

Determining the distribution of gulper sharks on Australia's eastern seamount chain and the selectivity of Minor Line fishing in regard to seamounts populations of Blue-eye Trevalla and Harrison's Dogfish

Interim report – April 2012

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Executive summary

The Taupo and Barcoo Seamounts, which form part of the Tasmantid Seamount chain located in Commonwealth fishery waters off eastern Australia, were closed to fishing by AFMA in 2009 to help protect the Harrison's Dogfish – a species of 'gulper shark' being considered for threatened species listing. It has been proposed by a section of the commercial fishing industry that fishing access to these seamounts is re-established for a method of mechanised handline fishing called "Minor Line". Industry maintains that these seamounts are key to the economic viability of a fishery harvesting quota-managed Blue-eye Trevalla (*Hyperoglyphe antarctica*), and that Blue-eye can be harvested by Minor Line fishing without being a threat to Harrison's Dogfish. Blue-eye Trevalla is a premium temperate Australian scalefish and an iconic seafood in regions including Tasmania. The Blue-eye catch on the Taupo and Barcoo Seamounts presently makes up some 10% (~40 of 320 tonnes in 2011) of the Total Allowable Catch of the Commonwealth fishery.

Collaborative research to inform management decisions on the future spatial management of the Tasmantid seamounts is being undertaken by CSIRO, AFMA and two commercial fishing companies. Specifically, the project is examining the selectivity of Blue-eye Trevalla fishing by Minor Line fishing and its interactions with Harrison's Dogfish, as well as the distribution and demography of Harrison's Dogfish on other Tasmantid seamounts. Additionally, project data will provide insights to related questions concerning ecosystem-based fishery management of the seamount chain (e.g. fishing-related mortality of sharks). Most immediately, the project's findings will inform fishery management arrangements being considered for gulper sharks – specifically, the development of AFMA's Upper Slope Dogfish Management Strategy (which responds to the listing evaluation process), as well as the design and zoning of proposed Commonwealth Marine Reserves in the Eastern Temperate Marine Region. The latter process has proposed the Taupo and Barcoo Seamounts are enclosed within a Sanctuary Zone that will prohibit all fishing in perpetuity.

This interim report has been prepared to distribute information at a key point (late April) in the listing process, and fishery and conservation planning timetables. The project's sampling program will be completed after the next allocation of Blue-eye Trevalla quota in May 2012. Quota availability determines the activities of the companies supporting the field program, and there is none currently available to them. A full analysis and final project report will be completed in mid-2012 when all data have been collected and analysed.

This interim report provides initial assessments of information collected to date by an experienced scientific observer during commercial Minor Line fishing on the Tasmantid Seamount chain in regard to all four project objectives: the ability of Minor Line operations to avoid Harrison's Dogfish while targeting Blue-eye Trevalla (Objective 1), and the environmental factors that determine why the species of interest are captured or avoided by Minor Line fishing (Objective 2). This report considerably enhances knowledge on the distribution of Harrison's Dogfish on the east Australian seamount chain (Objective 3), and provides some preliminary comments on the relative abundance of Harrison's Dogfish on inhabited seamounts (Objective 4), and on its survival following capture.

Objective 1: A total of three Harrison's Dogfish (two from Barcoo Seamount and one from Taupo) have been captured by Blue-eye Trevalla fishing using Minor Line gear during four surveys which set 9306 hooks to catch 2,413 Blue-eye Trevalla (est. 23 tonnes). The three Harrison's Dogfish were caught during targeted fishing for this species in an experimental design that has two *a priori* defined "Gulper" fishing strata: daytime fishing in depths greater than 550 m, and nighttime fishing in the 280-550 m depth zone. Thus, the early results of the experimental work conducted on Taupo and Barcoo Seamounts (4 of 10 planned surveys completed) support the industry proposition that gulper sharks can be avoided using Minor Line fishing methods to target Blue-eye Trevalla, at least on these seamounts.

Objective 2: These interim results suggest that the combination of shallow daytime fishing (in 280-550 m depths) on the Taupo and Barcoo Seamounts is a big influence on the ability of commercial Minor Line

fishing to avoid catching Harrison's Dogfish when targeting Blue-eye Trevalla. This is consistent with the diel migration by Harrison's Dogfish, ascending from deep daytime depths to feed in the deep scattering layer in shallower waters at night, as documented on the continental margin.

Objectives 3 and 4: A total of 96 Harrison's Dogfish were captured from 4620 hooks set on the Fraser, Recorder, Queensland and Britannia Seamounts during normal Minor Line fishing operations. Fraser produced the lowest catch rate of Harrison's Dogfish (shark/hooks) and may be close to the northern distributional limit of this species. Catch rates on the other seamounts were higher than observed on Taupo and Barcoo, but cannot be quantitatively compared across the seamount chain due to differences in fishing operations – principally the relatively shallow depth of daytime fishing at Taupo and Barcoo. Nonetheless, these results show that Harrison's Dogfish is widespread on the Tasmantid chain with relatively high abundance in its mid-reach. The conservation management implications of the demographic patterns seen include the high importance of the Britannia Seamount for maintaining breeding populations because of the high ratio of females, and the need to establish the location(s) of mature males, and pupping areas.

All Harrison's Dogfish captured were returned to the sea in a vigorous state. Characteristics of Minor Line fishing contributing to likely high survival include short gear soak time (<15 mins) and favourable handling practices facilitated by low volumes of fish landed together on small numbers of hooks (~18) per line. Post-capture survival will continue to be monitored during the rest of the field work; tagging activities, supported by fishing industry, will progressively add to our understanding of post-release survival.

1 Introduction

The Taupo and Barcoo seamounts were closed to all forms of commercial fishing during Stage 1 implementation of AFMA's Upper Slope Dogfish Management Strategy (USDMS) in June 2010. The USDMS is AFMA's response to the nomination of several species of upper slope dogfish species (mainly from the gulper shark family Centrophoridae) for threatened species listing under the EPBC Act following dramatic declines in abundance over large parts of their distributional ranges. The Taupo and Barcoo Seamounts were closed to fishing to protect one of these species, Harrison's Dogfish (*Centrophorus harrissoni*). This is the species of greatest conservation concern and, in 2010 when the closure was made, Taupo Seamount had recently been surveyed and identified as one of the few known locations where mature adults of this species occurred.

The need to evaluate the selectivity and impact of Minor Line fishing exists because Minor Line fishing operators have argued that Harrison's Dogfish can be avoided whilst harvesting Blue-eye Trevalla, particularly on Taupo and Barcoo Seamounts. The basis for their argument is that their method is highly selective (Harrison's Dogfish catches are very low) and is non-threatening because post-capture survival is high (few Harrison's Dogfish are killed). The explanation for these arguments is that their gear targets mobile schools of Blue-eye and has minimal bottom contact in areas where Harrison's Dogfish reside, with fishing occurring in depths and at times of day that naturally avoid Harrison's Dogfish. Operators also believe post-release survivorship is higher with Minor Line fishing compared with other fishing methods because there is continuous attendance of the gear during short deployments and only small numbers of individual fish taken per deployment (permitting rapid return of incidentally-caught individual Dogfish).

A second need for the USDMS is to determine the extent of Harrison's Dogfish on the Tasmanid seamount chain. The decision to close Taupo and Barcoo was made on the basis of Taupo being the only Tasmanid seamount where an extant population of this species had been identified. Importantly, the population included mature male and female sharks, indicating it is likely to be a breeding site. Further evaluation of management options – in regard to AFMA's USDMS, and SEWPaC's marine reserve network in the Eastern Temperate Region – will benefit from additional information on the distribution of Harrison's Dogfish on the other Tasmanid seamounts in Commonwealth managed waters: Barcoo, Derwent Hunter, Britannia, Queensland, Recorder and Fraser.

The project therefore aims to evaluate whether Minor Line fishing access to Blue-eye Trevalla stocks on the Taupo and Barcoo Seamounts could be re-established without adversely impacting the viability of Harrison's Dogfish populations, and provides context for management decision-making by establishing the broader range of the species on adjacent seamounts.

1.1 Outcomes

1. Evaluating whether Minor Line fishing for Blue-eye Trevalla on the Taupo and Barcoo Seamounts avoids Harrison's Dogfish so that AFMA can determine whether this method can re-commence on the Taupo and Barcoo Seamounts. The beneficiaries are primarily the industry operators who have invested in this fishery, associated down-stream processors, and the consumers of a high quality fish species (Blue-eye Trevalla).
2. Insights on the factors important to gear selectivity, and to the extent possible, post-capture and release survivorship, will inform AFMA's consideration of differential access to fishery closures in similar situations.
3. Data will add considerably to scientific knowledge of the populations of sharks inhabiting offshore seamounts, especially Harrison's Dogfish which is very likely to be listed in the near future.

1.2 Objectives

1. Establish whether Harrison's Dogfish can be avoided during normal Minor Line fishing operations to harvest Blue-eye Trevalla on offshore seamounts.
2. Identify environmental factors such as depth and time of day, together with gear/ method characteristics, that determine why the species of interest are captured or avoided by Minor Line fishing.
3. Determine the distribution of Harrison's Dogfish on the east Australian seamount chain.
4. Provide an estimate of relative abundance of Harrison's Dogfish on inhabited seamounts.

2 Methods

2.1 Areas of operation

The Tasmanid Seamount chain comprises seven large individual seamounts (Figure 2.1) that rise from abyssal depths (> 2000 m) to shallower depth ranges (Table 2.1). Because all have peak depths at ~500 m or shallower, they support commercial fish species found elsewhere on the eastern Australian continental margin in corresponding depths. This study focuses on the Taupo, Barcoo and Derwent Hunter Seamounts off the coast of New South Wales and the Fraser, Recorder, Queensland, Britannia Seamounts off the coast of Queensland.

Table 2.1 Seamount characteristics, ranked in order of increasing latitude.

Seamount	Depth range	Area (km ²)	%
Fraser	>200 m	0	0
Peak depth ~400 m	200–700 m	28.38	18
Total area < 2000m = 162 km ²	700–1000 m	16.78	10
	1000–2000 m	116.84	72
Recorder	>200 m	0	0
Peak depth ~500 m	200–700 m	5.7	1
Total area < 2000m = 469km ²	700–1000 m	50.9	11
	1000–2000 m	412.3	88
Queensland	>200 m	0	0
Peak depth ~300 m	200–700 m	264.1	33
Total area < 2000m = 806 km ²	700–1000 m	145.8	18
	1000–2000 m	396	49
Britannia	>200 m	0.7	<1
Peak depth ~200 m	200–700 m	507.4	26
Total area < 2000m = 1981 km ²	700–1000 m	563.9	28
	1000–2000 m	909	46
Derwent Hunter	>200 m	0	0
Peak depth ~400 m	200–700 m	549.5	43
Total area < 2000m = 1291 km ²	700–1000 m	210.6	16
	1000–2000 m	530.9	41
Barcoo	>200 m	0	0
Peak depth ~300 m	200–700 m	137.3	35
Total area < 2000m = 395 km ²	700–1000 m	47.7	12
	1000–2000 m	209.6	53
Taupo	>200 m	311	23
Peak depth ~200 m	200–700 m	467	34
Total area < 2000m = 1360 km ²	700–1000 m	112.1	8
	1000–2000 m	469.9	35

The Fraser and Recorder Seamounts are approximately 50 nautical miles apart and lie 90–110 nautical miles east of Fraser Island (Figure 2.2). The Queensland and Britannia Seamounts are less than 30 nautical miles apart and lie 90–110 nautical miles east of Stradbroke Island and the Gold Coast (Figure 2.3). The Derwent Hunter Seamount lies 160 nautical miles east of South West Rocks and the Taupo/Barcoo Seamounts are approximately 20 nautical miles apart and lie approximately 200 nautical miles east of Newcastle (Figure 2.4).

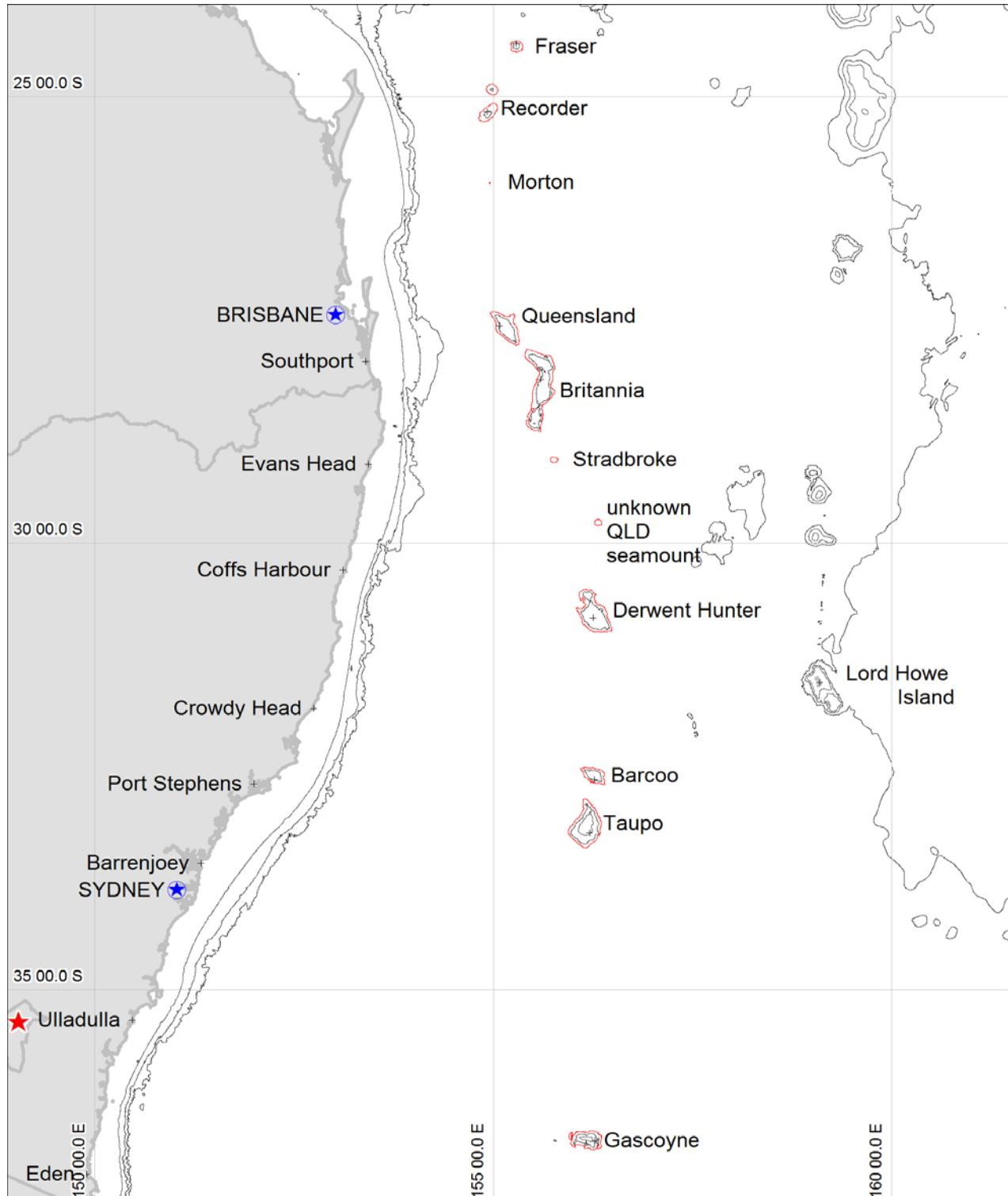
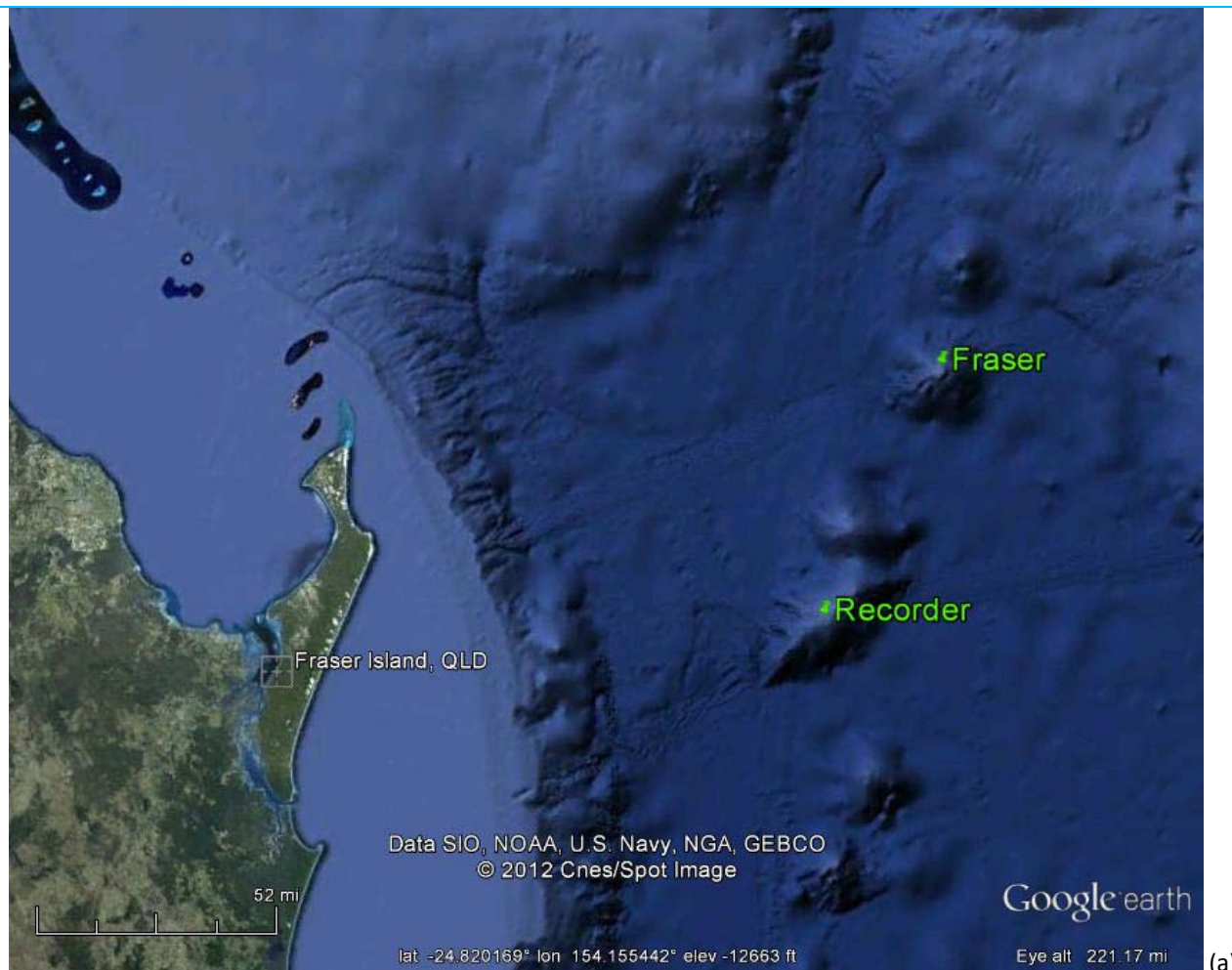
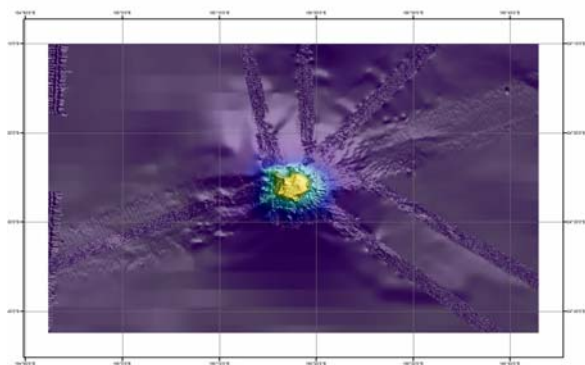


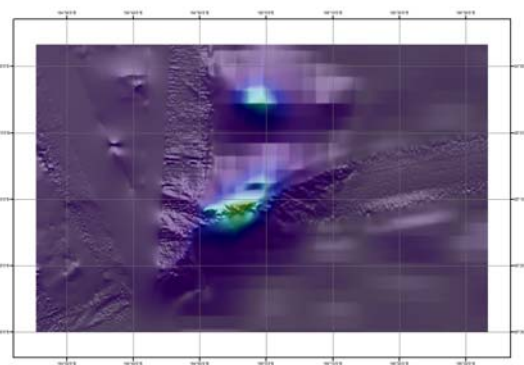
Figure 2.1 Overview map showing the seamounts (red outline of 2000 m contour) in the southern part of the Tasmanid Seamount chain. Contours: 200m, 1000m, 2000m depth.



(a)

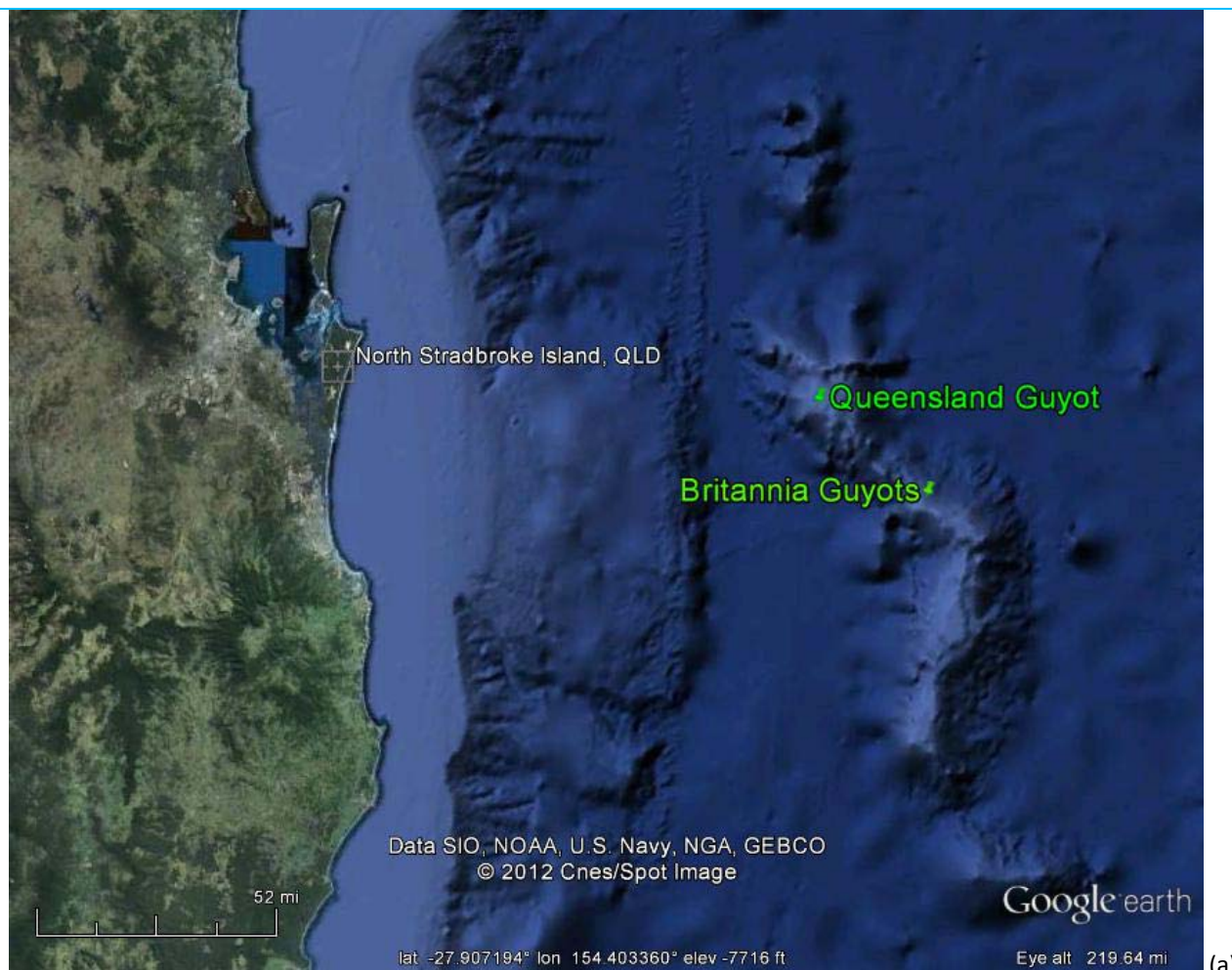


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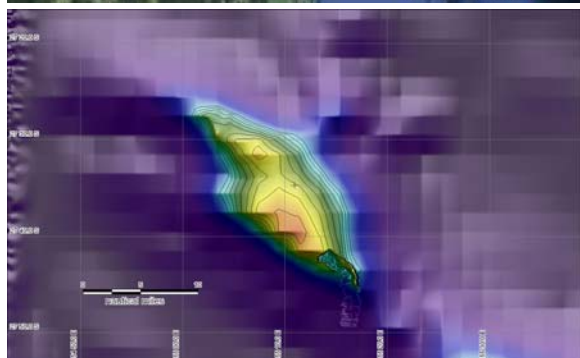


(c)

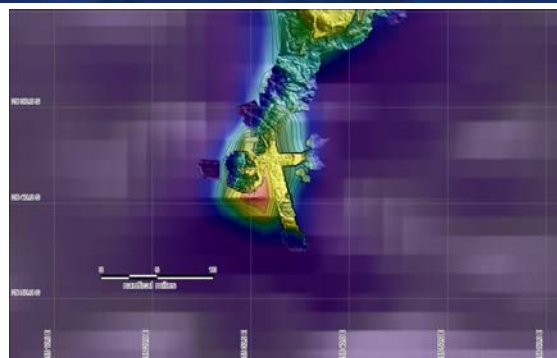
Figure 2.2 General bathymetry of Fraser and Recorder Seamounts (a). Colour coded swath bathymetry of Fraser (b) and Recorder (c) showing high resolution swath (where available) overlain on low-resolution swath and/or interpolated (GA, 2009) DEM.



(a)

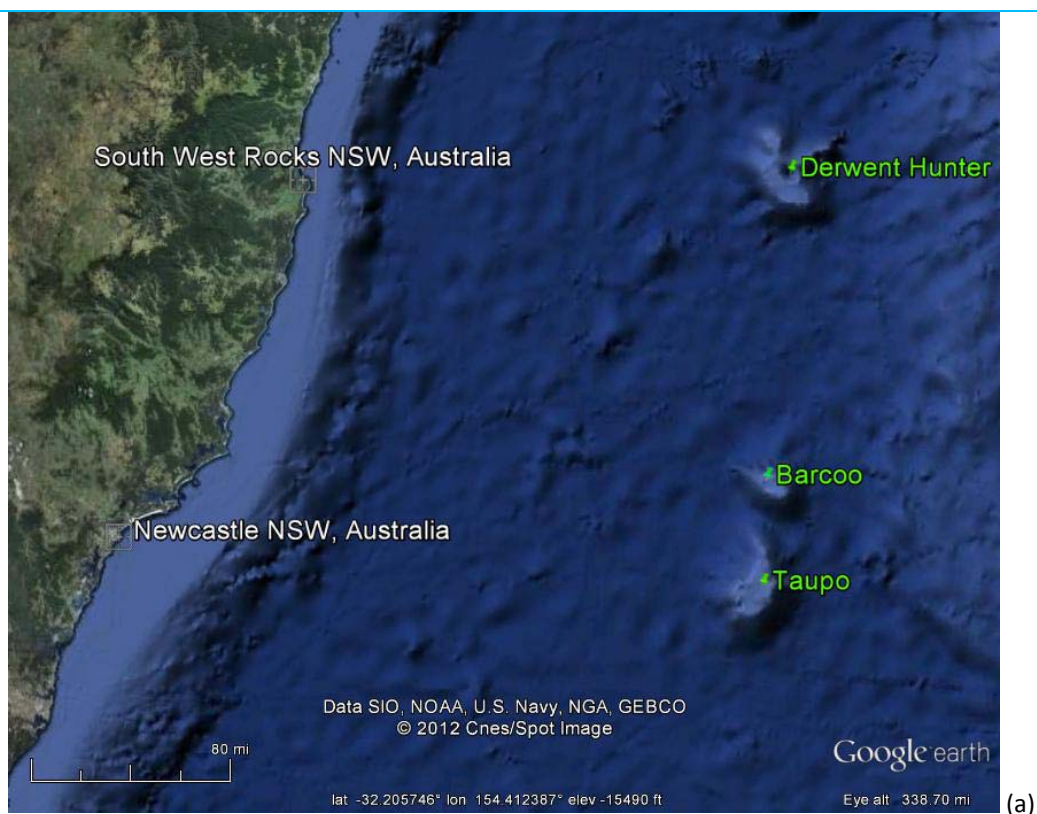


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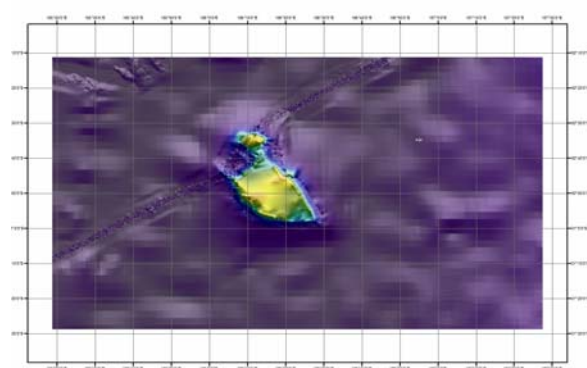


(c)

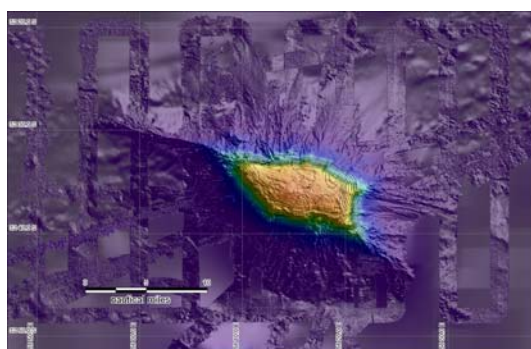
Figure 2.3 General bathymetry of Queensland and Britannia Seamounts (a). Colour coded swath bathymetry of Queensland (b) and Britannia (c) showing high resolution swath (where available) overlain on low-resolution swath and/or interpolated (GA, 2009) DEM.



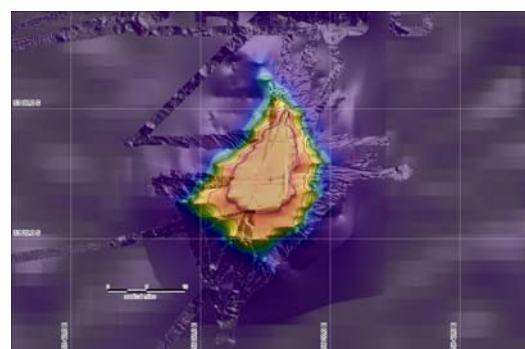
(a)



(b)



(c)



(d)

Figure 2.4 General bathymetry of Barcoo and Taupo Seamounts currently closed to commercial fishing (a). Colour coded swath bathymetry of Derwent Hunter (b), Barcoo (c) and Taupo (d) showing high resolution swath (where available) overlain on low-resolution swath and/or interpolated (GA, 2009) DEM.

2.2 Sampling procedures and protocols

2.2.1 FISHING VESSELS AND EQUIPMENT

Minor Line fishing (“Deep Drop Target Fishing”) is a mechanised handline method using hooks and 1500 m of Dyneema® line¹ on hydraulic reels that targets mobile schools of Blue-eye Trevalla on seamounts off Australia’s east coast; a description of the method is provided by Graham (2011). Two commercial vessels set up with this equipment contributed to the fishing program that provides the project data (Table 2.2). Each vessel is fitted with four hydraulic reels in the same relative positions with one reel located on the port quarter, and three on the starboard side spaced from the stern to amidships; a maximum of three lines are deployed at any one time, referred to as a ‘drop’.

Typically, each line is fitted with 18 hooks² and weighted with 5–10 kg of welded lengths of reinforcing steel. When set, the lines are allowed to free spool to the bottom before being adjusted for length. During each fishing drop, the vessel drifts across the bottom feature or fish schools targeted using a deep water echosounder. Lines are tended by hand and are hauled when it is felt that several fish have been hooked; bites are easily felt on the line and experienced crew can generally distinguish between those of Blue-eye and dogfish or other species. During typical commercial operations the lines are fished on the bottom for 5–10 minutes. Minor Line fishing for Blue-eye Trevalla is typically conducted only during daylight hours.

Table 2.2 Fishing vessel details

Vessel name	<i>Claudarah</i>	<i>Nelson Bay</i>
Home Port	Tuncurry (NSW)	Mooloolaba (QLD)
Owners	Whan and Boxsell Pty Ltd	Fortuna Fishing Pty Ltd
Length / breadth (metres)	18.3 / 5.6	12.0 / 4.0
Tonnage	40	20
Main engine (KW)	442	2 x 246

2.2.2 SAMPLING AND EXPERIMENTAL DESIGN

Gulper shark distribution: all data on the seamounts north of Taupo and Barcoo were collected by a project scientist during normal fishing operations on the fishing vessel (FV) *Nelson Bay*. No experimental design was required for these areas as the objective for the northern seamounts was to collect data on distribution and relative abundance of Harrison’s Dogfish in these regions.

Selectivity: all data from the closed Taupo and Barcoo seamounts were collected by a project scientist on board the FV *Claudarah*, with fishing and additional sampling conducted under a scientific permit. This work was guided by the hypothesis, “**a bycatch of gulper shark can be avoided during ‘standard’ targeted commercial Blue-eye fishing on the Taupo and Barcoo Seamounts**”. To address this hypothesis three tests were identified.

Test 1: Gulpers are avoided because standard (daytime, mid-depth) fishing avoids ‘gulper habitat’ [gulpers occupy deep depths during the day and mid-depths only at night]

¹ Dyneema is a registered trade name for fishing line made from Ultra-High Molecular Weight Polyethylene. It has high strength and durability and the grade used for Minor Line fishing is 1.1 mm diameter and rated at 180 kg breaking strain.

² If the fisher expects to catch a number of large fish such as Eight-bar Grouper on a line they may reduce the number of hooks to 10 rather than the standard 18.

Test 2: Gulpers are avoided because the standard blue eye fishing method [gear/practice/Blue-eye schools targeted] selects strongly for Blue-eye

Test 3: Gulpers are avoided because they are not present in sufficient abundance on the seamounts to be caught by Minor Line fishing. [Minor Line is not as effective as dropline in capturing gulpers, or there are too few gulpers on the Seamounts to be caught by either fishing method]

An experimental design was constructed in consultation with fishers to develop fishing protocols to ensure all the three tests were implemented during fishing operations (Figure 2.5). Other recent work has shown that Harrison's Dogfish and Southern Dogfish (*Centrophorus zeehaani*) have a pattern of diel movement where they occupy deeper depths during the day and move into shallower waters during the night to feed (Williams et al, 2012). Our experimental design accounts for diel ascent/descent by incorporating deeper fishing shots during the day (deeper than normal fishing operations targeting Blue-eye), and fishing at night to demonstrate that gulper sharks are present during surveys and can be captured by Minor Line fishing. Drop-lining is used as a supplementary fishing method to confirm the presence of Harrison's Dogfish on Taupo and Barcoo because some of the catch on the Taupo Seamount during fishing survey work in 2009 (CMAR, 2009) was taken with droplines. The experimental design is explained as a fishing protocol (as supplied to the vessel skippers) in Section 2.2.3.

		NIGHT	DAY
Shallow seamount peak <155 fm (<280 m)		N/A	N/A
Mid-depth Blueeye fishing depths (155-300 fm) (280-550 m)	avoid Blue-eye signs on sounder	1 drop/day Expectation: catch gulpers because they migrate into shallower depths at night (proviso the Minor Lines actually can catch them)	2 drops/day Expectation: no gulper catch because they avoid these depths in the day -time
	target Blue-eye signs on sounder	1 drop/day Expectation: Blue-eye catches with little gulper bycatch (i.e. targetting Blue-eye signs avoids gulpers)	NORMAL FISHING Expectation: Blue-eye catches with <u>no</u> gulper bycatch (i.e. targetting Blue-eye avoids gulpers and they are not in this depth zone during the day)
	Gulper presence (Use droplines)	1 drop/day Qualitative - show gulpers are in these depths at night (even if not caught on Minor Lines)	N/A
Deep (300-450 fm) (550-830 m)	avoid Blue-eye signs on sounder	N/A	1 drop/day Expectation: catch gulpers because they occupy deeper depths during the day (proviso the Minor Lines actually can catch them)
	target Blue-eye signs on sounder	N/A	N/A
	Gulper presence (Use droplines)	N/A	1 drop/day Qualitative - show gulpers are in these depths during the day (even if not caught on Minor Lines)
seamount flank >450 fm (>830 m)		N/A	N/A

Figure 2.5 Diagram of experimental design. The number of drops shown represent minimum effort. report

2.2.3 FISHING PROTOCOLS

Each individual fishing trip is expected to follow normal commercial practice because the project's aim is to determine selectivity of Minor Line during 'normal' fishing operations:

- fishing during each trip is at Barcoo or Taupo, or both seamounts – with an even spread of fishing across both seamounts on each trip if possible,
- Minor Line gear is used to target Blue-eye trevalla,
- some aspects of normal fishing are expected to vary and will not affect the project's result: the number of drops completed in any day, the targeted location on seamount (features such as gullies, rocky knobs), moon phase and season .

However, there are some specific requirements that are necessary for the catch data to be properly analysed. These same requirements are likely to be necessary for future fishing if the seamounts are re-opened to Minor Line fishing:

- Minor Line fishing uses a standard rig (tuna circle size 15/0); no more than 18 hooks/line, three lines per drop = 54 hooks/drop),
- dropline fishing uses 54 hooks on a single line, minimum soak time 1 hour, max 4 hours. Can be set at dusk or pre-dawn and hauled first light,
- individual Minor Line drops follows a set method (soak time < 20 mins; contact is made with bottom; gear is attended),
- fishing is in specific depth ranges and at specific times of day
 - depths: shallow (<280 m); mid (280–550 m); deep (550–830 m)
 - time: day = fishing completed between 30 mins before sunrise to 30 mins after sunset; night = the opposite.

A key need for the project is to determine that the absence of gulper sharks in catches during normal fishing operations is due to the selectivity of the method (gear type + fishing pattern), and not due to the absence of sharks on the seamounts when fishing occurs. For this reason some fishing is conducted specifically to target gulper sharks. These (minimum requirements) science shot protocols are:

During each day, 2 Minor Line drops in the 'Mid' depth (not targeting Blue-eye marks), 1 Minor Line drop in 'Deep' depth (not targeting Blue-eye marks, minimum depth 500 m), 1 Dropline in 'Deep' depth (not targeting Blue-eye marks, minimum depth 500 m). Position and timing of these science shots at discretion of skipper in consultation with scientific observer.

During each night, 1 Minor Line drop in 'Mid' depth (not targeting daytime Blue-eye marks), 1 Minor Line drop in 'Mid' depth (targeting daytime Blue-eye marks), 1 Dropline in 'Mid' depth. Position and timing of these science shots at discretion of skipper in consultation with scientific observer but expect Dropline in first and out last.

We note here that, given the low number of Gulper sharks captured in the Barcoo and Taupo experiments to date, possibly because the sharks are not abundant, it will be necessary to increase the number of targeted scientific shots (each fishing operation) in the remaining surveys, i.e. those in "Gulper" habitat and "not targeting Blue-eye".

2.2.4 DATA HANDLING

At the conclusion of each fishing trip the catch data was tabulated into spreadsheets for the catch composition and the length/frequency. These data were also summarised into a short report and the reports and data emailed by the observer to CSIRO. The data was checked for QC, corrected if necessary and then accumulated into three spreadsheets, one for catch composition, one for length/frequency and

one for the names of the fish species captured. These spreadsheets were uploaded regularly into CSIRO's Fish Data Warehouse, an Oracle 10 database from which data can be served through the Data Trawler or through OGC web services. Data was checked for QC again during uploads.

In addition, a number of fish reference (voucher) specimens were collected for verification of species and other taxonomic purposes.

Metadata to create data descriptions for the project were recorded on the CSIRO MarLIN database.

2.3 Statistical analysis

Demonstration of 'selectivity' (capture of Blue-eye Trevalla whilst avoiding Harrison's Dogfish).

This demonstrates that nil or low capture of Harrison's Dogfish are due to the highly selective method for Blue-eye and not because Harrison's Dogfish were absent on the seamounts during the experiment. While evidence of Harrison's Dogfish (12 sharks) was provided by auto-longline and dropline captures during the Diana survey (CMAR, 2009), catch rates from Minor Line fishing by the FV *Claudara* in early 2010 were reported as zero.

Selectivity in this context is the ability of this method to catch Blue-eye Trevalla in commercial quantities using normal fishing practices whilst taking only a minimal bycatch of Harrison's Dogfish. 'Calibration' to establish that Harrison's Dogfish are largely avoided in the areas where Blue-eye are being harvested is provided by comparing the catch rate of Harrison's Dogfish during normal commercial fishing with the catch rate taken during fishing targeted at Harrison's Dogfish (i.e. not targeting Blue-eye Trevalla). Targeting Harrison's Dogfish involves fishing in different depth strata at different times of day (deep/day and shallow/night). It is also possible to use droplines to target Harrison's Dogfish if none are caught during targeted fishing with the Minor Line method. Other dogfish species will be caught as bycatch to all fishing operations, with Greeneye Dogfish predicted to be taken at relatively high rates compared to other species.

Bycatch rate and confirmation of selectivity will be based on testing differences in catch rates between Minor Line targeted fishing (Blue-eye Trevalla vs Harrison's Dogfish) using a statistical model.

2.3.1 STATISTICAL MODEL FOR ANALYSIS

The planned approach is to use a generalized linear model to test whether there is an association between the observed catch rate of Harrison's Dogfish and select factors, for each of three tests described in Section 2.2.2. While some other variables can be controlled for a standard fishing operation, sampling effort will be randomised with respect to uncontrollable variables that could impact on catch rates of Harrison's Dogfish. The null hypothesis for each test are all of the form '**no difference in catch rates of Harrison's Dogfish**' due to the select factors.

Controlled variables (standard fishing operation) in the tests: [hook type; no. hooks; bait type; bottom contact; duration of drop]

For each test, random sampling with respect to: Location on seamount [fine scale features such as gullies, rocky knobs]; Moon phase; Season

Test 1: Gulpers are avoided because standard (daytime, mid-depth) fishing avoids 'gulper habitat' [gulpers occupy deep depths during the day and mid-depths only at night]

Factors: Seamount [Taupo; Barcoo]; "Gulper habitat", described by Depth stratum/ Time of day ["Gulper Habitat": 280–550 m (Night) or 550–830 m (Day); "Other Habitat": 280–550 m (day)]; Target Blue-eye Trevalla ["No" Blue-eye]

Test 2: Gulpers are avoided because the standard blue eye fishing method [gear/practice/Blue-eye schools targeted] selects strongly for Blue eye Trevalla

Factors: Seamount [Taupo; Barcoo]; Target Blue-eye Trevalla [“Yes” or “No”]; Time of day [Day; Night]; Depth stratum [280–550 m]

Test 3: Gulpers are avoided because they are not present in sufficient abundance on the seamounts to be caught with Minor Line fishing

Factors: Seamount [Taupo; Barcoo]; Fishing method [Dropline, Minorline]; Gulper habitat [“Yes”]; Target Blue-eye Trevalla [“No”]

3 Results

This report covers fishing operations from 26 July 2011 to 15 February 2012, representing a total of eight fishing voyages during that period. Four of these were to the northern seamounts and four of these were to Taupo and Barcoo Seamounts. The project aims to complete one more fishing voyage to a northern seamount and six more to Taupo and Barcoo Seamounts. See Table 3.1 for summary of completed fishing voyages.

The average fishing shot (line soak time prior to hauling) was 10 minutes, though shots of 3–5 minutes occurred for more than 35% of all operations. Shots longer than 20 minutes occur for less than 10% of all operations. A single dropline shot was set in the ‘mid’ depth during the day on the 4 February but this fouled on the bottom and had to be cut off by the fisher, subsequently we have no data from droplines so far.

Table 3.1 Summary of all fishing operations completed; ranked in order of date. Note the difference in fishing effort between the two vessels. *These fishing lines each had 10 hooks, rather than 18 hooks which were used for all other fishing operations; this was due to reduce expected catches of Eight-bar Grouper on Fraser Seamount. ** Two lines lost some hooks when recovered.

Dates (fishing)	Vessel	Seamounts	Minor Lines fished	Total hooks used
26–28 Feb 2011	Nelson Bay	Recorder, Queensland	62	1116
22–24 Sep 2011	Nelson Bay	Fraser	64	1152
5–6 Oct 2011	Claudarah	Taupo, Barcoo	131	2358
19–20 Oct 2011	Claudarah	Taupo, Barcoo	147	2646
10–11 Dec 2011	Nelson Bay	Fraser	57	570*
14–17 Dec 2011	Nelson Bay	Queensland, Britannia	99	1782
4–5 Feb 2012	Claudarah	Taupo, Barcoo	100	1800
14–15 Feb 2012	Claudarah	Taupo, Barcoo	139	2475**

A total of 517 Minor Lines were fished at the Taupo and Barcoo Seamounts. Of these, 91 (~18%) fishing lines were dedicated to the prescribed ‘scientific’ shots (as described earlier in the experimental design Section 2.2.2). These fishing operations are summarised in Table 3.2. No dropline fishing has been completed at either of the experimental seamounts.

Table 3.2 Summary of all fishing operations to date on the experimental sites of Taupo and Barcoo Seamounts. All operations targeting gulper sharks or at night are prescribed by the experimental design. Other fishing operations are considered normal commercial fishing practice. Note no dropline fishing has been completed as yet on either seamount.

Variables		Taupo Seamount		Barcoo Seamount	
Day or Night	Target Blue-eye? Yes or No	Minor Lines fished	%	Minor Lines fished	%
Day	Yes	166	85	260	81
Day	No	20	10	20	6
Night	Yes	0	0	28	9
Night	No	9	5	14	4

3.1 Gulper shark catch analysis

3.1.1 EXPERIMENTAL SELECTIVITY FISHING PROGRAM ON TAUPO AND BARCOO SEAMOUNTS

Three Harrison's Dogfish were observed in the catch at the southern seamounts. All three sharks were captured from prescribed 'scientific' shots. Two sharks were from daytime Minor Lines set in the 'deep' (550–830 m) depth and where Blue-eye Trevalla were not targeted. One individual was caught on Taupo Seamount and the other on Barcoo Seamount. An additional gulper was captured at night in the 'mid' (280–550 m) depth on Barcoo Seamount from a line targeting Blue-eye Trevalla. So far daytime fishing in the 'mid' depths targeting Blue-eye Trevalla has not captured any gulper sharks on Taupo or Barcoo Seamounts.

The observations for each test are described below.

Test 1: Gulpers are avoided because standard (daytime, mid-depth) fishing avoids 'gulper habitat' [gulpers occupy deep depths during the day and mid-depths only at night].

Result: Whilst not targeting Blue-eye, one Harrison's Dogfish was caught on Barcoo and one Harrison's Dogfish was caught on Taupo in "Gulper" habitat, 550–830 metres (DepthZone = deep; fishing during the Day). The data are preliminary; more observations are required for statistical analyses.

Test 2: Gulpers are avoided because the standard blue eye fishing method [gear/practice/Blue-eye schools targeted] selects strongly for Blue-eye.

Result: No Harrison's Dogfish were caught on Barcoo and Taupo seamounts in depths 280–550 m (DepthZone = mid) during the Day, regardless of whether Blue-eye were being targeted or not. One Harrison's Dogfish was caught on Barcoo in depths 280–550 m during night fishing, whilst targeting Blue-eye Trevalla. The data are preliminary; more observations are required for statistical analyses.

Test 3: Gulpers are avoided because they are not present in sufficient abundance on the seamounts to be caught with Minor Line fishing [e.g. soak time too short, hooks too few, gulpers too few].

Result: Too few Harrison's Dogfish have been captured during targeted "Gulper" fishing to date to support statistical analysis of these factors.

3.1.2 EXPLORATORY FISHING TO DETERMINE SHARK DISTRIBUTION ON OTHER SEAMOUNTS

Question: Are Harrison's Dogfish present on other Tasmanian seamounts to the north of Taupo and Barcoo?

Results: Harrison's Dogfish are present on all northern seamounts sampled to date (

Table 3.3) and on Barcoo, i.e. all Tasmantid seamounts except Derwent Hunter. Information from fishers indicates they are also present on Derwent Hunter, consistent with expectations given its intermediate location in the span of the seamount chain. Note that catch rate data for the northern seamounts are not directly comparable to that for Barcoo and Taupo Seamounts due to differences in fishing methods and seamounts (e.g. skipper experience, depth range of seamount, deeper average depth of “normal” fishing (but DepthZones are comparable), different baiting methods, different number of hooks per line) that cannot be disentangled from differences due to geographic location.

Table 3.3. Number of Harrison’s Dogfish caught by Minor Line on northern seamounts during four commercial fishing surveys in 2011/12. Fishing operations (FishingOps), generally comprising 3 set lines each with 10 or 18 hooks, targeting Blue-eye “marks” (with the aid of a sounder) and fishing during the Day. Key: DepthZone: 2 = 280–550 m; 3 = 550–830 m. Operations marked with ‘G’ are “Gulper” (Harrison’s Dogfish) habitat (DepthZone=3; fishing during Day). Note that data for the northern seamounts are not directly comparable to that for Barcoo and Taupo due to differences in fishing methods and seamounts.

Survey	Seamount	DepthZone	Northern seamounts		
			FishingOps	Hooks	No. Gulper
NB201102	Fraser	2	20	1044	0
NB201103	Fraser	2	19	570	1
NB201102	Fraser	3 ^G	2	108	0
NB201101	Recorder	2	3	162	6
NB201101	Recorder	3 ^G	4	216	10
NB201101	Queensland	2	5	270	4
NB201104	Queensland	2	1	54	2
NB201101	Queensland	3 ^G	9	468	7
NB201104	Queensland	3 ^G	2	108	0
NB201104	Britannia Guyot	2	25	1314	64
NB201104	Britannia Guyot	3 ^G	6	306	12

3.2 Relative abundance and catch composition

A total of 96 Harrison’s Dogfish have been captured so far during this project. A summary of the gulper shark catch rates (fish/hooks) is presented in Table 3.4. An overview of the catch rate composition from the Minor Line fishing operations from this investigation are presented in Figure 3.1. The highest catch rates of Harrison’s Dogfish were recorded from Recorder and Britannia Seamounts.

All of the gulper sharks observed during this project were alive when brought on board and were returned to the sea alive and in a vigorous state.

Table 3.4 Summary of catch rate for Harrison’s Dogfish from the eastern seamounts using Minor Line fishing method.

Seamounts	Total hooks used	Harrison’s Dogfish	Catch rate ($\times 10^{-4}$)
Fraser	1722	1	5.81
Recorder	378	16	423
Queensland	900	12	133
Britannia	1620	64	395
Barcoo	5796	2	3.45
Taupo	3510	1	2.85

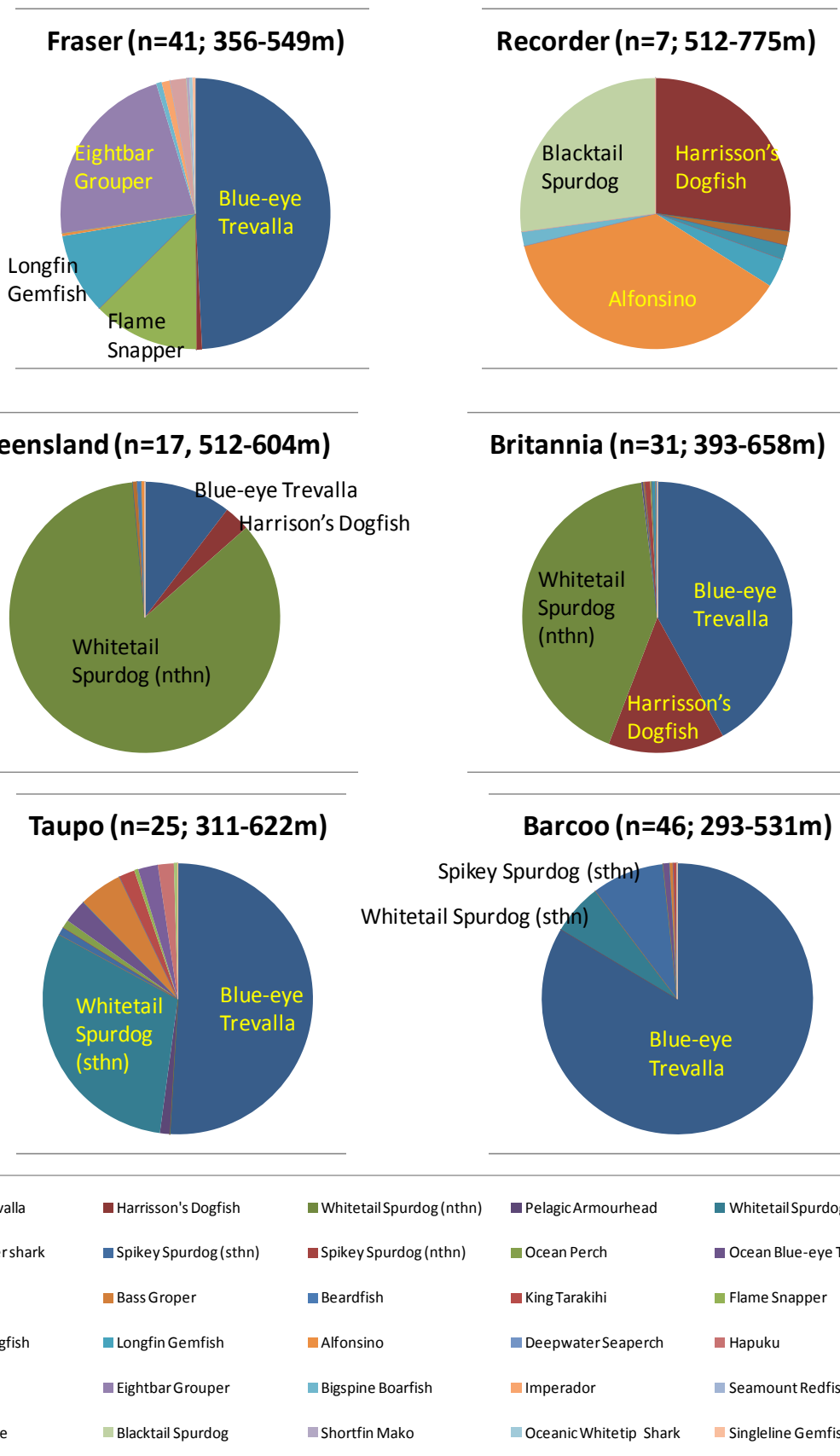


Figure 3.1 Overview of the Minor Line catch species composition (expressed here as proportional catch rate) from east coast seamounts. “n” represents the number of fishing drops on each seamount and the depth range of fishing operations is also presented. Note that these figures do not include data from ‘science’ fishing shots on Taupo and Barcoo Seamounts when gulper sharks are targeted.

3.3 Measuring and tagging

Most (89 of 96) Harrison's Dogfish were measured and sexed; length and sex data is combined and presented in Figure 3.2. Information on size at maturity (Last and Stevens, 2009) suggests only two immature Harrison's Dogfish were observed in the catch (one male at 79 cm and female at 96 cm).

Forty of the Harrison's Dogfish captured were tagged with a 'Jumbo' tag fitted to the first dorsal fin. A summary of this information and the breakdown of male to females on each seamount is presented in Table 3.5. It is obvious from the data presented in this section that the samples of Harrison's Dogfish contained mostly female sharks and most of these were on Britannia Seamount.

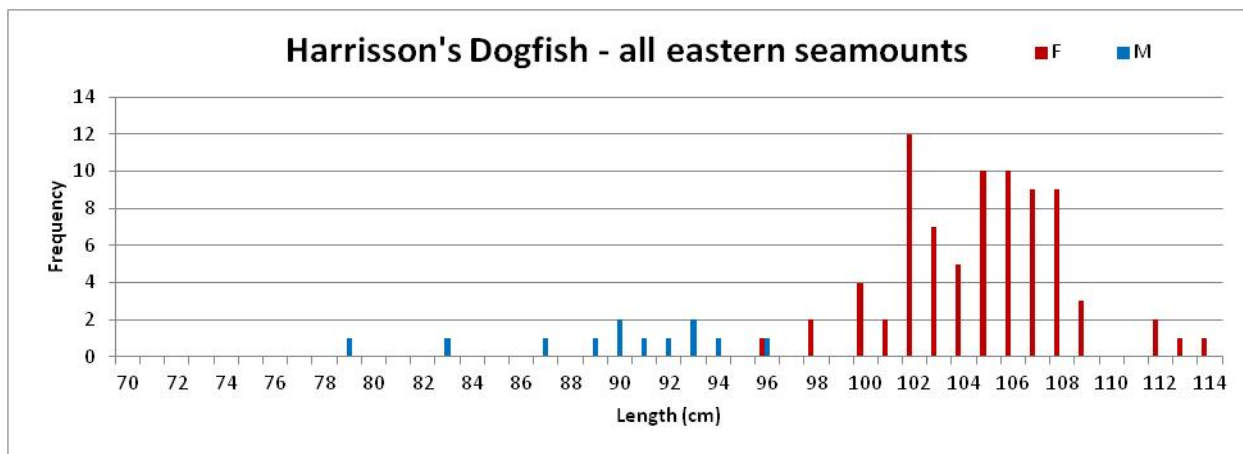


Figure 3.2 Length / Frequency plot for Harrison's Dogfish captured during fishing operations on all eastern seamounts sampled during this investigation. Female fish are represented by red bars and male fish are represented by blue bars.

Table 3.5 Summary of Harrison's Dogfish captured, measured, sexed and tagged from each seamount. Sex ratio is included where the sample is big enough for a comparison to be made.

Seamounts	Total captured	Males		Females		Sex ratio Males:Females
		measured	tagged	measured	tagged	
Fraser	1			1	1	Sample too small
Recorder	16	4	0	12	0	1:3
Queensland	12	3	0	4	1	1:1.3
Britannia	64	5	5	56	30	1:11.2
Barcoo	2			2	2	Sample too small
Taupo	1			1	1	Sample too small

4 Discussion

The early results of the experimental work conducted on Taupo and Barcoo Seamounts (4 of 10 surveys completed) support the industry proposition that gulper sharks can be avoided using Minor Line fishing methods to target Blue-eye Trevalla because very few Harrison's Dogfish have been captured. What remains to be fully established is that the observed absence of gulpers in the catch is due to the fishing method and not because gulper sharks were absent on these two seamounts during the surveys. All three gulper sharks observed at Taupo and Barcoo were captured from 'scientific' shots, one of which was targeting Blue-eye, rather than from normal fishing during the day in the 'mid' depths of 280–550 m. This demonstrates the importance of implementing the experimental design to provide the required data. More targeted 'scientific' fishing is needed, and this is planned for the remaining surveys, i.e. fishing in the deeper waters and in the 'mid' zones at night by Minor Line and dropline. These shots need to be completed to provide a definitive answer to the question about the presence and relative abundance of gulper sharks during the period of the experiment.

If we can establish that Harrison's Dogfish is present in sufficient numbers to be caught routinely during scientific targeted shots on Barcoo and Taupo Seamounts, then these interim results suggest that the combination of depth structure of the Taupo and Barcoo Seamounts and fishing during the day is a big influence on the ability of commercial Minor Line fishing to avoid catching gulper sharks when they are targeting Blue-eye Trevalla. Daytime fishing in the depths between 280 and 550 metres so far has not captured any gulper sharks.

Results regarding the distribution and relative abundance of Harrison's Dogfish on the east Tasmanian seamount chain clearly indicate that Harrison's Dogfish is distributed on all the seamounts sampled. It seems likely that the low catch rate of Harrison's Dogfish observed at Fraser Seamount is an indication it may be close to northern distributional limit of this species – consistent with the finding of Last and Stevens (2009). Although the catch rates at Recorder, Queensland and Britannia Seamounts are two orders of magnitude higher than Fraser, and of Taupo and Barcoo Seamounts, it is important to note that these values are indicative and cannot be quantitatively compared across the seamount chain due to differences in fishing operations – principally the relatively shallow depth of daytime fishing at Taupo and Barcoo.

It is noteworthy that the highest catch rate of Harrison's Dogfish, resulting from a low amount of sampling on Recorder Seamount, coincided with a zero catch of Blue-eye Trevalla and a high catch rate of the commercial Imperador (*Beryx decadactylus*); unusual currents at the time of fishing reported by the skipper may have affected the composition of the catch. While the one remaining survey to establish the range of Harrison's Dogfish is planned to target the as-yet unsampled Derwent Hunter Seamount, we note that additional samples from Recorder will reduce uncertainty about the representativeness of the low sampling effort there.

The sample of Harrison's dogfish from Britannia Seamount indicates this area has a high proportion of adult females. This may represent sexual segregation of the species, consistent with patterns observed for this species east of Flinders Island, and for Southern Dogfish (*Centrophorus zeehaani*) in the Great Australian Bight. The low number (two) of juvenile Harrison's Dogfish in seamount samples may be the result of further segregation of shark populations into areas of mature and immature animals. The conservation management implications of these observations include a high importance of the Britannia Seamount for maintaining breeding populations, and the need to establish the location(s) of mature males and pupping areas.

Observations regarding post-capture and post-release survival of Harrison's Dogfish during Minor Line fishing, based on the capture of 96 individuals, include that all were captured alive and returned to the water in vigorous condition. These positive indicators stem from short gear soak time and low volumes of fish landed together (i.e. from ~18 hooks per line). The great majority of gulpers were caught during daylight when it was possible to clearly observe the sharks swimming away. Survival will continue to be monitored during the rest of the field work; tagging activities, supported by fishing industry, will progressively add to our understanding of post-release survival.

References

- CMAR (2009). Mapping distribution and movement of gulper sharks, east coast survey: Locating and mapping *Centrophorus harrissoni*. Unpublished voyage report, Appendix E4 in: Williams A, Daley R, Green M, Barker B & Knucky I. (2012) Mapping the distribution and movement of gulper sharks, and developing a non-extractive monitoring technique, to mitigate the risk to the species within a multi-sector fishery region off southern and eastern Australia. FRDC Final Report Project 2009/024. Fisheries Research and Development Council, Australia. pp 338.
- Daley R, Green M, Barker B, and Williams A (2009). Mapping the distribution and movement of gulper sharks, and developing a non-extractive monitoring technique, to mitigate the risk to the species within a multi-sector fishery region off southern and eastern Australia. Interim report on exploratory survey to the Fisheries Research and Development Corporation.
- GA (2009). Australian bathymetry and topography grid, June 2009. Australian Government Geoscience Australia, ANZLIC Metadata ANZCW0703013116.
<http://www.ga.gov.au/meta/ANZCW0703013116.htm> Minor Line
- Graham, K. (2011). Minor-Line Fishing on Seamounts: a description of the gear and methods. Report to AFMA, 15 pp.
- Last PR and Stevens JD (2009). Sharks and Rays of Australia, 2nd Ed. CSIRO Publishing, Victoria, Australia. pp 644.
- Williams A, Daley R, Green M, Barker B & Knucky I. (2012). Mapping the distribution and movement of gulper sharks, and developing a non-extractive monitoring technique, to mitigate the risk to the species within a multi-sector fishery region off southern and eastern Australia. FRDC Final Report Project 2009/024. Fisheries Research and Development Council, Australia. pp 338.

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Gulper shark movements

Ross Daley, Tony Smith, Alan Williams CSIRO 27 April 2012

Management arrangements are under development to help recover gulper shark populations, particularly Harrison's dogfish and Southern Dogfish, including areas closed to all methods of fishing. While the locations of the planned closures are based on survey data, the basis for determining appropriate size is limited. This short paper summarises the current information about scales of movements that can be used to consider the appropriate size of closures, and the configuration of closures, in terms of their proximity to each other.

The temperate upper-slope (200–650 m) around much of the south of the Australian continent is extremely narrow, only 2 miles wide in many places. Consequently the scale of movements across the slope for upper slope dwelling species is highly constrained. By contrast, movements along the slope are not constrained in the same way. These two types of movements are considered separately below.

The best information on across-slope movements comes from passive acoustic monitoring of Southern Dogfish in the '60 mile closure' off South Australia. Transmitters with depth and temperature sensors were fitted successfully to 59 sharks. Sharks were tracked successfully by an array of five curtains of receivers (Figure 1). On average, sharks moved into shallower waters at night, returning to deeper waters during the day (Figure 2). Movements were typically across the seafloor between the 300 and 600 m contours. In winter, when nights were longer, sharks moved into shallower waters earlier in the night and returned later.

The scale of along-slope movements has been measured in three ways: 1. acoustic tracking of Southern Dogfish in the '60 mile' closure, 2. conventional tagging of three species of gulper shark, and 3. demographic separation in three species of gulper sharks. Acoustic tracking detected most (35–45/59) individual sharks within the 60-mile closure in any given month. Data from the first months of the experiment were excluded to reduce the effect of the release point on detection location. Subsequent detection frequencies were highest near the eastern and western curtains during summer and autumn (Figure 3). Detection rates during winter were highest at the central curtain.

A limited amount of information on the scale of along slope movements is available from conventional tagging data. A total of 868 Southern Dogfish have been tagged at four locations (Figure 4). Of these nine (1%) have been recaptured after up to 4 years at liberty. The largest movement was 100 miles but seven out of the nine recaptured sharks moved only half that distance or less. Of 309 Harrison's Dogfish tagged and released to date, only one has been recaptured: 0.2 miles from its release point off Flinders Island. Similarly of 187 tagged Endeavour Dogfish only two have been recaptured: 0.5–3.7 miles from the release points near Coffs Harbour.

Most deep sea shark species, including gulper sharks are known to form populations that segregate according to sex and stage of maturity along the continental slope. The distance between male, female and juvenile demographic components of the population then represents the minimum scale of movements required for breeding success, that is, the distance needed to move for mating. Data

from CSIRO-Industry surveys where sex and size data were recorded indicate that populations meet this criterion at smaller scales in some cases e.g. 30 miles for Southern Dogfish in the region of the Port MacDonnell closure , but only at larger scales e.g. 100 miles for Harrison's Dogfish in the Flinders Research Zone.

When considering appropriate scales for closures it is important to consider both the across slope and along slope scales of movement. It is important to note that the inner and outer boundaries of the closure (that run parallel to the bathymetric contours) are up to 30 times longer than the boundaries that run across the slope, which are only 1-2 miles long. Therefore it is important to consider any edge effects or implementation uncertainty at the deep and shallow margins in particular.

The largest movements observed using conventional or acoustic tagging over periods of less than one year are < 50 miles. There have been two observations from conventional tagging of Southern Dogfish moving over 65 – 100 miles over longer periods.

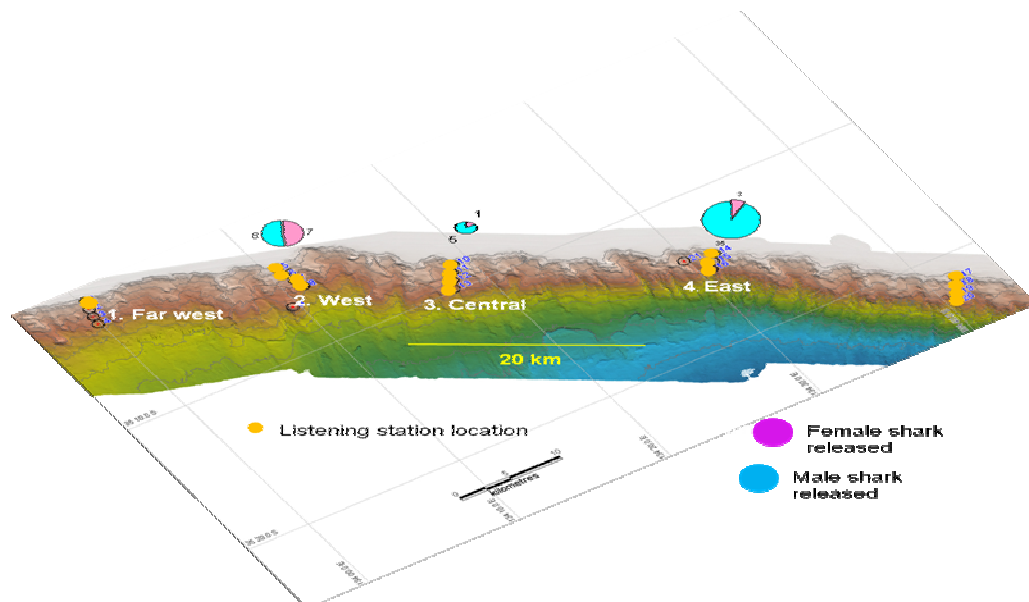


Figure 1: Acoustic receiver array used for passive acoustic tracking of Southern Dogfish in the '60-mile' closure in the Great Australian Bight

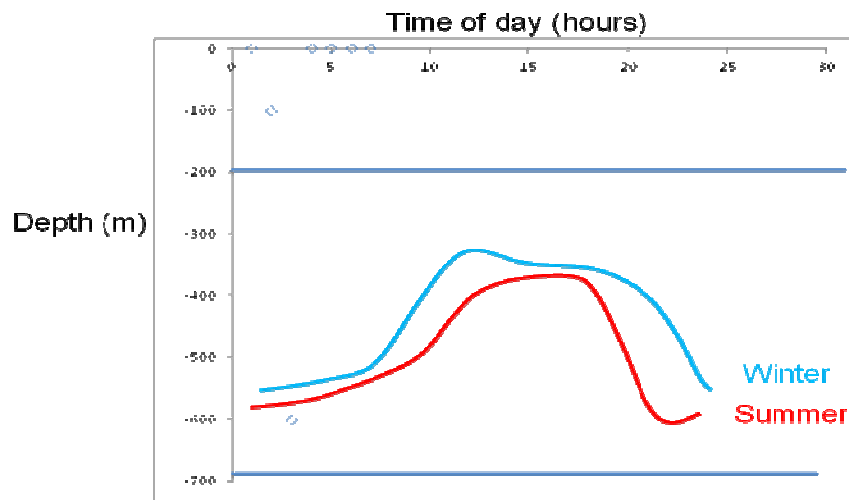


Figure 2: Diurnal movement model of Southern Dogfish between deep and shallow waters showing seasonal differences in the '60 mile' closure off South Australia. Based on detections pooled for 59 individuals in 24 hourly bins

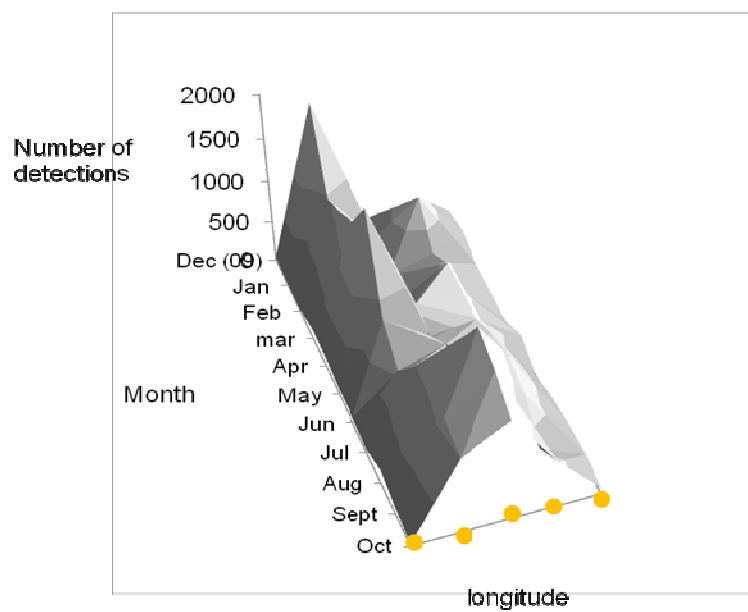


Figure3: Variation in detection frequency over time and longitude for Southern Dogfish in the '60-mile' closure in the Great Australian Bight. Number of detections = average number of detections per receiver per month

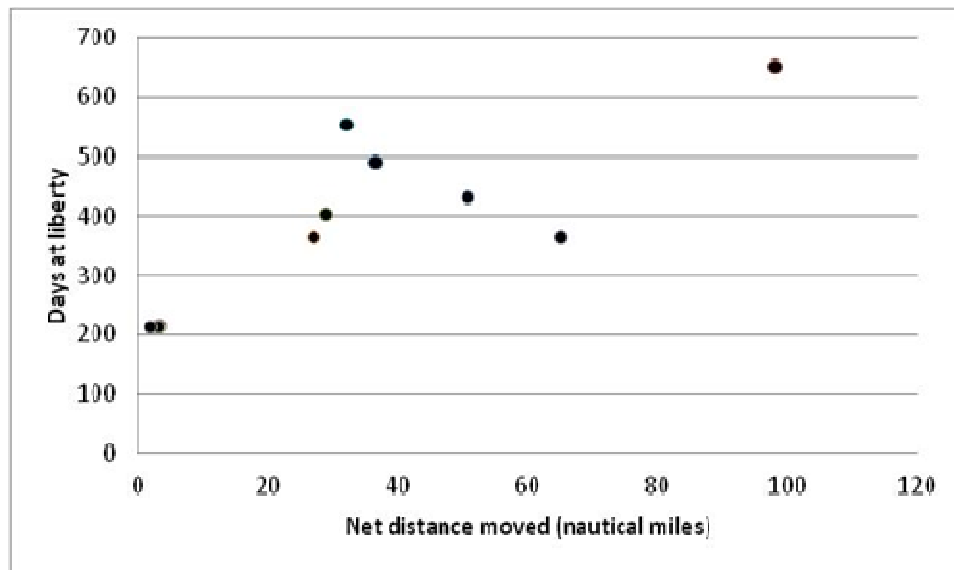


Figure 4: Conventional tagging recaptures for Southern Dogfish released from GAB closure (597), Port MacDonnell -SA (200), East Coast Australia (64), Bass Strait (7)

