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Resource Survey of the Great Australian Bight Trawl Sector 2015

Ian Knuckey, Matt Koopman and Russell Hudson

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GABIA

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Executive Summary

The Great Australian Bight Trawl Sector (GABTS) of the Southern and Eastern Scalefish and Shark Fishery (SESSF) targets two main species, Deepwater Flathead (*Neoplatycephalus conatus*) and Bight Redfish (*Centroberyx gerrardi*). Industry-based fishery-independent resource surveys of the Great Australian Bight (GAB) have been conducted since 2005 with the primary goal of obtaining robust annual indices of relative biomass of these two main species. These indices are incorporated into formal stock assessments, which were previously hampered by input data with little contrast.

The Great Australian Bight Industry Association (GABIA) supported implementation of the industry-based fishery-independent resource survey of the GABTS, driven largely by industry's desire for a better understanding of the extent of shelf resources of their main target species. Surveys are conducted during February–April each year using a 'standard' research net. Relative biomass estimates are calculated using swept area calculations, avoiding the need to make assumptions regarding the catchability and efficiency of the gear. Industry observations, supported by preliminary analysis of data from the 2005 survey, showed large diurnal effects on catch rates of Bight Redfish, but not Deepwater Flathead. Consequently, only data from night shots (when catch rates are higher) are used in calculations of relative biomass estimates of Bight Redfish, but data from both day and night shots are used in calculations for Deepwater Flathead.

This report details the results of the 2015 GABTS resource survey — the seventh survey.

The two trips of the GABTS resource survey are generally conducted during the week leading up to the full moon in March and April. During 2015, the occurrence of the full moon was on 5th March and 4th April. Seventy-five valid survey shots were completed over the two surveys; Deepwater Flathead and Bight Redfish occurred in 100% and 76% of the shots respectively.

Due to the age and fatigue of the original and backup survey nets, the footlines had been removed subsequent to the 2011 survey and a new survey net was constructed for the 2015 survey based on the original survey net plans, using an old net as a backup. During Trip 1, catch rates appeared abnormally low. On inspection, there appeared to be problems with under-weighting of the footline in the central part of the net that effected its fishing efficiency. Following completion of the first trip, the footline was completely rebuilt to ensure it replicated the original survey ground gear based on archived pictures and input from the designer. The net performed as expected during Trip 2, but catch rates of the main species were still very low.

It is also relevant that two seismic surveys were being conducted in about the same region and time that the GAB surveys were being undertaken. The TGS-NOPEC Nerites Multi Client 3D Marine Seismic Survey was being conducted close by the Central 2 stratum and the PGS Ceduna 3D seismic survey was being conducted near Central 1 stratum. Seismic impacts on fish behaviour and it is not clear to what extent these seismic surveys may have impacted catch rates.

For the above reasons, results in this report are presented combined for both trips and also for each trip separately.

Relative biomass indices with CVs<0.2 were obtained for Deepwater Flathead and many other main species within the survey area, using swept area estimates from trawl shots in a stratified random survey design. Using data from night shots only, the CV of the relative biomass for Bight Redfish was 0.2 when data from both trips were used, but was 0.28 when only data from Trip 2 was used.

The effect of using data from only Trip 2 on relative biomass estimates varied by species, resulting in higher estimates for Deepwater Flathead, Common Sawshark, Gummy Shark, Jackass Morwong, Latchet, Ornate Angelshark, Spikey Dogfish and “other species”, but lower estimates for Bight Redfish, Ocean Jacket, Yellowspotted Boarfish and Knifejaw. Using data from both trips, the relative biomass estimate of Bight Redfish for 2015 was 3,633 t (CV = 0.20), which is 72% lower than the 2011 estimate and 75–87% lower than 2005–2009 estimates. Estimates of relative biomass of Bight Redfish in 2005, 2006, 2007, 2008, 2009 and 2011 were 20,887 t (CV = 0.13), 25,380 t (CV = 0.16), 25,713 t (CV = 0.16), 14,591 t (CV = 0.11), 27,610 t (CV=0.13) and 13,189 t (CV=0.18) respectively. When only data from Trip 2 is used, the relative biomass estimate of Bight Redfish for 2015 was 2,573 t (CV = 0.28), which is 80% lower than the 2011 estimate and 82 –91% lower than 2005 – 2009 estimates.

Using data from both trips, the relative biomass estimate of Deepwater Flathead during 2015 was 4,657 t (CV=0.07). This is 50% lower than the 2011 estimate of 9,227 t, and 40% – 62% lower than 2005–2009 estimates. Estimates of relative biomass of Deepwater Flathead in 2005, 2006, 2007, 2008, 2009 and 2011 were 12,152 t (CV = 0.05), 8,415 t (CV = 0.06), 8,540 t (CV = 0.05), 7,725 t (CV = 0.06), 9,942 t (CV=0.05) and 9,227 t (CV=0.05) respectively. When only data from Trip 2 is used, the relative biomass estimate of Deepwater Flathead for 2015 was 5,065 t (CV = 0.09), which is 45% lower than the 2011 estimate and 34 –58% lower than 2005 – 2009 estimates.

During 2005–2008 surveys, Bight Redfish had been the most commonly caught species during the survey (20%–26% of the catch composition). Bight Redfish comprised 19% of the catch during 2009 (second to Ocean Jacket), then in 2011 comprised only 11% of the total catch. During the 2015 survey, Bight Redfish comprised only 7% of the catch and was the fifth most commonly caught species behind Wide Stingaree (20%), Latchet (18%), Deepwater Flathead (11%) and Ocean Jacket (10%).

Length-frequency measurements were made on 1,062 Bight Redfish and 1,337 Deepwater Flathead during the 2015 survey. The modal length of Bight Redfish was 31 cm, and has stabilised at 30-32cm over the last four years of the survey after displaying a declining trend from around 35 cm recorded from the 2005 inaugural survey to 31cm during the 2008 survey. Modal length of Deepwater Flathead from 2015 samples (43 cm) was similar to the previous surveys.

Otolith samples of 229 Deepwater Flathead and 196 Bight Redfish were also collected during the survey. Data from the ageing of these otoliths will be used during future assessments to be conducted for Bight Redfish and Deepwater Flathead.

The results of this survey provide the seventh year of a fishery-independent index of abundance for both Deepwater Flathead and Bight Redfish. The biomass index for both Deepwater Flathead and Bight Redfish appeared much reduced during the 2015 survey compared to previous surveys. This time-series now provides a fishery independent estimate of relative stock biomass that is incorporated into the stock assessments in conjunction with commercial CPUE and length and age data. In addition to these two important target species, we now have a six-year time-series of relative abundance indices for many of the important bycatch and byproduct species in the GABTS including Ocean Jacket, Common Sawshark, Gummy Shark, Yellowspotted Boarfish, Jackass Morwong, Knifejaw, Latchet, Ornate Angelshark and Spikey Dogfish.

Table of Contents

List of Tables

List of Figures

Introduction

The Great Australian Bight Industry Association (GABIA) has supported the implementation of an industry-based fishery-independent resource survey of the Great Australian Bight Trawl Sector (GABTS) since its implementation in 2005. This has been largely driven by industry's desire for a better understanding of the extent of shelf resources of their main target species, Deepwater Flathead (*Neoplatycephalus conatus*) and Bight Redfish (*Centroberyx gerrardi*), and the level of impact that fishing might be having on these resources.

Until 2006, the GABTS was managed by input controls limiting the number of operators in the fishery to ten. Only a small number (typically 4–5) of the ten SFR holders had been active in the fishery during any one year over the decade to 2002. Catch and effort data from these vessels' logbooks showed no overall trend in catch rates for either Deepwater Flathead or Bight Redfish and there remained little contrast in these data. Time series of length- and age-frequency data did not indicate any significant impact on the resources from this level of fishing either. Stock assessment models up to 2006 for Bight Redfish and Deepwater Flathead were advanced, but suffered from the lack of contrast in any of the main fishery indicators. As a result, there was considerable uncertainty surrounding model outputs including estimates of stock biomass.

There was increased participation in the fishery and increases in fishing effort and fishing efficiency of active vessels during 2003–2005. Given the uncertain status of the stocks at this time, this raised concerns about future sustainability of the shelf resources. Under this scenario, industry agreed that quota management of the main target species would be introduced from 2006. They also agreed on equal allocation of quota between the ten SFR holders.

With the pending introduction of quotas during 2006, there was concern that low TACs would be introduced based on the high uncertainty of biomass estimates resulting from stock assessment models and this may inhibit the sustainable development of the fishery. Moreover, once quotas were introduced it was believed the use of commercial CPUE data as the main index of abundance in these models would be compromised and unlikely to provide the contrast that is needed to improve model outputs.

Industry investigated the feasibility of conducting a fishery-independent survey to provide a time-series of relative abundance indices for Deepwater Flathead and Bight Redfish that can be used as an input to stock assessment models (FRDC Project 2002/072). Surveys of the main shelf areas of the fishery were successfully conducted during 2005 (Knuckey *et al.* 2006), and continued during 2006 (Knuckey and Hudson, 2007a), 2007 (Knuckey and Hudson, 2007b), 2008 (Knuckey *et al*. 2008), 2009 (Knuckey *et al*. 2009) and 2011 (Knuckey *et al*. 2011).

With 6 consecutive years of survey data, GABIA, with support from the Resource Assessment Group (GABRAG) and Management Advisory Committee (GABMAC) decided that a cost benefit analysis should be undertaken to help determine whether ongoing surveys continue to be conducted annually or whether biennial survey or some other period may be more appropriate. Due to funding constraints, surveys were not conducted during 2012-2014 inclusive and the cost-benefit analysis has yet to be conducted. It is understood, however, that a more holistic assessment of the value of SESSF fishery independent surveys — including the GATF survey — will be undertaken as part of FRDC project 2014/203 run by AFMA "SESSF Monitoring and Assessment – Strategic Review". Regardless of the outcomes of this Strategic Review, GABIA, GABRAG and GABMAC supported the conduct of a survey during 2015. This report provides the results of the 2015 survey.

Objectives

1. To obtain a relative abundance index for Bight Redfish and Deepwater Flathead.
2. To collect biological and population data on Bight Redfish and Deepwater Flathead.
3. To determine a relative abundance index of other main by-product species in the shelf fishery.
4. To prepare all survey information available for use in fishery stock assessments.

Material and Methods

Survey Design

Detailed description of survey design and vessel and gear specifications are reported in Knuckey *et al.*, (2006). A briefly description is given below.

Although fishing for shelf species occurs outside of these areas, the survey was restricted to depths of 120–200 m and between longitude 126º00’ and 132º30’. The longitudinal range was divided into four primary strata; 126º00’–127º45’(West1), 127º45’–129º00’ (West2), 129º00’–130º15’ (Central1), 130º 45’–132º30’ (Central2) (Table 1). This represents the main fishing areas of the shelf component of the fishery. Catch rates of Bight Redfish fluctuate throughout the year, being highest during February–April. Catch rates of Deepwater Flathead also fluctuate seasonally, however, not as much as Bight Redfish. Consequently the survey is conducted during February–April.

Initial analyses of the commercial catch and effort data indicated catch rates for Bight Redfish were not affected by time of day of the shot, while catches of Deepwater Flathead were higher during the day from February to April. However, results from the preliminary survey during 2005 indicated catches of Bight Redfish were higher during night shots, and that future analyses of Bight Redfish should only include night shots (Knuckey *et al.*, 2006). For Deepwater Flathead there was no significant difference between day and night shots, and further analyses of this species would pool all shots. These indications have proven correct in subsequent years, so survey design and methods have been repeated annually.

Analysis of the catch and effort data suggested the variation of catch rates for Bight Redfish was higher for trawl durations <2.5 hours (including setting and retrieving net). A similar result was observed for Deepwater Flathead but was not as pronounced. To maintain a consistent sampling time it was agreed for each survey shot the net should be trawled for 2.5 hours from the time the net reached the bottom to the time retrieval began.

Further analysis of logbook data indicated a minimum of 76 shots would be needed to achieve a CV of <20% for Bight Redfish. This analysis was based on combining both day and night shots. After the preliminary survey was conducted in 2005, it was observed the number of 0 catches (a contributing factor to a high CV) of Bight Redfish was not as high as expected, and hence an analyses of only night shots (approximately half of the 76 shots) have provided a acceptable CVs for that species (Knuckey *et al*., 2006).

Number of shots allocated to each of the primary strata was proportional to the catch-weighted standard deviation of CPUE. Shot locations were selected randomly within each strata. A shot is deemed to be acceptable if the shot passes within 500 m of the selected position. If the shot has to be abandoned due to gear problems, it can still be considered acceptable if towed for a minimum of 1 hour and passed through the position. The start and finish position of each shot was recorded along with minimum and maximum depths, average trawl speed, environmental conditions and direction of tow.

The shots were completed in a specified order to reduce temporal biases in the data collection, though the order of some shots are occasionally re-arranged for logistical reasons. Shots were conducted at a speed ranging 3.1–3.4 knots, with the skipper deciding on the starting position and direction of the tow. When the shot was completed, the net was hauled aboard and the catch emptied on to the deck. Commercial species were gathered in fish bins and approximate weights of each species estimated. Discarded bycatch were identified to species where possible and an approximate weight of each species estimated. When the catch was unloaded in port the correct weights of Bight Redfish and Deepwater Flathead were obtained and compared to the survey estimates. If there was a difference of ± >2% then the survey estimates were adjusted. Length measurements were collected randomly during the survey for Deepwater Flathead and Bight Redfish, the total length measured for flathead and fork length for Bight Redfish. Otolith samples of the two species were also collected randomly during the survey recording the length and sex of each sample.

Calculation of Relative Biomass and Coefficient of Variation

The estimation of the relative biomass is based on the method adopted by Schnute and Haigh (2003), where in simplistic terms, typical surveys consist of numerous tows, each shot giving a biomass density estimate

$$Mean\ density = \frac{biomass\ captured}{area\ swept\ by\ net}$$

And total biomass (abundance) estimated by calculating the mean density (with an associated coefficient of variation) from all shots and applying that to habitat or stratum area

Total biomass = mean density x total area (Schnute and Haigh, 2003)

Determining the density

For shots where Bight Redfish and Deepwater Flathead are present in the catch (non-zero measurements), the mean density for each stratum is

$$\mu_h = \frac{1}{n_h}\sum_{i=1}^{n_h}\mu_{hi}$$

The squared inverse of the CV is

$$v_h = \mu_h^2 / s_h^2$$

The mean density of measurements for each stratum is

$$\delta_h = (1 - p_h)\mu_h$$

The variance of density of measurements each stratum is

$$\sigma_h = \sqrt{\left((1 - p_h)(1 + p_h v_h)\left(\mu_h^2 / v_h\right)\right)}$$

The estimated biomass of each stratum *h* is

$$b_h = A_h \delta_h$$

The CV of biomass estimate of each stratum is

$$cv_h = \sqrt{\sigma_h} \big/ b_h\, n_h$$

Where p_h is the proportion of hauls with zero catch for the species in stratum h, μ_h is the mean kgs per area swept (m^2) of species where catch >zero, s_h is the std kgs per area swept (m^2) of species where catch >zero, A_h is the total area of stratum, n_h is the number of shots and b_h is the estimated relative biomass.

Total relative biomass and CV for each species were calculated as follows

$$B = \sum_h b_h$$

$$cv = \sum_h cv_h$$

The number of shots, n_h, in each stratum that produced the desired coefficient of variation, cv_h, was randomly allocated within each stratum.

Relative biomass was estimated using the swept area method.

The density measure was estimate as follows

$$\mu_{hi} = {C_{hi}} \big/ {v_{hi} d_{hi} E_{hi}}$$

Where each shot i in spectrum h has a known catch of C_{hi}, effort (shot duration hour) E_{hi}, vessel speed (m/hour) v_{hi} and net width d_{hi}.

The swept area of the trawl net can be expressed as either the area swept by the net or the area swept by the doors. Net width was estimated as 50% of the headline length while door width involved measuring the distance between the warps at the pulleys (blocks) then 1 metre along the warps towards the trawl net. The difference in width would then be multiplied by the length of the warp let out

$$d = (w_1 - w_2) \times WL + (w_2)$$

where w_1 is the distance between the warps one meter down from the blocks, w_2 is the distance between the warps at the back of the blocks and WL is the warp length.

Quality Assurance

All data are recorded in an observer version of ORLAC Dynamic Data Logger (DDL), which includes quality insurance protocols including automatic data capture (time, date and position), field restrictions, range checks, mandatory fields and lookup tables. All data are manually error checked against data sheets before loading into the shore version of ORLAC DDL. This database is regularly backed up, and used to extract data for analyses.

In previous years, data analyses and CV estimates were conducted using SAS. This year, all analyses were undertaken using R (R Core Team, 2014). To ensure accuracy in the conversion of the code from SAS to R, analyses were undertaken for data from previous years, and results compared to those from previous years. Further, a subset of outputs are reproduced and compared using an alternative software package.

Results and their interpretations and conclusions were discussed amongst the research team, GABIA and GABRAG. Draft reports were reviewed by all co-authors, and made available to GABRAG and GABMAC members for comment. Where required, comments were addressed in preparation of the final report.

Results and Discussion

Survey Coverage

The random stratified survey sampled 75 of the 76 sites during two trips in March and April 2015 (Figure 1, Table 1). One shot (shot 4) was missed for logistical reasons. The mean shot lengths ranged 14.9 km – 16.0 km resulting in areas swept (assuming net width of 16.3 m) ranging 0.243 km^2 – 0.261 km^2 (Table 2).

The primary objective of the random stratified survey was to determine a relative abundance index for Bight Redfish and Deepwater Flathead in the current region of the main GABTS shelf fishery. No attempts have been made to estimate absolute biomass from the survey results. The survey was also designed to collect biological and population data on these species, to determine a relative abundance index of other main species in the current shelf fishery and to prepare all survey data for use in fishery stock assessments. All of these objectives were met, with 75 sites successfully surveyed during March and April 2015, adding to the existing six-year time series.

Gear Performance

It has been continually stressed that there are many uncertainties and assumptions regarding herding, escapement and catchability associated with trawl nets and use of the GABTS trawl survey results as an absolute index of abundance (eg. Knuckey and Gason 2006; Knuckey *et. al.* 2006). Additional uncertainties relate to species' population dynamics and that the survey strata do not encompass the entire population of either Bight Redfish or Deepwater Flathead either spatially or temporally. One example is the fact that Deepwater Flathead, Bight Redfish and other shelf species are regularly caught in depths to at least 250 m, but survey coverage is only between 120 – 200 m depth in each stratum. Importantly, because of diurnal migrations of Bight Redfish through the water column, relative biomass estimates for that species are calculated from night shots only.

For the above reasons, the data collected during these surveys are only intended to be used as a relative index of biomass to be input into the stock assessment models. With respect to performance of the gear, it is only necessary to ensure that it performs consistently from year to year. Door spread is the main measure of gear performance during the survey. Measurements of warp angle have allowed estimates of door spread and the 2015 results appear to be consistent with previous years.

Door spread was estimated on 6 occasions to monitor gear performance. One of those measurements was taken during a turn and so considered unreliable (door spread of that measurement was 153 m). The remaining 5 measurements ranged 90 – 122 m reflecting the uncertainty and difficulty in measuring the distance between warps to the nearest centimetre a metre from the blocks. Mean door spread was 105.4 m (± 11.7 m SD). This is within the range of mean door spreads calculated for previous surveys of 84.0 m – 109.6 m Door width and (StDev) for each year were 2005 – 92.6m (12.7) (Knuckey *et. al.* 2006); 2006 – 107.0m (6.3) 109m (9.8); (Knuckey and Hudson, 2007a); 2007 – 84m (6.3) 99.6m (3.3) 109.6m (4.2) (Knuckey and Hudson, 2007b); 2008 – 104.5m (3.8) (Knuckey *et. al.* 2008); 2009 – 107.5m (8.2) (Knuckey *et al*, 2009); and 2011 – 106.3m (13.6) (Knuckey *et al*, 2011).

Due to the age and fatigue of the original and backup survey nets, the footlines had been removed subsequent to the 2011 survey and a new survey net was constructed for the 2015 survey based on the original survey net plans. At the beginning of the first trip, it was clear that the new net was not preforming as well as it should, and a decision was made after Day 2 to adjust the attachment of the footline to the net and resample the affected shots at the end of the Trip. To avoid fishing over recently towed ground, back-up shot locations were used for those shots. Despite these adjustments to the net, however, concern remained about catch rates during the first trip. Following completion of the first trip, the footline was completely removed, rebuilt and re-attached to the survey net in order to ensure it replicated the original survey ground gear based archived pictures and input from the designer. It appeared the footline used in the first trip had been under-weighted in the central part of the net.

It is also relevant that two seismic surveys were being conducted in about the same region and time that the GAB surveys were being undertaken. Seismic vessels were operating within sight of the survey vessel for a number of days during Trip 1. The TGS-NOPEC Nerites Multi Client 3D Marine Seismic Survey was being conducted close by the Central 2 stratum and the PGS Ceduna 3D seismic survey was being conducted near Central 1 stratum (Figure 1). Seismic is known to impact the behaviour of fish (e.g. Engås 1996; and see review by Weilgart 2013). Weilgart cites that behavioral reactions of fish to anthropogenic noise include dropping to deeper depths, milling in compact schools, ‘‘freezing’’, or becoming more active and that reduced catch rates of 40%–80% and decreased abundance have been reported near seismic surveys in species such as Atlantic cod, haddock, rockfish, herring, sand eel, and blue whiting at distances of more than 30 km from a seismic survey. The seismic surveys in the GAB may have influenced the lower catch rates of Bight Redfish and Deepwater Flathead during the surveys.

For the above reasons, results in this report are presented combined for both trips and also for each trip separately.

Catch Composition and Length Frequencies

The total catch from the 38 shots undertaken during Trip 1 was 17.1 t, and comprised 69 different species or species groups (Table 3). Ocean Jacket 2.8 t (17%), Deepwater Flathead 2.7 t (16%), Latchet 2.5 t (14%) and Bight Redfish 1.4 t (8%), and made up the majority of the catch during Trip 1, followed by Ornate Angelshark 0.9 t (5%), Gummy Shark 0.8 t (5%) and Gould Squid 0.7t (4%) (Table 3, Figure 3). Deepwater Flathead and Bight Redfish occurred in 100% and 76% of shots respectively during Trip 1.

In comparison, the total catch during Trip 2 was 35.5 t from 37 shots, and comprised 70 different species or species groups (Table 4). Main species caught during Trip 2 were Wide Stingaree 10.2 t (29%), Latchet 7.1 t (20%), Deepwater Flathead 3.3 t (9%), Ocean jacket 2.4 t (7%), Bight Redfish 2.4 t (7%), Ornate Angelshark 1.8t (5%), Gummy Shark 0.9 t (3%) and Smooth Stingray 0.9 t (2%) (Table 4, Figure 3). As in Trip 1, Deepwater Flathead and Bight Redfish occurred in 100% and 76% of shots respectively during Trip 2.

Catches of Bight Redfish were positively skewed, with most of the catches most catches less than 50 kg (Figure 4, Figure 5, Table 5). Only three shots caught more than 200 kg, and only one more than 350 kg. The largest shot of Bight Redfish was 1,225 kg, and was undertaken on 31 March starting at 10:34 am.

Catches of Deepwater Flathead were more consistent, with most of the catches most catches between 50 – 100 kg (Figure 6, Figure 7, Table 5). Catches were generally lower during Trip 1 with only four shots with more than 100 kg compared to 17 shots during Trip 2. Only three shots caught more than 200 kg, and only one more than 350 kg. The largest catch of Deepwater Flathead was 201 kg from a shot undertaken during Trip 1.

Overall, catches of Bight Redfish were highest in shots that commenced between midnight and midday, and lowest in shots commencing between midday and 17:59 hours (Figure 8). Looking at each trip separately, mean catch per shot followed the usual pattern with higher catches between 18:00 and 05:59 hours for Trip 1 (Figure 9). During Trip 2 the one very large catch resulted in the highest mean catch per shot occurring between 06:00 and 11:59 hours, but there was little difference in catch per shot of Bight Redfish between the other time periods.

Catches of Deepwater Flathead were more consistent throughout the day (Figure 10). . The mean catch per shot was highest in shots commencing between midday and 18:00 and 23:59 hours. There was more variability between time periods when looking at the trips separately (Figure 11), with mean catch per shot higher at night during Trip 1 and higher during the day during Trip 2.

There was a large difference in mean catch per shot of Bight Redfish between strata, with much higher catches in the two Central strata compared to the Western strata (Figure 12). The high variability in the Central1 stratum was largely caused by the 1225 kg shot, without which the overall mean catch per shot in that stratum is a lot more similar to those of the Western strata than to Central2. This is reflected in plot for Trip 1 only, which shows the mean catch per shot was much higher in Central2 than in all others (Figure 13).

Catches of Deepwater Flathead were lowest in Central 2 for both Trips (Figure 14, Figure 15). Overall catches were highest in West1 and West2, but the highest mean catch per shot during Trip 2 was in Central1.

The lengths of 1,062 Bight Redfish were measured during the 2015 surveys (Table 6). Lengths ranged 23 – 50 cm, and most fish measured were between 28 – 39 cm (Figure 16). The modal length was 31 cm.

The lengths of 1,337 Deepwater Flathead were measured during the 2015 surveys (Table 6). Lengths ranged 32 – 76 cm, and most fish measured were between 40 – 49 cm (Figure 17). The modal length was 43 cm.

Otoliths were collected from 196 Bight Redfish and 229 Deepwater Flathead (Table 6).

Until the 2009 survey, Bight Redfish had comprised the largest portion of the catch in all surveys (apart from the December 2005 survey); 22% in 2005 (Knuckey *et. al.* 2006), 26% in 2006 (Knuckey and Hudson, 2007a), 25% in 2007 (Knuckey and Hudson, 2007b) and 20% in 2008 (Knuckey *et. al.* 2008). Due to a large increase in catches of Ocean Jacket (25% of the catch) in 2009 (Knuckey *et. al.*, 2009), Bight Redfish comprised the second largest portion of the catch at 19%, and has since fallen to the fifth largest portion of the catch (7%) in 2015 (Figure 3). This drop is due to both considerable decline in Bight Redfish catches, and increases in catches of other species such as Ocean Jacket, Wide Stingarees and Latchet. The proportion of the total catch comprising Deepwater Flathead was 19% in 2005, but has since ranged 11–15%. During 2015, Latchet, Gummy Shark and Wide Stingaree all comprised greater proportions of the catch than in previous year, while Ocean Jacket comprised a much smaller proportion of the catch than in most other years. More detailed species composition graphs broken down to different levels are shown in Appendix 1.

Modal lengths of Bight Redfish measured during 2005, 2006, 2007, 2008, 2009, 2011 and 2015 surveys were 35 cm, 35 cm, 34 cm, 31 cm, 31 cm, 30 cm and 31 cm respectively (Figure 16). As noted in Knuckey *et al*. (2011), the length frequency appears to have stabalised after decreases in size over the first five surveys. This holds true for the 2015. The proportion of fish 30 cm and smaller increased over the first six surveys, and was highlighted as a potential indication of the impact of fishing pressure on Bight Redfish stocks. Percent of fish under 30 cm increased in successive surveys from 9% in 2005, through 18%, 25%, 30% to 34% in 2009. This somewhat reversed during 2011 with 27% of fish measured 30 cm or less. During the 2015 survey, 29% of Bight Redfish measured were 30 cm or less.

Modal lengths of Deepwater Flathead measured during 2005, 2006, 2007, 2008, 2009, 2011 surveys were 46 cm, 43 cm, 43 cm, 45 cm, 44 cm, 44 cm and 43 cm respectively (Figure 17). Modal length of Deepwater Flathead from 2011 samples appears similar to the previous three years but smaller than that from 2005. The length-frequency distribution in 2011 contained a greater number of fish over a reduced and smaller size range compared with previous years, but the 2015 distribution resembled more like that from 2009.

Relative Biomass Estimates

Using only night shots (18:00 – 05:59 hours), both trips and net-width in swept-area calculations, the relative biomass estimate of Bight Redfish for the 2015 survey is 3,633 t with a CV of 0.20 (Table 7). The relative biomass estimate for 2015 is 72% lower than the 2011 estimate of 13,189 t and 75–87% lower than 2005–2009 estimates (Figure 18). Using only data from Trip 2, the relative biomass estimate of Bight Redfish for the 2015 survey is 2,573 t with a CV of 0.28 (Table 8). The relative biomass estimate for 2015 using data from Trip 2 only is 80% lower than the 2011 estimate of 13,189 t and 82 –91% lower than 2005 – 2009 estimates (Figure 20).

Using both day and night time shots, both trips and net-width in swept-area calculations, the relative biomass estimate of Deepwater Flathead for the 2015 survey is 4,657 t with a CV of 0.07 (Table 7). The relative biomass estimate for 2015 is 50% lower than the 2011 estimate of 9,227 t, and 40% – 62% lower than 2005–2009 estimates (Figure 18). Using only data from Trip 2, the relative biomass estimate of Deepwater Flathead for the 2015 survey is 5,065 t with a CV of 0.09 (Table 8). The relative biomass estimate for 2015 using data from Trip 2 only is 45% lower than the 2011 estimate of 9,227 t and 34 –58% lower than 2005 – 2009 estimates (Figure 20).

Relative biomass estimates for a number of other important GABTS species were also calculated (Table 7). CVs of these species were generally below 0.30. Other species with the greatest relative biomass estimates during 2015 were Latchet (12,418 t) and Ocean Jacket (3,702 t) and Ornate Angelshark (2,629 t). Trends in relative biomass estimates varied from species to species (Figure 18 and Figure 19). Species that showed a decrease in during 2005–2015 were Bight Redfish, Deepwater Flathead, Ocean Jacket and Jackass Morwong, Knifejaw and Spikey Dogfish, while relative biomass estimates Gummy Shark, Common Sawshark and other species increased. Relative biomass estimates of Yellowspotted Boarfish and Latchet were similar between 2005 and 2011 surveys. The implication of using data from Trip 2 only in estimates of relative biomass varies between species, resulting in higher relative biomass estimates for Deepwater Flathead, Common Sawshark, Gummy Shark, Jackass Morwong, Latchet, Spikey Dogfish and other species, but lower for Bight Redfish, Ocean Jacket, Yellowspotted Boarfish and Knifejaw. Trends in relative biomass over time using data from Trip 2 only for 2015 are shown in Figure 20 and Figure 21.

The abnormally low catch rates during Trip 1 may have resulted from problems with the footline construction of the new survey net. This was rectified for Trip 2. Summary results have therefore been presented for trips combined and separated, and relative biomass estimates provided for trips combined and for Trip 2 only. The decision as to what relative biomass estimate will be used for stock assessments will made by GABRAG.

Bight Redfish

Regardless of whether data from Trip 1 is included in calculations of relative biomass, results for 2015 represent significant reductions from previous years. Relative biomass is higher when both trips are included (3,633 t) compared with 2,573 t when only data from Trip 2 is used. These results are 72% and 80% lower than 2011 relative biomass estimates respectively. It is notable that the largest catch of Bight Redfish, and the only one greater than 300 kg was take during the day, and so was not included in relative biomass calculations because those for Bight Redfish use night shots only.

The CVs are higher than in previous years (0.11–0.18), and is particularly high (0.28) when data from only Trip 2 is used because of the low sample size.

Deepwater Flathead
Relative biomass estimates for Deepwater Flathead (day and night shots combined) were also much lower than the 2011 regardless of whether data from both trips (50% reduction) or Trip 2 only were used (45%). CVs were low for estimates from using both trips (0.07) and Trip 2 only (0.09), and both slightly higher than CVs from other years, which ranged 0.05–0.06.

Other species
There was considerable annual variation in relative biomass estimates of other main species. Species that showed a decrease in during 2005–2015 were Ocean Jacket and Jackass Morwong, Knifejaw and Spikey Dogfish, while relative biomass estimates Gummy Shark, Common Sawshark and other species increased. Relative biomass estimates of Yellowspotted Boarfish and Latchet were similar between 2005 and 2011 surveys. The consistent increase of Gummy Shark over time and dramatic decrease in Ocean Jacket since 2011 are notable.

Conclusions

Regardless of which measures are used, overall catch rates for both Bight Redfish and Deepwater Flathead during the 2015 survey were the lowest on record. This suggest low abundance or availability of these species during 2015. Whilst a problem with the footline may have influenced low catch rates in Trip 1, this was not an issue for Trip 2, where catch rates of Bight Redfish and Deepwater Flathead were also very low. It is uncertain to what extent the 2015 results may have been influenced by the two 3D Marine Seismic Surveys running concurrently and in close proximity to the survey, particularly with respect to the Central 1 and Central 2 stratum. It is important to note, however, that 2015 catch rates for a number of other species byproduct and bycatch species were either similar to or higher than in previous surveys.

The 2015 GAB resource survey achieved all of its objectives. The target CVs for relative biomass estimates were achieved for both Bight Redfish (target <0.20) and Deepwater Flathead (target <0.10), however if data from Trip 2 only are used, the CV for Bight Redfish is higher than the target. Relative biomass estimates of the main target species were much lower than from previous years, but were higher for some other species. In addition, relative biomass estimates of other important species were estimated with low to medium CVs. CVs for each of these species are higher when only data from Trip 2 are used. Sufficient length-frequency and otolith samples were collected for both target species for use in the stock assessments.

The results of this survey provide the seventh year of a fishery-independent index of abundance for both Deepwater Flathead and Bight Redfish and are now providing an valuable indicator of stock status which is being quantitatively incorporated into the stock assessments. In addition to these two important target species, we now have a six-year time-series of relative abundance indices for many of the important bycatch and byproduct species in the GABTS including Ocean Jacket, Common Sawshark, Gummy Shark, Yellowspotted Boarfish, Jackass Morwong, Knifejaw, Latchet, Ornate Angelshark and Spikey Dogfish.

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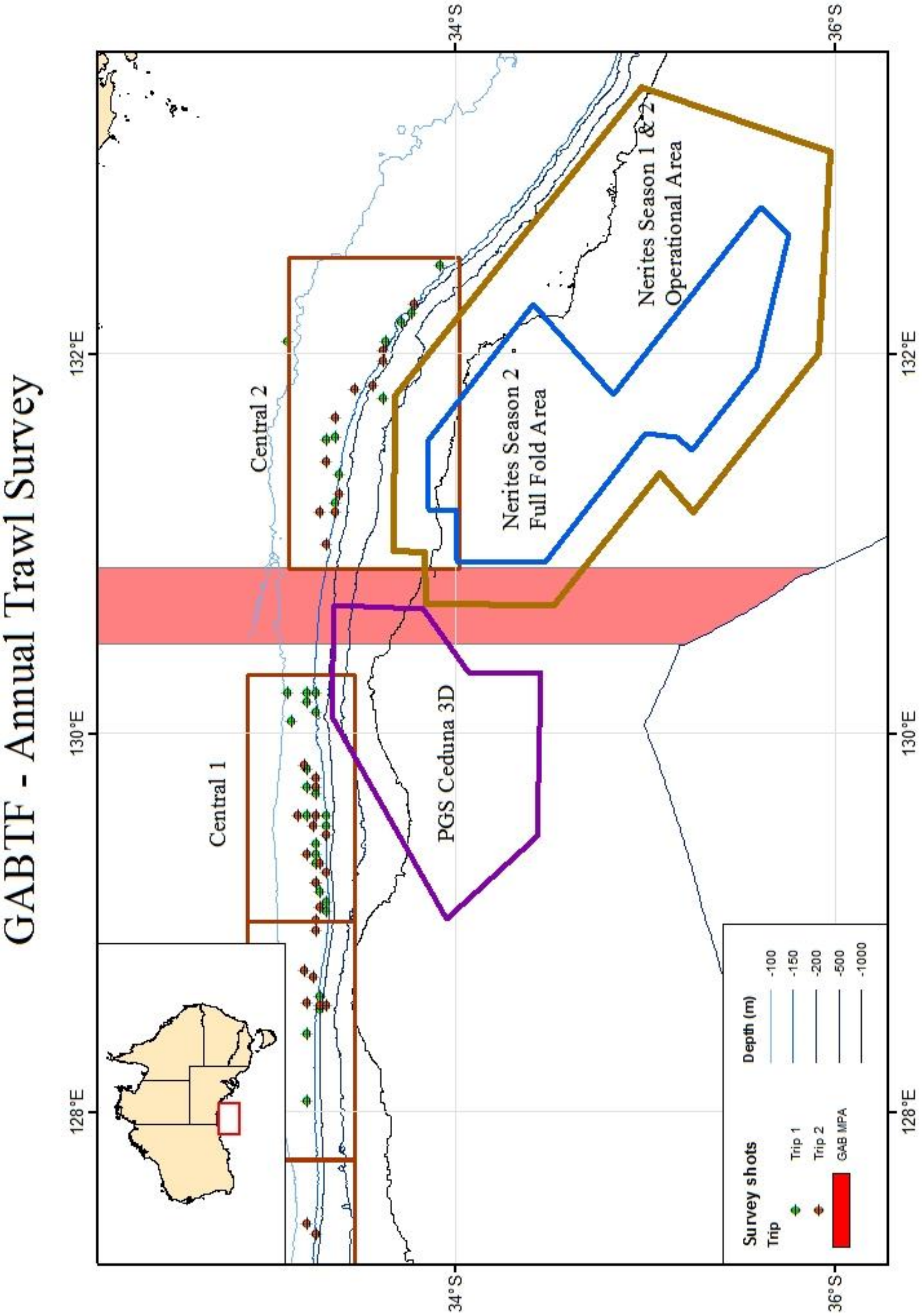


Figure 1. Survey strata and shot locations of trawl survey and region of the TGS-NOPEC Nerites Multi Client 3D Marine Seismic Survey.

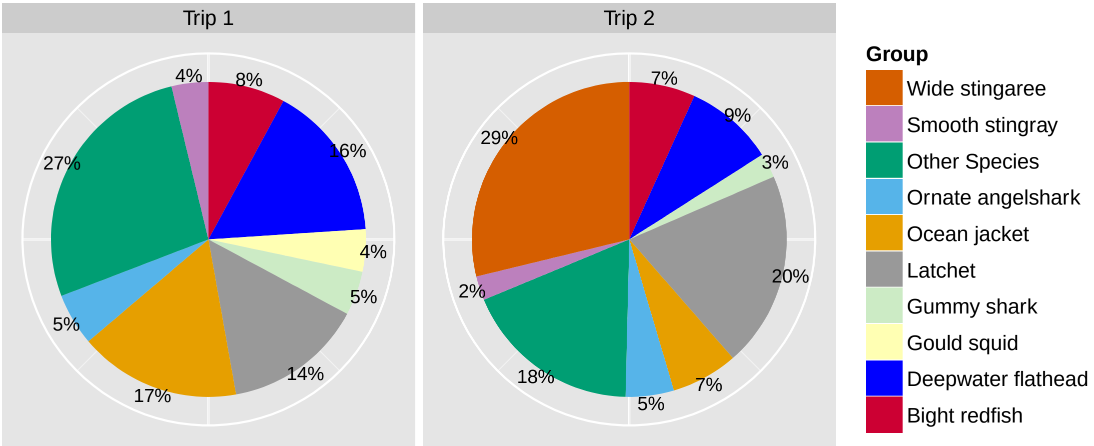


Figure 2. Percent weight of major species captured during each trip.

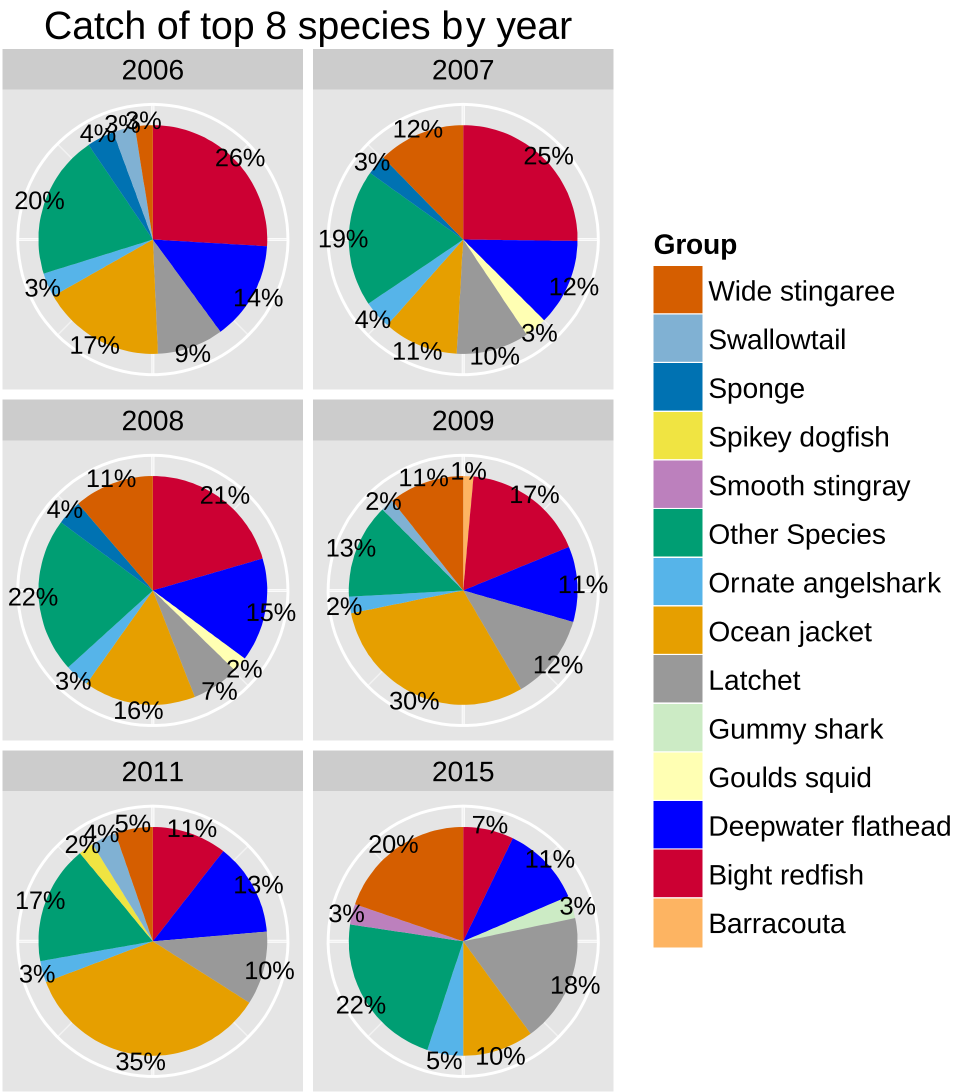


Figure 3. Percent (of weight) of major species captured during each survey.

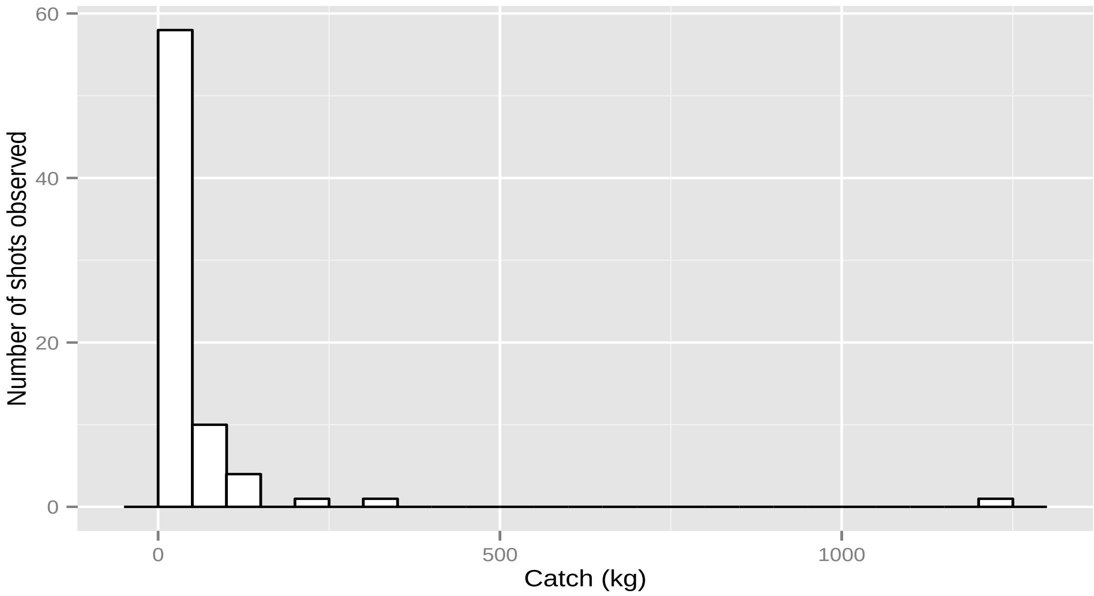


Figure 4. Frequency of catches (kg) of Bight Redfish during the 2015 survey (trips combined).

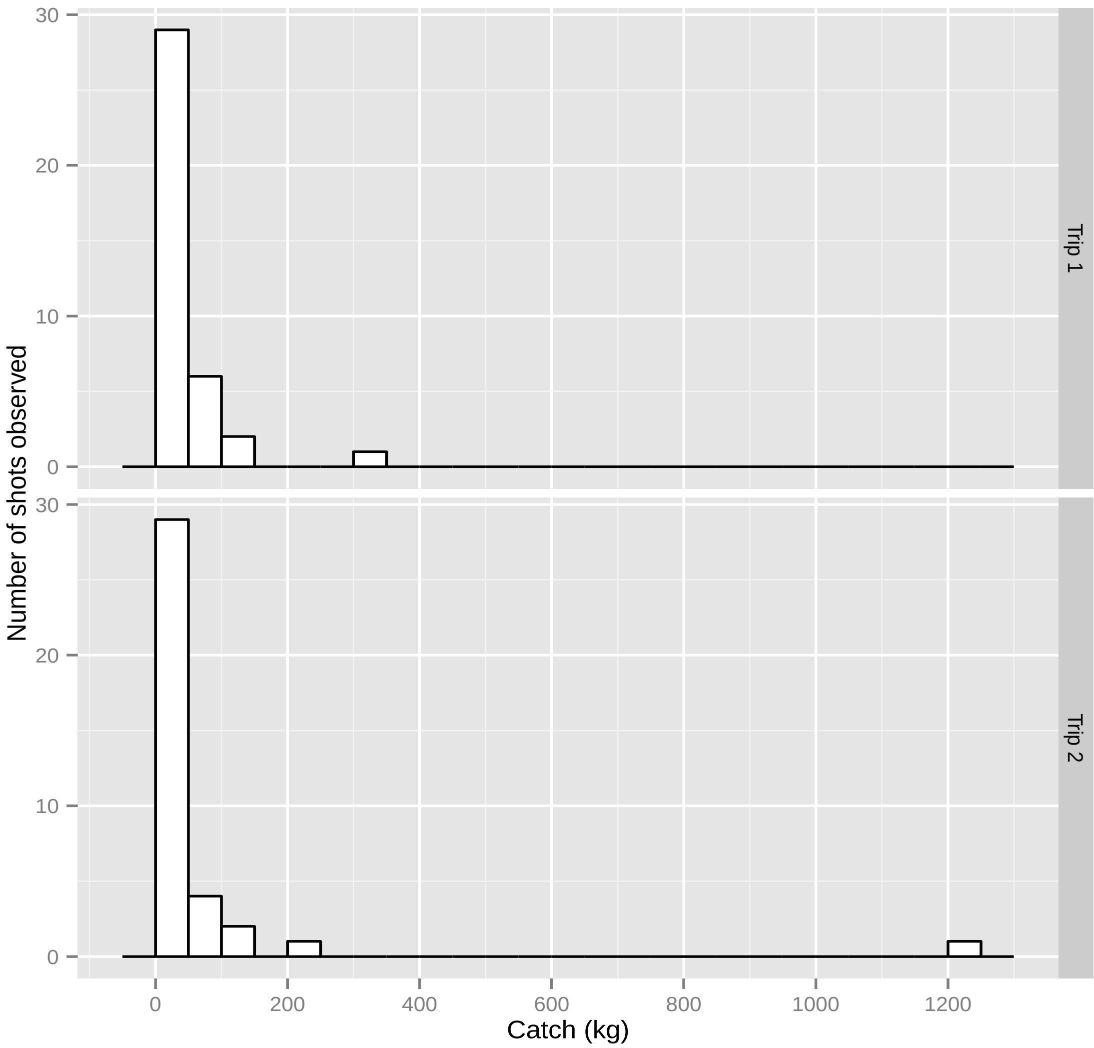


Figure 5. Frequency of catches (kg) of Bight Redfish during the each trip of the 2015 survey.

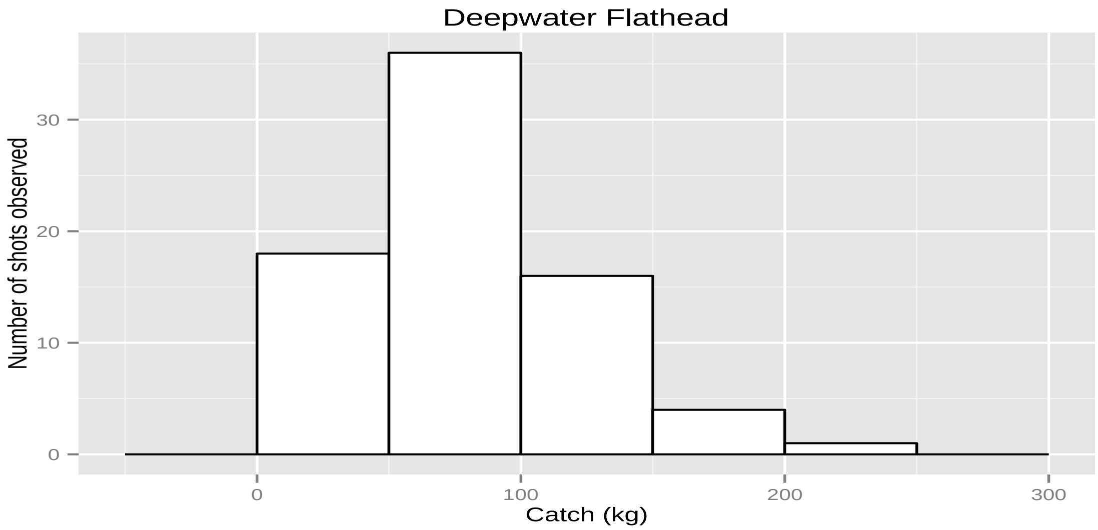


Figure 6. Frequency of catches (kg) of Deepwater Flathead during the 2015 survey (trips combined).

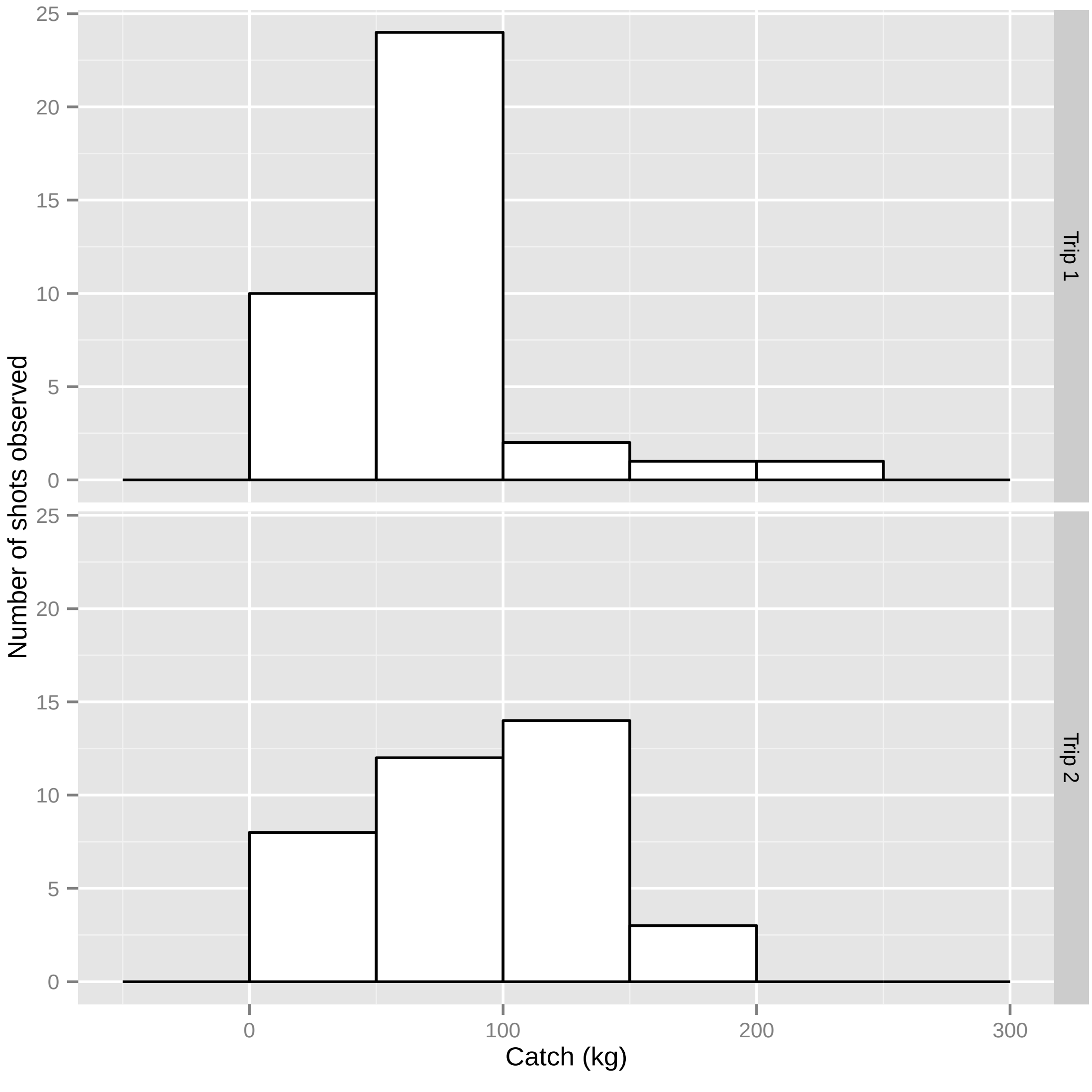


Figure 7. Frequency of catches (kg) of Deepwater Flathead during each trip of the 2015 survey.

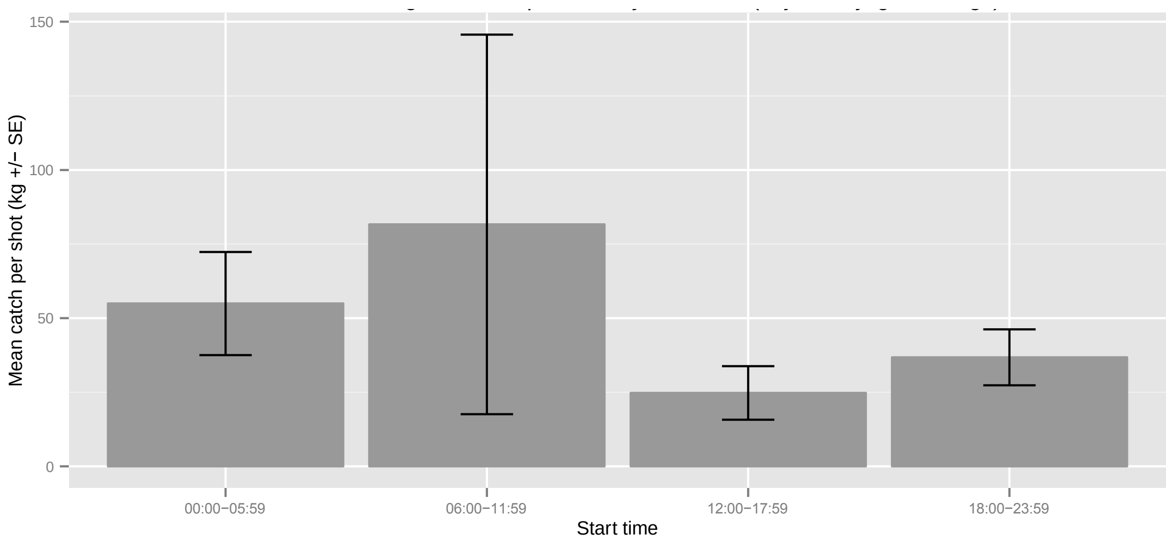


Figure 8. Mean and standard error of Bight Redfish catches by time of day during the 2015 survey (adjusted for daylight savings).

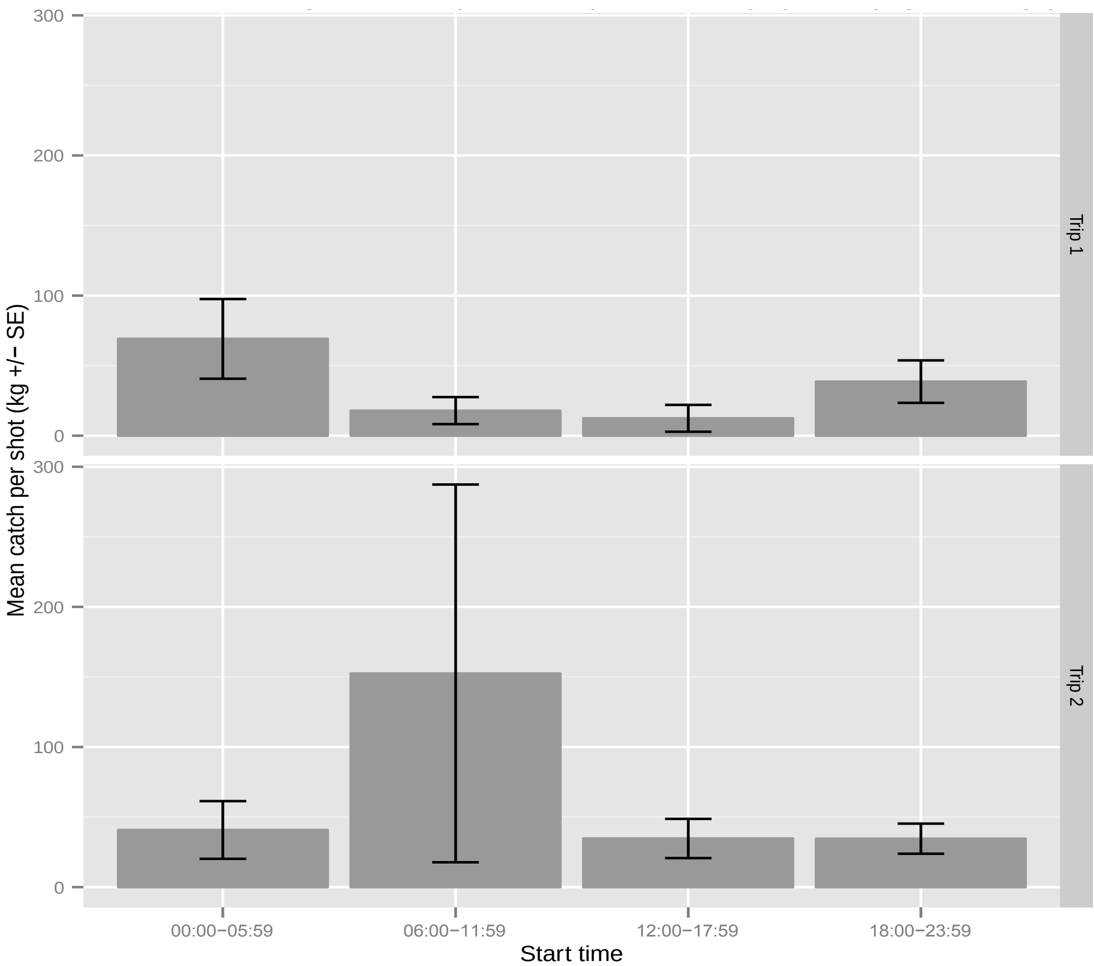


Figure 9. Mean and standard error of Bight Redfish catches by trip and time of day during the 2015 survey (adjusted for daylight savings).

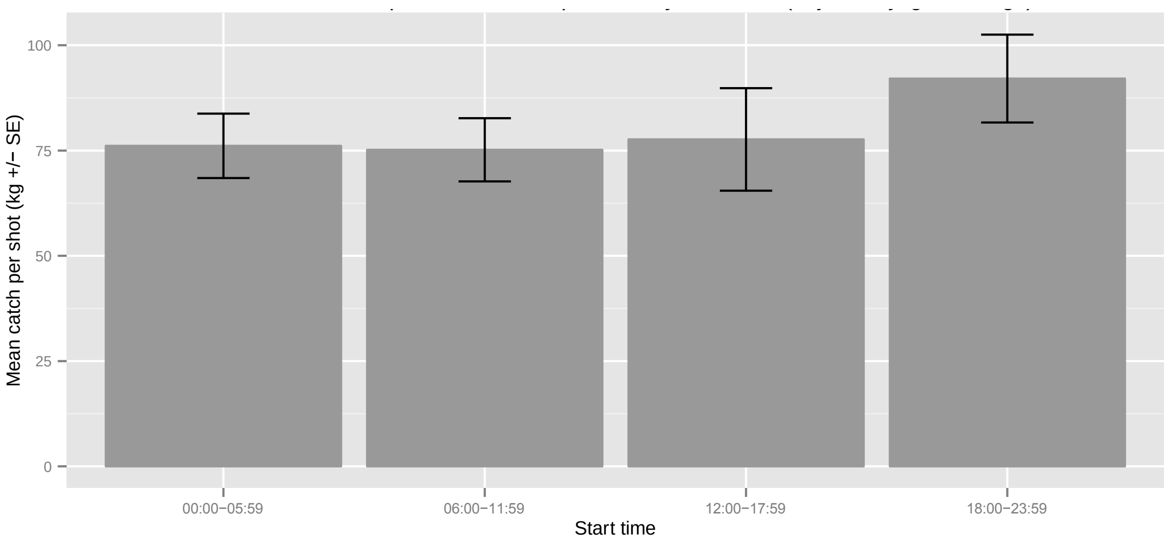


Figure 10. Mean and standard error of Deepwater Flathead catches by time of day during the 2015 survey (adjusted for daylight savings).

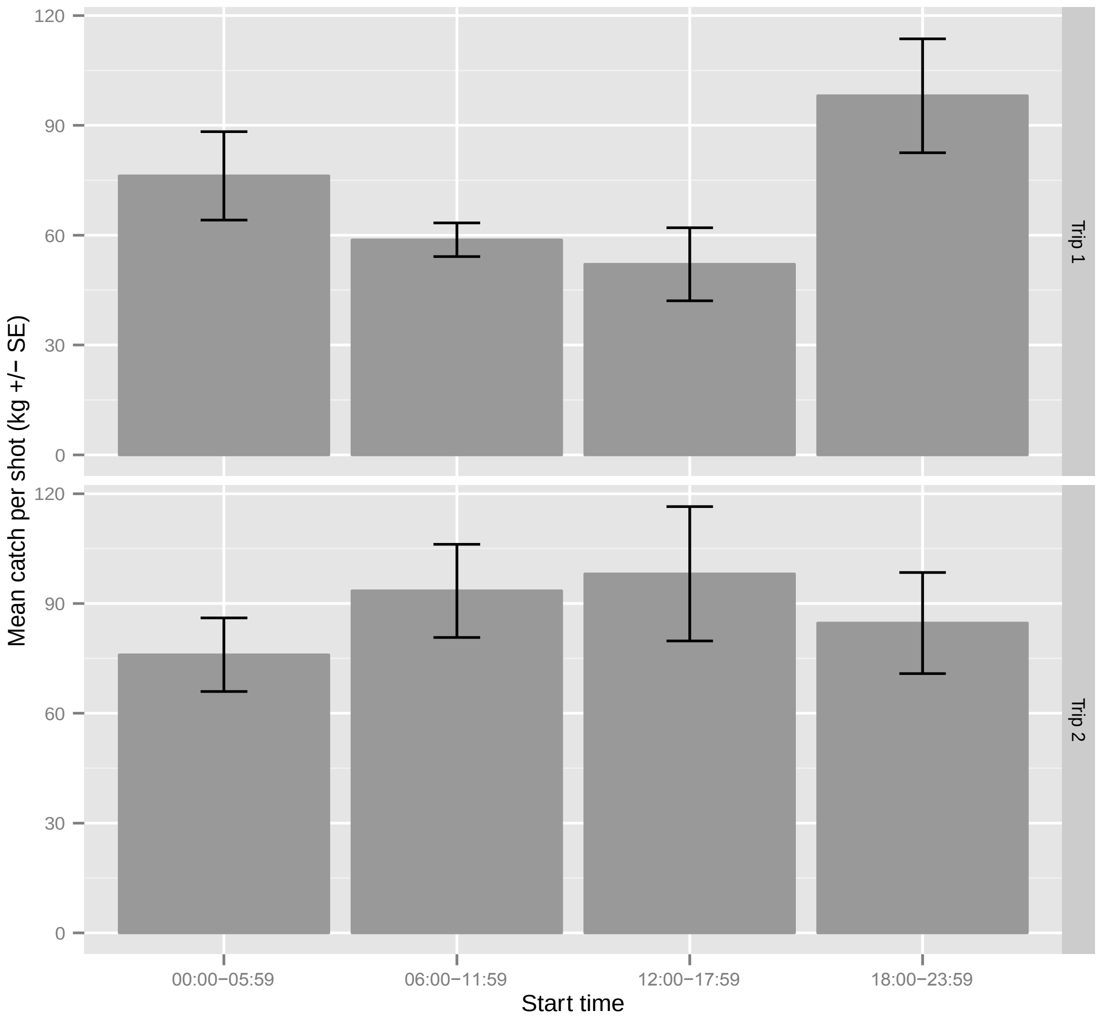


Figure 11. Mean and standard error of Deepwater Flathead catches by trip and time of day during the 2015 survey.

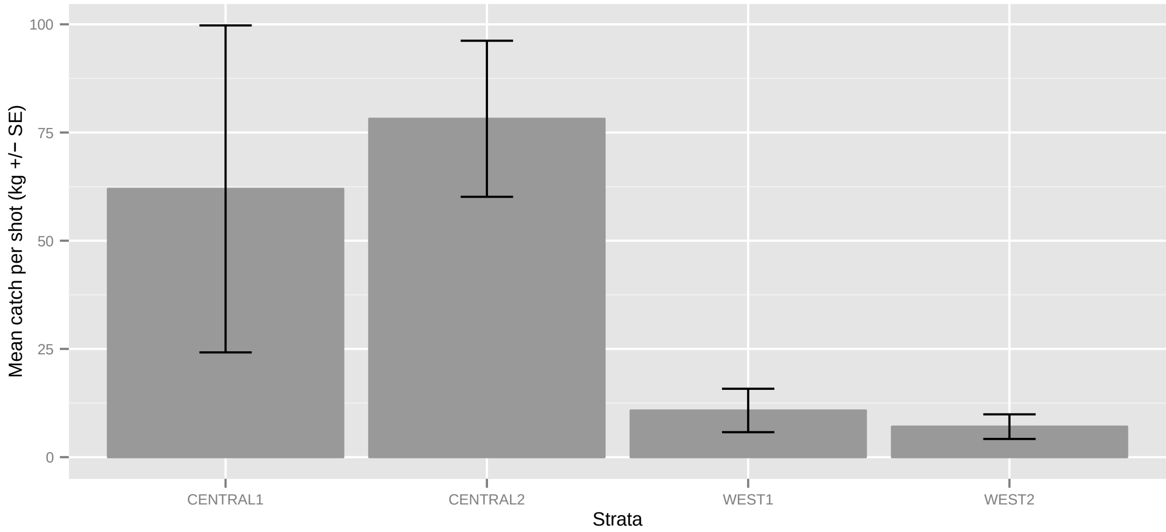


Figure 12. Mean and standard error of Bight Redfish catches by stratum during the 2015 survey.

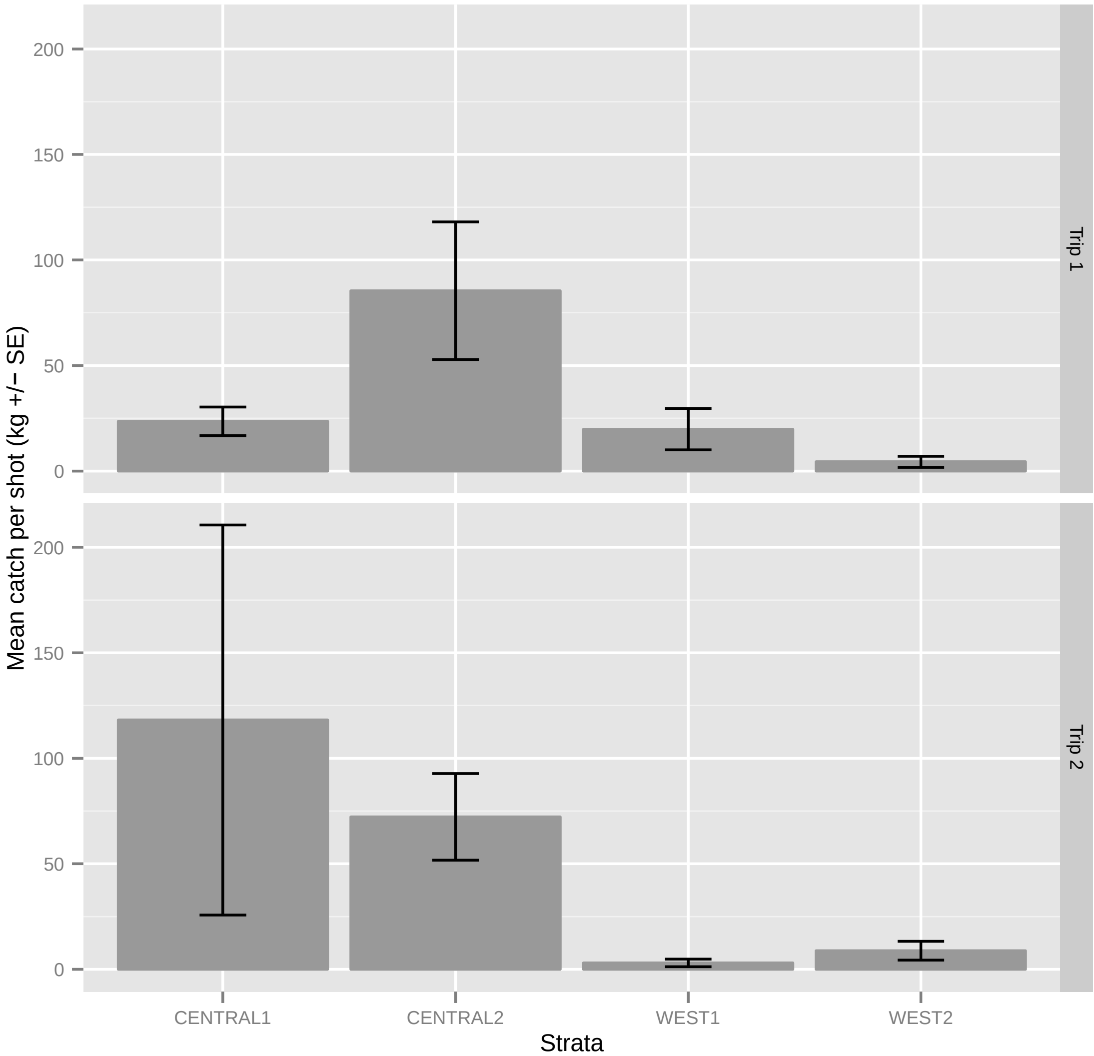


Figure 13. Mean and standard error of Bight Redfish catches by stratum during the 2015 survey by trip.

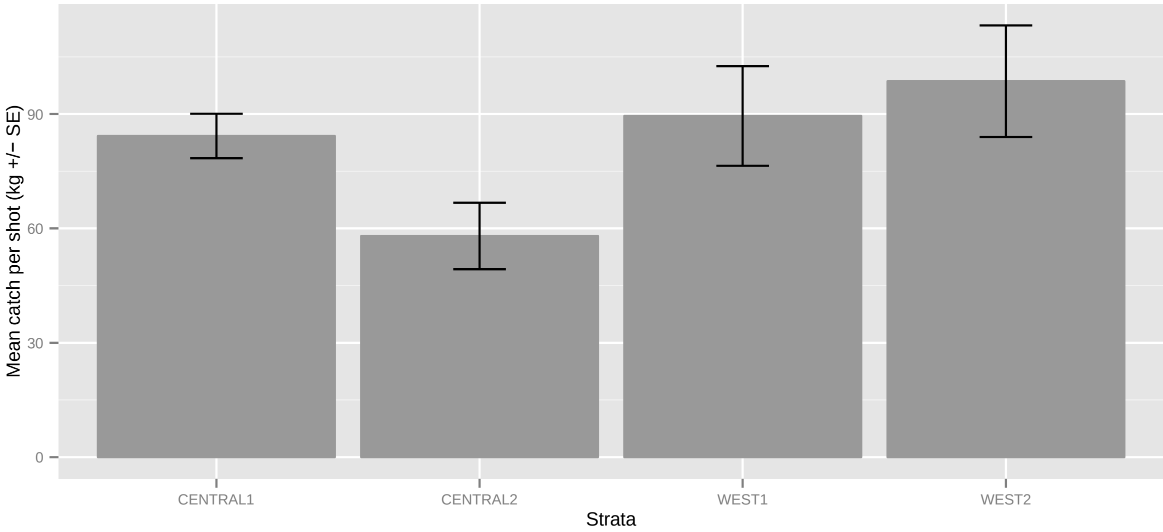


Figure 14. Mean and standard error of Deepwater Flathead catches by stratum during the 2015 survey.

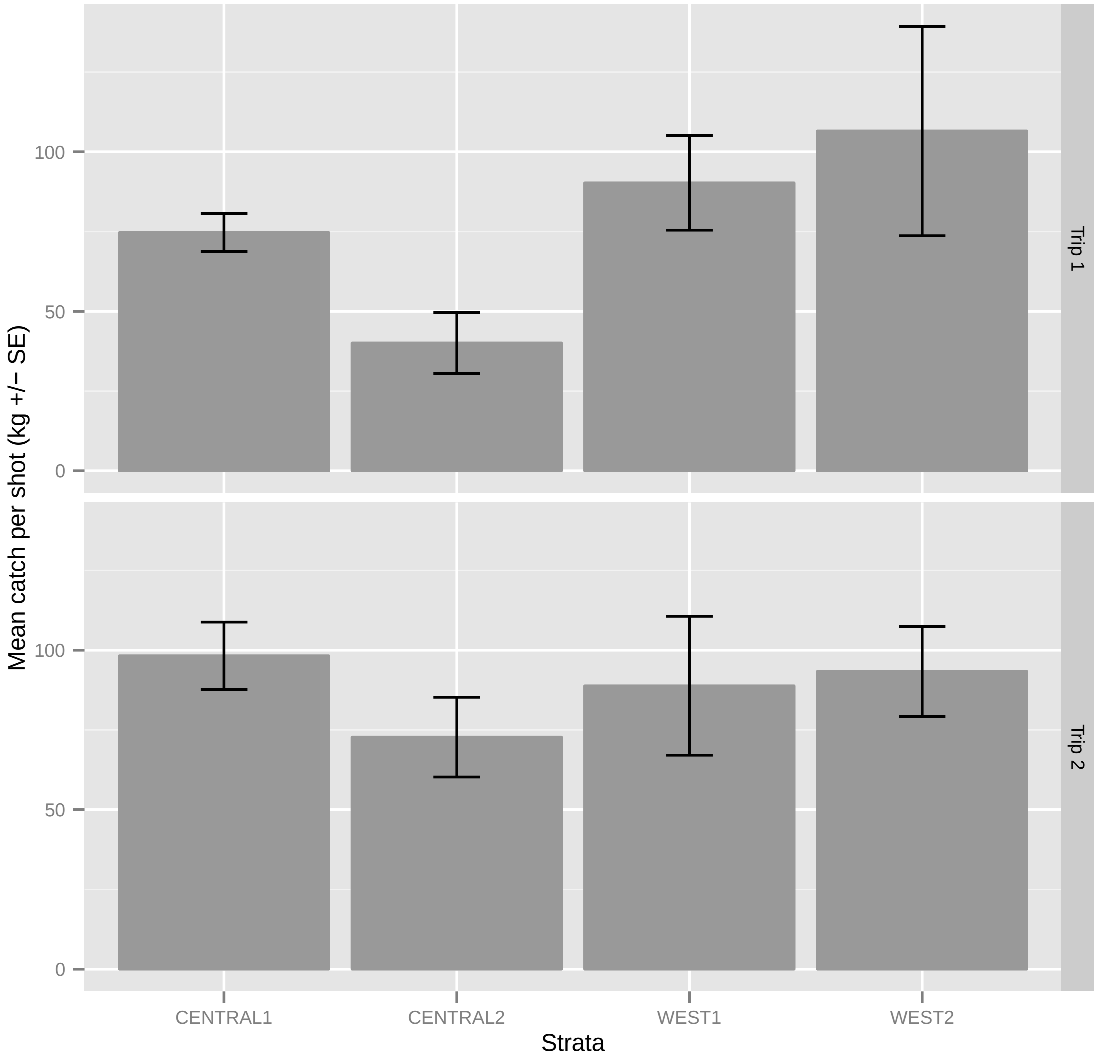


Figure 15. Mean and standard error of Deepwater Flathead catches by stratum during the 2015 survey by trip.

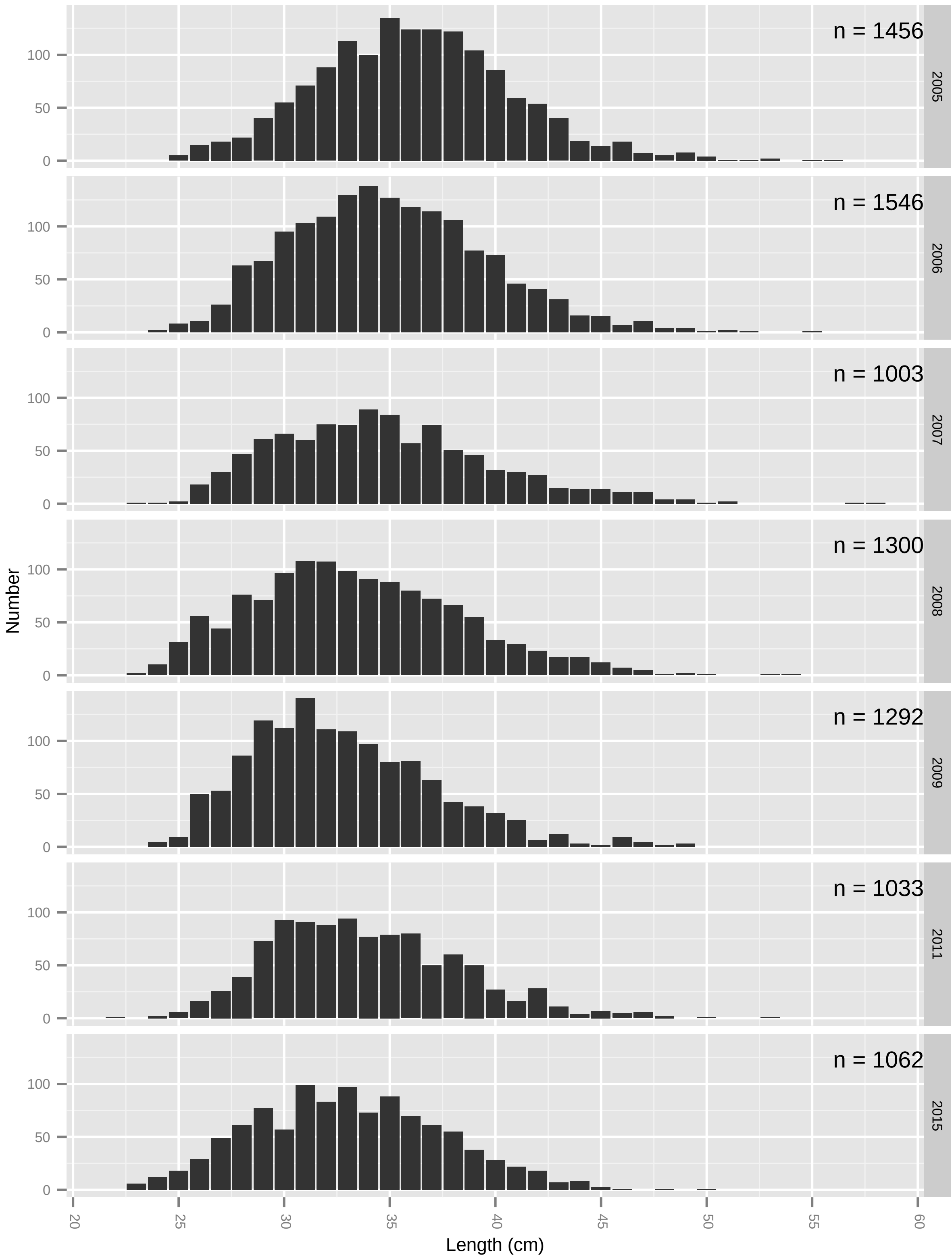


Figure 16. Length-frequencies (caudal fork length) of Bight Redfish during the 2005–2015 surveys.

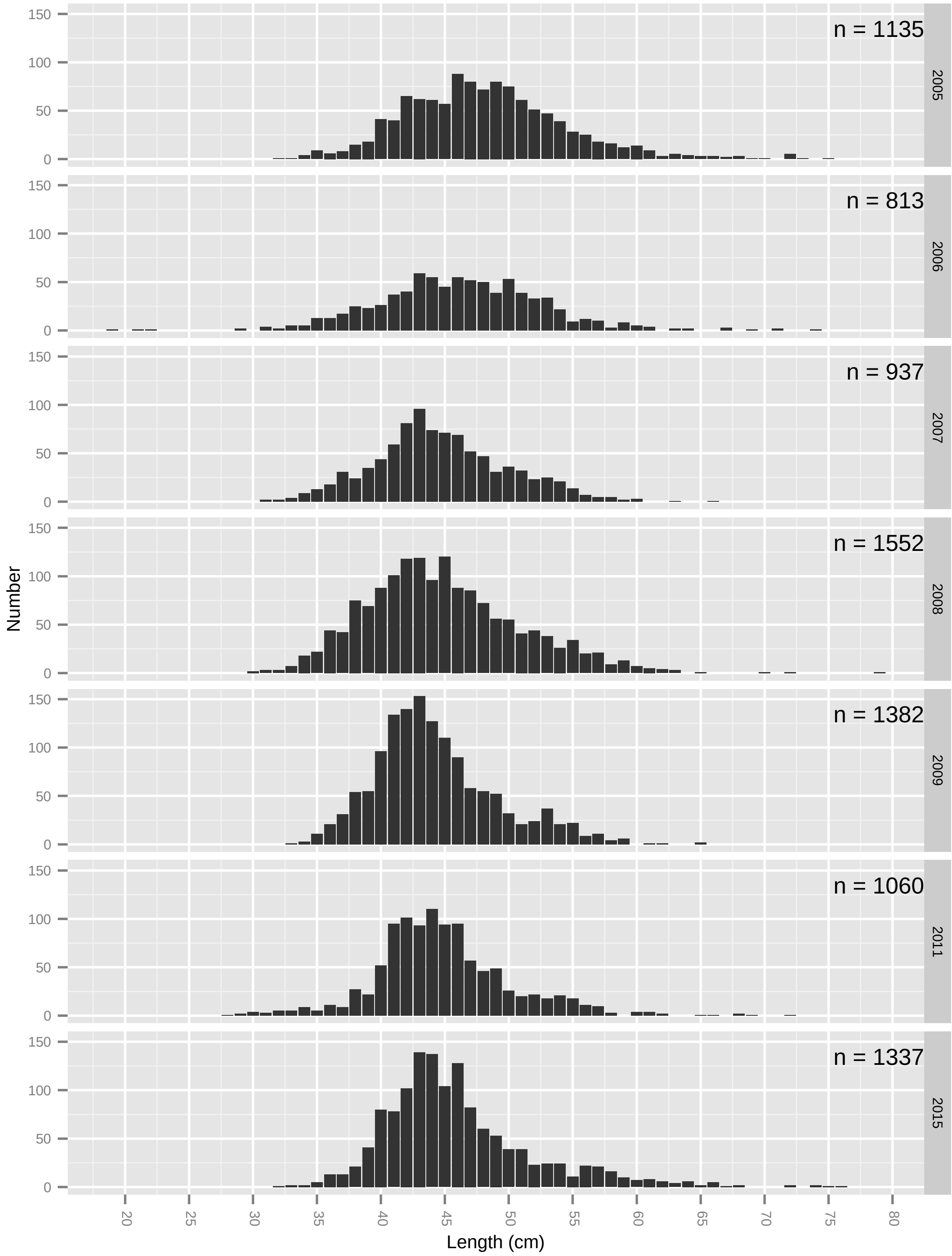


Figure 17. Length-frequencies (total length) of Deepwater Flathead during the 2005–2015 surveys.

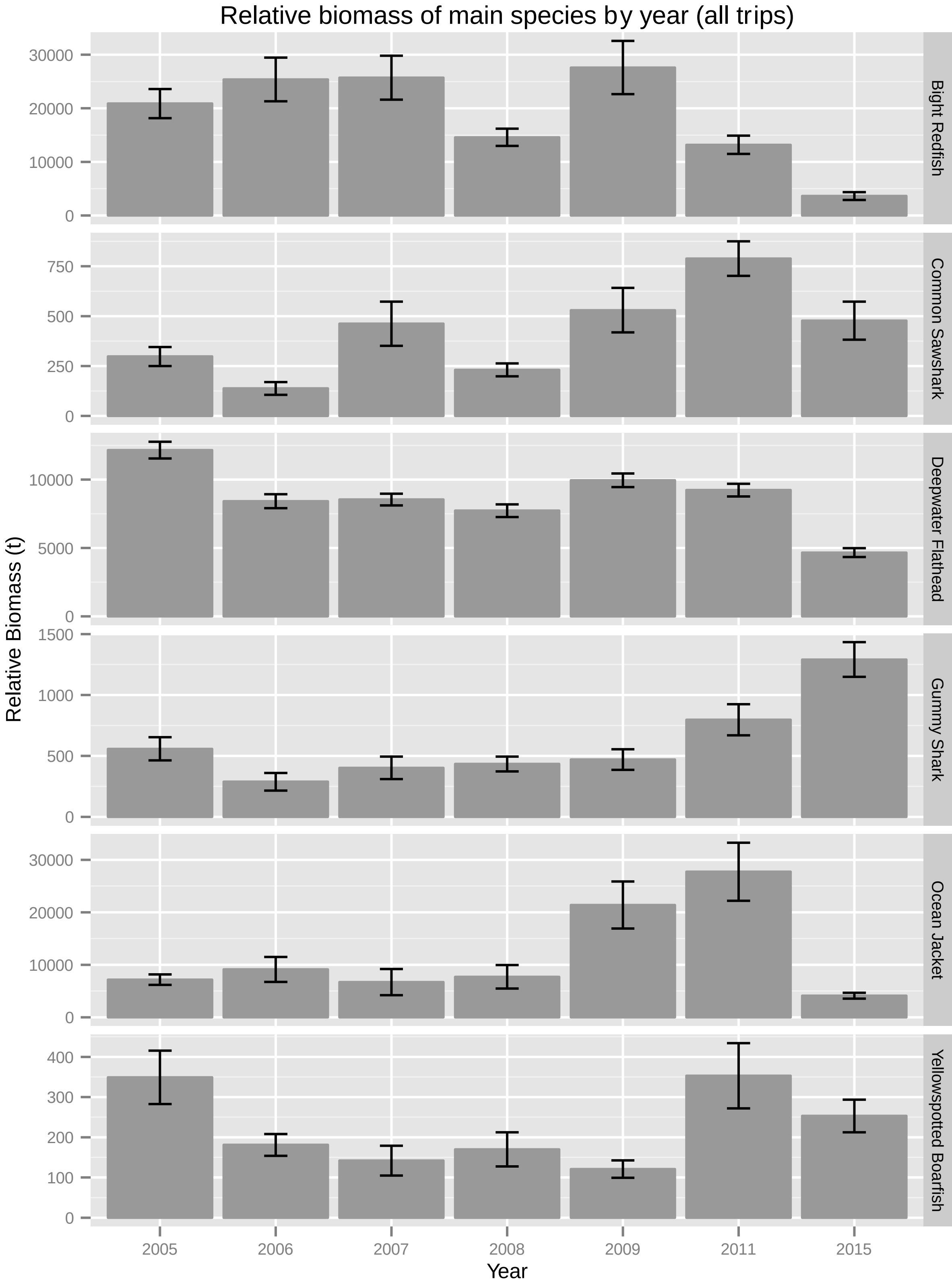


Figure 18. Relative biomass estimate (t ±SE) of Bight Redfish, Common Sawshark, Deepwater Flathead, Gummy Shark, Ocean Jacket and Yellowspotted Boarfish from annual surveys.

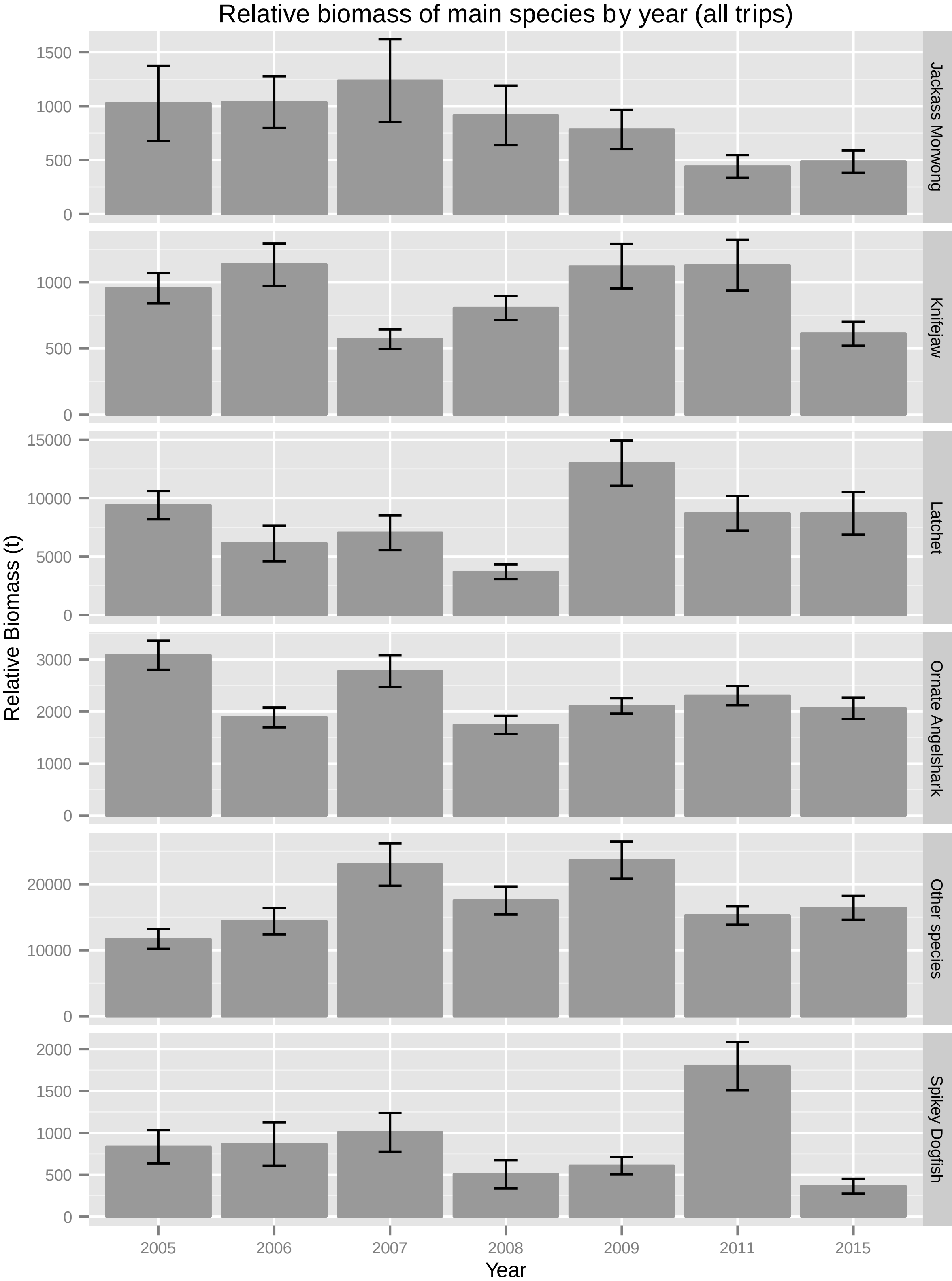


Figure 19. Relative biomass estimate (t ±SE) of Jackass Morwong, Knifejaw, Latchet, Ornate Angelshark, Spikey Dogfish and all other species from annual surveys.

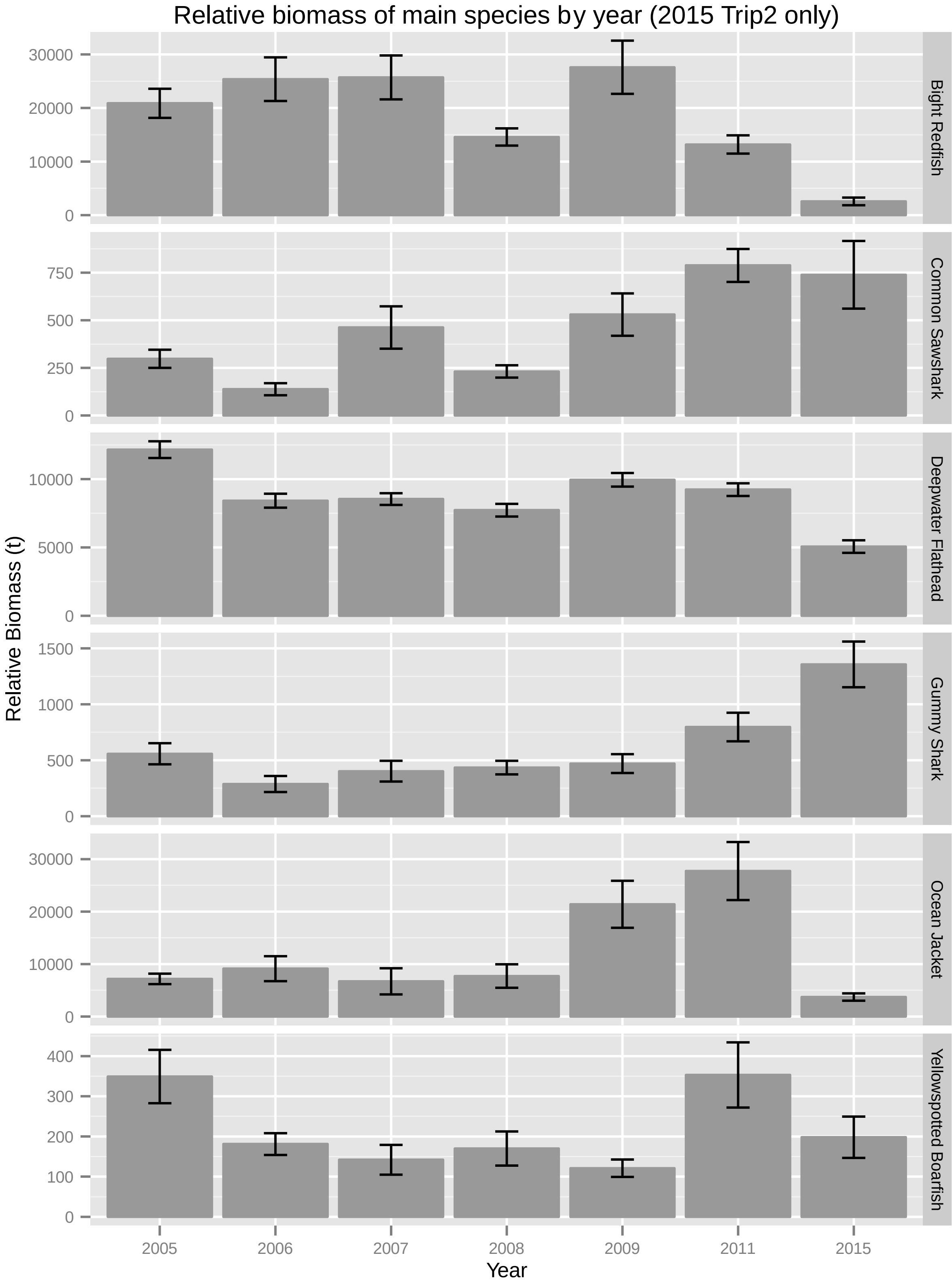


Figure 20. Relative biomass estimate (t ±SE) of Bight Redfish, Common Sawshark, Deepwater Flathead, Gummy Shark, Ocean Jacket and Yellowspotted Boarfish from annual surveys (**for 2015, Trip 2 only is used**).

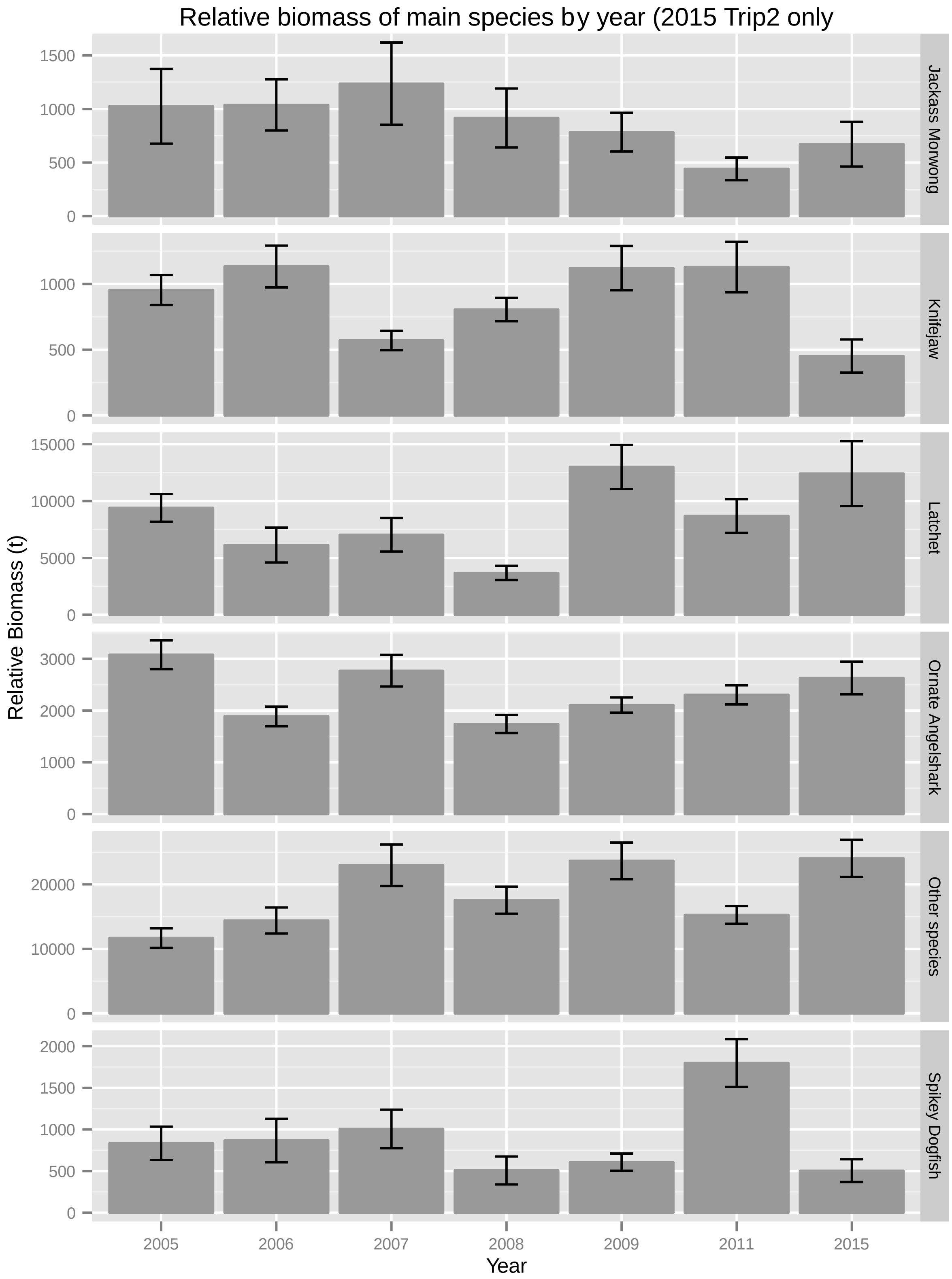


Figure 21. Relative biomass estimate (t ±SE) of Jackass Morwong, Knifejaw, Latchet, Ornate Angelshark, Spikey Dogfish and all other species from annual surveys (**for 2015, Trip 2 only is used)**.

Table 1. Description of strata sampled during the 2015 survey.

Stratum	Depth (m)	Longitude	Area (km^2)	Number of shots Trip 1	Number of shots Trip 2
Central 2	120–200	130.75–132.50	5720	9	11
Central 1	120–200	129.00–130.25	3965	19	13
West 2	120–200	127.75–129.00	2700	4	6
West 1	120–200	126.00–127.75	2600	6	7

Table 2. Mean and standard deviation (SD) length (m), swept area (km^2), speed (knots) and depths (m) of shots in each stratum during the 2015 survey.

Trip	Stratum	Shot length		Area swept†		Shot speed		Shot depth	
		Mean (km)	SD	Mean (km^2)	SD	Mean (knots)	SD	Mean (m)	SD
1	Central 2	15.577	0.345	0.254	0.006	3.3	0.1	135	7
1	Central 1	14.923	2.241	0.243	0.037	3.3	0.1	133	7
1	West 2	15.389	0.813	0.251	0.013	3.3	0.1	133	13
1	West 1	15.336	0.441	0.250	0.007	3.3	0.1	130	8
2	Central 2	15.829	0.479	0.258	0.008	3.4	0.1	136	9
2	Central 1	16.042	1.836	0.261	0.03	3.4	0.1	132	6
2	West 2	15.490	0.957	0.252	0.016	3.3	0.1	132	10
2	West 1	15.358	0.369	0.250	0.006	3.3	0.1	130	12

† Note: Area swept calculated using width of net (16.3 m)

Table 3. Total catch (kg) of all species in each stratum during Trip 1 of the 2015 survey.

Common name	Species name	Catch (kg)				
		Central 2	Central 1	West 2	West 1	Total
Australian Burrfish	*Allomycterus pilatus*	2	36.5	3	1.5	43
Barracouta	*Thyrsites atun*	43.5	2.9	0	0	46.4
Bearded Rock Cod	*Pseudophycis barbata*	3.2	2	0	1	6.2
Bigeye Ocean Perch	*Helicolenus barathri*	0	3.2	0.5	2.8	6.5
Bighead Gurnard Perch	*Neosebastes pandus*	26.3	58.7	8	45.5	138.5
Bight Redfish	*Centroberyx gerrardi*	769	447.5	17.5	119	1353
Black Stingray	*Dasyatis thetidis*	0	0	100	80	180
Blackspot Boarfish	*Zanclistius elevatus*	72.7	34.7	29	37	173.4
Blackspotted Gurnard Perch	*Neosebastes nigropunctatus*	77	31.7	40	63.2	211.9
Blue Mackerel	*Scomber australasicus*	0	0	0	20	20
Blue Morwong	*Nemadactylus valenciennesi*	14.1	18.2	17	73.2	122.5
Blue Warehou	*Seriolella brama*	0.3	0	0	0	0.3
Bug	*Ibacus & Thenus spp*	1.2	0.7	0	0	1.9
Common Sawshark	*Pristiophorus cirratus*	22.3	59.6	12	60	153.9
Common Veilfin	*Metavelifer multiradiatus*	2.7	5.5	2	0.5	10.7
Conger Eel	*Conger sp.*	3	5	0	0	8
Cosmopolitan Rubyfish	*Plagiogeneion rubiginosum*	0	0	0	5	5
Cuttlefish (U)	*Sepiidae - undifferentiated*	0.2	0.5	0	0	0.7
Deepwater Flathead	*Platycephalus conatus*	360.5	1419	426	541.5	2747
Deepwater Stargazer	*Kathetostoma nigrofasciatum*	10.8	12.7	3	5.5	32
Footballer Sweep	*Neatypus obliquus*	2.8	0	0	0	2.8
Fourspine Leatherjacket	*Eubalichthys quadrispinis*	3.9	12.2	7	8.5	31.6
Gemfish	*Rexea solandri*	5.8	0.3	12	0	18.1
Gould Squid	*Nototodarus gouldi*	174	379	55	136	744
Greeneye Dogfish	*Squalus mitsukurii*	35	8	3	7	53
Gulf Gurnard Perch	*Neosebastes bougainvillii*	1.5	0	0	0	1.5
Gummy Shark	*Mustelus antarcticus*	46.8	323.3	117	288.5	775.6
Hermit Crab (U)	*Paguroidea - undifferentiated*	0.5	0.5	0	0	1
Jack Mackerel	*Trachurus declivis*	105	145.2	42	143	435.2
Jackass Morwong	*Nemadactylus macropterus*	48.3	60.8	44	36	189.1
John Dory	*Zeus faber*	0	13.3	0.5	3.8	17.6
Knifejaw	*Oplegnathus woodwardi*	76.4	319.1	74	56.5	526
Latchet	*Pterygotrigla polyommata*	730	954.5	61.2	709	2454.7
Melbourne Skate	*Spiniraja whitleyi*	0	20	0	12	32
Mosaic Leatherjacket	*Eubalichthys mosaicus*	11	15	5.3	6.5	37.8
Ocean Jacket	*Nelusetta ayraud*	885.2	1465.8	118	374	2843
Ornate Angelshark	*Squatina tergocellata*	107	392	131	288	918
Port Jackson Shark	*Heterodontus portusjacksoni*	38	197	13	57	305
Red Gurnard	*Chelidonichthys kumu*	12.5	23.4	2	39.3	77.2
Ringed Toadfish	*Omegophora armilla*	23.2	56.3	11	72	162.5
Rusty Carpetshark	*Parascyllium ferrugineum*	4.8	9.1	1	9	23.9
Samsonfish	*Seriola hippos*	13	0	0	0	13
Sandyback Stingaree	*Urolophus bucculentus*	6	0	0	0	6
School Shark	*Galeorhinus galeus*	17	0	0	0	17
Seastar (U)	*Asteroidea - undifferentiated*	0	0.1	0	0.5	0.6
Sergeant Baker	*Aulopus purpurissatus*	32.7	14.5	5.2	30.5	82.9
Short-Tail Torpedo Ray	*Torpedo macneilli*	0	0	0	23	23
Silver Dory	*Cyttus australis*	0	2	0	0	2
Silver Trevally	*Pseudocaranx dentex*	0	1.3	2	17	20.3
Smooth Stingray	*Dasyatis brevicaudata*	150	31	165	300	646
Snapper	*Pagrus auratus*	3	19.2	0	0	22.2
Southern Eagle Ray	*Myliobatis australis*	2	13	3	0	18
Southern Fiddler Ray	*Trygonorrhina dumerilii*	3.5	65	100	67	235.5
Southern Round Skate	*Irolita waitii*	6.5	0	0	0	6.5
Southern Sawshark	*Pristiophorus nudipinnis*	11.5	3.5	0	14.5	29.5
Spider Crab (U)	*Majidae - undifferentiated*	0.2	0	0	0	0.2
Spikey Dogfish	*Squalus megalops*	44.5	90	0	1	135.5
Spiny Boxfish	*Capropygia unistriata*	3.7	2.2	0.5	0	6.4
Sponge (U)	*Grantiidae - undifferentiated*	80	37	8	65	190
Swallowtail	*Centroberyx lineatus*	32	213	22	37	304
Tasmanian Numbfish	*Narcine tasmaniensis*	0	1.5	0	0	1.5
Thetis Fish	*Neosebastes thetidis*	12.6	13.3	0	13	38.9
Tusk	*Dannevigia tusca*	3.3	27.1	3	0	33.4
Velvet Leatherjacket	*Meuschenia scaber*	0	0	0	4	4
Western Smooth Boxfish	*Anoplocapros amygdaloides*	0.6	0.5	0.5	1	2.6
Whitebarred Boxfish	*Anoplocapros lenticularis*	0	0	0	0.5	0.5
Wide Stingaree	*Urolophus expansus*	0	153	2.5	12.5	168
Yelloweye Redfish	*Centroberyx australis*	0	14.4	1.1	8	23.5
Yellowspotted Boarfish	*Paristiopterus gallipavo*	49.8	56.4	28.2	36.3	170.7
Total		4192.4	7291.2	1696	3932.6	17112.2

Table 4. Total catch (kg) of all species in each stratum during Trip 2 of the 2015 survey.

Common name	Species name	Catch (kg)				
		Central 2	Central 1	West 2	West 1	Total
Australian Burrfish	*Allomycterus pilatus*	2	16.5	1	2	21.5
Banded Wobbegong	*Orectolobus ornatus*	20	110	0	0	130
Barracouta	*Thyrsites atun*	514	16.5	0	0	530.5
Barred Grubfish	*Parapercis allporti*	0	0	0	0.1	0.1
Bearded Rock Cod	*Pseudophycis barbata*	7.3	1	0	1	9.3
Bigeye Ocean Perch	*Helicolenus barathri*	0.1	6.5	0	1	7.6
Bighead Gurnard Perch	*Neosebastes pandus*	53	21.5	11.1	42	127.6
Bight Redfish	*Centroberyx gerrardi*	794.6	1536	53	21.2	2404.8
Black Stingray	*Dasyatis thetidis*	0	20	30	36	86
Blackfin Ghostshark	*Hydrolagus lemures*	5	0	0	8	13
Blackspot Boarfish	*Zanclistius elevatus*	133.1	68.3	24.7	12.2	238.3
Blackspotted Gurnard Perch	*Neosebastes nigropunctatus*	57.7	7.6	28.5	17.8	111.6
Blue Mackerel	*Scomber australasicus*	0.5	0	1	0	1.5
Blue Morwong	*Nemadactylus valenciennesi*	45.2	92.4	60	8	205.6
Bug	*Ibacus & Thenus spp*	0.5	0.8	0.5	0	1.8
Coffin Ray	*Hypnos monopterygius*	3	0	0	0	3
Common Sawshark	*Pristiophorus cirratus*	51.2	261.2	30.5	177.5	520.4
Common Veilfin	*Metavelifer multiradiatus*	8.9	4	0	0	12.9
Conger Eel	*Conger sp.*	4	0	0	0	4
Cosmopolitan Rubyfish	*Plagiogeneion rubiginosum*	0	48	0	0	48
Cuttlefish (U)	*Sepiidae - undifferentiated*	1	0	0	0	1
Deepwater Flathead	*Platycephalus conatus*	800	1277	560	622	3259
Deepwater Stargazer	*Kathetostoma nigrofasciatum*	29.9	21.3	4.5	11	66.7
Footballer Sweep	*Neatypus obliquus*	0.7	0.5	0	0	1.2
Fourspine Leatherjacket	*Eubalichthys quadrispinis*	1.2	1	0.8	2	5
Gemfish	*Rexea solandri*	5.3	26.2	4.5	0.5	36.5
Gould Squid	*Nototodarus gouldi*	145.5	148	34	276	603.5
Greeneye Dogfish	*Squalus mitsukurii*	8	4.5	0	38	50.5
Gummy Shark	*Mustelus antarcticus*	175	285	145	285	890
Hermit Crab (U)	*Paguroidea - undifferentiated*	0.5	0	1	0	1.5
Jack Mackerel	*Trachurus declivis*	11	35	108	7	161
Jackass Morwong	*Nemadactylus macropterus*	92.4	284.1	61.4	17	454.9
John Dory	*Zeus faber*	2.9	12.7	10.8	2	28.4
Knifejaw	*Oplegnathus woodwardi*	46.9	117.2	48.6	94.5	307.2
Latchet	*Pterygotrigla polyommata*	3330	1608.6	1949	239	7126.6
Melbourne Skate	*Spiniraja whitleyi*	4	15	8	15	42
Mosaic Leatherjacket	*Eubalichthys mosaicus*	15.8	13	12	6	46.8
Ocean Jacket	*Nelusetta ayraud*	662	819	230	720	2431
Ornate Angelshark	*Squatina tergocellata*	188	615.5	338	615	1756.5
Port Jackson Shark	*Heterodontus portusjacksoni*	26	46.5	19	28	119.5
Red Gurnard	*Chelidonichthys kumu*	8	19.5	15.3	36.2	79
Ringed Toadfish	*Omegophora armilla*	36	69.1	17.5	37	159.6
Rusty Carpetshark	*Parascyllium ferrugineum*	11.5	5.5	2	25	44
Sandpaper Fish	*Paratrachichthys macleayi*	2	0	0	0	2
Sandyback Stingaree	*Urolophus bucculentus*	0	7	0	0	7
Sawtail Catshark	*Figaro boardmani*	0.2	0	0	0	0.2
School Shark	*Galeorhinus galeus*	0	5	2	7	14
Seastar (U)	*Asteroidea - undifferentiated*	0.3	0	0	0	0.3
Sergeant Baker	*Aulopus purpurissatus*	37.3	16	12	13	78.3
Sharpnose Sevengill Shark	*Heptranchias perlo*	3	0	4	46	53
Short-Tail Torpedo Ray	*Torpedo macneilli*	0	12	0	0	12
Silver Trevally	*Pseudocaranx dentex*	22	11.6	0	0	33.6
Smooth Stingray	*Dasyatis brevicaudata*	77	321	208	272	878
Snapper	*Pagrus auratus*	5.5	27	0	0	32.5
Southern Eagle Ray	*Myliobatis australis*	0	0	0	7	7
Southern Fiddler Ray	*Trygonorrhina dumerilii*	69	99	34	67	269
Southern Round Skate	*Irolita waitii*	5.3	0	0	3	8.3
Southern Sawshark	*Pristiophorus nudipinnis*	15.1	28.9	25.4	161.5	230.9
Spikey Dogfish	*Squalus megalops*	85	116.5	88.2	34	323.7
Spiny Boxfish	*Capropygia unistriata*	4.5	3.5	0	0	8
Splendid Perch	*Callanthias australis*	0.2	1.2	0	0	1.4
Sponge (U)	*Grantiidae - undifferentiated*	171	13	10	40	234
Swallowtail	*Centroberyx lineatus*	3	552.5	31	0	586.5
Thetis Fish	*Neosebastes thetidis*	13.7	6.3	0	2.5	22.5
Tusk	*Dannevigia tusca*	4.6	6.1	4.5	1.2	16.4
Velvet Leatherjacket	*Meuschenia scaber*	1	1	0	1	3
Western Shovelnose Ray	*Aptychotrema vincentiana*	0	8	14	12	34
Wide Stingaree	*Urolophus expansus*	809	3491	1980	3930	10210
Yelloweye Redfish	*Centroberyx australis*	7.7	129.1	3.5	0	140.3
Yellowspotted Boarfish	*Paristiopterus gallipavo*	64.2	26.1	15.6	6.3	112.2
Total		8702.3	12516.3	6241.9	8006.5	35467

Table 5. Catch (kg) Bight Redfish and Deepwater Flathead for each stratum point sampled during the 2015 survey – Trip 1.

Trip	Survey point	Shot start date	Shot start date	Start point		End point		Catch (kg)	
				Latitude	Longitude	Latitude	Longitude	Bight redfish	Deepwater flathead
1	1	8-Mar-15	14:01	-33.345	131.407	-33.378	131.556	9	8.5
1	2	9-Mar-15	7:06	-33.680	132.119	-33.773	132.253	86	75
1	3	9-Mar-15	0:29	-33.440	131.851	-33.530	131.986	127	43
1	4								
1	5	8-Mar-15	10:17	-33.364	131.281	-33.386	131.446	0	43
1	6	7-Mar-15	16:37	-33.267	130.214	-33.251	130.368	0	56
1	7	7-Mar-15	9:09	-33.213	130.009	-33.242	130.160	1.5	62
1	8	7-Mar-15	13:21	-33.276	130.020	-33.265	130.176	0	59
1	9	7-Mar-15	5:40	-33.218	129.804	-33.231	129.968	3.1	65
1	10	2-Mar-15	23:03	-33.194	129.576	-33.230	129.432	25	97
1	11	6-Mar-15	18:35	-33.210	129.577	-33.291	129.456	34	94
1	12	3-Mar-15	2:45	-33.248	129.468	-33.295	129.317	83	75
1	13	3-Mar-15	6:18	-33.263	129.325	-33.299	129.174	62	48
1	14	6-Mar-15	22:05	-33.240	129.504	-33.202	129.647	1.6	81
1	15	3-Mar-15	10:09	-33.318	129.071	-33.272	128.926	1.2	72
1	16	3-Mar-15	15:21	-33.283	128.553	-33.266	128.403	0	78
1	17	3-Mar-15	19:42	-33.221	128.189	-33.221	128.048	10.5	96
1	18	4-Mar-15	5:20	-33.167	126.969	-33.173	126.808	62	68
1	19	4-Mar-15	11:27	-33.263	126.321	-33.305	126.174	8	44.5
1	20	4-Mar-15	14:51	-33.288	126.209	-33.219	126.339	0	72
1	21	4-Mar-15	18:06	-33.210	126.329	-33.231	126.171	0	143
1	22	5-Mar-15	0:06	-33.168	126.598	-33.170	126.757	16	120
1	23	5-Mar-15	4:02	-33.208	126.898	-33.211	127.057	33	94
1	24	5-Mar-15	15:27	-33.221	128.363	-33.232	128.522	7	51
1	25	5-Mar-15	18:55	-33.275	128.585	-33.277	128.745	0	201
1	26	5-Mar-15	23:25	-33.317	129.018	-33.299	129.175	24	81
1	27	6-Mar-15	2:37	-33.275	129.202	-33.256	129.255	20	44
1	28	6-Mar-15	4:44	-33.284	129.288	-33.246	129.439	41.5	70
1	29	6-Mar-15	8:24	-33.297	129.390	-33.314	129.548	0	60
1	30	6-Mar-15	11:43	-33.319	129.550	-33.304	129.710	0	37
1	31	6-Mar-15	15:20	-33.222	129.738	-33.196	129.593	3.6	81
1	32	7-Mar-15	2:01	-33.166	129.684	-33.167	129.834	5	155
1	33	7-Mar-15	23:25	-33.212	130.152	-33.233	130.310	94	93
1	34	7-Mar-15	19:57	-33.228	130.331	-33.209	130.183	48	89
1	35	8-Mar-15	6:51	-33.355	131.102	-33.363	131.271	19	72
1	36	8-Mar-15	17:54	-33.352	131.490	-33.384	131.646	79	11
1	37	8-Mar-15	21:17	-33.387	131.686	-33.429	131.832	148	6
1	38	9-Mar-15	3:42	-33.548	131.997	-33.665	132.102	300	28
1	39	9-Mar-15	10:54	-33.798	132.266	-33.708	132.136	1	74

Table 5 contd… Catch (kg) Bight Redfish and Deepwater Flathead for each stratum point sampled during the 2015 survey – Trip 2.

Trip	Survey point	Shot start date	Shot start date	Start point		End point		Catch (kg)	
				Latitude	Longitude	Latitude	Longitude	Bight redfish	Deepwater flathead
2	40	30-Mar-15	5:26	-33.799	132.288	-33.710	132.171	45	42
2	41	30-Mar-15	9:24	-33.640	132.027	-33.571	131.886	2.6	92
2	42	30-Mar-15	13:06	-33.478	131.857	-33.468	131.702	0	55
2	43	30-Mar-15	17:46	-33.317	131.442	-33.319	131.281	141	146
2	44	30-Mar-15	21:30	-33.364	131.214	-33.338	131.056	94	118
2	45	31-Mar-15	1:31	-33.316	131.025	-33.273	130.880	216	38
2	46	31-Mar-15	10:34	-33.267	129.861	-33.269	129.684	1225	49
2	47	1-Apr-15	5:41	-33.302	129.522	-33.322	129.375	21	102
2	48	1-Apr-15	2:06	-33.292	129.417	-33.226	129.534	46	107
2	49	1-Apr-15	13:14	-33.314	129.210	-33.306	129.052	9	75
2	50	1-Apr-15	9:24	-33.320	129.356	-33.313	129.194	3	105
2	51	1-Apr-15	17:09	-33.285	129.093	-33.284	128.941	37	62
2	52	1-Apr-15	20:58	-33.269	128.976	-33.275	128.828	15	71
2	53	2-Apr-15	0:49	-33.245	128.759	-33.244	128.620	5	69
2	54	2-Apr-15	4:35	-33.268	128.612	-33.257	128.443	5	61
2	55	3-Apr-15	1:39	-33.214	126.545	-33.230	126.382	0	36
2	56	2-Apr-15	17:56	-33.174	126.772	-33.170	126.615	2.2	197
2	57	2-Apr-15	21:32	-33.166	126.589	-33.206	126.441	0	56
2	58	3-Apr-15	5:15	-33.237	126.306	-33.277	126.162	0	84
2	59	3-Apr-15	11:57	-33.273	126.305	-33.246	126.461	0	31
2	60	3-Apr-15	16:08	-33.168	126.632	-33.162	126.790	12	118
2	61	3-Apr-15	22:27	-33.263	127.301	-33.272	127.463	7	100
2	62	4-Apr-15	7:45	-33.267	128.493	-33.291	128.653	0	154
2	63	4-Apr-15	11:37	-33.271	128.652	-33.264	128.487	0	102
2	64	4-Apr-15	16:12	-33.200	128.745	-33.194	128.912	28	103
2	65	4-Apr-15	20:12	-33.261	128.886	-33.266	129.046	39	126
2	66	5-Apr-15	8:02	-33.230	129.446	-33.202	129.589	14	113
2	67	5-Apr-15	0:06	-33.300	129.191	-33.273	129.351	60	127
2	68	5-Apr-15	3:48	-33.271	129.354	-33.316	129.530	10	94
2	69	5-Apr-15	12:55	-33.168	129.554	-33.170	129.718	0	166
2	70	5-Apr-15	17:02	-33.267	129.673	-33.273	129.848	46	23
2	71	5-Apr-15	20:54	-33.200	129.822	-33.203	129.983	26	128
2	72	6-Apr-15	7:33	-33.278	131.098	-33.320	131.247	128	70
2	73	6-Apr-15	11:29	-33.382	131.251	-33.381	131.421	0	125
2	74	6-Apr-15	15:12	-33.359	131.513	-33.367	131.679	72	36
2	75	6-Apr-15	19:41	-33.516	131.798	-33.587	131.922	40	56
2	76	6-Apr-15	23:16	-33.600	131.985	-33.660	132.117	56	22

Table 6. Species and numbers of fish for which length and otolith samples were collected during 2015 survey.

Species	Length frequency (unsexed)	Otoliths collected
Deepwater Flathead	1337	229
Bight Redfish	1062	196

Table 7. Estimated total relative biomass (t) with coefficient of variation (c.v.) of major commercial species in across all strata from 2005, 2006, 2007, 2008, 2009, 2011 and 2015 surveys, using all trips and assuming net width of 16.3 m.

Species	Estimated Relative biomass													
	2005		2006		2007		2008		2009		2011		2015	
	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.
Bight Redfish [A]	20887	0.13	25380	0.16	25713	0.16	14591	0.11	27610	0.18	13189	0.13	3633	0.20
Deepwater Flathead	12152	0.05	8415	0.06	8540	0.05	7725	0.06	9942	0.05	9227	0.05	4657	0.07
Ocean Jacket	7163	0.14	9111	0.26	6701	0.37	7709	0.29	21374	0.21	27712	0.20	4103	0.14
Common Sawshark	298	0.16	138	0.23	462	0.24	231	0.14	530	0.21	788	0.11	477	0.20
Yellowspotted Boarfish	349	0.19	181	0.15	142	0.26	170	0.25	121	0.18	353	0.23	253	0.16
Gummy Shark	558	0.17	288	0.25	402	0.23	434	0.14	470	0.18	797	0.16	1291	0.11
Jackass Morwong	1025	0.34	1037	0.23	1236	0.31	916	0.30	783	0.23	441	0.24	486	0.21
Knifejaw	955	0.12	1133	0.14	570	0.13	806	0.11	1121	0.15	1129	0.17	612	0.15
Latchet	9401	0.13	6135	0.25	7040	0.21	3688	0.17	12997	0.15	8690	0.17	8698	0.21
Ornate Angelshark	3078	0.09	1887	0.10	2770	0.11	1742	0.10	2107	0.07	2305	0.08	2060	0.10
Spikey Dogfish	834	0.24	867	0.30	1006	0.23	508	0.33	607	0.17	1799	0.16	362	0.24
Other species	11693	0.13	14405	0.14	22990	0.14	17558	0.12	23666	0.12	15272	0.09	16422	0.11

[A] night hauls only

Table 8. Estimated total relative biomass (t) with coefficient of variation (c.v.) of major commercial species in across all strata from 2005, 2006, 2007, 2008, 2009, 2011 and 2015 surveys, **using trip two only (for 2015)** and assuming net width of 16.3 m.

Species	Estimated Relative biomass													
	2005		2006		2007		2008		2009		2011		2015	
	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.
Bight Redfish [A]	20887	0.13	25380	0.16	25713	0.16	14591	0.11	27610	0.18	13189	0.13	2573	0.28
Deepwater Flathead	12152	0.05	8415	0.06	8540	0.05	7725	0.06	9942	0.05	9227	0.05	5065	0.09
Ocean Jacket	7163	0.14	9111	0.26	6701	0.37	7709	0.29	21374	0.21	27712	0.20	3702	0.19
Common Sawshark	298	0.16	138	0.23	462	0.24	231	0.14	530	0.21	788	0.11	739	0.24
Yellowspotted Boarfish	349	0.19	181	0.15	142	0.26	170	0.25	121	0.18	353	0.23	198	0.26
Gummy Shark	558	0.17	288	0.25	402	0.23	434	0.14	470	0.18	797	0.16	1357	0.15
Jackass Morwong	1025	0.34	1037	0.23	1236	0.31	916	0.30	783	0.23	441	0.24	671	0.31
Knifejaw	955	0.12	1133	0.14	570	0.13	806	0.11	1121	0.15	1129	0.17	452	0.28
Latchet	9401	0.13	6135	0.25	7040	0.21	3688	0.17	12997	0.15	8690	0.17	12418	0.23
Ornate Angelshark	3078	0.09	1887	0.10	2770	0.11	1742	0.10	2107	0.07	2305	0.08	2629	0.12
Spikey Dogfish	834	0.24	867	0.30	1006	0.23	508	0.33	607	0.17	1799	0.16	505	0.27
Other species	11693	0.13	14405	0.14	22990	0.14	17558	0.12	23666	0.12	15272	0.09	24052	0.12

[A] night hauls only

Appendix 1. Species composition of catch for each survey.

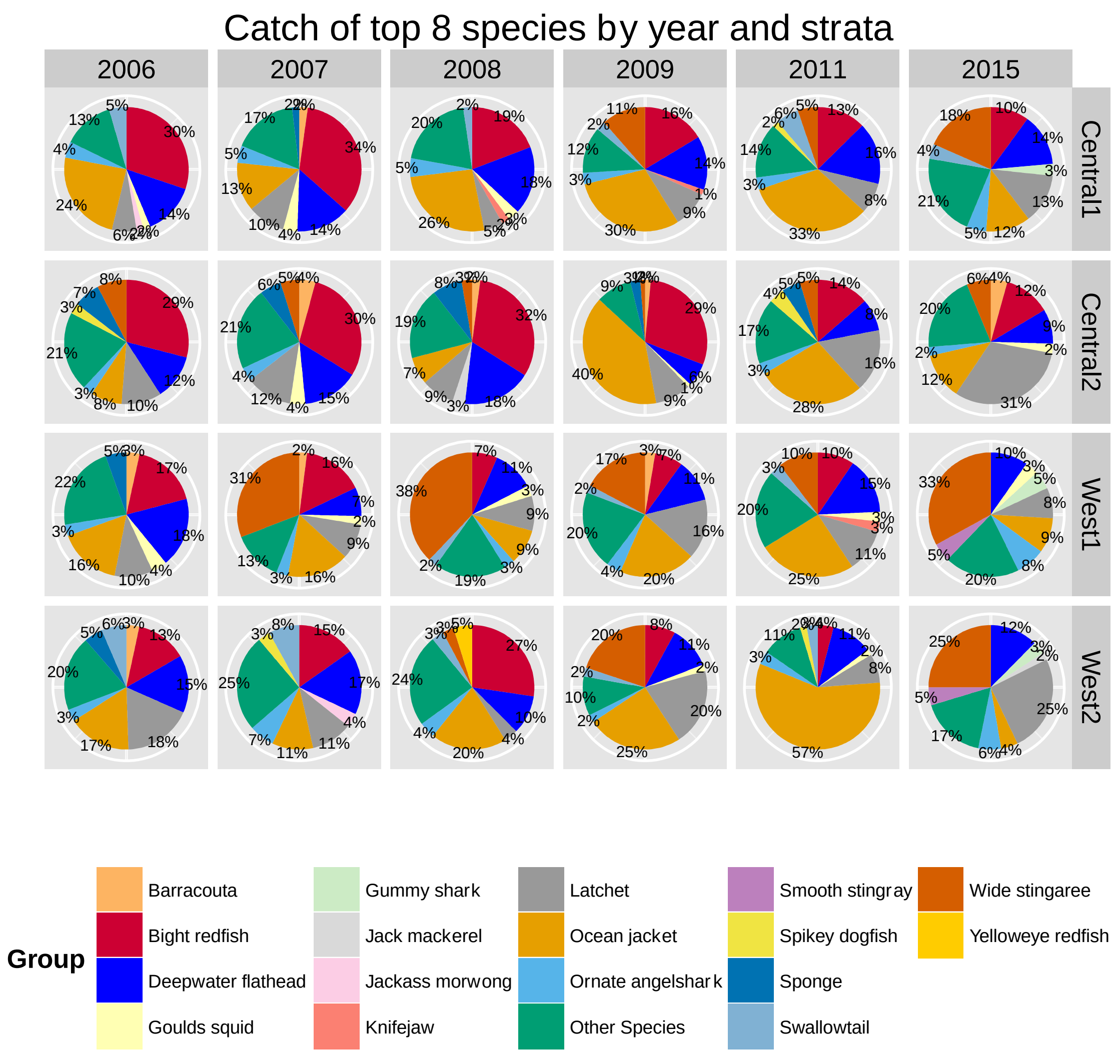


Figure 22. Percent (of weight) of major species captured during each survey by strata.

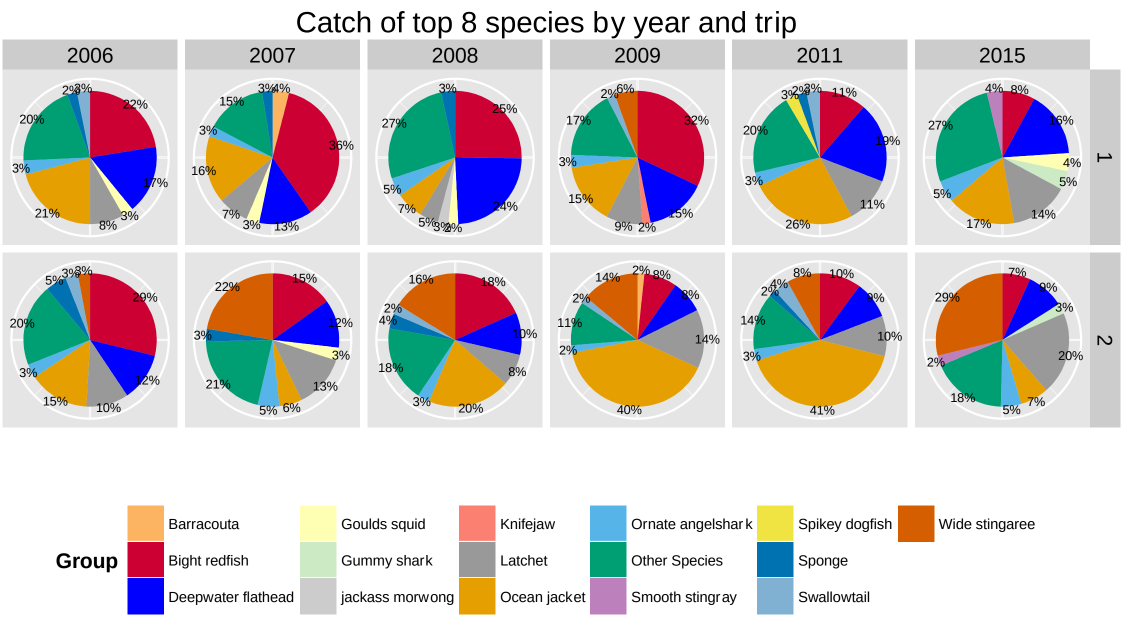
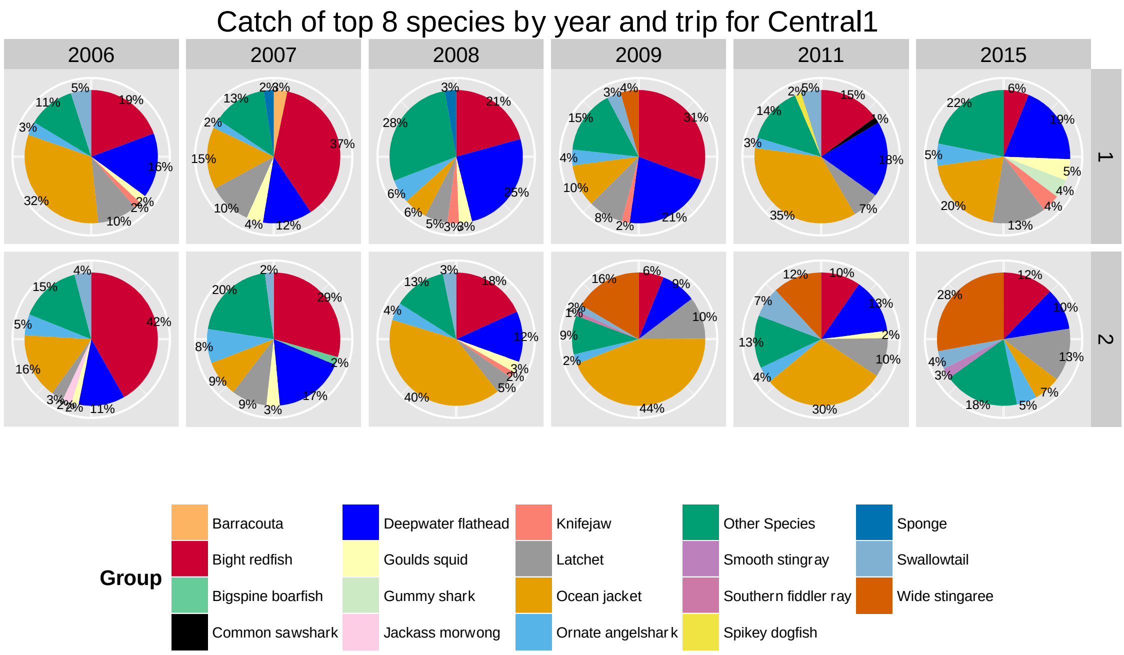


Figure 23. Percent (of weight) of major species captured during each survey by trip (1 and 2).



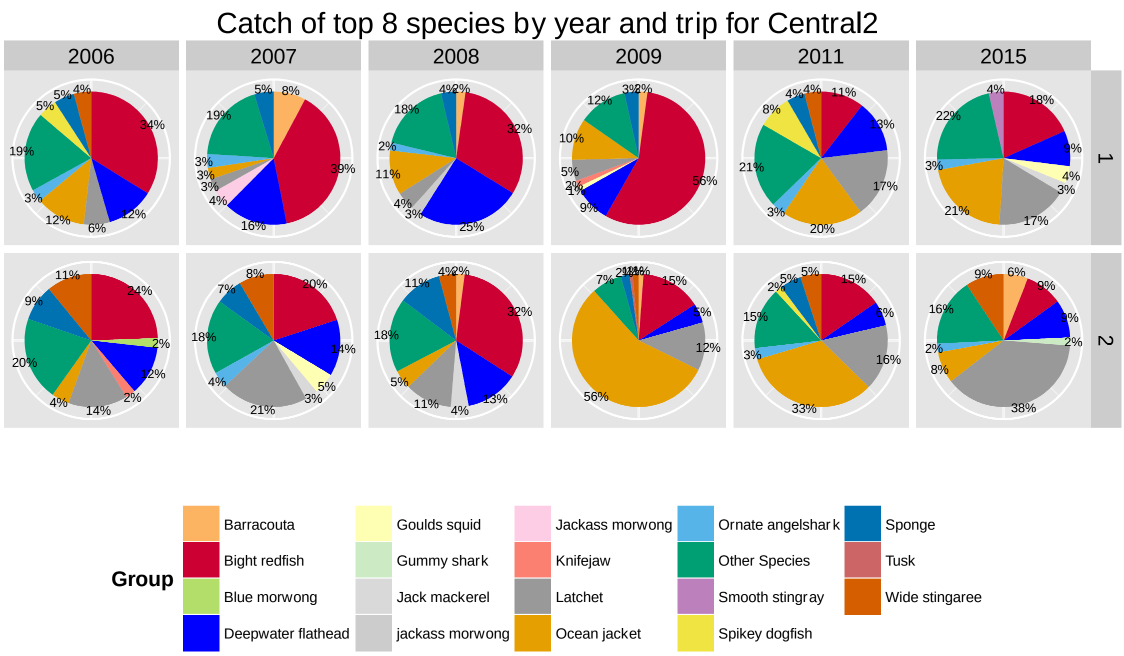
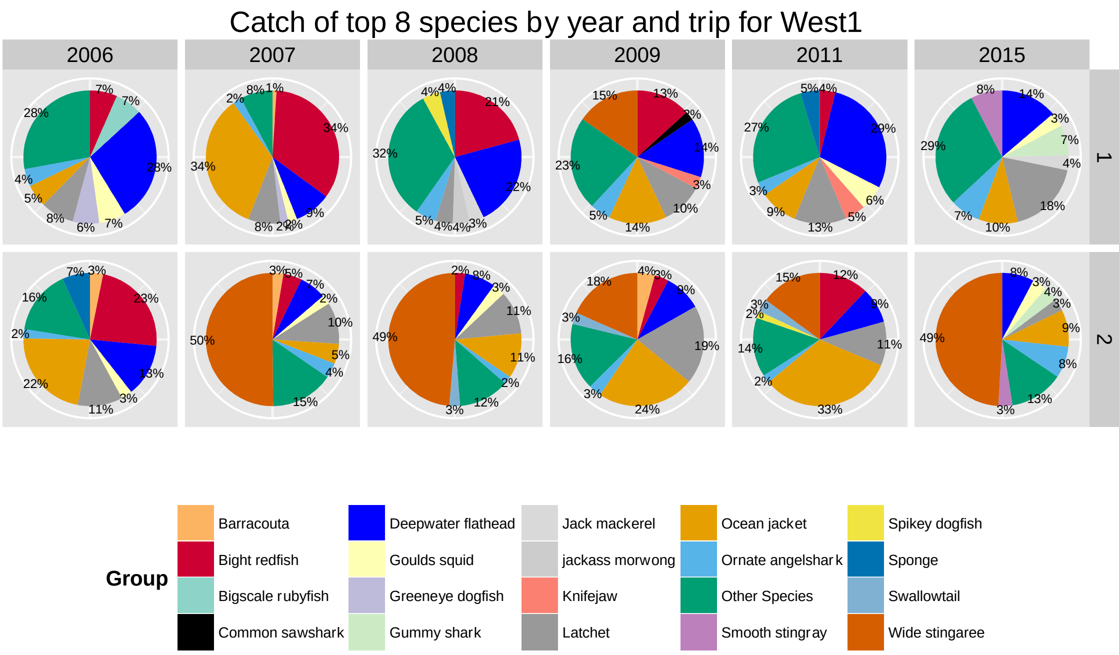


Figure 24. Percent (of weight) of major species captured during each survey by trip (1 and 2) for Central1 and Central2 strata.



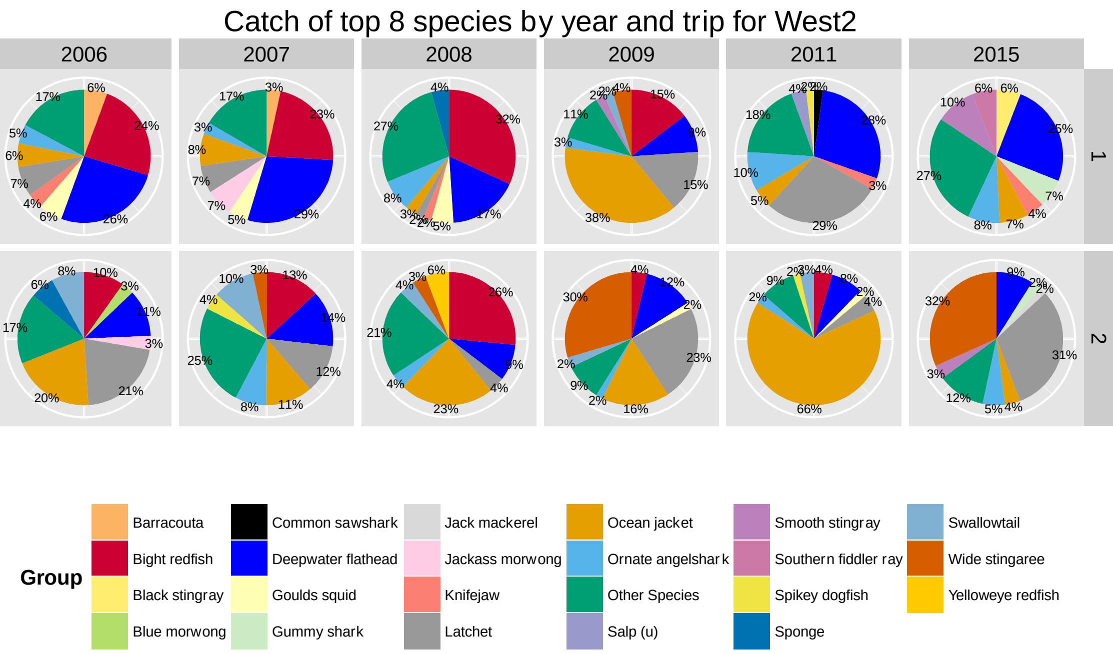


Figure 25. Percent (of weight) of major species captured during each survey by trip (1 and 2) for West1 and West2 strata.