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Resource Survey of the Great Australian Bight Trawl Fishery 2006

Ian Knuckey and Russell Hudson

2007

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GABIA

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Executive Summary

The Great Australian Bight Trawl Fishery (GABTF) targets two main shelf species: deepwater flathead (*Neoplatycephalus conatus*), and Bight redfish (*Centroberyx gerrardi*). There has been considerable uncertainty in the stock assessments for these species due to a lack of contrast in any of the main fishery indicators such as commercial catch rates, length- or age-frequency. 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 primary goal of a resource survey of the Great Australian Bight (GAB) was to obtain robust annual indices of the relative biomass of deepwater flathead and Bight redfish that would reduce the uncertainty in the stock assessment models.

The inaugural industry-based fishery-independent resource survey of the Great Australian Bight (GAB) was conducted during 2005. This report details the results of the 2006 GABTF resource survey – the second consecutive annual survey.

Two industry-based fishery-independent trawl surveys were successfully conducted in selected strata within the GAB during February and March 2006. Deepwater flathead and Bight redfish occurred in 100% and 87% respectively of the seventy-five valid survey tows that were completed and comprised 40% of the catch during the survey. Ocean jacket, wide stingaree, latchet, ornate angel shark, swallowtail and sponge were other commonly caught species.

Using swept area estimates from trawl shots in a stratified random survey design, relative biomass indices with CVs<0.2 were obtained for deepwater flathead, Bight redfish and other main species within the survey area. The relative biomass estimate of Bight redfish for 2006 was 25,380 t (CV = 0.16), which is 22% higher than the 2005 estimate (20,887 t, CV = 0.13). The relative biomass estimate of deepwater flathead during 2006 was 8,415 t (CV = 0.06). This is 31% lower than the 2005 estimate (12,152 t, CV = 0.05).

Modal length of Bight redfish in samples from 2006 (35 cm) was the same as in samples from 2005. Modal length of deepwater flathead in samples from 2006 (43 cm) was smaller than in 2005 (46 cm). Otolith samples of deepwater flathead and Bight redfish were also collected during the survey.

The 2006 survey achieved all of its objectives and the results provided the second year of fishery-independent abundance indices for both deepwater flathead and Bight redfish and other important GABTF shelf species.

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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.

Until 2006, the GABTF 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 do 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 suffer 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 has 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). A preliminary survey of the main shelf areas of the fishery was successfully conducted during 2005 (Knuckey *et. al.* 2006). Continuing the random stratified survey during 2006 extends the time series of relative biomass estimates of Bight redfish and deepwater flathead and can be used as additional information to help support the setting of appropriate TACs..

Objectives

1. Determine a relative abundance index for Bight redfish and deepwater flathead in the current region of the main GABTF shelf fishery during 2006.
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

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

Although fishing for shelf species occurs outside of these areas to a limited extent, the survey was restricted to depth of 120–200 m and between longitude 126º00' and 132º30'. The longitudinal range was divided into four primary strata; 126º00'–127º45'(West2), 127º45'–129º00' (West1), 129º00'–130º15' (Central1), 130º 45'–132º30' (Central2) (Figure1, 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 fathead also fluctuate seasonally, however, not as much as Bight redfish. Consequently the survey is conducted during February–April.

Initial analyses of the catch and effort data indicated catch rates for Bight redfish was 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 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 based on these analyses.

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 and time setting and retrieving the net not included.

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 zero catches (a contributing factor to a high CV) of Bight redfishes was not as high as expected, and hence an analysis of only night shots (approximately half of the 76 shots) has provided an acceptable CV (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. 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 tows were completed in a specified order to reduce temporal biases in the data collection, though the order of 1–3 tows was rearranged for logistical reasons. Tows were conducted at a speed ranging 3–3.2 knots, with the skipper deciding on the starting position and direction of the tow. When the tow 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 by 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 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 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

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

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 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 75 sites of the 76 sites during February and March 2006 (Figure 1). One site was abandoned after two consecutive pin-ups while attempting to trawl it. The mean tow lengths in the four strata were 14.9 km (Central 1), 14.9 km (Central 2), 14.9 km (West 1) and 15.0 km (West 2) (Table 1).

Gear Performance

Door spread was estimated on 23 occasions. Door spread measurements ranged 94-123 m, with a mean door spread of 107.0 m (±6.3 m SD) during February and 109 m (±9.8 m SD) during March.

Catch Composition and Length Frequencies

The total catch during the February and March surveys combined (73.4 t) comprised 100 identified species or species groups with the largest catches occurring in the Central2 stratum (Table 3). Bight redfish 19.0 t (26%) and ocean jackets 12.8 t (17%) made up the majority of the catch, followed by deepwater flathead 10.3 t (14%), and latchets 6.9 t (9%) (Figure 2). Deepwater flathead and Bight redfish occurred in 100% and 89% of tows respectively.

Catches of Bight redfish during the survey varied more than catches of deepwater flathead (Figure 3, Figure 4, Table 4). Four hauls contained more than 1000 kg of Bight redfish while 72% of the hauls contained between 50–150 kg of deepwater flathead (Figure 4).

Catch of Bight redfish varied considerably with time of day. Tows commencing during 1800 hours and 0600 hours caught about ten times more Bight redfish than catches between 1200 hours and 1800 hours (Figure 5). In contrast there was no difference in catches of deepwater flathead between night and day tows (Figure 6).

The lengths of 1546 Bight redfish were measured during the 2006 surveys (Figure 7). Substantially more Bight redfish were measured in the central zones, than the western zones because of the larger number of shots and fish caught in these zones. Lengths ranged 24–55 cm, however, most fish measured were between 28–40 cm (Figure 7).

The lengths of 818 deepwater flathead were measured during the 2006 surveys (Table 5). Lengths ranged 19–74 cm, however, most fish measured were between 41–53 cm (Figure 8).

A total of 240 otoliths were collected from deepwater flathead, while 561 were collected from Bight redfish (Table 5).

Relative Biomass Estimates

Using only night shots (1800–0600 hours) and net-width in swept-area calculations, the relative biomass estimate of Bight redfish for the 2006 survey was 25,380 t with a CV of 0.16 (Table 6). The relative biomass estimate for 2006 was 22% higher than the 2005 estimate of 20,887 t (Figure 9).

Using both day and night time shots net-width in swept-area calculations, the relative biomass estimate of deepwater flathead for the 2006 survey was 8,415 t with a CV of 0.06 (Table 6). The relative biomass estimate for 2006 was 31% lower than the 2005 estimate of 12,152 t (Figure 9).

Relative biomass estimates for a number of other important GABTF species were also calculated (Table 6). CVs of these species were generally below 0.30. Other important species with the greatest relative biomasses estimates were ocean jackets (9,111 t) and latchets (6,135 t). Trends in relative biomasses estimates varied from species to species (Figure 9 and Figure 10). Species that showed an increase in relative biomasses estimates between 2005 and 2006 survey estimates were ocean jackets and knifejaw. Common sawshark, gummy shark, latchet and ornate angel sharks all showed a decrease in relative biomasses estimate between 2005 and 2006 surveys. There was no difference in relative biomass estimates of jackass morwong and piked dogfish between survey years.

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. 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, and to determine a relative abundance index of other main species in the current shelf fishery. All of these objectives were met, with 75 sites successfully surveyed during February and March 2006, adding to the 2005 data.

Gear Performance

A major reason for conducting the 2005 survey was to assist in determining appropriate quotas for deepwater flathead and Bight redfish. 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 survey results to provide an absolute abundance index for deepwater flathead and Bight redfish.

There are many uncertainties and subsequent assumptions that would have to 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 available to capture; what proportion is captured and 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, the proportion of catch attributed to herding could be calculated for only 5 species.

At the simplest level for the current surveys, it is unclear whether all the fish between the trawl doors are herded into the net and captured, only a portion are herded in, or only the fish in the path of the net are captured.

Until further research is conducted to determine the effect of herding on survey catches, relative biomass estimates obtained using net width in swept-area calculations will be presented.

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 relative 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 in a 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 relative biomass estimates for Bight redfish calculated from night shots are more applicable than day shot estimates and day and night shots combined estimates.

Additional uncertainties in using the relative biomass estimates as absolute abundance indices are related to strata definition, species' population dynamics and measurement of strata area not accurately representing the true area along a sloping stretch of sea floor.

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 such as ocean jackets. There was no significant diurnal difference for deepwater flathead.

Catch Composition and Length Frequencies

Bight redfish were the most commonly caught species in both 2005 and 2006 surveys (apart from the December 2005 survey); comprising 22% of the total catch in 2005 (Knuckey *et. al.* 2006) and 26% of the total catch in 2006 (Figure 2). The proportion of the total catch comprising deepwater flathead has decreased from 19% in 2005 (Knuckey *et. al.* 2006) to 14% in 2006 (Figure 2). Ocean jackets were the second most commonly caught species during 2006 (17%) followed by deepwater flathead and latchet (9%) (Figure 2).

Modal lengths of Bight redfish measured during 2005 and 2006 surveys were 35 cm (Knuckey *et. al.* 2006) and 35 cm (Figure 7). Despite these similarities, there appears to be a larger portion of the fish smaller than 34 cm in samples measured during 2006 than in the previous year.

Modal lengths of deepwater flathead measured during 2005 and 2006 surveys were 46 cm (Knuckey *et. al.* 2006) and 43 cm (Figure 8). The distribution of length-frequencies is similar to that of samples collected in 2005.

Relative Biomass Estimates

Bight redfish

The 2006 relative biomass estimate of 25,380t Bight redfish was 22% higher than the 2005 estimate (20,887 t) (Knuckey *et. al.* 2006). These estimates were based on night shots only.

The CV for night shots during 2006 (0.16) was slightly larger than the 2005 estimates (0.13) (Knuckey *et. al.* 2006). The high CV during 2006 is a result of a single shot producing a very large catch (>2000 kg) of Bight redfish.

Deepwater flathead

The relative biomass estimate of deepwater flathead (day and night combined) during 2006 was about 31% lower than the 2005 estimates (Knuckey *et. al.* 2006). It is unclear whether the decline in relative biomass estimates during 2006 represents a decline in the population or simply seasonal variability in the estimate. A longer time series of surveys is needed better interpret this trend.

The CV obtained during 2006 for (0.06) was slightly higher than that obtained during 2005 (0.05) (Knuckey *et. al.* 2006).

Other species
There was considerable variation between the 2006 relative biomass estimates and the 2005 estimates for other main species. Two species showed an increase in relative biomasses estimates, while four other species showed declines in relative biomasses estimates (Figure 9 and Figure 10).

Conclusions

The 2006 Great Australian Bight resource surveys achieved all objectives. The target CVs for relative biomass estimates were achieved for both Bight redfish and deepwater flathead and the relative biomass estimates were comparable to the 2005 results. In addition, relative biomass estimates of other main species were estimated with low to medium CVs. Sufficient length-frequency and otolith samples were collected for both target species.

The survey also demonstrated that a scientifically rigorous fishery-independent survey can be consistently 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 2006 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 Mrs Anne Gason for providing the statistical analysis of the data and Ms Lauren Brown who assisted with on-board sampling during the survey.

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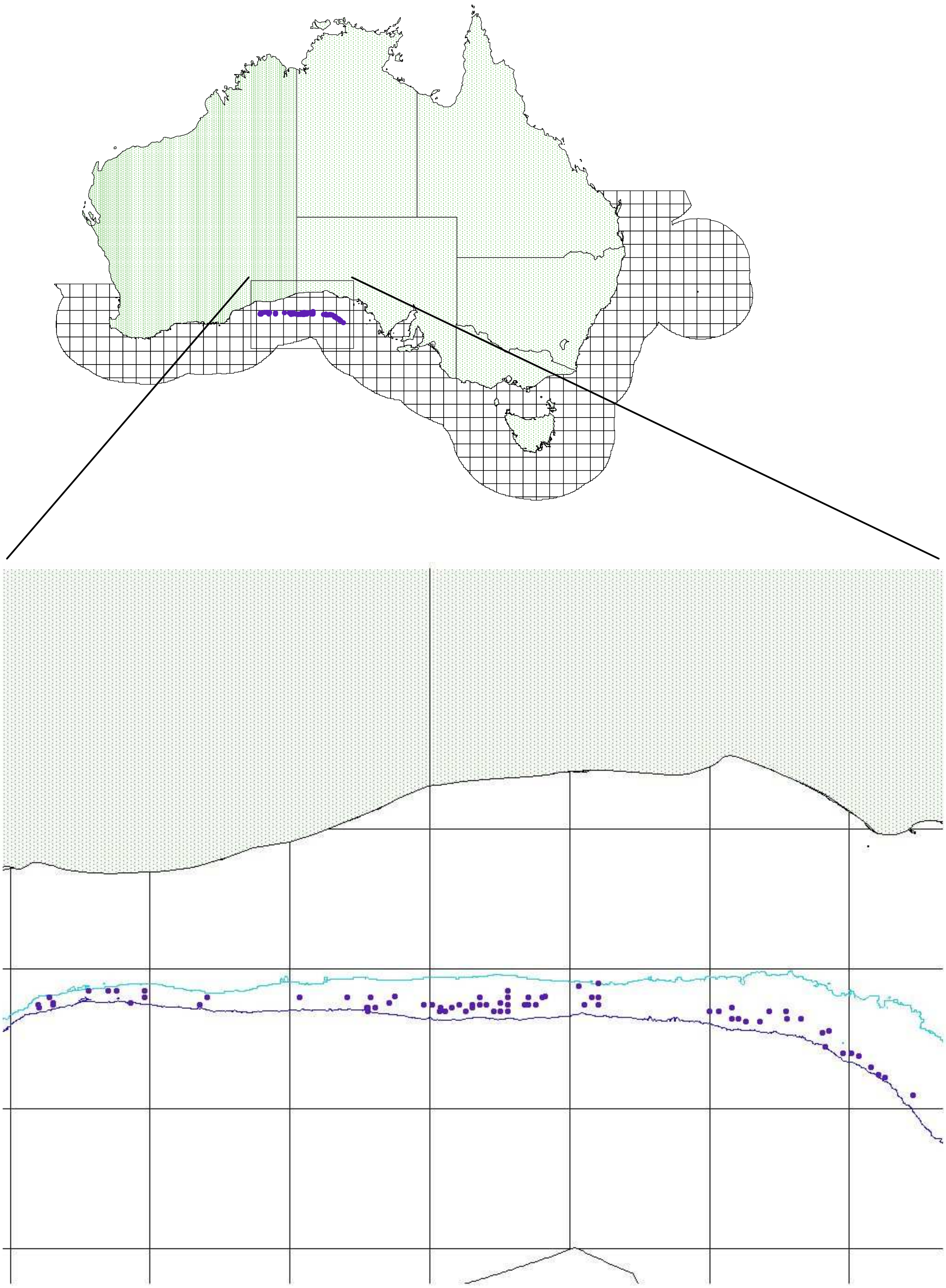

Figure 1. Shot locations of trawl survey.

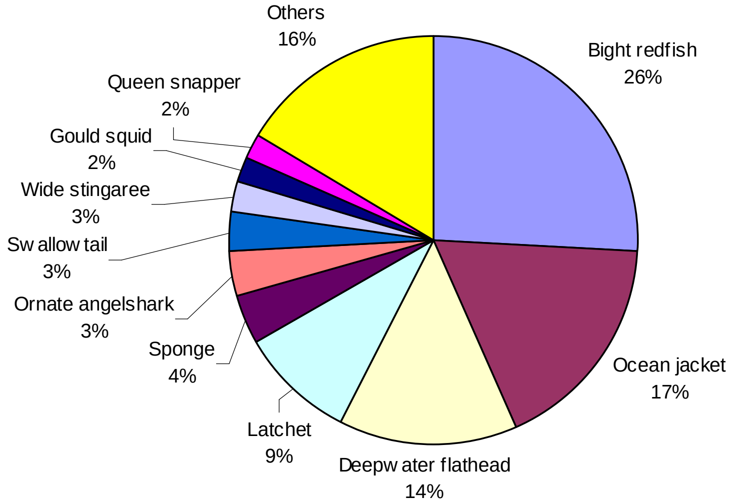

Figure 2. Proportion (of weight) of major species captured during the 2006 survey.

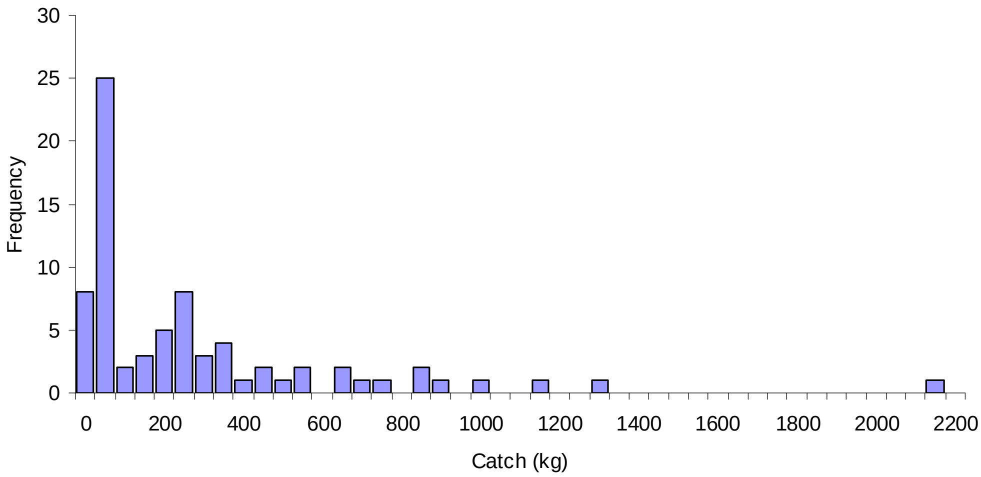

Figure 3. Frequency of catches (kg) of Bight redfish during the 2006 survey.

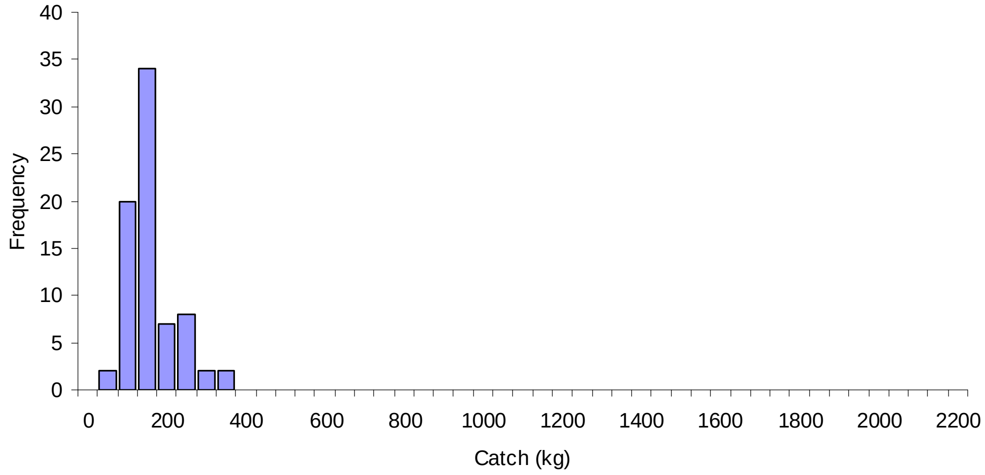

Figure 4. Frequency of catches (kg) of deepwater flathead during the 2006 survey.

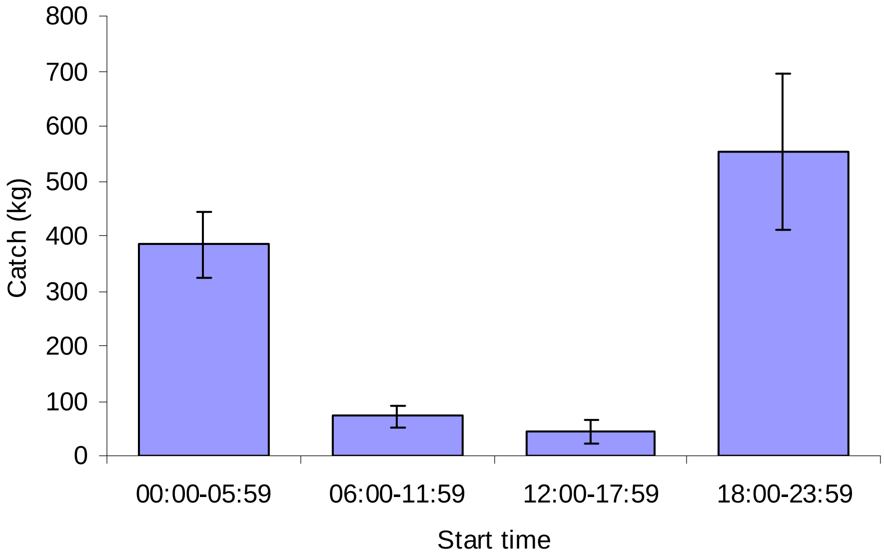

Figure 5. Mean and standard error of Bight redfish catches by time of day during the 2006 survey.

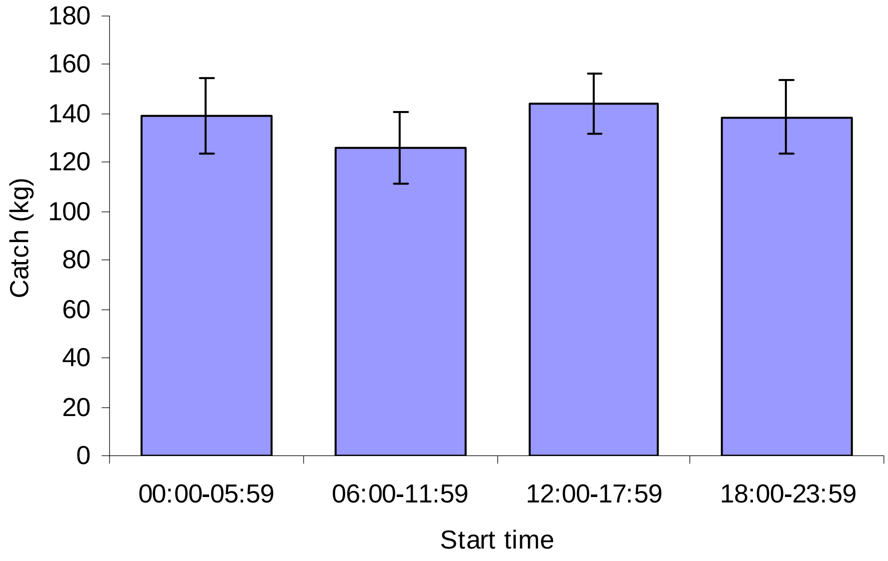

Figure 6. Mean and standard error of deepwater flathead catches by time of day during the 2006 survey.

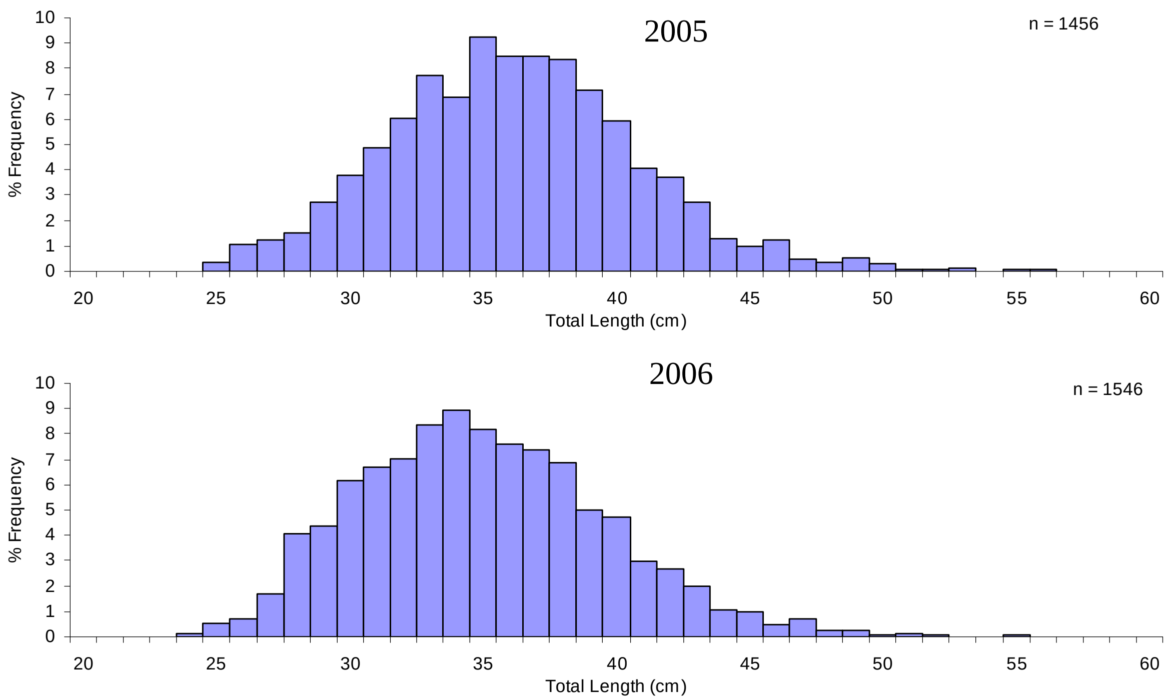

Figure 7. Length-frequencies of Bight redfish during each survey.

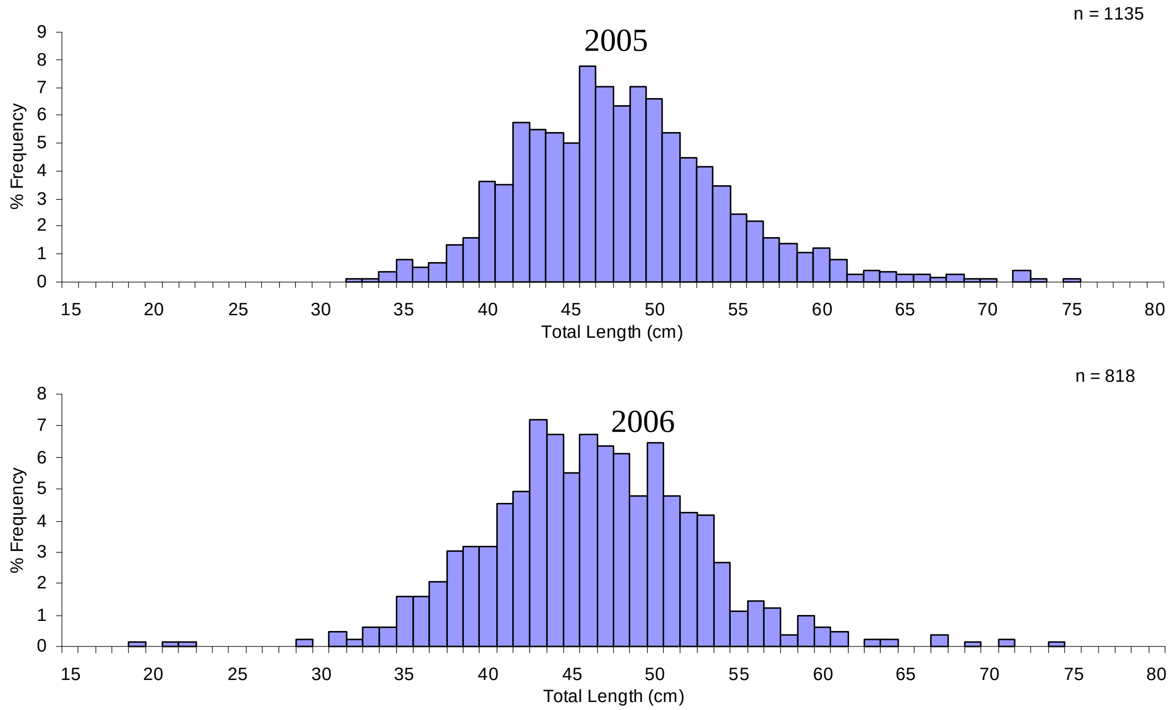

Figure 8. Length-frequencies of deepwater flathead by zone during the 2006 survey.

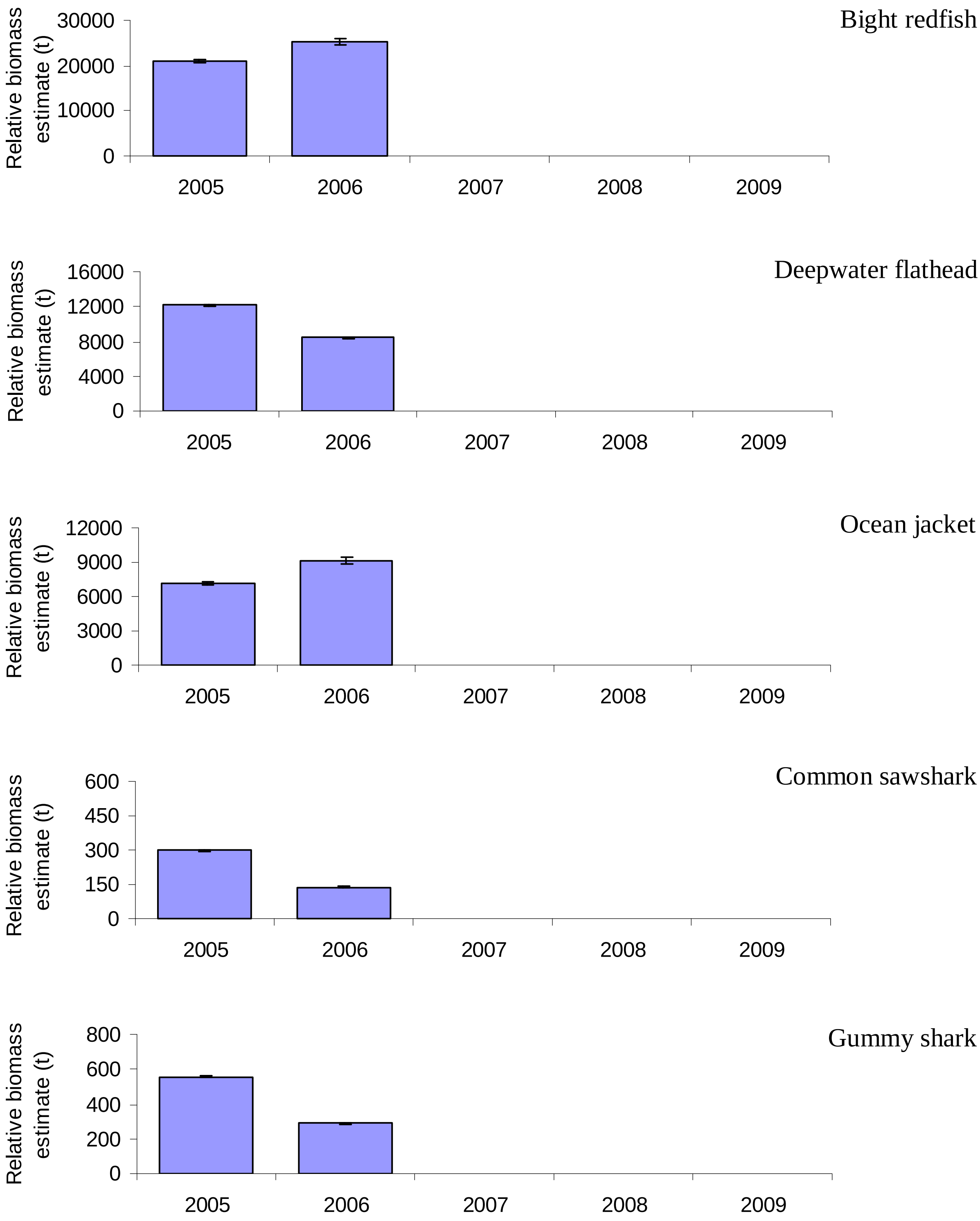

Figure 9. Relative biomass estimate (t ±SE) of Bight redfish, deepwater flathead, ocean jacket, common sawshark and gummy shark from annual surveys.

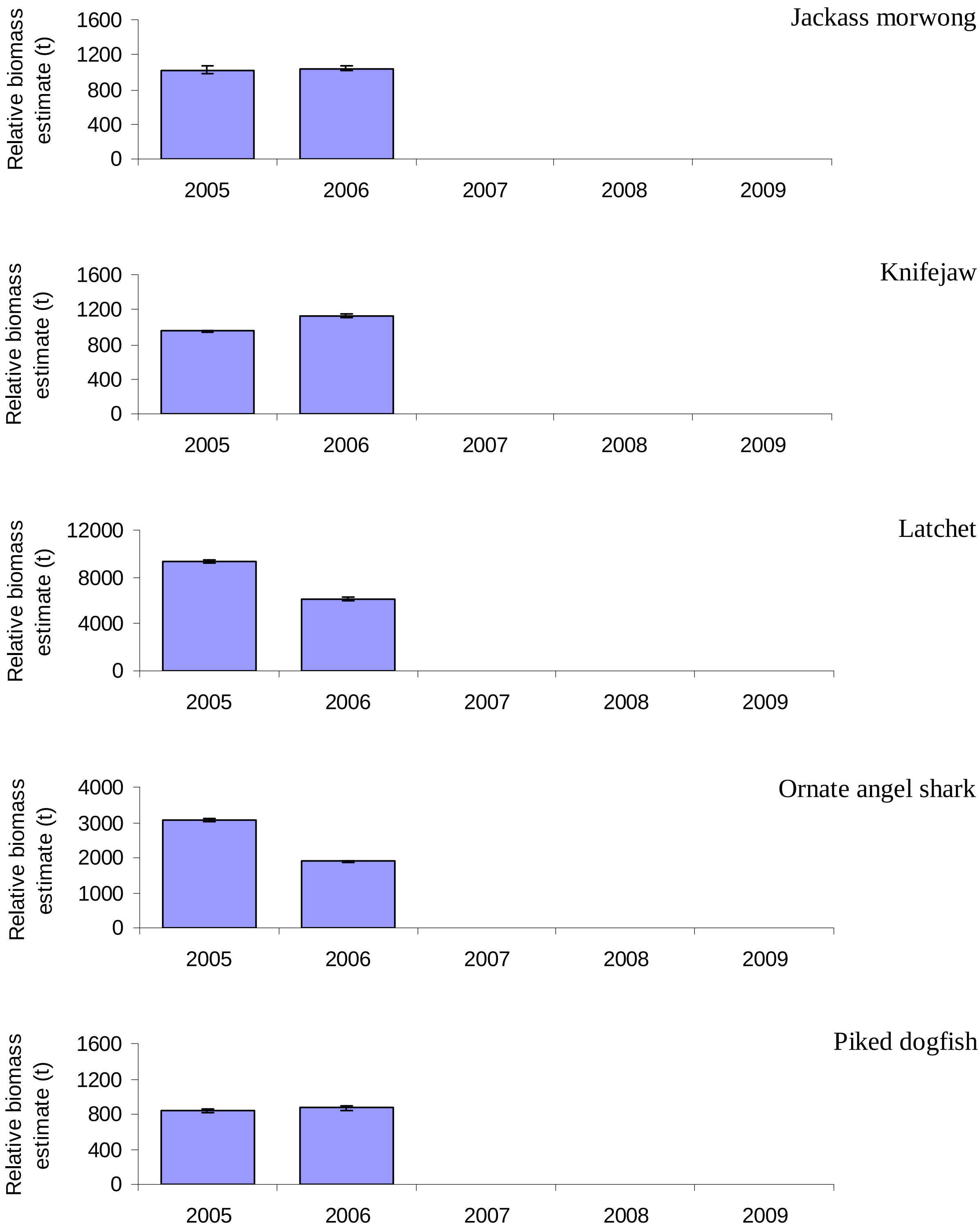

Figure 10. Relative biomass estimate (t ±SE) of jackass morwong, knifejaw, latchet, ornate angel shark and piked dogfish from annual surveys.

Table 1. Description of strata sampled during the 2006 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. 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 1	Feb	14996	323	1.636	0.084	3.24	0.06	132	6
Central 2	Feb	14950	446	1.591	0.110	3.20	0.00	138	8
West 1	Feb	15089	429	1.549	N/A	3.23	0.08	132	5
West 2	Feb	14322	988	1.508	0.114	3.25	0.10	132	5
Central 1	Mar	14823	191	1.665	0.037	3.20	0.04	133	7
Central 2	Mar	14933	627	1.718	0.145	3.22	0.13	139	15
West 1	Mar	15146	225	1.521	0.143	3.27	0.05	129	9
West 2	Mar	14909	207	1.679	N/A	3.22	0.04	129	10

Table 3. Total catch (kg) of all species in each stratum and across all strata during the 2006 survey.

Species	Catch (kg)				
	Central 2	Central 1	West 2	West 1	Total
Arrow Squid	608	253	501	205	1567
Australian Tusk	44.2	28	22	33	127.2
Bailer Shells	1				1
Barracouta	256	200	427	255	1138
Barred Grubfish	1		1		2
Bearded Rock Cod	4	11	11	0.5	26.5
Bight Redfish	9775	6112	2187	1368	19442
Bight Skate		15			15
Black Stingray	9	3	10		22
Black-Spotted Gurnard Perch	87.6	143	24	98	352.6
Blue Warehou		72		11	83
Bronze Whaler		65			65
Bugs	3.3	3.6		0.5	7.4
Ocean jacket	7826	1714	2051.5	1335	12926.5
Common Bellowsfish	4.4	1.1	1	0.6	7.1
Common Saw Shark	28.5	29	61.2	50	168.7
Coner Family (Unknown)		0.1	1		1.1
Cuttlefish	41.2	37	9	3	90.2
Cypraediae-Cowrie		0.3			0.3
Deepwater Burrfish	78	237	64	25.5	404.5
Deepwater Flathead	4444.8	2485	2281.5	1422.3	10633.6
Deepwater Stargazer	42	71	28	13	154
Degen's Leatherjacket	12	10	8	17	47
Dusky Morwong		3			3
Eagle Ray			15	15	30
Electric Ray	30	20			50
Elephant Fish		1	3		4
Fiddler Ray	9		5		14
Footballer Sweep	7	2		2	11
Four-Spined Leatherjacket	50.8	2	2.4		55.2
Gemfish	5	18	47	10	80
Giant Boarfish	6	16			22
Green-Eyed Dogfish		80	315	13	408
Gulf Gurnard Perch	9	24	2	2	37
Gummy Shark	168	72	93	45	378
Hapuku	33				33
Hard Coral	0.7	20	3	0.3	24
Hermit Crabs	1.7	4	5.5		11.2
Jack Mackerel	27	52.5	27	27	133.5
Jackass Morwong	584.5	290	195	250	1319.5
John Dory	5	8	11		24
King Crab (Tasmanian Giant)		3			3
Knifejaw	499	423	164.5	248	1334.5
Latchet	2084.8	2193	1243.7	1425.6	6947.1
Long-Finned Boarfish	145.5	211	131	97	584.5
Mosaic Leatherjacket				1	1
Numbfish		4			4
Ocean Perch - Offshore	83.2	86	10	46	225.2
Octopus			0.6		0.6
Orange Perch	0.4				0.4
Ornate Angel Shark	1390	538	370	279	2577
Piked Dogfish	117	581	134	78	910
Port Jackson Shark	132	106	20	12	270
Queen Snapper	452	484	175	254	1365
Red Cod		3	1		4
Red Gurnard	134	107	26.7	16	283.7
Redbait	12.5	9.7	12		34.2
Ringed Toadfish	118	70	88	44	320
Round Skate		21			21
Rubyfish	256	120	303	30	709
Ruddy Gurnard Perch	15	12	6	2	35
Rusty Catshark	25	59	22	8	114
Sandpaper Fish	136.5	2	5		143.5
Sandy-Backed Stingaree		5			5
Sawtail Shark		2			2
School Shark			4		4
Sea Urchin			0.2		0.2
Sergeant Baker	68	84	24	56	232
Sharpnose Seven-Gill Shark		18	3		21

Species	Catch (kg)				
	Central 2	Central 1	West 2	West 1	Total
Silver Dory	13	53	2	5.8	73.8
Silver Trevally	96	23			119
Smooth Stingray	181		255	35	471
Snapper	41	4			45
Southern Conger Eel	64	14	36	3	117
Southern Rock Lobster	5				5
Southern Saw Shark		18.2	26	2	46.2
Spiny Boxfish	19.7	11.1	3.7	7.2	41.7
Splendid Sea Perch	5.4	3.1		4.2	12.7
Sponge	334	1455	680	713	3182
Starfish	2.4	2.9	0.7	8.1	14.1
Stingray Family (Unknown)		28			28
Swallowtail	1453	236	100	556	2345
Thetis Fish	22.5	28	8.2	5	63.7
Thornback Skate		10			10
Three-Spined Cardinalfish			1		1
Tiger Flathead		2			2
Tube Worm		20			20
Veilfin	19	8	12	16	55
Velvet Leatherjacket	5	1		1	7
Western Sea Perch		10	0.5		10.5
White-Barred Boxfish	7.5	8	17.5	9	42
Whitley's Skate	60	125	35		220
Wide Stingaree	136	1608	102	2	1848
Wilson's Conger Eel	0.1				0.1
Wobbegong	40				40
Yellow-Backed Stingaree		42			42
Yellow-Eyed Snapper	84	11	29	12	136
Yellow-Spotted Boarfish	48	80	42	32	202
Total	32508.2	21045.6	12506.4	9209.6	75269.8

Table 4. Catch (kg) Bight redfish and deepwater flathead for each stratum point sampled during the 2006 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
C2-01-2006	1	33°55'	132°28'	11/02/2006	22:00	33°54.77'	132°25.92'	33°55.59'	132°29.64'	616	92
C2-02-2006	2	33°43'	132°10'	12/02/2006	01:30	33°47.20'	132°16.25'	33°42.14'	132°08.59'	421	130
C2-03-2006	3	33°27'	131°52'	12/02/2006	05:45	33°32.40'	131°58.06'	33°26.27'	131°51.31'	1102	100
C2-05-2006	5	33°37'	131°46'	12/02/2006	11:10	33°23.16'	131°26.96'	33°22.98'	131°17.16'	0	190
C2-04-2006	4	33°22'	131°07'	12/02/2006	14:45	33°22.17'	131°08.73'	33°20.92'	130°59.29'	0	160
C1-06-2006	6	33°16'	130°13'	12/02/2006	21:19	33°17.69'	130°19.23'	33°13.90'	130°12.50'	324	130
C1-07-2006	7	33°07'	130°13'	13/02/2006	01:05	33°06.40'	130°13.18'	33°14.48'	130°11.78'	486	90
C1-08-2006	8	33°16'	130°07'	13/02/2006	04:10	33°15.84'	130°10.22'	33°14.71'	130°00.92'	216	130
C1-09-2006	9	33°13'	129°49'	13/02/2006	07:15	33°14.31'	129°58.15'	33°12.89'	129°48.05'	162	200
C1-10-2006	10	33°15'	130°00'	17/02/2006	11:25	33°13.01'	129°53.01'	33°13.78'	130°01.70'	210	140
C1-11-2006	11	33°13'	129°34'	13/02/2006	12:55	33°13.86'	129°40.90'	33°13.57'	129°30.97'	2	100
C1-12-2006	12	33°16'	129°25'	13/02/2006	15:55	33°14.00'	129°28.85'	33°18.21'	129°20.57'	0	130
C1-13-2006	13	33°16'	129°19'	13/02/2006	19:15	33°16.07'	129°21.54'	33°15.97'	129°12.32'	227	210
C1-14-2006	14	33°17'	129°10'	13/02/2006	22:15	33°16.11'	129°12.02'	33°18.70'	129°02.89'	842	210
C1-15-2006	15	33°19'	129°04'	16/02/2006	10:55	33°18.37'	128°55.44'	33°19.02'	129°05.72'	2	210
W2-16-2006	16	33°17'	128°33'	14/02/2006	06:15	33°17.99'	128°37.50'	33°16.32'	128°27.66'	15	65
W2-17-2006	17	33°13'	128°04'	14/02/2006	11:30	33°13.33'	128°08.67'	33°14.18'	127°58.51'	259	140
W1-18-2006	18	33°10'	126°58'	14/02/2006	19:15	33°10.34'	127°01.32'	33°11.20'	126°51.96'	4	70
W1-19-2006	19	33°16'	126°19'	15/02/2006	00:40	33°14.66'	126°23.89'	33°15.05'	126°14.45'	240	350
W1-20-2006	20	33°17'	126°13'	15/02/2006	03:50	33°15.19'	126°15.51'	33°17.91'	126°07.08'	20	250
W1-21-2006	21	33°13'	126°17'	15/02/2006	07:05	33°16.88'	126°08.48'	33°12.87'	126°17.54'	22	280
W1-22-2006	22	33°10'	126°42'	15/02/2006	12:00	33°10.16'	126°37.95'	33°10.96'	126°47.67'	3	140

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
W1-23-2006	23	33°13'	126°58'	15/02/2006	15:25	33°12.43'	126°52.02'	33°13.32'	126°00.36'	0	140
W2-24-2006	24	33°13'	128°25'	16/02/2006	03:00	33°12.83'	128°24.46'	33°14.43'	128°33.81'	42	140
W2-25-2006	25	33°17'	128°37'	16/02/2006	06:05	33°16.28'	128°34.73'	33°16.26'	128°44.07'	132	140
C1-26-2006	26	33°19'	129°07'	16/02/2006	13:20	33°19.17'	129°05.94'	33°15.43'	129°14.30'	0	110
C1-27-2006	27	33°16'	129°13'	16/02/2006	16:35	33°15.71'	129°12.67'	33°16.67'	129°22.24'	180	140
C1-28-2006	28	33°16'	129°22'	16/02/2006	19:50	33°15.91'	129°21.37'	33°13.02'	129°30.90'	96	110
C1-30-2006	30	33°19'	129°31'	16/02/2006	23:00	33°14.69'	129°32.98'	33°13.06'	129°23.81'	360	140
C129-2006	29	33°19'	129°34'	17/02/2006	02:15	33°13.28'	129°24.29'	33°19.07'	129°32.00'	240	110
C1-31-2006	31	33°17'	129°33'	17/02/2006	05:20	33°18.99'	129°33.47'	33°15.06'	129°40.39'	180	250
C1-32-2006	32	33°13'	129°50'	17/02/2006	08:25	33°13.38'	129°41.42'	33°12.83'	129°51.40'	8	65
C1-33-2006	33	33°13'	130°10'	17/02/2006	14:25	33°12.78'	130°02.49'	33°12.50'	130°11.83'	4	140
C1-34-2006	34	33°13'	130°13'	17/02/2006	17:30	33°12.94'	130°12.10'	33°14.47'	130°22.02'	12	140
C2-35-2006	35	33°22'	131°13'	18/02/2006	00:20	33°19.10'	131°05.81'	33°21.45'	131°14.88'	120	110
C2-36-2006	36	33°22'	131°34'	18/02/2006	04:20	33°21.56'	131°28.09'	33°23.22'	131°37.87'	690	50
C2-37-2006	37	33°25'	131°46'	18/02/2006	07:25	33°23.18'	131°38.27'	33°24.88'	131°47.93'	210	110
C2-38-2006	38	33°38'	132°04'	18/02/2006	11:55	33°35.37'	132°00.60'	33°38.81'	132°09.09'	5	20
C2-39-2006	39	33°46'	132°13'	18/02/2006	15:00	33°38.88'	132°10.10'	33°46.45'	132°13.62'	9	110
C2-40-2006	40	33°47'	132°16'	9/03/2006	15:00	33°47.70'	132°19.57'	33°44.52'	132°10.35'	0	220
C2-41-2006	41	33°37'	131°58'	9/03/2006	19:00	33°38.70'	131°58.48'	33°30.77'	131°58.63'	256	90
C2-42-2006	42	33°28'	131°49'	9/03/2006	22:05	33°29.80'	131°57.39'	33°27.56'	131°47.43'	864	60
C2-43-2006	43	33°19'	131°26'	10/03/2006	02:35	33°20.36'	131°31.07'	33°20.40'	131°31.37'	448	80
C2-44-2006	44	33°22'	131°10'	10/03/2006	05:40	33°20.02'	131°19.42'	33°22.06'	131°09.46'	192	130
C2-45-2006	45	33°19'	131°00'	10/03/2006	08:50	33°21.49'	131°07.48'	33°18.92'	130°58.31'	5	140
C1-46-2006	46	33°16'	129°46'	10/03/2006	17:55	33°15.15'	129°52.06'	33°15.36'	129°42.57'	32	171
C1-47-2006	47	33°16'	129°34'	10/03/2006	21:05	33°15.24'	129°42.80'	33°15.79'	129°32.75'	960	232
C1-48-2006	48	33°15'	129°31'	11/03/2006	00:25	33°17.50'	129°33.21'	33°14.68'	129°25.02'	704	71
C1-49-2006	49	33°13'	129°22'	11/03/2006	04:15	33°12.56'	129°23.94'	33°17.37'	129°16.35'	320	140
C1-50-2006	50	33°19'	129°16'	11/03/2006	07:45	33°19.07'	129°16.92'	33°17.30'	129°07.33'	15	112
C1-51-2006	51	33°17'	129°05'	15/03/2006	01:30	33°09.99'	129°51.65'	33°11.41'	130°01.43'	160	140.8
W2-52-2006	52	33°16'	128°58'	11/03/2006	12:50	33°17.74'	129°00.78'	33°12.87'	128°53.55'	3	140
W2-53-2006	53	33°15'	128°43'	11/03/2006	15:50	33°13.01'	128°51.91'	33°15.04'	128°42.40'	30	170.5
W2-54-2006	54	33°19'	128°34'	11/03/2006	18:55	33°14.80'	128°41.06'	33°16.05'	128°32.20'	20	92
W1-55-2006	55	33°13'	127°25'	12/03/2006	04:05	33°14.79'	127°30.15'	33°12.81'	127°20.70'	224	112
W1-56-2006	56	33°15'	126°52'	12/03/2006	10:25	33°10.56'	126°48.29'	33°09.99'	126°38.46'	0	111
W1-57-2006	57	33°10'	126°34'	12/03/2006	13:25	33°09.82'	126°36.48'	33°10.56'	126°26.96'	4	70
W1-58-2006	58	33°16'	126°12'	12/03/2006	17:10	33°13.25'	126°19.62'	33°16.27'	126°10.60'	6	320
W1-59-2006	59	33°15'	126°19'	12/03/2006	20:40	33°15.14'	126°17.56'	33°13.77'	126°27.54'	1280	250.5
W1-60-2006	60	33°10'	126°46'	13/03/2006	00:45	33°04.32'	126°40.84'	33°10.03'	126°51.27'	256	112
W1-61-2006	61	33°16'	127°22'	13/03/2006	06:05	33°15.45'	127°14.08'	33°16.16'	127°29.09'	128	71
W2-62-2006	62	33°17'	128°34'	13/03/2006	14:10	33°16.26'	128°26.27'	33°15.14'	128°35.68'	3	75.8
W2-63-2006	63	33°13'	128°35'	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
W2-64-2006	64	33°12'	128°45'	13/03/2006	22:50	33°11.97'	128°43.34'	33°13.65'	128°53.19'	512	184
C1-65-2006	65	33°16'	129°01'	14/03/2006	02:15	33°15.66'	128°58.59'	33°17.03'	129°08.55'	832	210
C1-66-2006	66	33°16'	129°13'	14/03/2006	05:25	33°17.21'	129°08.56'	33°15.93'	129°28.85'	640	140
C1-67-2006	67	33°17'	129°19'	14/03/2006	08:40	33°17.01'	129°18.44'	33°19.96'	129°27.50'	32	110
C1-68-2006	68	33°19'	129°28'	14/03/2006	11:40	33°19.52'	129°27.89'	33°12.27'	129°32.35'	9	70
C1-69-2006	69	33°10'	129°34'	14/03/2006	15:05	33°09.61'	129°33.53'	33°16.61'	129°31.38'	320	120
C1-70-2006	70	33°16'	129°43'	14/03/2006	18:15	33°16.32'	129°34.01'	33°15.47'	129°44.31'	2133	142
C1-71-2006	71	33°12'	129°50'	14/03/2006	22:25	33°16.90'	129°44.43'	33°11.24'	129°50.04'	341	91
C2-72-2006	72	33°17'	131°10'	15/03/2006	09:50	33°16.43'	131°05.23'	33°19.23'	131°14.56'	64	95
C2-73-2006	73	33°23'	131°16'	15/03/2006	12:55	33°20.72'	131°14.75'	33°14.75'	131°23.37'	5	185
C2-74-2006	74	33°22'	131°40'	15/03/2006	16:55	33°21.30'	131°36.43'	33°25.06'	131°45.30'	248	100
C2-75-2006	75	33°34'	131°50'	15/03/2006	20:50	33°33.64'	131°49.81'	33°38.54'	131°57.77'	0	113
C2-76-2006	76	33°37'	132°01'	16/03/2006	00:15	33°36.82'	131°58.41'	33°39.77'	132°08.66'	533	70

Table 5. Species and numbers of fish for which length, sex, and otolith samples were collected during the 2006 survey.

Species	Length frequency	Otoliths collected
Deepwater flathead	796	240
Bight redfish	1404	561
Ocean jacket	283	
Gemfish	2	
Yellow spotted boarfish	28	
Jackass morwong	273	
Knifejaw	207	
Latchet	226	
Queen Snapper	109	
Red gurnard	18	
Ornate angel shark	8	
Long-finned boarfish	78	

Table 6. Estimated total relative biomass (t) with coefficient of variation (c.v.) of major commercial species in across all strata from 2005 and 2006 surveys assuming net width of 16.3 m.

Species	Estimated Relative biomass			
	2005		2006	
	t	c.v.	t	c.v.
Bight redfish[A]	20887	0.13	25380	0.16
Deepwater flathead	12152	0.05	8415	0.06
Ocean jacket	7163	0.14	9111	0.26
Common sawshark	298	0.16	138	0.23
Yellow spotted boarfish	349	0.19	181	0.15
Gummy shark	558	0.17	288	0.25
Jackass morwong	1025	0.34	1037	0.23
Knifejaw	955	0.12	1133	0.14
Latchet	9401	0.13	6135	0.25
Ornate angel shark	3078	0.09	1887	0.10
Piked dogfish	834	0.24	867	0.30
Other species	11693	0.13	14405	0.14

[A] night hauls only