish	5.9	3.07	0.68	9.36	64.51
Maori Wrasse	2.85	1.9	0.55	5.79	70.31
	Released Catch				
	Average Abundance	Average Similarity	Similarity/ Std. Devation	Contribribution %	Cumulative Contribution %
North					
Snapper	14.19	21.53	1.88	49.05	49.05
Bluespot Flathead	6.76	6.19	0.58	14.1	63.15
Eastern Red Scorpionfish	4.93	5.75	0.87	13.09	76.24
Sergeant Baker	3.08	3.17	0.79	7.22	83.47
Sweep	2.81	2.54	0.62	5.78	89.24
Central					
Snapper	1.16	4.11	0.56	25.86	25.86
Bluespot Flathead	6.33	3.41	0.27	21.48	47.33
Tiger Flathead	2.98	2.95	0.35	18.59	65.92
Ocean Perch	1.37	1.68	0.27	10.56	76.48
Sergeant Baker	0.62	1.09	0.3	6.83	83.32
South					
Snapper	3.15	4.57	0.61	21.5	21.5
Sergeant Baker	2.69	4.05	0.73	19.06	40.56
Redfish	2.9	2.59	0.44	12.19	52.76
Ocean Perch	1.51	2.14	0.36	10.06	62.82
Mado	2.81	1.86	0.5	8.73	71.55
	Total Catch				
	Average Abundance	Average Similarity	Similarity/ Std. Devation	Contribribution %	Cumulative Contribution %
North					
Snapper	24.46	21.78	1.75	49.47	49.47
Bluespot Flathead	13.76	8.48	0.65	19.26	68.74
Eastern Red Scorpionfish	5.02	3.63	0.88	8.24	76.97
Sergeant Baker	3.41	2.19	0.91	4.97	81.94
Sweep	3.49	1.73	0.68	3.94	85.88
Central					
Ocean Leatherjacket	15.68	5.11	0.57	19.63	19.63
Bluespot Flathead	9.27	3.99	0.37	15.32	34.95
Redfish	7.98	3.69	0.65	14.18	49.13
Grey Morwong	5.46	2.87	0.66	11.02	60.15
Snapper	3.3	2.84	0.77	10.91	71.06
South					
Grey Morwong	8.27	6.43	1.12	17.6	17.6
Snapper	8.8	5.59	1.12	15.3	32.91
Redfish	8.8	4.71	0.88	12.88	45.79
Sweep	8.88	4.26	0.8	11.65	57.44
Sergeant Baker	4.86	3.6	1.37	9.85	67.29

Table 3.5. Summary of PERMANOVA analyses comparing the composition of total, kept and released catches across ports and seasons for each region.

		Kept Catch				Released Catch			
	df	MS	Pseudo-F	P(perm)	% Variation	MS	Pseudo-F	P(perm)	% Variation
North									
Port	1	11068	4.9566	0.0001	26.71	10956	9.3699	0.0001	28.65
Season	2	5156	2.309	0.003	17.77	2293.5	1.9614	0.0243	11.24
PxS	2	2299.9	1.03	0.4116	3.80	3318.6	2.8381	0.001	21.97
Residual	33	2233			51.71	1169.3			38.14
Total	38								
Central									
Port	1	20150	6.9992	0.0001	32.76	14548	4.4927	0.0003	27.78
Season	3	3333.9	1.158	0.2359	7.33	2643.4	0.81635	0.7447	0.00
PxS	3	2947.4	1.0238	0.4214	4.02	3645.1	1.1257	0.2876	10.28
Residual	40	2878.9			55.88	3238.1			61.94
Total	47								
South	df								
Port	1	7638.2	3.3719	0.0004	17.55	16129	5.4894	0.0001	26.67
Season	4	4498.4	1.9859	0.0002	17.50	3232.7	1.1002	0.2721	6.16
PxS	4	2927.7	1.2925	0.0918	13.48	3350.1	1.1402	0.2163	10.31
Residual	49	2265.2			51.47	2938.2			56.85
Total	58								

		Total Catch			
	df	MS	Pseudo-F	P(perm)	% Variation
North					
Port	1	12508	9.5422	0.0001	31.15
Season	2	2958.1	2.2567	0.0086	13.82
PxS	2	2153.8	1.6432	0.0611	13.98
Residual	33	1310.8			41.04
Total	38				
Central					
Port	1	20063	7.6403	0.0001	34.45
Season	3	2150.4	0.81894	0.7247	0.00
PxS	3	2989.2	1.1384	0.2868	9.70
Residual	40	2625.9			55.85
Total	47				
South	df				
Port	1	10807	5.4724	0.0001	23.75
Season	4	3596.9	1.8213	0.0022	15.74
PxS	4	2288.4	1.1588	0.2167	9.79
Residual	49	1974.9			50.72
Total	58				

Table 3.6. Summary of SIMPER analyses identifying the five species that contributed greatest to the dissimilarity of kept, released and total catches between ports within each region.

	Kept Catch					
	Average Abundance	Average Abundance	Average Dissimilarity	Dissimilarity/ Std. Deviation	Contribution %	Cumulative %
North	Wooli	Coffs Harbour				
Snapper	12.53	7.95	18.5	1.12	24.22	24.22
Bluespot Flathead	0.84	6.9	11.58	1.09	15.16	39.39
Teraglin	0.53	3.75	5.41	0.69	7.08	46.47
Silver Trevally	3.11	0	5.22	0.67	6.83	53.3
Yellowtail Scad	3.26	0.05	4.56	0.36	5.97	59.27
Central	Sydney	Port Hacking				
Ocean Leatherjacket	0.07	17.82	18.39	0.74	20.72	20.72
Redfish	0.36	8.38	11.61	1.01	13.08	33.81
Bluespot Flathead	5.21	2.59	9.77	0.79	11.01	44.81
Grey Morwong	1.07	6.26	8.49	0.85	9.57	54.38
Ocean Perch	0	4.82	6.29	0.88	7.09	61.47
South	Kiama	Shoalhaven				
Blue Mackerel	3.98	9.75	8.42	0.86	11.52	11.52
Sweep	4.81	9.5	8.16	0.99	11.17	22.69
Grey Morwong	8.09	7.5	6.65	1.04	9.1	31.79
Snapper	4.79	7.94	6.39	1.14	8.74	40.52
Redfish	7.02	2.88	5.94	0.98	8.12	48.65
	Released Catch					
	Average Abundance	Average Abundance	Average Dissimilarity	Dissimilarity/ Std. Deviation	Contribution %	Cumulative %
North	Wooli	Coffs Harbour				
Snapper	18.58	13.3	14.38	1.37	22.67	22.67
Eastern Red Scorpionfish	9.21	2.85	8.57	1.52	13.51	36.18
Bluespot Flathead	0.68	7.3	7.64	1.01	12.04	48.23
Sweep	5.11	1.45	5.85	1.09	9.23	57.45
Yellowtail Kingfish	4.68	0.05	5.27	0.68	8.3	65.76
Central	Sydney	Port Hacking				
Bluespot Flathead	19.36	3.27	40.55	1.39	47.04	47.04
Tiger Flathead	0.93	4.42	11.23	0.64	13.03	60.07
Snapper	1.14	1.36	5.44	0.67	6.31	66.38
Ocean Perch	0.07	1.48	5.32	0.53	6.17	72.54
Redfish	0.07	1.7	4.81	0.5	5.58	78.12
South	Kiama	Shoalhaven				
Snapper	1.53	7.5	11.96	1.2	14.33	14.33
Mado	0.86	8.06	11.83	1.02	14.17	28.5
Sweep	1.7	5.75	8.99	0.93	10.76	39.27
Bluespot Flathead	1.07	4.63	8.4	0.79	10.06	49.32
Redfish	3.37	1.63	6.29	0.88	7.53	56.86
	Total Catch					
	Average Abundance	Average Abundance	Average Dissimilarity	Dissimilarity/ Std. Deviation	Contribution %	Cumulative %
North	Wooli	Coffs Harbour				
Snapper	31.11	21.25	14.94	1.28	22.55	22.55
Bluespot Flathead	1.53	14.2	8.93	1.11	13.47	36.02
Eastern Red Scorpionfish	9.37	2.9	5.16	1.49	7.79	43.81
Sweep	7.16	1.5	4.58	1.1	6.92	50.73
Yellowtail Kingfish	5.37	0.05	3.69	0.78	5.57	56.3
Central	Sydney	Port Hacking				
Bluespot Flathead	24.57	5.76	20.99	1.24	24.84	24.84
Ocean Leatherjacket	0.07	18	13.07	0.66	15.48	40.32
Redfish	0.43	10.03	8.81	0.98	10.43	50.75
Tiger Flathead	1	7.29	6.68	0.68	7.91	58.65
Grey Morwong	1.21	6.47	5.45	0.83	6.46	65.11
South	Kiama	Shoalhaven				
Sweep	6.51	15.25	7.36	1.12	10.54	10.54
Snapper	6.33	15.44	7.22	1.35	10.34	20.88
Bluespot Flathead	3.26	10.81	5.95	1.04	8.52	29.4
Blue Mackerel	4.12	9.88	5.68	0.87	8.13	37.53
Redfish	10.4	4.5	5.57	1.1	7.98	45.51

Table 3.7. The three species that contributed (%) greatest to the similarity matrix of kept and released catches of each habitat classification in each region as determined by the SIMPER analyses.

Kept Catch	**Reef**	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel**	**%**
North	Snapper	75.8	Snapper	56.1	Bluespot Flathead	99.6	Snapper	55.4
	Pearl Perch	4.7	Bluespot Flathead	20.1	Snapper	0.1	Bluespot Flathead	29.3
	Grey Morwong	4.1	Teraglin	9.4	Tiger Flathead	0.1	Sergeant Baker	3.6
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel/Sand**	**%**
Central	Ocean Leatherjacket	33.7	Grey Morwong	23.6	Bluespot Flathead	88.9	Bluespot Flathead	52.4
	Grey Morwong	22.1	Redfish	21.6	Ocean Leatherjacket	8.4	Snapper	13.4
	Redfish	9.2	Ocean Leatherjacket	20.7	Redfish	1.0	Grey Morwong	6.7
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**		
South	Grey Morwong	30.4	Snapper	25.5	Bluespot Flathead	62.5		
	Snapper	15.1	Blue Mackerel	21.8	Sweep	13.1		
	Redfish	14.3	Grey Morwong	11.9	Trawl Whiting	11.0		
Released Catch	**Reef**	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel**	**%**
North	Snapper	59.5	Snapper	67.1	Bluespot Flathead	93.8	Snapper	64.9
	Eastern Red Scorpionfish	14.4	Eastern Red Scorpionfish	19.9	Painted Grinner	4.0	Bluespot Flathead	21.6
	Sergeant Baker	8.2	Sergeant Baker	5.4	Tiger Flathead	0.7	Sergeant Baker	7.2
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel/Sand**	**%**
Central	Ocean Perch	30.3	Snapper	37.5	Bluespot Flathead	86.3	Snapper	55.6
	Snapper	28.8	Tiger Flathead	26.6	Tiger Flathead	12.4	Sergeant Baker	44.4
	Redfish	10.7	Ocean Perch	13.8	Longspine Flathead	1.0		
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**		
South	Snapper	21.1	Snapper	23.2	Bluespot Flathead	84.6		
	Sergeant Baker	20.0	Sergeant Baker	18.8	Mado	8.8		
	Redfish	18.3	Bluespot Flathead	16.5	Sergeant Baker	2.6		

Table 3.8. Mean (+SE) number of each of the ten most abundant kept species kept per client in each region (data pooled across seasons).

Species	North		Central		South	
	Mean	SE	Mean	SE	Mean	SE
Snapper	1.20	0.17	0.21	0.04	0.69	0.08
Bluespot Flathead	0.76	0.14	0.25	0.06	0.38	0.08
Ocean Leatherjacket	0.02	0.01	1.54	0.34	0.35	0.11
Grey Morwong	0.11	0.02	0.51	0.09	1.00	0.12
Tiger Flathead	0.05	0.01	0.27	0.07	0.12	0.04
Sweep	0.08	0.03	0.03	0.01	0.71	0.13
Ocean Perch	0.00	0.00	0.39	0.09	0.19	0.07
Redfish	0.00	0.00	0.65	0.11	0.78	0.16
Sergeant Baker	0.03	0.01	0.16	0.03	0.26	0.04
Blue Mackerel	0.04	0.02	0.26	0.12	0.65	0.16

Table 3.9. Summary of two-factor univariate PERMANOVA analyses comparing the numbers of species, individuals and ten key species in kept and released catches across regions and seasons. * = P<0.05, ** = P<0.01, *** = P<0.001, ns = P>0.05.

	Kept			Released		
	Region	Season	R x S	Region	Season	R x S
Degrees of Freedom	2, 166	4, 166	8, 166	2, 166	4, 166	8, 166
Total Species	***	ns	ns	***	ns	ns
Total Individuals	***	ns	*	***	ns	**
Snapper	***	***	ns	***	**	ns
Bluespot Flathead	***	***	***	**	**	**
Grey Morwong	***	ns	ns	ns	ns	ns
Ocean Leatherjacket	***	ns	ns	-	-	-
Redfish	***	ns	ns	*	ns	ns
Tiger Flathead	**	ns	ns	***	ns	ns
Ocean Perch	***	ns	ns	***	ns	ns
Eastern Red Scorpionfish	**	ns	ns	***	ns	ns
Sergeant Baker	***	ns	ns	***	ns	**
Sweep	***	ns	ns	***	ns	ns

Figure 3.1. Map showing the location of the six ports sampled.

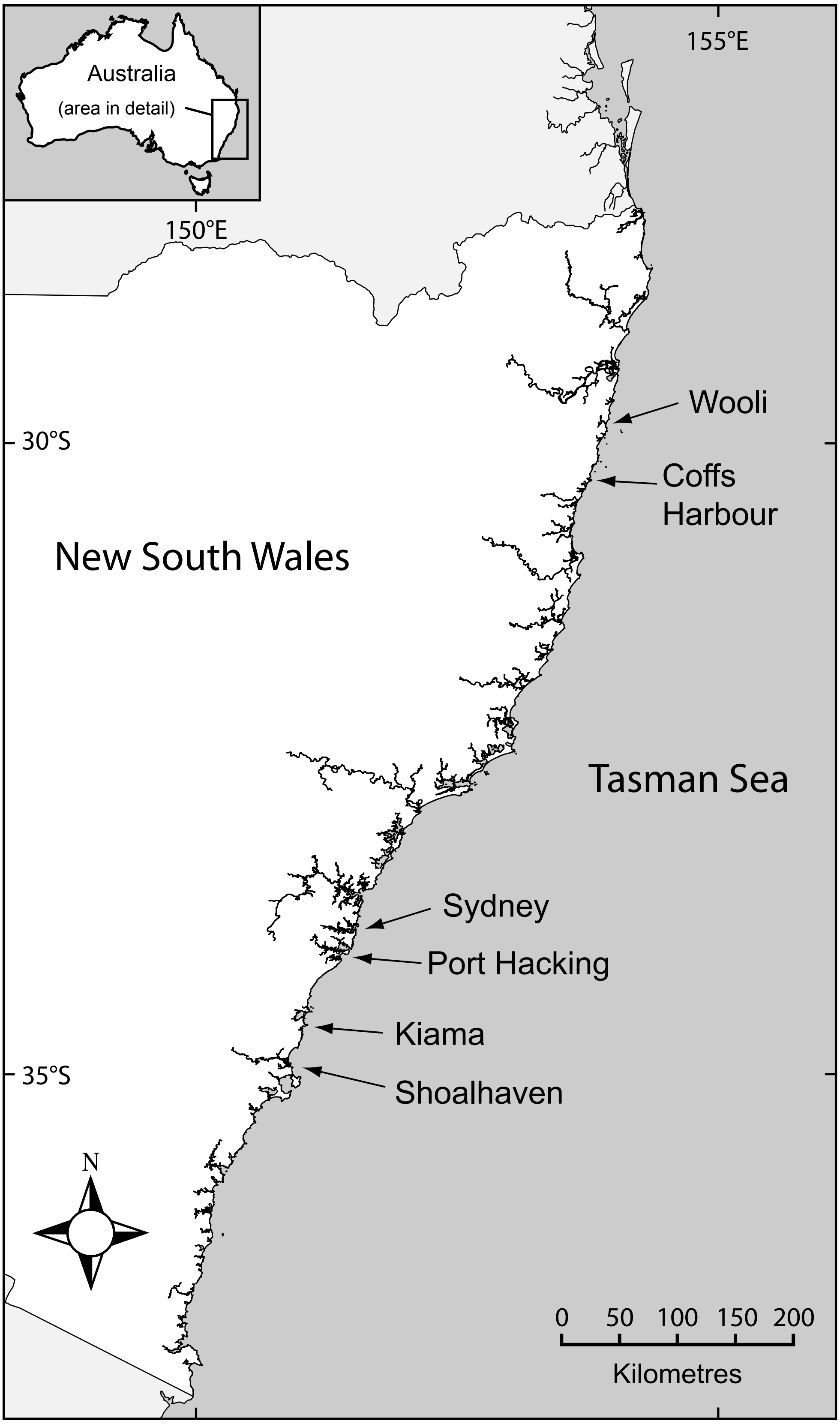


Figure 3.2. Mean (+SE) number of fishing clients and hours fished per fishing trip in each of the three regions across the five sampled seasons.

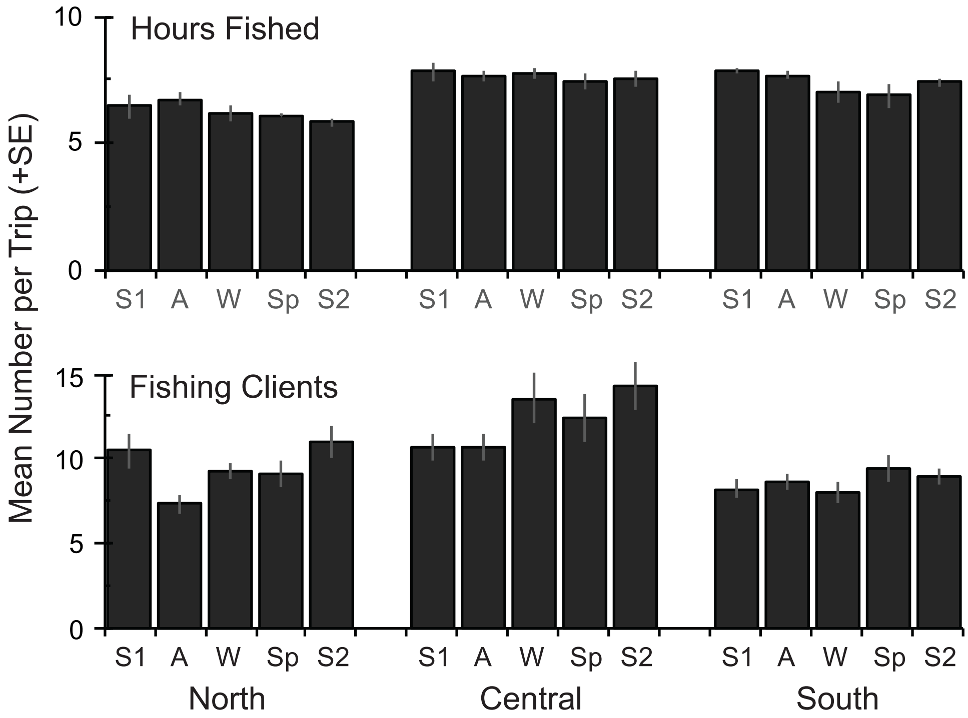


Figure 3.3. MDS plots showing relationships among total, kept and released catches for sampled trips.

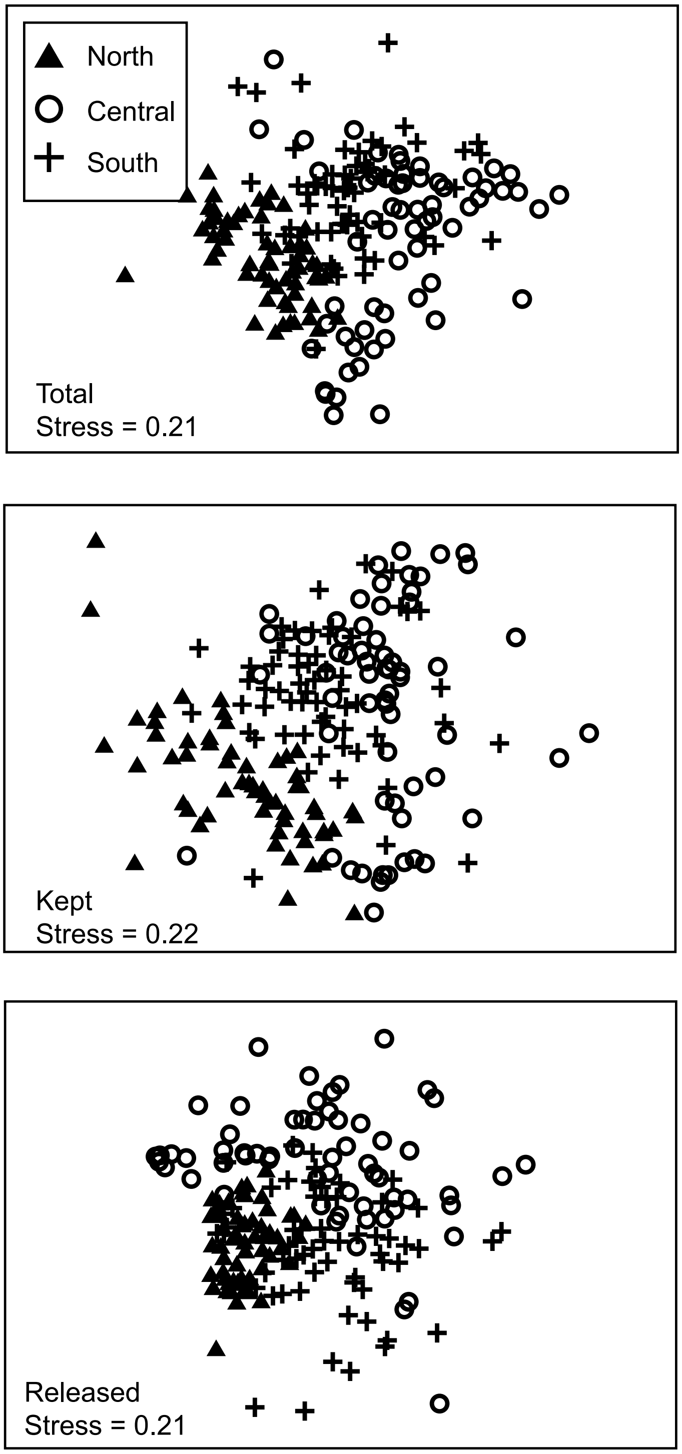


Figure 3.4. Mean (+SE) number of individuals kept and released per fishing trip, fished hour, client and client/hour in each of the three regions across the five sampled seasons.

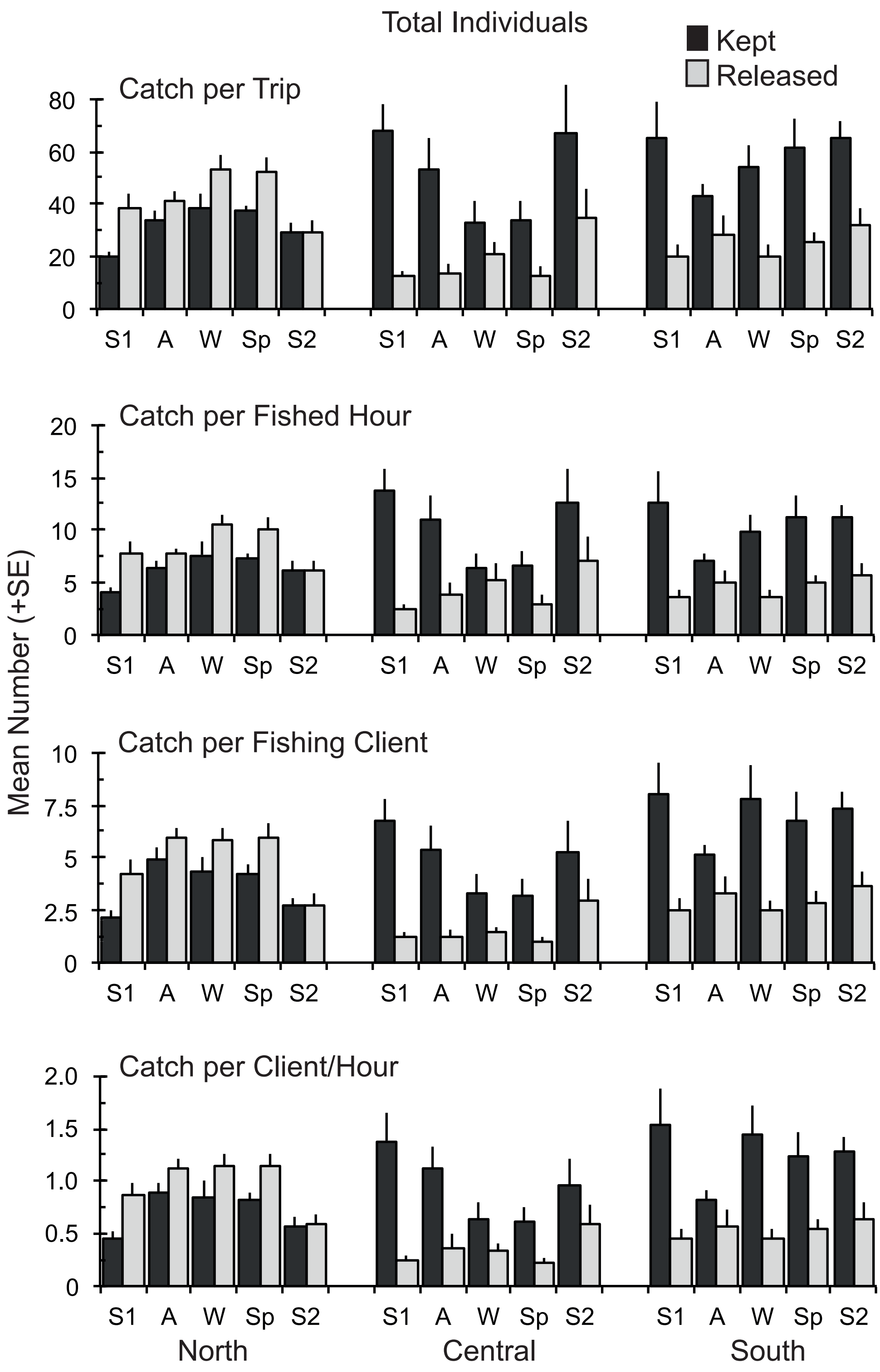


Figure 3.5. Mean (+SE) number of snapper kept and released per fishing trip, fished hour, client and client/hour in each of the three regions across the five sampled seasons.

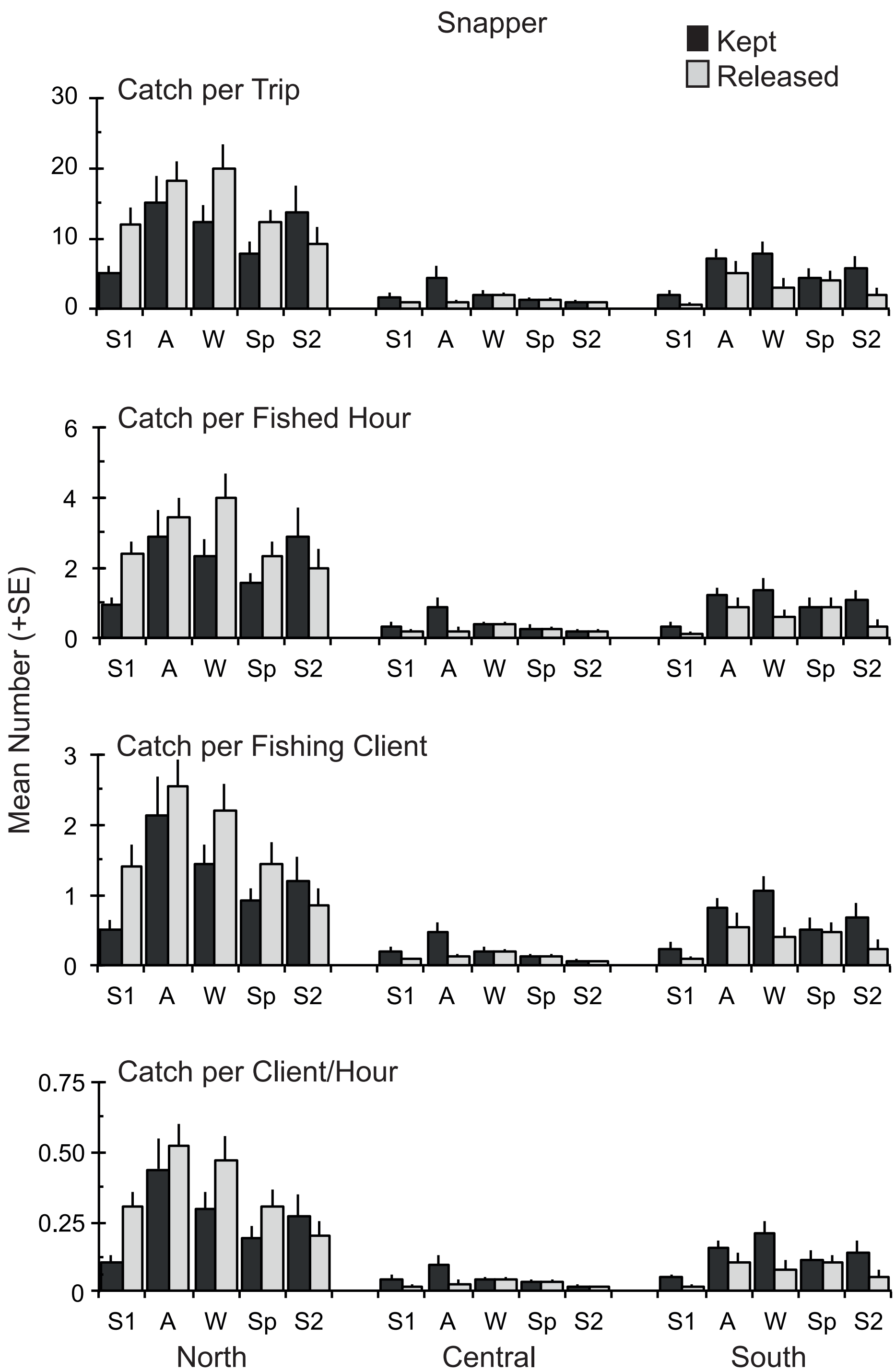


Figure 3.6. Mean (+SE) number of species and and individuals kept and released per fishing trip in each of the three regions across the five sampled seasons.

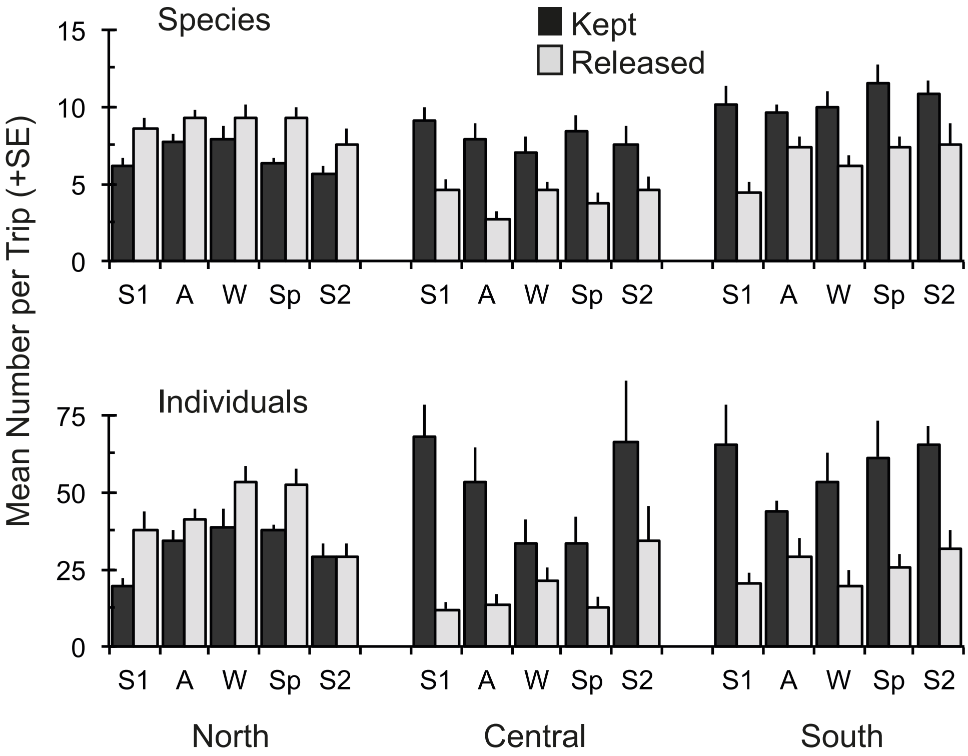


Figure 3.7. Mean (+SE) number of snapper, bluespot flathead, grey morwong, ocean leatherjacket and redfish kept and released per fishing trip in each of the three regions across the five sampled seasons.

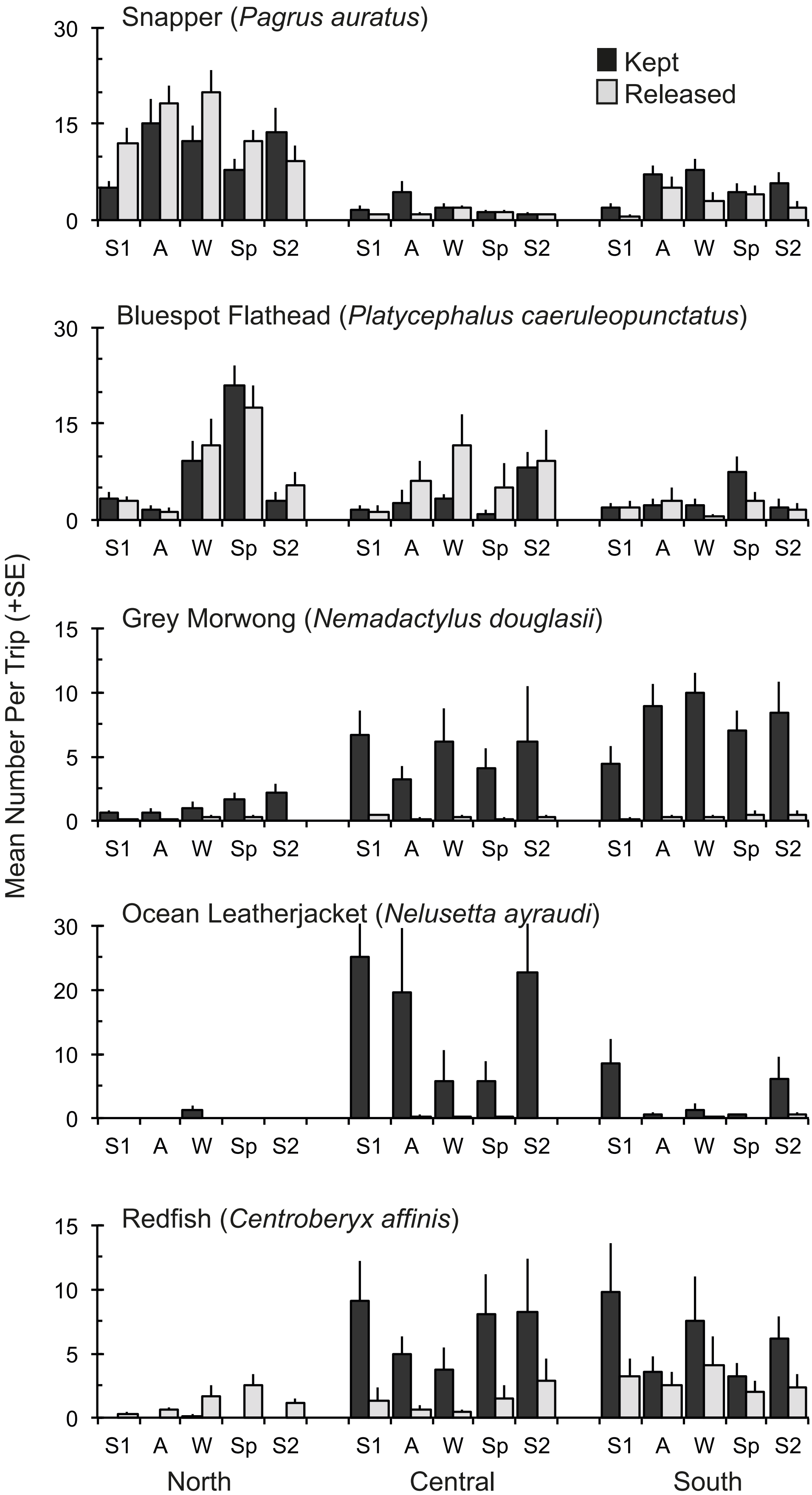


Figure 3.8. Mean (+SE) number of sweep, sergeant baker, tiger flathead, ocean perch and eastern red scorpionfish kept and released per fishing trip in each of the three regions across the five sampled seasons.

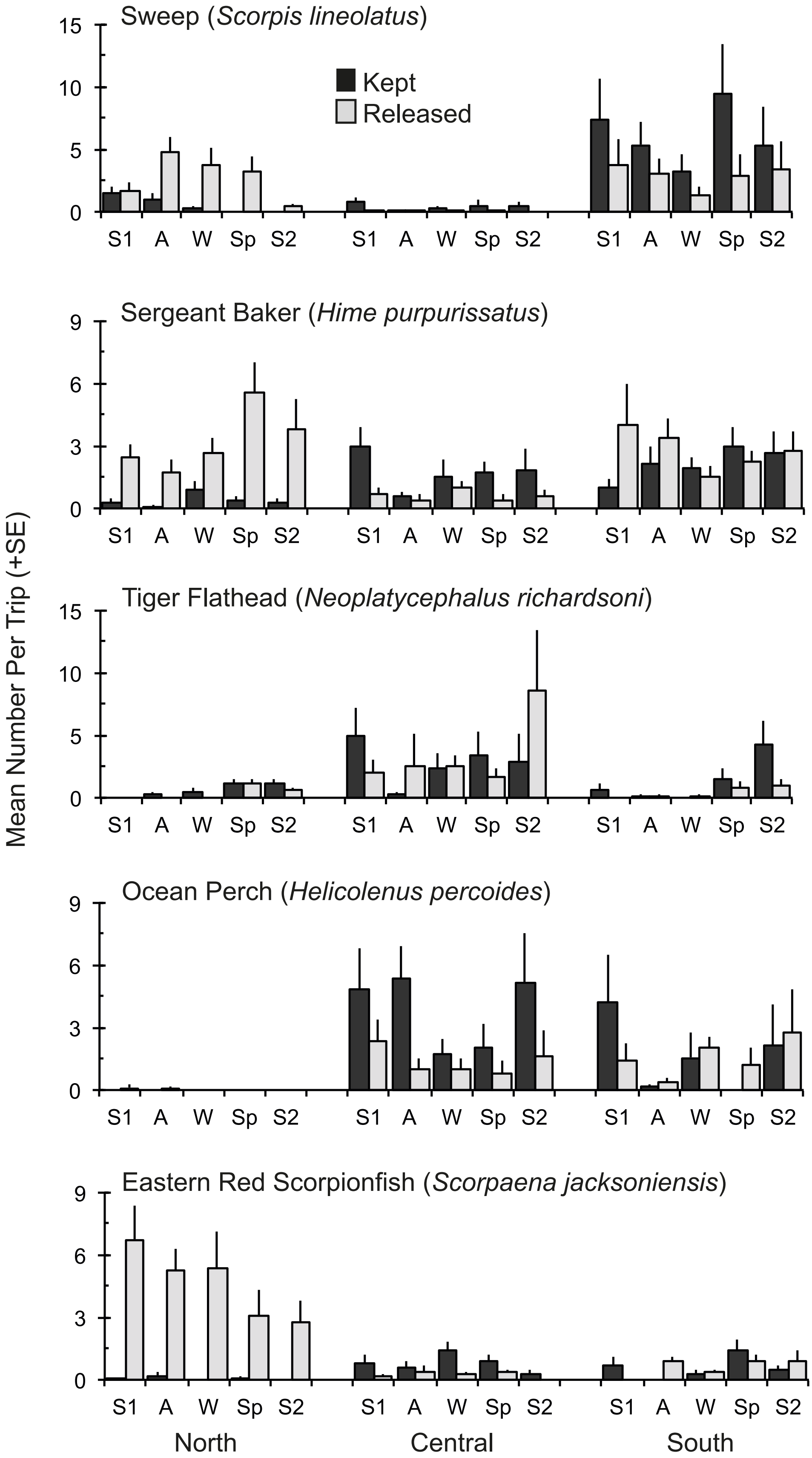


Figure 3.9. Mean (+SE) number of eastern blackspot pigfish, maori wrasse, longfin perch, pearl perch and teraglin kept and released per fishing trip in each of the three regions across the five sampled seasons.

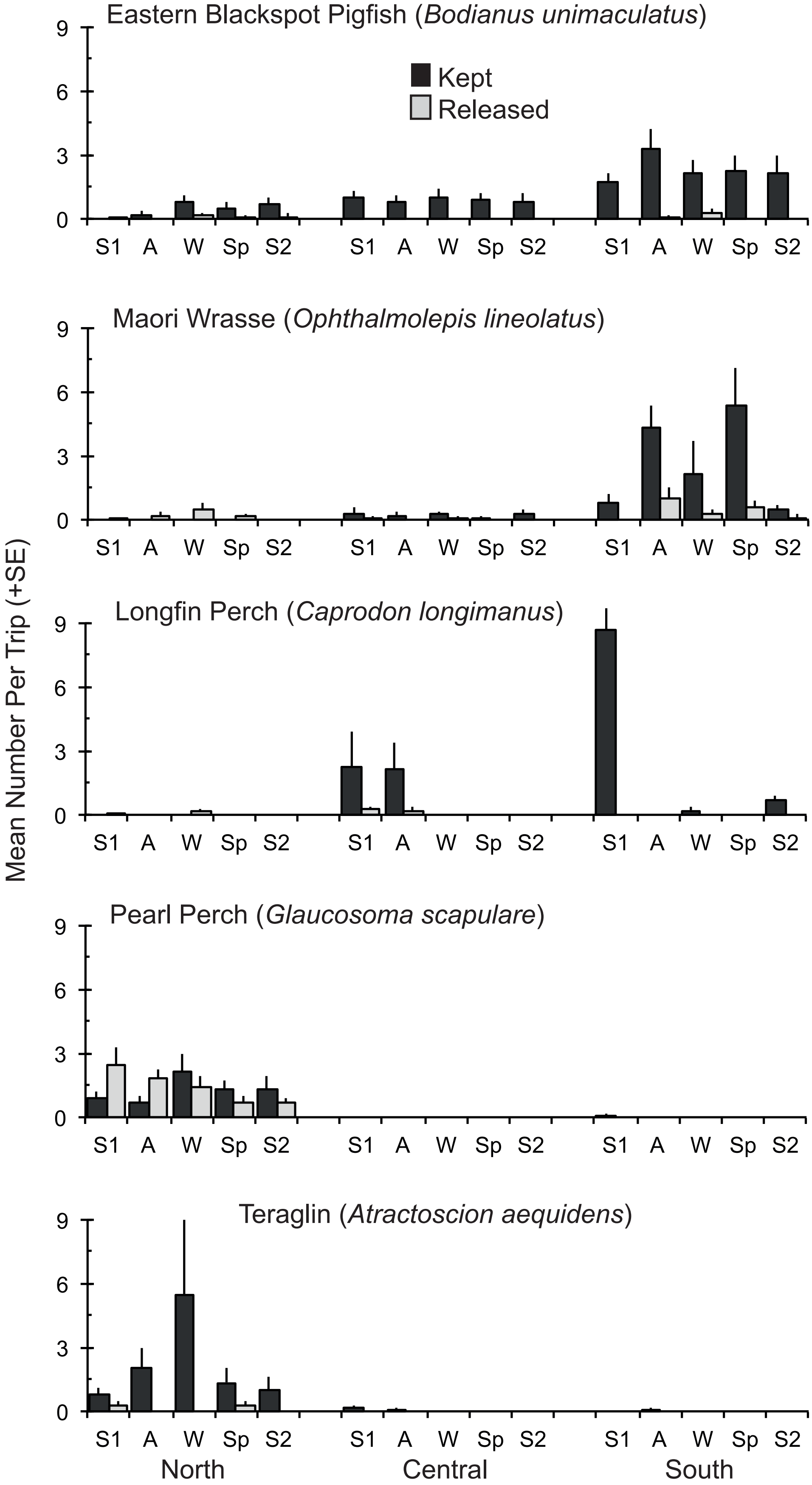


Figure 3.10. Mean (+SE) number of yellowtail scad, yellowtail kingfish, silver trevally, blue mackerel, and mado kept and released per fishing trip in each of the three regions across the five sampled seasons.

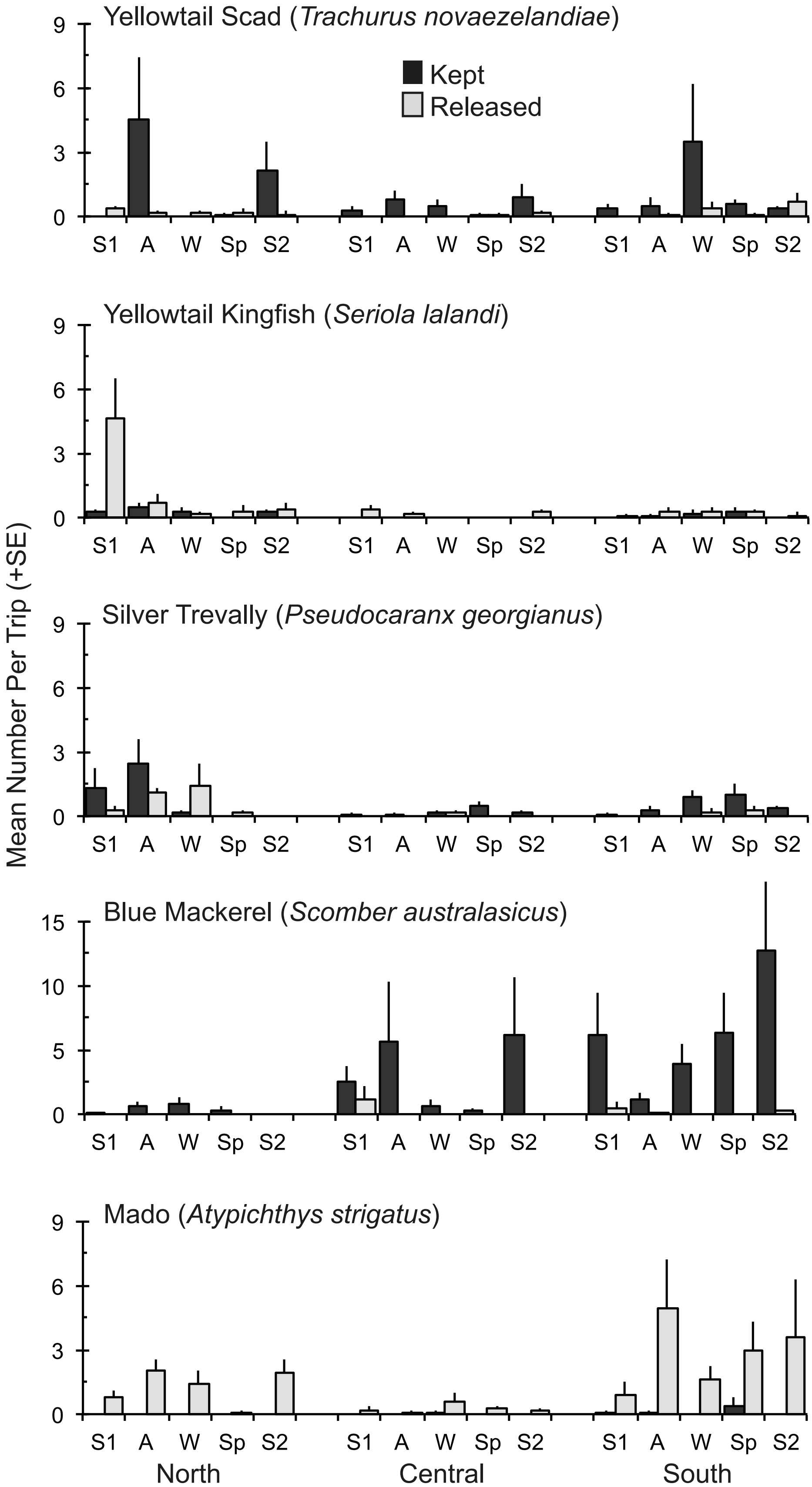


Figure 3.11. Length compositions of observed kept and released catches of snapper and bluespot flathead across each of the three regions. Data pooled across seasons.

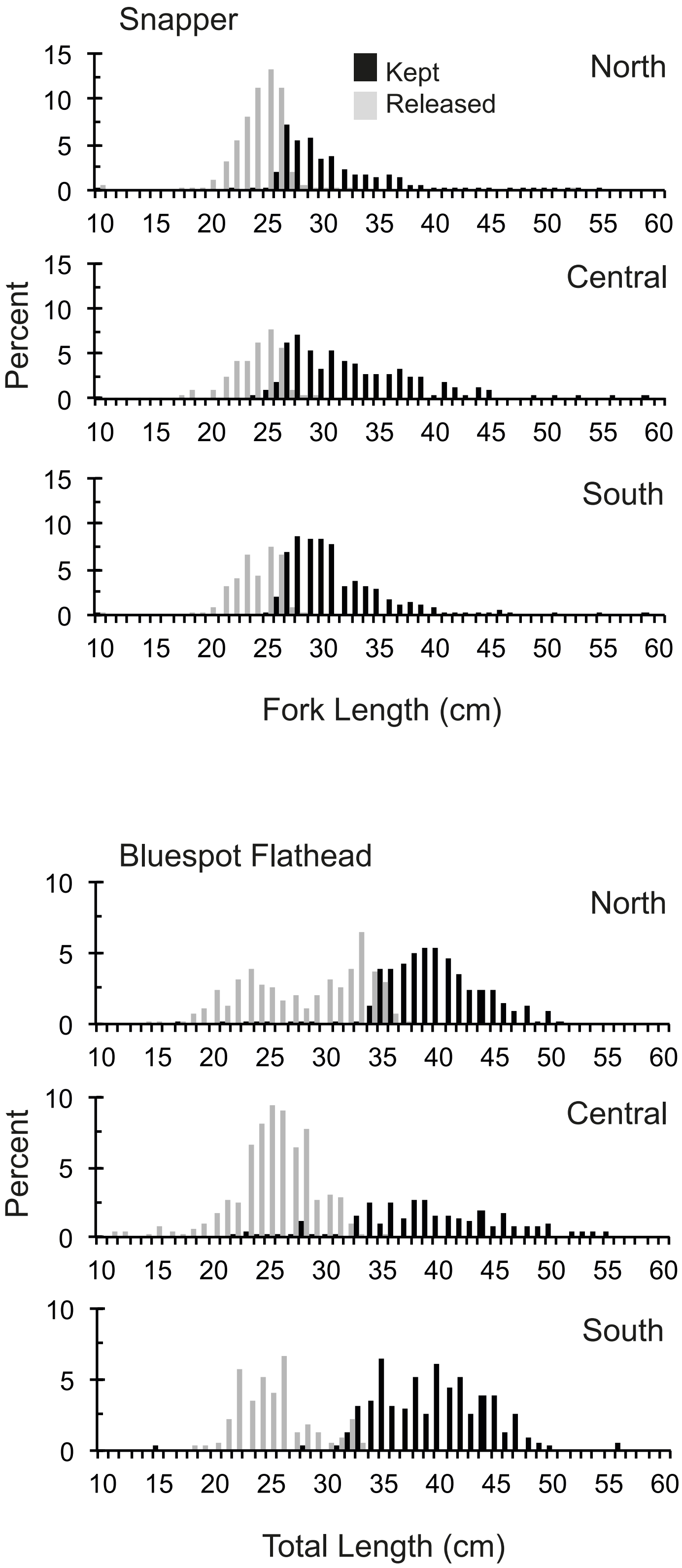


Figure 3.12. Length compositions of observed kept and released catches of grey morwong and ocean leatherjacket across each of the three regions. Data pooled across seasons.

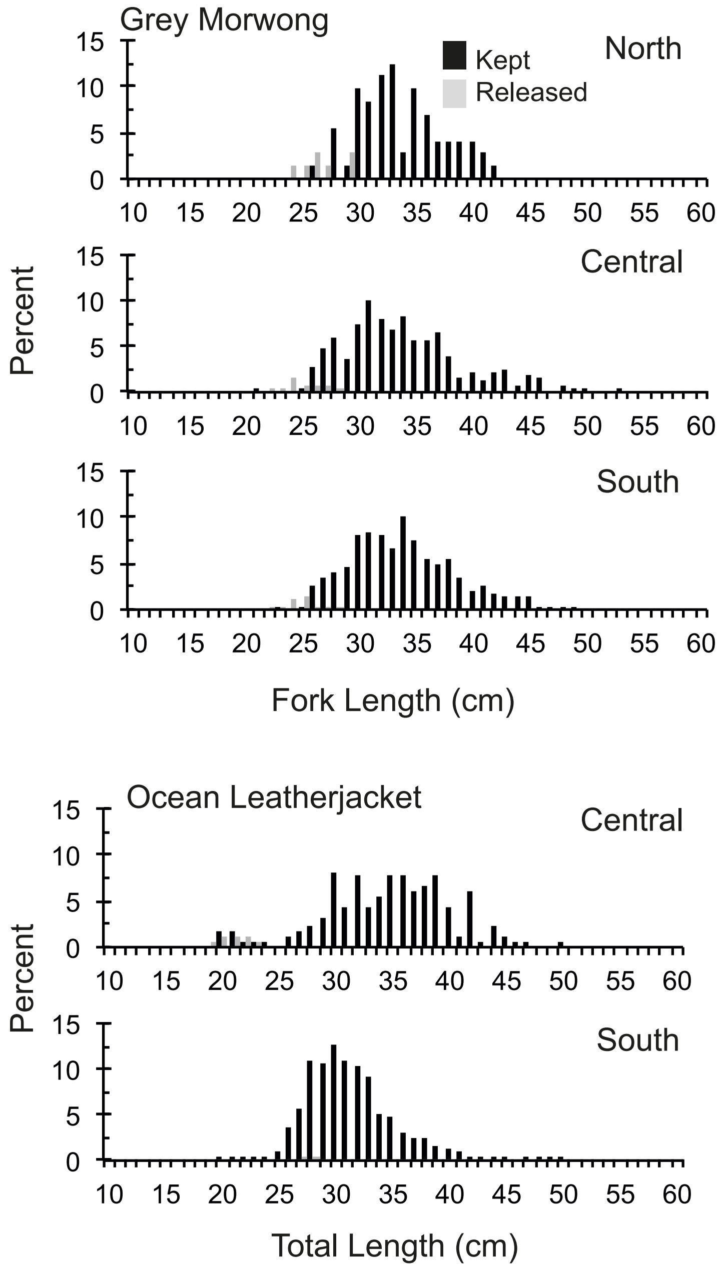


Figure 3.13. Length compositions of observed kept and released catches of redfish and eastern red scorpionfish across each of the three regions. Data pooled across seasons.

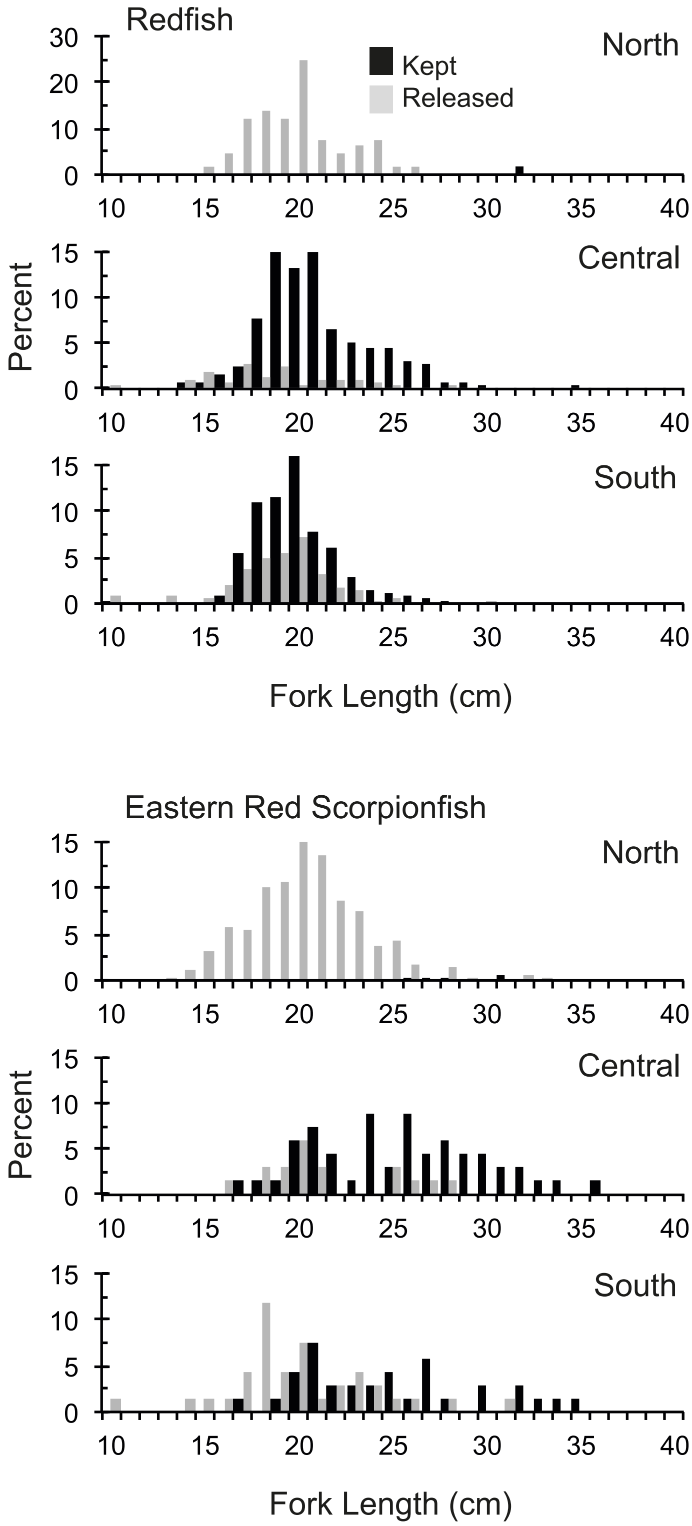


Figure 3.14. Length compositions of observed kept and released catches of ocean perch, sweep and blue mackerel across each of two regions. Data pooled across seasons.

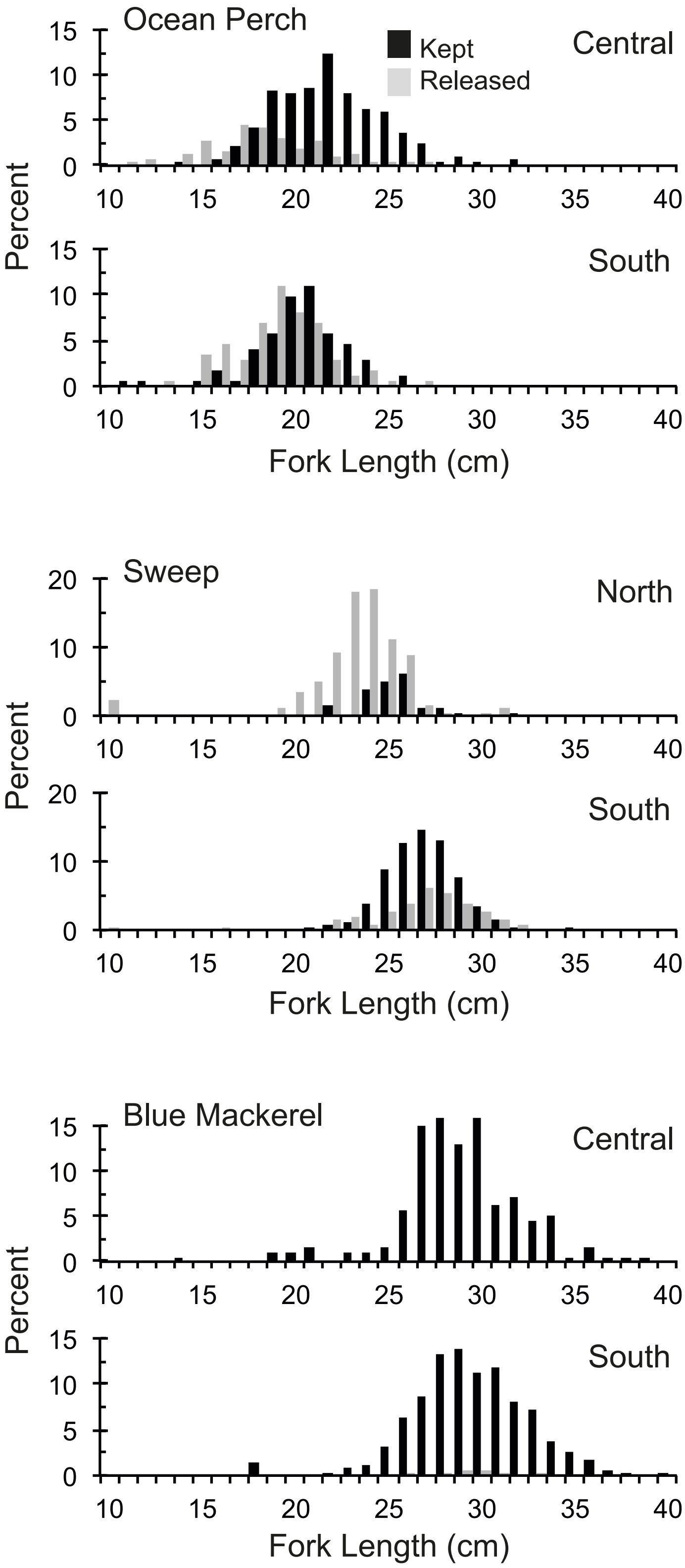


Figure 3.15. Length compositions of observed kept and released catches of sergeant baker and tiger flathead across each of the three regions. Data pooled across seasons.

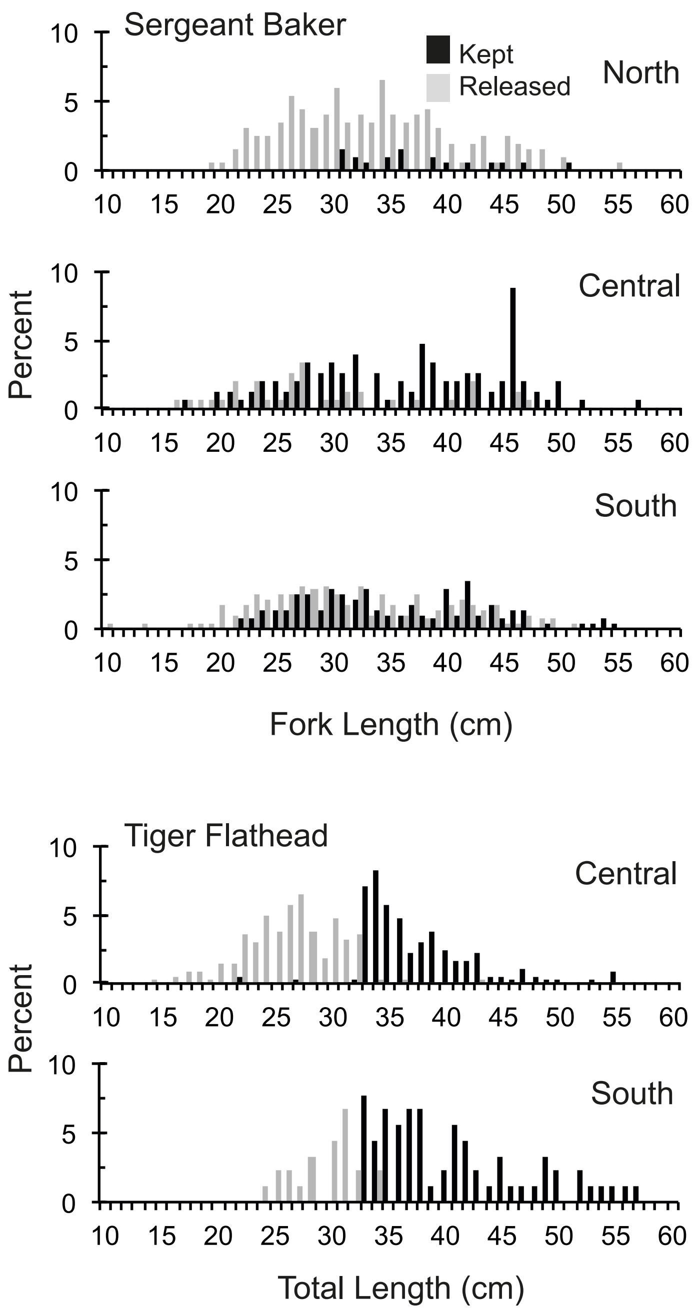


Figure 3.16. Length compositions of observed kept and released catches of pearl perch, teraglin, longfin pike, eastern blackspot flathead, longfin perch and southern maori wrasse within a particular region. Data pooled across seasons.

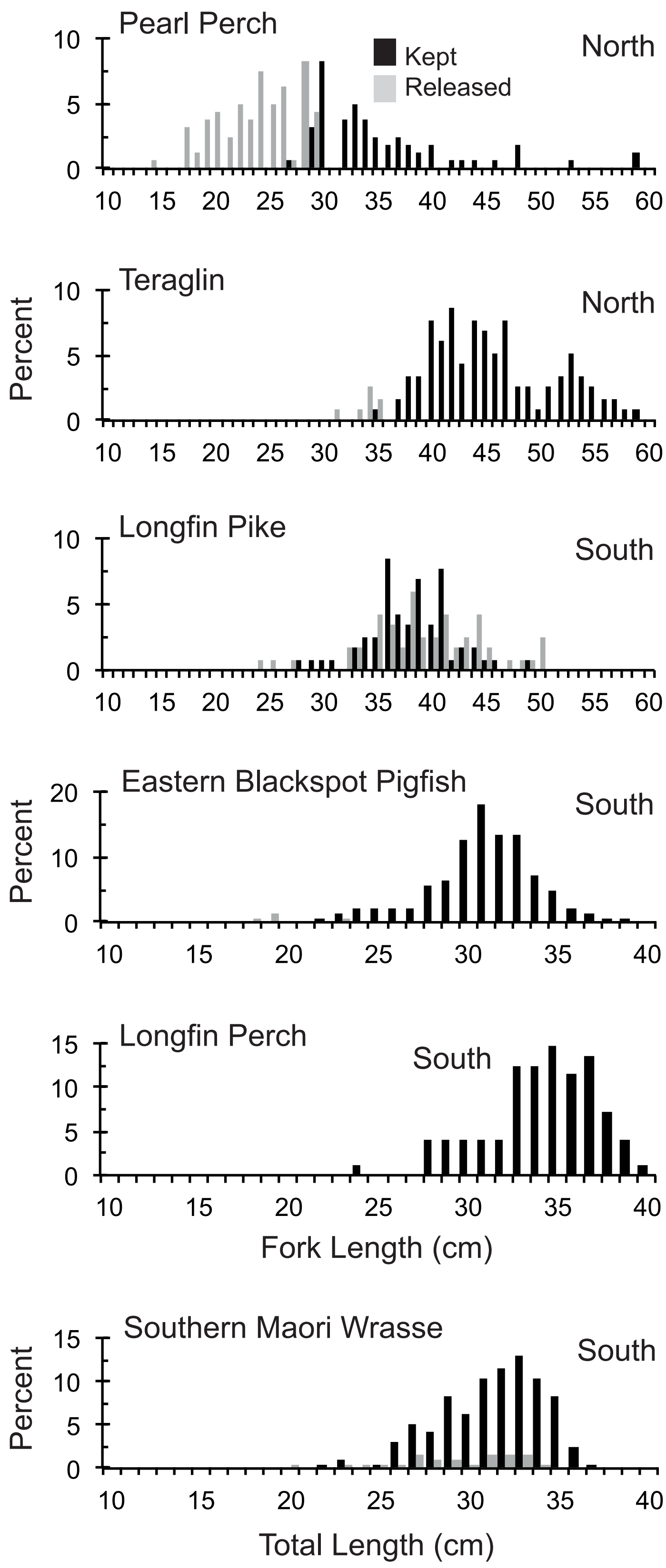


Figure 3.17. The number, lengths and ages of snapper, bluespot flathead, pearl perch and grey morwong sampled for otoliths. Data pooled across regions and seasons.

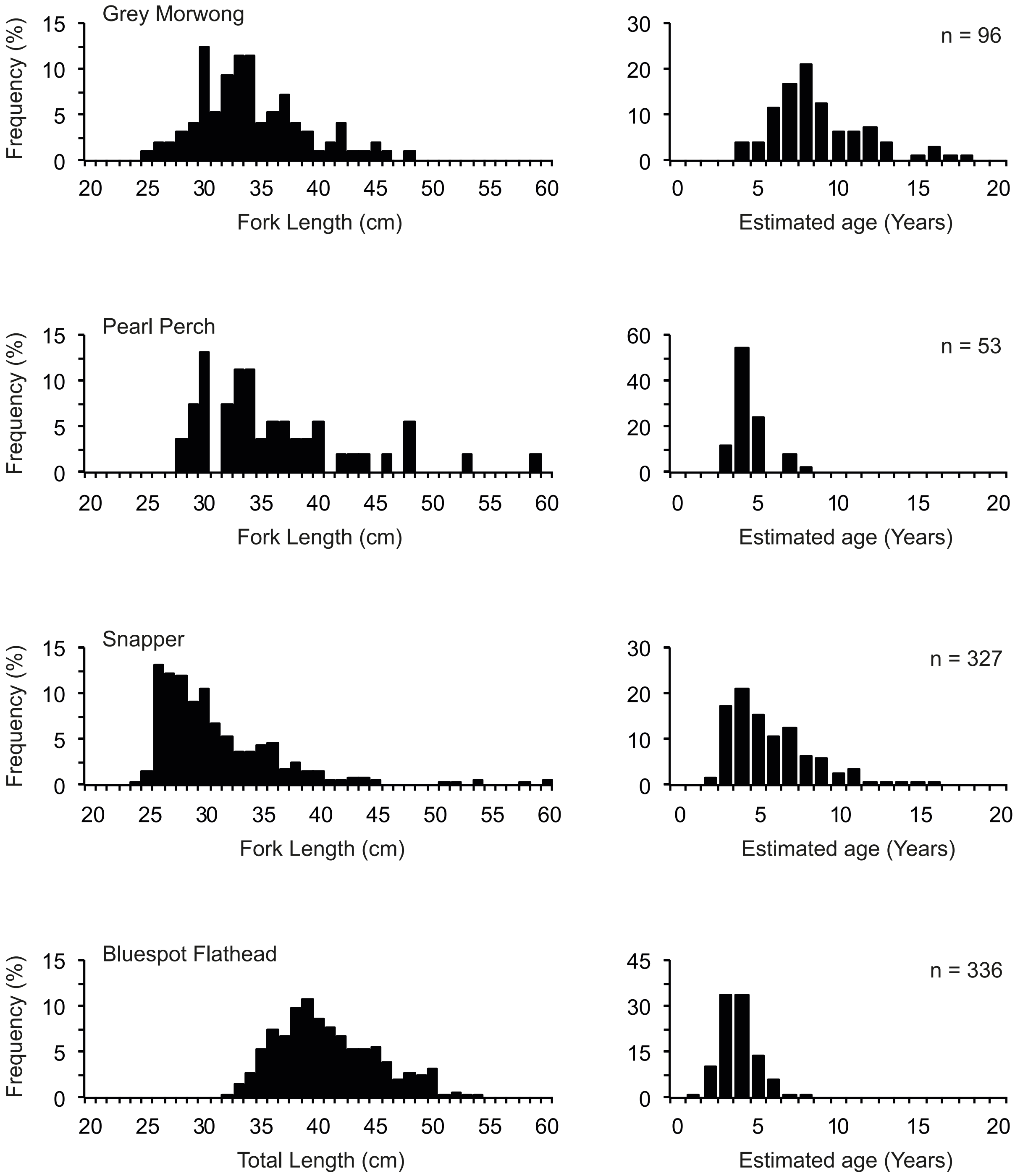
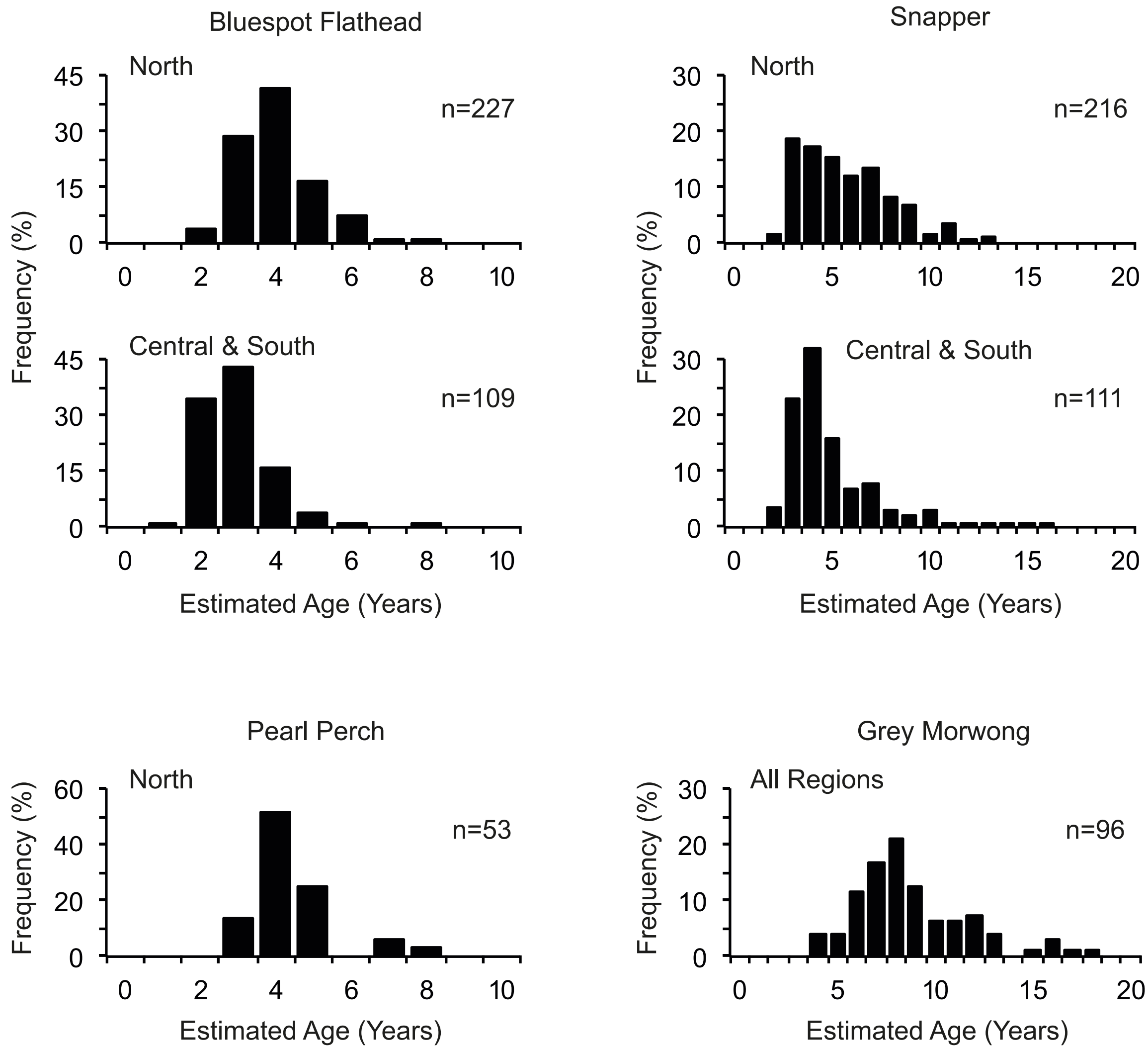


Figure 3.18. Estimated age compositions of kept catches of snapper and bluespot flathead for the northern and the combined central and southern regions, pearl perch from the northern region and grey morwong for all regions combined. Region-specific age-length keys were used where applicable.



4. Overview of Charter Boat Clients

4.1. Overview

For each observed trip, data were collected on the type of charter as to whether the vessel was a private charter (i.e. vessel chartered by one group) or was public (i.e. several groups/individual clients). Information on the number and type of client groups, numbers of persons within each group and the numbers of total clients were determined for each trip. Clients were also interviewed to obtain some basic demographic and participation information. This was done to achieve Objective 4.

Objective 4. Deliver summary profiles of charter boat clients to industry

4.2. Client Composition

Charter boat clients were dominated by adult males (> 77%) across all ports (Table 4.1), which is a general reflection of that mostly reported in other surveys of recreational angler participation (Henry and Lyle, 2003; West et al., 2016). The greatest proportion of adult females was encountered on Sydney-based trips, with higher proportions also observed at Coffs Harbour along with the highest proportions of juveniles of each gender (< 18 years). The latter was most likely due to there being more families and holiday makers undertaking trips in Coffs Harbour. Very few females < 18 years were encountered on trips. ≥

Table 4.1. The total number of clients and the percentage according to demographics encountered on charter boat trips across each port.

Region/Port	Number of Clients	Adult (≥ 18 Years)		Juvenile (< 18 Years)	
		Male %	Female %	Male %	Female %
North					
Wooli	143	87.4	4.2	8.4	0.0
Coffs Harbour	413	77.7	9.2	11.6	1.5
Central					
Sydney	249	79.5	15.3	4.4	0.8
Port Hacking	513	94.9	3.5	1.4	0.2
South					
Kiama	366	91.0	6.5	2.5	0.0
Greenwell Point	144	93.0	3.5	3.5	0.0
Grand Total	1828	87.4	7.1	5.0	0.5

4.3. Charter Type

4.3.1. Private Charters

Overall, private charters accounted for approximately 52% of observed trips, but this varied greatly among ports (Table 4.2). Notably, the high percentage of private trips in Port Hacking was the direct result of most operators only offering whole boat hire (i.e. private) charters, whereas elsewhere general seats along with the option to hire the entire boat as a private charter were offered.

Fishing clubs made a significant contribution to private charters in the southern region and in Port Hacking. The majority of these fishing clubs were Sydney-based, primarily from the south-western suburbs. Many such clubs had regular monthly or bi-monthly trips booked on the same vessels, several which had been ongoing for many years. Work groups were also important in the central and southern regions, particularly in the lead up to Christmas. Social/family group charters were often associated with special events such as birthdays, weddings (especially 'bucks parties') and specific holiday-associated fishing trips.

Table 4.2. The number of trips that were either private or public charters according to port and the primary type of group responsible for private charters.

Region/Port	Number Trips	No Private	% Private	Fishing Club	Social/Family Group	Work Group
North						
Wooli	19	9	47.4		100.0	
Coffs Harbour	40	0	0.0			
Central						
Sydney	14	1	7.1			100.0
Port Hacking	49	47	95.9	44.7	36.2	19.1
South						
Kiama	43	23	53.5	34.8	52.2	13.0
Greenwell Point	16	14	87.5	21.4	71.4	7.1
Grand Total	181	94	51.9			

4.3.2. Public Charters

For public charters, the mean number of groups varied between 3.2 and 5.9 among ports, whereas the mean number of persons per group varied between 2.2 and 3.0; the greatest number for each variable occurring in Sydney (Table 4.3). A greater proportion of holiday-based trips were evident in the northern region and least in Sydney. Non-holiday social/family groups were most prevalent in Sydney and Kiama. The proportion of people participating in a trip due to a gift (primarily birthday and father's day presents) was greatest in Sydney. People citing that they undertook a trip to specifically fish for food was least in Sydney and greatest in Kiama. Overall, 96% of clients interviewed expressed that they expected to take fish home from the trip. However, less than 20% of those interviewed expressed this was the primary reason for undertaking the particular trip.

Table 4.3. The mean number of individual groups, the mean number of persons per-group and primary participation reason for each group in each port.

Region/Port	Number of Trips	Number of Groups Per Trip	Number of Persons per Group	Participation: Social/Family Non-Holiday (%)	Social/Family Holiday (%)	Fish for Food (%)	Gift (%)	Work-Related (%)
North								
Wooli	10	3.2	2.5	10.0	80.0	5.0	0.0	5.0
Coffs Harbour	40	4.5	2.2	21.1	56.6	12.6	6.3	3.4
Central								
Sydney	13	5.9	3.0	46.7	11.7	2.6	39.0	0.0
Port Hacking	NA	NA	NA					
South								
Kiama	20	3.2	2.8	55.4	16.1	19.6	5.4	3.6
Greenwell Point	NA	NA	NA					

5. Comparison of industry logbook- and observer-based catch and effort data

5.1. Overview

Fishery-dependent data obtained from industry completed logbooks are often used as primary sources of information to monitor and assess spatial and temporal changes in fishery catch compositions, and the rates (i.e. catch-per-unit-of-effort [CPUE]) and total harvests of key species (Hilborn and Walters 1992). Unfortunately, such data are often of limited value for population and fisheries assessments and for management deliberations due to their often prescribed potential limitations and biases (Rotherham et al 2007, Salas et al 2007, Defeo et al 2014).

There currently exists a logbook program in the NSW recreational charter boat fishery which is supposed to provide necessary data for inclusion in resource assessments and for management of the fishery and of harvested species. However, the data collected have not been independently validated and may lack accuracy, therefore compromising their utility in fisheries assessments and management and as a credible source of information for stakeholders. The most pertinent and well-accepted way to validate such self-reported logbook data is to use scientific observer programs (Uhlmann et al 2014, Kennelly 2015).

This particular specific of this project component compared charter boat catch and effort data sourced from industry logbooks and an independent observer program. This directly addressed project objectives 5, 6 and 7.

5.2. Methods

5.2.1. Data Sources

The comparison of industry logbook and observer catch data covered six ports (Wooli, Coffs Harbour, Sydney, Port Hacking, Kiama and Shoalhaven) for the period 1 December 2014 to 30 November 2015. For the logbook data charter operators are mandated to provide for each fishing trip the type and general location of fishing, the numbers of clients and hours fished, as well as the numbers of each species (or species complex) retained (including those used for bait). Operators also have the option to record information on released catches if they desire. The logbook data (without vessel identification) was supplied by NSW DPI and included catch and effort data for each trip per study port over the 1-year period. The corresponding observer-based catch and effort data were obtained as described in Chapter 3. Across the six ports, data from a total of 1357 completed logbooks (individual trips) and 154 observed trips were available for this comparison. Since the logbook data only included information on released catches for 122 trips (Coffs Harbour - 43, Sydney - 56, Port Hacking – 1, Kiama - 3, Shoalhaven - 19) that yielded 161 released individuals, the comparative analyses between the two data sources were only done for the kept catch component.

Industry-generated length data of kept catches recorded on logbooks for the period 2001- 2003 as reported in Stewart and Hughes (2008) were used to compare with the kept catch length compositions from the observer data. Data across all ports combined were used for these comparisons.

5.2.2. Data Analyses

Differences between the two data sources and across the six ports in the numbers of clients and fished hours, the catch rates (i.e. CPUE) of total species, total individuals and of key species, were examined using permutational analyses of variance (PERMANOVA; Anderson et al 2008). In each two-factor analysis, the term data source (i.e. logbook v observer) was considered a fixed factor and port a random factor. Each univariate (i.e. effort and catch rates) analysis was based on the Euclidean distance measure with Type III (partial) sums-of-squares calculated using 9999 unrestricted permutations of the raw data (Anderson et al 2008). Where appropriate, separate pair-wise comparisons using the PERMANOVA interactive effects routine were subsequently used to determine across which ports the logbook and observer data significantly differed. All analyses were done using the Primer 6 and Permanova+ programs (Clarke 1993, Anderson et al 2008).

Total harvests of total individuals and key species as reported in logbooks and that estimated by scaling the observer catch data to the total number of reported trips in each port and across all ports combined were compared.

5.3. Results

5.3.1. Fishing effort and client numbers

The mean number of clients and fished hours significantly differed according to the interaction of data source and port (d.f. = 5, 1499; $P < 0.001$ in both cases). The pairwise comparisons identified that the mean number of clients per trip was significantly greater for the observer compared to the logbook data for Sydney, Port Hacking and Shoalhaven, but did not differ between data sources for the other three ports (Figure 5.1). In contrast, the mean hours fished per trip was greater for logbooks than observed trips across all ports, except Port Hacking (which did not differ between data sources) (Figure 5.1). The mean observed total trip length significantly differed among ports, and ranged from 1 to 3 hours greater than observed fishing time (Figure 5.1).

5.3.1. Kept Catch Composition

A total of 109 taxonomic/species complexes were recorded as being kept in industry logbooks (n=1357), and in comparison, observers identified 85 kept species across the 154 trips (Table 5.1). Greater total numbers of species were reported in logbooks for Sydney, Port Hacking and Kiama, but the opposite was evident for the Shoalhaven. Similar total species numbers were reported across both data sources at Coffs Harbour. Differences between data sources in total species numbers were mostly attributable to species/groups that occurred in low actual numbers (i.e. infrequently caught). Moreover, the logbook data included a number of ‘other’ (e.g. flathead other, leatherjacket other) and combined taxonomic/species groupings (e.g. leatherjacket, tailor and salmon, yellowtail scad and jack mackerel) that did not exist in the observer data.

Six species– grey morwong, bluespot flathead, snapper, ocean leatherjacket, redfish and sweep - were the most commonly kept species across both the logbook and observer data, contributing 67 and 61% to total logbook and observed kept catch. Similarly, the ten most numerous kept species contributed 79 and 76%, and the top twenty 91 and 89%, towards the total logbook and observed total kept catch, respectively (Table 5.2).

5.3.2. Catch Rates of Key Species

For both data sources, the catch rates of total individuals and the three key species (snapper, grey morwong and bluespot flathead) displayed the same results across the four units of fishing effort (i.e. catch per trip, client, hour and client/hour) (Table 5.3). Differences between ports in mean catch rates of total individuals and the three key species were also similar across the four units of fishing effort (Figure 5.2). Since these results indicated that all units of fishing effort displayed similar patterns, further analyses comparing catch rates between data sources were done at the catch per trip level.

Across all ports, mean catch rates per trip for some key species (grey morwong, snapper, silver sweep and pigfish) did not significantly differ between the logbook and observer data (Table 5.4, Figure 5.3). For snapper and grey morwong, this trend was also consistent across seasons for the three ports examined (Table 5.5, Figure 5.4). In contrast, mean catch rates of blue mackerel were significantly greater for the observer compared to the logbook data across all ports, and similarly for sergeant baker except for Wooli and Sydney where catches were very low.

Differences between data sources in mean catch rates for numbers of species and individuals and for some key species were not consistent across all ports (Table 5.4). Notably, the mean number of species retained was significantly greater for the observer than the logbook data for all ports but Sydney (where there was no difference). Similarly, the mean number of individuals kept per trip was greater for logbook data for Port Hacking and Shoalhaven, but the opposite was evident for Sydney and Kiama (Figure 5.3). Similar opposing trends in data sources were evident for bluespot flathead (Sydney versus Port Hacking), ocean leatherjacket, redfish and tiger flathead (Port Hacking versus Kiama) (Figure 5.3).

Differences between data sources in mean catch rates of total species and individuals and for the three key species examined displayed temporal consistency across each of the three ports examined (Table 5.5, Figure 5.4).

5.3.3. Total Harvests

Summed across all ports, a total of 49028 individuals were reported as being kept in industry logbooks. In comparison, an estimated total harvest of 48337 individuals was obtained by scaling the observer data to total reported fishing effort (number of trips) for all these ports (Table 5.6). However, differences between data sources in total harvests were evident for individual ports. For example, the logbook and observer estimates of total individuals kept were similar for Wooli and Coffs Harbour, but were much greater for logbooks than for observer data for Sydney and Kiama, but the opposite pattern was evident for Port Hacking and Shoalhaven (Table 5.6).

Notable differences in total harvests of individual species were also evident across some ports; for example: (1) catches of most key species (except bluespot flathead, blue mackerel and silver trevally) were greater on logbooks than observer estimates for Sydney, (2) catches of several species including ocean leatherjacket, redfish and sergeant baker were much greater for observer estimates than reported on logbooks for Port Hacking, (3) total harvests of snapper were similar across all ports except Sydney, where 3x more were reported in logbooks than in observer estimates, (4) for bluespot flathead, total harvests were greater for logbooks for Port Hacking, but less on logbooks for Wooli, Sydney and Kiama, and similarly (5) total grey morwong harvests were greater for logbooks for Sydney and Kiama but not elsewhere (Table 5.6).

5.3.4. Length Compositions of Kept Catches

The length compositions of kept catches differed between data sources for all eight species examined, with a greater proportion of larger individuals recorded in logbooks (Figure 5.5a,b). Notably, the sample sizes of measured fish were much greater for the logbook data.

5.4. Discussion

Comparative studies like that done here can help identify the suitability and cost-efficiencies of alternative data sources for determining long-term fishery monitoring, assessment and management strategies (Lunn and Dearden 2006, Gray 2016). In doing such a study, however, several assumptions were required, including that the observed vessels and trips sampled were representative of the fleet in each port, and that operators did not change their habits of fishing and recording information on logbooks during the study period.

The comparative analyses identified that the mean catch rates of total individuals and of most key species for the logbook and observer data were the same for each sampled port except Sydney. Moreover, both data sources revealed similar spatial differences among ports in total kept catch composition and catch rates of key species. These results suggest that the industry supplied logbook data could potentially be used as the primary source of longitudinal monitoring of catch rates (CPUE) of key species in this fishery. This would be a more cost-effective means of obtaining such data than utilising an ongoing large-scale, fleet-wide, observer program. Moreover, data from only an appropriately stratified subset of reliable operators would be required for monitoring spatio-temporal trends in catch rates. Furthermore, such data would provide a means to incorporate recreational fisheries information in stock assessments of key harvested species, bearing in mind that the long-term provision of reliable industry-reported data depends on maintaining good industry-management relations.

For assessment purposes, it does not appear vital for either data source which unit of fishing effort (trip, client, hour) is used to determine and examine trends in kept catch rates (CPUE) for key species. For most analyses here, we used the coarsest unit of fishing effort (i.e. 'trip') as this was the least subjective (e.g. compared to reported numbers of clients and hours fished – which differed inconsistently among ports for the two data sources). For example, the hours fished was calculated as that time between the start and end of fishing and included travel between different locations within this time band. Likewise, the number of clients that actually participated in fishing often varied throughout a trip as individuals had breaks, and often the number of clients actively fishing declined as the trip progressed. Moreover, such effort determinations do not account for each client's fishing avidity.

Total harvest determinations of total individuals and key species for each data source varied among ports. The precision of the observer-based estimations was reliant on accurate reported total fishing effort data and representative observed mean catch rates across the same unit of effort. Total harvest determinations based solely on logbook data relied on the compliance of operators to supply both accurate effort and catch information. A recent report suggests that only about 50% of operators comply with completing logbooks (McIlgorm and Pepperell 2014), but significant efforts are currently being made to greatly increase this (Geoff Barrett pers. comm.). Increased compliance procedures and online reporting may facilitate 100% uptake of completing logbooks. Nevertheless, the data presented provide evidence that large numbers of some species are harvested by the coastal charter boat fishery. Whilst direct comparisons with the recreational trailer boat fishery and the commercial sectors cannot be made here, the fishery is clearly an important contributing component to total fishery harvests that needs to be monitored and reported.

Before the acceptance of the logbook-based data collection strategy for fishery monitoring and species assessments in this fishery, several anomalies require attention. Notably, the mean diversity of kept catches (i.e. mean number of total kept species) was significantly less for the logbook than the observed data across all ports. This indicated that not all operators reported all species kept on each trip, most likely omitting those species deemed unimportant, and/or caught infrequently and in low numbers. This occurred even though total reported diversity of kept catches across the study was greater for the logbook than the observer data. This latter result was to be expected, given the far greater (x9) sample size of logbook trips compared to observer trips. Nevertheless, it is important for catch biodiversity monitoring that the numbers of all kept species be recorded for each trip. The current industry logbooks compound this situation due to the recording of mixed species complexes (e.g. leatherjacket, flathead) and species amalgamations (e.g. tailor and salmon, yellowtail scad and jack mackerel). Explaining the importance of such information and the provision of species identification guides to operators could assist in rectifying this situation.

The mean catch rates of several important species, including those used for bait (e.g. blue mackerel and sergeant baker), were lower in logbooks compared to the observer data. Organisms caught and used in-situ as bait are an important component of kept catches and operators should be encouraged to report their numbers accurately. For baitfish, this is potentially more difficult than for other kept organisms that can be counted at the end of the days fishing.

The logbook data is currently restricted to the numbers of each individual species/complex kept for each trip. If deemed necessary to monitor and report on released catches, then there is the option to either mandate that operators also record such information as part of the logbook program, or use an independent observer program (as reported in Chapter 3). Whilst it would be cheaper to obtain such data directly from operators, it is probably an unrealistic and logistically difficult task as it would need to be recorded throughout each fishing trip. In most circumstances this would compromise the primary duty of operators catering for their paying clients.

Observers collected data on the lengths of kept and released species (Chapter 3) which can be incorporated in species assessments. Previously, as part of the logbook program charter operators also recorded the lengths of some key kept species, which differed to the observer data for the species examined. The reasons for these differences are not determinable, but could be due to a combination of fork and total length being measured by industry operators for some species, spatio-temporal variability, and length truncation among populations between the data collection periods (Stewart 2011).

Whilst industry-recorded length data may be credible, it may be difficult to reintroduce this data collection strategy in this fishery. Importantly, the collection of length data was abandoned in 2008 due to a combination of operator burden and management concerns that the data were not representative (although this was not actually tested). Whilst again it would obviously be cheaper to obtain such data directly from operators, it would probably prove to be a challenging management option with strong opposition from many operators. Whilst these data could potentially be collected dockside upon completion of each trip, this again would most likely be an unrealistic option as it would burden clients and mean they could not depart straight after disembarkation. This is a concern among operators and could negatively impact client satisfaction and their utilisation of charter boat services.

The observer sampling also obtained additional finer detail information of catch, location, depth and habitat of each individual fishing event during each trip. Such information has important considerations for interpreting spatio-temporal variability in catches (Gray and Kennelly in press) and for spatial management of the marine estate. Again, this type of information could be recorded by operators if required, but this would add another level of detail to logbooks that would most likely further overladen operators in data collection.

In conclusion, this pilot study has identified that industry logbooks could be a credible source of information of obtaining catch rates (CPUE) of total individuals and key species kept in this fishery and potentially be of value for longitudinal monitoring and assessment of key harvested species. This is a more cost-effective option than deploying independent observers to collect this information.

However, this study was done only across six ports and one year and further examinations are required to assess broader applicability and inter-annual variability. Furthermore, and most importantly, industry logbooks currently provide no reliable data on released catches from the fishery.

The current logbook data are problematic regarding diversity of kept catches and appear to under report catch rates of some species, especially those kept for bait. Whilst these issues can be rectified via education and changes to logbooks, it would be unrealistic for operators to collect additional data on the diversity and numbers of released catches as well as the lengths of fish. Presently, it would be most beneficial for management to concentrate on educating charter operators to supply accurate kept catch data for all species, and most importantly, put systems in place that ensure all charter operators comply with submitting logbooks as currently mandated.

There is a raft of options for the future monitoring and assessment of this fishery and harvested recreational species in NSW. These range in scale and costs from a large-scale fishery-wide annual observer program that reports on kept and released catches and demographics of species, to industry logbooks that report data on kept catches and effort. Clearly, the overall strategy is dependent on the information needs to satisfy management and conservation objectives, the frequency of such data needs, and the overall costs and cost-efficiencies compared to alternative fishery data sources (such as obtaining lengths and ages from other recreational and commercial fisheries). It is clear that the relevant authorities need to prioritise management objectives and data information needs for the fishery and key recreational species, upon which an appropriate long-term monitoring and assessment strategy can be developed.

It is most likely that a future monitoring and assessment strategy will include a combination of both industry and observer data. For example, it could involve an ongoing industry logbook program of kept catches and a periodic (e.g. every 5 years) observer-based program that collects quantitative data on the diversity and numbers of released catches, and the length compositions (and potentially age compositions) of kept and released species. This would pave the way for greater assessment and reporting of discarding and biodiversity impacts for ecosystem-based fishery management in the fishery. Such a sampling program would also prove vital in validating the ongoing industry logbook data, and so mitigate any criticism regarding the reliability of industry-reported data for assessment and management purposes.

Table 5.1. The total number of reported and observed trips, total number of kept species and individuals and the average number of individuals per trip as reported on industry logbooks and observer data across each of the six study ports.

	Logbook				Observer			
	No. Trips	Species	Individuals	Ind/Trip	No. Trips	Species	Individuals	Ind/Trip
North								
Wooli	126	43	4429	35.2	19	35	605	31.8
Coffs Harbour	151	30	4603	30.5	31	29	933	30.1
Central								
Sydney	506	67	11695	23.1	12	23	157	13.1
Port Hacking	296	61	13005	43.9	42	43	2478	59.0
South								
Kiama	183	43	11097	60.6	37	36	1928	52.1
Greenwell Poin	95	23	4199	44.2	13	38	843	64.8
Total	1357	109	49028	36.1	154	85	6944	45.1

Table 5.2. The twenty most numerous species reported as being kept on industry logbooks and those observed in kept catches and their percent contribution to the total catch of each data source.

Logbook (n = 1357)				Observer (n = 154)			
Rank	Species/Complex	Total Number	% Total Number	Rank	Species/Complex	Total Number	% Total Number
1	Morwong Grey/Blue	7700	15.7	1	Leatherjacket Ocean	927	13.3
2	Flathead Bluespot	6676	13.6	2	Snapper	897	12.9
3	Snapper	6125	12.5	3	Morwong Grey/Blue	718	10.3
4	Leatherjacket Ocean	5672	11.6	4	Flathead Bluespot	679	9.8
5	Redfish	4168	8.5	5	Redfish	654	9.4
6	Sweep Silver	2401	4.9	6	Sweep Silver	375	5.4
7	Flathead Tiger	2087	4.3	7	Mackerel Blue	361	5.2
8	Pigfish Eastern Blackspot	1423	2.9	8	Perch Ocean	262	3.8
9	Southern Fusiler	1191	2.4	9	Sergeant Baker	215	3.1
10	Mackerel Blue	1131	2.3	10	Flathead Tiger	203	2.9
11	Yellowtail Kingfish	1041	2.1	11	Pigfish Eastern Blackspot	183	2.6
12	Teraglin	920	1.9	12	Wrasse Maori	175	2.5
13	Perch Longfin	777	1.6	13	Perch Longfin	154	2.2
14	Wrasse Maori	732	1.5	14	Yellowtail Scad	152	2.2
15	Sergeant Baker	730	1.5	15	Teraglin	104	1.5
16	Trevally Silver	617	1.3	16	Trevally Silver	99	1.4
17	Perch Orange	362	0.7	17	Eastern Red Scorpionfish	83	1.2
19	Dolphinfish	345	0.7	18	Sea Pike Longfin	78	1.1
18	Pearl Perch	331	0.7	19	Barracuota	60	0.9
20	Flathead Southern Sand	329	0.7	20	Perch Pearl	57	0.8

Table 5.3. Summary of PERMANOVA's comparing between data sources and among the six ports catch rates of the total numbers of kept individuals, snapper, grey morwong and bluespot flathead for each of the four units of effort (per trip, client, hour, client & hour).
* = P < 0.05, ** = P < 0.01, *** = P < 0.001, ns = P > 0.05.

	Data Source	Port	DS x P
	1, 1499	5, 1499	5, 1499
Total Individuals			
Trip	ns	***	**
Client	ns	***	*
Hour	*	***	**
Client/Hour	ns	***	ns
Morwong Grey			
Trip	ns	*	ns
Client	ns	*	ns
Hour	ns	*	ns
Client/Hour	ns	*	ns
Snapper			
Trip	ns	***	ns
Client	ns	***	ns
Hour	ns	***	ns
Client/Hour	ns	***	ns
Flathead Bluespot			
Trip	ns	***	**
Client	ns	***	**
Hour	ns	***	**
Client/Hour	ns	***	***

Table 5.4. Summary of PERMANOVA's comparing catch rates (per trip) of total numbers of kept species and individuals and numbers of ten key species between data sources among the six ports.
* = P < 0.05, ** = P < 0.01, *** = P < 0.001, ns = P > 0.05.

	Data Source	Port	DS x P
	1, 1499	5, 1499	5, 1499
Total Species	***	***	***
Total Individuals	ns	***	**
Morwong Grey	ns	*	ns
Snapper	ns	***	ns
Flathead Bluespot	ns	***	**
Leatherjacket Ocean	ns	***	***
Redfish	ns	***	***
Sweep Silver	ns	***	ns
Mackerel Blue	**	**	ns
Sergeant Baker	***	***	*
Flathead Tiger	ns	***	***
Pigfish Eastern Blackspot	ns	***	ns

Table 5.5. Summary of PERMANOVA's comparing catch rates (per trip) of total numbers of kept species and individuals and numbers of three key species between data sources across seasons and among three ports.
* = P < 0.05, ** = P < 0.01, *** = P < 0.001, ns = P > 0.05.

	df	Total Species	Total Individuals	Snapper	Bluespot Flathead	Grey Morwong
Data Source	1	***	ns	ns	ns	ns
Port	2	***	***	***	***	*
Season	3	ns	ns	***	**	ns
Da x Po	2	ns	*	ns	*	ns
Da x Se	3	ns	ns	ns	ns	ns
Po x Se	6	ns	*	ns	**	ns
Da x Po x Se	6	ns	ns	ns	ns	ns
Residual	716					

Table 5.6. Reported logbook and observer estimated total harvests of key species across each of the six ports for the period 1 December 2014 to 30 November 2015.

	Wooli		Coffs Harbour		Sydney		Port Hacking		Kiama		Shoalhaven		Total	
	Logbook	Observer	Logbook	Observer	Logbook	Observer	Logbook	Observer	Logbook	Observer	Logbook	Observer	Logbook	Observer
Total Individuals	4429	4012	4603	4545	11695	6620	13005	17464	11097	9536	4199	6160	49028	48337
Morwong Grey	76	46	173	190	2894	590	1922	1875	2072	1499	563	650	7700	4850
Flathead Bluespot	19	106	1754	1797	1828	2614	2129	402	166	406	780	680	6676	6005
Snapper	1515	1592	1315	1203	807	253	843	867	829	930	816	680	6125	5524
Leatherjacket Ocean	5	0	56	44	832	42	2861	5624	1756	559	162	44	5672	6313
Redfish	0	0	2	5	1024	169	1275	2516	1544	1266	323	263	4168	4219
Sweep Silver	179	259	15	5	695	337	101	106	892	930	519	906	2401	2543
Flathead Tiger	108	0	0	97	791	42	545	1078	643	129	0	22	2087	1368
Pigfish Eastern Blackspot	0	0	41	68	284	84	366	338	586	519	146	102	1423	1112
Southern Fusiler	1191	298	0	0	0	0	0	0	0	0	0	0	1191	298
Mackerel Blue	2	46	29	63	42	295	513	853	457	608	88	658	1131	2524
Yellowtail Kingfish	183	86	53	0	642	0	20	0	21	5	122	44	1041	135
Teraglin	352	66	521	438	42	0	5	21	0	5	0	0	920	531
Perch Longfin	0	0	1	0	134	0	246	451	344	425	52	29	777	906
Wrasse Maori	0	0	1	0	119	169	140	49	266	351	206	680	732	1249
Sergeant Baker	0	0	18	83	163	0	252	662	271	401	26	168	730	1314
Trevally Silver	260	391	94	0	27	169	83	42	27	40	126	161	617	803
Perch Orange	0	0	0	0	37	0	3	0	322	275	0	7	362	262
Dolphinfish	1	0	95	127	245	0	4	7	0	0	0	7	345	141
Pearl Perch	146	153	184	161	1	0	0	0	0	0	0	7	331	321

Figure 5.1. Mean (+ SE) number of clients and fished hours per fishing trip for each port as determined from the logbook and observer data sources.

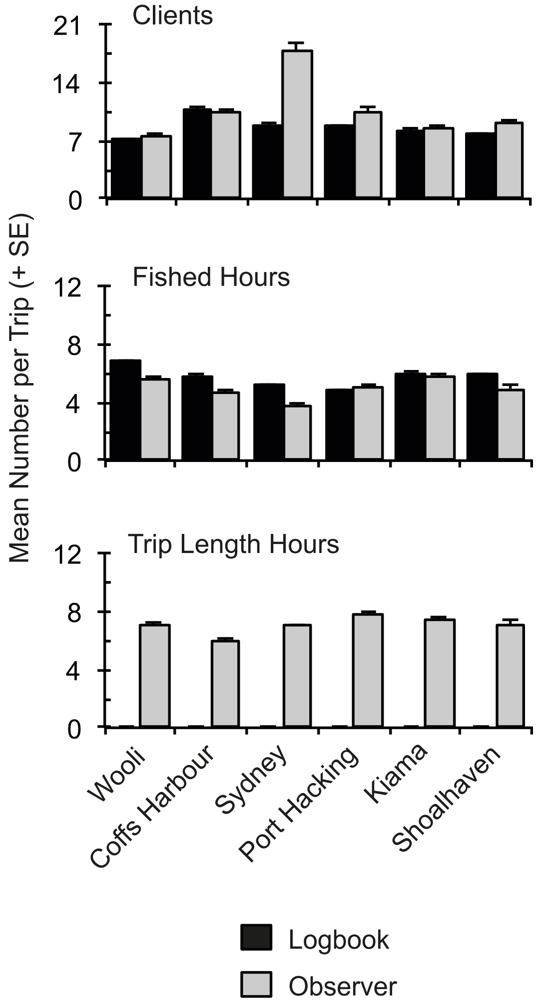


Figure 5.2. Mean (+ SE) number of kept total individuals, grey morwong, snapper and bluespot flathead across different effort combinations for each port as determined from the logbook and observer data sources.

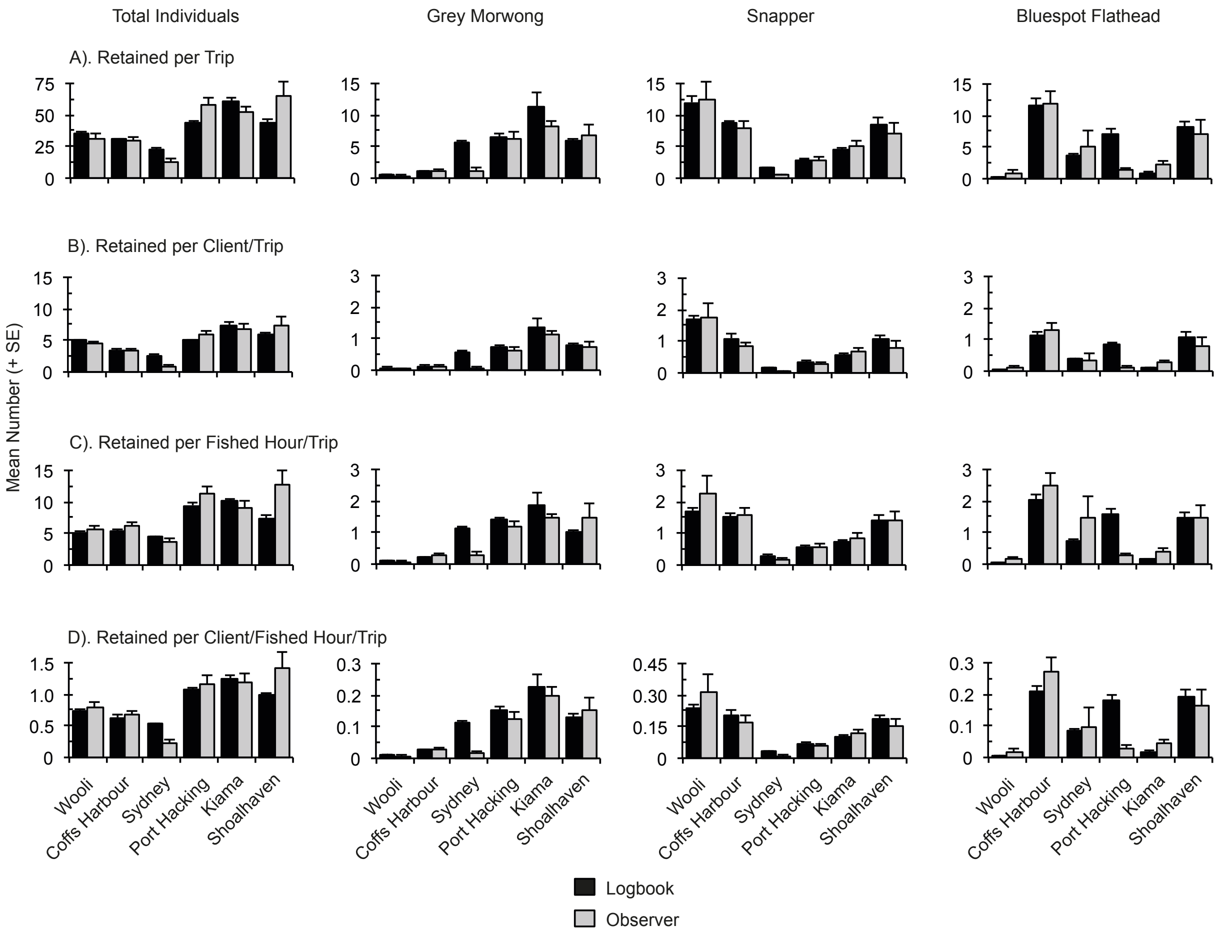


Figure 5.3. Mean (+ SE) number of total species, total individuals and key individual species kept per fishing trip for each port as determined from the logbook and observer data sources. Data pooled across all seasons.

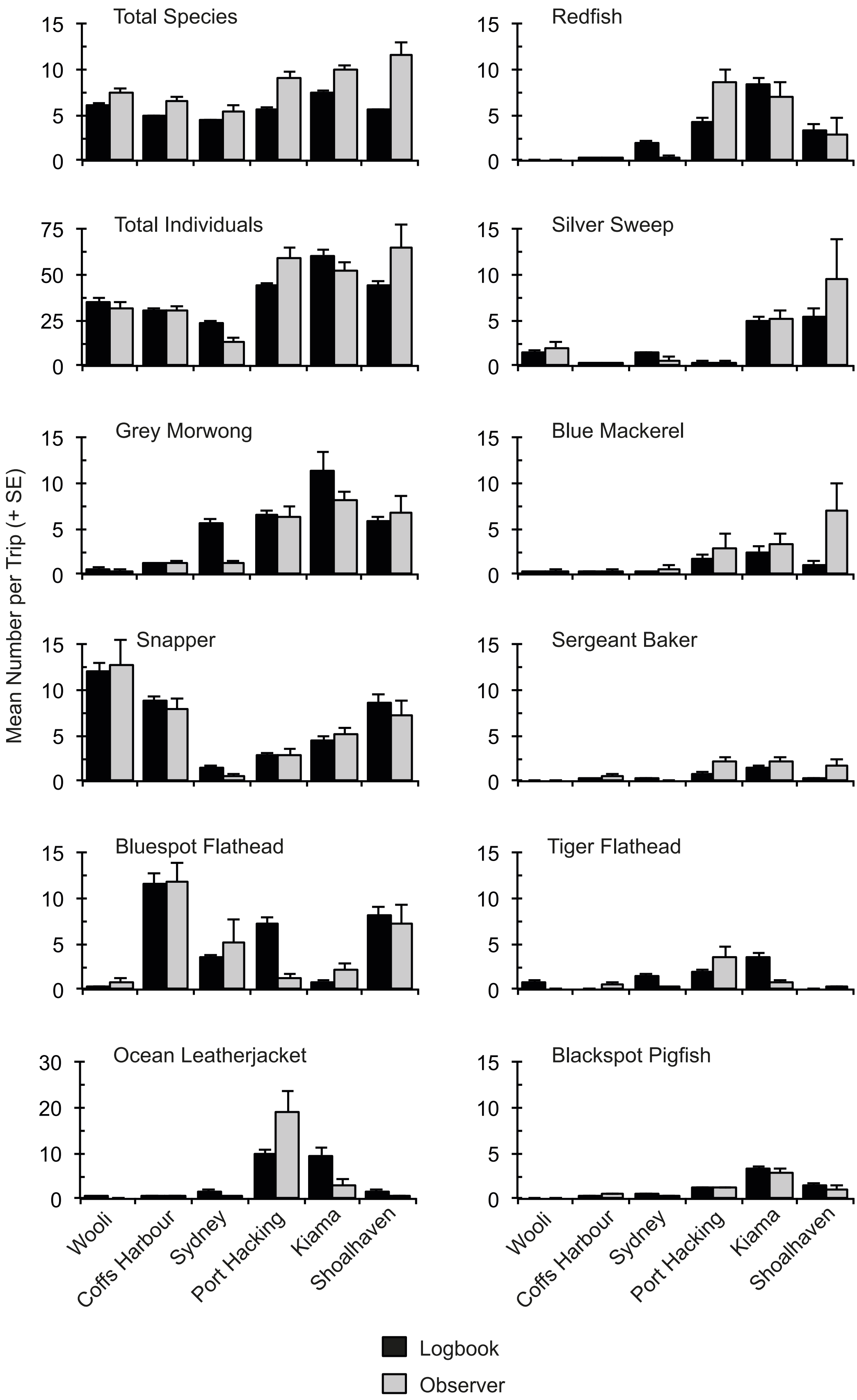


Figure 5.4. Mean (+ SE) number of total species, total individuals and key individual species kept per fishing trip per season for three ports as determined from the logbook and observer data sources.

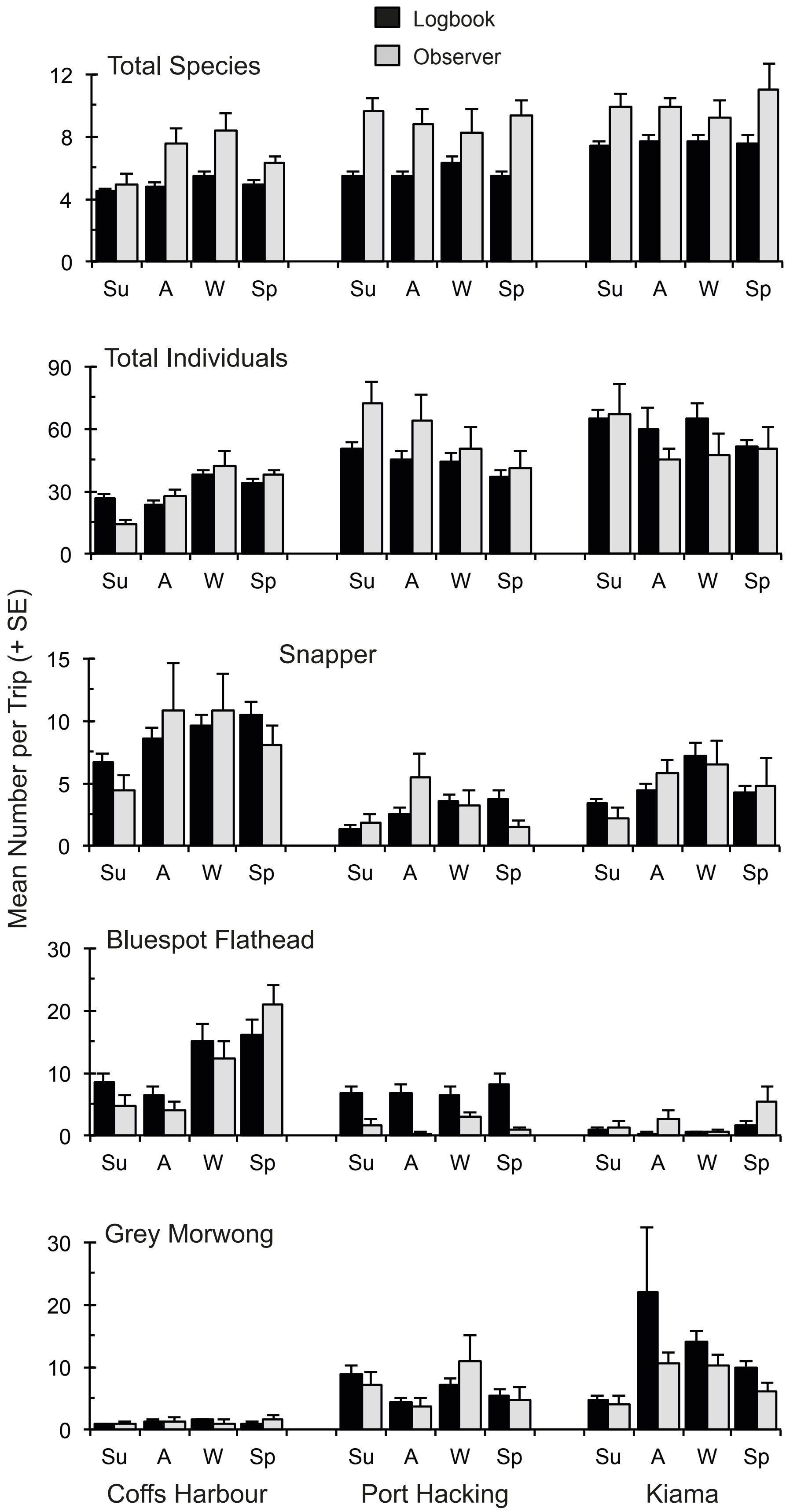


Figure 5.5a. Length compositions of some key species as determined from industry logbook (2001-2003) and the observer data sources.

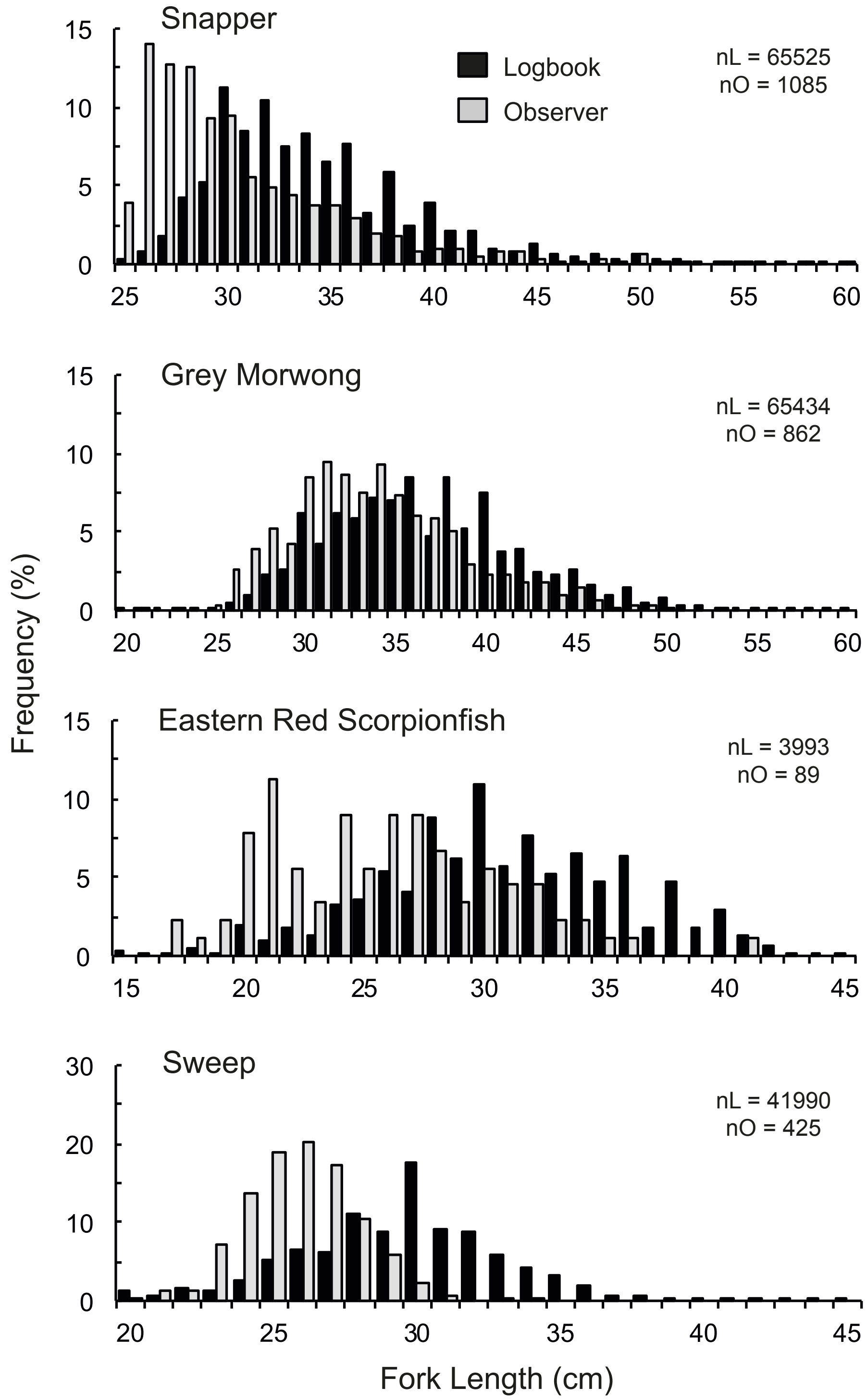
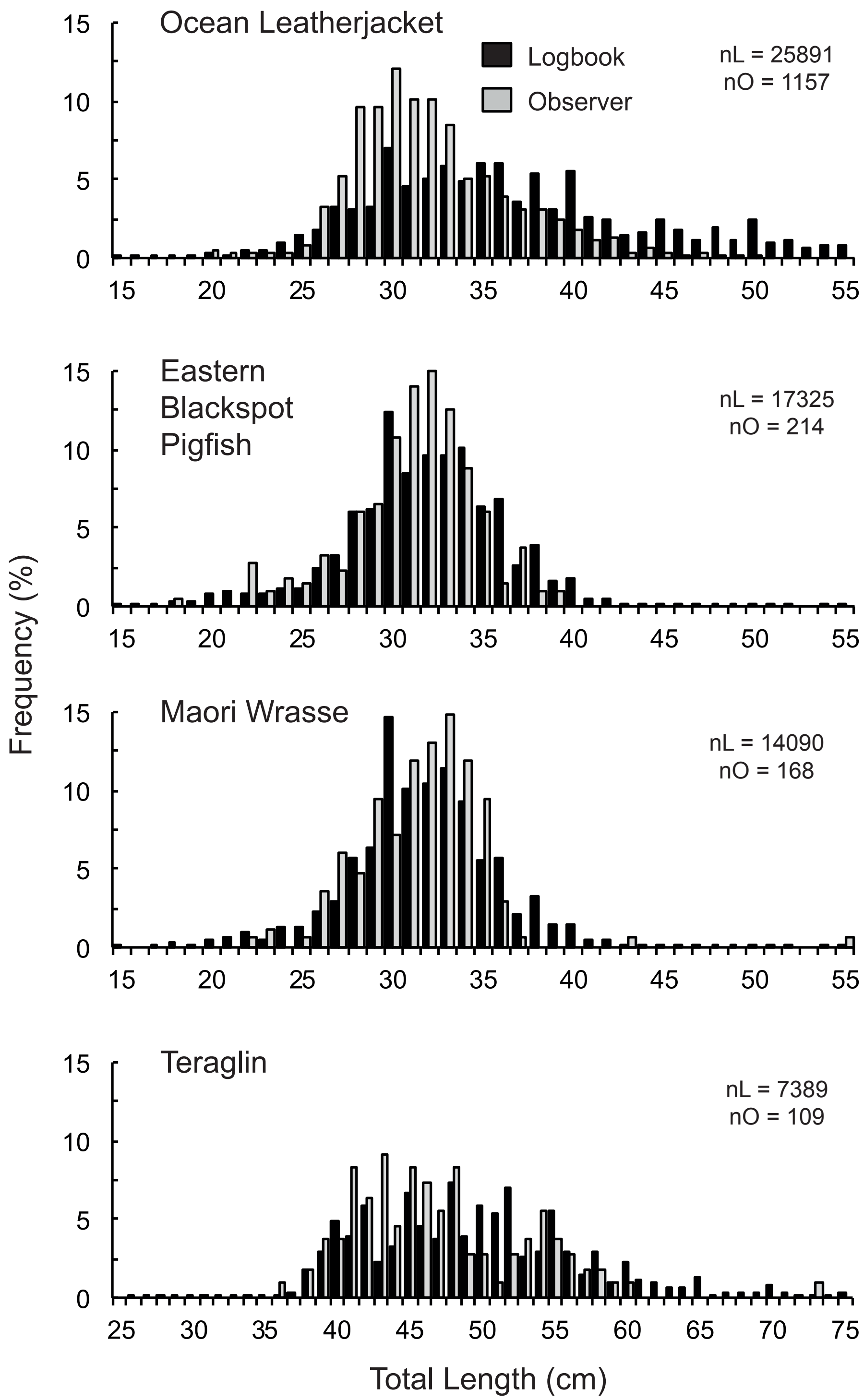


Figure 5.5b. Length compositions of some key species as determined from industry logbook (2001-2003) and the observer data sources.



6. Conclusions

This study provides the first formal quantification of kept and released catches in an Australian charter boat fishery. The project (i) successfully implemented and tested a standardised observer-based sampling strategy to assess kept and released catches from coastal charter boats in NSW, (ii) reported on habitat, regional and seasonal variations in the composition and rates of kept and released catches, (iii) evaluated observer versus industry logbook data sources for assessing the fishery and key species, (iv) presented an overview of charter boat clients, and (v) provided directions for future monitoring and assessment strategies in the fishery.

The observer sampling identified significant small-scale (among ports and habitats) as well as region-scale (latitudinal) variability in the compositions and rates of kept and released catches that need to be considered in managing and monitoring the fishery. Legal length restrictions determined whether many species were kept or released, whereas client and operator preferences primarily influenced such determinations for species without such restrictions.

This study not only demonstrated the value and utility of observer work in providing independent information about the fishery, but also about the demographics of some common and key recreational fish species. Our study showed that longitudinal sampling of charter boat catches can provide valuable indices of CPUE and length and age compositions of key recreational fish species for resource assessment and management. However, prior to the implementation of any large-scale and long-term sampling program, the logistics and cost efficiencies of observer sampling in this fishery compared to alternative species monitoring strategies (e.g. sampling commercial catches, standardised fishery-independent surveys) needs consideration.

The comparative analyses of the logbook and observer data sources identified some deficiencies in the current logbook, but once rectified the data could be a credible source of information of obtaining catch rates (CPUE) of kept total individuals and key species in this fishery and potentially be of value for longitudinal monitoring and assessment of key harvested species. This is a more cost-effective option than deploying independent observers to collect this information on a fulltime basis. However, this study was done only across six ports and one year and further examinations are required to assess broader applicability and inter-annual variability.

However, the logbook data are restricted to kept catches and not released fish, so the data are not able to be used to provide estimates of the total impact of the fishery on all individuals caught. But it would be unrealistic for operators to collect additional and reliable quantitative data on the diversity and numbers of released catches as well as the lengths of fish. This would overburden operators with data collection and most likely negatively impact the servicing of clients.

Future long-term monitoring and assessment of the fishery and harvested species could incorporate a combination of the current logbook program (with some modifications) and a periodic (e.g. every 5 years) observer-based program that collects quantitative data on the diversity and numbers of released catches, and the length compositions (and potentially age compositions) of kept and released species. This would provide quantitative data for greater assessment and reporting of discarding and biodiversity impacts for ecosystem-based fishery management. The periodic need for each of the different types of data should be determined using risk-assessment techniques. Such a sampling program would also be vital in validating the industry logbook data, which would help mitigate any criticism regarding the reliability of industry-reported data for assessment and management purposes.

Before an appropriate data sampling strategy can be determined for this fishery, the relevant authorities need to determine the objectives, information needs and available finances for managing a sustainable and viable charter boat fishery. Only then can an appropriate cost-effective and robust long-term monitoring and assessment program be designed and implemented.

7. Implications

This study provided the first quantitative estimates of the compositions and rates of kept and released catches in the NSW charter boat fishery. In doing so it demonstrated the utility and value of a standardised observer program for independently evaluating catches and the current logbook data. These data are valuable to management and industry for inclusion in any environmental assessment of the fishery and most importantly in determining future monitoring and assessment strategies for the fishery and key harvested species. The methods and results reported here have applicability to other recreational fisheries in other management jurisdictions in Australia and elsewhere.

8. Recommendations

The relevant management and industry authorities need to prioritise the objectives and data information needs for managing the NSW Charter Boat Fishery and the sustainable harvesting of recreational species, after which an appropriate long-term monitoring and assessment strategy can be developed. Clearly, the overall strategy must be aligned with stated management and reporting objectives and for data-poor fisheries and species like those studied here, the development of an appropriate strategy is best approached using a risk-based framework. Some factors that need consideration in such deliberations include the frequency and precision of each type of data need (e.g. diversity and numbers of released catch, catch length compositions, total kept harvests), and the overall costs and cost-efficiencies of obtaining such data compared to alternative fishery data sources (such as obtaining lengths and ages from other recreational and commercial fisheries).

The results from this study show that both industry logbook and independent observer data can provide catch and species demographic information beneficial to assessing and managing the NSW Charter Boat Fishery and associated recreational species. Like all fisheries and harvested species, however, there are a plethora of options for the future monitoring and assessment of the NSW Charter Boat Fishery and harvested recreational species. These range in scale and costs from an ongoing fishery-wide observer program that reports on the composition and levels of kept and released catches and demographics of species on an annual basis, to industry logbooks that report on kept catches and effort. Total costs and any cost-sharing agreements between government and industry will be an important consideration in determining the long-term viability of the various sampling strategies.

It is most likely that a future monitoring and assessment strategy for the NSW Charter Boat Fishery and associated species will include a combination of both industry and observer data. For example, it could involve an ongoing industry logbook program of kept catches and a periodic (e.g. every 5 years) observer-based program that collects quantitative data on the diversity and numbers of released catches, and the length compositions (and potentially age compositions) of kept and released species. This would pave the way for greater assessment and reporting of discarding and biodiversity impacts for ecosystem-based fishery management systems. Cost-benefit and risk-assessment techniques would best determine the required periodicity for each type of data. Such a sampling program would be vital in validating the industry logbook data, which would help mitigate any criticism regarding the reliability of industry-reported data for assessment and management purposes.

Clearly, the next step in this process is for the relevant management, scientific and industry authorities to consider the results of this study in formulating an appropriate cost-efficient long-term sampling strategy to deliver the necessary information to satisfy the management objectives of the NSW Charter Boat Fishery and fisheries resources of the NSW Marine Estate.

Further development

Further research is required for a greater understanding of the retained and released catches taken in other charter boat operations throughout NSW and elsewhere. These include those done in deep water and estuarine environments. Industry logbooks also should be validated in other charter sectors not examined in this study. Knowledge of the survival rates of released fish would assist in understanding potential ecosystem impacts of charter operations and contribute to total mortality estimates for stock assessments. The potential for electronic monitoring of catches requires examination in this fishery, but logistic issues will probably limit its applicability for the types of vessels and fishing practices examined here. Nevertheless, such systems could potentially be applicable for examining catches on small boats where there is no space for an observer.

9. Extension and adoption

Industry and Government representatives were briefed on project progress and results throughout the study and the project was promoted in the NSW DPI Charter Boat Newsletter. Individual charter boat operators and their clients were updated on project progress throughout the study. The project report will be available to all interest groups.

Data derived from the project were supplied to NSW DPI scientists and incorporated in species assessments at the 2015 and 2016 NSW DPI Resource Assessment Workshop.

Project coverage

The project was advertised in the NSW DPI Charter Boat Newsletter. There are no known media reports concerning this project.

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11. Project materials developed

Industry Publication:

1. What's the catch from charter boats? NSW DPI Charter Boat Newsletter.

Scientific publication:

1. Gray CA, Kennelly SJ (in press). Geographic, seasonal and habitat-related differences in the composition and diversity of retained and released catches in a coastal recreational pay-for-hire charter fishery. Fisheries Research.

12. Appendices

List of Appendices:

1. Intellectual property
2. Persons and businesses subcontracted to work on the project
3. Copy of: Gray CA, Kennelly SJ (in press). Geographic, seasonal and habitat-related differences in the composition and diversity of retained and released catches in a coastal recreational pay-for-hire charter fishery. *Fisheries Research*.

Appendix 1.

Intellectual property

No intellectual property that resulted in commercialisation was developed from this project.

Appendix 2.

People/Businesses contracted to work on the project.

Jennifer Marshall

Toby Piddock

Ricky Tate

Derrick Cruz

Krystle Keller

Stephanie Brodie

Brendan Findlay

Kim Elder

Grant Clark

Sascha Schulz

Martin Hing

Steve Kennelly

Charles Gray

KeeData

Fish Ageing Services Pty Ltd

IC Independent Consultants

WildFish Research

Appendix 3.

Gray CA, Kennelly SJ (in press). Geographic, seasonal and habitat-related differences in the composition and diversity of retained and released catches in a coastal recreational pay-for-hire charter fishery. Fisheries Research.

Geographic, seasonal and habitat-related differences in the composition and diversity of retained and released catches in a coastal recreational pay-for-hire charter fishery

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ABSTRACT

A scientific observer program was used to quantify, for the first time, the composition and diversity of retained and released catches in a coastal charter boat fishery off the Australian east coast. A total of 181 trips were observed across three regions (six ports) and five seasons that yielded 129 species and 13357 individuals. Overall, 90 and 92 species were retained and released, respectively, with 37 and 39 species either solely retained or released. Mean release rates of total species and total individuals varied across regions and seasons, ranging between 8 and 51%, and 15 and 66%, respectively. The 10 most numerous species captured accounted for 84% of the total individuals, with 41 species encountered only once. The composition and diversity of catches significantly varied across different spatial scales; among regions, ports within each region and the habitat (substratum) fished. Regional differences in retained and released catch compositions were consistent across seasons. Species diversity of retained and released catches was greatest in the northern most region, probably because it abuts the convergence zone between tropical and temperate water masses. The smaller-scale, port-related geographic differences in catches were driven by certain species being more or less frequent and abundant in catches from vessels from one port compared to the other. This was the result of localised and often vessel-specific differences in fishing practices, fishing grounds, the habitats fished and the requirements of clients. Habitat-related differences were greatest between bare sand and structured reef and reef/gravel habitats. The results show that fisheries management and longitudinal monitoring and assessments of the fishery need to account for both port- and regional-scale spatial variability in catch compositions and diversity.

Keywords: Recreational Fishing, Observer, Fisheries Management, Monitoring Strategy, Bycatch, Discard

1. Introduction

It is well accepted that many fisheries have significant impacts on the diversity and abundances of aquatic fauna across a plethora of habitats throughout the world (Dayton et al., 1995; Jackson et al., 2001). Whilst traditional fisheries assessments and management arrangements have primarily concentrated on harvested organisms, there is now global acceptance that other ecosystem impacts, including effects on the organisms discarded from fishing activities, be assessed and reported (Davies et al., 2009; Bellido et al., 2011; FAO, 2015). This is particularly important in the context of ecosystem-based fisheries management (Crowder et al., 2008; Hobday et al., 2011). A necessary component in achieving such management goals is identifying and quantifying the composition and diversity of retained and released catches across appropriate spatial and temporal scales (Uhlmann et al., 2014).

Many methods have been used to monitor fisheries catches, bycatches and discards including: scientific surveys using research vessels, Coast Guard inspections, post-trip sampling of landings, post-trip interviews of captains and crews, and getting fishers to self-record data by completing logbooks at sea (FAO, 2015). But by far the most reliable and accurate way to collect data on actual catches, bycatches and discards in a fishery is through the use of onboard observer programs (Kennelly, 2015). Many such programs now exist throughout the world and they have become a major, mainstream source of fisheries information (see papers in McVea and Kennelly, 2007; Uhlmann et al., 2014).

Whilst many observer-based surveys have been implemented in commercial fisheries, fewer have been incorporated into recreational fisheries. Worldwide, recreational fisheries are a major contributing component to total fishery harvests and ecosystem impacts (Coleman et al., 2004; Cook and Cowx, 2004). Consequently, there has been a call for greater emphasis on monitoring and reporting catches and impacts of recreational fisheries. Pay-for-hire recreational charter fishing enterprises occur globally and, depending on fleet sizes, they may contribute to large harvests at all spatial and temporal scales. Despite this, surveys of catches from charter fishing fleets have been rarely evaluated (and not at all in Australia), yet they potentially are ideally suited to observer-based data collection strategies.

The recreational charter (pay-for-hire) boat fishery is the single most valuable fishery in New South Wales (NSW), Australia, providing an estimated annual $AUD 50.2 million of output to the local economy from operators and their clients (McIlgorm and Pepperell, 2014). This is around twice the value of the most economically important commercial fishery (the oceanic prawn trawl fishery). As with any fishery, quantitative data on the diversity and sizes of retained and released catches, biological information on key species such as ages and reproductive capacity, and information about the areas and habitats fished, are required to manage the fishery and its stocks sustainably.

This study used an observer program to quantify the species composition and diversity of the retained and released catches in the coastal charter line fishery in NSW. Sampling was stratified spatially and temporally to test for geographic and seasonal variability in catches. We also assessed small-scale habitat-related influences on catches and examined if these were consistent across larger spatial scales.

2. Methods

2.1. Fishery and fishing practices

The NSW coastal charter boat line fishery has 276 endorsements with registered vessels ranging between 10 and 30 m that can host up to 35 fishing clients per trip (the actual maximum number of clients per individual boat is determined by survey regulations but generally between 8 and 15). Vessels typically undertake day trips of up to 8 hr duration, but actual times are dependent on client requirements, weather and fishing conditions. Vessels generally target demersal fish by drifting across fishing grounds (usually between 10 and 130 m deep), but some vessels anchor when targeting specific reef locations. Substratum types vary from bare sand to complex reef and reef/gravel habitats and their combinations. The location and habitat fished often varies within each trip, with individual fishing events ranging from < 5 to 80 minutes in duration. Operators often tow (troll) surface lures to and from demersal fishing grounds targeting seasonal pelagic species. The fishing gears used by clients are mostly provided by the operators with rod and non-electric reels (side-cast or overhead) typically used with a Paternoster hook (maximum 2 hooks) and sinker rig. Bait usually consists a mixture of frozen squid, pilchards and prawns but is often supplemented with fresh fish caught *in-situ* (typically *Scomber australasicus*, *Trachurus novaezealandiae* and *Hime purpurissatus*).

Several ‘primary’ fish species in this fishery have mandated minimum legal lengths (MLL) that dictate whether each individual fish caught is retained or released. In contrast, many other ‘secondary species’ have no length prescriptions so the choice of whether they are retained or released is determined by client and operator preferences - which can vary among individuals on a vessel and change throughout a trip. Several primary species also have maximum catch limits per trip, but each vessel has a total catch endorsement that covers all clients.

2.2. Sampling

The sampling of catches in this study was stratified spatially across three geographic regions off the coast of NSW and temporally across five seasons between December 2014 and February 2016. Catches from charter boats based in two ports were sampled in each region: these were Wooli (-29.89S) and Coffs Harbour (-30.31S) in the Northern Region, Port Jackson (-33.83S) and Port Hacking (-34.07S) in the Central Region and Kiama (-34.67S) and Shoalhaven (-34.90S) in the

Southern Region. Not all ports were sampled each season due to variable rates of operator participation during the study.

Catch data were collected by scientific observers who accompanied regular charter fishing trips. For each trip, the charter operator was paid the normal per person charter fee for taking the observer. On each trip, the observer identified and counted all retained and released fish and, when possible, measured their length (nearest cm). They also collected operational information including the number of clients, fishing times, depth, bottom topography (as determined by the operator), fishing gear, bait types and general weather and sea conditions. This was done for each fishing event throughout each trip.

2.3. Data analyses

Data on retained and released catches were nominally examined as catch-per-trip for geographic analyses (region and port) and catch-per-fishing event for habitat analyses. Separate two-factor permutational analyses of variance (PERMANOVA; Anderson, 2001; Anderson et al., 2008) were used to test for differences in the compositional structures of retained and released catches among (1) regions and seasons, and (2) between ports within each region. For the latter, separate analyses were done for each region as not all ports were sampled each season. Catch data for each fishing trip were used as the replicate samples in each of these analyses. One-factor PERMANOVAS were used to test for habitat-related differences in the compositions of catches in each region. Separate analyses were done for each region as not all habitats were fished in all regions. Catch data at the level of fishing event were used as replicates in these analyses, with the habitat fished identified by the operator. Analyses were done on raw and standardised data for both the retained and released catch components. These multivariate analyses (i.e. species composition data) were based on the Bray-Curtis dissimilarity measure and Type III (partial) sums-of-squares were calculated using 9999 unrestricted permutations of the data. Where appropriate, separate pair-wise comparisons were subsequently used to determine which levels of each significant factor differed for each level of the other factor using the PERMANOVA routine. The proportion of variation attributable to each factor and interaction term in each model was calculated to aid the interpretation of results. Similarity percentage analyses (SIMPER) were used to identify individual species that contributed greatest to differences in the compositional structure of catches among regions, ports and habitats. All analyses were done using the Primer 6 and Permanova+ programs (Clarke, 1993; Anderson et al., 2008).

The release rates (% released) of total species and total individuals was determined for each observed trip. Differences across regions and seasons in the release rates, and in the numbers of total species and total individuals retained or released, were tested using two-factor PERMANOVAS. Each of these univariate analyses were based on the Euclidean distance measure (Anderson et al., 2008), and again

Type III (partial) sums-of-squares were calculated using 9999 unrestricted permutations of the raw data. Again, separate pair-wise comparisons were subsequently used to determine which levels of each significant factor differed for each level of the other factor using the PERMANOVA routine.

3. Results

3.1. Catch composition and diversity

A total of 129 species was identified in catches in the 181 observed trips over the three regions and five seasons, of which 90 and 92 species were retained and released, respectively (Table 1, S1). Overall, 53 species were both retained and released, whereas 37 and 39 species were either uniquely retained or released, respectively. Many species in the latter categories were rare with few individuals observed in catches. Collectively, *Pagrus auratus* and *Platycephalus caeruleopunctatus* accounted for 29%, and the 10 and 20 most numerous species accounted for 74.8% and 90.7% of total individuals, respectively (Table S1). A total of 41 species was only observed in catches once, and 74 species $\leq$ five times.

Overall, 70% of total species were retained, but this varied among regions and seasons (48-91%) (Table 1). A similar total number of species was retained across the three regions, whereas a greater number (and therefore proportion) of species was released in the north (43%) compared to the central (20%) and southern (10%) regions.

The mean number of species retained or released per trip was significantly influenced by region (PERMANOVA, d.f. = 2,166; MS = 198.62 and $P = 0.0001$ for retained; MS = 321.6 and $P = 0.0001$ for released) but not season or the interaction term ($P > 0.05$ in all cases). A significantly greater mean number of species (pooled across seasons) were retained in the south and fewest in the north, and conversely the mean number of released species was greatest in the north and least in the central region (Fig. 1).

The percentage of total species released per trip significantly differed among regions (PERMANOVA, d.f. = 2,166; MS = 9.178; $P = 0.0001$), but not seasons (d.f. = 4,166; MS = 0.123; $P = 0.7143$) or their interaction (d.f. = 8,166; MS = 0.302; $P = 0.2325$). The pairwise comparisons identified that the release rates were greater in the northern region than in the central and southern regions, which did not differ (Table 1).

A total of 13357 individuals were sampled in catches with, overall, 62% (range 34-85% among regions and seasons) of individuals retained (Table 1). Similar numbers of total individuals were caught across the three regions, but a greater proportion of these were released in the northern compared to the central and southern regions (Table 1).

The mean number of individuals retained or released per trip was significantly influenced by the interaction of region x season (PERMANOVA, d.f. = 8,166; MS = 2244.1 and P = 0.0166 for retained; MS = 905.14 and P = 0.0052 for released). The pairwise comparisons identified that changes among seasons in both the mean retained and released individuals were not the same across regions (Fig. 1). For example, mean numbers of retained individuals were greatest in both summer seasons in the central region, but were least in these seasons in the north (Fig. 1). In a similar manner, the mean number of retained individuals was lower in the north compared to the south across all seasons, and similarly against the central region except winter and spring, when they did not differ. Likewise, the number of released individuals was significantly greater in the north than in the central and south regions across all seasons except the second summer sampled, when no differences were evident across the three regions (Fig. 1).

The proportion of total individuals released per trip significantly differed among regions (PERMANOVA, d.f. = 2,166; MS = 11.902; P = 0.0001), but not seasons (d.f. = 4,166; MS = 0.595; P = 0.7826) or the region x season interaction (d.f. = 8,166; MS = 2.239; P = 0.0885). A greater proportion (pooled across seasons) of total individuals was released in the northern region compared to the central and southern regions (Table 1). There was considerable variability in the release ratios among individual trips, as the residual term in the PERMANOVA explained 71.5% of total variation in the model (as opposed to 28.5% for region).

3.2. Geographic and temporal differences in catch compositions

Spatio-temporal relationships of the composition of retained and released catches were complex as they significantly differed among regions and seasons and their interaction, and this was consistent for the raw and standardised data (PERMANOVA, Table 2). Nevertheless, the pairwise comparisons identified that differences among regions in retained and released catch compositions were consistent across seasons (P < 0.05 in all cases), but differences among seasons were not consistent among regions. For example, there were no significant (P > 0.05) differences in the composition of retained catches between the two sampled summer seasons in the central and southern regions, but they significantly (P < 0.01) differed in the northern region. Similarly, for released catches, there was no significant (P > 0.05) difference in catch compositions between autumn and spring in the central and southern regions, but they significantly (P < 0.001) differed in the northern region.

Variability in compositional structure among individual trips (the residual term in the analyses) accounted for approximately 50% of the variation among the terms in each analysis (Table 2). Region contributed greater variation than season in all analyses, highlighting the importance of small- and large-scale geographic variabilities in catch compositions.

The SIMPER analyses identified the species that contributed greatest to characterising catches within each region (Table 3). *Pagrus auratus* and *P. caeruleopunctatus* contributed greatest to similarity among catches (retained and released) in the north, with *Glaucasoma scapulare* and *Atractoscion aequidens* also important in distinguishing retained catches in the north. Both *P. auratus* and *P. caeruleopunctatus* were the most important species in characterising released catches in the central region, but *Nelusetta ayraudi*, *Centroberyx affinis* and *Nemadactylus douglasii* were more important in characterising retained catches. In the south, *N. douglasii* and *P. auratus* contributed greatest to characterising retained catches, and *P. auratus* and *Hime purpurissatus* to the released catches (Table 3).

Significant differences in the compositions of both retained and released catches were also evident between the two sampled ports within each region (Table 4). These differences were driven by particular species being caught in different quantities and frequencies across trips. The five species that contributed greatest to the dissimilarities of retained and released catches between the two ports within each region are listed in Table 5. Some species were important in distinguishing catches across regions and both retained and released catches; for example, *P. caeruleopunctatus* occurred on average (retained and released) in greater quantities from Coffs Harbour than Wooli, Sydney than Port Hacking and Shoalhaven than Kiama (Table 5).

2.3. Habitat-related differences in catch compositions

The habitat fished (substratum type) also played a significant role (PERMANOVA, $P < 0.001$ in all six analyses) in distinguishing the composition of retained and released catches across all regions. In particular, the pairwise tests identified that retained and released catches on sand differed significantly to those taken on reef and reef/gravel locations. The primary species driving such differences was *P. caeruleopunctatus* (Table 6), which was most prevalent and contributed greatest to the similarity of retained and released catches from the sand habitat.

Differences in retained and released catches between reef, gravel and reef/gravel locations were less obvious and not consistent across regions because the primary species contributing mostly to the similarity of catches were similar across these habitats. Nonetheless, the pairwise test distinguished significant ($P < 0.05$) differences in the composition of retained and released catches among reef and reef/gravel catches in the northern and central regions, but not in the south ($P > 0.05$). *P. auratus*, *N. douglasii* and *C. affinis* were important in characterising retained catches along with *H. purpurissatus* for released catches in both reef and reef/gravel habitats across regions (Table 6).

4. Discussion

4.1. Retained and released catch compositions

The data presented here revealed several general patterns concerning the composition of retained and released catches taken in the coastal demersal charter boat line fishery in NSW. Notably, the composition of catches (both retained and released) was very diverse, exceeding the diversity quantified in the co-occurring inshore coastal commercial line fishery (Macbeth and Gray, 2016). Nevertheless, the primary finfish species retained (e.g. *P. auratus*, *P. caeruleopunctatus*, *N. douglasii* and *Scorpis lineolata*) were similar in both these fisheries and, in general, mirrored that taken in the coastal recreational trailer boat fishery (Steffe and Murphy, 2011). Taken in combination, these studies show that these different fishing sectors compete for the same primary resources, indicating the need to take account of the impacts of all harvest sectors in species assessments and consequent management arrangements for these stocks.

The observed retained catch was more diverse and greater than the released catch in the central and south regions, but the opposite occurred in the north. The reasons for such differences are not clear, but probably reflects client and operator preferences and perceived quality and satisfaction regarding the levels of overall catches - especially those of key species such as *P. auratus* and *P. caeruleopunctatus*. Regardless of the reasons, this variation demonstrates that no overall generalisations concerning rates of releasing species and concomitant ecosystem impacts can be made across the entire fishery, an important consideration for any environmental assessment of the fishery, and for the development of management or monitoring arrangements for the fishery.

The overall release rates for both species and individuals as determined here were relatively low (30.2 and 37.6% respectively) and less than generally reported in the commercial fisheries of Australia (55.3% by Kelleher, 2005), but similar to those recently estimated for those in NSW (Kennelly, unpublished). Nevertheless, potentially large quantities of various fish species could be released across the entire charter boat fleet. For released fish, we made no attempt to assess any physical damage or rates of survival upon release, yet this is an important avenue of research that has recently received considerable attention both regionally (Broadhurst et al., 2012; Butcher et al., 2012) and internationally (Cooke and Schramm, 2007; Brownscombe et al., 2016). Most regional studies have, however, only examined a few important 'primary' species in shallow water (< 50 m), but little knowledge exists of survival rates of the many so-called 'secondary' species, such as *Scorpaena jacksoniensis* and *H. purpurissatus,* that are mostly released in this fishery. Although permitted, no release-assistance methods such as release weights or venting of fish were observed during our study.

4.2. Geographic influences on catches

Geographic region (latitude) was a strong driver of the variation in both the retained and released portion of the catch and corresponds with latitudinal clines in the distributions of marine fauna along the east Australian coast (Malcolm et al., 2007). Similar latitudinal variations have been documented in other estuarine and coastal regional fisheries (Kennelly et al., 1998; Gray and Kennelly, 2003; Macbeth and Gray, 2016). Specifically, the northern region sampled here is considered subtropical as it borders the convergence zone of tropical and temperate waters (Suthers et al., 2011), with retained and released catches showing a greater diversity of organisms compared to the ports further south. Catches in the northern region also had more occurrences of warm water ichthyofauna such as *Choerodon venustus*, *Seriola hippos* and *G. scapulare* and also contained a greater number of species captured only once.

In contrast, catches in the central and southern regions contained mostly temperate cold water species such as *Helicolenus percoides*, *C. affinis*, *N. douglassi* and specifically *Lepidoperca pulchella* and *Ophthalmolepis lineolatus*. It is therefore likely that the compositions of charter boat catches beyond the regions covered here would also vary as a result of differing latitudes and corresponding environmental conditions. Changes in oceanography and water temperatures due to climate change could see a shift in the species diversity and composition of charter boat catches, as well as other recreational and commercial fisheries, along the Australian east coast (Hobday and Lough, 2011; Last et al., 2011). It is important, therefore, that regular longitudinal sampling of the fishery be scheduled to monitor such impacts.

Smaller-scale (port-related) geographic differences in retained and released catches were also evident within each region, with certain species being more or less frequent and abundant in catches from vessels based out of one port compared to the other. Such differences were the result of localised and often vessel-specific differences in fishing practices, fishing grounds, the habitats fished and client requirements. For example, in the central region, retained and released catches of *P. caeruleopunctatus* (but none of the other key species) were on average greater on vessels based in Sydney than those based in Port Hacking. The Sydney vessels typically targeted flathead occurring on bare substrata adjacent to the harbour entrance. In contrast, vessels from Port Hacking typically fished a variety of habitats and locations, providing a broader range of fishing conditions, encountering a greater range of species and therefore afforded different types of fishing experiences than the Sydney vessels. Importantly, the primary clientele in each port and their expectations also varied, with the Sydney vessels particularly catering more for tourists and local persons desiring a combined "Sydney fishing and sightseeing experience" whereas the Port Hacking clientele were generally less touristic, more experienced fishers, including regular fishing club members, fishing for particular species in particular habitats (Gray and Kennelly, unpublished data).

4.3. Temporal Influences on Catches

Seasonal differences in catch compositions were subtle and less influential on characterising catches than geographic and habitat differences. This coincides with that observed for reef-associated species along the NSW coast in other studies (Malcolm et al., 2007). Temporal differences in catches were typically region-specific, most likely being influenced by local environmental and fishing conditions such as water temperature, current direction and strength and their effects on the behaviours and catchability of resident and transient species. There was some evidence that species like *P. auratus* and *N. douglassi* were more prevalent in winter in the south and others like *N. ayraudi* in summer in the central region. However, such trends were not consistent across all regions. Although this study mainly examined demersal fishing, seasonal pelagic species such as *Coryphaena hippurus* and *Seriola lalandi* were observed in summer catches (primarily caught using lures whilst travelling to and from demersal fishing grounds). Before definitive assessments of the influence of temporal scales on retained and released catches can be made, additional years need be examined to determine if any of the patterns observed here remain consistent over longer periods of time.

4.4. Habitat influences on catches

Some port-related differences in catch composition and catch rates were most likely related to local seabed topography and depth along with the targeting practices of individual operators taking consideration of client requirements. For example, in the northern region, the Wooli-based fishing practices often involved anchoring and targeting particular reefs specifically for *P. auratus* and *G. scapulare*, and only rarely fished bare substrata, whereas the Coffs Harbour-based operations targeted both reef fish (drifting) and flathead inhabiting sand habitats regularly (hence greater catches of *P. caeruleopunctatus*). Similarly, in the southern region, the retained and released catches from Kiama-based vessels primarily contained reef-associated species, whereas those from the adjacent Shoalhaven port contained more *P. caeruleopunctatus*, where available sand habitat was more pronounced and fished.

The habitat fished, particularly reef versus bare sand, played a significant role in distinguishing and characterising retained and released catches within each region. Nonetheless, differences in catch compositions among reef, gravel and reef/gravel habitats were less clear as many species were common to all such habitats. Importantly, most vessels drifted whilst fishing and, given the general complex spatial heterogeneity of habitats, any particular fishing event could cover a mixture of habitats. This potentially confounded comparisons among the latter habitats as it was not possible to explicitly define in all instances the exact habitat that each fish occurred in within each fishing event, but only the general habitat as defined by the operator.

Depth impacted some catches with observed depths fished varying from 10 to 130 m. Notably, some species such as *Atypichthys strigatus* were primarily caught in shallow waters whereas other species such as *P. auratus* and *N. douglassi* were caught across all depths. The depth and the habitat fished often changed within each fishing trip, precluding to the identification of a "typical" day's fishing and associated catch characteristics, as this depended on sea/wind conditions and client preferences, particularly for private charters where the entire boat is hired. Nevertheless, some observed trips followed a pattern of targeting reef species first then moving to flathead grounds prior to returning to port.

4.5. Conclusions

This study is the first formal quantification of catches and bycatches in an Australian charter boat recreational fishery. It identified the nature of very significant small- and large-scale spatial variabilities in retained and released components of the catch. It is reasonable to assume that charter boat catches from operators throughout the rest of the east Australian coast would also differ depending on factors such as those examined here. Any future monitoring of catches in this sector for fisheries management and reporting should be stratified to account for variations in catch compositions and diversity at the small geographic scale (port-to-port), the larger regional scale and over appropriate temporal scales (seasonal and between years).

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Figure caption

Figure 1. Mean (+SE) number of species and and individuals retained and released per fishing trip in each of the three regions across the five sampled seasons.

S1 = summer one, A = autumn, W = winter, Sp = spring, S2 = summer two.

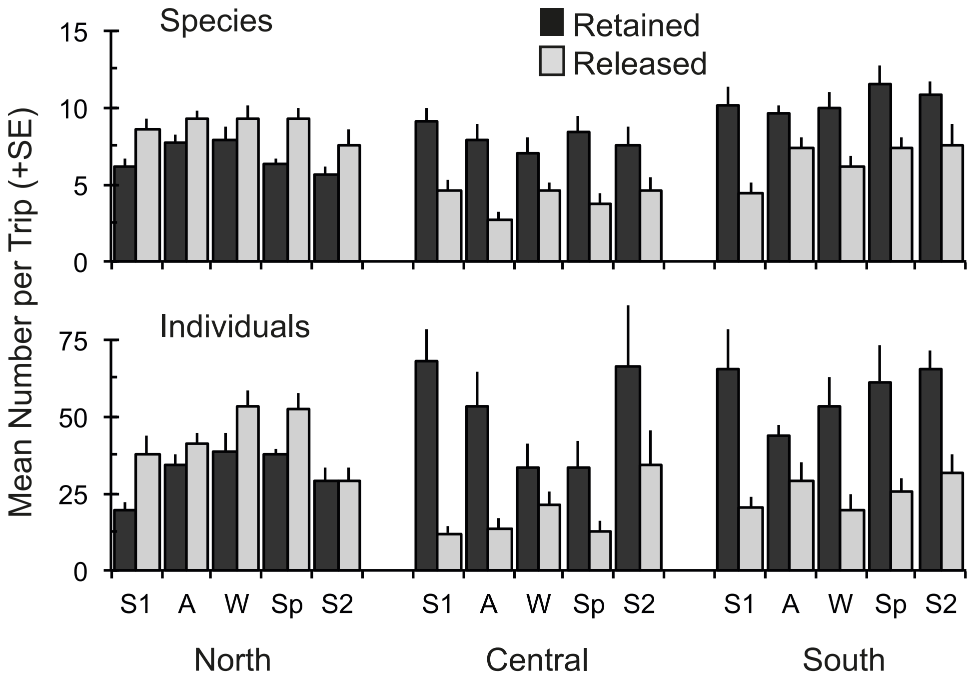

Table 1. Summary of the total number of trips, total species and individuals retained and released across the three regions and five seasons sampled.

	Trips Completed	Species Retained	Species Released	Species Total	Species % Retained		Individuals Retained	Individuals Released	Individuals Total	Individuals % Retained
North										
Summer 1	17	27	42	53	50.9		339	647	986	34.4
Autumn	14	38	36	55	69.1		479	578	1057	45.3
Winter	8	21	25	33	63.6		307	426	733	41.9
Spring	11	17	29	35	48.6		413	572	985	41.9
Summer 2	9	15	23	29	51.7		264	256	520	50.8
Total	59	51	67	90	56.7		1802	2479	4281	42.1
Central										
Summer 1	15	27	23	34	79.4		1017	183	1200	84.8
Autumn	14	31	16	34	91.2		749	189	938	79.9
Winter	13	27	21	31	87.1		430	274	704	61.1
Spring	13	27	19	33	81.8		439	161	600	73.2
Summer 2	8	23	16	30	76.7		533	276	809	65.9
Total	63	50	40	63	79.4		3168	1083	4251	74.5
South										
Summer 1	10	27	16	31	87.1		654	202	856	76.4
Autumn	13	33	27	41	80.5		565	373	938	60.2
Winter	14	27	23	32	84.4		752	277	1029	73.1
Spring	13	30	22	35	85.7		800	329	1129	70.9
Summer 2	9	31	25	35	88.6		593	280	873	67.9
Total	59	53	36	59	89.8		3364	1461	4825	69.7
Overall	181	90	92	129	69.8		8334	5023	13357	62.4

Table 2. Summary of PERMANOVA analyses comparing the composition of retained and released catches across the three regions and five seasons.

		Raw Data						Standardised Data				
	df	MS	Pseudo-F	P(perm)	Unique Perms	% Variation		MS	Pseudo-F	P(perm)	Unique Perms	% Variation
Retained Catch												
Region	2	45285	17.404	0.0001	9885	26.10		48594	20.711	0.0001	9889	27.68
Season	4	6692.7	2.5722	0.0001	9841	10.32		6471.5	2.7581	0.0001	9878	10.56
RxS	8	5444.2	2.0923	0.0001	9779	14.82		5027.3	2.1426	0.0001	9813	14.67
Residual	166	2602				48.76		2346.3				47.09
Released Catch												
Region	2	43220	15.078	0.0001	9873	26.65		36267	13.549	0.0001	9900	26.00
Season	4	4622.1	1.6125	0.0061	9861	7.11		4668.1	1.744	0.0034	9865	8.09
RxS	8	4725.7	1.6487	0.0002	9797	12.60		3832.8	1.4319	0.0072	9821	10.62
Residual	165	2866.4				53.64		2676.7				47.08

Table 3. Summary of SIMPER analyses identifying the five species that contributed greatest to the similarity of retained and released catches in each region.

	Retained Catch				
	Average Abundance	Average Similarity	Similarity/ Std. Devation	Contribribution %	Cumulative Contribution %
North					
Pagrus auratus	10.27	16.99	1.12	48.49	48.49
Platycephalus caeruleopunctatus	7	10.73	0.59	30.64	79.12
Glaucasoma scapulare	1.15	1.22	0.53	3.48	82.6
Nemadactylus douglasii	1.1	1.19	0.43	3.41	86.01
Atractoscion aequidens	1.85	1.08	0.38	3.07	89.08
Central					
Nelusetta ayraudi	15.59	6.14	0.59	25.78	25.78
Centroberyx affinis	6.78	3.92	0.67	16.48	42.26
Nemadactylus douglasii	5.22	3.57	0.65	14.98	57.25
Platycephalus caeruleopunctatus	2.94	3.03	0.39	12.71	69.96
Pagrus auratus	2.14	1.48	0.48	6.22	76.17
South					
Nemadactylus douglasii	7.93	9.01	1.16	27.45	27.45
Pagrus auratus	5.64	5.94	0.99	18.1	45.54
Scorpis lineolata	6.08	3.15	0.58	9.61	55.15
Centroberyx affinis	5.9	3.07	0.68	9.36	64.51
Ophthalmolepis lineolatus	2.85	1.9	0.55	5.79	70.31
	Released Catch				
	Average Abundance	Average Similarity	Similarity/ Std. Devation	Contribribution %	Cumulative Contribution %
North					
Pagrus auratus	14.19	21.53	1.88	49.05	49.05
Platycephalus caeruleopunctatus	6.76	6.19	0.58	14.1	63.15
Scorpaena jacksoniensis	4.93	5.75	0.87	13.09	76.24
Hime purpurissatus	3.08	3.17	0.79	7.22	83.47
Scorpis lineolata	2.81	2.54	0.62	5.78	89.24
Central					
Pagrus auratus	1.16	4.11	0.56	25.86	25.86
Platycephalus caeruleopunctatus	6.33	3.41	0.27	21.48	47.33
Neoplatycephalus richardsoni	2.98	2.95	0.35	18.59	65.92
Helicolenus percoides	1.37	1.68	0.27	10.56	76.48
Hime purpurissatus	0.62	1.09	0.3	6.83	83.32
South					
Pagrus auratus	3.15	4.57	0.61	21.5	21.5
Hime purpurissatus	2.69	4.05	0.73	19.06	40.56
Centroberyx affinis	2.9	2.59	0.44	12.19	52.76
Helicolenus percoides	1.51	2.14	0.36	10.06	62.82
Atypichthys strigatus	2.81	1.86	0.5	8.73	71.55

Table 4. Summary of PERMANOVA analyses comparing the composition of retained and released catches across ports and seasons for each region.

		Retained Catch					Released Catch			
	df	MS	Pseudo-F	P(perm)	% Variation		MS	Pseudo-F	P(perm)	% Variation
North										
Port	1	11068	4.9566	0.0001	26.71		10956	9.3699	0.0001	28.65
Season	2	5156	2.309	0.003	17.77		2293.5	1.9614	0.0243	11.24
PxS	2	2299.9	1.03	0.4116	3.80		3318.6	2.8381	0.001	21.97
Residual	33	2233			51.71		1169.3			38.14
Total	38									
Central										
Port	1	20150	6.9992	0.0001	32.76		14548	4.4927	0.0003	27.78
Season	3	3333.9	1.158	0.2359	7.33		2643.4	0.81635	0.7447	0.00
PxS	3	2947.4	1.0238	0.4214	4.02		3645.1	1.1257	0.2876	10.28
Residual	40	2878.9			55.88		3238.1			61.94
Total	47									
South	df									
Port	1	7638.2	3.3719	0.0004	17.55		16129	5.4894	0.0001	26.67
Season	4	4498.4	1.9859	0.0002	17.50		3232.7	1.1002	0.2721	6.16
PxS	4	2927.7	1.2925	0.0918	13.48		3350.1	1.1402	0.2163	10.31
Residual	49	2265.2			51.47		2938.2			56.85
Total	58									

Table 5. Summary of SIMPER analyses identifying the five species that contributed greatest to the dissimilarity of retained and released catches between ports within each region.

	Retained Catch					
	Average Abundance	Average Abundance	Average Dissimilarity	Dissimilarity/ Std. Deviation	Contribution %	Cumulative %
North	Wooli	Coffs Harbour				
Pagrus auratus	12.53	7.95	18.5	1.12	24.22	24.22
Platycephalus caeruleopunctatus	0.84	6.9	11.58	1.09	15.16	39.39
Atractoscion aequidens	0.53	3.75	5.41	0.69	7.08	46.47
Pseudocaranx georgianus	3.11	0	5.22	0.67	6.83	53.3
Trachurus novaezealandiae	3.26	0.05	4.56	0.36	5.97	59.27
Central	Sydney	Port Hacking				
Nelusetta ayraudi	0.07	17.82	18.39	0.74	20.72	20.72
Centroberyx affinis	0.36	8.38	11.61	1.01	13.08	33.81
Platycephalus caeruleopunctatus	5.21	2.59	9.77	0.79	11.01	44.81
Nemadactylus douglasii	1.07	6.26	8.49	0.85	9.57	54.38
Helicolenus percoides	0	4.82	6.29	0.88	7.09	61.47
South	Kiama	Shoalhaven				
Scomber australasicus	3.98	9.75	8.42	0.86	11.52	11.52
Scorpis lineolata	4.81	9.5	8.16	0.99	11.17	22.69
Nemadactylus douglasii	8.09	7.5	6.65	1.04	9.1	31.79
Pagrus auratus	4.79	7.94	6.39	1.14	8.74	40.52
Centroberyx affinis	7.02	2.88	5.94	0.98	8.12	48.65
	Released Catch					
	Average Abundance	Average Abundance	Average Dissimilarity	Dissimilarity/ Std. Deviation	Contribution %	Cumulative %
North	Wooli	Coffs Harbour				
Pagrus auratus	18.58	13.3	14.38	1.37	22.67	22.67
Scorpaena jacksoniensis	9.21	2.85	8.57	1.52	13.51	36.18
Platycephalus caeruleopunctatus	0.68	7.3	7.64	1.01	12.04	48.23
Scorpis lineolata	5.11	1.45	5.85	1.09	9.23	57.45
Seriola lalandi	4.68	0.05	5.27	0.68	8.3	65.76
Central	Sydney	Port Hacking				
Platycephalus caeruleopunctatus	19.36	3.27	40.55	1.39	47.04	47.04
Neoplatycephalus richardsoni	0.93	4.42	11.23	0.64	13.03	60.07
Pagrus auratus	1.14	1.36	5.44	0.67	6.31	66.38
Helicolenus percoides	0.07	1.48	5.32	0.53	6.17	72.54
Centroberyx affinis	0.07	1.7	4.81	0.5	5.58	78.12
South	Kiama	Shoalhaven				
Pagrus auratus	1.53	7.5	11.96	1.2	14.33	14.33
Atypichthys strigatus	0.86	8.06	11.83	1.02	14.17	28.5
Scorpis lineolata	1.7	5.75	8.99	0.93	10.76	39.27
Platycephalus caeruleopunctatus	1.07	4.63	8.4	0.79	10.06	49.32
Centroberyx affinis	3.37	1.63	6.29	0.88	7.53	56.86

Table 6. The three species that contributed (%) greatest to the similarity matrix of retained and released catches of each habitat classification in each region as determined by the SIMPER analyses.

Retained Catch	**Reef**	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel**	**%**
North	*Pagrus auratus*	75.8	*Pagrus auratus*	56.1	*Platycephalus caeruleopunctatus*	99.6	*Pagrus auratus*	55.4
	Glaucasoma scapulare	4.7	*Platycephalus caeruleopunctatus*	20.1	*Pagrus auratus*	0.1	*Platycephalus caeruleopunctatus*	29.3
	Nemadactylus douglasii	4.1	*Atractoscion aequidens*	9.4	*Neoplatycephalus richardsoni*	0.1	*Hime purpurissatus*	3.6
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel/Sand**	**%**
Central	*Nelusetta ayraudi*	33.7	*Nemadactylus douglasii*	23.6	*Platycephalus caeruleopunctatus*	88.9	*Platycephalus caeruleopunctatus*	52.4
	Nemadactylus douglasii	22.1	*Centroberyx affinis*	21.6	*Nelusetta ayraudi*	8.4	*Pagrus auratus*	13.4
	Centroberyx affinis	9.2	*Nelusetta ayraudi*	20.7	*Centroberyx affinis*	1.0	*Nemadactylus douglasii*	6.7
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**		
South	*Nemadactylus douglasii*	30.4	*Pagrus auratus*	25.5	*Platycephalus caeruleopunctatus*	62.5		
	Pagrus auratus	15.1	*Scomber australasicus*	21.8	*Scorpis lineolata*	13.1		
	Centroberyx affinis	14.3	*Nemadactylus douglasii*	11.9	*Sillago flindersi*	11.0		
Released Catch	**Reef**	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel**	**%**
North	Pagrus auratus	59.5	*Pagrus auratus*	67.1	*Platycephalus caeruleopunctatus*	93.8	*Pagrus auratus*	64.9
	Scorpaena jacksoniensis	14.4	*Scorpaena jacksoniensis*	19.9	*Trachinocephalus myops*	4.0	*Platycephalus caeruleopunctatus*	21.6
	Hime purpurissatus	8.2	*Hime purpurissatus*	5.4	*Neoplatycephalus richardsoni*	0.7	*Hime purpurissatus*	7.2
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**	**Gravel/Sand**	**%**
Central	*Helicolenus percoides*	30.3	*Pagrus auratus*	37.5	*Platycephalus caeruleopunctatus*	86.3	*Pagrus auratus*	55.6
	Pagrus auratus	28.8	*Neoplatycephalus richardsoni*	26.6	*Neoplatycephalus richardsoni*	12.4	*Hime purpurissatus*	44.4
	Centroberyx affinis	10.7	*Helicolenus percoides*	13.8	*Platycephalus longispinis*	1.0		
	Reef	**%**	**Reef/Gravel**	**%**	**Sand**	**%**		
South	*Pagrus auratus*	21.1	*Pagrus auratus*	23.2	*Platycephalus caeruleopunctatus*	84.6		
	Hime purpurissatus	20.0	*Hime purpurissatus*	18.8	*Atypichthys strigatus*	8.8		
	Centroberyx affinis	18.3	*Platycephalus caeruleopunctatus*	16.5	*Hime purpurissatus*	2.6		

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