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Resource Survey of the Great Australian Bight Trawl Sector — 2021

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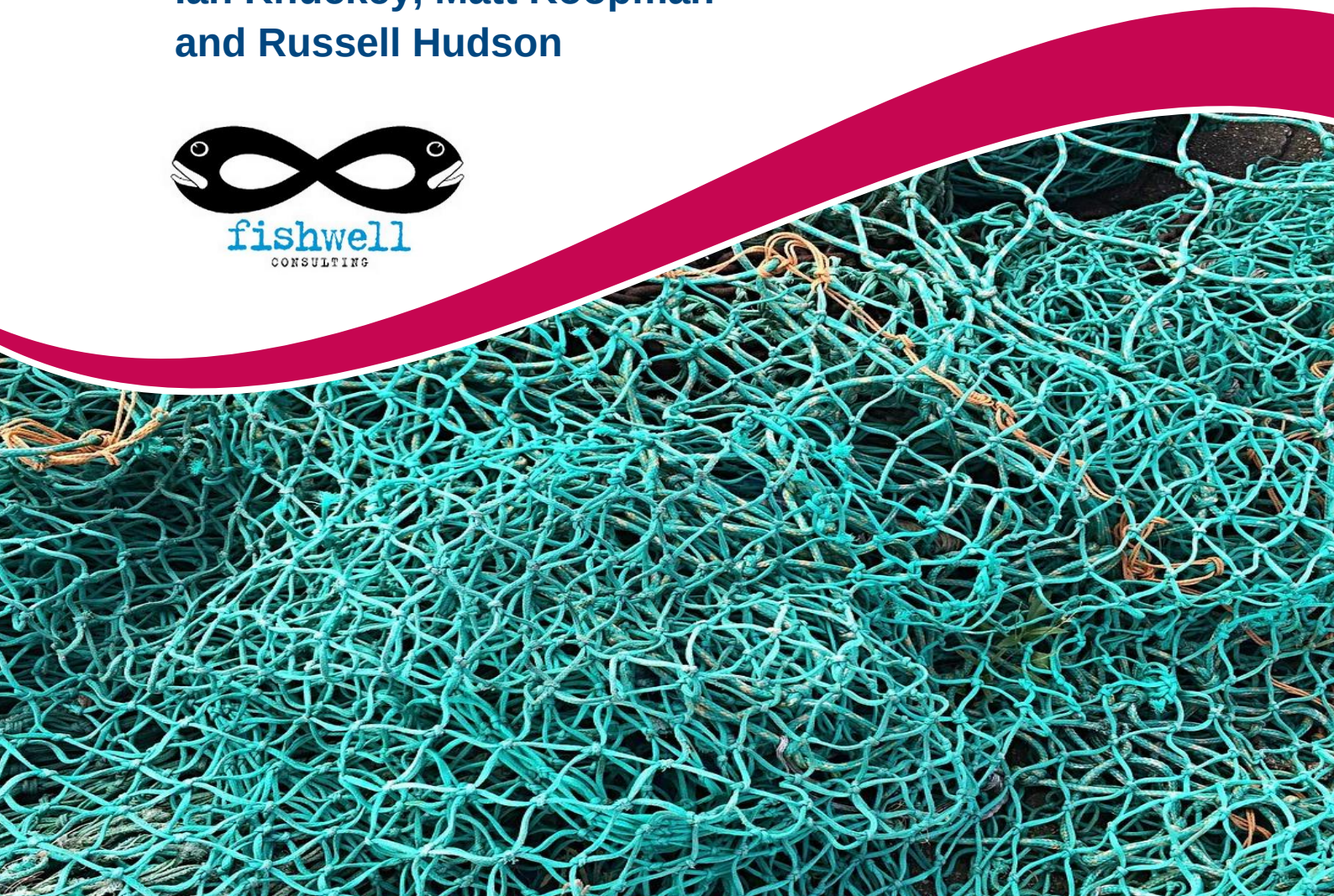
fishwell CONSULTING



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Executive Summary

Fishery-independent surveys of target species and other species important to the Great Australian Bight Trawl Sector (GABTS) were conducted in March 2021 continuing a time series of surveys commencing in 2005. Stratified random surveys involving 37 shots within four strata over an area of about 15,000 km^2 yielded precise estimates of the relative abundance of target species (CV < 0.21). Biomass estimates of Deepwater Flathead (*Neoplatycephalus conatus*) (5,225 t, CV 0.08) and, particularly, Bight Redfish (*Centroberyx gerrardi*) (3, 447 t, CV 0.21) show continued decline (2021, 2018, 2015) relative to estimates provided from surveys from 2005− 2011. However, 2021 estimates for Deepwater Flathead are more than 50% greater than 2018 estimates (3,396 t, CV 0.06).

Notably, the 2021 survey catch was dominated by Wide Stingaree (*Urolophus expansus*) (64% of total) (compared with 23% in 2018). Species composition of byproduct and bycatch species varied among strata with 86 different species or species groups recorded. Other dominant species caught included Ocean Jacket (*Nelusetta ayraud*) (10%) and Deepwater Flathead (5%). Bight Redfish comprised only 2% of the catch (compared with 11% of the total survey in 2018).

The biomass of Ocean Jacket was estimated to be 11,908 t (CV 0.64). The high variance of the Ocean Jacket estimate reflects high shot to shot variation for this species. Biomass estimates of Latchet (*Pterygotrigla polyommata*) (2,054 t, CV 0.18), Ornate Angelshark (*Squatina tergocellata*) (1,700 t, CV 0.11) and Gummy Shark *Mustelus antarcticus* (1,429 t, CV 0.09) are also noteworthy particularly for Gummy Shark which is more than double the 2018 survey estimate.

The 2021 survey continues to provide useful relative abundance estimates for other byproduct and bycatch species including Common Sawshark (*Pristiophorus cirratus*) (1022 t, CV 0.18), Yellow spotted Boarfish (*Paristiopterus gallipavo*) (167 t, CV 0.22), Jackass Morwong (*Nemadactylus macropterus*) (567 t, CV 0.22), Knifejaw (*Oplegnathus woodwardia*) (452 t, CV 0.20), and Spikey Dogfish (*Squalus megalops*) (870 t, CV 0.42). Notably, the biomass of “other species” at 70,586 t (CV 0.11) was more than four times greater than that estimated in 2018 (16,256 t, CV 0.24). This increase was driven mainly by substantial catches of Wide Stingaree that comprised 82% of the catch weight for the 2021 survey.

The length-frequency of Bight Redfish was skewed towards the modal length of 28 cm. The mean size of Bight Redfish has decreased since surveys began with 45% of Bight Redfish below 30 cm (9% in 2005). In contrast, the length of Deepwater Flathead has remained relatively constant across surveys.

1 Introduction

Fishery-independent trawl surveys have been an important part of assessment and management of the Great Australian Bight trawl sector (GABTS) since surveys began in 2005 (Moore et al. 2020). The GABTS forms part of the Southern and Eastern Scalefish and Shark Fishery (SESSF). The GABTS targets two main species: Deepwater Flathead (*Neoplatycephalus conatus*) and Bight Redfish (*Centroberyx gerrardi*) on the upper continental slope of the Great Australian Bight using otter trawl or Danish-seine methods (Moore et al. 2020). These two species are managed under a total allowable catch (TAC) regime set every five years (Moore et al. 2020).

Surveys engage commercial vessels equipped with a 'standard' research net to avoid biases in catchability or other gear-related sources of variation (Knuckey and Gason 2006, Knuckey et al. 2006). Annual surveys have been undertaken on the main fishing grounds (February to April) up to 2009 (Knuckey and Hudson 2007 a.b., Knuckey et al. 2008, 2009). Thereafter, surveys have been conducted periodically: 2011 (Knuckey et al. 2011), 2015 (Knuckey et al. 2015), and 2018 (Knuckey et al. 2018).

A review (O'Driscoll and Doonan 2015) reinforced the value of the surveys. In particular, use of standard gear yields precise relative biomass estimates of target species (and other important species in the fishery) complementing stock assessment and providing valuable input into the TAC setting process (Moore et al. 2020). However, O'Driscoll and Doonan (2015) and Knuckey et al. (2017) noted large decreases in the abundance of target species (particularly Bight Redfish). This prompted a decrease in the total allowable catch (TAC) for Bight Redfish (Moore et al. 2020) and a recommendation of a survey frequency more than once every four years. O'Driscoll and Doonan (2015) also suggested that survey gear standardisation would be improved with net sensors – this has since been implemented (Knuckey et al. 2018).

In addition to provision of relative abundance (biomass) estimates, surveys also yield useful biological and environmental information including: composition of byproduct and bycatch species; length-frequency data for target species, length at age, and temperature/depth data. This current survey (2021) continues the time series of fishery independent surveys of Great Australian Bight trawl fish stocks.

2 Objectives

1. To obtain a relative abundance index for Bight Redfish and Deepwater Flathead.
2. To collect biological and population data on Bight Redfish and Deepwater Flathead.
3. To determine a relative abundance index of other main byproduct and bycatch species in the shelf fishery.
4. Continue to collect general species composition data and temperature-depth data to monitor long-term changes in demersal fish assemblages.
5. To prepare all survey information available for use in fishery stock assessments.

3 Material and Methods

3.1 Survey Design

The survey was restricted to depths of 120–200 m and between longitude 126º00’ and 132º30’. Although fishing occurs outside this spatial and depth range, the area represents the main fishing grounds of the upper shelf component of the fishery. The longitudinal range was divided into four primary strata; 126º00’–127º45’(West1), 127º45’–129º00’ (West2), 129º00’–130º15’ (Central1), 130º 45’–132º30’ (Central2) (Table 1, Figure 1). Surveys are usually undertaken between February and April of any year: the current survey was completed in one trip from March 20-28, 2021.

As in previous surveys, a “standard” net was used to reduce any gear-related sources of variation in abundance. Detailed descriptions of vessel and gear specifications are provided by Knuckey et al. (2006). A comprehensive description and images of the standard net specifications used in the surveys are provided in Appendix 1.

The number of shots allocated to each stratum was proportional to the catch-weighted standard deviation of CPUE to achieve a coefficient of variation (CV) for estimated means of target species < 0.2. Shot locations were selected randomly within each stratum. In general, each survey shot is of 2.5 hours duration (from the time the net reaches the bottom to the time retrieval begins). 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, it can still be considered acceptable if towed for a minimum of 1 hour and transiting the position. The start and finish position of each shot was recorded as were minimum and maximum depths, average trawl speed, environmental conditions and direction of tow.

Shots were completed in a specified order to reduce temporal biases in the data collection. However, this was occasionally changed for logistical reasons. Shots were undertaken at a speed ranging from 3.1 to 3.4 knots, with the skipper deciding on the starting position and the direction of the tow. Following completion of the shot, the net is hauled aboard and the catch sorted on deck. Commercial species were gathered in fish bins and catches of target species and important byproduct species were weighed to the nearest 100 g using calibrated motion-compensated scales (Knuckey et al. 2018). Discarded bycatch was identified to species where possible and an approximate weight of each species estimated. Length measurements of Deepwater Flathead and Bight Redfish were collected randomly during the survey: total length was measured for Deepwater Flathead and fork length for Bight Redfish. Otolith samples of the two species were also collected randomly during the survey recording the length and sex of each fish processed.

3.2 Calculation of Relative Biomass and Coefficient of Variation

Each shot provides a density estimate calculated by dividing the biomass of the catch of a particular species by the area swept by the net. Mean density is then estimated (with an associated coefficient of variation) from all shots within each stratum:

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

Total biomass can then be estimated (for each species) as the product of mean density and total area following a stratified random survey design (Schnute and Haigh, 2003) (Knuckey et al. 2018).

3.2.1 Determining the density

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

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

The squared inverse of the coefficient of variation (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 for each stratum *h* is

$$b_h = A_h \delta_h$$

The CV of the biomass estimate for 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 weight in kilograms per area swept (m^2) of species where catch >zero, s_h is the standard kilograms per area swept (m^2) of species where catch >zero, A_h is the total area of stratum, n_h is the number of shots and b_h is the estimated relative biomass.

Total relative biomass (*B*) 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 estimated as follows

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

Where each shot *i* in stratum *h* has a known catch of C_{hi}, effort (shot duration hour) E_{hi}, vessel speed (m/hour) v_{hi} and net width d_{hi}, where net width was estimated to be 50% of the headline length (16.3m).

The swept area of the trawl net can be expressed as either the area swept by the net or the area swept by the doors. Net width was estimated as 50% of the headline length whereas 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 was then multiplied by the length of the warp let out (*WL*):

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

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.

3.2.2 Quality Assurance

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

As for the 2018 survey, all analyses were undertaken using R (R Core Team, 2021).

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

4 Results and Discussion

4.1 Survey Coverage

The stratified random survey of the GABTS sampled 37 sites within four strata covering an area of about 15,000 km^2 during March 2021 (Figure 1, Table 1). The mean shot lengths were similar among strata (15.8 km – 16.2 km), as were areas swept (0.254 km^2 – 0.265 km^2), and shot depth (128m – 135m) (Table 2).

4.2 Gear Performance

Door spread, as the main indicator of gear performance, was measured with a net monitor on 25 occasions with values ranging from 120 – 144 m. Mean door spread was 130.7 m (± 5.2 m SD) and is the value applied for biomass estimates in the current survey. This value was similar to that measured in 2018 (121.7 ± 6.1).

4.3 Catch Composition and Length Frequencies

The total catch from the 37 shots undertaken during the 2021 survey was 65.7 t, and comprised 86 different species or species groups (Table 3). Most of the catch comprised Wide Stingaree 41.9 t (64%), Ocean Jacket 6.7 t (10%) and Deepwater Flathead 3.4 t (5%) (Figure 2). Bight Redfish comprised only 2% of the catch (1.2 t) as did Ornate Angelshark and Latchet. Other species comprised 14% of the total catch. Species composition varied among strata. In particular, the Central2 stratum was dominated by Ocean Jackets (52% of the catch, 5.0t) with Deepwater Flathead (8%, 0.8t), Bight Redfish, Latchet and Wide Stingaree comprising 7% of the catch (0.7t) (Figure 3, Table 3). In contrast, catches from the other strata were dominated by Wide Stingaree (68% - 82%) and Deepwater Flathead (4%-6%). Of these other strata, Bight Redfish was caught only in Central1 (2% of the catch) and Central 2 (7% of the catch) (Figure 3, Table 3). The decrease in abundance of Bight Redfish reflects a considerable decline in Bight Redfish catches but also increased catches of other species such as Wide Stingaree (12% in 2005 – 64% in 2021). The proportion of the total catch comprising Deepwater Flathead was 19% in 2005 but has since decreased to 5%.

The current dominance of Wide Stingaree in the catch is in contrast to previous surveys: early surveys featured a high proportion of Bight Redfish in the catch (>20%) together with Deepwater

Flathead (~ 12%) and Ocean Jackets (12% - 35%) (

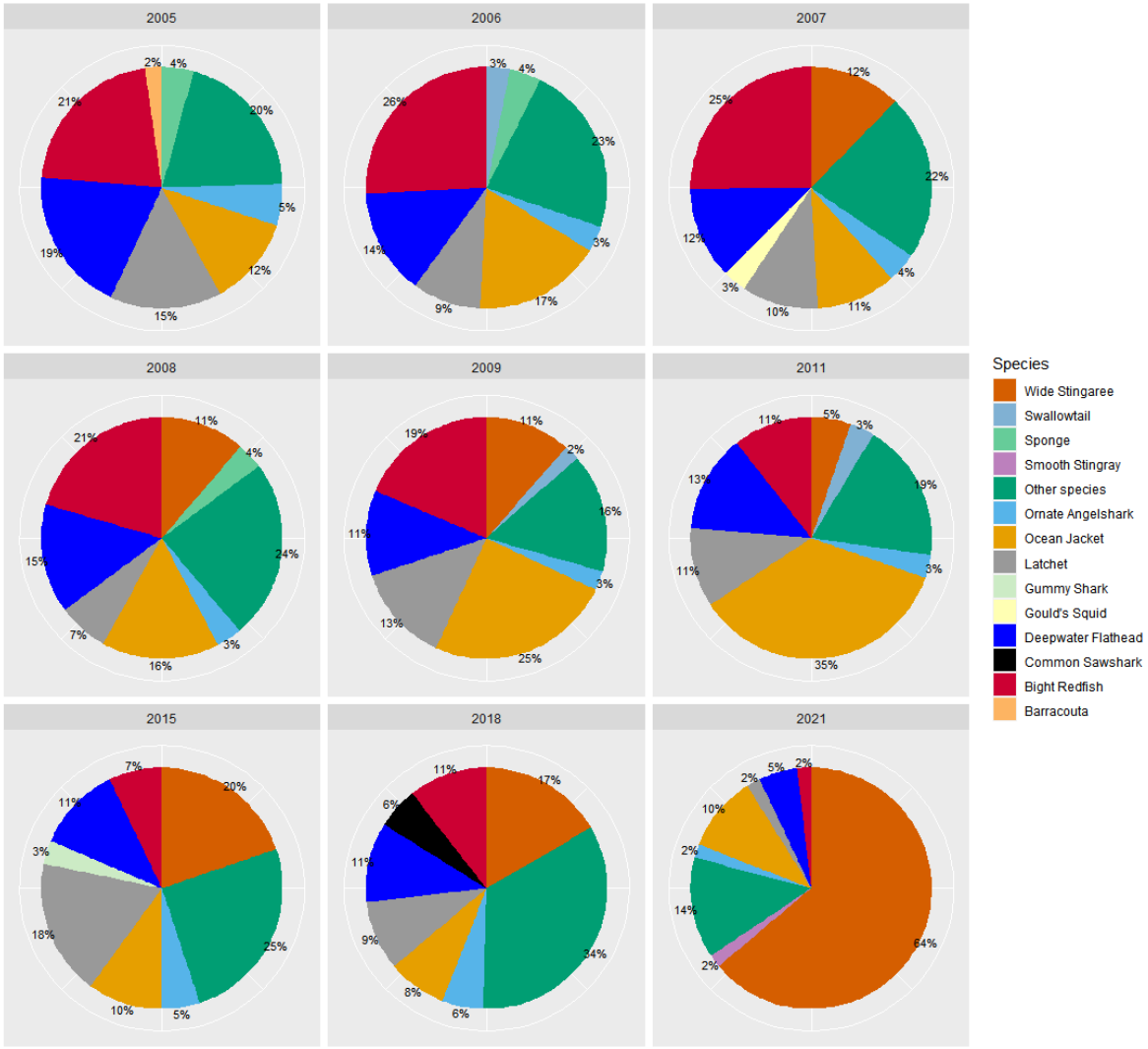

Figure 4Figure 4). Since 2015 and particularly for 2021, relative catches of Wide Stingaree have increased (Figure 4).

Catches of Bight Redfish were positively skewed, with most catches less than 50 kg (Figure 5, Table 4). Only two shots caught more than 200 kg with a further three shots between 50 kg and 100 kg: most were below 100 kg (Table 4). Catches of Deepwater Flathead were more consistent, with most catches between 50 – 100 kg (Figure 5, Table 4). Eleven shots caught more than 100 kg with the highest catch of Deepwater Flathead (249 kg) caught 24th March 2021.

On average, catches of Bight Redfish were highest in shots that commenced in the morning between midnight and 06:00, and lowest in shots commencing between 6:00 and 17:59 hours (Figure 6). Catches of Deepwater Flathead were more consistent with the mean catch per shot highest in shots commencing between 06:00 and 17.59 (Figure 6).

There was a large difference in mean catch per shot of Bight Redfish among strata, with higher catches in the two Central strata (in particular Central2) compared with the Western strata (Figure 7). However, variability among shots masks variation among strata except for the low catch per shot of Bight Redfish for West2 (Figure 7). Catches of Deepwater Flathead were similar among strata although, in general, catch per shot was higher in West1 than in the other strata (Figure 7).

The lengths of 422 Bight Redfish were measured during the 2021 survey (Table 5). Lengths ranged 28 – 52 cm but, compared with previous surveys, were positively skewed with most fish measured were between 27 – 32 cm (Figure 8). The modal length was 28 cm continuing a decreasing trend shown from past surveys (Figure 8). The current results show a decrease in the modal length compared with previous surveys, and a reduction in large fish, particularly those 35 cm or longer: more than 45% of Bight Redfish surveyed were below30 cm in length (Figure 8).

The lengths of 757 Deepwater Flathead were measured during the 2021 surveys (Table 5). Lengths ranged 32 – 79 cm but most fish measured were between 40 – 45 cm (Figure 8). The modal length was 43 cm. In contrast to Bight Redfish, the modal size of Deepwater Flathead was similar among surveys (Figure 8). However, the time series shows a gradual decrease in the frequency of larger fish (Figure 8).

Otoliths were collected from 94 Bight Redfish and 165 Deepwater Flathead (Table 5).

4.4 Relative Biomass Estimates

4.4.1 Bight Redfish

Using only night shots (18:00 – 05:59 hours), the relative biomass estimate of Bight Redfish for the 2021 survey was estimated to be 3,447 t with a CV of 0.21 (Table 6). This estimate is lower than, but not significantly different from, the estimate of 4,053 t in 2018. The relatively high variance reflects the high among-stratum variation. However, the 2021 estimate is more precise than that in 2018 (CV 0.25) or 2015 (CV 0.28). More generally, since 2011 there has been a substantial decline in the biomass of Bight Redfish (Table 6,Figure 9.

4.4.2 Deepwater Flathead

Using both day and night time shots, and net-width in swept-area calculations, the relative biomass estimate of Deepwater Flathead was 5,225 t with a CV of 0.08 (Table 6). This estimate is 54% higher than the 2018 estimate of 3,396 t, and 3% higher than the 2015 estimate of 5,065 t (Figure 9). However, these values are all significantly lower than biomass estimates of Deepwater Flathead from previous surveys (Figure 9).

The CV of biomass estimates for Deepwater Flathead was low (0.08), and within the range calculated from previous surveys 0.05–0.09.

4.4.3 Other species

Relative biomass estimates for a number of other important GABTS species are also shown (Table 6). Notably, the relative biomass of Ocean Jacket was estimated to be 11,908 t. This is significantly greater than the estimate for 2018 (2,706) (Figure 9). However, the estimate of Ocean Jacket had a high variance (CV 0.64) reflecting high shot to shot variation in catches (Figure 9) and large differences in the relative proportion of Ocean Jacket among strata (Figure 3). The biomass estimated for other important species included Latchet (2,054 t, CV 0.18), Ornate Angelshark (1,700 t, CV 0.11) and Gummy Shark (1,429 t, CV 0.09) (Table 6). Although the estimate for

Gummy Shark is the greatest biomass recorded since surveys began, it is not significantly different to the value recorded in 2015 (Table 6).

Figure 10shows a decrease in the biomass of Latchet and an increase in the biomass of Spiky Dogfish compared with 2018 estimates. More generally, biomass estimates of Jackass Morwong have been relatively constant across nine surveys. Similarly, estimates of Knifejaw have been homogeneous for the past three surveys but collectively show a decrease in biomass compared with 2011 estimates (Figure 10).

Notably, the biomass of "other species" at 70,586 t (CV 0.11) was more than four times greater than that estimated in 2018 (16,256 t, CV 0.24). This increase was driven mainly by substantial catches of Wide Stingaree (*Urolophus expansus*) that comprised up to 82% of the catch weight (Stratum West2). Although, Wide Stingaree was unusually abundant in this survey, there was substantial spatial variation in abundance with Stratum Central2 showing 7% of Wide Stingaree by catch weight (Figure 3).

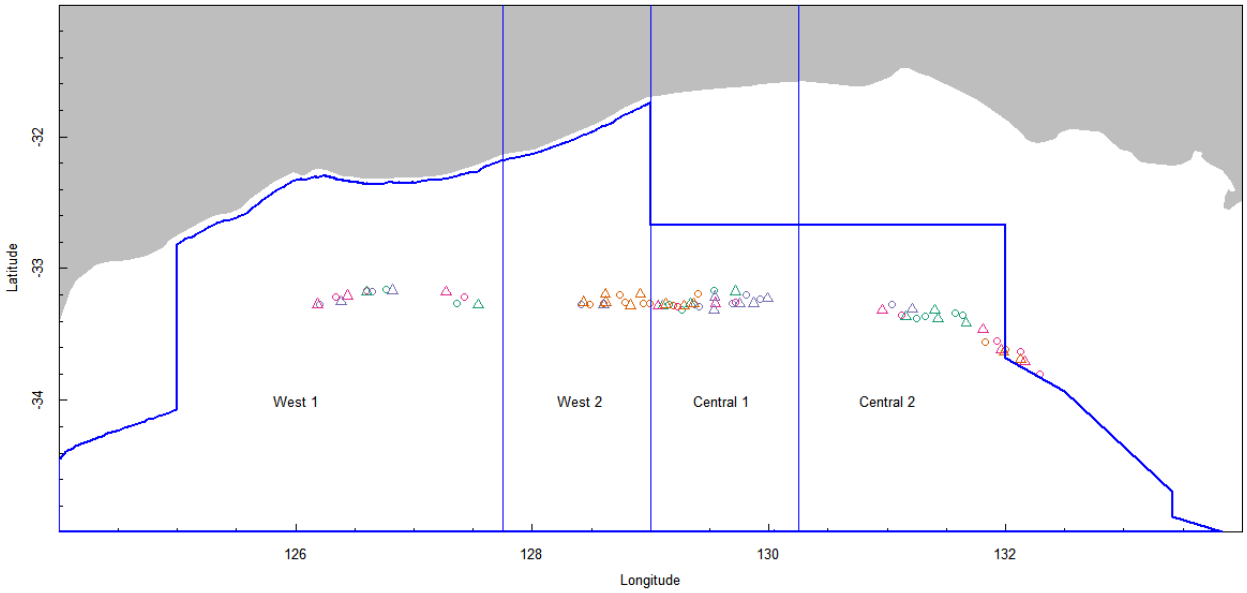

Figure 1. Survey strata and start and end shot locations of trawl survey.

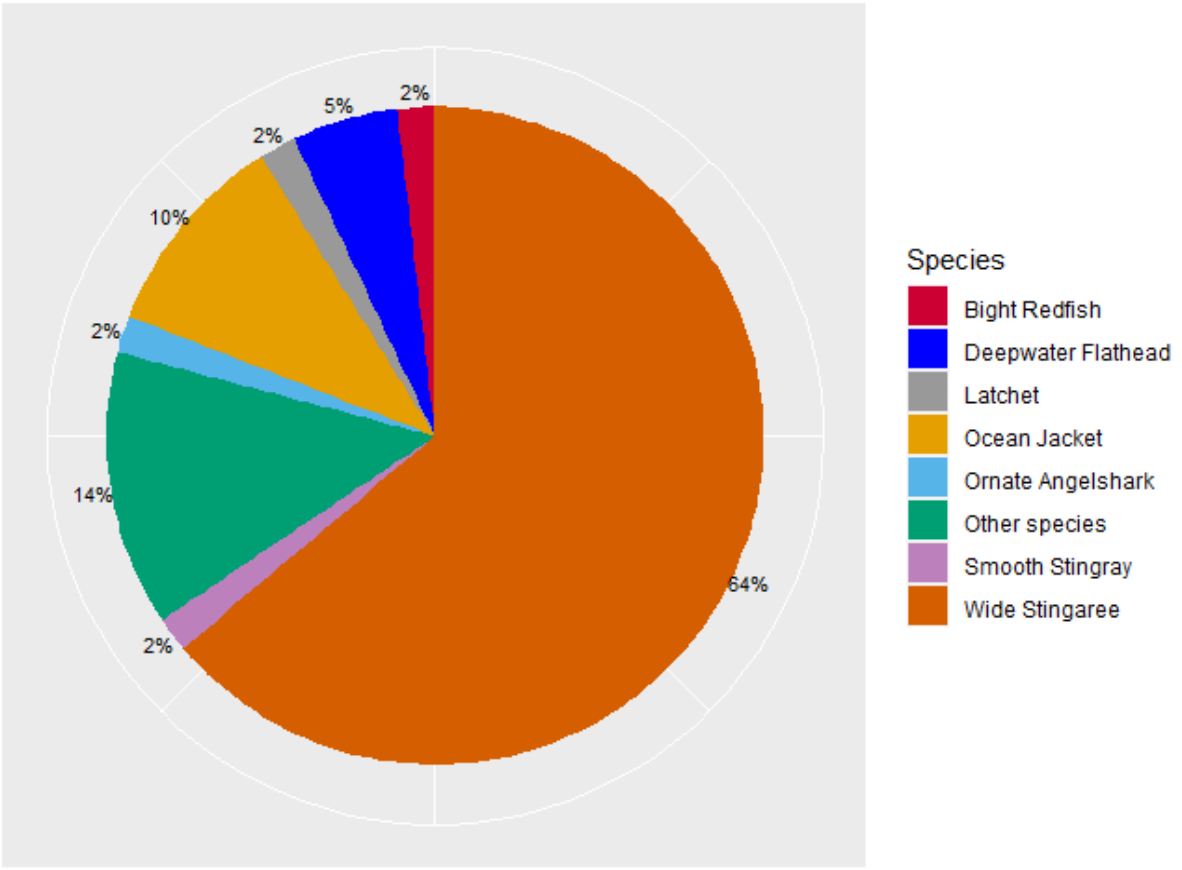

Figure 2. Overall percent weight of major species caught during the 2021 survey.

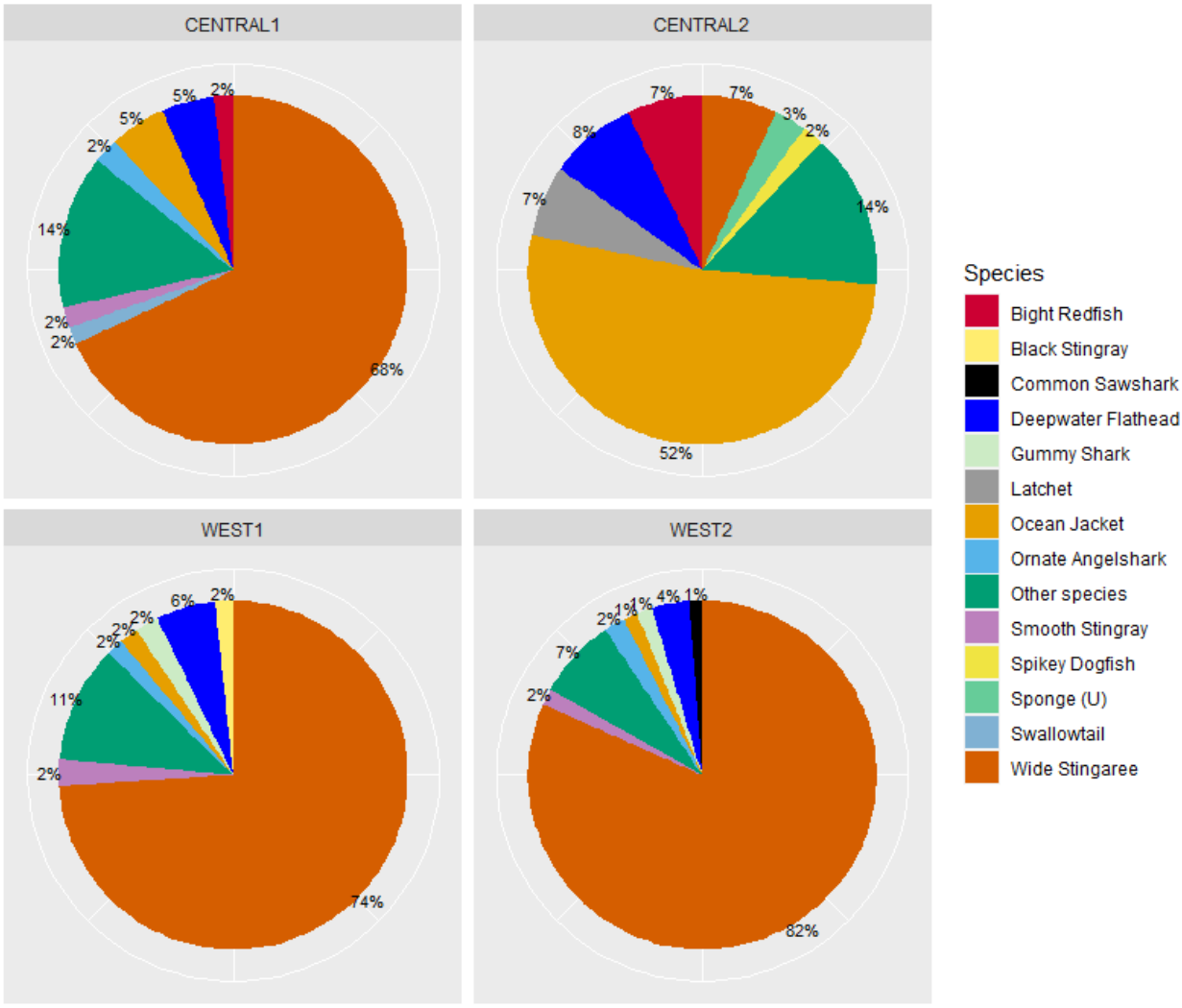

Figure 3. Percent weight of major species captured by stratum during the 2021survey.

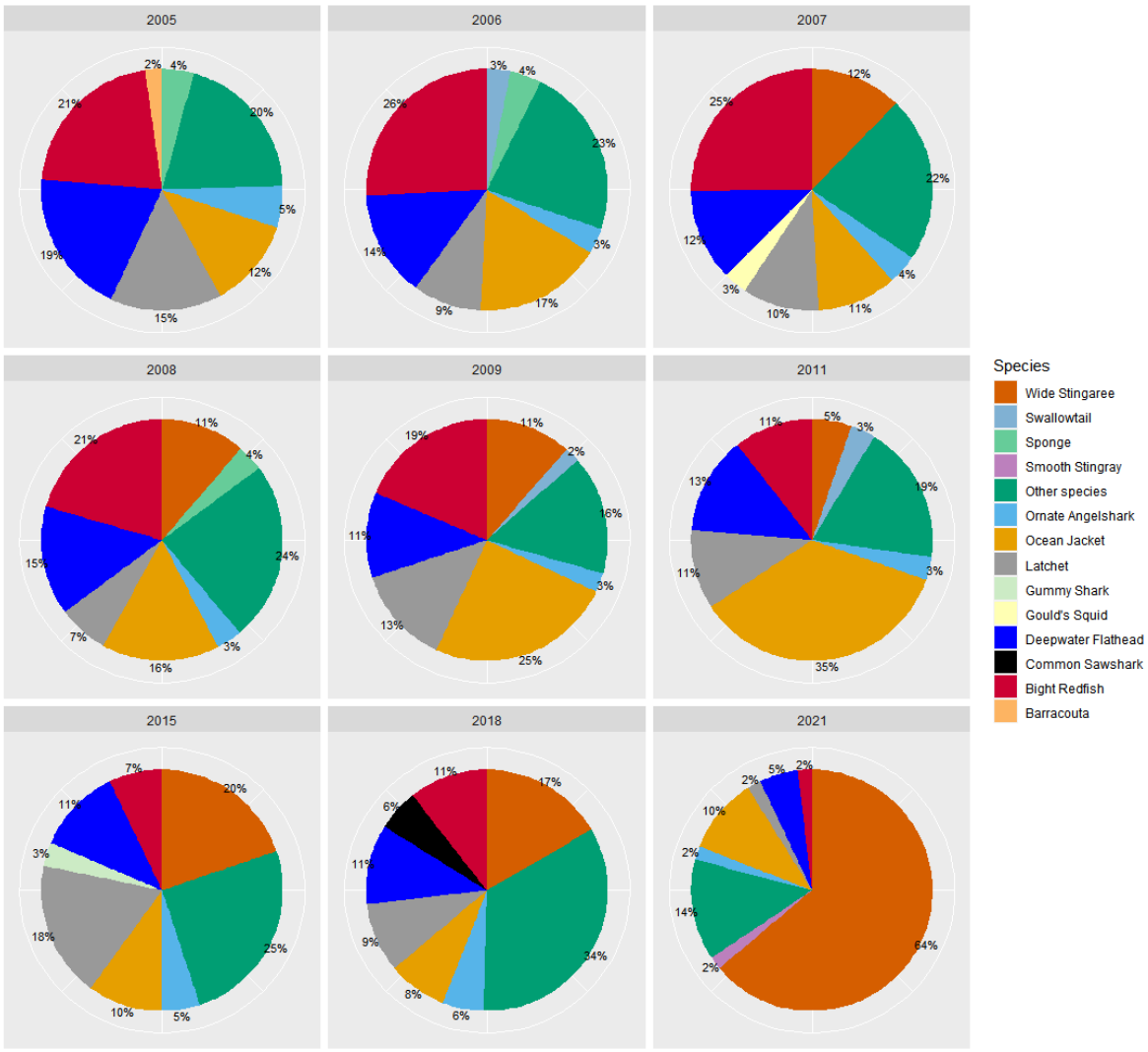

Figure 4. Percent weight of major species captured during each survey.

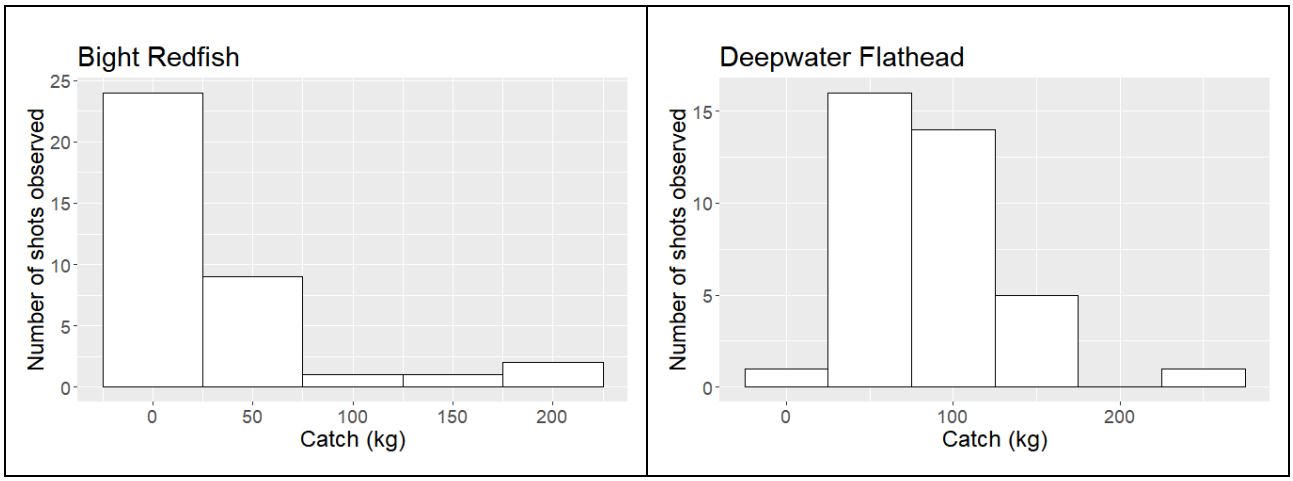

Figure 5. Frequency of catches (kg) of Bight Redfish and Deepwater Flathead during the 2021 survey.

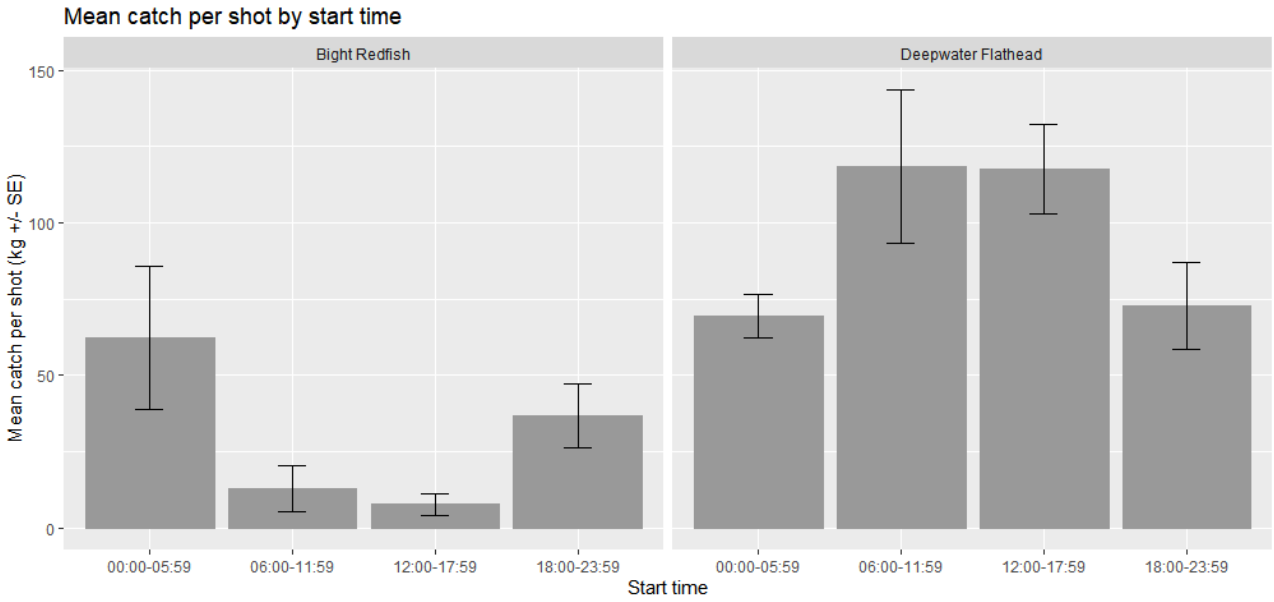

Figure 6. Mean and standard error of Bight Redfish and Deepwater Flathead catches by time of day during the 2021 survey.

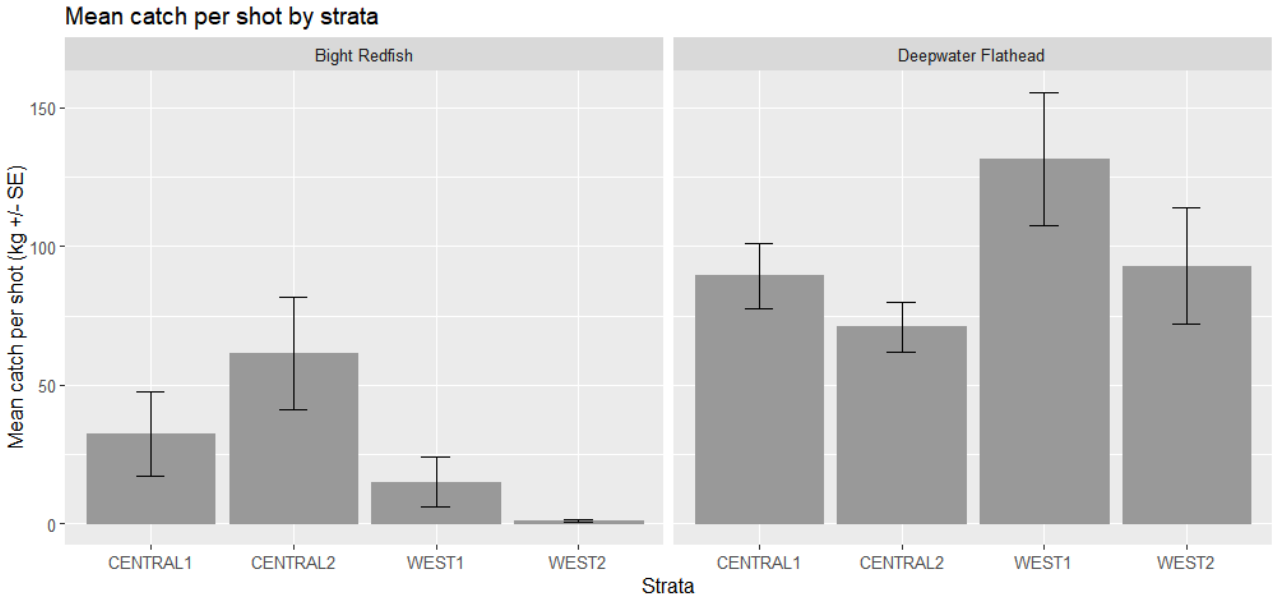

Figure 7. Mean and standard error of catches by stratum during the 2021 survey.

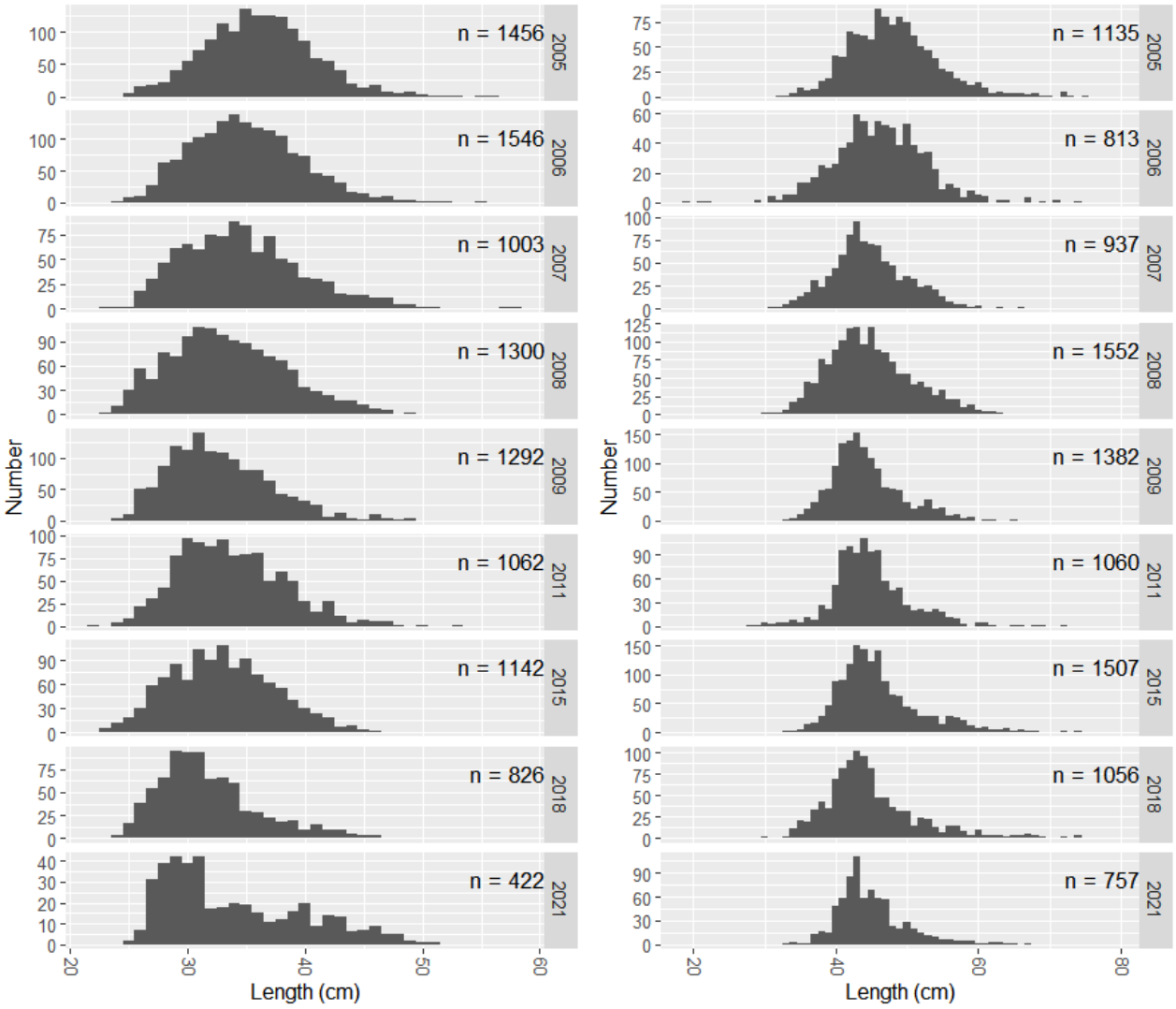

Figure 8. Length-frequencies (total length) of Bight Redfish and Deepwater Flathead during the 2005–2021 surveys.

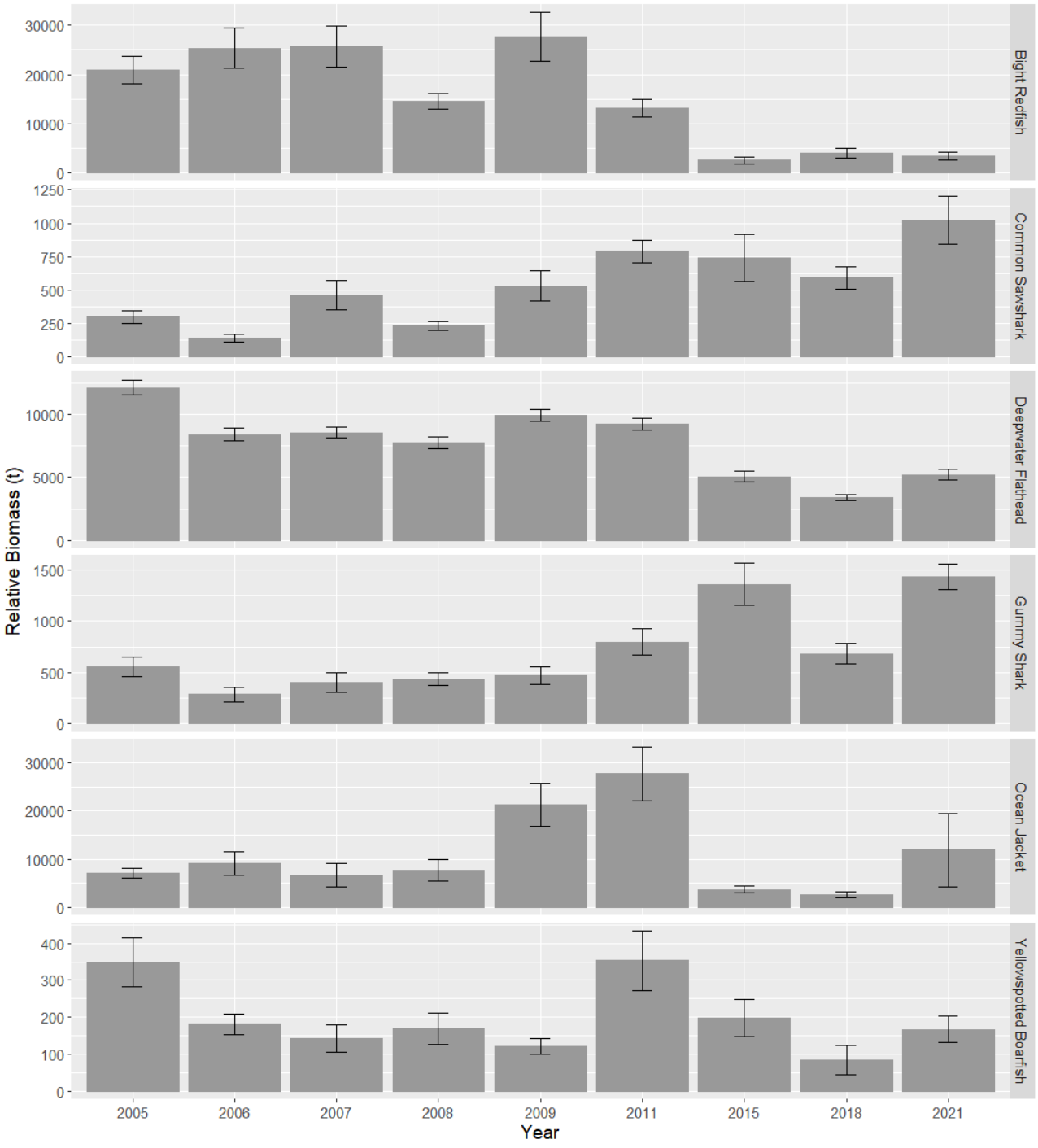

Figure 9. Relative biomass estimate (t ±SE) of Bight Redfish, Common Saw shark, Deepwater Flathead, Gummy Shark, Ocean Jacket and Yellow-spotted Boarfish from annual surveys. Note that 2015 relative biomass calculated using data from trip 2 only.

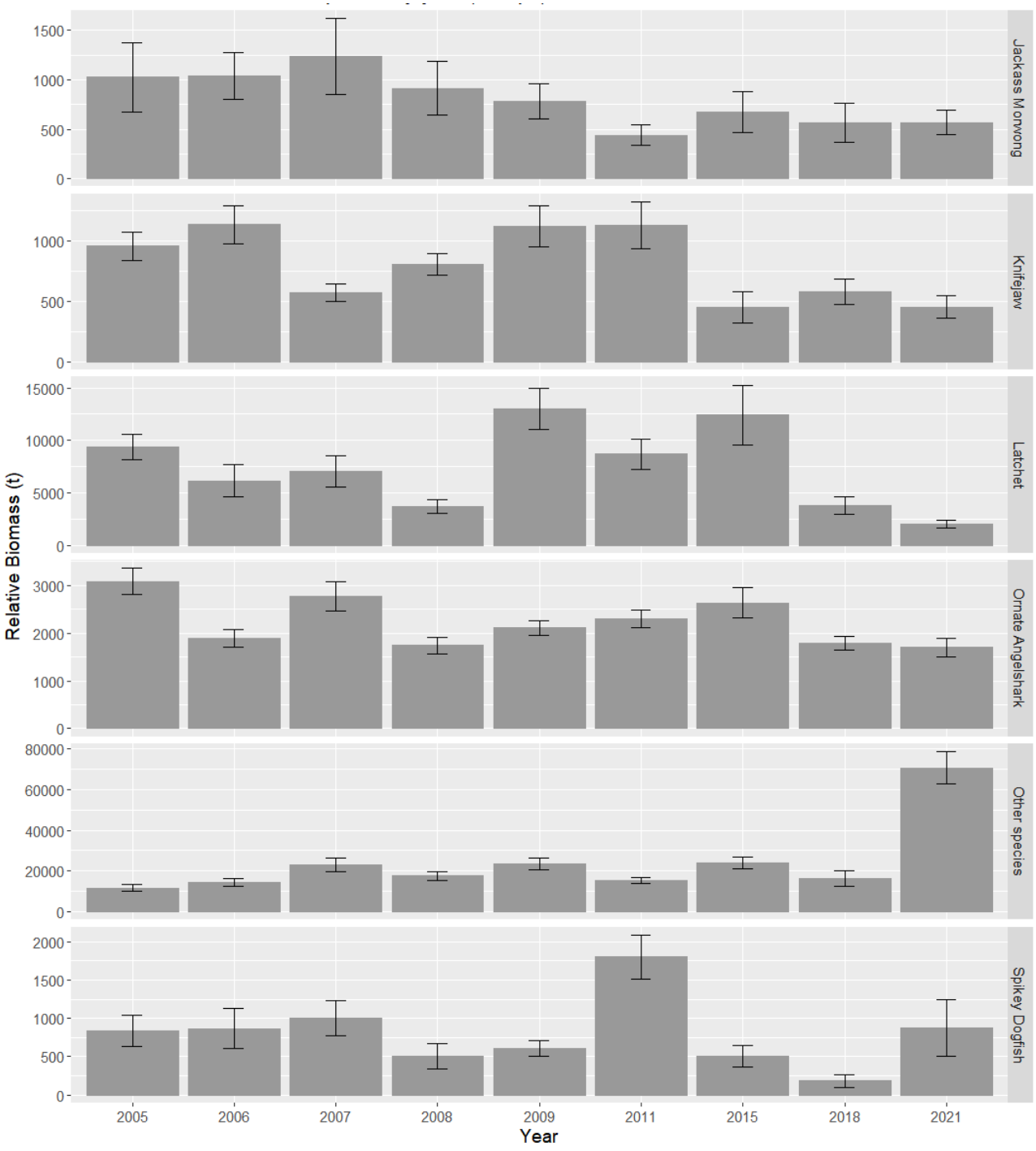

Figure 10. Relative biomass estimate (t ±SE) of Jackass Morwong, Knifejaw, Latchet, Ornate Angelshark, Spikey Dogfish and all other species from annual surveys. Note that 2015 relative biomass calculated using data from trip 2 only.

Table 1. Description of strata sampled during the 2021 survey.

Stratum	Depth (m)	Longitude	Area (km2)	Number of shots
Central 2	120–200	130.75–132.50	5720	11
Central 1	120–200	129.00–130.25	3965	13
West 2	120–200	127.75–129.00	2700	6
West 1	120–200	126.00–127.75	2600	7

Table 2. Mean and standard deviation (SD) length (m), swept area (km^2), speed (knots) and depths (m) of shots in each stratum during the 2021 survey.

Trip	Stratum	Shot length		Area swept†		Shot speed		Shot depth	
		Mean (km)	SD	Mean (km^2)	SD	Mean (knots)	SD	Mean (m)	SD
1	Central 2	15.573	2.461	0.254	0.04	3.5	0.2	135	7
1	Central 1	16.232	0.748	0.265	0.012	3.5	0.1	133	5
1	West 2	15.813	0.797	0.258	0.013	3.5	0.2	128	6
1	West 1	15.9	0.999	0.259	0.016	3.5	0.2	131	9

Table 3. Total catch (kg) of all species in each stratum during the 2021 survey.

COMMON NAME	SCIENTIFIC NAME	Central 2	Central 1	West 2	West 1	Total
Australian Burrfish	*Allomycterus pilatus*	1	0	0	1	2
Barracouta	*Thyrsites atun*	11	8.7	0	0.5	20.2
Barred Grubfish	*Parapercis allporti*	0	0.3	0	0	0.3
Bearded Rock Cod	*Pseudophycis barbata*	1	1	0	2	4
Bighead Gurnard Perch	*Neosebastes pandus*	41.1	20.4	6	20.3	87.8
Bight Redfish	*Centroberyx gerrardi*	677	421.8	6.6	104.7	1210.1
Black Stingray	*Dasyatis thetidis*	0	97	100	275	472
Blackspot Boarfish	*Zanclistius elevatus*	45.5	136.4	47	49.7	278.6
Blackspotted Gurnard Perch	*Neosebastes nigropunctatus*	48.8	65	26.5	63.5	203.8
Blue Mackerel	*Scomber australasicus*	0	0.6	0	0.3	0.9
Blue Morwong	*Nemadactylus valenciennesi*	43	76	4	53	176
Blue Warehou	*Seriolella brama*	0	0.8	0	0	0.8
Coffin Ray	*Hypnos monopterygius*	0	1	0	0	1
Common Gurnard Perch	*Neosebastes scorpaenoides*	2.4	0.8	0	0	3.2
Common Sawshark	*Pristiophorus cirratus*	31.5	281	186	225	723.5
Common Veilfin	*Metavelifer multiradiatus*	3	0	0	1	4
Conger Eel	*Family Congridae*	1	0	0	4	5
Cosmopolitan Rubyfish	*Plagiogeneion rubiginosum*	0	45.8	0	0	45.8
Cucumberfish, Greeneye & Flathead Lizardfish (U)		1	0	0	0	1
Cuttlefish (U)	*Sepiidae - undifferentiated*	4	0	0.3	0	4.3
Deepwater Bug	*Ibacus spp. & Thenus spp.*	0	0	0	0.2	0.2
Deepwater Flathead	*Platycephalus conatus*	779.7	1161.5	557	920.5	3418.7
Deepwater Stargazer	*Kathetostoma nigrofasciatum*	12.7	7.8	9	4.5	34
False Bailer Shell	*Volutidae (volutes)*	0	0.7	0.2	0	0.9
Footballer Sweep	*Neatypus obliquus*	0	0	0.5	0	0.5
Gemfish	*Rexea solandri*	2.3	0	0	0	2.3
Gould Squid	*Nototodarus gouldi*	191	188	82	117	578
Greenback Stingaree	*Urolophus viridis*	1.5	0	0	0	1.5
Greeneye Dogfish	*Squalus spp.*	32	0	9	10.5	51.5
Gummy Shark	*Mustelus antarcticus*	75.5	326	226	359	986.5
Hard Coral	*Undifferentiated Coral*	142	8	0	0.5	150.5
Hermit Crab (U)	*Undifferentiated Anomura*	0.7	1.5	0	0.5	2.7
Jack Mackerel	*Trachurus declivis & Trachurus murphyi*	33.4	9.9	5.3	2	50.6
Jackass Morwong	*Nemadactylus macropterus*	97.6	203.5	25	47.8	373.9
John Dory	*Zeus faber*	6	21.5	11.3	11	49.8
Knifejaw	*Oplegnathus woodwardi*	34	167.4	37	93.5	331.9
Latchet	*Pterygotrigla polyommata*	638	232.5	124.5	205	1200
Melbourne Skate	*Spiniraja whitleyi*	31	139	30	5	205
Mixed Fish		1	0	7	0	8
Mosaic Leatherjacket	*Eubalichthys mosaicus*	3.5	33.6	2	17	56.1
Ocean Jacket	*Nelusetta ayraud*	4981	1220	200	290	6691
Ogilby Ghostshark	*Chimaera ogilbyi*	3.5	0	0	0	3.5
Oilfish	*Ruvettus pretiosus*	0	0	15	0	15
Ornate Angelshark	*Squatina tergocellata*	74.5	551	314	258	1197.5
Peacock Skate	*Pavoraja nitida*	10	0	0	0	10
Port Jackson Shark	*Heterodontus portusjacksoni*	30	153	39	107	329
Red Cod	*Pseudophycis bachus*	5	1.5	0	0	6.5
Red Gurnard	*Chelidonichthys kumu*	14.2	85.6	48.5	47.6	195.9
Redbait	*Emmelichthys nitidus*	1.5	0.5	0	0	2
Reef Ocean Perch	*Helicolenus percoides*	0	18.7	0	0	18.7
Ringed Toadfish	*Omegophora armilla*	11.3	31.6	10.5	13.5	66.9
Rusty Carpetshark	*Parascyllium ferrugineum*	42.7	17	3.5	20.4	83.6
Samsonfish	*Seriola hippos*	0	0	0	8	8
Sandpaper Fish	*Paratrachichthys macleayi*	0.6	2.4	0	0	3
Sandyback Stingaree	*Urolophus bucculentus*	0	0	0	4	4
Sawtail Catshark	*Figaro boardmani*	0.5	0	0	0	0.5
School Shark	*Galeorhinus galeus*	2.5	10	12	3	27.5
Seastar (U)		0.5	0	0	0.5	1
Sergeant Baker	*Latropiscis purpurissatus*	28	5	0	8	41
Sharpnose Sevengill Shark	*Heptranchias perlo*	9	0	0	5	14
Shell		0	0.5	0	0	0.5
Short-Tail Torpedo Ray	*Tetronarce nobiliana*	0	0	5	25	30
Silver Dory	*Cyttus australis*	1.3	1	0	0	2.3
Silver Trevally	*Pseudocaranx georgianus*	0	21.6	0.4	48.8	70.8
Smooth Stingray	*Dasyatis brevicaudata*	18	457	242	410	1127
Southern Calamari	*Sepioteuthis australis*	1	0	1	0	2
Southern Eagle Ray	*Myliobatis tenuicaudatus*	0	92	0	98	190
Southern Fiddler Ray	*Trygonorrhina dumerilii*	97	311.5	80	181	669.5
Southern Rocklobster	*Jasus edwardsii*	0	7	0	0	7
Southern Round Skate	*Irolita waitii*	7	0	0	1	8
Southern Sawshark	*Pristiophorus nudipinnis*	3.5	24	16.7	24.4	68.6
Spikey Dogfish	*Squalus megalops*	196	167	162	15	540
Spiny Boxfish	*Capropygia unistriata*	0.9	1.8	0	0.4	3.1
Splendid Perch	*Callanthias australis*	0	0.8	0.5	0	1.3
Sponge (U)		287	71	59	103	520
Spotted Wobbegong	*Orectolobus maculatus*	0	45	0	0	45
Stingray (U)	*Dasyatidae - undifferentiated*	0	122	128	0	250
Swallowtail	*Centroberyx lineatus*	67.5	385.3	3	12	467.8
Thetis Fish	*Neosebastes thetidis*	5.9	2.9	1.2	16.3	26.3
Triggerfish & Leatherjacket (U)	*Balistidae, Monacanthidae - undifferentiated*	0.5	0	0	0	0.5
Tusk	*Dannevigia tusca*	16	10.2	9	3	38.2
Western Shovelnose Ray	*Aptychotrema vincentiana*	0	33	26	12	71
Whitebarred Boxfish	*Anoplocapros lenticularis*	0.5	0	0.5	6.2	7.2
Wide Stingaree	*Urolophus expansus*	666	16078	12900	12300	41944
Yelloweye Redfish	*Centroberyx australis*	3	10.5	0.4	7	20.9
Yellowspotted Boarfish	*Paristiopterus gallipavo*	31.2	51.8	16	9	108
Total		9610.3	23647.7	15795.4	16631.1	65684.5

Table 4. Catch (kg) of Bight Redfish and Deepwater Flathead for each stratum point sampled during the 2021 survey.

Trip	Survey point	Shot start date	Shot start time	Start point		End point		Catch (kg)	
				Latitude	Longitude	Latitude	Longitude	Bight Redfish	Deepwater Flathead
1	40	20/03/2021	17:08:19	-33.7996	132.2879	-33.705	132.1642	0	63
1	41	20/03/2021	20:44:55	-33.6312	132.1304	-33.616	131.9628	72.3	30
1	42	21/03/2021	0:12:28	-33.5509	131.9326	-33.4618	131.8106	94	57
1	43	21/03/2021	5:49:44	-33.3339	131.5734	-33.3152	131.4027	140.7	91
1	44	21/03/2021	9:38:08	-33.3618	131.3234	-33.3659	131.1557	1.1	119.8
1	45	21/03/2021	12:46:12	-33.3522	131.1211	-33.3153	130.9585	10	71
1	46	21/03/2021	22:57:44	-33.2343	129.9233	-33.2677	129.7571	30.3	13
1	47	22/03/2021	3:03:40	-33.2562	129.7156	-33.2639	129.55	203	71.5
1	48	26/03/2021	13:43:43	-33.2915	129.4134	-33.2142	129.5418	1.7	168
1	49	22/03/2021	9:48:57	-33.1905	129.3987	-33.2828	129.2801	33	98
1	50	22/03/2021	13:06:52	-33.3167	129.2687	-33.2858	129.1057	0	75
1	51	22/03/2021	16:57:50	-33.2867	129.2265	-33.2833	129.0611	19.5	91
1	52	22/03/2021	20:18:38	-33.2644	128.9896	-33.2814	128.8305	0	101
1	53	23/03/2021	0:20:50	-33.2548	128.7893	-33.2541	128.6188	1.3	36
1	54	23/03/2021	3:39:26	-33.2667	128.6071	-33.2564	128.4348	0	73
1	55	23/03/2021	17:11:28	-33.2189	127.4249	-33.1759	127.2692	35	92.5
1	56	24/03/2021	0:16:49	-33.1593	126.7627	-33.1765	126.6015	61	71
1	57	24/03/2021	3:30:05	-33.1637	126.5996	-33.2053	126.438	1.3	69
1	58	24/03/2021	7:00:29	-33.2148	126.3415	-33.2705	126.1864	4.4	249
1	59	24/03/2021	10:17:35	-33.272	126.2032	-33.2499	126.3818	1	151
1	60	24/03/2021	15:02:50	-33.179	126.6514	-33.1657	126.8199	0	166
1	61	24/03/2021	21:16:02	-33.2666	127.3616	-33.2737	127.5462	2	122
1	62	25/03/2021	4:38:16	-33.273	128.4165	-33.274	128.6058	2	123
1	63	25/03/2021	8:36:26	-33.2716	128.4872	-33.196	128.6185	2	49
1	64	25/03/2021	17:08:08	-33.2001	128.7422	-33.1941	128.916	1.3	175
1	65	25/03/2021	21:29:40	-33.2642	128.9357	-33.2717	129.1302	22.3	98
1	66	26/03/2021	1:16:51	-33.2734	129.1591	-33.268	129.3386	8.5	41
1	67	26/03/2021	5:38:34	-33.2818	129.1901	-33.2693	129.3652	0	90
1	68	26/03/2021	8:46:36	-33.2727	129.3702	-33.3159	129.5335	0	98
1	69	26/03/2021	16:58:31	-33.1656	129.5406	-33.1738	129.7193	7.5	168
1	70	26/03/2021	21:36:44	-33.2612	129.689	-33.2652	129.8693	74	82
1	71	27/03/2021	1:14:58	-33.2022	129.8073	-33.2248	129.9907	22	68
1	72	27/03/2021	10:29:51	-33.2765	131.043	-33.3075	131.2115	50	64
1	73	27/03/2021	13:54:41	-33.3813	131.2473	-33.3807	131.431	1.9	106.4
1	74	27/03/2021	18:05:32	-33.3534	131.6411	-33.4127	131.6693	64	38
1	75	27/03/2021	21:04:46	-33.5598	131.8321	-33.6343	131.9879	29	98.5
1	76	28/03/2021	0:20:20	-33.6108	132	-33.6903	132.1286	214	41

Table 5. Species and numbers of fish for which length and otolith samples were collected during 2021 survey.

Species	Length frequency (unsexed)	Otoliths collected
Deepwater Flathead	757	165
Bight Redfish	422	94

Table 6. Estimated total relative biomass (t) with coefficient of variation (c.v.) of major commercial species in across all strata from 2005, 2006, 2007, 2008, 2009, 2011, 2015, 2018 and 2021 surveys, using all trips and assuming net width of 16.3 m.

Species	Biomass																	
	2005		2006		2007		2008		2009		2011		2015[B]		2018		2021	
	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.	t	c.v.
Bight Redfish [A]	20887	0.13	25380	0.16	25713	0.16	14591	0.11	27610	0.18	13189	0.13	2573	0.28	4053	0.25	3447	0.21
Deepwater Flathead	12152	0.05	8415	0.06	8540	0.05	7725	0.06	9942	0.05	9227	0.05	5065	0.09	3396	0.06	5225	0.08
Ocean Jacket	7163	0.14	9111	0.26	6701	0.37	7709	0.29	21374	0.21	27712	0.20	3702	0.19	2706	0.23	11908	0.64
Common Sawshark	298	0.16	138	0.23	462	0.24	231	0.14	530	0.21	788	0.11	739	0.24	591	0.14	1022	0.18
Yellowspotted Boarfish	349	0.19	181	0.15	142	0.26	170	0.25	121	0.18	353	0.23	198	0.26	84	0.47	167	0.22
Gummy Shark	558	0.17	288	0.25	402	0.23	434	0.14	470	0.18	797	0.16	1357	0.15	684	0.14	1429	0.09
Jackass Morwong	1025	0.34	1037	0.23	1236	0.31	916	0.30	783	0.23	441	0.24	671	0.31	563	0.35	567	0.22
Knifejaw	955	0.12	1133	0.14	570	0.13	806	0.11	1121	0.15	1129	0.17	452	0.28	579	0.18	452	0.20
Latchet	9401	0.13	6135	0.25	7040	0.21	3688	0.17	12997	0.15	8690	0.17	12418	0.23	3827	0.22	2054	0.18
Ornate Angelshark	3078	0.09	1887	0.10	2770	0.11	1742	0.10	2107	0.07	2305	0.08	2629	0.12	1790	0.08	1700	0.11
Spikey Dogfish	834	0.24	867	0.30	1006	0.23	508	0.33	607	0.17	1799	0.16	505	0.27	182	0.43	870	0.42
Other species	11693	0.13	14405	0.14	22990	0.14	17558	0.12	23666	0.12	15272	0.09	24052	0.12	16256	0.24	70586	0.11

[A] Based on night shots only

5 Conclusions

Compared with 2018 estimates, this ninth fishery-independent survey of the Great Australian Bight trawl sector shows continued low biomass of Bight Redfish (3,447t, CV 0.21) but increased biomass (> 50%) of Deepwater Flathead (5,225 t, CV 0.08) in 2021. Estimates of Bight Redfish are less precise than those of Deepwater Flathead because of relatively high among-strata variance: Bight Redfish were only caught in the two central strata. Notably, the GABTS catch in the 2021 survey was dominated by Wide Stingaree (64%) and Ocean Jacket (10%) revealing a marked change in species composition over the time that surveys have been undertaken. In particular, a substantial increase (> 4-fold) in the relative biomass of “other” species was recorded in 2021 compared with the estimate in 2018. This was caused mainly by a large increase in the abundance of Wide Stingaree.

The length composition of Bight Redfish showed an accumulation of smaller fish (mode 28 cm) with relatively few larger fish compared with previous surveys. In contrast, the length composition of Deepwater Flathead has remained relatively constant over the time that surveys have been conducted. The results of this survey will continue to inform and reinforce stock assessment of target species of the GABTS.

6 Acknowledgments

We thank the owners of Silver Phoenix Holdings Pty Ltd and the skipper Scott Longman and the crew of the Silver Phoenix for their professional approach to conducting the 2021 survey. Particular thanks to Marcia Valente for coordination of the survey on behalf of Silver Phoenix.

The tedious work of Jim Raptis and his netmaker Brent “Barney” Williams in constructing the net and refurbishing the old net in 2018 is much appreciated, as was the independent review of the nets in that year against the plans by Thorsteinn Benediktsson of Hampidjan Australia P/L.

Paul McShane is thanked for editing and proof-reading the Final Report.

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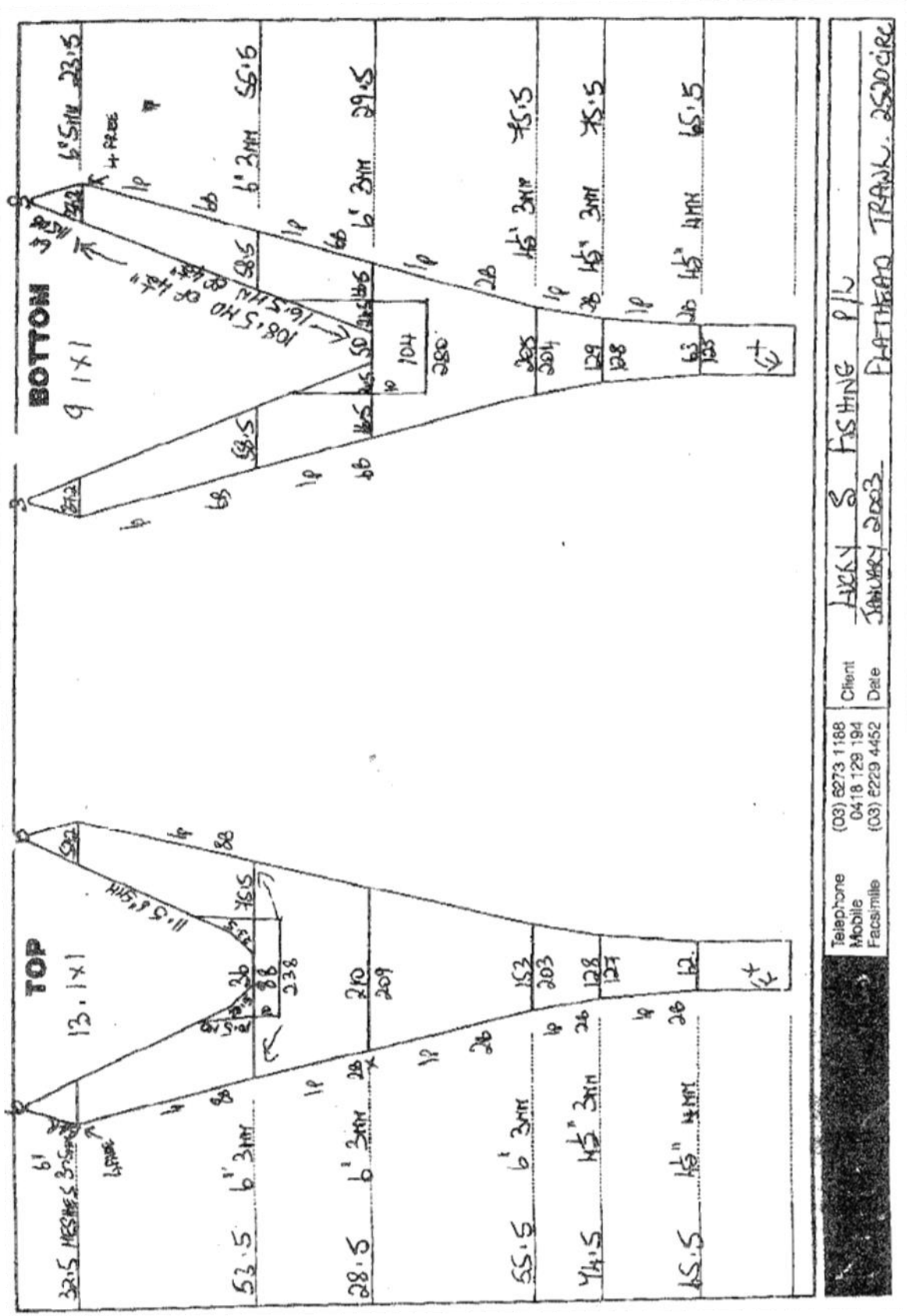
8 Appendix 1. Net Specifications

8.1 The Net

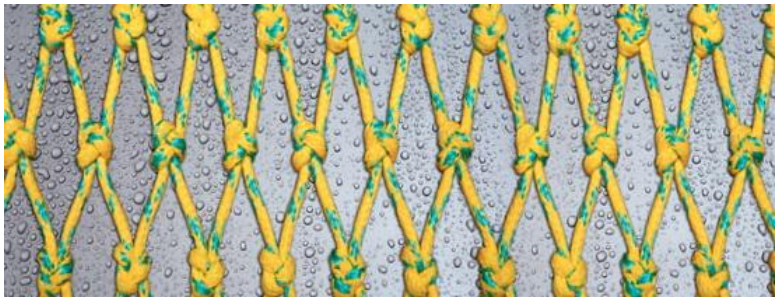
The overall dimensions of the net are as follows:

Headline:	Length = 32.6 m,
	V = X.45,
	Middle to last flymesh = 3.05,
	Centre = 2.24.
Footline:	Length = 39 m (originally 38.5),
	V = 3.95 m
	Centre = 2.24.
Codend mesh:	90 mm.
Bridles:	37 m.
Sweeps:	160 m.

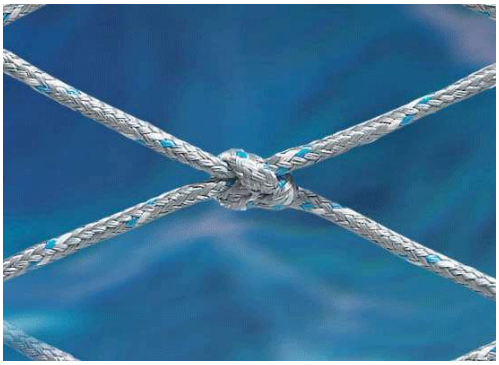
The design of the net has been well established and documented from the 2005 survey as shown below.


BOTTOM
9 1x1
TOP
13, 1x1
Telephone
Mobile
Facsimile
(03) 6273 1188
0418 129 194
(03) 6229 4452
Client
Date
LUCKY 8 FISHING P/L
JANUARY 2003
FLATHEAD TRAWL ASSOCIATE

The yellow twine is a product called Premium plus made by Euronete The diameter of the twine is 3mm, and is made from polyethylene. The twine has a runnage of 230 m/kg and a breakage of 240 kg.



Where grey twine is present, it is a product called magnet grey, made by Hampidjan. The diameter is 3.1 mm has a runnage of 186 m/kg with a breakage of 310 kg.

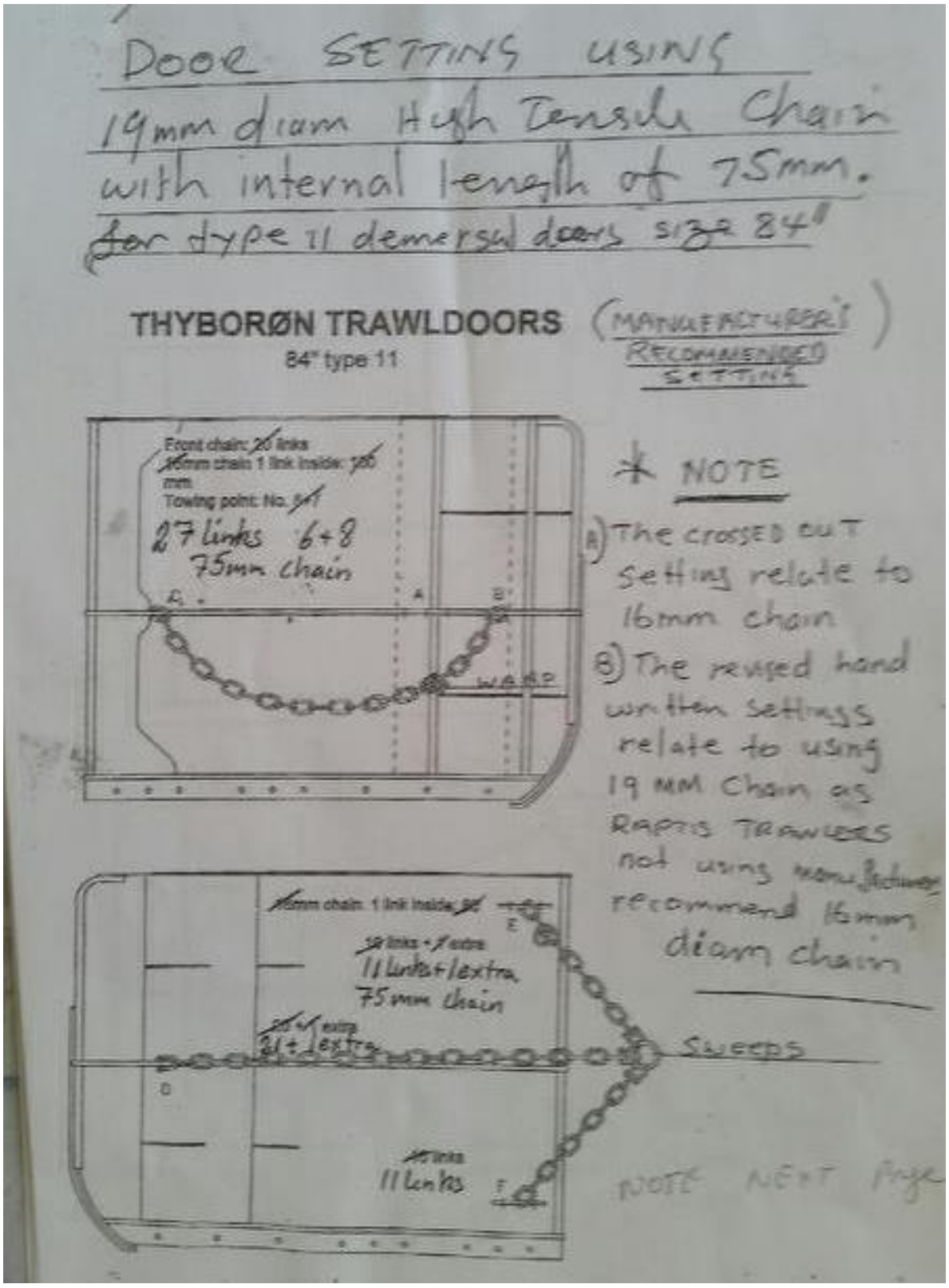


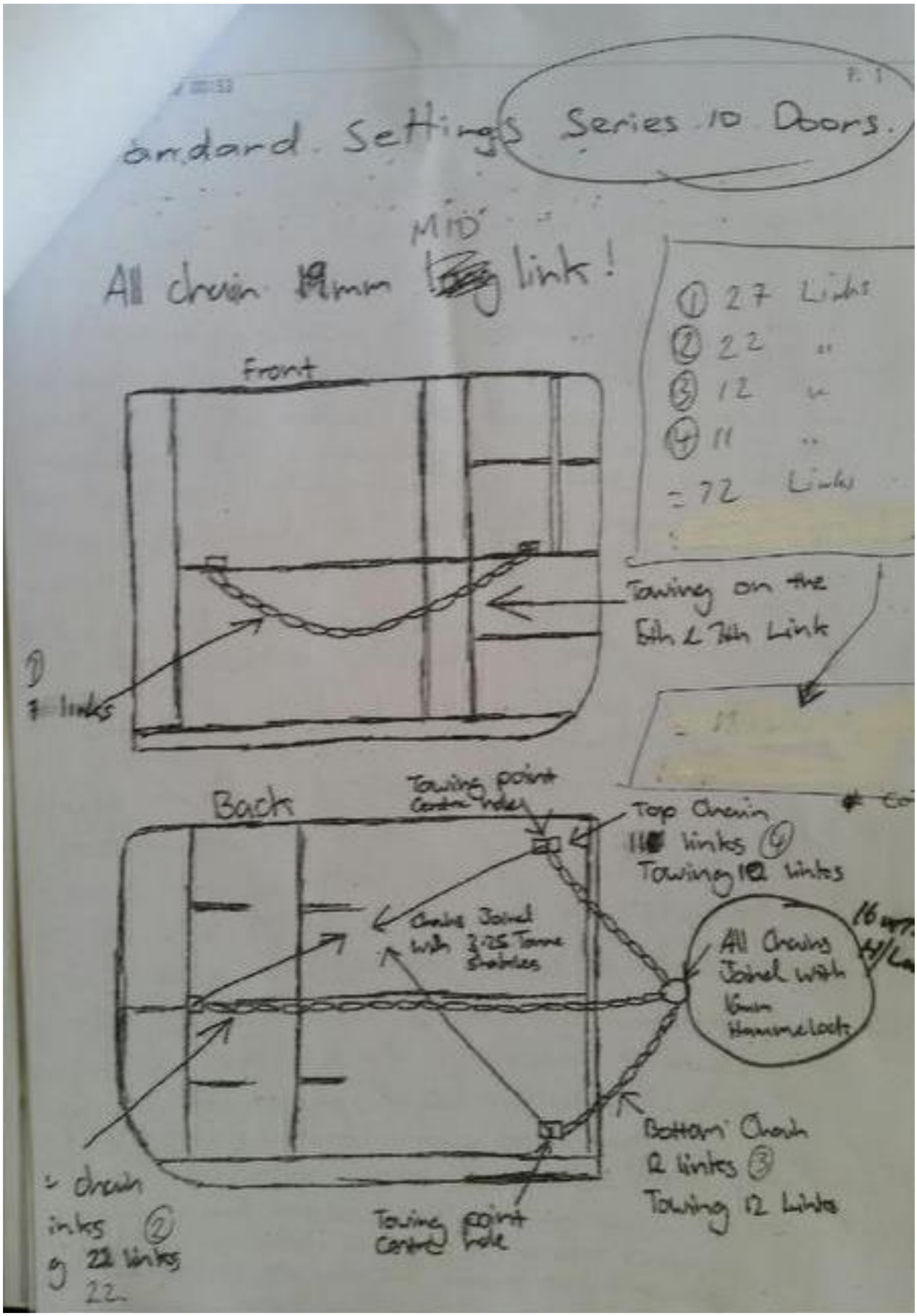
8.2 Trawl Boards

The same type of trawl boards has been used for all surveys. They are Thyboron boards Type 11 heavy duty, 84 inch. Each board weighs 667 kg and has an area of 3.39 sq metres.

During 2018 and 2021, the boards were fitted with sensors to record the distance between boards.

Chains are attached to the boards as per specification below.


DOOR SETTING USING
19mm diam High Tensile Chain
with internal length of 75mm.
for type 11 demersal doors size 84"
THYBORØN TRAWLDOORS
84" type 11
(MANUFACTURERS RECOMMENDED SETTING)
Front chain: 20 links
16mm chain 1 link inside: 380 mm
Towing point: No. 5
27 links 6+8
75mm chain
A
B
WARP
* NOTE
A) The crossed out setting relate to 16mm chain
B) The revised hand written settings relate to using 19 MM Chain as RAPIS TRAWLERS not using manufacturers recommend 16mm diam chain
16mm chain: 1 link inside: 380
E
11 Links + 1 extra
75mm chain
21 + 1 extra
SWEEPS
D
11 Links
F
NOTE NEXT Page


andard Settings Series 10 Doors.
MID
All chain link!
① 27 Links
② 22 "
③ 12 "
④ 11 "
= 72 Links
Front
Towing on the 5th & 7th Link
Back
Towing point
Top Chain
links ④
Towing 12 links
All Chains Joined with 6mm Hammerlocks
Chains Joined with 3.25 Tonne Shackles
Bottom Chain
12 links ③
Towing 12 Links
Towing point hole
chain
links ②
22 links
22

8.3 Headline

The headline is 32.6m in length with a rope diameter of 15 mm. Sixty-six bubble floats have been attached. Each bubble float is 200 mm (8 inch) diameter with a lifting capacity of 2.5 kg. The bubbles are rated to 1200m depth. The floats are attached in 12 groups of 5 spread evenly along the net with the remaining six buoys, three attached near each end of the headline.

8.4 Ground Gear

8.4.1 Footline

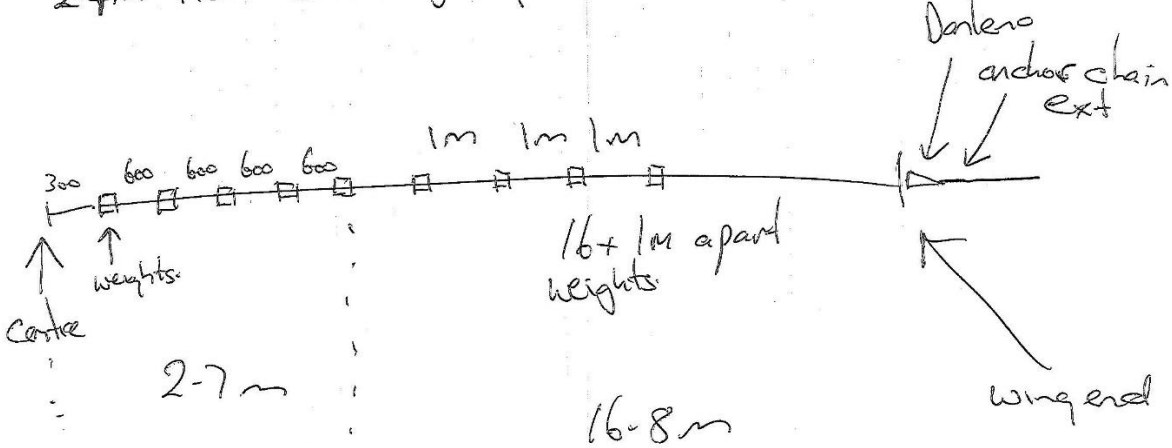
The footline is constructed of wire rope 20 mm in diameter and 39 m long with a mixture of weights, rubber discs and toggles attached.

Prior to the first survey the ground rig was never weighed. In the net-maker's opinion this could be in the range of 500-700 kg.

The footline is 39 m long and is constructed of 20 mm diameter wire rope with a mixture of weights, rubber discs and chain attached. A total of 42 x 2.5 kg weights is placed along the length of the ground-line. From the centre going out a weight is placed every 600mm for the first 2.7m, and for the remaining 16.8m, a weight is secured every 1m. The distribution of the rubber discs, weights and hangers along the footline are set out below.

In addition, 16 x 1 metre lengths of chain have been placed along the footline, each consisting of 13 x 75mm links of 12mm gauge steel.

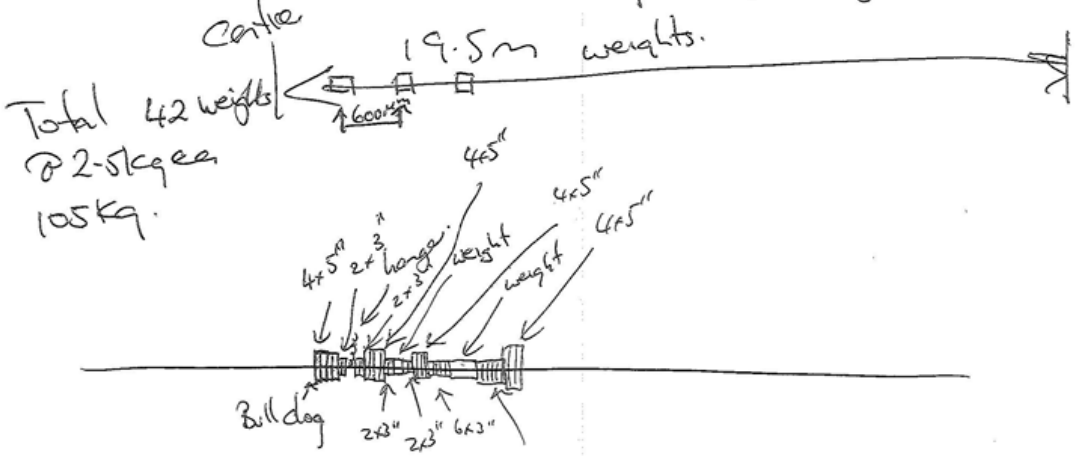
From centre have 5 weights @ 600mm apart until 2.9m from centre of rig



TOTAL 19.5m

hangers @ 600 apart up till 5m out from centre then 7-800mm apart to the wings

39m Rig 21 weights.



in centre approx first 2.9m have 5+ weights @ 2.5kg.

all rubber to be 5" and with 3" spacers
toggles to be approx 440 mm in height
wire to be 20mm 6/19 weights to be approx 2.5kg ea

8.4.2 Botch Line

The botch line has been connected to the fishing line using white rope, similar to how it was done on the first survey (photo 1). In addition, the rope used to tie them on has been coated with two pack resin. They are tied on every 600 mm (photo 2)

Photo 1

Photo 2

8.4.3 Toggles/chain on fishing and botch line.

There is a difference of opinion re the use of either the toggles or chain to connect the botch line to the fishing line. Photos 1 and 2 suggest chain was used to connect the fishing line to the botch line. Photo 3 shows the rebuilt net with toggles connecting the botch line to the fishing line. Photo 4 shows the botch line connected to the fishing line by chains. We believe, and from the recommendation of Thorsten, there is little difference between the two and both nets meet the specifications for the survey net.

Photo 3

Photo 4

8.5 General Pictures