Identifying options for spatial closures to conserve Harrisson's and Southern Dogfish using a Management Strategy Evaluation (MSE) approach

A discussion paper for AFMA and stakeholders

DRAFT 3 for consultation

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Executive Summary

This paper is the third in a series of discussion papers intended to help stakeholders evaluate options for enhancing a closed area network to help protect Harrisson's and Southern Dogfish ('gulper sharks') as part of AFMA's Upper Slope Dogfish Management Strategy (USDMS).

The first paper provided information relevant to the conservation of gulper sharks in the form of spatial units. These Habitat Segments are short sections of upper continental slope habitat that collectively cover the sharks' distributional ranges. Evaluation of the 113 segments permitted stakeholders to identify prospective Candidate Areas for gulper shark conservation. The second paper presented methods for estimating the pre-fishery carrying capacity and depletion of gulper sharks to help quantify the contribution of closures to the management target for recovery: 25% of original population biomass. In the absence of data on carrying capacity and depletion, performance against the 25% target reference point will need to be assessed primarily as the area within closures as a proportion of species ranges. This third paper provides additional information for Candidate Areas in a form similar to a Management Strategy Evaluation (MSE) to identify Area Options and Network Options. MSE is a decision support tool to assist in making decisions between alternative courses of action where there are conflicting objectives and where there is significant scientific uncertainty in predicting outcomes. The method is a refinement of the one used to identify closed areas to mitigate fishing impacts on gulper sharks in the second implementation phase of AFMA's management strategy (Daley et al. 2010).

In overview, the method to identify options for a network of spatial closures for gulper sharks - that follow the TSSC guidelines for threatened species listing - includes three distinct steps; the MSE represents steps 2 and 3:

1. Locating the most prospective general areas (Candidate Areas) within the distributional range of each species in a screening process
2. Identifying options for closures (Area Options) in each Candidate Area that contrast a range of conservation and socioeconomic objectives
3. Evaluating the collective properties of sets of Area Options as a network (Closure Network)

The method's step-wise progression is illustrated in Figure 1, while the attributes and criteria used, and the uncertainties associated with each, are summarised – and detailed in Table 1. Options for evaluation are described, and tabulated: Area Options (Tables 2 and 3) and Network Options (Tables 4 and 5). The primary performance measure is the inclusion of 25% of the habitat (or carrying capacity if that can be determined) of each species in a closure network (as a proxy for the equivalent limit reference point in Harvest Strategy Policy). A summary of individual Area Options showing their area, management arrangements, and percentage contribution to the target closed area for each species is shown in Table 6. Notes on key aspects of the network design are also provided for information.

This early draft was produced ahead of consultative meetings with the fishing industry but after area options had been put forward by environmental NGOs. Based on meetings to date with the fishing industry, we anticipate being able to update this paper in relation to industry-suggested Candidate Areas (e.g. Smithy's Corner, Tuross, Western Eyre, Zeehan), and alternative or complementary management measures including day vs night fishing on the slope, e-monitoring, industry codes of practice

and industry contributions to a monitoring program. Note, however, fishing industry suggestions have not yet been formally proposed or considered.

Separate analyses are underway to determine the potential contribution of the "700 m trawl exclusion zone" and rocky (untrawlable) refuge habitats to the closure network, and the status of Southern Dogfish in the 'Far West' region of the GAB.

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Background

Following Smith (1993), Daley et al. (2010) described management strategy evaluation (MSE) as "a method to assess the consequences of applying alternative management strategies in a way that lays bare the tradeoffs across a range of management objectives". It is also a way of formally taking account of scientific uncertainty in providing this information. In other words, MSE is a decision support tool to assist in making decisions between alternative courses of action where there are conflicting objectives and where there is significant scientific uncertainty in predicting outcomes.

The aims of AFMA's USDMS are to mitigate fishing impacts on gulper sharks and support the recovery of two species. This is set in the wider context of AFMA's objectives on economic efficiency and ESD. Thus, the alternative management strategies include different combinations of closure (and other mitigation) options that could protect and recover gulper shark species while minimising costs to the fishing industry in harvesting other species. The conservation objective is likely to be met by closing a large area of fishing ground, while the sustainable use objective is likely to be met by minimising the amount of area closed to fishing.

The application of MSE methods in the SESSF was reviewed by Daley et al. (2010) who concluded that qualitative MSE methods – necessary for gulper sharks where quantitative data are sparse – can be used effectively. The key to the method is not so much how the predictions are made, but in structuring the analysis through a series of steps. These include (Smith 1993):

1. Identifying all relevant objectives.
2. Identifying performance measures or criteria by which success in meeting each objective will be measured.
3. Choosing a set of management options to evaluate.
4. Predicting how each option would perform against each of the criteria, stating key assumptions and taking suitable account of key uncertainties.
5. Presenting the results in a "decision table" that lays bare the tradeoffs in achieving the separate objectives.

Identifying options for a network of spatial closures - that follow the TSSC guidelines for threatened species listing - includes considerations in three distinct steps (Figure 1):

1. Locating the most prospective general areas (Candidate Areas) within the distributional range of each species in a screening process
2. Identifying options for closures (Area Options) in each Candidate Area that contrast a range of conservation and socioeconomic objectives
3. Evaluating the collective properties of sets of Area Options as a network (Closure Network)

The step-wise progression of the method employed is illustrated in Figure 1, while the attributes and criteria used and the uncertainties associated with each are detailed in Table 1. Options for evaluation are described, and tabulated: Area Options (Tables 2 and 3) and Network Options (Tables 4 and 5).

The performance measure is the inclusion of 25% of the habitat of each species in a closure network (as a proxy for the equivalent limit reference point in Harvest Strategy Policy). The areas of all potential options can be summed from Table 6.
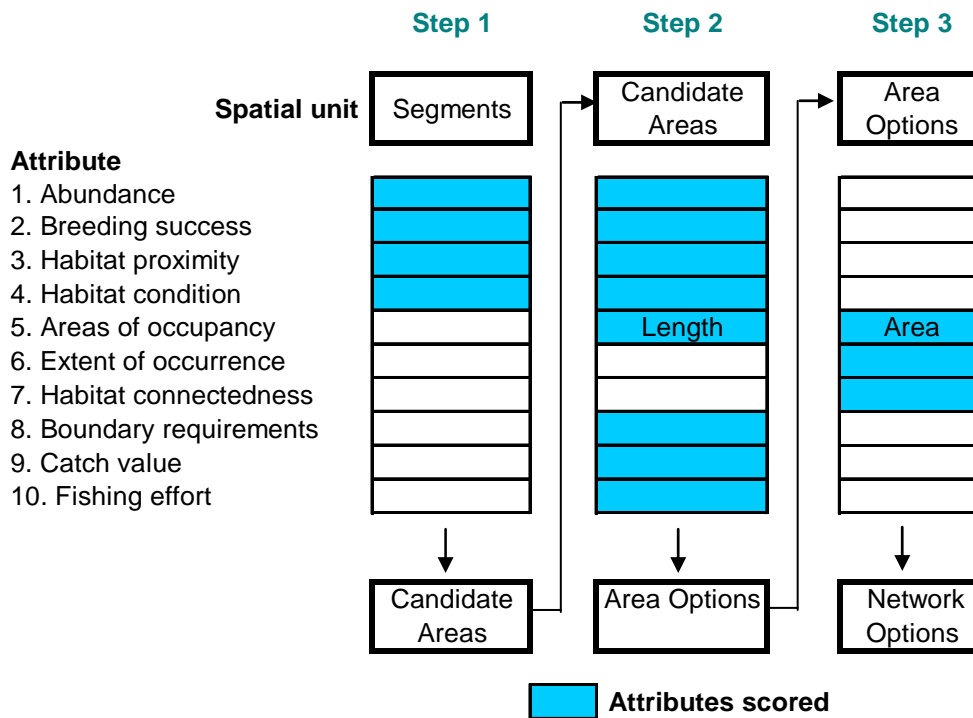
	Step 1	Step 2	Step 3
Spatial unit	Segments	Candidate Areas	Area Options

Attribute
1. Abundance
2. Breeding success
3. Habitat proximity
4. Habitat condition
5. Areas of occupancy
6. Extent of occurrence
7. Habitat connectedness
8. Boundary requirements
9. Catch value
10. Fishing effort

(Step 1 → Candidate Areas; Step 2 → Area Options; Step 3 → Network Options; Length; Area)

☐ **Attributes scored**

Figure 1 Schematic showing the stepwise process to identify a network of closed areas for Harrisson's and Southern Dogfish on Australia's upper continental slope. Eight attributes relevant to the conservation of these sharks, and two fisheries related attributes are used in 3 steps: (1) in a screening process to locate the most prospective general areas (Candidate Areas); (2) to identify options for closures in each Candidate Area that contrast a range of conservation and socioeconomic objectives (Area Options), and (3) to evaluate the collective value of the Area Options (Closure Network)

Attributes used to identify prospective closed areas

Ten attributes were used to score areas of the upper slope in the process to identify a closure network (Figure 1). Each attribute is described below, while the scoring scheme is provided in Table 1. The thresholds shown below in Table 1 are not distinct cut-offs, nor necessarily based on 'hard data'. They represent contrasts in attributes, and are based on stakeholder and expert judgement that includes a broad knowledge of the biology and ecology of the species and the marine ecosystems in which they exist.

1. Abundance of existing populations

The closure network should protect remaining viable populations. Abundance helps to identify viable populations, and, conversely, also those that are unlikely to recover. Each species is now represented mostly by scattered remnant aggregations. Relative abundance, based on catch rates, is used as an index of population viability together with breeding success (attribute 2). (Note, only auto-longline and minor line data were available for this analysis.) Scoring for Area Options used the highest abundance value where more than one Habitat Segment was included.
Uncertainties: the extent to which catch rates reflect local abundance and the areas over which catch rates sample abundance.

2. Breeding success

The most important determinant of population regulation in sharks is survival of young individuals. A key recommendation from a range of approaches is for

management to maintain reserves to protect juveniles and breeding adults (Dulvey et al. 2010). A key scale consideration is that closure options are large enough to include each of these components. Scattered remnant aggregations rarely contain mature adults of both sexes. Presence of mature individuals of both sexes, and/or presence of juveniles is used to identify potential for areas to support breeding success: Condition 1: mature males present. Condition 2: mature females present. Condition 3: numerous juveniles present. High, medium and low scores are assigned according to the number of conditions met. Scoring for Area Options used the highest breeding success value where more than one Habitat Segment was included.
Uncertainties: the minimum population size or density required to maintain a viable local breeding population; the degree of connectedness needed to maintain a viable local breeding population. Frequency of mating, geographic scale of mating movement, and juvenile mortality rate.

3. Habitat proximity

Habitats in close proximity to viable populations have higher potential to support recovery through immigration and recruitment. "Adjacent": habitat segments adjacent to segments supporting viable populations, or within the home range distance from segments with viable populations. [Based on acoustic telemetry data, the foraging range of gulper sharks is estimated as up to 50 n.m., thus half this distance is used either side of segment boundary]. "Close": habitat segments adjacent to segments scoring high. Distant: habitat segments adjacent to segments scoring medium. None: other segments. Seamounts are treated as being non-adjacent, i.e. there is no connection of upper slope habitats.
Uncertainties: the degree of connectedness needed for immigration and recruitment to re-establish a viable population in an adjacent area. The scale of breeding and dispersal movements over periods exceeding one year may be larger than the ranges measured using telemetry. The frequency of mating is unknown and potentially de-coupled in space and time from pupping.

4. Habitat condition

Degraded habitats have lower potential to support recovery; for example, removal of structural habitat may affect the survival of juvenile sharks. The intensity and extent of direct impact by historical trawl and auto-longline (ALL) fishing is used as a proxy to identify habitat condition. Dropline and minor line are considered to have negligible impact; gillnets were used in only a small area of the SESSF. Scoring of Area Options covering large areas (e.g. several segments) used expert judgement where survey data provided additional insights and where effort data varied between segments.

A. Heavily fished by trawl and ALL
B. Heavily fished by trawl or ALL
C. Moderately fished by trawl or ALL
D. Lightly fished or unfished

Uncertainties: the relative impacts of different gear types and the cumulative impacts across gear types is poorly understood, but assumed to be additive - in part because ALL is able to fish some habitat areas inaccessible to trawls. Habitat preferences of juveniles are unknown.

5. Areas of occupancy (length and size of protected areas)

A greater collective size of closed area increases the likelihood that decline is halted and recovery enabled. The size of individual area options contribute to the total target area for closure. There is a minimum area needed to support and protect a viable local breeding population (the 'home range'). The home range for gulper sharks is based on acoustic telemetry data collected in the GAB 60-mile closure that shows that gulper sharks forage over a range of ~50 n.m. along-slope and migrate across most of their depth range on a daily basis. For this reason, *size is measured as length along-slope when evaluating Area Options* and all Area Options (except existing closures) are assumed to encompass the entire identified depth range (including deep & shallow buffers) of the gulper sharks. Larger segments are more likely to support recovery because edge effects are minimised. Thus, *size is measured as area when summing individual Area Options to evaluate Network Options*.

Uncertainties: The scale of breeding and dispersal movements over periods exceeding one year may be larger than the ranges measured using telemetry.

6. Extent of occurrence (geographical range of protected populations)

Extent of occurrence from the EPBC listing guidelines describes the range of a species. Protection over a broad range is more likely to support the viability and recovery of a species than protection in only a narrow part of its range. Range is described as the geographical span of area options within the original core range. Scoring for Network Options included only the Area Options with extant (existing) shark populations of medium or high abundance. Extent of Occurrence was considered separately for the western and eastern populations of Southern Dogfish, and for the continental margin and seamount populations of Harrisson's Dogfish, because there are large geographical gaps in both instances.

Uncertainties: the degree of connectedness needed to maintain viable breeding populations.

7. Number of closures (genetic diversity)

Future population viability will be higher if genetic diversity is maintained across a broad part of the existing range of a species. Number of closures per species is used as a proxy for genetic diversity. Scoring for Network Options included only the Area Options with extant (existing) shark populations of medium or high abundance. The number of closures was considered separately for the western and eastern populations of Southern Dogfish, and for the continental margin and seamount populations of Harrisson's Dogfish.

Uncertainties: genetic structure is not known for either species.

8. Boundary requirements (depth)

The effectiveness of closures is reduced where boundaries do not fully contain the core depth range. Depth bounds are well established for both species and high resolution bathymetry data is available to map boundaries precisely in the great majority of the fishery area. Area calculations for Area Options presented here have included the entire identified depth range (including deep & shallow buffers) of the gulper sharks except for existing closures that do not currently cover the full depth range. (Note, the depth range of Harrisson's Dogfish (180-1000m) was used for all boundaries on the east coast.

Uncertainties: no uncertainties associated with defining effective depth boundaries.

9. Catch value

There is a financial cost to industry by closing areas of gulper shark habitat. The annual average sum of weight of quota species over 5 years (2006-2010 inclusive) caught by trawl and autolongline is used as a proxy for cost. Catch value of seamounts relates almost exclusively to Blue-eye trevalla caught by minor line and auto-longline methods – but this was not able to be captured quantitatively in this paper. At the time of writing, catch values for closure options that overlay NSW Fisheries jurisdiction had not been finalised.
Uncertainties: this metric does not fully reflect the opportunity cost of closed areas that are currently fished.

10. Fishing effort

There is a potential cost to industry, and implications for fishery managers, of displacing effort from closed areas to other fishery areas. The annual average sum of trawl and autolongline fishing operations (ops.) over 5 years (2006-2010 inclusive) is used as a proxy for effort. Fishing effort on seamounts relates almost exclusively to Blue-eye trevalla caught by minor line and auto-longline methods – but this was not able to be captured quantitatively in this paper. Fishing effort for closure options that overlay NSW Fisheries jurisdiction is being estimated based on effort data in the appropriate latitudinal band sub-set to vessels that have reported gulper catches. The annual average sum of trawl (prawn and fish) and demersal line fishing operations over 3 years (2008-2010 inclusive) will be used. At the time of writing, effort values for closure options that overlay NSW Fisheries jurisdiction had not been finalised.
Uncertainties: this metric does not capture the consequences of displacing effort.

Table 1 Scoring scheme for the 10 attributes used in the stepwise process to identify a network of closed areas for Harrisson's and Southern Dogfish on Australia's upper continental slope. Figure 1 shows which attributes are scored in the 3 steps of the process.

Aspect	Attribute	Metric	Contribution to closure network			
			None	Low	Medium	High
Status of existing populations	**1** Abundance of existing population	Max. catch rate: no. sharks per 100 hooks	0	<0.1	0.1	1
	2 Breeding success	Number of conditions met	0	1	2	3
Potential for recovery	**3** Habitat proximity	Adjacency and overlap with home range measured along 400 m contour	None	Distant	Close	Adjacent
	4 Habitat condition	Habitat segment dominated by: A, B, C or D	A	B	C	D
Efficacy of protected areas and area network	**5** Areas of occupancy (length and size of protected areas)	Length of protected area in linear nautical miles	<10 n.m.	10-25 n.m.	25-50 n.m.	≥50 n.m.
	6 Extent of occurrence (geographical range of protected populations)	Proportion of original core range	Single location	>25%	>50%	>75%
	7 Habitat connectedness (genetic diversity)	Numbers of areas protected	0-1	2	3	>3
	8 Boundary requirements	Core depth range included within protected area	Slivers	Incompletely	Mostly	Fully
Fishery cost	**9** Catch value	Catch weight (tonnes)	N/A	Industry review	Industry review	Industry review
	10 Fishing effort	Effort (hours or tows)				

Candidate Areas

Stakeholder identified Candidate Areas

A set of potential Candidate Areas (Set 1) was identified by the authors using a method presented to stakeholders (Williams et al. 2012a) and reviewed in the stakeholder meeting on 23 February 2012.

The conservation sector also identified a set of Candidate Areas (Set 2) it "would like to see further investigated". These were in similar locations to the Candidate Areas in Set 1, but larger. Their larger extent reflects the conservation sector's suggestion that "it is better to be inclusive rather than exclusive of areas at this early stage".

Set 1
Harrison's Dogfish
- Flinders area and adjacent segments
- Port Stephens and adjacent segments
- Tasmantid Seamount chain, especially Queensland and Brittania Seamounts

Southern Dogfish
- GAB 60-mile closure (existing closure)
- Lincoln canyon area and adjacent segments
- Port MacDonnell (existing closure)
- Endeavour Dogfish Closure to Five Canyons

Set 2
Harrison's Dogfish
- 1: North boundary: Smithy's Corner – South boundary: Banks Strait Gullies (*the highest priority for assessment*)
- 2: North boundary: Crowdy Head (potentially as far as Coffs) – South boundary: South of Endeavour Closure (*high priority for assessment*)
- 3: North boundary: Byron Bank – South boundary: 30 Canyon
- 4: All seamounts should to be closed.

Southern Dogfish
- 1: North boundary: West of the Fence – South boundary: 60 mile ATF
- 2: North boundary: 60 mile ATF – South boundary: West of KI
- 3: North boundary: Beachport Canyon – South boundary: Portland 2nd Main Drag
- 4: North boundary: Five Canyons – South boundary: Kiama

Additional Candidate Areas

In addition to the 7 Candidate Areas mapped through the stakeholder process, 5 others should be considered because they are pre-existing or proposed managed areas that overlap the distribution of Harrisson's or Southern Dogfish – and have the potential to contribute to the network. These are 3 proposed Commonwealth Marine Reserves and 2 former fishery closures.

All 12 areas are mapped below for Harrisson's Dogfish (Figure 2) and Southern Dogfish (Figure 3).

Area Options for each Candidate Area are detailed below and summarised in Table 2.
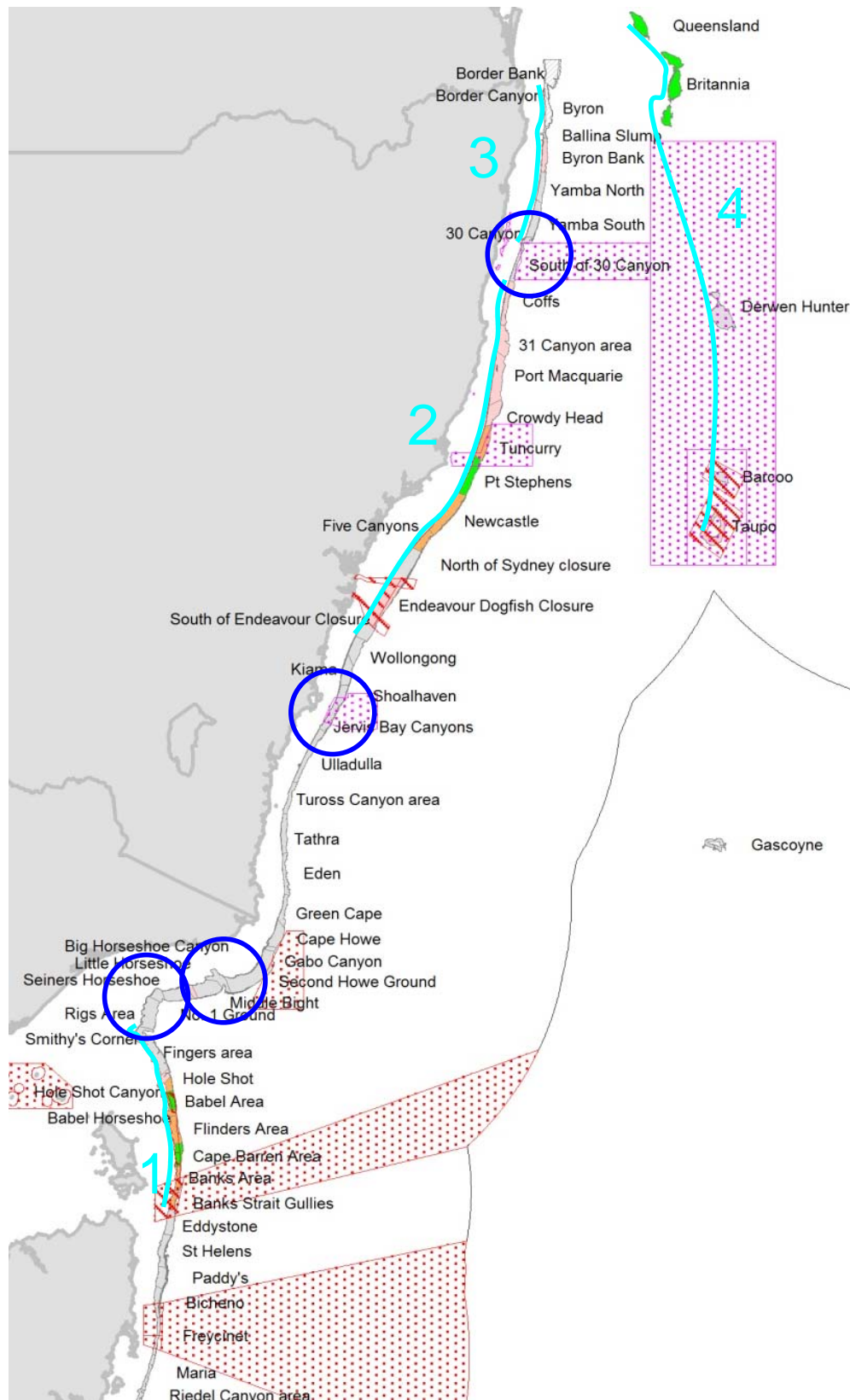
Figure 2 Candidate Areas for Harrisson's Dogfish conservation: Set 1 examples mapped (high suitability = green; medium = orange; low = pink; no data = grey); Four numbered Set 2 suggestions shown by blue lines; additional areas shown by blue circles. Proposed and existing closures shown as stippled polygons.
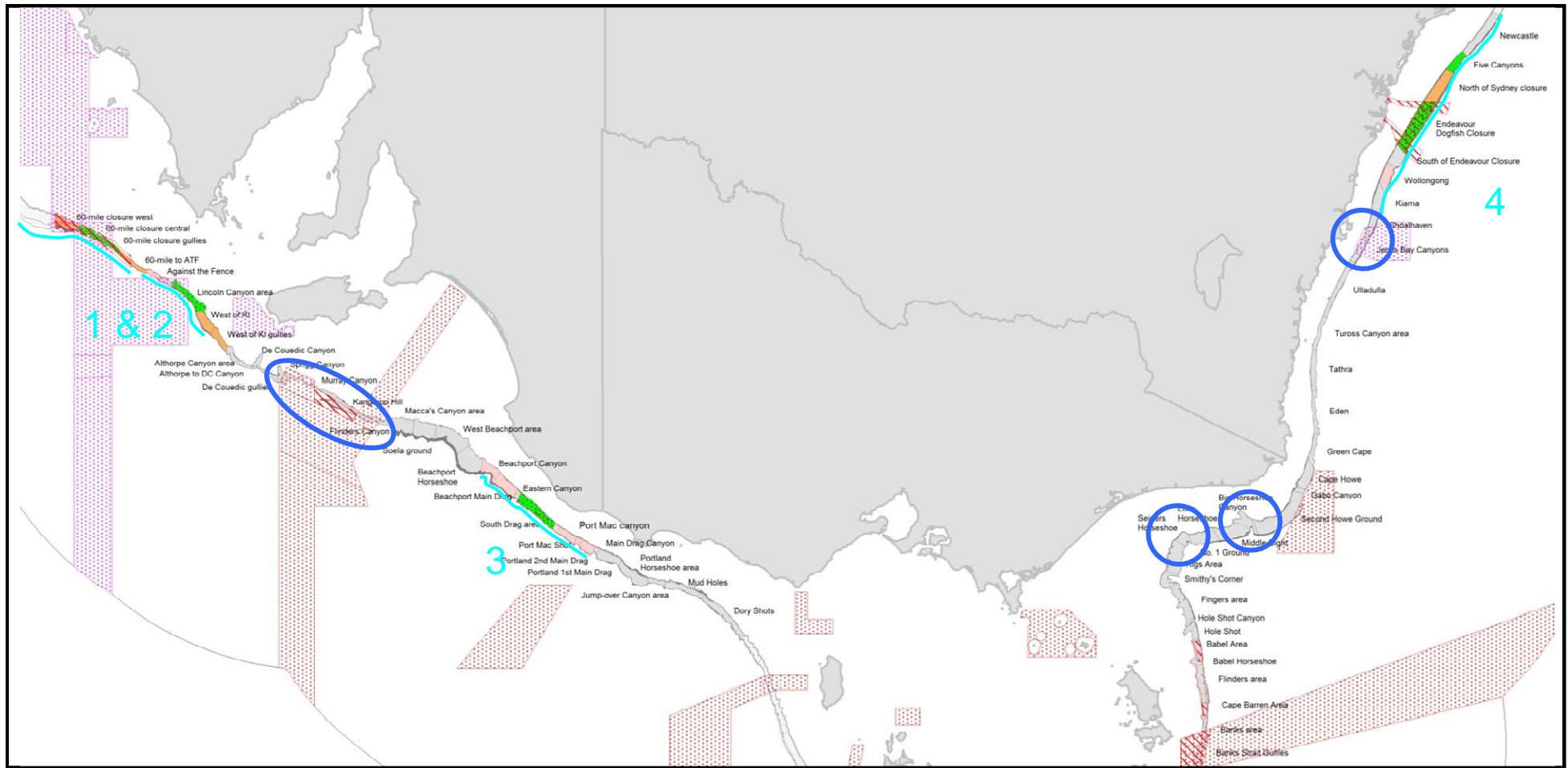
Figure 3 Candidate Areas for Southern Dogfish conservation: Set 1 examples mapped (high suitability = green; medium = orange; low = pink; no data = grey); 4 numbered Set 2 suggestions shown by blue lines; additional areas shown by blue circles. Proposed and existing closures shown as stippled polygons.

Area Options

Area Options for the set of 12 Candidate Areas are detailed below, separately for the 7 areas identified in Set 1 and the 5 relevant pre-existing areas. Note, however, fishing industry suggestions have not yet been formally proposed or considered. Scored attributes are shown, respectively, in Tables 2 and 3. A map of each option is provided at the end of the paper, and the area and management arrangements (where know) are provided in Table 6. Options within each Candidate Area are listed in order from current status to largest (most conservative).

Notes on attribute scoring for Area Options

1. Habitat segments are used as the spatial units for scoring attributes 1 to 5.
2. For options covering large areas (e.g. several segments), the highest attribute score is used for abundance and breeding success
3. In some instances for options covering large areas (e.g. several segments), and some specific options (e.g. Flinders), expert judgement is used to score habitat condition (e.g. considering survey data in addition to effort data that may vary between segments).
4. For options covering areas where both shark species occur, the score reflects the principal species (as shown in Table 2).
5. Boundary attribute scores for all new options assume that (1) depth boundaries will cover the full depth range for the species in question (i.e. 180-1000 m for Harrisson's Dogfish and 180-900 m for Southern Dogfish), and (2) that CMR boundaries are as originally proposed (i.e. shapefiles on DSEWPaC website). Any modification to boundaries will change the efficacy of closures and change the area estimates for each option.
6. Small, fragmented areas of existing closures that overlap the upper slope ('polygon slivers') are not considered because, individually or collectively, they provide no protection for these sharks which make daily movements upslope and regular movements along-slope.
7. Area of occupancy measured as linear n.m. along the 400 m contour, and proximity, are not able to be calculated for the individual seamounts. Area of occupancy should refer to the upper slope area of each seamount.

Area Options within Candidate Areas

GAB 60-mile closure

Area with large existing gulper shark closure; persistence of viable population confirmed by survey data (Williams et al., 2012c). Options:

1. 60-mile closure: status quo – existing closure.
2. 60-mile closure + Western Eyre CMR: includes small portion of CMR at western boundary (although this is outside the core range of Southern Dogfish).
3. 5 segments (West of Fence to 60-mile to ATF): eNGO suggested area for further investigation.

Western Eyre CMR off Kanagaroo Island

Area with proposed CMR (SW Marine Region). Options:

1. Western Eyre CMR: proposed CMR section off Kangaroo Island.
2. Extended Western Eyre CMR: CMR boundary extended to span home range (50 n.m.).
3. 3 segments (60-mile to ATF to West of KI): eNGO suggested area for further investigation.

Port MacDonnell

Area with small existing gulper shark closure. Options:

1. Existing Port Mac closure: status quo – existing closure.
2. Port Mac closure covering depth range: widened to fully cover species depth range.
3. Extended Port Mac closure: extended north-west to Eastern Canyon, to span approximately half the home range (25 n.m.); extension is to extensively used trawl grounds and ALL in canyon.
4. 7 segments (Beachport Canyon to Portland 2nd Main Drag): eNGO suggested area for further investigation.

Flinders

Area containing a large fishery managed area for gulper sharks (the Flinders Research Zone) with 2 small closures embedded; complex management arrangement complicates scoring of habitat proximity and condition. Habitat condition has been elevated to medium based on the presence of untrawlable bottom in the central part of the FRZ, and the presence of high coral abundance in the Babel Horseshoe. eNGO highest priority. Note: Options 2 and 3 do not differ in their areal coverage but in their management arrangements.

1. Flinders Research Zone: status quo – existing closure.
2. FRZ covering depth range: widened to fully cover species depth range.
3. FRZ covering depth range and fully closed: full closure of FRZ.
4. 10 segments (Banks Strait Gullies to Smithy's Corner): eNGO suggested area for further investigation.

Sydney

Area with moderately large existing gulper shark closure (that is assumed here to include the telecommunication cable closures). eNGO high priority for Southern Dogfish. Options:

1. Existing Endeavour Closure (inc. cable closures): status quo – existing closure.
2. Endeavour Closure covering depth range: widened to fully cover species depth range.
3. Extended Endeavour Closure: extended to the north to span home range and include area of medium abundance (Southern Dogfish) in Five Canyons segment.
4. 6 segments (Kiama to 5 Canyon): eNGO suggested area for further investigation.

Hunter CMR

Area with proposed CMR (East Temperate Marine Region). High abundance of Harrisson's Dogfish observed in CSIRO survey just south of CMR. Habitat condition adjusted to include NSW effort (not accounted for in mapping provided in Williams et al., 2012a). eNGO high priority (suggested area for Harrisson's Dogfish has some overlap with Sydney suggestion for Southern Dogfish). Options:

1. Hunter CMR: proposed CMR.
2. Hunter CMR covering depth range: widened to fully cover species depth range over the entire width of the proposed CMR.
3. Extended Hunter CMR (covering depth range): CMR boundary extended to span home range (50 n.m.).
4. 10 segments (Coffs to Endeavour Dogfish Closure): eNGO suggested area for further investigation.

Tasmantid seamounts

A chain of 6 prominent seamounts, all closed to bottom trawling, and which include a fishery closure to all methods on the Taupo and Barcoo Seamounts implemented as part of AFMAs USDMS. CSIRO surveys (Williams et al., 2012d) confirm all seamounts support populations of Harrisson's Dogfish – but these are expected to have low connectivity between seamounts or with the continental margin of NSW/ Qld due to the great depth of the intervening Tasman Sea. Options:

1. CMR (Taupo/ Barcoo closed + others Zone VI)
2. Taupo/ Barcoo open + others Zone IV
3. Brittania/ Queensland closed + others Zone IV
4. All seamounts closed: eNGO suggested area for further investigation.

Additional Candidate Areas

Murray CMR

Area with existing CMR and orange roughy closure. Options:

1. Murray CMR + Kangaroo Hill fishery closure: status quo – existing closure.
2. Extended fishery closure: Kangaroo Hill closure widened to fully cover species depth range.

Seiners Horseshoe

Previous fishery closure for pink ling spawning aggregations. Boundaries difficult to measure for gulper sharks due to complex canyon topography. Options:

1. Original design: status quo – existing closure.
2. Enhanced design: widened to fully cover species depth range in the canyon head.

Everard Horshoe (Big Horseshoe Canyon)

Previous fishery closure for pink ling spawning aggregations. Boundaries difficult to measure for gulper sharks due to complex canyon topography. Habitat condition elevated to account for large area of untrawlable bottom. Options:

1. Original design: status quo – existing closure.
2. Enhanced design: widened to fully cover species depth range in the canyon head.

Jervis Bay CMR

Area with proposed CMR (East Temperate Marine Region). Options:

1. Jervis Bay CMR: proposed CMR.
2. Extended Jervis Bay CMR: extended south to span approximately half the home range (25 n.m.).

Clarence CMR

Area with proposed CMR (East Temperate Marine Region) which overlaps with upper slope as a series of slivers. Options:

1. Clarence CMR: proposed CMR.
2. Clarence CMR covering depth range: widened to fully cover species depth range over the entire width of the proposed CMR.
3. Extended Clarence CMR (covering depth range): widened to fully cover species depth range and extended north to span home range (50 n.m.).
4. 4 segments (30 Canyon to Byron Bank) + CMR (covering depth range): eNGO suggested area for further investigation.

Table 2 : Area Options coloured to show their expected performance against each attribute as scored using Table 1 (High benefit to gulpers/ low industry cost -green; Medium benefit to gulpers/ medium industry cost -orange; Low benefit to gulpers/ high industry cost -pink; Grey-none; White-no data). Cost to trawl Commonwealth trawl sector shown as raw data. Note, fishing recorded in closed areas is pre-closure effort. * see explanatory text above; ^ NSW fisheries data used (see explanation of attributes 9 and 10)

Stakeholder Candidate Areas / AREA OPTIONS	Option no.	Map no.	Species	eNGO	1 Abundance	2 Breeding success	3 Habitat proximity	4 Habitat condition	5 Area of occupancy (linear n.m.)	8 Boundary	9 Trawl Catch value (t/year)	10 Trawl Fishing effort (ops/year)	9 Auto-longline Catch value (t/year)	10 Auto-longline Fishing effort (ops/year)
GAB 60-mile closure		1	S											
60-mile closure	1						N/A		60		1.0	5.8		
60-mile closure + Western Eyre CMR	2								63		1.6	9		
5 segments	3			#1					105		9.3	19.2		
Western Eyre CMR off Kanagaroo Is		2	S											
Western Eyre CMR	1						N/A		26		0.0	0		
Extended Western Eyre CMR	2								48		4.3	9.4		
3 segments	3			#2					67		11.4	10		
Port Macdonnell		4	S											
Existing Port Mac closure	1						N/A		10		1.8	36.2		
Port Mac closure covering depth range	2								10		7.1	96		
Extended Port Mac closure	3								27		50.9	355.2		
7 segments	4			#3					96		411.9	1112.8		
Flinders		5	H (S)											
Flinders Research Zone	1								78*		7.2	97.6		
FRZ covering depth range	2						*	*	78		7.4	98.2		
FRZ covering depth range and fully closed	3								78*		7.4	98.2		
10 segments	4			#1					156		305.0	767.2		
Sydney		9	S (H)											
Existing Endeavour Closure (inc. cable closures)	1						N/A		35*					
Endeavour Closure covering depth range	2								35		^	^		
Extended Endeavour Closure	3								77					
6 segments	4			#4					120					
Hunter CMR		10	H											
Hunter CMR	1				*			*	10					
Hunter CMR covering depth range	2				*			*	30		^	^		
Extended Hunter CMR (covering depth range)	3							*	50					
10 segments	4			#2				*	255					
Tasmantid seamounts		12	H										*	*
CMR (Taupo/ Barcoo closed + others Zone VI)	1				*		N/A		*					
Taupo/ Barcoo open + others Zone IV	3				*		N/A		*					
Brittania/ Queensland closed + others Zone IV	2						N/A		*					
All seamounts	4			#4			N/A		*					

Table 3 Area Options for pre-existing/proposed managed areas coloured to show their expected performance against each attribute as scored using Table 1 (High benefit to gulpers/ low industry cost -green; Medium benefit to gulpers/ medium industry cost -orange; Low benefit to gulpers/ high industry cost -pink; Grey-none; White-no data). Cost to trawl Commonwealth trawl sector shown as raw data. Note, fishing recorded in closed areas is pre-closure effort. * see explanatory text above; ^ NSW fisheries data used (see explanation of attributes 9 and 10)

Pre-existing Candidate Areas / AREA OPTIONS	Option no.	Map no.	Species	eNGO	1 Abundance	2 Breeding success	3 Habitat proximity	4 Habitat condition	5 Area of occupancy	8 Boundary	Trawl 9 Catch value (t/year)	Trawl 10 Fishing effort (ops/year)	Auto-longline 9 Catch value (t/year)	Auto-longline 10 Fishing effort (ops/year)
Murray CMR		3	S											
Murray CMR + Kanagaroo Hill fishery closure	1				(white)	(white)	(grey)	(orange)	47	(orange)	8.1	19.2	(orange)	(pink)
Extended fishery closure	2			--	(white)	(white)	(grey)	(orange)	83	(green)	8.9	19.6	(pink)	(pink)
Seiners Horseshoe		6	S (H)											
Original design	1				(pink)	(orange)	(grey)	(pink)	10	* (orange)	8.7	111.2	(orange)	(orange)
Enhanced design	2			--	(pink)	(orange)	(grey)	(pink)	~10	* (green)	30.2	222.2	(pink)	(orange)
Everard Horshoe (Big Horseshoe Canyon)		7	H (S)											
Original design	1				(pink)	(pink)	(grey)	(pink)	11	* (orange)	7.0	56.6	(orange)	(orange)
Enhanced design	2			--	(pink)	(pink)	(grey)	*	11	* (green)	12.3	135.6	(pink)	(orange)
Jervis Bay CMR		8	Both											
Jervis Bay CMR	1				(orange)	(pink)	(grey)	(pink)	21	(green)	25.9	190	(grey)	(grey)
Extended Jervis Bay CMR	2			--	(orange)	(pink)	(grey)	(pink)	27	(green)	32.2	252.4	(grey)	(grey)
Clarence CMR		11	H											
Clarence CMR	1				(pink)	(orange)	(grey)	*	7	(grey)	^	^	(grey)	(grey)
Clarence CMR covering depth range	2				(orange)	(orange)	(grey)	*	27	(green)	^	^	(grey)	(grey)
Extended Clarence CMR (covering depth range)	3				(orange)	(orange)	(grey)	*	61	(green)	^	^	(grey)	(grey)
4 segments + CMR (covering depth range)	4			#3	(orange)	(orange)	(grey)	*	104	(green)	^	^	(grey)	(grey)

Network Options

Identifying options for the network of closed areas is the final step in the process.

The three key considerations at this step are the locations of closures in relation to the overall range of each species (attribute 6, the 'extent of occurrence'); the maintenance of genetic diversity (attribute 7, the number of closures protecting genetically distinct populations); and the total area in which species are protected (attribute 5 – here the 'area of occupancy' measured in square kilometres). In the methodology applied here, attributes 5 and 6 can be measured with reasonable certainty, while the number of closures in the network is used as a simple proxy for genetic diversity in the absence of data on genetic composition of populations.

It is not possible to provide descriptions and scenarios for all potential combinations of Area Options in a network because there are too many combinations. However, evaluation is possible by considering how combinations of Candidate Areas would perform against each of the key attributes. Candidate Areas can be used to evaluate Extent of Occurrence, and counted to evaluate Number of Closures (see Figures 4 and 5). Finally, the performance against the target of 25% of the habitat of each species can be summed from Table 6.

Notes on attribute scoring for Network Options

1. Area of occupancy is measured in square kilometres. Percentages are calculated against the core range distribution of each gulper species for their entire depth range:
   a. Harrisson's Dogfish (22,707 km^2): Hyppolyte Area to Byron Bank (1157 n.m. linear extent) and seamounts, 180-1000 m;
   b. Southern Dogfish - eastern population (11,980 km^2): Banks Strait Gullies to Newcastle (726 n.m. linear extent), 180-900 m.
   c. Southern Dogfish – GAB population (10,156km^2): 60-mile Closure West to Dory Shots (762 n.m. linear extent), 180-900 m.
2. Existing and proposed closed areas differ in being fully closed to all fishing methods, closed only to some methods, or regulated to permit fishing in certain circumstances. These need to be summed separately as identified in Table 6.
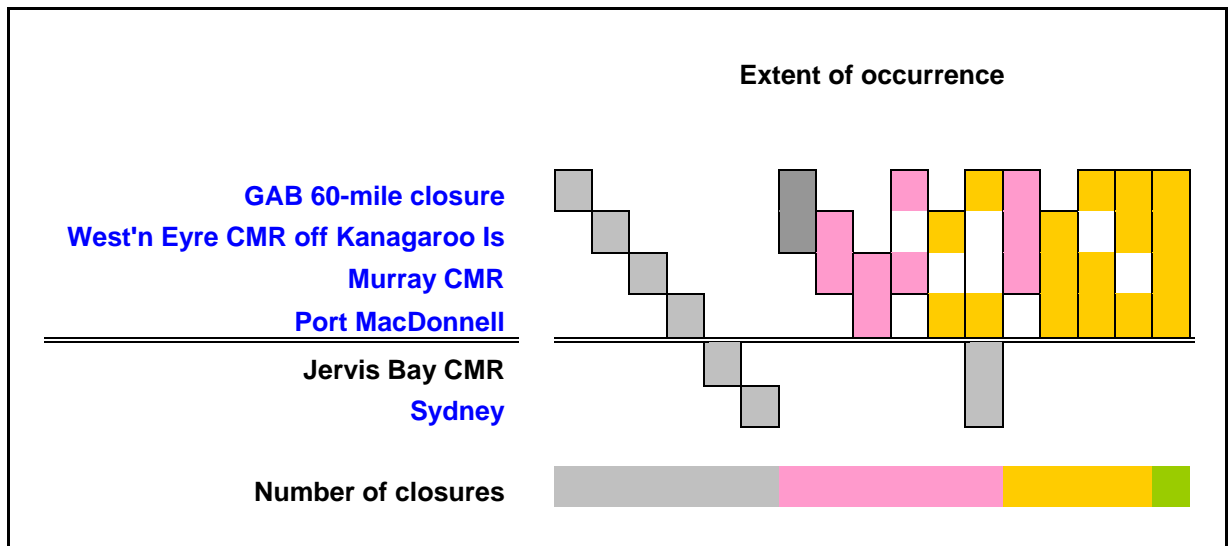
Figure 4 Schematic showing the potential combination of Candidate Areas in the closure network against Attribute 6 (Extent of occurrence) and Attribute 7 (Number of closures) for Southern Dogfish. Colours show expected performance against each attribute as scored using Table 1 (High-green; Medium-orange; Low-pink; Grey-none)
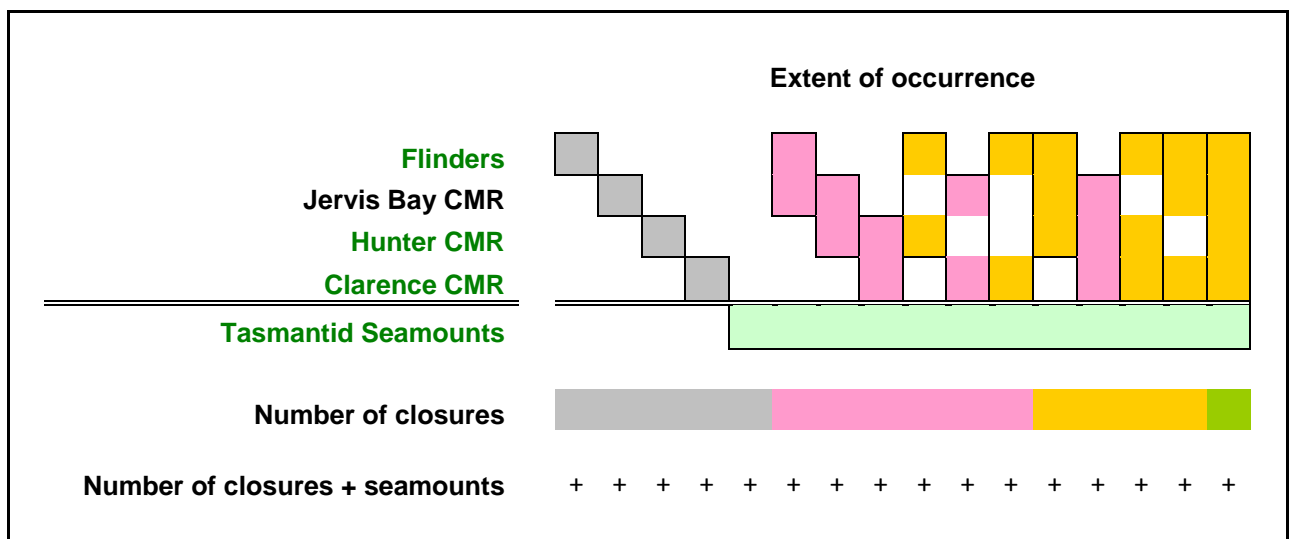

Figure 5 Schematic showing the potential combination of Candidate Areas in the closure network against Attribute 6 (Extent of occurrence) and Attribute 7 (Number of closures) for Harrisson's Dogfish. Colours show expected performance against each attribute as scored using Table 1 (High-green; Medium-orange; Low-pink; Grey-none). Note, seamount closures are expected to add at least one additional closure to the number of closures.

Additional notes on the network design

Northern NSW

During the early implementation phases of AFMAs USDMS, the need was identified for at least one large, appropriate closure for both species of gulper sharks (covering the depth and along-slope "home" range) to mitigate fishery impacts. A gap in the existing network – identified in numerous communications between stakeholders – is a full closure for Harrisson's Dogfish in an area where a viable population persists over a broad area. Northern NSW presents the only opportunity for this part of the network (and was identified by the conservation sector as a high priority for assessment for this reason). A closure centred on the Hunter CMR was previously identified as the best conservation opportunity. The Hunter Area Option 3 outlined in this paper will perform well as assessed by attributes for an individual closure, and in the context of the closure network; it will add 4.6% to the closure network.

The Tasmantid Seamount chain

Data gathered by CSIRO and the fishing industry over the last 12 months in an AFMA-funded project (Williams et al., 2012d) strongly suggest that Harrisson's Dogfish is present on the Queensland and Brittania Seamounts in greater abundance than Taupo and Barcoo. Tasmantid Seamounts Area Option 3 presents a good opportunity to enhance the gulper shark closure network and simultaneously reduce the cost to industry. This can be accomplished with closure of the Brittania and Queensland Seamounts and applying IUCN Level IV zoning (habitat protection) to the Derwent Hunter, Taupo and Barcoo Seamounts. Level IV zoning limits fishing access to hydraulic reel drop-line fishing only (referred to here as 'minor-line fishing'). Minor line fishing (Graham et al. 2011) is an attended and 'high-tech' style of dropline fishing using small numbers of hooks (<20) with short soak-times (<10 mins); as a consequence, gulper sharks brought to the surface are in vigorous condition, can be quickly released, and are expected to have a very high survival rate (>90%). Because the method is highly selective for Blue-eye Trevalla and has very limited bottom contact, there are negligible ecosystem level effects. The bycatch of Harrisson's Dogfish during Blue-eye Trevalla fishing by 'minor line' fishing on Taupo and Barcoo is negligible (Williams et al., 2012d).

Closure options for the seamount chain will need to also refer to the Eastern Temperate Marine Region planning process, and consider the broader implications for the identified conservation values of the proposed Tasmantid Commonwealth Marine Reserve - especially reduced protection for the shallow seamount ecosystem represented only on the Taupo Seamount – as discussed at greater length elsewhere (CSIRO, 2012). Broader consultation on seamount options involving DSEWPaC, AFMA and other fishery representatives is needed. This Closure Option 3 has the prospect of providing an effective 3% net increase to the gulper shark closed area network.

Flinders

The large Flinders Research Zone protects the only known viable population of Harrisson's Dogfish south of Sydney. The FRZ was designed to balance the competing management considerations of resource use, and gulper shark sustainability. The Research Zone contains two fully closed areas: 'Barren' that contains mainly mature females, and 'Babel' that contains mainly mature males and

juveniles; the remaining area is to be managed with a set of regulations tailored to achieve the conservation goals while being feasible and cost-effective to manage, and providing a source of scientific information to fill key knowledge gaps.
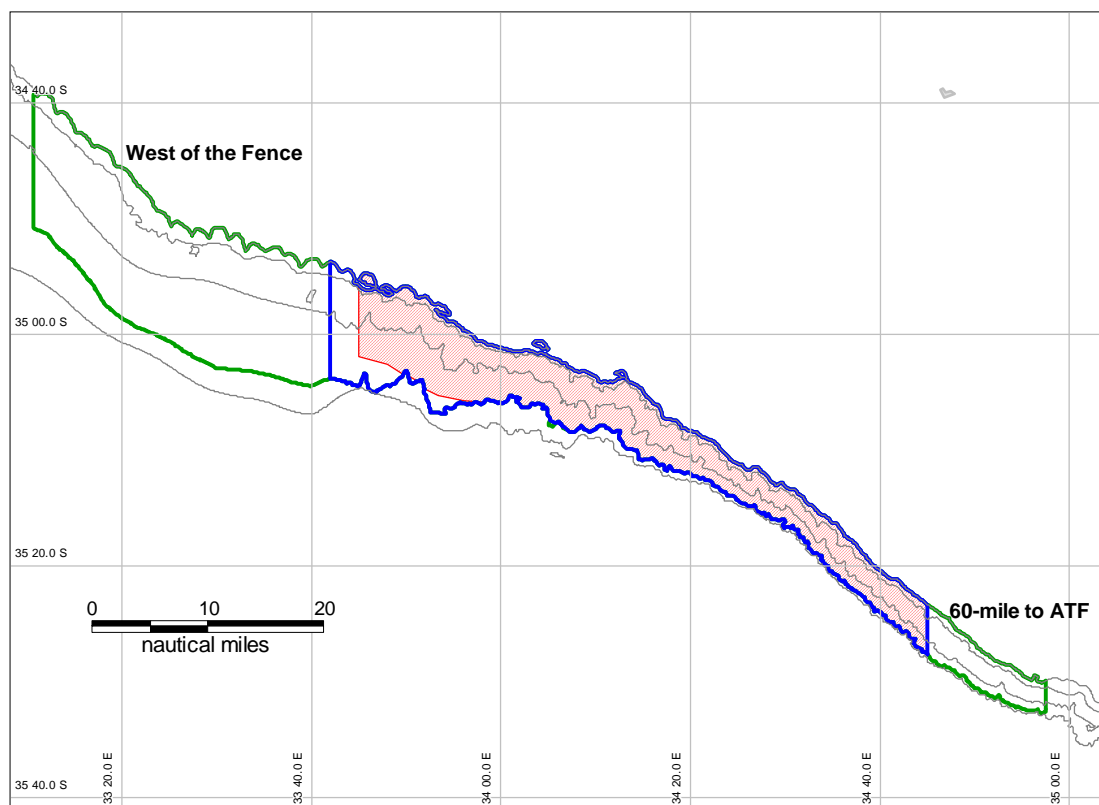
Establishing the Flinders Research Zone instead of a large full-closure was a trade-off between protecting the gulper shark population and reducing the economic cost to commercial fishers; the economic cost of full closure would have been high for trawl fishers and very high for auto-longline fishers (Daley et al. 2010). The key needs from the USDMS are to mitigate fishing impacts on gulper sharks by preventing capture and mortality of individuals, and to provide opportunities for longer-term population expansion. A critical part of the USDMS, however, is to continue to gain a better understanding of gulper shark population dynamics, and this is enabled through the structure of the Research Zone. Thus, establishing the conservation effectiveness of the USDMS is immediately contingent on minimising fishing mortality within the Research Zone but still being able to collect important information on the gulper shark population it protects. Within the FRZ, there is a possibility of catching gulpers sharks in the 'Trawl Corridor' closely adjacent to the shark population in the Babel closure, and in the 'Middle Ground' where continued breeding success is assumed to require successful movement of sharks between the Babel and Barren closures.

Research and monitoring undertaken within the Research Zone will be a key part of assessing the performance of management measures, and will potentially provide a cost-effective and regular source of quality-assured data to measure performance and to substantially increase biological and ecological knowledge that will assist in long term recovery, e.g. catch rate data and survival estimates. Stakeholders recognise that further restrictions to fishing could be considered if conservation objectives are not being met, e.g. if fishing mortality rates lead to further population declines within closures.

A view has been expressed that the evolving management arrangements for the FRZ remain inadequate (CSIRO, 2011).

Table 6: Areas of individual Area Options, their management arrangements, and percentage contribution to the target closed area for each species. The areas of upper continental slope in the range of each species are: 22,707 km^2 for Harrisson's Dogfish (H); and 11,980 km^2 and 10156 km^2 for the eastern and western ranges of Southern Dogfish [S(e) & S(w), respectively].
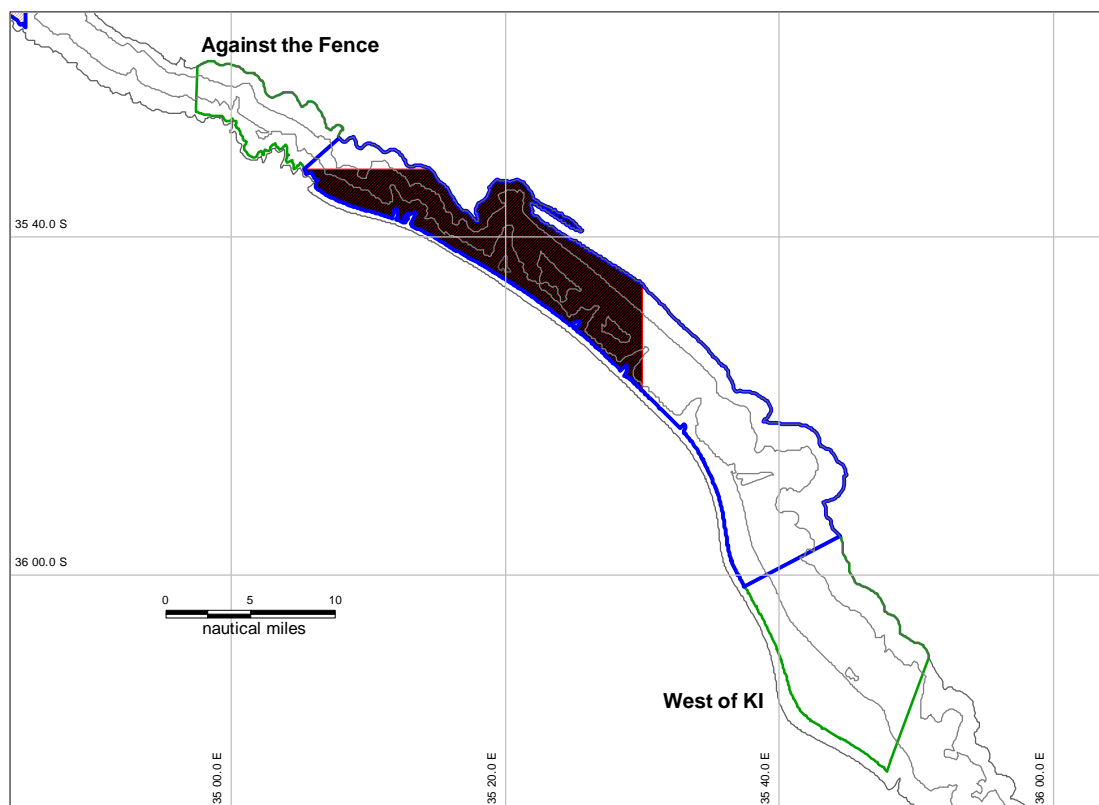
Fully closed to all gears						
Managed fishery area						
Managed fishery area with some coverage of upper slope						
Marine Reserve Zoning regulates some fishing gears						

AREA OPTIONS	No.	Area (km²)	% H	% S (e)	% S (w)	Management arrangements
GAB 60-mile closure						
60-mile closure	1	808			8.0	Existing AFMA closure
60-mile closure + Western Eyre CMR	2	846			8.3	Mix of fishery and CMR Zoning
5 segments	3	969			9.5	
Western Eyre CMR off Kanagaroo Is						
Western Eyre CMR	1	274			2.7	Proposed Mutliple Use zone VI
Extended Western Eyre CMR	2	608			6.0	
3 segments	3	972			9.6	
Port Macdonnell						
Existing Port Mac closure	1	89			0.9	Existing AFMA closure
Port Mac closure covering depth range	2	157			1.6	
Extended Port Mac closure	3	528			5.2	
7 segments	4	1923			18.9	
Flinders						
Flinders Research Zone	1	497	2.2	4.1		Trawl and ALL regulated; 1.7% fully closed
FRZ covering depth range	2	709	3.1	5.9		
FRZ covering depth range and fully closed	3	709	3.1	5.9		
10 segments	4	1955	8.6	16.3		
Flinders CMR	--	345	1.5	2.9		CMR + AFMA closure for ALL
Sydney						
Existing Endeavour Closure (inc. cable closures)	1	972	4.3	8.1		Existing AFMA closure; NSW/ recreational in review
Endeavour Closure covering depth range	2	1220	5.4	10.2		
Extended Endeavour Closure	3	2293	10.1	19.1		
6 segments	4	3535	15.6	29.5		
Hunter CMR						Proposed Mutliple Use zone VI
Hunter CMR	1	387	1.7			
Hunter CMR covering depth range	2	654	2.9			
Extended Hunter CMR (covering depth range)	3	1036	4.6			*extended area would also for Southern Dogfish
10 segments	4	6298	27.7	*		
Tasmantid seamounts						Existing trawl closure + AFMA all gears closure on Taupo/Barcoo+ proposed CMR inc. Derwent Hunter. Individual seamount details: Taupo (607 km2, 2.7%); Barcoo (185 km2, 0.8%); Derwent Hunter (760 km2, 3.3%); Brittania (1072 km2, 4.7%); Queensland (410 km2, 1.8%); Recorder (57 km2, 0.2%). NOTE - figures given exclude benefits from CMR zoning.
CMR (Taupo/ Barcoo closed + others Zone VI)	1		3.5			
Taupo/ Barcoo open + others Zone IV	2		--			
Brittania/ Queensland closed + others Zone IV	3		6.5			
All seamounts	4		13.5			
Murray CMR						Multiple use zone VI (ALL permitted)
Murray CMR + Kanagaroo Hill fishery closure	1	649			6.4	Orange roughy fishery closure
Extended fishery closure	2	888			8.7	
Seiners Horseshoe						
Original design	1	194	0.9	1.6		Previous AFMA closure; covers much of upper slope
Enhanced design	2	266	1.2	2.2		
Everard Horshoe (Big Horseshoe Canyon)						
Original design	1	141	0.6	1.2		Previous AFMA closure; covers much of upper slope
Enhanced design	2	228	1.0	1.9		
Jervis Bay CMR						Proposed Mutliple Use zone VI
Jervis Bay CMR	1	354	1.6	3.0		
Extended Jervis Bay CMR	2	497	2.2	4.1		
Clarence CMR						Proposed Mutliple Use zone VI
Clarence CMR	1	60	0.3			
Clarence CMR covering depth range	2	221	1.0			
Extended Clarence CMR (covering depth range)	3	824	3.6			
4 segments + CMR (covering depth range)	4	1437	6.3			
Freycinet CMR			0.0			
Freycinet	--	74	0.3			Recreational use zone IUCN II
Freycinet	--	189	0.8			Multiple use zone VI (ALL permitted)
Existing totals			12.6	15.1	15.2	

GAB option 1	133º 45'	-34º 55.728'
	134º 45.06'	-35º 23.388'
	134º 45'	-35º 27.642'
	133º 45'	-35º 1.95'
GAB option 2	133º 42'	-35º 3.792'
	134º 45.06'	-35º 23.388'
	133º 42'	-34º 53.73'
	134º 45'	-35º 27.642'
GAB option 3	133º 10.62'	-34º 50.784'
	133º 10.68'	-34º 38.934'
	134º 57.54'	-35º 29.898'
	134º 57.48'	-35º 32.598'

Map 1. Closure options for the GAB closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.

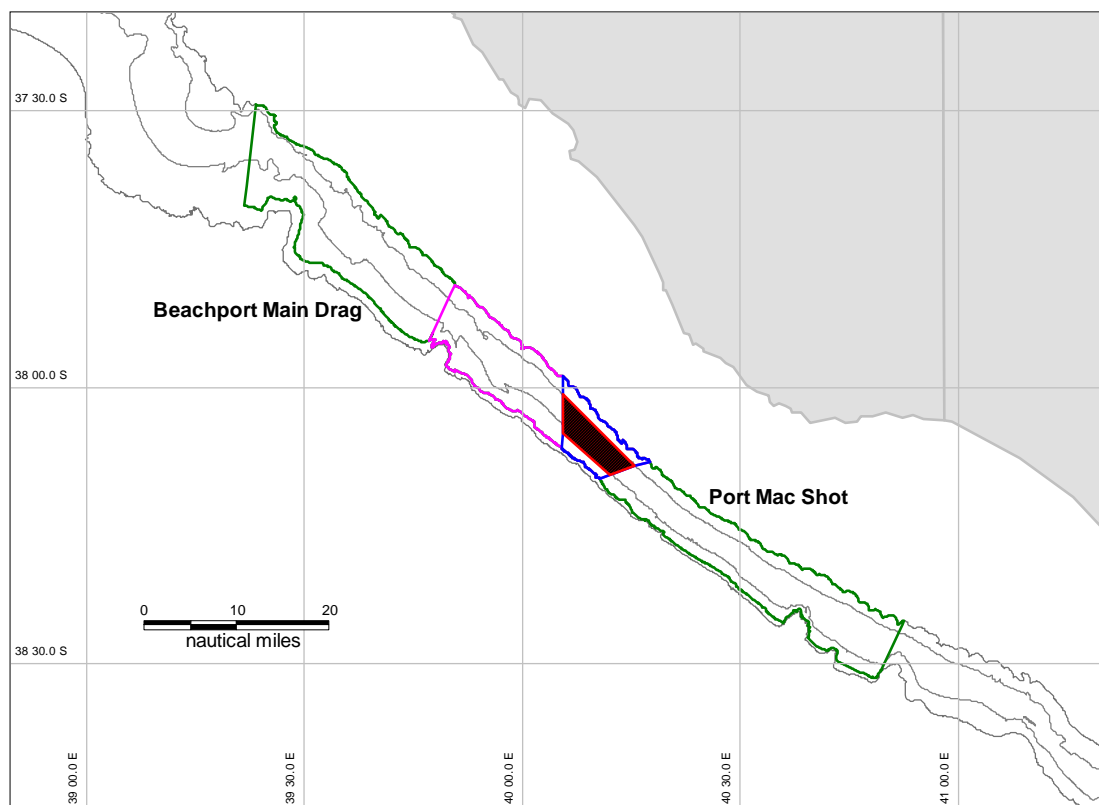1. 60-mile closure: status quo – existing closure.
2. 60-mile closure + Western Eyre CMR: includes small portion of CMR at western boundary (although this is outside the core range of Southern Dogfish).
3. 5 segments (West of Fence to 60-mile to ATF): eNGO suggested area for further investigation.

Western Eyre CMR option 1	135º 5.34'	-35º 36'
	135º 14.52'	-35º 36'
	135º 30'	-35º 42.834'
	135º 30'	-35º 49.14'
Western Eyre CMR option 2	135º 7.86'	-35º 34.14'
	135º 5.34'	-35º 36'
	135º 44.46'	-35º 57.774'
	135º 37.44'	-36º 0.69'
Western Eyre CMR option 3	134º 57.54'	-35º 29.898'
	134º 57.48'	-35º 32.598'
	135º 50.94'	-36º 4.944'
	135º 47.82'	-36º 11.622'

Map 2. Closure options for the Western Eyre closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.
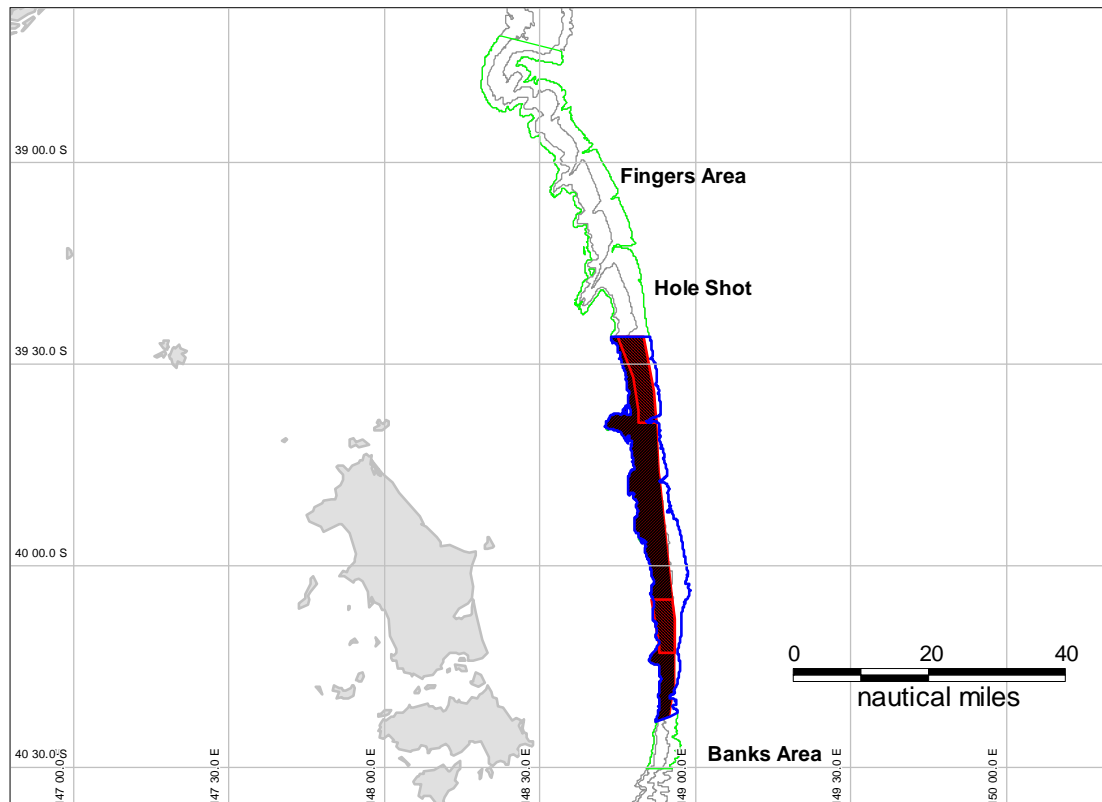
1. Western Eyre CMR: proposed CMR section off Kangaroo Island.
2. Extended Western Eyre CMR: CMR boundary extended to span home range (50 n.m.).
3. 3 segments (60-mile to ATF to West of KI): eNGO suggested area for further investigation.

Murray CMR option 1	137º 43.8'	-37º 1.536'
	137º 10.2'	-36º 43.506'
	137º 10.2'	-36º 44.616'
	137º 45.3'	-36º 59.892'
	136º 46.2'	-36º 35.664'
	136º 44.04'	-36º 39.912'
	138º 2.52'	-37º 4.92'
	138º 0.24'	-37º 7.488'
Murray CMR option 2	136º 46.2'	-36º 35.664'
	136º 44.04'	-36º 39.912'
	138º 2.52'	-37º 4.92'
	138º 0.24'	-37º 7.488'

Map 3. Closure options for the Murray CMR closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.

1. Murray CMR + Kangaroo Hill fishery closure: status quo – existing closure.
2. Extended fishery closure: Kangaroo Hill closure widened to fully cover species depth range.

Port MacDonnell option 1	140º 12'	-38º 9.498'
	140º 5.52'	-38º 4.998'
	140º 5.52'	-38º 0.666'
	140º 15.48'	-38º 8.502'
Port MacDonnell option 2	140º 5.64'	-37º 58.776'
	140º 5.46'	-38º 6.63'
	140º 17.52'	-38º 7.986'
	140º 10.68'	-38º 9.948'
Port MacDonnell option 3	139º 47.22'	-37º 54.858'
	139º 50.76'	-37º 48.804'
	140º 17.52'	-38º 7.986'
	140º 10.68'	-38º 9.948'
Port MacDonnell option 4	139º 23.22'	-37º 29.25'
	139º 21.66'	-37º 40.302'
	140º 52.56'	-38º 25.284'
	140º 49.44'	-38º 30.564'

Map 4. Closure options for the Port MacDonnell closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.
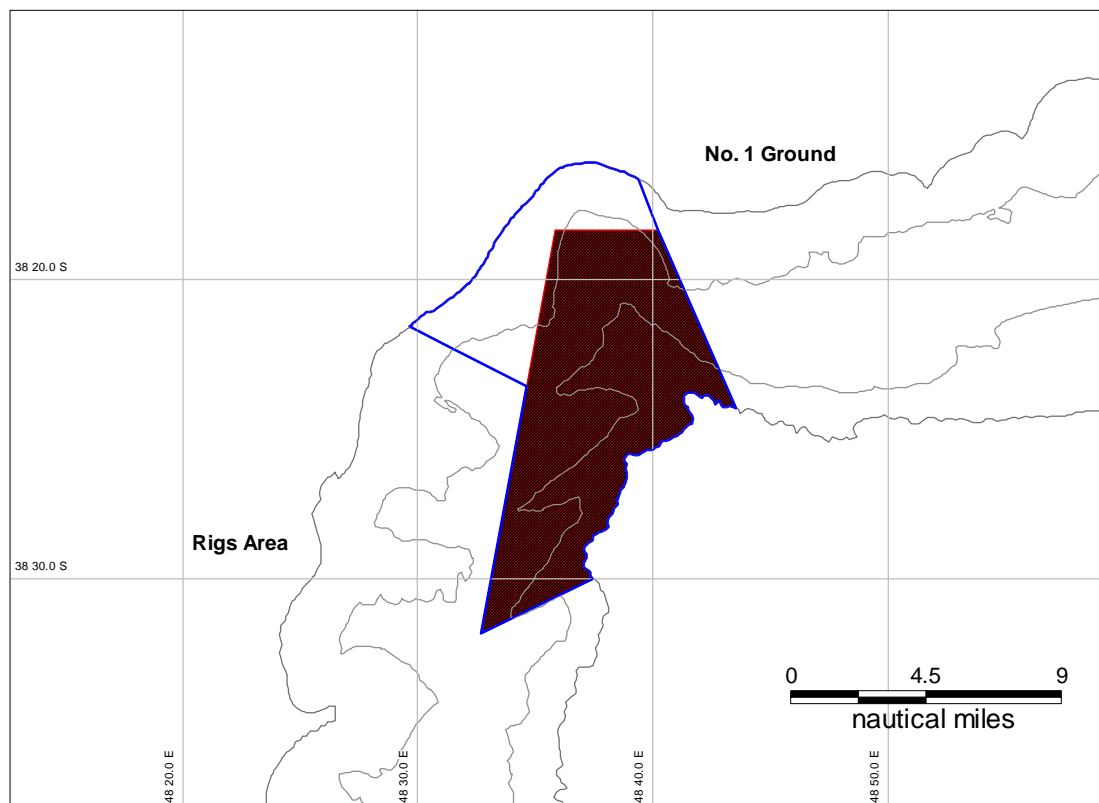
1. Existing Port Mac closure: status quo – existing closure.
2. Port Mac closure covering depth range: widened to fully cover species depth range.
3. Extended Port Mac closure: extended north-west to Eastern Canyon, to span approximately half the home range (25 n.m.); extension is to extensively used trawl grounds and ALL in canyon.
4. 7 segments (Beachport Canyon to Portland 2nd Main Drag): eNGO suggested area for further investigation.

Flinders option 1	148º 43.62'	-39º 26.004'
	148º 52.02'	-39º 33.996'
	148º 49.98'	-39º 25.998'
	148º 54.96'	-40º 22.356'
	148º 55.98'	-40º 18.042'
	148º 55.98'	-40º 7.998'
	148º 52.14'	-40º 23.13'
Flinders option 2	148º 43.62'	-39º 26.004'
	148º 51.12'	-39º 26.022'
	148º 56.58'	-40º 21.882'
	148º 52.14'	-40º 23.13'
Flinders option 3	Same coordinates as option 2	
Flinders option 4	148º 34.08'	-38º 43.584'
	148º 22.14'	-38º 41.304'
	148º 50.52'	-40º 30.114'
	148º 55.56'	-40º 30.09'

Map 5. Closure options for the Flinders closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.

1. Flinders Research Zone: status quo – existing closure.
2. FRZ covering depth range: widened to fully cover species depth range.
3. FRZ covering depth range and fully closed: full closure of FRZ.
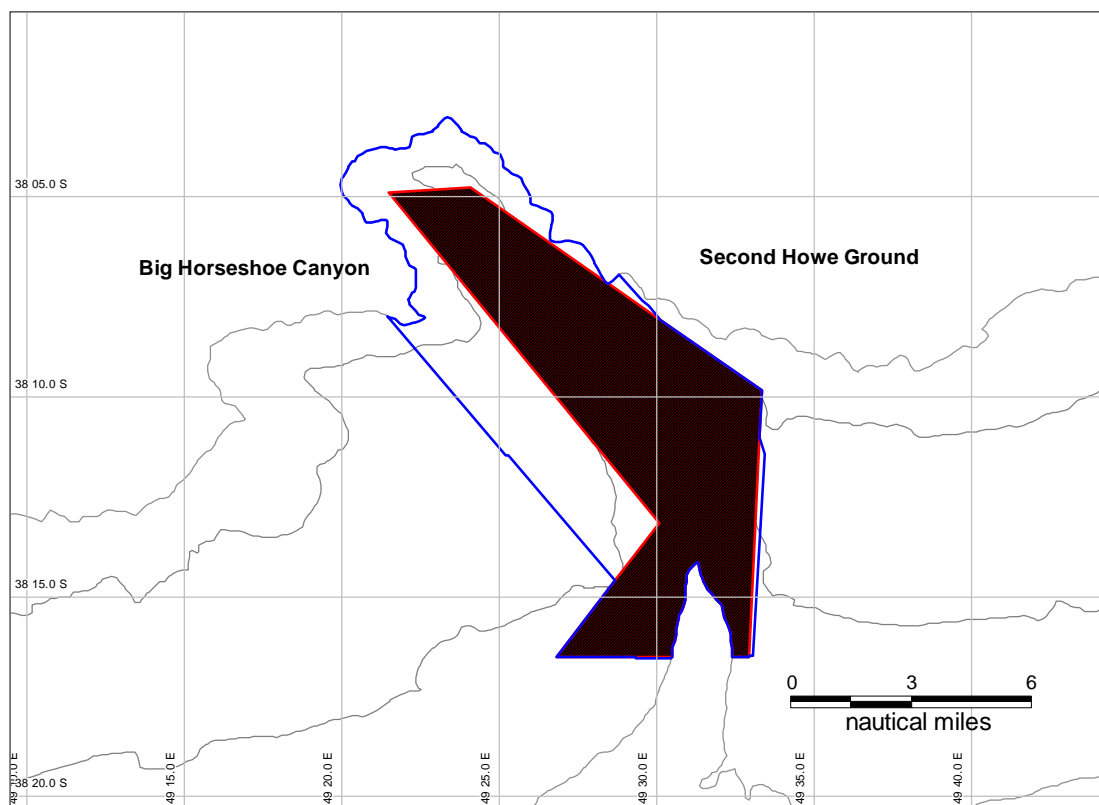4. 10 segments (Banks Strait Gullies to Smithy's Corner): eNGO suggested area for further investigation.

Seiners option 1	148º 37.44'	-38º 30.006'	
	148º 32.7'	-38º 31.8'	
	148º 35.88'	-38º 18.36'	
	148º 40.26'	-38º 18.36'	
	148º 43.56'	-38º 24.3'	
Seiners option 2	148º 37.44'	-38º 30.006'	
	148º 32.7'	-38º 31.8'	
	148º 39.42'	-38º 16.674'	
	148º 43.56'	-38º 24.3'	
	148º 29.64'	-38º 21.582'	
	148º 34.62'	-38º 23.574'	

Map 6. Closure options for the Seiners Horseshoe closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.
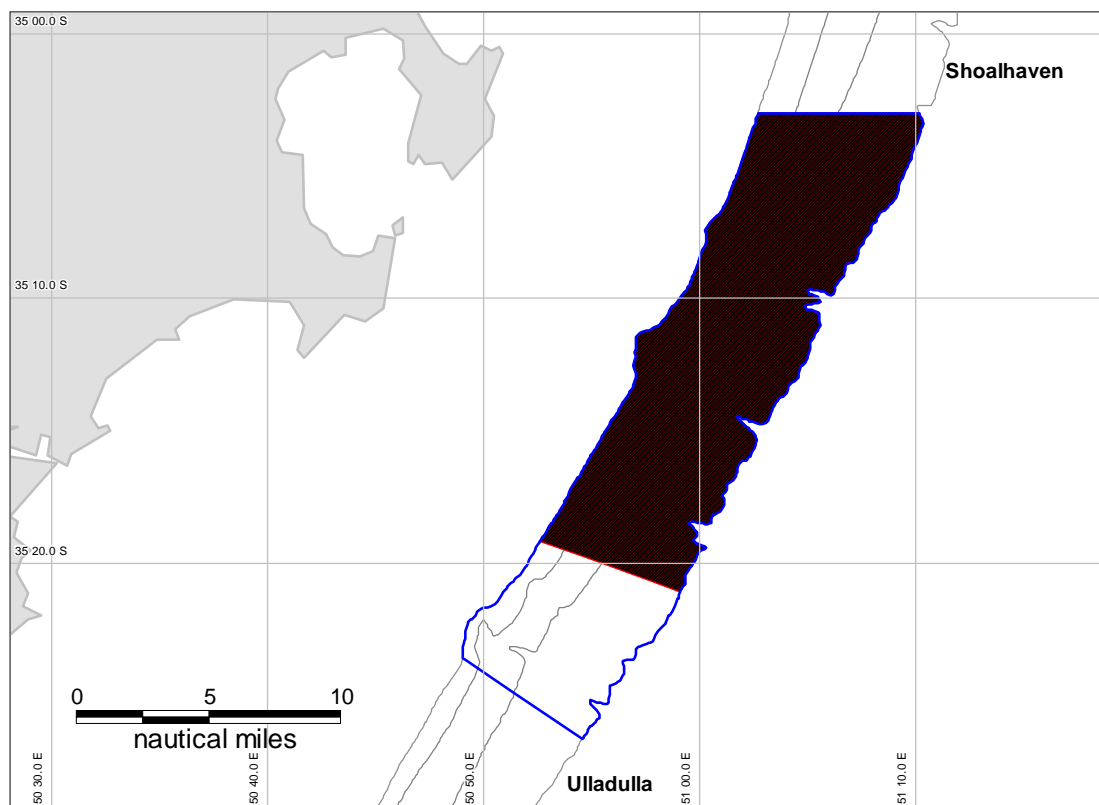
1. Original design: status quo – existing closure.
2. Enhanced design: widened to fully cover species depth range in the canyon head.

Everard (Big Horseshoe) Canyon option 1	149º 26.82'	-38º 16.5'
	149º 30.48'	-38º 16.536'
	149º 33.06'	-38º 16.482'
	149º 32.34'	-38º 16.5'
	149º 33.3'	-38º 9.84'
	149º 24.06'	-38º 4.788'
	149º 21.48'	-38º 4.914'
	149º 30.06'	-38º 13.152'
Everard (Big Horseshoe) Canyon option 2	149º 28.8'	-38º 6.966'
	149º 26.82'	-38º 16.5'
	149º 21.48'	-38º 8.022'
	149º 28.68'	-38º 14.598'
	149º 30.48'	-38º 16.536'
	149º 33.06'	-38º 16.482'
	149º 32.34'	-38º 16.5'
	149º 33.3'	-38º 9.84'

Map 7. Closure options for the Everard (Big Horseshoe) Canyon closure with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.

1. Original design: status quo – existing closure.
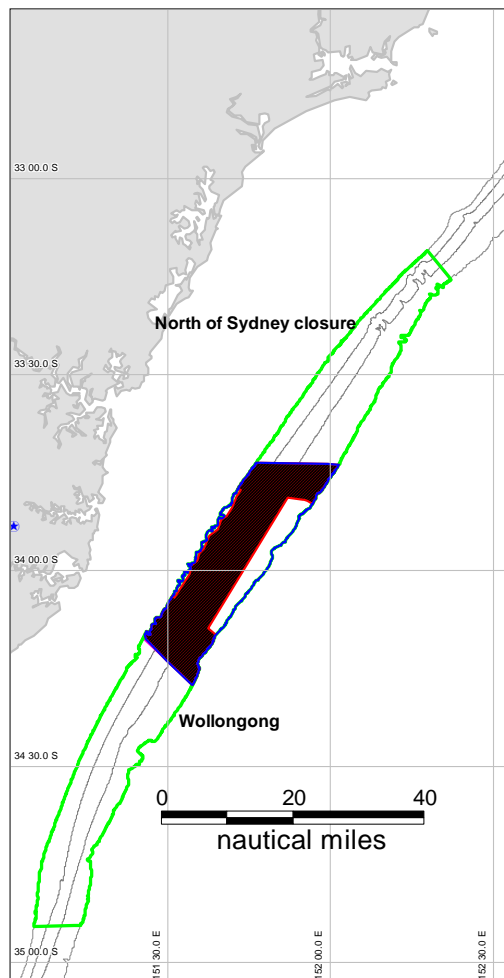2. Enhanced design: widened to fully cover species depth range in the canyon head.

Jervis Bay option 1	150º 59.1'	-35º 21.102'
	150º 52.62'	-35º 19.182'
	151º 10.2'	-35º 3'
	151º 2.7'	-35º 3'
Jervis Bay option 2	150º 54.6'	-35º 26.67'
	150º 49.02'	-35º 23.604'
	151º 10.2'	-35º 3'
	151º 2.7'	-35º 3'

Map 8. Closure options for the Jervis Bay CMR closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options.

1. Jervis Bay CMR: proposed CMR.
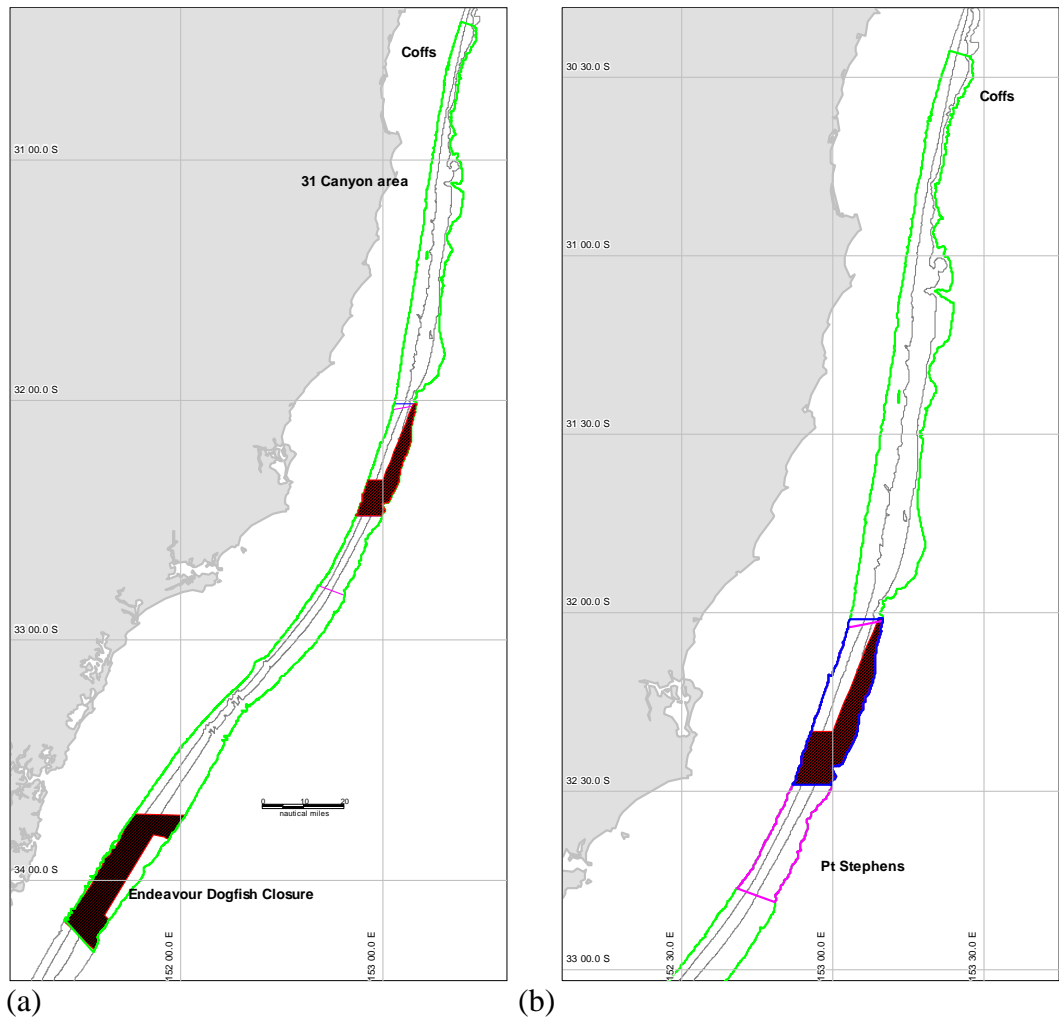2. Extended Jervis Bay CMR: extended south to span approximately half the home range (25 n.m.).
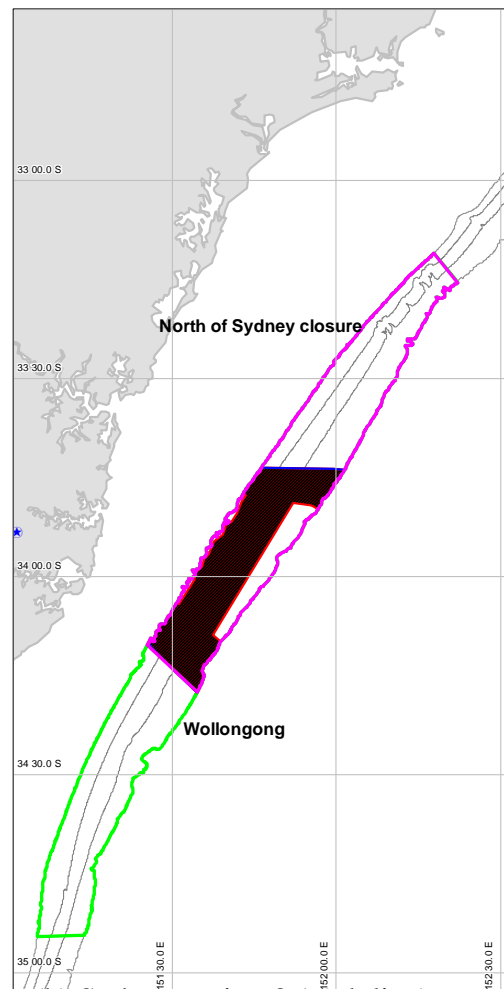
(a)   (b) Sydney option 3 (pink line)

Sydney option 1	152º 1.56'	-33º 43.8'
	151º 25.68'	-34º 10.056'
	151º 34.5'	-34º 17.544'
	151º 46.32'	-33º 43.422'
Sydney option 2	152º 1.56'	-33º 43.8'
	152º 1.56'	-33º 43.8'
	151º 34.5'	-34º 17.544'
	151º 46.32'	-33º 43.422'
Sydney option 3	151º 25.68'	-34º 10.056'
	151º 34.5'	-34º 17.544'
	152º 17.88'	-33º 10.92'
	152º 22.14'	-33º 15.384'
Sydney option 4	151º 13.86'	-34º 54.384'
	151º 5.28'	-34º 54.63'
	152º 17.88'	-33º 10.92'
	152º 22.14'	-33º 15.384'

Map 9. Closure options for the Sydney closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options. (a) Shows options 1, 2 and 4; (b) shows options 1, 3 and 4.
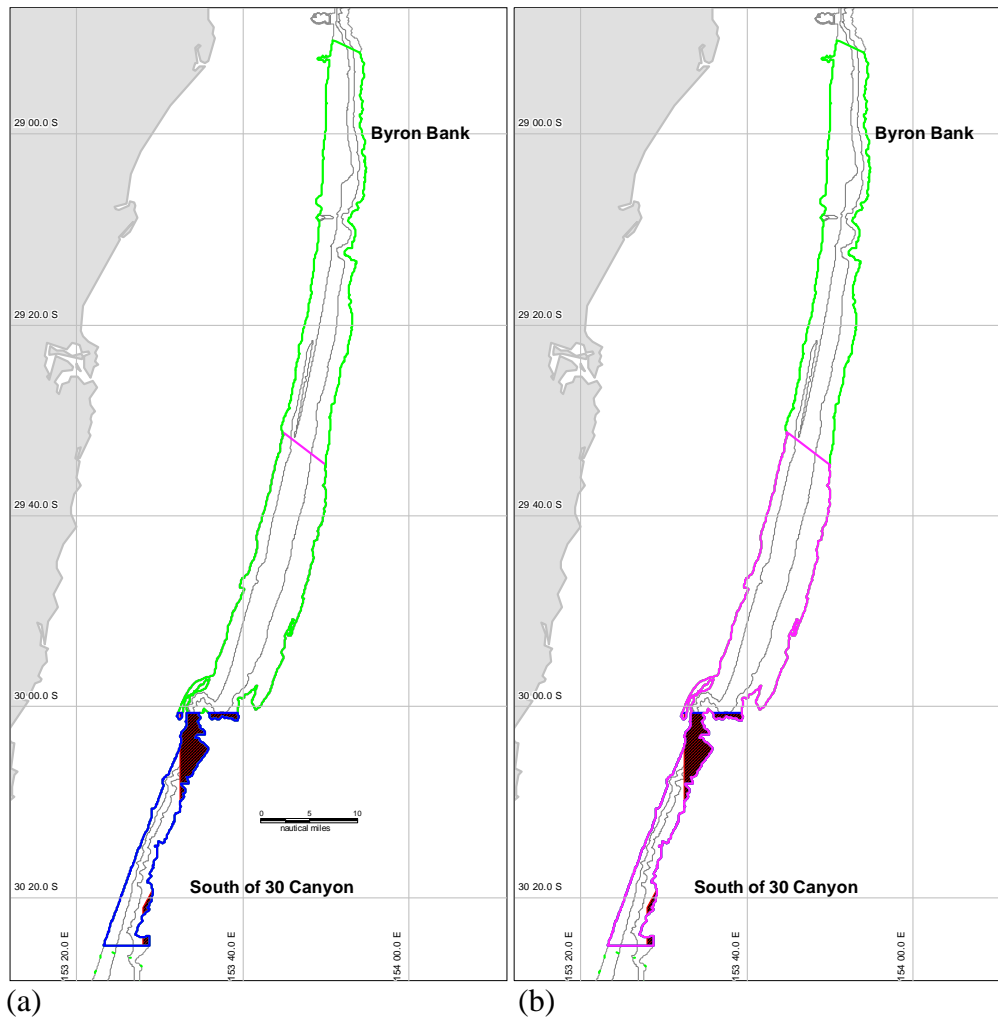
1. Existing Endeavour Closure (inc. cable closures): status quo – existing closure.
2. Endeavour Closure covering depth range: widened to fully cover species depth range.
3. Extended Endeavour Closure: extended to the north to span home range and include area of medium abundance (Southern Dogfish) in Five Canyons segment.
4. 6 segments (Kiama to 5 Canyon): eNGO suggested area for further investigation.

Hunter option 1	152º 55.68'	-32º 19.998'
	152º 52.02'	-32º 28.998'
	152º 59.76'	-32º 28.998'
	153º 0'	-32º 19.998'
	153º 9.96'	-32º 1.002'
	153º 9'	-32º 1.026'
Hunter option 2	152º 52.02'	-32º 28.998'
	152º 59.76'	-32º 28.998'
	153º 3.36'	-32º 1.02'
	153º 9.96'	-32º 1.002'
Hunter option 3	152º 41.04'	-32º 46.356'
	152º 48.66'	-32º 48.69'
	153º 3.06'	-32º 2.43'
	153º 9.9'	-32º 1.278'
Hunter option 4	151º 25.68'	-34º 10.056'
	151º 34.5'	-34º 17.544'
	153º 23.16'	-30º 25.44'
	153º 27.18'	-30º 26.472'

Map 10. Closure options for the Hunter closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options. (a) Shows the entire extent of option 4 (Coffs to Endeavour closure), (b) zoom in on options 1, 2 and 3.

1. Hunter CMR: proposed CMR.
2. Hunter CMR covering depth range: widened to fully cover species depth range over the entire width of the proposed CMR.
3. Extended Hunter CMR (covering depth range): CMR boundary extended to span home range (50 n.m.).
4. 10 segments (Coffs to Endeavour Dogfish Closure): eNGO suggested area for further investigation (note, this overlaps the Sydney Candidate Area)

Clarence option 1	153º 32.52'	-30º 9.858'
	153º 39.42'	-30º 0.666'
	153º 32.52'	-30º 0.672'
Clarence option 2	153º 28.74'	-30º 25.044'
	153º 23.28'	-30º 24.972'
	153º 39.42'	-30º 0.666'
	153º 32.22'	-30º 0.672'
Clarence option 3	153º 28.74'	-30º 25.044'
	153º 23.28'	-30º 24.972'
	153º 49.98'	-29º 34.662'
	153º 44.76'	-29º 31.176'
Clarence option 4	153º 28.74'	-30º 25.044'
	153º 23.28'	-30º 24.972'
	153º 54.12'	-28º 51.474'
	153º 50.82'	-28º 50.214'

Map 11. Closure options for the Clarence closure area with 180, 300, 600 and 1000 m depth contours and accompanying coordinates for boundary extents for different options. (a) Shows options 1, 2 and 4; (b) shows options 1, 3 and 4.

1. Clarence CMR: proposed CMR.
2. Clarence CMR covering depth range: widened to fully cover species depth range over the entire width of the proposed CMR.
3. Extended Clarence CMR (covering depth range): widened to fully cover species depth range and extended north to span home range (50 n.m.).
4. 4 segments (30 Canyon to Byron Bank) + CMR (covering depth range): eNGO suggested area for further investigation.
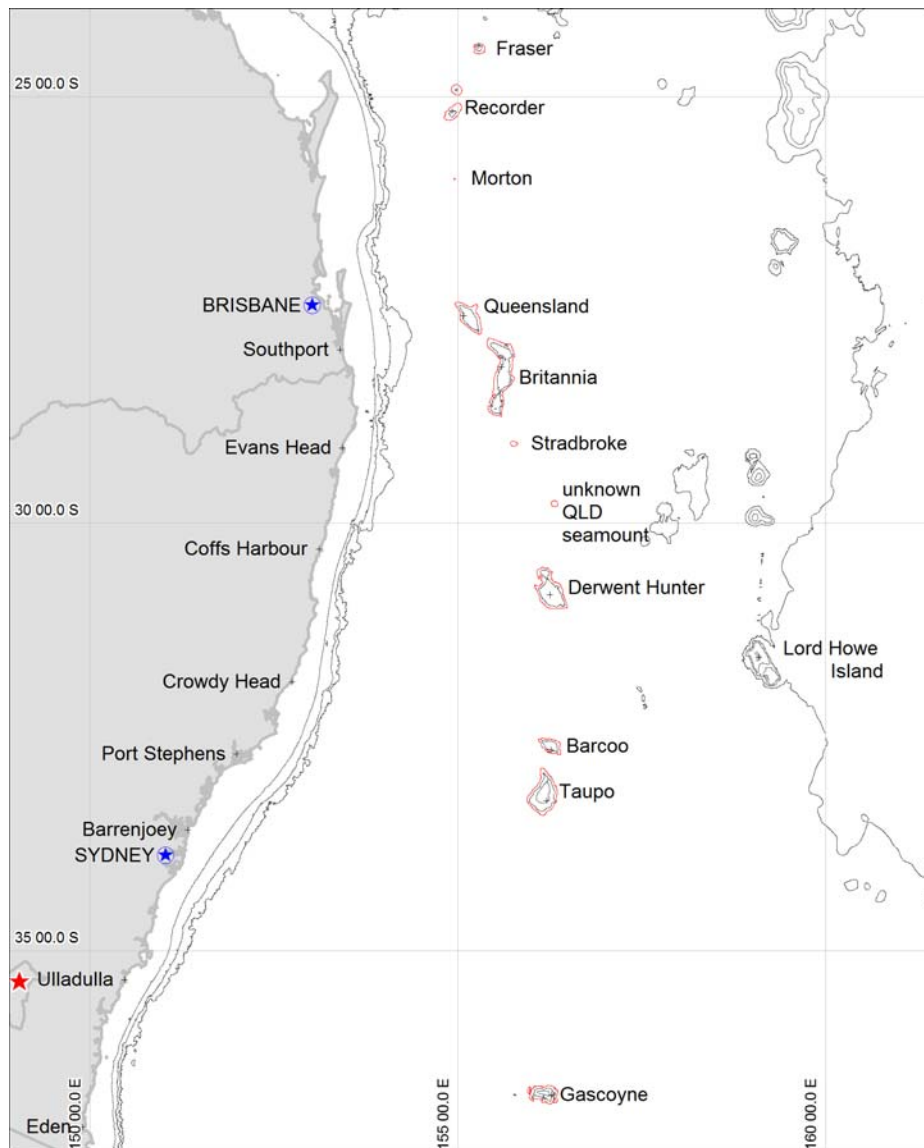
Map 12.   The southern part of the Tasmanid Seamount chain (red outline of 2000 m
contour) includes Queensland to Taupo (Gascoyne is outside the Australian EZ).
Contours: 200 m, 1000 m, 2000 m depth. The 6 prominent seamounts are all closed
to bottom trawling, and include a fishery closure to all methods on the Taupo and
Barcoo Seamounts implemented as part of AFMAs USDMS. CSIRO surveys
(Williams et al., 2012d) confirm all seamounts support populations of Harrisson's
Dogfish – but these are expected to have low connectivity between seamounts or with
the continental margin of NSW/ Qld due to the great depth of the intervening Tasman
Sea. Options:

1. CMR (Taupo/ Barcoo closed + others Zone VI)
2. Taupo/ Barcoo open + others Zone IV
3. Brittania/ Queensland closed + others Zone IV
4. All seamounts closed: eNGO suggested area for further investigation.

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