R04/1102 | 03/02/2006

Australian Government
Australian Fisheries Management Authority

Resource Survey of the Great Australian Bight Trawl Fishery 2005

Ian Knuckey, Matt Koopman,
Anne Gason and Russell Hudson

2006

Resource Survey of the Great Australian Bight Trawl Fishery – 2005

Ian Knuckey, Matt Koopman,
Anne Gason and Russell Hudson

AFMA Project R04/1102

2006

Resource Survey of the Great Australian Bight Trawl Fishery – 2005

Ian Knuckey, Matt Koopman, Anne Gason and Russell Hudson

AFMA Project R04/1102

2006

Published: Fishwell Consulting Pty Ltd
22 Bridge St Queenscliff VIC 3225

ISBN: 978-0-9756006-3-4

General disclaimer

Preferred way to cite:

Knuckey, I, Koopman, M., Gason, A. and R. Hudson (2006) Preliminary Resource Survey of the Great Australian Bight Fishery. AFMA Project R04/1102. Fishwell Consulting / Primary Industries Research Victoria, Queenscliff.

Executive Summary

The Great Australian Bight Trawl Fishery (GABTF) targets two main shelf species: deepwater flathead (*Neoplatycephalus conatus*), and Bight redfish (*Centroberyx gerrardi*). The implementation of an industry-based fishery-independent resource survey of the GABTF was supported by the Great Australian Bight Industry Association (GABIA), driven largely by industry's desire for a better understanding of the extent of their main target species and the level of impact that fishing might be having on these resources.

The GABTF is presently managed by input controls limiting the number of operators in the fishery to ten. Logbook data show no overall trend in catch rates for either deepwater flathead or Bight redfish and there is little contrast in these data. Also, time series data on length- and age- frequency do not indicate any significant impact on the resources from fishing. Stock assessment models for Bight redfish and deepwater flathead are advanced, but suffer from the lack of contrast in any of the main fishery indicators. As a result, there is considerable uncertainty surrounding model outputs and estimates of stock biomass.

The primary goal of a resource survey of the Great Australian Bight (GAB) was to improve this uncertainty by obtaining robust annual indices of relative biomass of deepwater flathead and Bight redfish that can be incorporated into formal stock assessments.

The design of the survey was determined over a one-year period with extensive liaison with GABIA operators. A random stratified survey was chosen with particular specifications on depth, longitude, month, trawl duration and how the trawls were to be conducted. The number of shots in the survey was determined through a power analysis to achieve a coefficient of variation for the relative abundance index of < 20%. Shot allocation to each of the strata was proportional to the catch-weighted standard deviation of CPUE.

The surveys were carried out over three separate trips: two during February and March for both species and a December survey was conducted specifically for deepwater flathead. The industry vessel Explorer S and an experience GABTF skipper were used throughout the surveys. Because the surveys were designed to get relative abundance indices of both Bight redfish and deepwater flathead, a good general net design was used. Tows were 2.5 hours in duration at a speed of approximately 3 knots and were completed in a specified order to reduce temporal biases in the data collection. Fish were identified to species where possible, and their total weights estimated. Length frequency measurements and otoliths were taken from important commercial species.

This report details the results of the inaugural 2005 GABTF resource surveys. The surveys were successfully completed well within the timeframe and budget allocated, with 76 sites sampled within the main fishing areas during February and March, and 37 sites sampled during one trip in December.

Deepwater flathead and Bight redfish occurred in 100% and 97% respectively of the seventy-six valid survey tows that were completed during February–March surveys, and in 100% and 82% of the thirty-three valid tows conducted during December.

Estimation of relative biomass was based on the swept area method adopted by Schnute and Haigh (2003), by calculating the mean density from all tows and applying that to stratum area. Relative biomass indices with CVs<0.2 were obtained for deepwater flathead, Bight redfish and a number of other main species within the survey area. The relative biomass estimate of Bight redfish based on February–March tows was 20,887 t (CV = 0.13). The relative biomass estimate of deepwater flathead was 12,152 t (CV = 0.05) during February–March, and 17,024 t (CV = 0.12) during December.

Bight redfish and deepwater flathead comprised the greatest portion of the catch during February–March. Latchet were also common during this period and were the most commonly caught species during December. Ocean jacket, angel shark, sponge and wide stingaree were other commonly caught species.

Modal length of Bight redfish in February–March samples was 35 cm. Modal lengths of deepwater flathead in February–March and December samples were 46 cm and 47 cm respectively. Otolith samples of deepwater flathead and Bight redfish were also collected during the survey.

The inaugural 2005 Great Australian Bight trawl survey achieved all of its objectives. The target CVs for relative biomass estimates were achieved for both Bight redfish and deepwater flathead. In addition, relative biomass estimates of other main species were estimated with low to medium CVs. Length frequency and otolith samples were collected for both target species and major by-product and by-catch species.

The results of this survey provide the starting point of an ongoing fishery-independent index of abundance for both deepwater flathead and Bight redfish.

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 Fishery (GABTF). 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.

The GABTF is presently 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 have been active in the fishery during any one year over the decade to 2002. Catch and effort data from these vessel's logbooks show no overall trend in catch rates for either deepwater flathead or Bight redfish and there is little contrast in these data. Time series data on length- and age-frequency do not indicate any significant impact on the resources from this level of fishing. Stock assessment models for Bight redfish and deepwater flathead are advanced, but suffer from the lack of contrast in any of the main fishery indicators. As a result, there is considerable uncertainty surrounding model outputs and estimates of stock biomass.

There has been increased participation in the fishery and significant increases in fishing effort and fishing efficiency of active vessels during 2003 and 2004. Given the uncertain status of the stocks, concern has been raised about the future sustainability of the shelf resources. Under this scenario, industry has agreed that quota management of the main target species should be introduced. They also agreed on equal allocation of quota between the ten SFR holders.

With the pending introduction of quotas, there is concern that low TACs will 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 are introduced it is believed the use of commercial CPUE data as the main index of abundance in these models will 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). Further, by conducting a random stratified survey, ball-park estimates of absolute abundance of Bight redfish and deepwater flathead would be obtained that can be used as additional information to help support the setting of appropriate TACs for 2006.

Objectives

1. Determine a relative abundance index for Bight redfish and deepwater flathead in the current region of the main GABTF shelf fishery.
2. Collect biological and population data on these species.
3. Determine a relative abundance index of other main species in the current shelf fishery.

Material and Methods

Survey Design

The design of the survey was determined over a one-year period with extensive liaison with GABIA operators. This was achieved through support of the FRDC-funded project 2002/072 “Assessing the feasibility of an industry-based fishery independent survey of the South East Fishery” which had been modified to include the GABTF. An explanation for the survey design is provided below with the final agreed recommendations highlighted.

Stratification

Depth

- Virtually all of the Bight redfish and deepwater flathead catches in the GABTF are taken between 120–200 m (Figure 1).
- There are only minor catches of both species outside this depth range (Graphs do not start at zero due to non-reporting of depth on some catch and effort logbooks).
- There is very low trawling effort in inshore waters (50–120 m) but incidental catches of Bight redfish are taken at these depths.
- There are some high catch rates at depth >200 m but these are derived from a very low percentage of the total catch (Figure 2, Figure 3).

- **Primary survey strata restricted to a depth range of 120 – 200 m.**
- **Option of a secondary inshore stratum from 50 m to 120 m (not used during 2005).**

Longitude

- The majority of the Bight redfish and deepwater flathead catch is taken between longitude 126o00’ and 132o30’ (Figure 4, Figure 5, Figure 6).
- Catch rates are not uniform across longitude for either species.
- Inconsistencies in catch, CPUE and CPUE variation suggest some stratification by longitude is required.

- **Four longitudinal primary strata for the February and March survey design are: 126^{o}00’–127^{o}45’(West2), 127^{o}45’–129^{o}00’ (West1), 129^{o}00’–130^{o}15’ (Central1), 130^{o}45’–132^{o}30’ (Central2)**
- **One additional strata 125^{o}00’–126^{o}00$^{’}$ (West3) and one depth strata (inshore, 100–120 m) are proposed for the December survey, but not the February/March survey.**

Month

- Seasonal catches and catch rates for Bight redfish are far more variable than those for deepwater flathead (Figure 7, Figure 8, Figure 9).
- The limiting factor in the survey design is obtaining precise estimates of catch rates for Bight redfish.

- Catches and catch rates of Bight redfish are highest during the early months of the year (February to April), (Figure 7, Figure 8).
- Bight redfish catch rate variation is also highest during these months but is less in March and April than in February (Figure 9).
- Although catches of Bight redfish during February are greater, there is higher variation in redfish CPUE during this month.
- Catches and catch rates of deepwater flathead are reasonably consistent throughout the year. Highest catch rates are near the end of the year.
- It was initially recommended that the survey be undertaken during the month of March alone, but industry was concerned that this may not allow for the between-year variability in the onset of the main redfish fishing season. Subsequently it was agreed to run the survey over the two months of February and March. Further meetings conducted later in the year decided an additional survey should be conducted during December for deepwater flathead.
- Within February and March it was agreed that the best time for targeting redfish was in the week leading up to the full moon.

> - **The primary survey is to be carried out over two separate trips on the week leading up to the full moon during both February and March for Bight redfish and an additional survey during December for deepwater flathead.**

Day/night

- Diurnal differences in the catch rate, CPUE and variation in CPUE are shown for deepwater flathead and Bight redfish (Figure 10).
- During February–April, catch rates of deepwater flathead are significantly higher during the day than during the night (Figure 11).
- There are no significant differences of catch rates of Bight redfish during the day and night (Figure 11).
- Inclusion of day and night shots in the survey will considerably reduce the amount of sea days required for the survey.

> - **Recommend data from day and night shots be pooled in the survey design.**

Trawl duration

- Most shots for either deepwater flathead or Bight redfish have a trawl duration of greater than four hours (Figure 12, Figure 13).
- Based on logbook data, the variation of catch rates for Bight redfish is much higher for shots <2.5 hours than for shots of longer duration (Figure 13). This trend is similar for deepwater flathead, but to a far lesser extent.
- Logbook data records shot time from net away to net retrieved (not bottom time) and half an hour was allowed for setting and retrieving.

> - **Recommend minimum trawl duration of 2.5 hours bottom time for each shot undertaken for the survey.**

Number of shots

- To determine the number of hauls required in each stratum to achieve a target coefficient of variation (CV) of 20% for Bight redfish and 10% of deepwater flathead, the mean and standard deviation of catch rates (per area swept) for each haul were calculated from logbook data for each species.
- For a given number of shots, the coefficients of variation (CVs) for Bight redfish are much higher than those for deepwater flathead (Figure 14).
- Estimates of a relative abundance index (with a given precision level of 20% CV) for Bight redfish is therefore the critical factor in the survey design.
- March is the optimal month for the survey as it combines high redfish catches and low variations in catch rates and therefore provides the lowest CVs for less number of shots. To allow for potential yearly variations in the onset of good redfish catches the months of February to April also provide relatively low CVs for a low number of shots (Figure 15, Figure 16, Figure 17, Figure 18).
- Abundance indices based on commercial catch rate data (as used in these analyses) may underestimate the variation that will occur in a random survey because fishers are endeavouring to maximise their catch rates.

- **Endeavour to achieve a target CV of 20% for Bight redfish from the random survey.**
- **A target CV of 10% should easily be achieved for deepwater flathead.**
- **Recommend 76 shots as the minimum number of shots required for the survey of the primary strata during February and March; and 35 shots required in December.**
- **Recommend 8 shots as the minimum number of shots required for the optional survey of inshore strata (not based on analysis of CVs).**

Allocation of shots to strata

- Shot allocation to each of the primary strata was proportional to the catch-weighted standard deviation of CPUE.
- Descriptions of the different strata and the number of shots allocated to each stratum are shown in Table 1. Additional strata and number of shots allocated to the December survey are shown in **Error! Reference source not found.**.
- Randomly chosen positions within each stratum are provided in Table 6 (February/March) and Table 6 (December survey) and Table 7 (additional December strata). The recommended position for the random shot is provided in column 1, but four alternate positions are provided for each shot to allow for replacement of a position that may not be able to be fished or that might fall outside the recommended depth range.

Number of sea days

- It will require some time to steam from one random position to the next during the survey.
- Based on a minimum 2.5 hour shot (bottom time), it is likely that only 4 shots may be completed in any one fishing day.

- Based on a minimum of 80 shots required for the main strata, it is likely that at least 20 fishing days will be required for the main strata. This will require two trips with 10 fishing days per trip, while the flathead survey will require slightly less, approximately 8 fishing days per trip.
- Each survey trip is likely to require a minimum of 3 days steaming (out and back inclusive).
- Therefore there will be a total of two 13-day and one 11 day survey trips.
- Fish from the survey will be retained by the vessel to help offset the cost and risk of lost fishing opportunity of being involved in the survey.

Vessel Specifications

GABIA members agreed on the vessel that would undertake the survey based on the vessel characteristics, availability of an experienced skipper and an agreed charter price. The fishing vessel *Explorer S* was used throughout the survey. It had the following specifications: length overall 30 m; beam 9 m; gross tonnage 430 t; power 1140 hp.

Gear Specifications

Because the survey was designed to get relative abundance indices of both Bight redfish and deepwater flathead, a good general net design was used but it was one that would not optimise catches of either flathead or redfish. The design of the net made for the survey is shown in Figure 19. Dimensions of the net are as follows.

Headline: Length = 32.6 m, V = X.45, Middle to last flymesh = 3.05, Centre = 2.24.

Footline: Length = 38.5 m, V = 3.95 m Centre = 2.24.

Codend mesh = 90 mm.

Bridles = 37 m.

Sweeps = 160 m.

A duplicate net was constructed and carried during the survey in case of damage to the main net.

Trawling Procedure

The surveys were carried out over three separate trips during February, March and December 2005. During the February and March surveys, the vessel departed from Port Lincoln and half of the tows were conducted while travelling west from Port Lincoln, the other half completed on the return journey. For the survey in December, the vessel departed from Esperance and completed half the tows while travelling east, the other half on the return to Esperance. The tows were completed in a specified order to reduce temporal biases in the data collection. If the selected random tow was untrawlable, alternative random tow locations were provided. The order of some tows was rearranged for logistical reasons (Figure 20).

Tows were 2.5 hours in duration at a speed of approximately 3 knots. Timing began from when the warps were fully deployed and stopped when gear retrieval began. For a successful tow to be completed, the vessel had to pass within 500 m of the selected position. This was achieved in every case. During each tow, operational and environmental details were noted. Door spread was estimated by measuring the distance between the warps at the block, and again one metre behind the blocks. Door spread was then calculated as follows:

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

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* if the warp length.

Once on board, fish were identified to species were possible, and their total weights estimated. For Bight redfish and deepwater flathead, the total estimated weights were then compared to the weight when the catch was unloaded and adjusted if there was a difference of >10%. Length frequency measurements were taken for important commercial species, and sex was determined for flathead and Bight redfish. Otolith samples were collected from flathead and Bight redfish along with length and sex.

Calculation of Relative Biomass and Coefficient of Variation

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

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

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

$Biomass = density \times area$ (Schnute and Haigh, 2003)

Determining the density

For tows 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

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

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 tows 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:

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

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

Results

Survey Coverage

The surveys were successfully completed well within the time frame and budget allocated. The random stratified survey sampled 76 sites within the main fishing areas during two trips in February and March, and 37 sites during one trip in December 2005.

During February and March all selected sites were surveyed, though alternate sites were required on five occasions because either: ground was untrawlable; location was outside of the depth range; or the location was identical to one from the first survey. The mean tow lengths in the four strata were 14.8 km, 14.6 km, 14.7 km and 14.7 km for the Central 2, Central 1, West 2 and West 1 strata respectively (Table 3, Figure 20).

During December a total of 37 sites were surveyed, though four shots were abandoned when the gear pinned-up. This resulted in one site missed in West2 stratum, and 2 sites missed in the Inshore stratum. On seventeen occasions alternate sites were required. The mean tow lengths for the strata were marginally longer than observed in the February, March surveys, 15.4 km,15.52 km, 14.8 km, 15.5 km, 15.2 km, 15.2 km for the Central 2, Central 1, West 3, West 2 and West 1 strata respectively (Table 3).

Gear Performance

Unfortunately, the net sonde was not functioning correctly during the surveys and actual readings of the net dimensions during tows were obtained. Door spread was estimated on 36 occasions during February and March and on 24 occasions during December. Door spread measurements ranged 84-115 m, during February, March surveys with a mean door spread of

103.4 m and a standard deviation of 7.4 m. During December door spread varied more, ranging 76–131 m with a mean door spread of 92.6 m and a standard deviation of 12.7 m. While no trends were observed between mean door spread and depth during the February and March surveys, a relationship between depth and door was established during the December survey (Door-width=0.62xMean depth + 12.41 (r^2=0.43). For the analysis on the February/March data a mean door spread was used for all swept area calculations. During February/March net opening height was recorded on 3 occasions, giving results of 3.4 m, 3.4 m and 3.8 m; during December net opening height was recorded on 3 occasions, 3.3 m, 3.3 m and 3.4 m.

Catch Composition and Length Frequencies

The total catch during the February/March survey (77.1 t) comprising 93 identified species or species groups (Table 4) was significantly larger than the 52 t comprising 92 species captured during December (Table 5). During February and March, Bight redfish (16.8 t, 22%) and deepwater flathead (15.1 t, 19%) made up the majority of the catch, followed by latchet (11.6 t, 14%), ocean jackets (9.6 t, 12%) and sponge (5.6 t, 7%) (Figure 21). During December the catch composition was very different (Figure 22). Latchets (10.4 t, 20%), sponge (7.6, 15%) and deepwater flathead (7.0 t, 13%) were the most commonly caught species. Over 50% of sponges captured were from the Inshore strata.

Deepwater flathead and Bight redfish occurred in 100% and 97% of tows respectively during February/March, and 100% and 82% respectively of valid tows during December 2005 (Table 6, Table 7).

Catches of Bight redfish during February/March were more positively skewed, than observed in deepwater flathead (Figure 23, Figure 24). Four hauls contained more than 750 kg of Bight redfish during February/March while there were no catches greater than 450 kg of deepwater flathead during that survey. There were only three catches of Bight redfish greater than 150 kg during December, however nearly half of the catches of deepwater flathead were greater than 150 kg during that survey (Figure 25, Figure 26). The largest catch of deepwater flathead during December was730 kg.

Catch of Bight redfish during February/March were three to six times higher at night than during the day (Figure 27). There was no difference between night and day shots in catches of deepwater flathead during February/March (Figure 28).

During the February/March surveys length-frequencies were collected from 1381 Bight redfish and 1122 deepwater flathead (Table 8). During the December survey length-frequencies were collected from 416 Bight redfish and 1231 deepwater flathead. Length-frequencies were also collected for 11 other species. Otoliths were taken from 320 and 150 Bight redfish and from 315 and 340 deepwater flathead during February/March and December surveys respectively (Table 8).

Length-frequencies of Bight redfish caught during February/March ranged from 25–56 cm (Figure 29). Modal length was 35 cm. Deepwater flathead caught during the same survey ranged from 33–75 cm with a modal length of 46 cm (Figure 30).

Length-frequencies of Bight redfish caught during December ranged from 26–47 cm (Figure 31). Modal length was 36 cm. Deepwater flathead caught during the same survey ranged from 17–76 cm with a modal length of 47 cm (Figure 32).

Relative Biomass Estimates

The primary goal of the surveys was to obtain relative biomass estimates for deepwater flathead and Bight redfish. Because the GABTF was moving towards quota management in

2006, there was considerable interest in using the surveys results as absolute biomass estimates for use in stock assessments and calculation of recommended biological catches. For swept area techniques to be used for estimations of absolute biomass, a number of factors need to be taken into account such as herding effects which influence the actual swept area of the trawl and escapement. Catchability can also vary depending on the species and the external environment during the shot. At the simplest level, it is unclear whether all, or just some, of the fish in the path of the trawl doors are herded into the net and captured. Two biomass estimates were made based two assumptions: that 100% of fish between the trawl doors were herded in and captured in the net without escapement (door-width biomass estimate), or only those fish in the direct path of the net were captured in the net with no escapement (net-width biomass estimate). It is unlikely that either of these assumptions is correct and a more likely scenario probably lies somewhere in between with some escapement. Further research needs to be undertaken to determine which measure is more appropriate for each species.

February and March Surveys

Survey results revealed there was a large and significant diurnal difference between the catch rates of Bight redfish (Figure 27). Interestingly, this difference was not apparent in the analysis of logbook data carried out prior to the survey (Figure 11) even though it was recognised by the fishers. Because of the difference noted in the survey results, biomass estimates were made using day time shots only, night time shots only and all shots combined.

The door-width estimates and net-width estimates of Bight redfish relative biomass within the survey area were 2,128 t and 13,498 t respectively, with a CV of 0.14 when both day time and night time shots were used (Table 9). Using only night time shots, door-width and net-width relative biomass estimates were 3,293 t and 20,887 t respectively with a CV of 0.13. Biomass estimates were much lower, and CVs considerably higher when only day time shots were used in the estimates. For this reason, the night time shots were considered to provide the better relative biomass estimates for Bight redfish.

The door-width and net-width estimates of deepwater flathead relative biomass within the survey area were 1,916 t and 12,152 t respectively, with a CV of 0.05 when both day time and night time shots were used.

Relative biomass estimates for a number of other important GABTF species were also calculated. CVs of other main species were generally below 0.2. Ornate angel sharks had the lowest CV of 0.09, while that of jackass morwong was highest at 0.34. Species with the greatest relative biomasses estimates apart from deepwater flathead and Bight redfish were latchet (1,482 t door-width and 9,401 t net-width) and ocean jackets (1,129 t and 7,163 t).

December surveys

The December survey was undertaken with a focus on obtaining a relative biomass estimate for deepwater flathead only. The relative biomass estimates and CV for deepwater flathead during December were slightly higher than those from February/March, with the door-width estimates and net-width estimates of 2,684 t and 17,024 t respectively (CV = 0.12, Table 10).

While catches were similar in the West1, West 2, Central1, Central2 and Inshore strata, catches in West3 were considerably higher (Table 5). West3 contributed about 13% towards the total deepwater flathead relative biomass estimate despite comprising only 4% of the total area. Nearly 40% of the relative biomass estimates came from the West3 and Inshore strata.

CVs of other main species varied, with common sawshark, giant boarfish, gummy shark knifejaw and latchet having CVs below 0.2. Biomass estimates for ‘other species’ was relatively high because it included sponge which was mostly captured in the inshore stratum.

Discussion

Survey Coverage

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 GABTF shelf fishery. The survey was also designed to collect biological and population data on these species, and to determine a relative abundance index of other main species in the current shelf fishery. All of these objectives were met, with 76 sites within the survey area successfully surveyed during two trips in February and March 2005 and 33 sites surveyed during December 2005.

The value of the results of the survey as a relative abundance measure increases as a time-series of surveys are conducted. Therefore, as the first in a time-series of such surveys, this individual survey has limited value in this respect. It was nevertheless, very useful as a preliminary survey in working through the design and implementation and reviewing the results as a basis for ongoing surveys.

Gear Performance

As stated previously, much of the impetus for conducting the survey during 2005 was that quotas were being introduced for deepwater flathead and Bight redfish in January 2006. Industry was concerned that the lack of contrast in logbook and biological data being input into the stock assessment model was resulting in high uncertainties in model estimates of biomass. It was considered that this uncertainty when combined with a precautionary management approach would result in inappropriately low Total Allowable Catches (TACs) being set, which may inhibit the sustainable development of the fishery. For this reason, there was an interest in the use of the survey results to provide an absolute abundance index for deepwater flathead and Bight redfish.

There are many uncertainties and subsequent assumptions that must be made to use the survey results as an absolute abundance index. The most problematic of these uncertainties is the determination of the proportion of fish that are available to capture and of those fish the proportion available to capture, what proportion escape the gear. An understanding of the species-specific herding behaviour of fish that are encountered by the trawl gear is important. If the fish are not herded at all by the boards and sweeps, it is not unreasonable to assume that the swept area is only equivalent to the opening (width) of the net. In contrast, some fish may be herded into the path of the net by the noise/plumes/vibrations of the trawl doors and sweeps (Main and Sangster 1981a), while a proportion might escape the gear (Main and Sangster 1981b). A review of fish herding models provided little information on the herding behaviour of deepwater flathead or Bight redfish (Hudson and Knuckey, 2005). Most research has been conducted on fish species in the northern hemisphere; in one study the proportion of the catch attributed to herding ranged 15% (no significant herding) to 49% (significant herding) (Somerton and Munro, 2001). The only research conducted in southern waters was based on a trawl fishery in northern Australia. Of the 22 species captured only on 5 could the proportion of catch attributed to herding be calculated.

At the simplest level for the current surveys, it is unclear whether all, or only a portion, of the fish between the trawl doors are herded into the net and captured or whether only the fish in the nets path are captured. Two biomass estimates were made based two assumptions: that 100% of fish between the trawl doors were herded in and captured in the net without escapement (door-width biomass estimate), or only those fish in the direct path of the net were captured in the net with no escapement (net-width biomass estimate). This resulted in six-fold difference between the door-width biomass estimates and the net-width biomass estimates, based on a door spread of 103.4 m or 93 m and a net spread of 16.3m. It is unlikely that either of these assumptions is correct and a more likely scenario probably lies somewhere in between with some escapement. Further research needs to be undertaken to determine which measure is more appropriate for each species.

It is highly unlikely that all Bight redfish and deepwater flathead encountered in the path of the net are captured. Observations of a similar species to deepwater flathead, tiger flathead were observed by remote camera escaping the trawl gear by passing underneath the trawl net (Piasente *et al*. 2004). Demersal trawl gear is designed to herd fish laterally into the nets by means of the doors and sweeps, but they have little ability to herd fish vertically down into the net, unless as a result of a response behaviour of the fish. So, in a demersal trawl with a headline height of about 3.6 m as used in the current survey, the issue of fish being above the swept area of the net warrants further consideration in regard to swept-area biomass estimation. Some fish species remain very close to the seabed and are unlikely to swim above the net, whereas other species may swim well off the seabed and will therefore not be caught in a demersal trawl net. Again, this behaviour is likely to be species dependent and may be influenced by a number of factors (migration, feeding spawning, oceanography). The diurnal migration of species into different water depths has been well known by fishers, but its effects on catch composition, and the variability between species is of a complex nature, depending on factors such as availability of prey or resting state (Helfman, 1993). Based on observations, flathead are considered to have similar characteristics to what are termed 'flatfish' being in constant touch, or settling on the sea-bottom while Bight redfish would be considered a 'groundfish', swimming near the sea-bottom. In the initial design of the survey, industry commented on the greater availability of redfish to trawling at night time. At the time, however, this was not supported in the data analyses that were conducted, but it has since been supported by the survey results which showed redfish catch rates approximately 50% greater during the night. One hypothesis for this difference confirms industry statements that redfish move down in the water column at night thus making them more available to capture by a demersal trawl net than during the day. For this reason, swept area biomass estimates for Bight redfish calculated from night shots would be more applicable than day shot estimates and day and night shots combined estimates.

It is unclear exactly why the preliminary analyses during the survey design did not pick up the diurnal difference in the logbook catch rates. One possibility is that the longer trawl duration during commercial tows (4-8 hours) masked the day/night differences. It is also possible that the temporal scale of the preliminary analyses was not fine-scale enough to detect the difference. Regardless of the reason, the survey results left no doubt that diurnal structuring of shots needs to be included in the ongoing survey design for Bight redfish. It was also an important factor for several other main species. There was no significant diurnal difference for deepwater flathead.

Catch Composition and Length Frequencies

Catch compositions varied markedly between February/March and December surveys. Bight redfish, deepwater flathead and latchet were the three most commonly caught species early in the year, while latchet, sponge and deepwater flathead were the three most commonly caught species during December. While it is clear that seasonality cause some of the difference (particularly of Bight redfish), the addition of two extra strata during the December survey resulted in very high catches of sponge.

There was also a large difference in length-frequency of deepwater flathead between February/March and December samples. There were very few fish smaller than 40 cm measured from February/March samples compared to December samples.

Relative Biomass Estimates

It was recognised that the timing of the original survey in February/March was optimal for Bight redfish in terms of catch rate and CVs. For deepwater flathead, however, this time was sub-optimal, with highest catch rates occurring during November – December. Although this does not matter if the results are to be used as a relative index of abundance, it is important for their use as an absolute index. Because the survey results were going to be used to some extent as an index of absolute abundance (albeit a very uncertain one with many assumptions) industry considered whether a supplementary survey targeted solely at flathead during November – December was desirable. Ultimately, the decision was made to carry out a flathead survey in December with the understanding that such a survey would not necessary have to be part of the ongoing relative abundance time series.

Bight redfish
Door and net relative biomass estimates for Bight redfish when only night time shots were used were 3,293 t and 20,887 t (CV = 0.13) respectively. For both species, the door-width relative biomass estimates appear too low as recent annual catches of Bight redfish and deepwater flathead have been 950t and 2000t respectively with apparently little impact on the size or age structure of the populations.

Deepwater flathead
Door-width and net-width relative biomass estimates for deepwater flathead when both day and night time shots were used were 1,916 t and 12,152 t (CV = 0.05) during February/March and 2,684 t and 17,024 t during December 2005. During the December survey, however, the contribution of the additional strata, inshore and west3, was 6,000–7,000 t on the net relative biomass estimates, putting the February/March survey estimates for the original strata similar to the December survey.

Conclusions

The 2005 Great Australian Bight trawl surveys achieved all objectives. The target CVs for relative biomass estimates were achieved for both Bight redfish and deepwater flathead. In addition, relative biomass estimates of other main species were estimated with low to medium CVs. Length frequency and otolith samples were collected for both target species and major by-product and by-catch species.

There are a lot of uncertainties in the use of the survey data as an absolute index of abundance. Some uncertainties are related to strata definition and species' population dynamics and are probably very difficult to refine. Many of the uncertainties, such as those mentioned above, can be reduced through targeted research programs that while technically challenging and probably quite expensive are nevertheless feasible. One must weigh up the value of such additional targeted research to gain improved absolute abundance estimates against the value of continuing the time-series of surveys as a relative index of abundance of which we now have the first point.

As a preliminary survey, the 2005 surveys were also useful in refining how future surveys could be conducted and identifying research opportunities that would assist to improve survey results. The survey also demonstrated that a scientifically rigorous fishery-independent survey could be conducted by the fishing industry.

Acknowledgments

We wish to thank the owner, Mr Semi Skoljarev, and the skipper and the crew of the Explorer S for their professional approach to conducting the 2005 survey, and Dr Mike Burge and Dr Paul Starr for assistance with the design of the survey. From the Department of Primary Industries Victoria, we wish to thank Mr Tony Dugdale who assisted with on-board sampling during the survey.

References

Helfman, G.S. (1993). Fish behaviour by day, night and twilight. *In* TJ Pitcher editor. Behaviour of teleost fishes, 2nd edition pp366–387. Chapman and Hall, London.

Hudson, R.J. and Knuckey, I. A. (2005). Herding models and their application to Bight redfish and deepwater flathead. GABRAG paper September 2005, 17 p.

Main, J., and Sangster, G.I. (1981a). A Study of the sand clouds produced by trawl boards and their possible effect on fish capture. Scott. Fish. Res. Rep. **20**:1:1–20

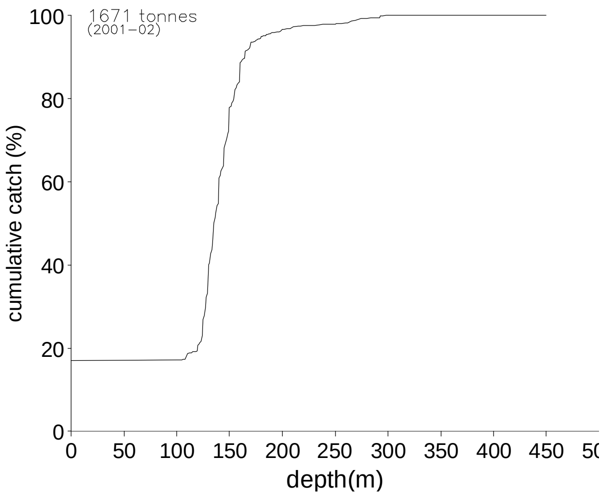
Main, J., and Sangster, G.I. (1981b). A study of the fish capture process in a bottom trawl by direct observations from a towed underwater vehicle. Scott. Fish. Res. Rep. **23**:1:1–23

Piasente, M. Knuckey, I. A. Eayrs S. McShane, P.E. (2004). In situ examination of the behaviour of fish in response to demersal trawl nets in an Australian trawl fishery. Mar. Freshwater Res. **55:**825–835.

Schnute, J.T. and Haigh, R. (2003). A simulation model for designing groundfish trawl surveys. Can. J. Fish. Aquat. Sci. **60**:640-656.

Somerton, D.A. and Munro, P. (2001). Bridle efficiency of a survey trawl for flatfish. Fish. Bull. **99**:641–652.

a



b

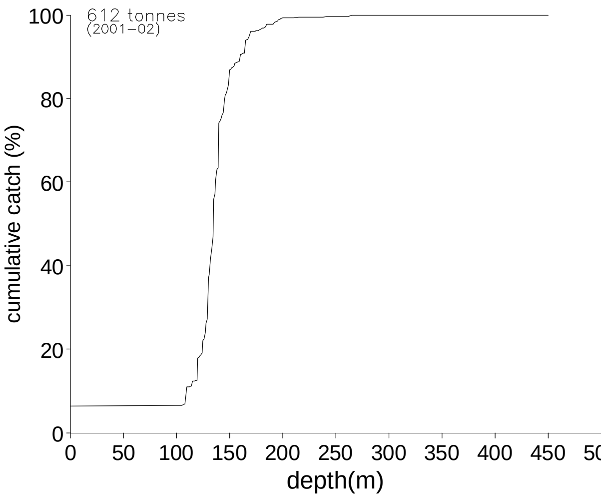
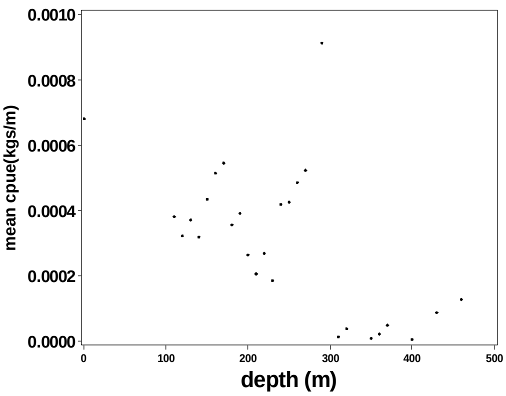


Figure 1. Cumulative percentage of 2001-2002 commercial catch by depth of: a) deepwater flathead and b) Bight redfish.

a



b

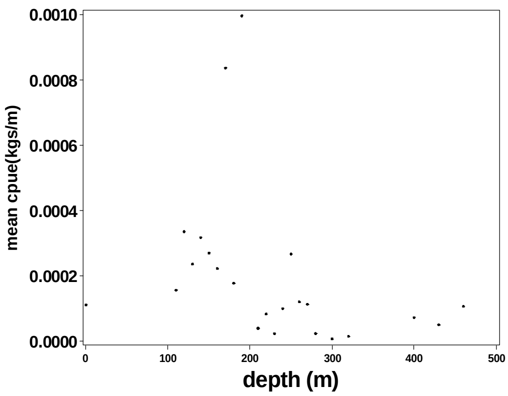


Figure 2. Mean 2001-2002 commercial catch per unit effort (kg/m^2) by depth of: a) deepwater flathead and b) Bight redfish.

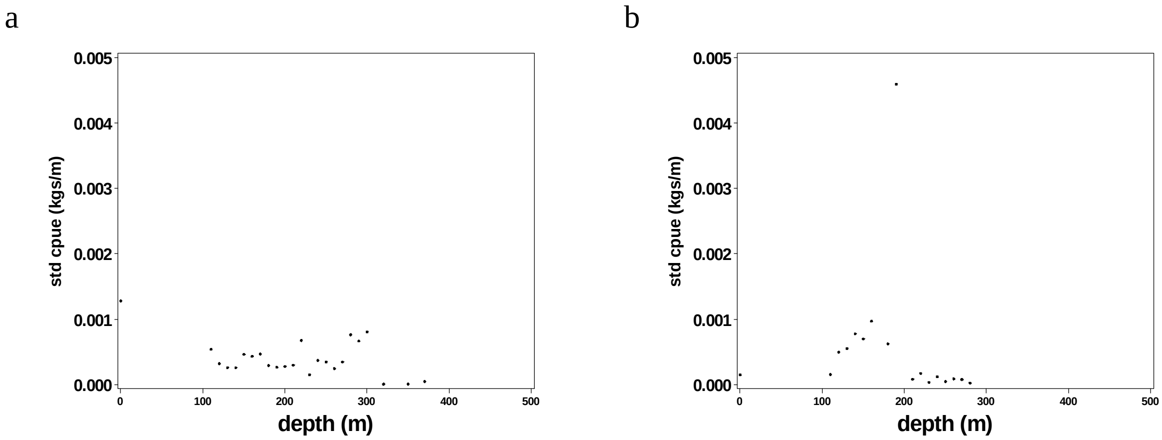


Figure 3. Standard deviation of 2001-2002 commercial catch per unit effort (kg/m^2) by depth of: a) deepwater flathead and b) Bight redfish.

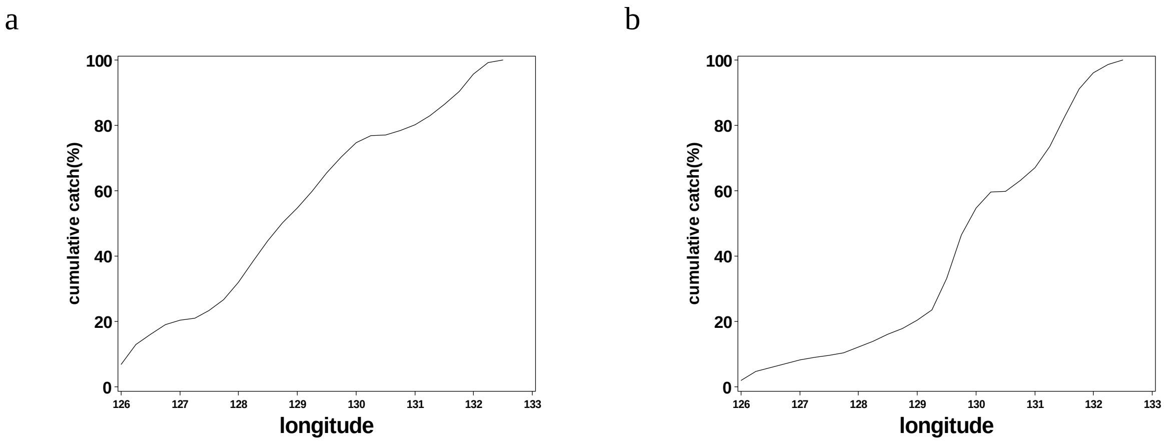


Figure 4. Cumulative percentage of 2001-2002 commercial catch by longitude of: a) deepwater flathead and b) Bight redfish.

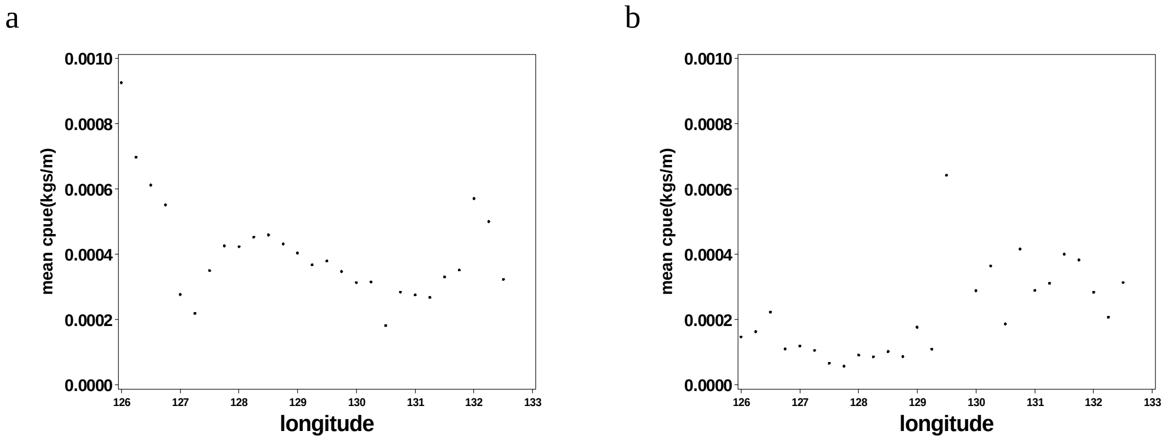


Figure 5. Mean 2001-2002 commercial catch per unit effort (kg/m^2) by longitude of: a) deepwater flathead and b) Bight redfish.

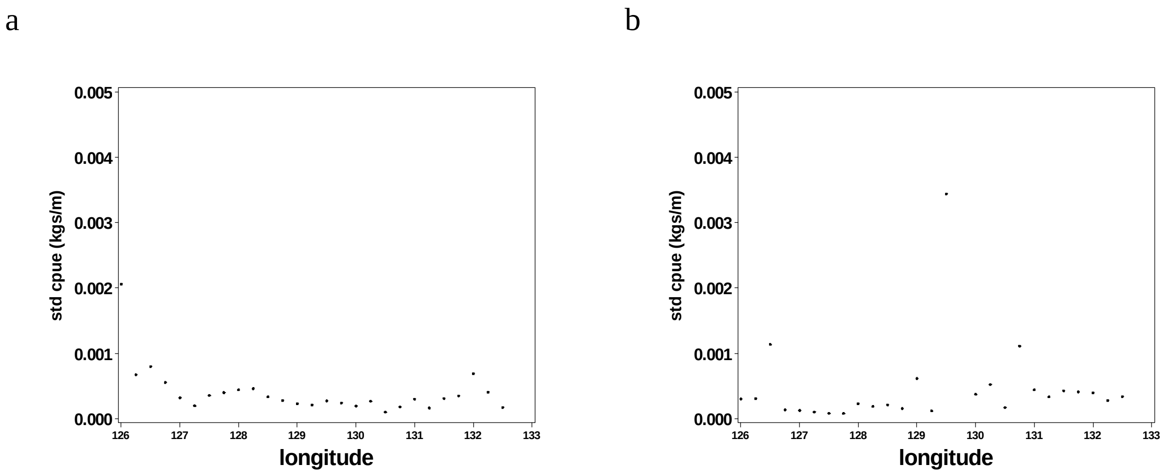


Figure 6. Standard deviation of 2001-2002 commercial catch per unit effort (kg/m^2) by longitude of: a) deepwater flathead and b) Bight redfish.

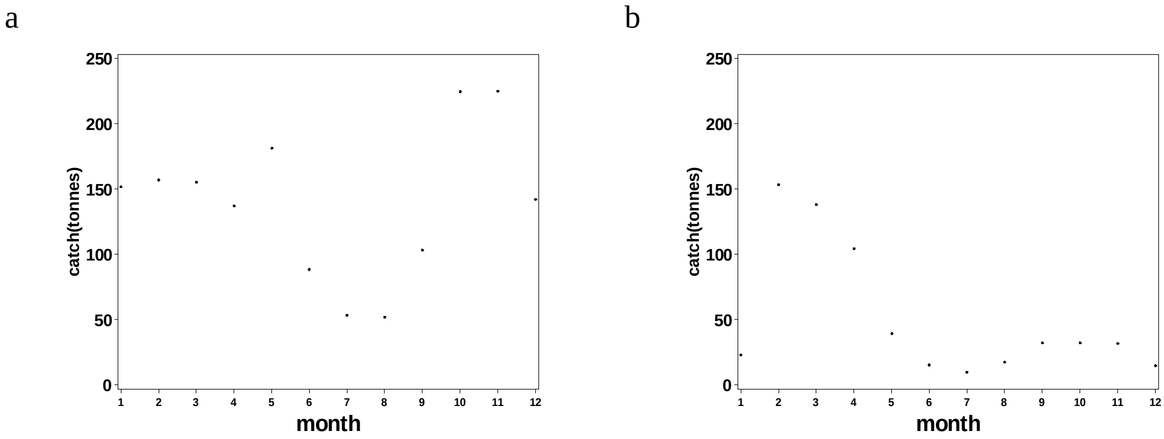


Figure 7. 2001-2002 commercial catch by month of: a) deepwater flathead and b) Bight redfish.

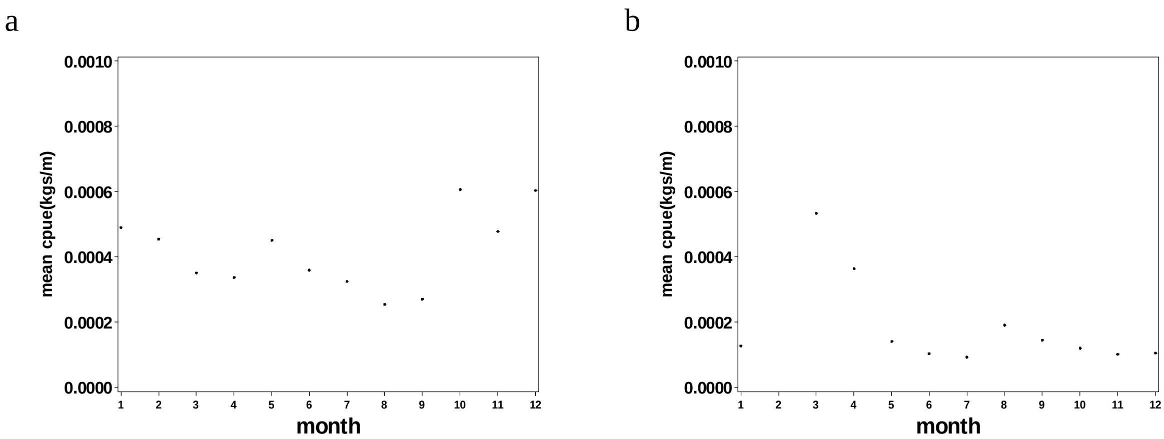


Figure 8. Mean 2001-2002 commercial catch per unit effort (kg/m^2) by month of: a) deepwater flathead and b) Bight redfish.

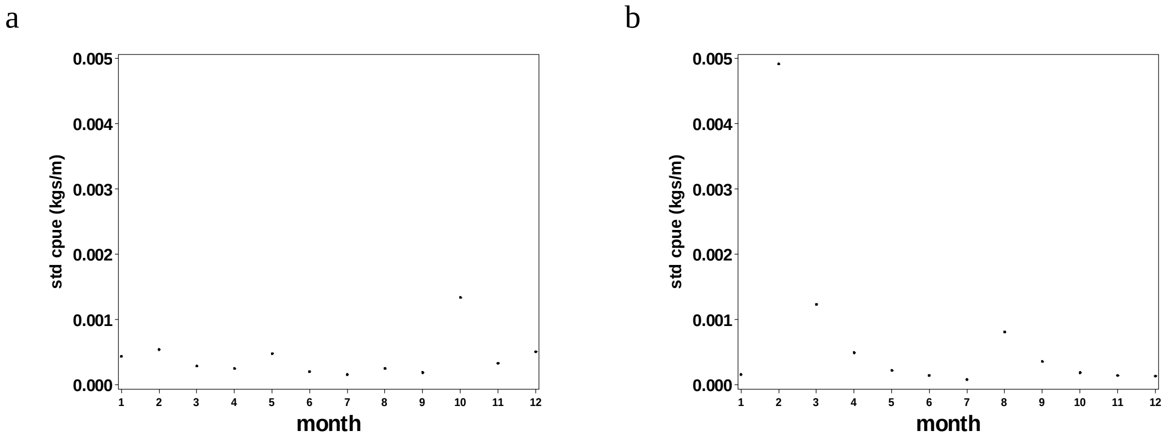


Figure 9. Standard deviation of 2001-2002 commercial catch per unit effort (kg/m^2) by month of: a) deepwater flathead and b) Bight redfish.

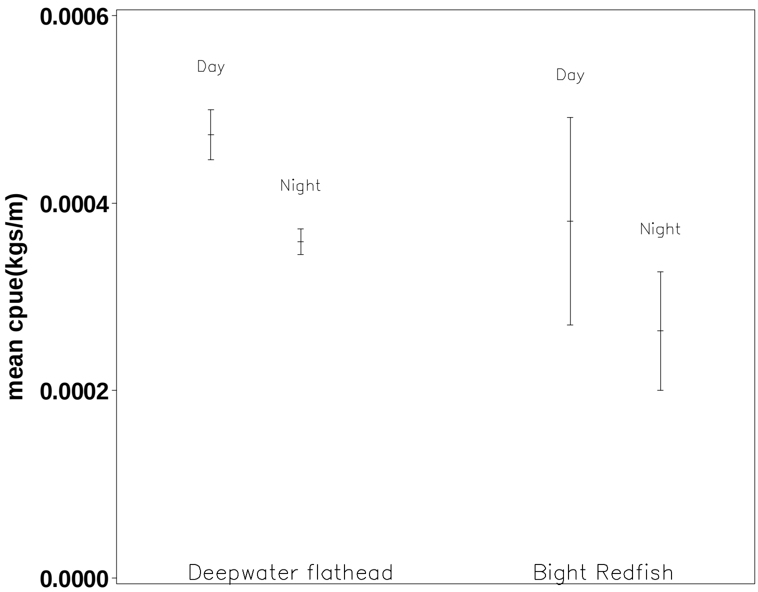


Figure 10. Mean catch per unit effort (kg/m^2 +/- 2 SD) of 2001-2002 commercial catches of deepwater flathead and Bight redfish caught during the day (0401–2000hrs) and night (2001–0400 hrs).

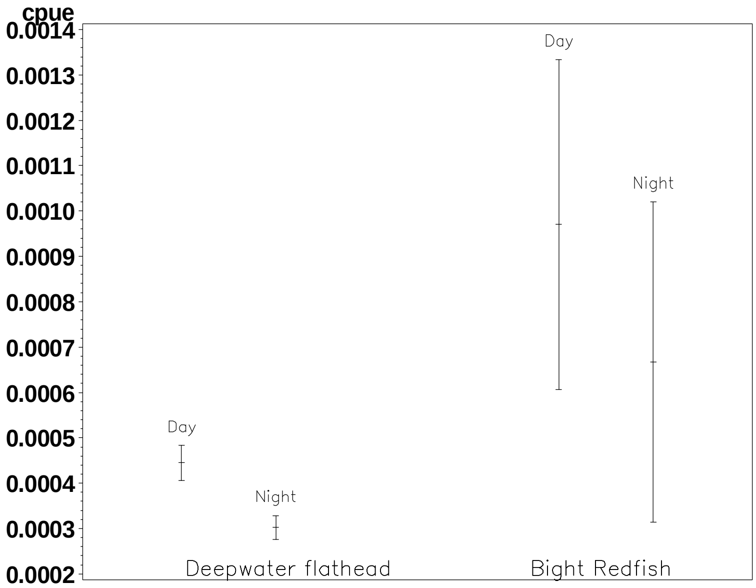
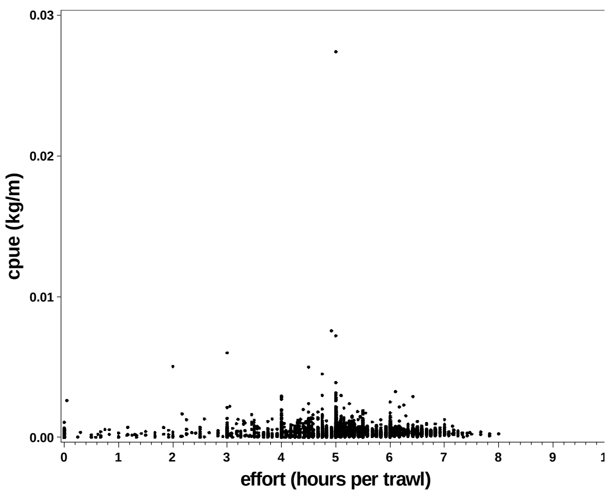


Figure 11. Mean catch per unit effort (kg/m^2 $\pm$2 SD) of 2001-2002 commercial catches of deepwater flathead and Bight redfish caught during the day (0401–2000hrs) and night (2001–0400 hrs) for the months of February and April only.

a



b

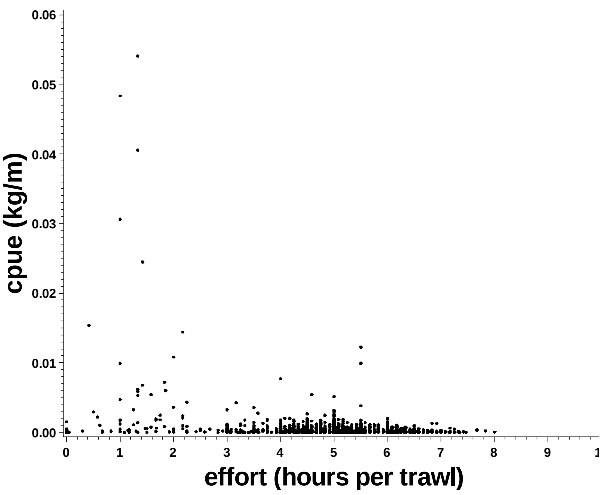


Figure 12. Catch per unit effort (kg/m^2) of 2001-2002 commercial shots plotted against trawl duration for: a) deepwater flathead; and b) Bight redfish.

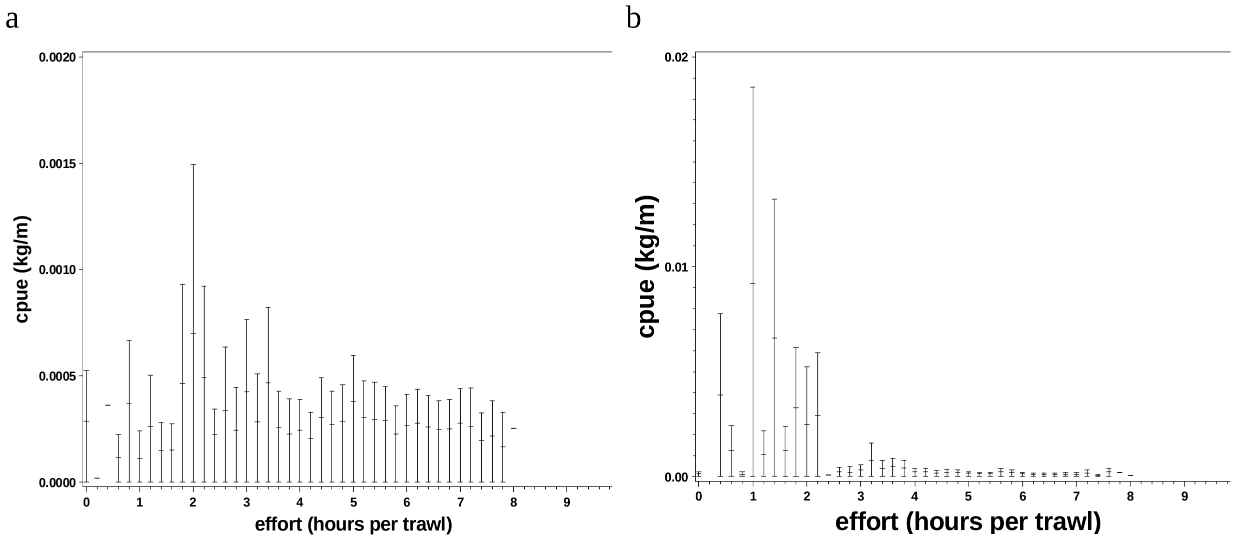


Figure 13. Mean catch per unit effort (kg/m^2 $\underline{+}$std) of 2001-2002 commercial shots plotted against trawl duration for: a) deepwater flathead; and b) Bight redfish.

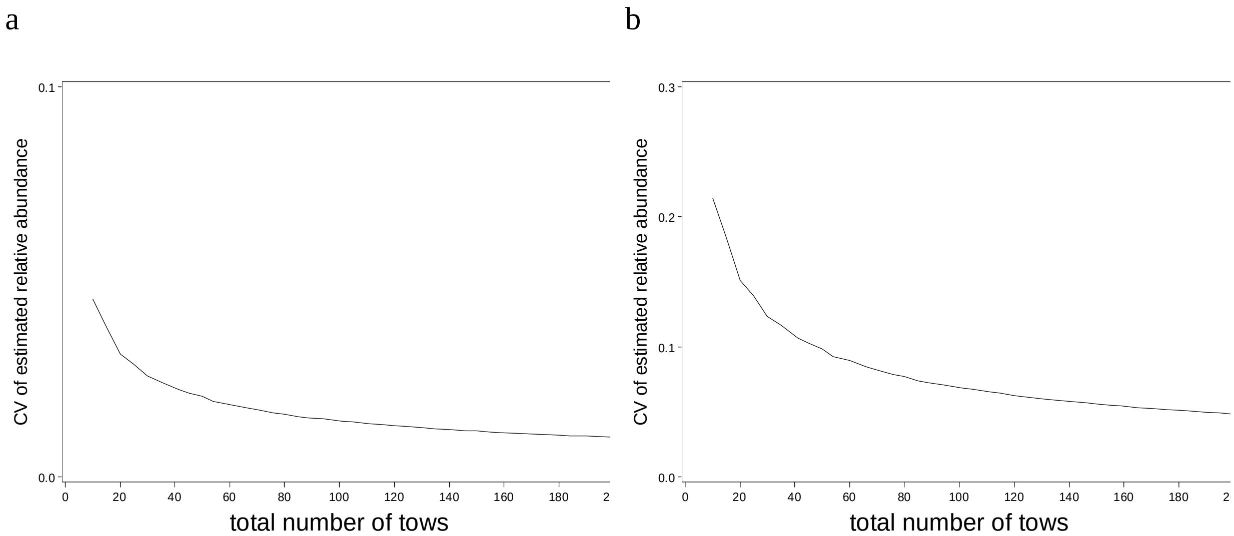


Figure 14. Coefficient of variation of estimated relative abundance index plotted against number of shots (February – April combined) for: a) deepwater flathead; and b) Bight redfish.

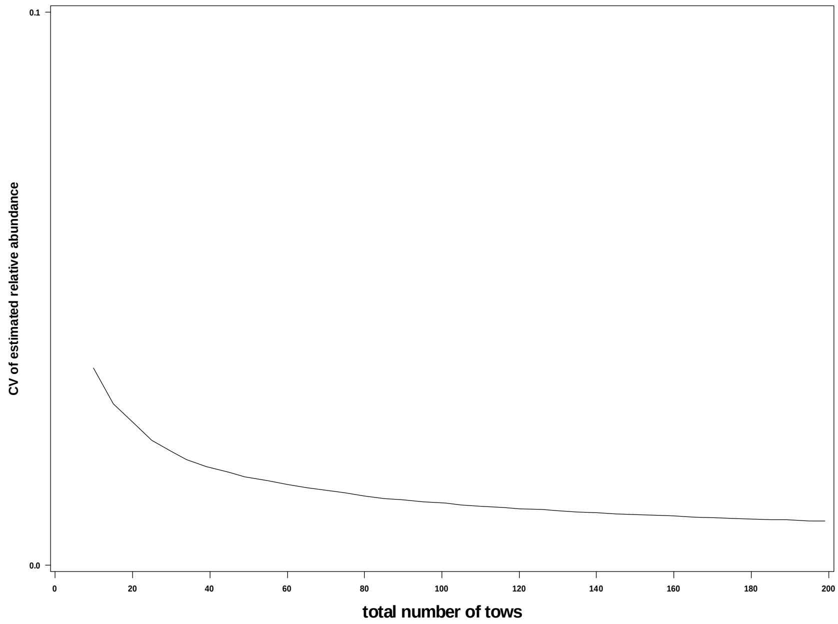


Figure 15. Coefficient of variation of estimated relative abundance index for deepwater flathead plotted against number of shots (March only).

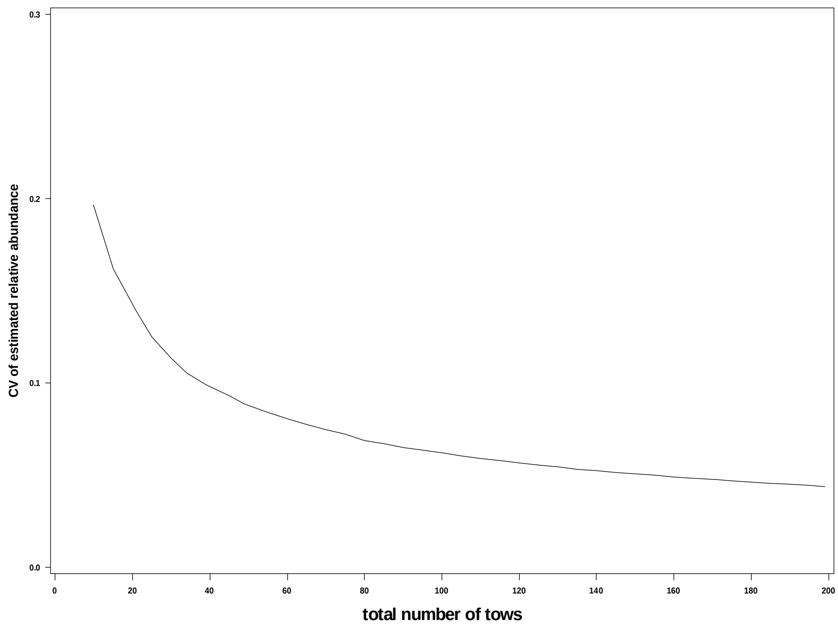


Figure 16. Coefficient of variation of estimated relative abundance index for Bight redfish plotted against number of shots (March only).

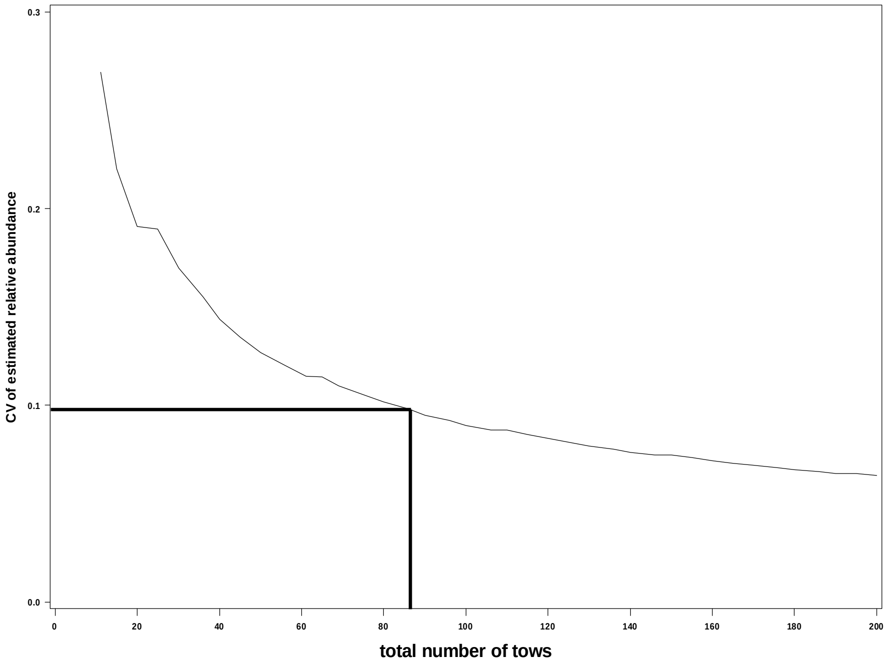


Figure 17. Coefficient of variation of estimated relative abundance index for Bight redfish plotted against number of shots for February.

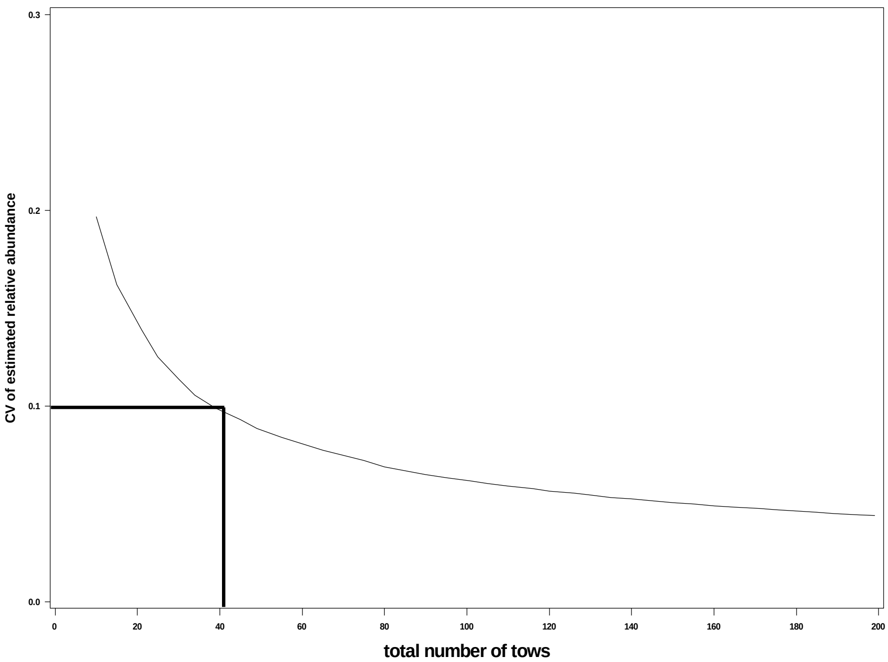


Figure 18. Coefficient of variation of estimated relative abundance index for Bight redfish plotted against number of shots for March.

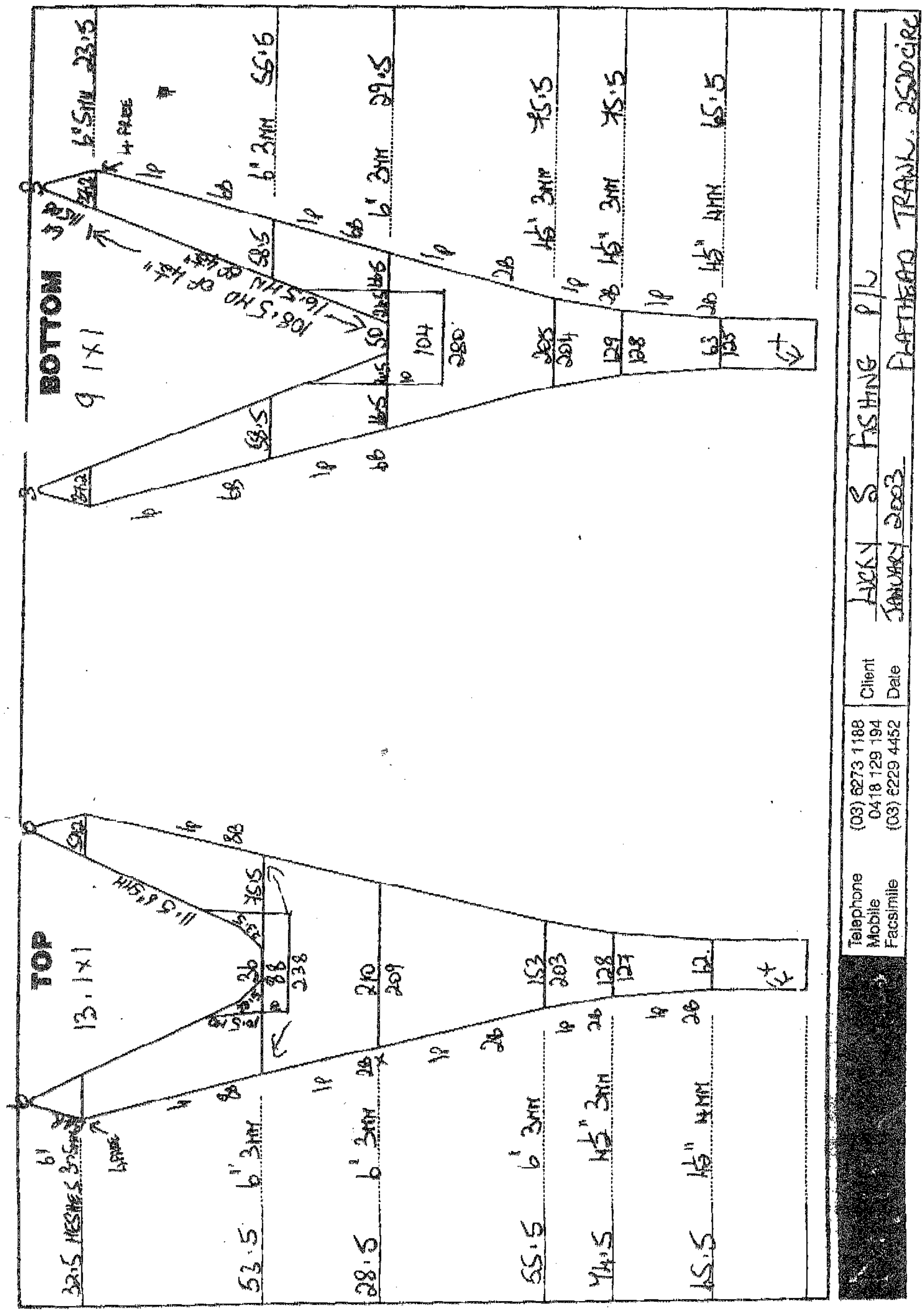


Figure 19. Design of net used during trawl survey.

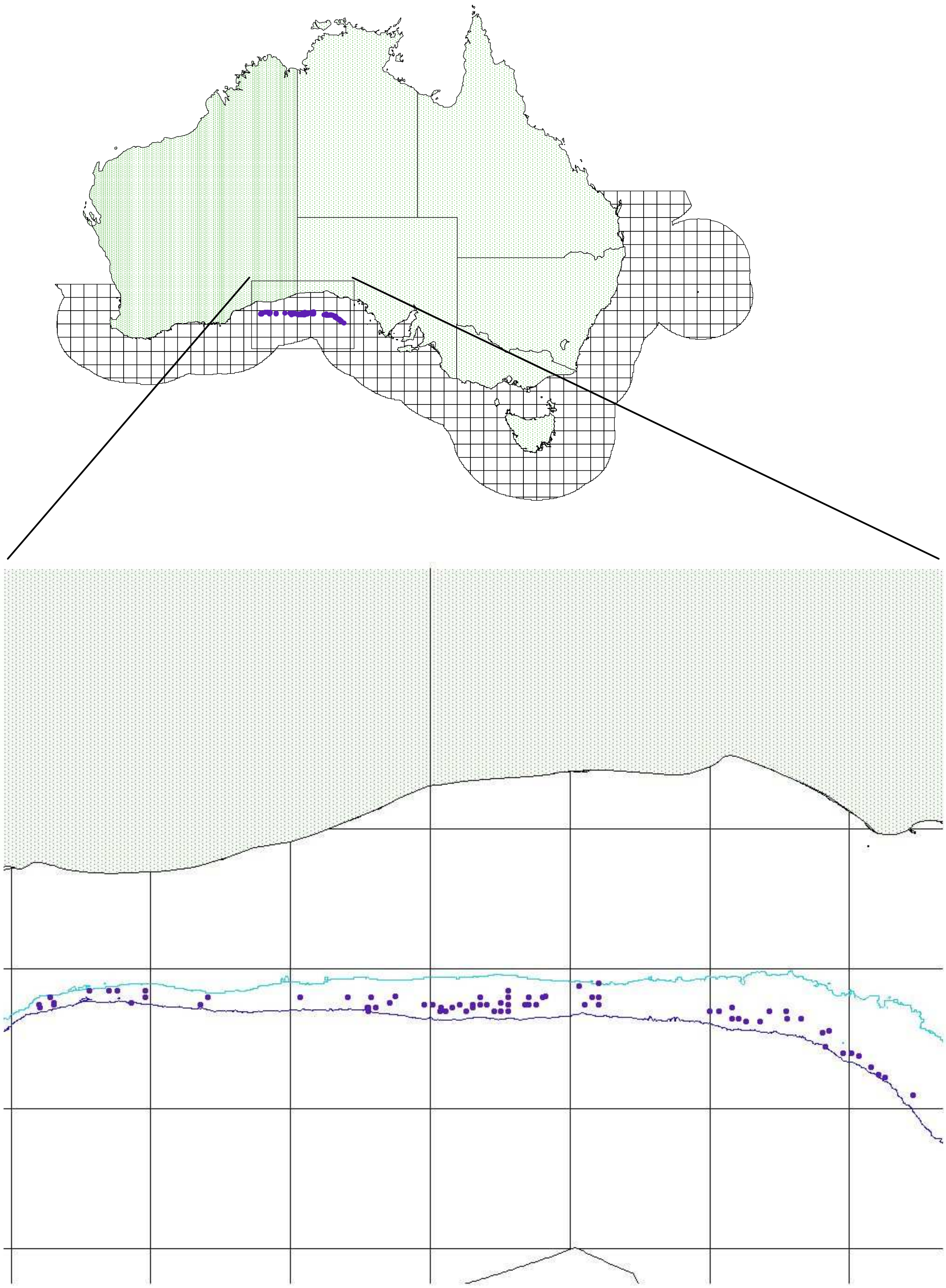


Figure 20. Shot locations of trawl survey.

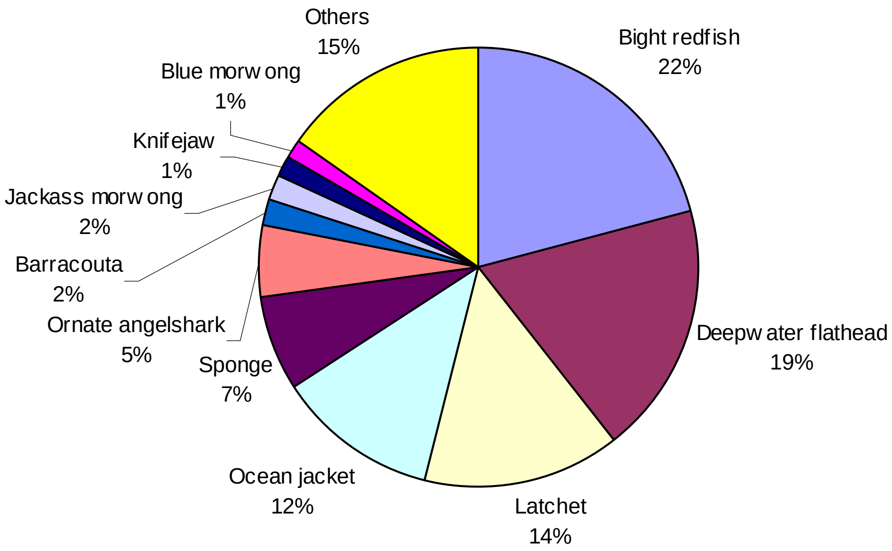


Figure 21. Proportion (of weight) of major species captured during the February/March 2005 survey.

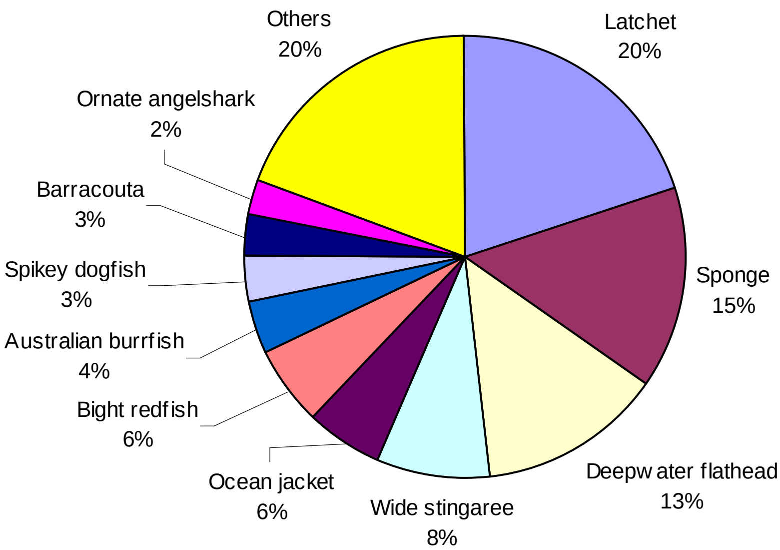


Figure 22. Proportion (of weight) of major species captured during the December 2005 survey.

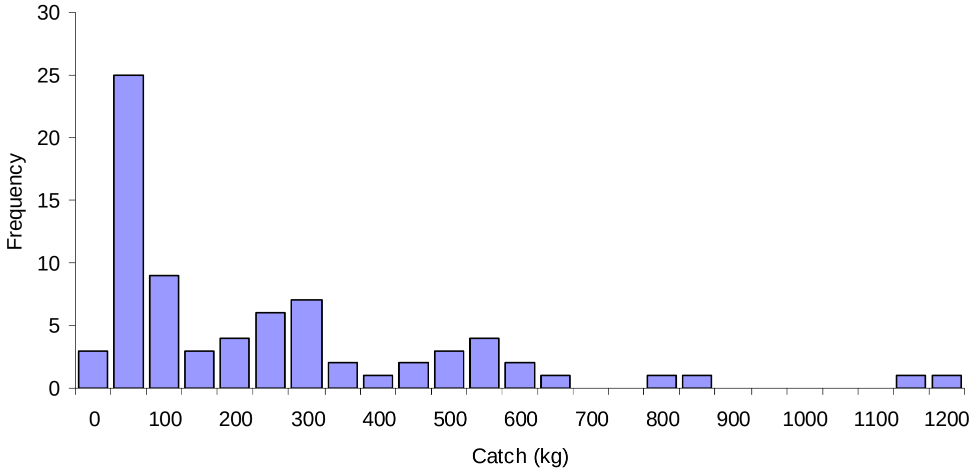


Figure 23. Frequency of catches (kg) of Bight redfish during the February/March 2005 survey.

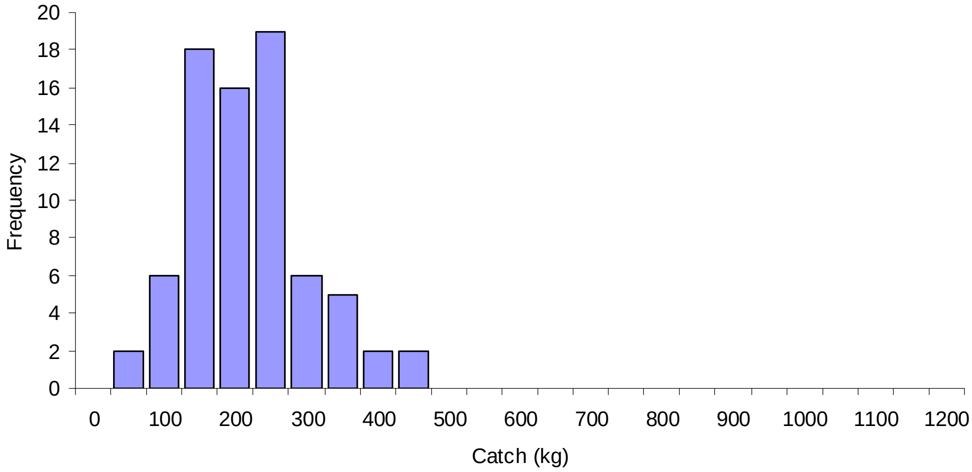


Figure 24. Frequency of catches (kg) of deepwater flathead during the February/March 2005 survey.

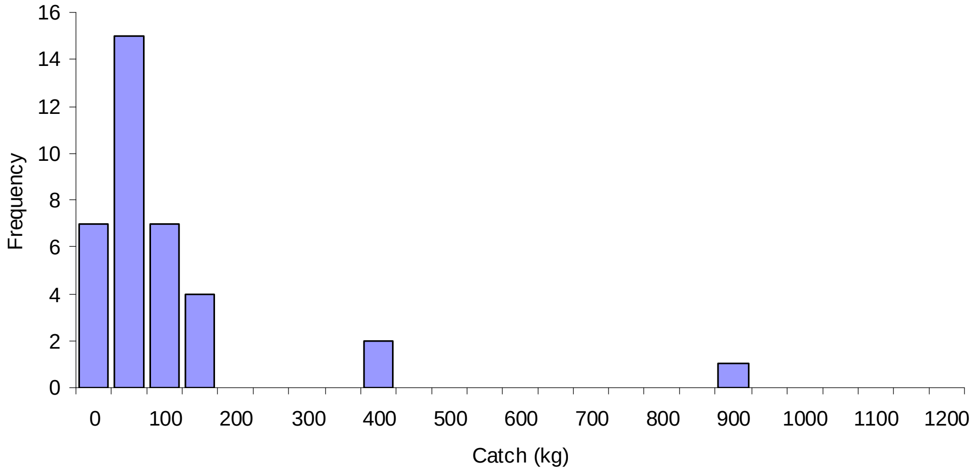


Figure 25. Frequency of catches (kg) of Bight redfish during the December 2005 survey.

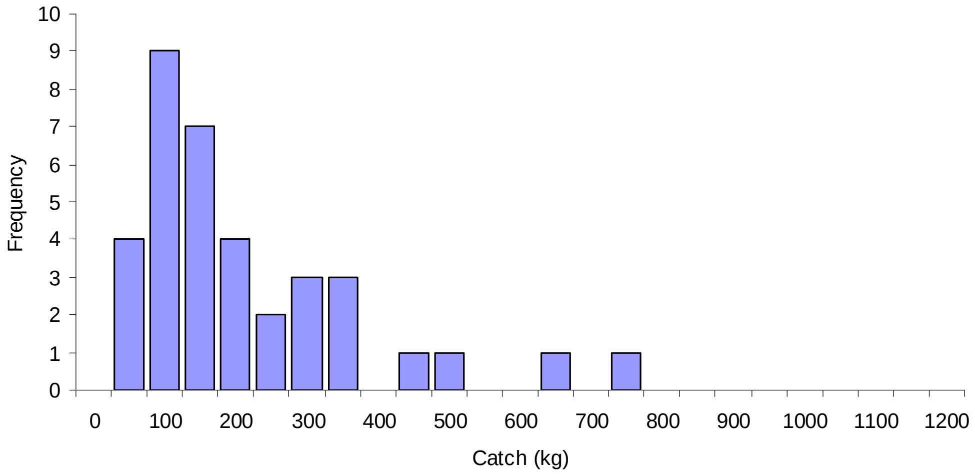


Figure 26. Frequency of catches (kg) of deepwater flathead during the December 2005 survey.

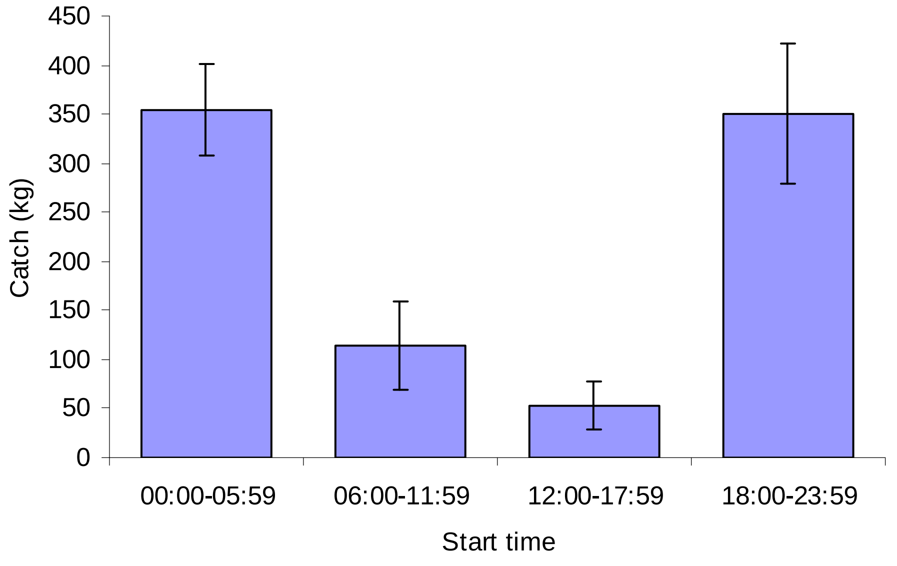


Figure 27. Mean and standard error of Bight redfish catches by time of day during the February/March 2005 survey.

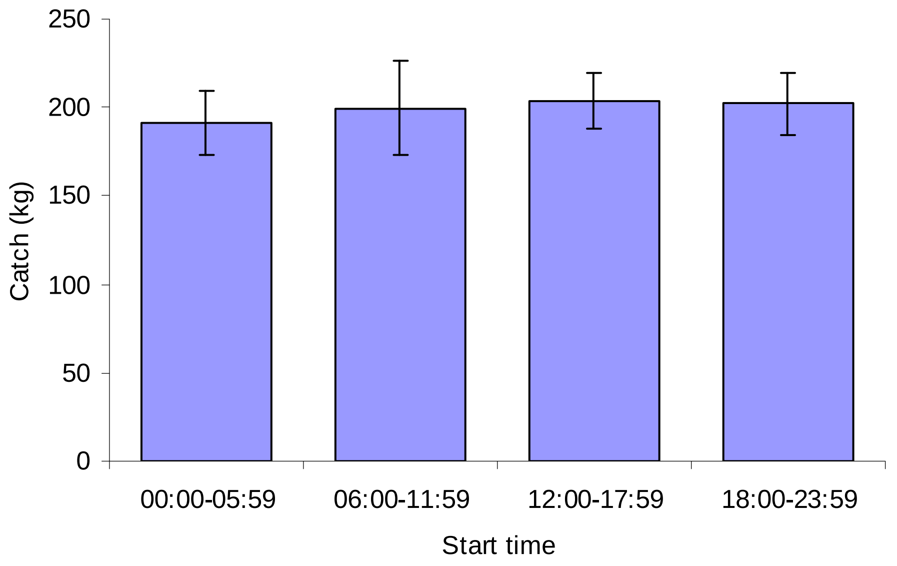


Figure 28. Mean and standard error of deepwater flathead catches by time of day during the February/March 2005 survey.

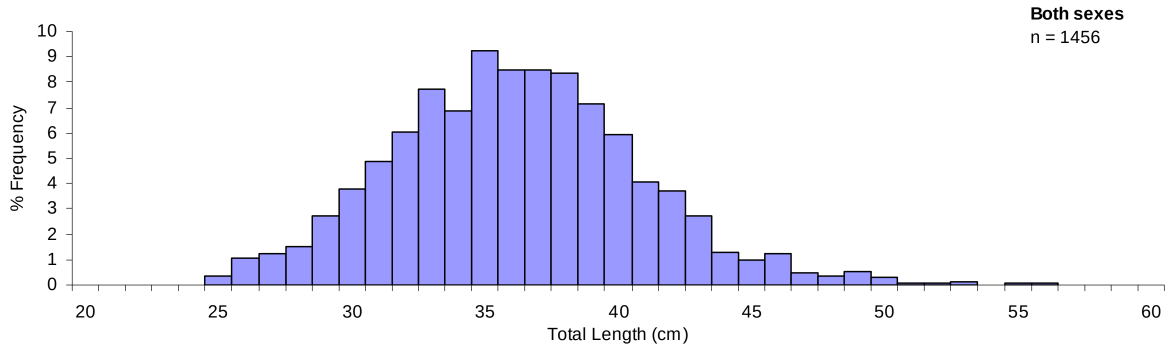


Figure 29. Length-frequencies of Bight redfish during the February/March 2005 survey.

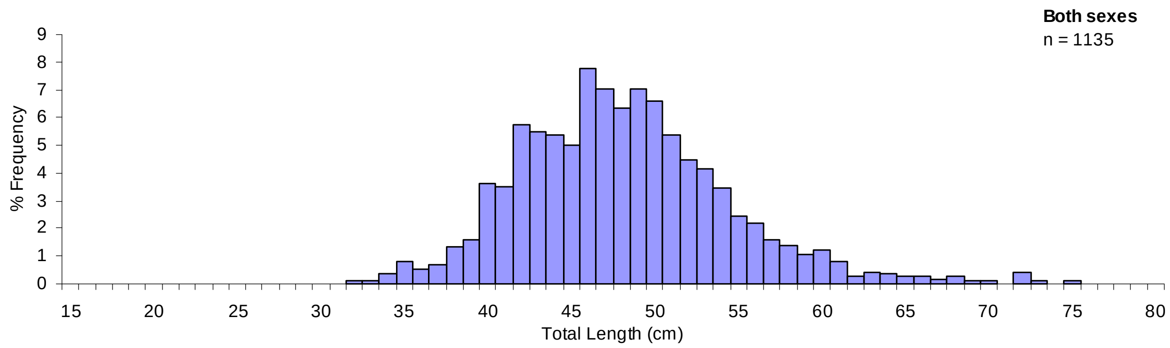


Figure 30. Length-frequencies of deepwater flathead during the February/March 2005 survey.

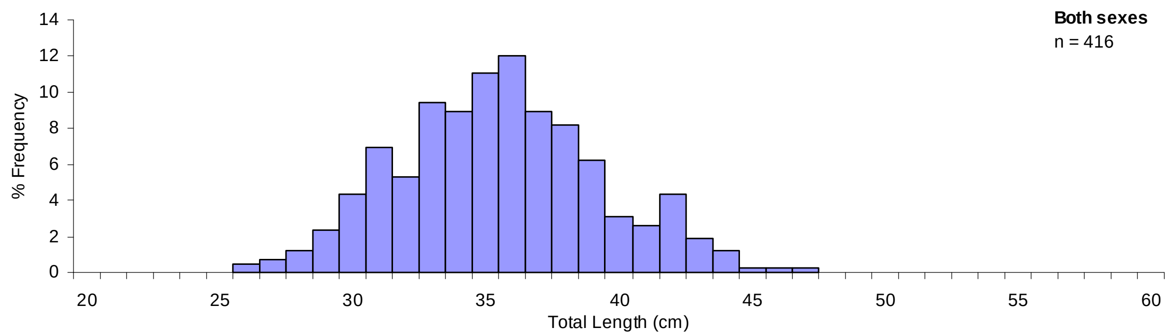


Figure 31. Length-frequencies of Bight redfish during the December 2005 survey.

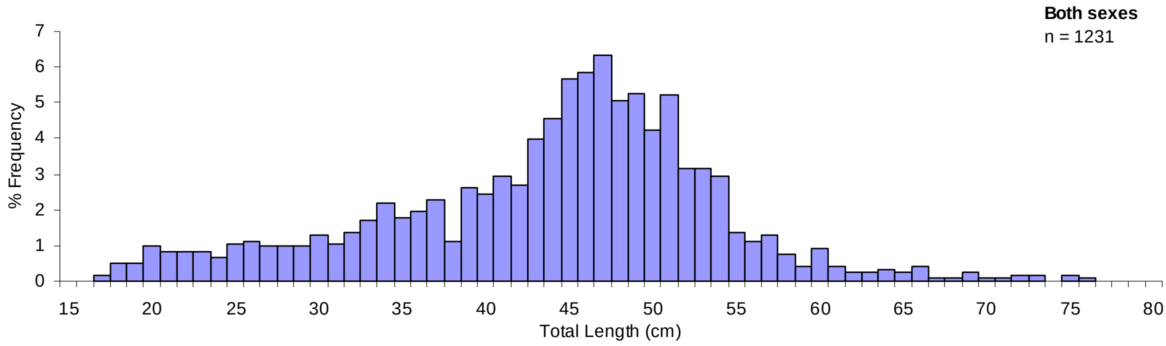


Figure 32. Length-frequencies of deepwater flathead during the December 2005 survey.

Table 1. Description of strata sampled during the February/March 2005 survey.

Stratum	Depth (m)	Longitude	Area (km^2)	Number of shots
Central 2	120–200	130.75–132.50	5720	22
Central 1	120–200	129.00–130.25	3965	30
West 2	120–200	127.75–129.00	2700	11
West 1	120–200	126.00–127.75	2600	13

Table 2. Description of strata sampled during the December 2005 survey.

Stratum	Depth (m)	Longitude	Area (km^2)	Number of shots
Inshore	100–120	126.00–133.00	n/a	8
West 3	120–200	125.00–126.00	n/a	4
West 1	120–200	126.00–127.75	2600	8
West 2	120–200	128.00–129.00	2700	7
Central 1	120–200	129.00–130.00	3965	4
Central 2	120- 200	130.75–132.5	5720	4

Table 3. Mean and standard deviation (SD) length (m), swept area (km^2)m, speed (knots) and depths (m) of tows in each stratum.

Stratum	Month	Tow length		Area swept		Tow speed		Tow depth	
		Mean (m)	SD	Mean (km^2)	SD	Mean (knots)	SD	Mean (m)	SD
Central 2	Feb/Mar	14830	445	1.533	0.046	3.20	0.1	137	8.7
Central 1	Feb/Mar	14579	831	1.507	0.086	3.20	0.1	135	17.0
West 2	Feb/Mar	14711	748	1.521	0.077	3.20	0.1	130	9.2
West 1	Feb/Mar	14662	617	1.516	0.064	3.20	0.1	128	9.1
Central 2	Dec	15405	444	1.303	0.242	3.33	0.1	132	9.2
Central 1	Dec	15520	267	1.412	0.079	3.35	0.06	138	9.1
West 3	Dec	14825	378	1.443	0.125	3.20	0.082	122	8.7
West 2	Dec	15487	365	1.531	0.161	3.34	0.07	133	17.0
West 1	Dec	15208	568	1.452	0.306	3.32	0.08	144	9.2
Inshore	Dec	15212	542	1.316	0.120	3.29	0.11	116	9.1

Table 4. Total catch (kg) of all species in each stratum and across all strata during February/March 2005 survey.

Species	Catch (kg)				
	Central 2	Central 1	West 2	West 1	Total
Arrow squid	222	356	52	185	815
Barracouta	281	919	240	310	1750
Barred grub fish		1		1	2
Bight ghostshark	4	10			14
Bight redfish	5457	7117	1995	1936	16505
Black shark				10	10
Black spotted gurnard perch	156	135	107	37	435
Black stingray		4			4
Blue grenadier	8	4			12
Blue mackerel	1	6		23	30
Blue warehou	20	81	3	5	109
Bugs	4.4	11	1	1	17.4
Common bellowfish	4	7	3	1	15
Common sawbelly	5	21	4	1	31
Common sawshark	52	174	49	114	389
Common slickhead			1		1
Crinoid		1			1
Cucumber fish		15			15
Cuttlefish unidentified	20	5	1	2	28
Deepwater burrfish	96	63	24	56	239
Deepwater flathead	3626	6012	2489	2831	14958
Deepwater stargazer	36	42	16	8.3	102.3
Degen's leatherjacket	11	11	7	7	36
Eagle ray		12			12
Eel unknown		1.1	1		2.1
Elephant fish		2		4	6
Footballer sweep	3	3		1	7
Frostfish				3	3
Gemfish	3	23		144	170
Giant boarfish	140	138	55	71	404
Gummy shark	111	268	201	102	682
Hapuku		250			250
Hermit crab	3	1	3	4	11
Jack mackerel	75	348	79	6	508
Jackass morwong	190	1056	93	157	1496
John dory	11	14	10	1	36
Knifejaw	389	463	150	159	1161
Latchet	3739	5000	1299	1515	11553
Long-finned boarfish	213	152	16	74	455
Melbourne skate	36	103	22		161
Ocean jacket	2298	4517	1020	1384	9219
Ocean perch	3	21	5		29
Orange perch				1	1
Ornate angel shark	502	2476	649	600	4227
Piked dogfish	211	413	65	349	1038
Pineapple fish				0.2	0.2
Pink ling		3			3
Port jackson shark	84	114	15	42	255
Queen snapper	461	330	143	208	1142
Red cod	2	5	4	3	14
Red gurnard	114	201	18	57	390

Species	Catch (kg)				
	Central 2	Central 1	West 2	West 1	Total
Ribbonfish			2		2
Ringed toadfish	31	72	41	48	192
Round skate	29	3	1		33
Rubyfish	4	555		75	634
Rusty catshark	127	15	11	14	167
Samson fish				20	20
Sandfish			1		1
Sawtail shark	1			5	6
School shark	14	4			18
Sergent baker	54	52	12	11	129
Sharpnose sevengill shark	24	11	4		39
Short-tailed torpedo ray	5	11		5	21
Silver dory	29	35	4	8	76
Silver trevally	20	61		28	109
Smooth stingray	95	332	139	224	790
Snapper	5	13		15	33
Southern calamari	22	4			26
Southern conger eel	40	138	31	33	242
Southern fiddler ray	39	40	5	33	117
Southern rock lobster				1	1
Southern sawshark	21	12	5	7	45
Southern shovelnose ray	6	2			7
Sparsely spotted stingaree		1			1
Spider crab			1		1
Spiny boxfish	16	57	7	4	84
Splendid sea perch	1	43			44
Sponge	1745	190	325	1000	3260
Starfish	6	2	1	4	13
Swallowtail	126	527	283	178	1114
Thetis fish	32	57	5	21	115
Tiger flathead	3				3
Tusk	15	58	84	17	174
Unidentified crabs				1	1
Unidentified octopus	2	1			3
Unidentified whiptail		20			20
Veilfin	16	5	1	13	35
Velvet leatherjacket	12	39	25	4	80
White-barred boxfish	2	7	3	13	25
White-finned swellshark	5				5
Wide stingaree	106	301	16	27	450
Wobbegong		110			110
Yellow-eye snapper		87	7	40	134
Total	21244.4	33774.1	9854	12262.5	77134

Table 5. Total catch (kg) of all species in each stratum and across all strata during the December 2005 survey.

Species	Catch (kg)						
	West3	West2	West1	Central1	Central2	Inshore	Total
Arrow squid	272	54	342	90	135	74	967
Australian tusk			55	5	1	1	62
Bailer shells			2		1		3
Barracouta	501	142	186	280	80	327	1516
Barred grubfish			2	0.2			2.2
Bearded rock cod			1			2	3
Bight ghost shark			2				2
Bight redfish	7	596	451	307	81	1491	2933
Bight skate			5				5
Blue grenadier			8				8
Blue mackerel	5	2				6	13
Blue warehou				2	8		10
Bugs			42			1	43
Common bellowsfish		1	2		1	2	6
Common saw shark	26	72	18	12	24	39	191
Crabs			1				1
Cucumber fish	0.5		8	1			9.5
Cuttlefish		1.5	5	3.5		2.2	12.2
Deepwater burrfish	475	221	340	83	690	330	2139
Deepwater flathead	2244	1012	1367	574	841	939	6977
Deepwater stargazer	1	25	100	11	8	12	157
Degen's leatherjacket	1		12	1	1	4	19
Draughtboard shark		15	12	6			33
Eagle ray		40	30		30		100
Eel (unknown)			<1				0
Elephant fish		4			18	6	28
Fiddler ray	87	232	247	132	76	188	962
Footballer sweep						3	3
Four-spined leatherjacket	2	3		1	5		11
Gemfish	32	17	60	14	2		125
Giant boarfish	60	122	104	21	121	349	777
Green-eyed dogfish	45	71	138		20	15	289
Gulf gurnard perch	1						1
Gummy shark	82	52	59	8	32	69	302
Hapuku	3	17	5	18		25	68
Hard coral		11			9	13	33
Hermit crabs	1			2			3
Jack mackerel	6	17	21	1	4	9	58
Jackass morwong	10	84	122	11	50	178	455
John dory		5		2		9	16
King george whiting						3	3
Knifejaw	111	116	255	62	56	75	675
Latchet	1377	1413	2313	736	2817	1749	10405
Long-finned boarfish	5	32	50	2	30	73	192
Ocean jacket	51	479	791	262	375	1002	2960
Ocean perch - offshore		15	51	5	51	177	299
Octopus			3				3
Ornate angel shark	41	276	203	231	384	148	1283
Piked dogfish	38	438	185	45	345	660	1711
Port jackson shark	51	43	15	5	64	14	192
Queen snapper	14	139	84	2	54	190	483

Species	Catch (kg)						
	West3	West2	West1	Central1	Central2	Inshore	Total
Red cod		2					2
Red gurnard	4	41	28	39	30	74	216
Redbait	1	1			2	14	18
Ringed toadfish	55	101	57	30	20	31	294
Round skate					4		4
Rubyfish	270	15		3	1		289
Ruddy gurnard perch		3		6	16	4	29
Rusty catshark		19	19		11	18	67
Sandpaper fish				19			19
Sawtail shark	1		2				3
Scallop	<1						0
School shark		14			3		17
Sergeant baker		31	5		39	82	157
Sharpnose seven-gill shark	12		8				20
Silver dory		1	2		5	4	12
Silver trevally						2	2
Smooth stingray	15	87	110		25	80	317
Snapper		5	3		3		11
Southern calamari						2	2
Southern conger eel		19	10	24		4	57
Southern frostfish			34			6	40
Southern rock lobster			1				1
Southern saw shark	7	32	7	3	13	75	137
Spiny boxfish		2	<1	1	2	4	9
Splendid sea perch		<1				10	10
Sponge	65	2925	295	75	160	4070	7590
Starfish	1		0.5		1	0.5	3
Swallow-tail		150	602	184	100	210	1246
Thetis fish	7	8	2	1	11	6	35
Tiger flathead						4	4
Tubeworms					10	30	40
Veilfin		31	10			133	174
Western sea perch		1				1	2
Whiskery shark						3	3
White-barred boxfish	2	6	22	2	36	45	113
White-spotted skate	5						5
Whitley's skate			12			65	77
Wide stingaree	4	525	276	8	450	3080	4343
Wobbegong		40				20	60
Yellow-backed stingaree						9	9
Yellow-eyed snapper			1	3	1		5
Total	5998.5	9826.5	9203.5	3333.7	7357	16271.7	51990.9

Table 6. Catch (kg) Bight redfish and deepwater flathead for each stratum point during the February/March 2005 survey.

Shot code	Shot	Stratum point		Shot date	Time of shot	Start Point		Finish Point		Catch (kg)	
		Lat	Long			Lat	Long	Lat	Long	Bight redfish	Deepwater flathead
C2-01-2005	1	33°55'	132°28'	18/02/2005	16:20	33°55.16'	132°31.45'	33°52.56'	132°33.22'	58	54
C2-02-2005	2	33°43'	132°10'	18/02/2005	20:50	33°44.10'	132°12.23'	33°40.01'	132°03.94'	150	105
C2-03-2005	3	33°27'	131°52'	19/02/2005	00:55	33°31.42'	131°57.19'	33°25.94'	131°49.58'	260	144
C2-04-2005	4	33°19'	131°04'	19/02/2005	10:20	33°20.60'	131°09.49'	33°18.72'	131°00.91'	69	14
C2-05-2005	5	33°23'	131°22'	19/02/2005	06:59	33°22.99'	131°22.04'	33°22.36'	131°11.98'	55	350
C1-06-2005	6	33°16'	130°13'	19/02/2005	22:36	33°14.91'	130°16.20'	33°16.45'	130°05.95'	270	100
C1-07-2005	7	33°07'	130°13'	19/02/2005	18:12	33°06.86'	130°13.72'	33°10.36'	130°05.01'	90	100
C1-08-2005	8	33°16'	130°07'	20/02/2005	02:05	33°16.12'	130°07.96'	33°12.57'	129°59.17'	240	140
C1-09-2005	9	33°13'	129°49'	20/02/2005	05:40	33°13.08'	129°51.40'	33°13.10'	129°41.67'	330	352
C1-10-2005	10	33°16'	129°41'	20/02/2005	09:10	33°15.93'	129°43.40'	33°17.39'	129°34.01'	600	140
C1-11-2005	11	33°13'	129°34'	20/02/2005	12:48	33°13.50'	129°36.54'	33°14.30'	129°26.67'	13	280
C1-12-2005	12	33°16'	129°25'	20/02/2005	15:45	33°15.21'	129°26.28'	33°19.43'	129°17.90'	18	245
C1-13-2005	13	33°16'	129°19'	20/02/2005	19:10	33°19.01'	129°12.86'	33°14.92'	129°21.15'	86	320
C1-14-2005	14	33°17'	129°10'	20/02/2005	22:39	33°15.74'	129°14.28'	33°18.65'	129°04.27'	300	280
C1-15-2005	15	33°19'	129°04'	21/02/2005	02:00	33°19.05'	129°05.92'	33°18.40'	128°55.61'	150	210
W2-16-2005	16	33°17'	128°33'	21/02/2005	07:17	33°17.00'	128°34.93'	33°15.08'	128°26.06'	10	250
W2-17-2005	17	33°13'	128°04'	21/02/2005	11:29	33°13.24'	128°11.21'	33°13.83'	128°01.20'	23	210
W1-18-2005	18	33°10'	126°58'	21/02/2005	20:17	33°10.25'	127°01.51'	33°10.16'	126°51.13'	248	240
W1-19-2005	19	33°16'	126°19'	22/02/2005	02:40	33°16.02'	126°18.95'	33°14.12'	126°27.74'	171	185
W1-20-2005	20	33°17'	126°13'	22/02/2005	06:23	33°16.23'	126°18.93'	33°15.82'	126°09.93'	25	445
W1-21-2005	21	33°13'	126°17'	22/02/2005	09:35	33°14.01'	126°13.65'	33°11.83'	126°23.38'	41	446
W1-22-2005	22	33°10'	126°42'	22/02/2005	13:55	33°10.06'	126°38.95'	33°09.47'	126°49.15'	6	222
W1-23-2005	23	33°13'	126°58'	22/02/2005	17:05	33°10.75'	126°52.37'	33°12.67'	127°02.14'	3	148
W2-24-2005	24	33°13'	128°25'	23/02/2005	04:45	33°12.83'	128°24.77'	33°14.67'	128°34.25'	404	292
W2-25-2005	25	33°17'	128°37'	23/02/2005	07:05	33°15.91'	128°35.59'	33°18.47'	128°46.25'	40	188
C1-26-2005	26	33°19'	129°07'	23/02/2005	12:59	33°19.36'	129°05.10'	33°15.97'	129°13.94'	7	292
C1-27-2005	27	33°16'	129°13'	23/02/2005	16:10	33°15.97'	129°12.32'	33°14.11'	129°22.13'	197	243
C1-28-2005	28	33°16'	129°22'	23/02/2005	19:52	33°16.87'	129°19.72'	33°12.51'	129°28.30'	390	212
C1-29-2005	29	33°19'	129°31'	23/02/2005	23:05	33°14.24'	129°26.30'	33°19.77'	129°32.99'	242	136
C1-30-2005	30	33°19'	129°34'	24/02/2005	02:10	33°19.01'	129°33.37'	33°16.23'	129°42.45'	424	224
C1-31-2005	31	33°13'	129°43'	24/02/2005	05:10	33°14.90'	129°42.21'	33°12.69'	129°50.48'	535	245
C1-32-2005	32	33°08'	130°04'	24/02/2005	09:06	33°07.85'	130°00.00'	33°10.98'	130°07.93'	18	125
C1-33-2005	33	33°13'	130°10'	24/02/2005	12:22	33°12.88'	130°05.47'	33°13.53'	130°14.99'	0	237
C1-34-2005	34	33°13'	130°13'	24/02/2005	15:36	33°12.87'	130°12.52'	33°13.29'	130°22.01'	12	197
C2-35-2005	35	33°22'	131°13'	24/02/2005	23:40	33°21.93'	131°12.25'	33°21.26'	131°21.49'	490	209
C2-36-2005	36	33°22'	131°34'	25/02/2005	05:50	33°19.52'	131°33.53'	33°25.18'	131°39.38'	807	130
C2-37-2005	37	33°19'	131°33'	25/02/2005	02:50	33°20.71'	131°25.09'	33°18.64'	131°34.84'	512	85
C2-38-2005	38	33°38'	132°04'	25/02/2005	11:45	33°37.79'	132°02.63'	33°41.94'	132°10.88'	4	100
C2-39-2005	39	33°46'	132°13'	25/02/2005	14:50	33°43.89'	132°09.52'	33°49.28'	132°16.95'	0	333
C2-40-2005	40	33°47'	132°16'	21/03/2005	19:42	33°47.64'	132°18.13'	33°43.51'	132°09.25'	99	138
C2-41-2005	41	33°37'	131°58'	21/03/2005	23:32	33°38.37'	132°00.51'	33°33.15'	131°53.24'	27	173

Shot code	Shot	Stratum point		Shot date	Time of shot	Start Point		Finish Point		Catch (kg)	
		Lat	Long			Lat	Long	Lat	Long	Bight redfish	Deepwater flathead
C2-42-2005	42	33°28'	131°49'	22/03/2005	02:40	33°30.71'	131°52.03'	33°26.43'	131°43.18'	182	190
C2-43-2005	43	33°19'	131°26'	22/03/2005	07:10	33°20.18'	131°29.86'	33°18.22'	131°20.97'	628	207
C2-44-2005	44	33°22'	131°10'	22/03/2005	10:30	33°20.18'	131°15.42'	33°21.81'	131°05.98'	11	137
C2-45-2005	45	33°19'	131°00'	22/03/2005	13:35	33°20.83'	131°03.63'	33°17.93'	130°54.71'	5	141
C1-46-2005	46	33°16'	129°46'	22/03/2005	21:58	33°16.65'	129°52.55'	33°15.18'	129°42.93'	595	259
C1-47-2005	47	33°16'	129°34'	23/03/2005	01:00	33°15.15'	129°40.21'	33°17.10'	129°30.58'	529	328
C1-48-2005	48	33°15'	129°31'	23/03/2005	04:00	33°16.81'	129°30.00'	33°11.01'	129°36.72'	231	243
C1-49-2005	49	33°13'	129°22'	23/03/2005	07:35	33°12.13'	129°31.25'	33°12.99'	129°21.70'	50	173
C1-50-2005	50	33°19'	129°16'	23/03/2005	11:01	33°16.89'	129°20.02'	33°18.15'	129°11.00'	33	156
C1-51-2005	51	33°17'	129°05'	23/03/2005	14:10	33°17.68'	129°09.21'	33°15.90'	128°59.88'	264	207
W2-52-2005	52	33°16'	128°58'	23/03/2005	17:10	33°15.71'	128°59.69'	33°16.16'	128°49.98'	19	212
W2-53-2005	53	33°15'	128°43'	23/03/2005	20:32	33°14.80'	128°43.97'	33°14.96'	128°34.11'	197	192
W2-54-2005	54	33°19'	128°34'	24/03/2005	00:25	33°18.99'	129°36.42'	33°17.84'	128°27.41'	34	33
W1-55-2005	55	33°13'	127°25'	24/03/2005	09:30	33°13.30'	127°26.48'	33°13.04'	127°16.41'	89	174
W1-56-2005	56	33°15'	126°52'	24/03/2005	14:02	33°13.17'	126°58.92'	33°13.25'	126°48.89'	0	160
W1-57-2005	57	33°10'	126°34'	24/03/2005	18:08	33°09.98'	126°36.66'	33°11.81'	126°26.79'	55	197
W1-58-2005	58	33°16'	126°12'	24/03/2005	21:36	33°13.29'	126°19.95'	33°15.93'	126°10.62'	498	138
W1-59-2005	59	33°15'	126°19'	25/03/2005	00:30	33°15.41'	126°11.29'	33°15.06'	126°21.10'	528	160
W1-60-2005	60	33°10'	126°46'	25/03/2005	05:10	33°10.38'	126°39.29'	33°10.08'	126°47.76'	264	128
W1-61-2005	61	33°16'	127°22'	25/03/2005	11:30	33°15.64'	127°18.08'	33°16.07'	127°28.11'	8	189
W2-62-2005	62	33°17'	128°34'	25/03/2005	20:42	33°13.75'	128°28.17'	33°16.32'	128°36.37'	206	207
W2-63-2005	63	33°13'	128°35'	26/03/2005	00:09	33°15.22'	128°41.10'	33°10.65'	128°33.70'	149	281
W2-64-2005	64	33°12'	128°45'	26/03/2005	03:42	33°11.90'	128°38.78'	33°13.60'	128°47.84'	334	133
C1-65-2005	65	33°16'	129°01'	26/03/2005	07:10	33°15.22'	128°53.36'	33°16.03'	129°03.43'	84	197
C1-66-2005	66	33°16'	129°13'	26/03/2005	10:15	33°17.12'	129°05.94'	33°17.05'	129°12.94'	275	88
C1-67-2005	67	33°17'	129°19'	26/03/2005	12:40	33°17.22'	129°12.44'	33°17.30'	129°21.39'	4	217
C1-68-2005	68	33°19'	129°28'	26/03/2005	15:35	33°18.19'	129°22.45'	33°18.07'	129°31.21'	3	188
C1-69-2005	69	33°10'	129°34'	26/03/2005	19:41	33°09.33'	129°34.49'	33°17.08'	129°34.22'	274	138
C1-70-2005	70	33°16'	129°43'	26/03/2005	22:40	33°17.03'	129°34.63'	33°15.76'	129°44.07'	1189	322
C1-71-2005	71	33°12'	129°50'	27/03/2005	02:05	33°16.52'	129°44.68'	33°11.08'	129°50.09'	776	190
C2-72-2005	72	33°17'	131°10'	27/03/2005	12:00	33°16.49'	131°09.00'	33°21.45'	131°16.13'	6	141
C2-73-2005	73	33°23'	131°16'	27/03/2005	14:55	33°22.44'	131°15.47'	33°22.57'	131°25.10'	1	150
C2-74-2005	74	33°22'	131°40'	27/03/2005	18:30	33°20.67'	131°33.02'	33°23.59'	131°41.93'	1134	369
C2-75-2005	75	33°34'	131°50'	27/03/2005	21:55	33°26.68'	131°46.66'	33°34.26'	131°50.29'	469	208
C2-76-2005	76	33°37'	132°01'	28/03/2005	01:15	33°34.17'	131°55.31'	33°39.01'	132°02.97'	221	126

Table 7. Catch (kg) Bight redfish and deepwater flathead for each stratum point during the December 2005 survey.

Shot code	Shot	Stratum point		Shot date	Time of shot	Start Point		Finish Point		Catch (kg)	
		Lat or depth	Long			Lat	Long	Lat	Long	Bight redfish	Deepwater flathead
125–126	1	120m	125°51	5/12/2005	13:15	33°46.11'	125°28.09'	33°40.66'	125°36.55'	2	462
125–126	2	128m	125°7	5/12/2005	16:30	33°37.76'	125°39.69'	33°32.68'	125°47.89'	1	630
126–127.75	3	33°2	126°2	5/12/2005	22:40	33°12.04'	126°11.55'	33°12.09'	126°20.78'	46	100
126–127.75	5#	33°2	126°8	6/12/2005	03:30	33°12.33'	126°41.45'	33°12.23'	126°52.82'	360	140
126–127.75	4	33°2	127	6/12/2005	06:45	33°10.86'	126°56.47'	33°12.86'	127°07.45'	0	211
126–127.75	7	33°3	127°5	6/12/2005	13:00	33°16.57'	127°24.44'	33°17.93'	127°34.91'	0	37
126–127.75	8	33°3	127°7	6/12/2005	17:10	33°18.14'	127°46.06'	33°16.46'	127°55.00'	60	72
128–129	9	33°2	128°2	6/12/2005	21:35	33°14.16'	128°11.34'	33°12.04'	128°19.13'	15	110
128–129	10	33°3	128°5	7/12/2005	02:25	33°17.62'	128°28.77'	33°19.00'	128°39.53'	90	19
128–129	11	33°2	128°7	7/12/2005	05:50	33°16.73'	128°42.10'	33°08.96'	128°43.12'	35	181
inshore	12	108m	128°79	7/12/2005	08:55	33°08.01'	128°45.08'	33°13.48'	128°54.25'	870	252
128–129	13	33°2	128°3	7/12/2005	12:15	33°12.48'	128°53.74'	33°17.95'	129°01.62'	6	210
129–130	14	33°3	129°5	7/12/2005	17:00	33°18.34'	129°20.00'	33°17.35'	129°31.56'	35	141
129–130	15	33°2	129°6	7/12/2005	20:20	33°17.36'	129°31.04'	33°11.46'	129°37.04'	150	183
129–130	16	33°3	129°9	8/12/2005	00:15	33°18.09'	129°44.10'	33°17.70'	129°55.17'	120	110
130.75–132.5	17	33°5	131°3	8/12/2005	08:15	33°17.94'	130°50.20'	33°18.32'	131°00.09'	0	320
130.75–132.5	18	33°3	131°4	8/12/2005	12:35	33°12.25'	131°22.87'	33°19.57'	131°25.79'	11	100
130.75–132.5	19	33°4	131°5	8/12/2005	16:25	33°24.60'	131°30.62'	33°12.96'	131°12.03'	40	350
130.75–132.5	20	33°7	132°2	8/12/2005	19:30	33°17.96'	131°12.03'	33°17.50'	131°11.72'	30	71
inshore	21	107m	130°88	9/12/2005	00:05	33°08.88'	131°00.76'	33°08.94'	130°51.64'	60	70
inshore	22	111m	129°89	9/12/2005	07:30	33°07.45'	130°07.80'	33°08.26'	129°52.47'	0	140
129–130	23	33°2	129°9	9/12/2005	11:05	33°11.99'	129°56.09'	33°09.92'	129°46.85'	2	140
Inshore	24	112m	129°48	9/12/2005	15:25	33°06.56'	129°31.34'	33°08.21'	129°21.35'	400	71
128–129	25	33°2	129	9/12/2005	19:30	33°11.29'	129°08.58'	33°09.95'	128°54.85'	150	323
128–129	26	33°2	128°8	9/12/2005	22:40	33°11.63'	128°56.07'	33°12.37'	128°45.75'	60	282
128–129	27#	33°3	128°6	10/12/2005	02:30	33°18.88'	128°41.68'	33°17.50'	128°31.83'	60	100
128–129	29#	33°2	128°3	10/12/2005	08:05	33°13.78'	128°21.50'	33°12.07'	128°12.11'	7	181
126–127.75	31#	33°2	127°7	10/12/2005	14:55	33°13.10'	127°45.76'	33°11.40'	127°36.19'	90	96
126–127.75	33	33°2	126°9	10/12/2005	23:20	33°12.47'	127°00.95'	33°11.00'	126°51.60'	60	140
inshore	34	117m	126°71	11/12/2005	03:05	33°09.46'	126°46.06'	33°10.28'	126°35.90'	126	180
126–127.75	35	33°2	126°6	11/12/2005	06:25	33°11.99'	126°36.81'	33°14.61'	126°27.56'	0	280
125–126	36	134m	125°85	11/12/2005	14:20	33°28.31'	125°53.37'	33°34.09'	125°45.69'	4	420
125–126	37		125°54	11/12/2005	18:35	33°39.37'	125°38.91'	33°43.15'	125°30.55'	0	732

Note: Shots 6, 28, 30 and 32 were pinned up and not completed.

Table 8. Species and numbers of fish for which length, sex, and otolith samples were collected during 2005 survey.

Species	Length frequency		Otoliths collected	
	Feb/Mar	Dec	Feb/Mar	Dec
Deepwater flathead	1122	1231	315	340
Bight redfish	1381	416	320	150
Ocean jacket	335	336		
Gemfish	0	10		
Giant boarfish	72	241		
Hapuku	21	1		
Jackass morwong	252	95		
Knifejaw	161	155		
Latchet	21	331		
Queen Snapper	80	75		
Red gurnard	70	70		
Ornate angel shark	26	104		
Blue warehou	11	0		

Table 9. Estimated total relative biomass (t) with coefficient of variation (c.v.) of major commercial species in across all strata from 2005.

	Day and night (hauls=76)				Day time (hauls=37)				Night time (hauls=39)			
Assumed swept width	103.4 m		16.3 m		103.4 m		16.3 m		103.4 m		16.3 m	
Species	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.
Bight redfish	2128	0.14	13498	0.14	847	0.36	5375	0.36	3293	0.13	20887	0.13
Deepwater flathead	1916	0.05	12152	0.05	1903	0.09	12070	0.09	1899	0.06	12046	0.06
Ocean jacket	1129	0.14	7163	0.14	388	0.16	2459	0.16	1813	0.14	11499	0.14
Common sawshark	47	0.16	298	0.16	46	0.24	293	0.24	44	0.14	277	0.14
Giant boarfish	55	0.19	349	0.19	55	0.29	347	0.29	56	0.28	354	0.28
Gummy shark	88	0.17	558	0.17	38	0.34	243	0.34	135	0.17	854	0.17
Jackass morwong	62	0.34	1025	0.34	143	0.18	906	0.18	173	0.59	1099	0.59
Knifejaw	151	0.12	955	0.12	185	0.16	1176	0.16	121	0.18	770	0.18
Latchet	1482	0.13	9401	0.13	1673	0.20	10616	0.20	1366	0.16	8666	0.16
Ornate angel shark	485	0.09	3078	0.09	373	0.12	2363	0.12	591	0.13	3752	0.13
Piked dogfish	132	0.24	834	0.24	79	0.50	498	0.50	186	0.32	1181	0.32
Queen snapper	160	0.20	1015	0.20	162	0.25	1025	0.25	162	0.32	1028	0.32
Other species	1843	0.13	11693	0.13	1555	0.19	9862	0.19	2052	0.18	13017	0.18

Table 10. Estimated total relative biomass (t) with coefficient of variation (c.v.) of major commercial species in across all strata from the December 2005 survey. Day and night shots are combined (Number of tows = 33).

Assumed swept width	93 m		16.3 m	
Species	t	c.v.	t	c.v.
Bight redfish	1668	0.41	10581	0.41
Deepwater flathead	2684	0.12	17024	0.12
Ocean jacket	1497	0.24	9495	0.24
Common sawshark	74	0.19	469	0.19
Giant boarfish	420	0.14	2665	0.14
Gummy shark	123	0.18	781	0.18
Jackass morwong	241	0.32	1526	0.32
Knifejaw	241	0.19	1529	0.19
Latchet	5344	0.11	33902	0.11
Ornate angel shark	700	0.24	4443	0.24
Piked dogfish	985	0.30	6250	0.30
Queen snapper	237	0.23	1503	0.23
Other species	10672	0.17	67700	0.17