Quantitative ecological risk assessment for effects of fishing on deepwater chondrichthyans in the southern Indian Ocean

SIOFA ECOLOGICAL RISK ASSESSMENT WORKING GROUP

ABARES, CSIRO, JCU

Hobart, Australia 23-24 October 2017

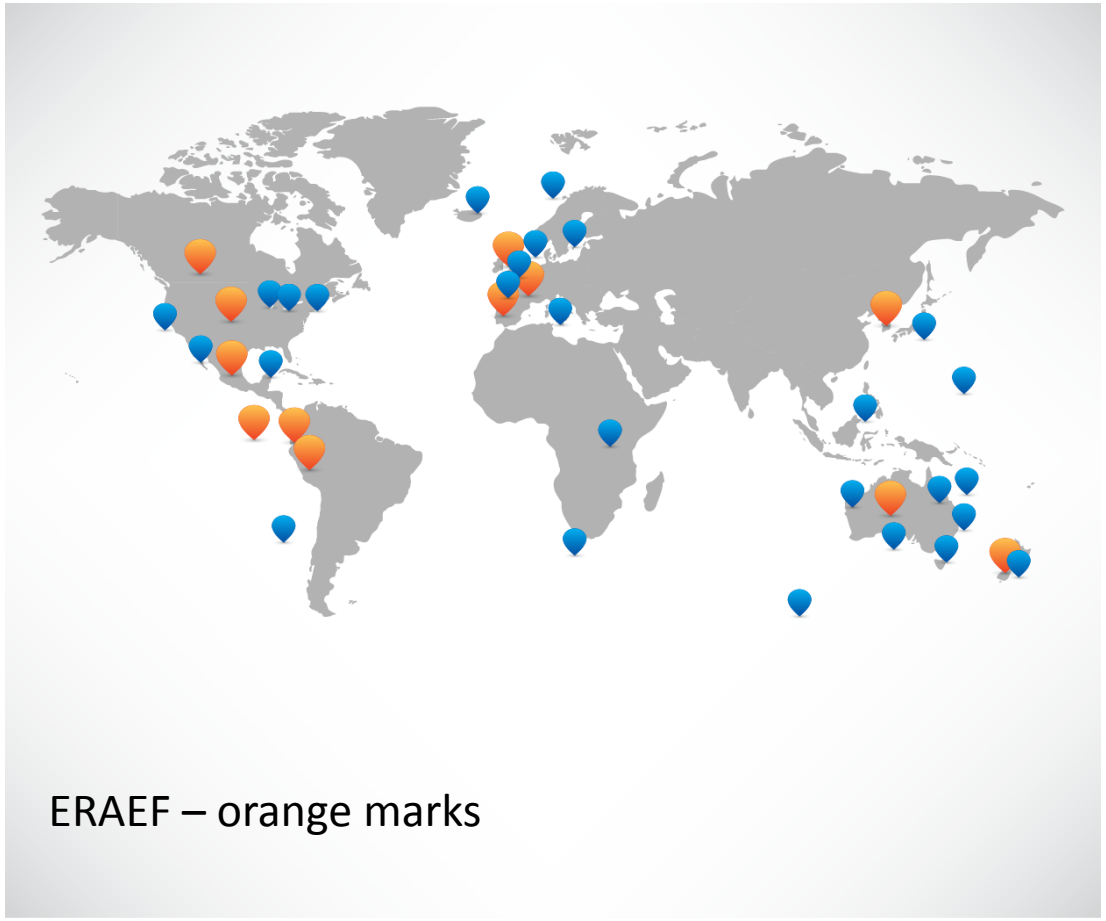
Outline

- Overview of ERAEF framework and methods
- Background to deepwater sharks ERA
- Development of species list
- Productivity attributes and risk categorisation
- Susceptibility attributes and risk categorisation
- Species maps and fishing effort data
- PSA-SAFE outputs
- Proposed next steps

How can we assess sustainability for fisheries with many species?

- A large number of species in each fishery and often many gear types
- Little data available: often limited catch and no abundance information
- This can necessitate application of risk-based methods, such as ecological risk assessment

Ecological Risk Assessment for the Effects of Fishing (ERAEF)
A method used around the world



ERAEF – orange marks

Fisheries Research 108 (2011) 372–384

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Ecological risk assessment for the effects of fishing

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e.g. recent example in Indian Ocean

Contents lists available at ScienceDirect

Deep–Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

Vulnerability of teleosts caught by the pelagic tuna longline fleets in South Atlantic and Western Indian Oceans

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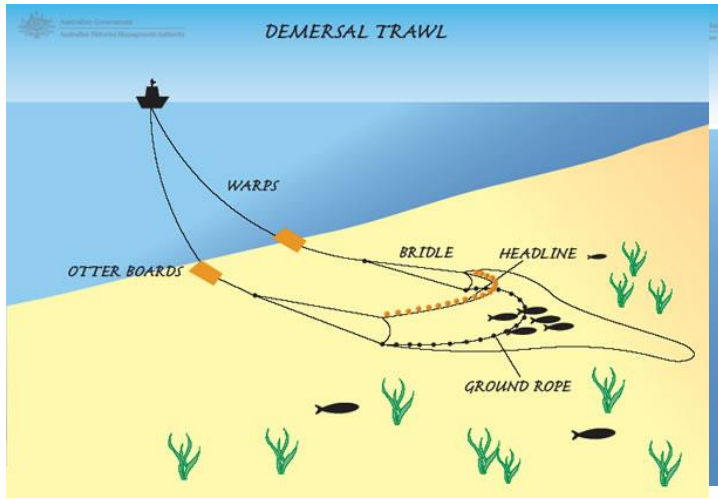
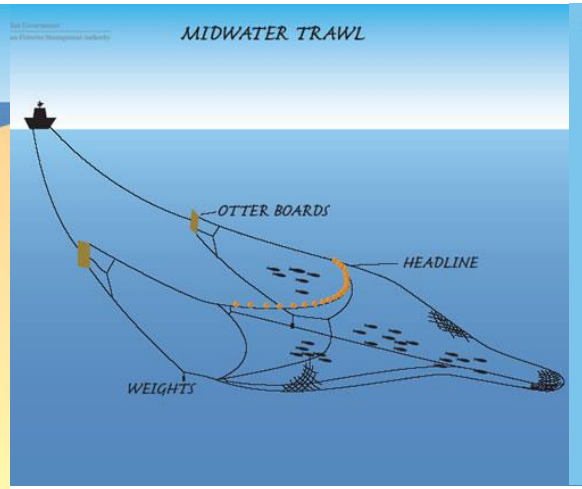
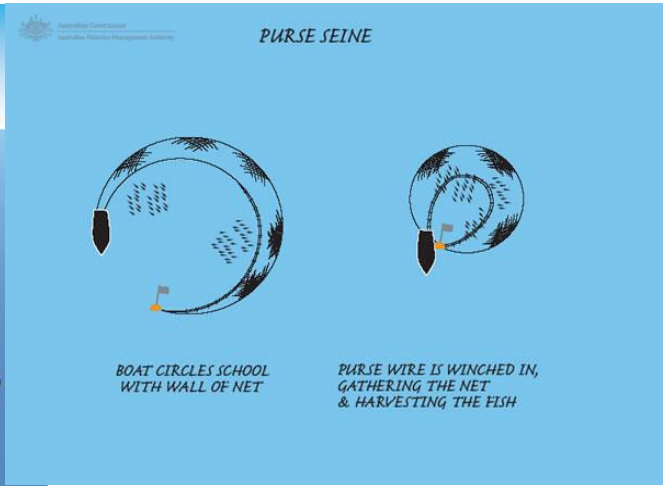
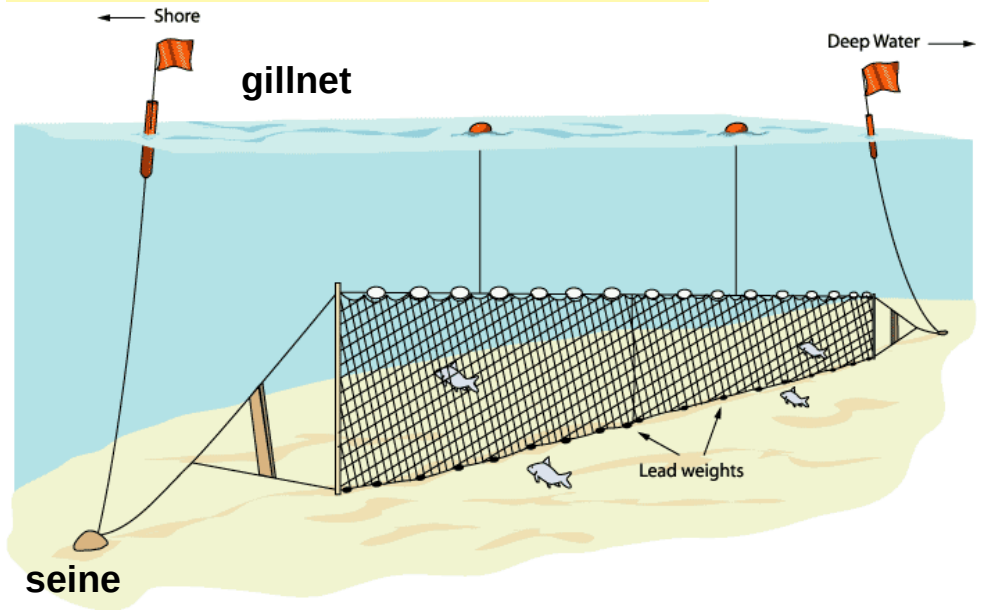
ARTICLE INFO ABSTRACT

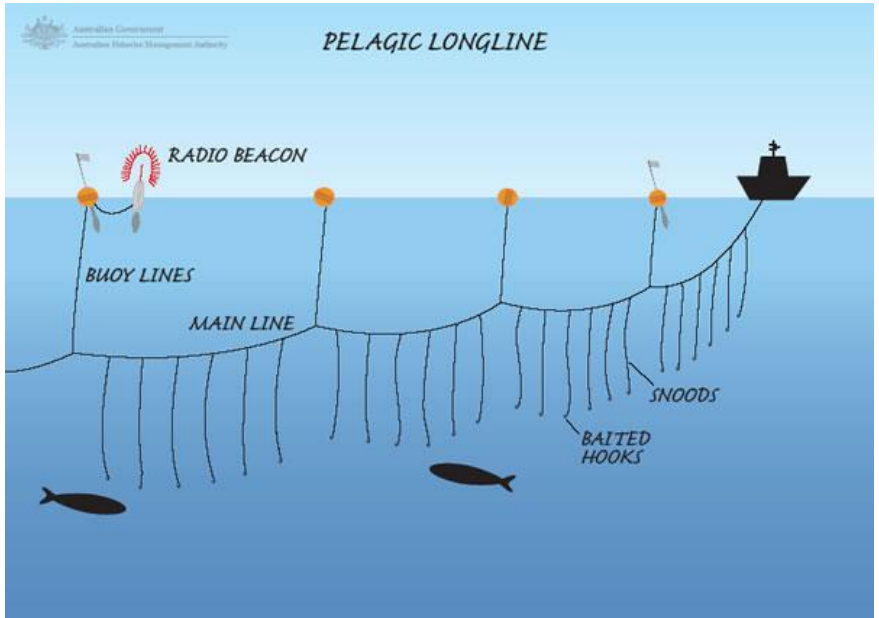
ERAEF methods used for a range of gear types….





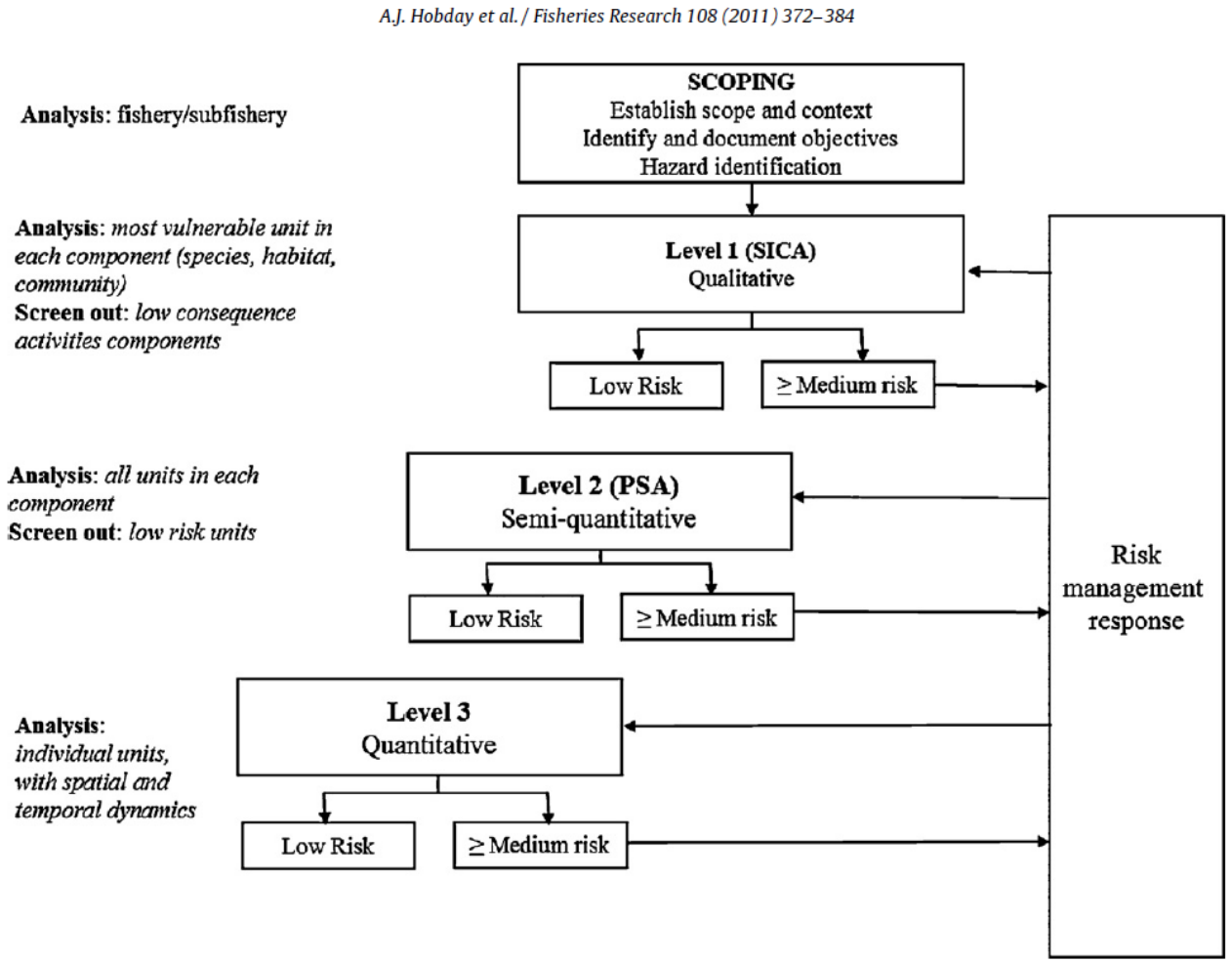






ERAEF approach can be hierarchical (or just choose a level)

- Scoping – review of fishery
- Level 1 - qualitative
- Level 2 – semi-quantitative (sharks ERA)
- Level 3 – quantitative



ERAEF - Level 2 tools – assess species risk

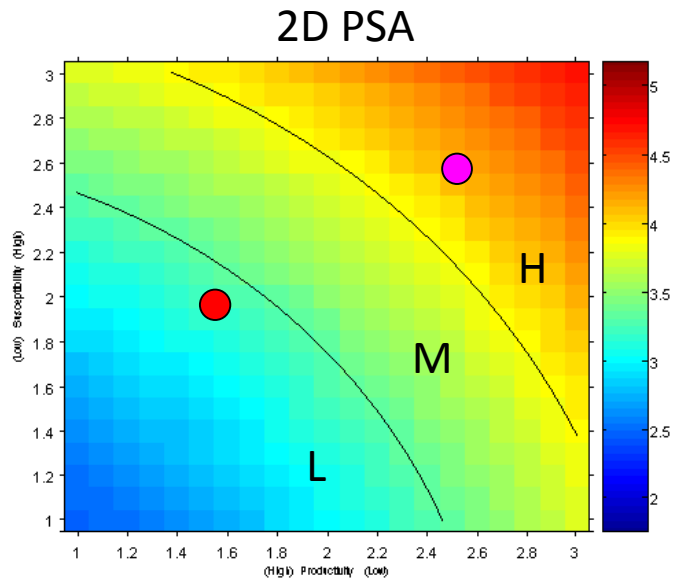
	Productivity-Susceptibility Analysis (PSA)	**Sustainability Assessment for Fishing Effects (SAFE)**
Risk assessed	Relative risk of overfishing	Quantitative assessment of fishing mortality (F) (reference points)
Strengths	Transparent (easy) Suitable for protected species Widely used	Quantitative reference points for F Cumulative risk can be determined
Limitations	No explicit reference points Detection of overfished: No assessment of biomass Accuracy: False positives (bias) more likely than false negatives	Detection of overfished: No assessment of biomass Accuracy: False negatives slightly higher than false positives, both relatively low.

See Zhou et al 2016

ERAEF – Productivity Susceptibility Analysis (PSA)

- PSA is a risk-based approach
- PSA accounts for biology and some fishery characteristics in input controls and technical measures (area allowed, gear type- mesh)
  - Gives estimate of potential risk

- PSA estimates the intrinsic rate of increase “r” and the catchability “q”
  - Use available productivity and susceptibility attributes related to these terms



$$\frac{dB}{dt} = rB\left(1 - \frac{B}{K}\right) - qEB$$

Attributes for the species in a PSA

Productivity attributes

- Maximum age
- Age at maturity
- Size at maturity
- Annual fecundity
- Maximum size
- Reproductive strategy
- Trophic level

$P = \text{average}(A_1, A_2, A_3 \ldots A_7)$

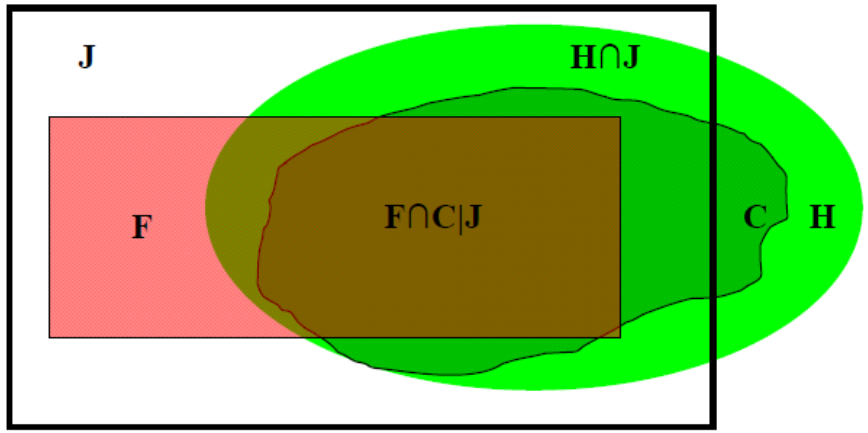
Susceptibility attributes

- Availability
  - Overlap with fishery
  - Global distribution
- Encounterability
  - Water column position
  - Adult Habitat
- Selectivity
  - Size at Maturity
- Post-capture mortality
  - Expert/Observer data

$S = A \times E \times S \times PCM$

Sustainability Assessment for Fishing Effects (SAFE)

- Indicators and reference points based on fishing mortality rate *u*
- Estimates:
  - spatial overlap between species distribution and fishing effort
  - catchability in terms of probability of encountering gear and size-dependent selectivity
  - Post capture mortality



- Productivity attributes inform *r, M*
- Uses average of the six methods below to relate life history and susceptibility (*u/F*) to biological reference points
- The model is tuned to automatically select for chondrichthyans or teleosts (Zhou et al. 2007)

1 $F_{msm} = r/2$, $F_{lim} = 0.75\ r$, and $F_{crash} = r$;

2 $F_{msm} = M$, $F_{lim} = 1.5\ M$, and $F_{crash} = 2M$;

3 $F_{msm} = M$, $F_{lim} = 1.5\ M$, and $F_{crash} = 2M$, where

$\ln(M) = -0.0152 - 0.279\ln(L_\infty) + 0.6543\ln(k) + 0.4634\ln(T)$ (Pauly 1980; Quinn and Deriso 1999);

4 $F_{msm} = M$, $F_{lim} = 1.5\ M$, and $F_{crash} = 2M$, where $\ln(M) = 1.44 - 0.982\ln(t_m)$ (Hoenig 1983).

5 $F_{msm} = M$, $F_{lim} = 1.5\ M$, and $F_{crash} = 2M$, where $M = 10^{0.566 - 0.718\ln(L_\infty)} + 0.02T$ (www.Fishbase.org);

6 $F_{msm} = M$, $F_{lim} = 1.5\ M$, and $F_{crash} = 2M$, where $M = 1.65/t_{mat}$ (Jensen 1996);

SAFE ctd.

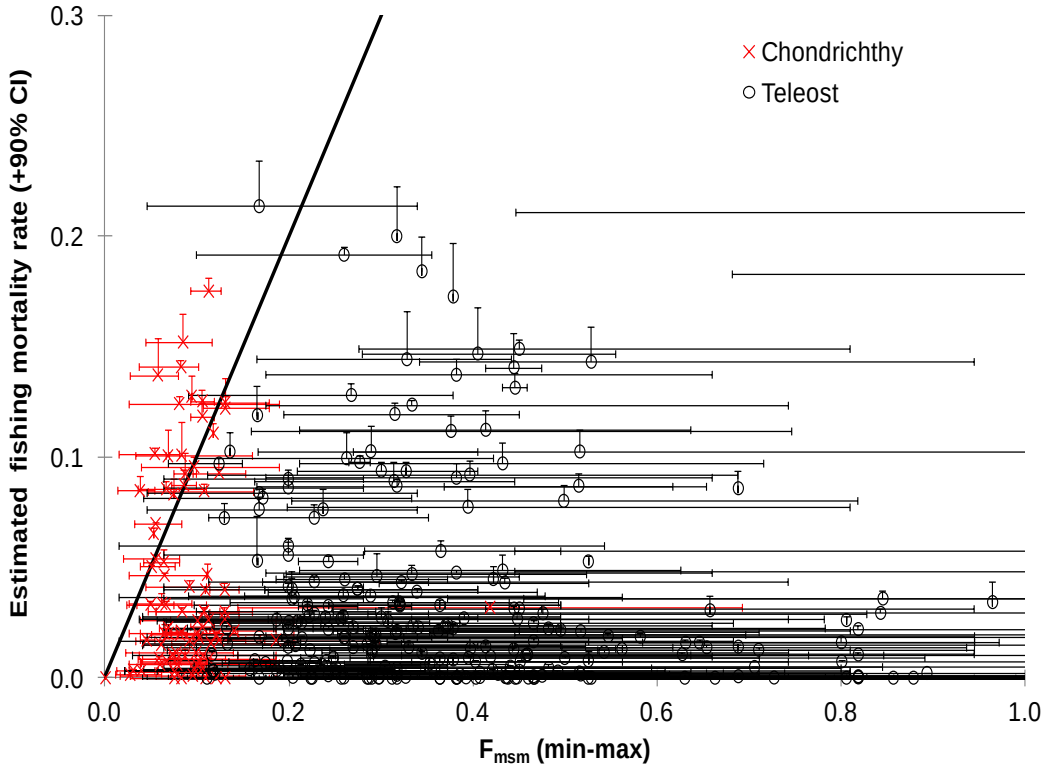
Reference points

1. *umsm* – Fishing mortality rate corresponding to maximum sustainable fishing mortality (*MSM*) at *Bmsm* (biomass that supports *MSM*, equivalent to *MSY*)
2. *ulim* – Fishing mortality rate corresponding to limit biomass *Blim*, where *Blim* is defined as 50% biomass that supports the *MSM*
3. *ucrash* – minimum unsustainable fishing mortality rate that theoretically may lead to population extinction in the long term

SAFE ctd.

Risk categories

1. Low risk: *u* is less than *umsm*
2. Medium risk: *u* is greater than *umsm* but less than *ulim*
3. High risk: *u* is greater than *ulim* but less than *ucrash*
4. Extreme high risk: *u* us greater than *ucrash*



Comparison between PSA and SAFE.

	PSA	SAFE
Key assumptions	1. Risk is measured by productivity and susceptibility attributes; 2. Fish randomly or homogeneously distribute over their distribution range; 3. 3-level catchability: low, medium, and high; 4. Productivity relate to life history traits.	1. Risk is measured by fishing mortality and reference points; 2. Same as PSA; 3. 3-level catchability: 0.33, 0.67, and 1; 4. Reference points relate to life history traits.
Productivity or reference point axis	**Attributes used:** 1. Maximum length; 2. Age at maturity; 3. Maximum age; 4. Fecundity; 5. Size at maturity; 6. Reproductive strategy; 7. Trophic level. **Scoring Rules:** 1. Each attribute is divided into 1, 2, and 3 scores; 2. Uses genera average when species-specific attributes are missing; 3. Missing data scored as high; 4. Final score P = average of all attribute scores.	**Attributes used:** 1. Same as PSA; 2. Same as PSA; 3. Same as PSA; 4. Natural mortality; 5. Growth rate; 6. Intrinsic population increase r. **Equations:** 1. $F_{msy} = r/2$; 2. Estimating M using 1–5 life history parameters above: $F_{msy} = 0.87M$ (teleost) and $F_{msy} = 0.41M$ (elasmobranch); 3. Mean F_{msy} = average all F_{msy}; 4. $F_{lim} = 1.5 F_{msy}$ and $F_{crash} = 2F_{msy}$.
Susceptibility or fishing mortality axis	**Attributes used:** 1. Availability (A) 2. Encountability (E) 3. Selectivity (S) 4. Post-capture mortality (D) **Scoring Rules:** Final score S = A × E × S × D	**Fishing mortality:** 1. Availability (A) 2. Encountability (E) 3. Selectivity (S) 4. Post-capture mortality (D) **Scoring Rules:** Fishing mortality F = A × E × S × D
Risk category	Divide possible scores into 1/3rds 1. Low risk: <2.64 2. Medium risk: 2.64–3.18 3. High risk: >3.18	1. Low risk: $F < F_{msy}$ 2. Medium risk: $F_{msy} < F < F_{lim}$ 3. High risk: $F > F_{lim}$

PSA-SAFE comparison (methodology)

See Zhou et al 2016

Deepwater sharks ERA - background

- Australia and other states sought binding measure on prohibition of deepwater gillnets in SIOFA (SIOFA SC1 2015), citing gear's non-selective nature, lack of data to estimate bycatch and risk of ghost fishing
  - Particular concern for deepwater shark populations due to their generally slow growth, low productivity
- SIOFA SC1 could not reach consensus and agreed that:
  - a risk assessment should be undertaken
  - with an appropriate harvest strategy and harvest control rules, fishing for deepwater sharks (and other low productivity species/stocks) could be managed sustainably regardless of gear used: **if suitable information is available**
- Broader requirement from MoP to SC to assess impacts of fisheries on bycatch species

Fishery overview

Table 2 Fleet composition in SIOFA fisheries, 2011–16

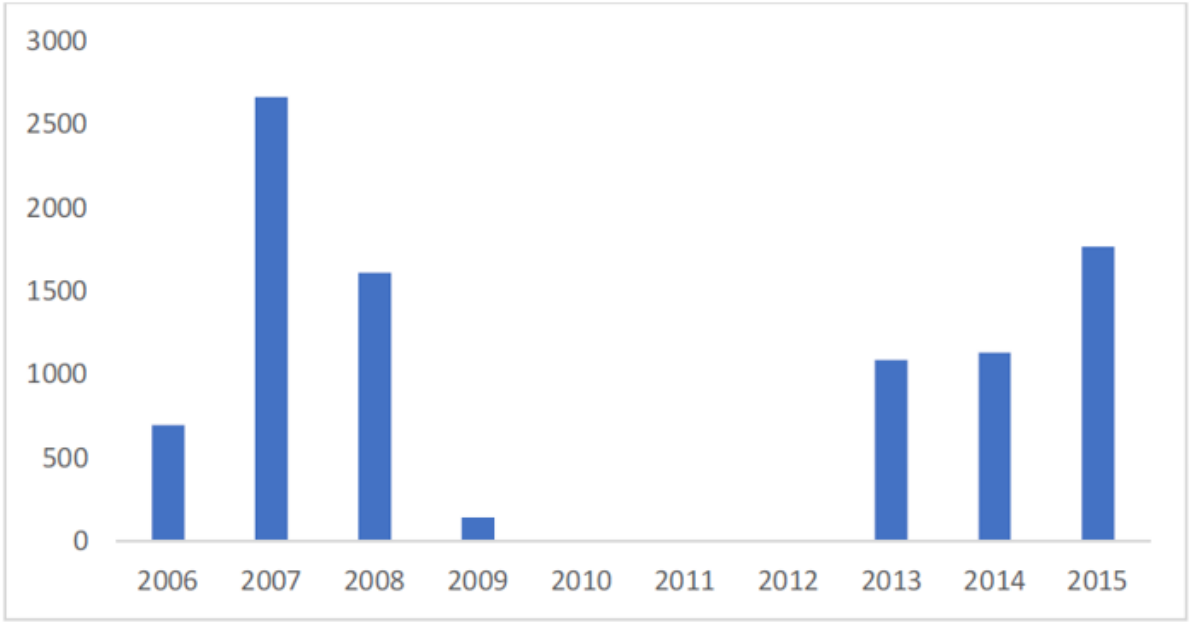
Flag	Gear	Year					
		2011	2012	2013	2014	2015	2016
Australia	Trawl	1	1	1	1	1*	1*
	Bottom Longline	0	0	0	0	1*	1*
Cook Islands	Trawl	3	3	2	2	2	2
European Union	Bottom Longline	2	2	2	1	1	2
	Gillnet	0	0	1	1	1	0
France Overseas Territories	Bottom Longline	2	2	2	2	2	2
Japan	Trawl	1	2	2	1	2	2
	Bottom Longline	0	0	1	0	0	0
Korea	Trawl	1	1	1	0	0	0
	Bottom Longline	1	1	3	0	0	0
Total Trawl		**6**	**7**	**6**	**4**	**4**	**4**
Total Bottom Longline		**5**	**5**	**8**	**3**	**2**	**4**
Total Gillnet				**1**	**1**	**1**	

* vessel is multipurpose (trawl and bottom longline)

Table 3 Fishing effort in SIOFA fisheries, 2011–15

Flag	Gear	2011	2012	2013	2014	2015
Australia	Trawl days	132	104	32	63	12
	Trawl hrs	294	252	62	106	14
	Longline hooks	0	0	0	0	1,800
Cook Islands	Trawl days	599	490	524	523	501
European Union	Longline hooks	na	na	na	na	2,221,000
	Gillnet km	0	0	5,442	4,945	1,121
France Overseas Territories	Longline hooks	509,414	503,478	731,883	634,682	443,492
Japan	Trawl days	58	90	118	126	356
	Trawl Hrs	550	528	1,001	707	2,260
	Longline hooks	0	0	96,480	0	0
Korea	Trawl days	50	238	217	0	0
	Trawl hrs	286	623	233	0	0
	Longline hooks	355,192	2,193,460	1,023,252	0	0
Total Trawl days		**839**	**922**	**891**	**712**	**869**
Total Trawl hrs*		**1130**	**1403**	**1,296**	**813**	**2,274**
Total hooks		**864,606**	**2,696,938**	**1,851,615**	**634,682**	**2,664,492**
Total Gillnet km		**0**	**0**	**5,442**	**4,945**	**1,121**

Figure 3 Provisional annual catches (tonnes) between 2006 and 2015 for 'deepwater sharks'[1] reported by contracting parties



Note: This catch history does not include the historical or current catch of non-contracting parties. Source: SIOFA 2017.

'Deepwater sharks' is not defined in the source for these data, but these catch figures are presumed to predominantly include the known target deepwater shark species (*Centrophorus squamosus* and *Dalatias licha*) and may include some byproduct species.

Gears assessed in this ERA

- Southern Indian Ocean - Demersal Trawl
- Southern Indian Ocean - Midwater Trawl
- Southern Indian Ocean – Demersal Longline
- Southern Indian Ocean – Deepwater Gillnet

Southern Indian Ocean fisheries – Chondrichthyans Species List

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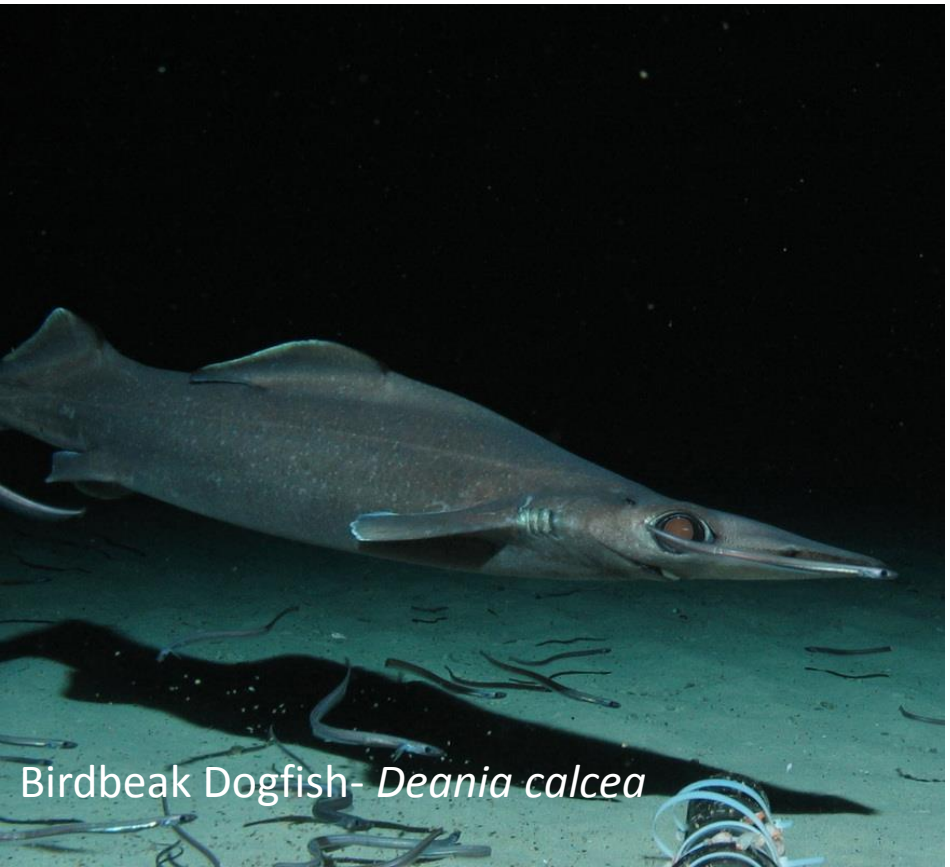
Dalatias licha- kitefin shark

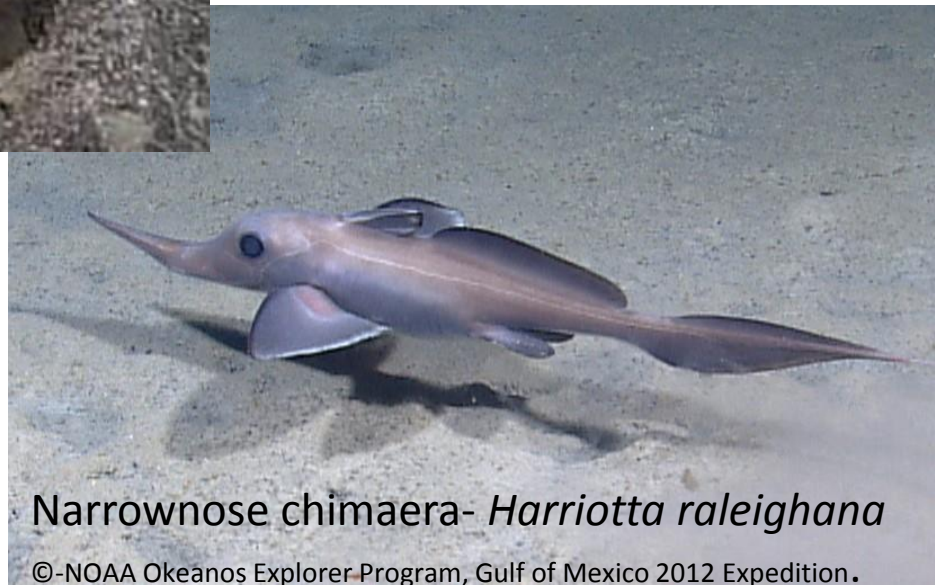
Deep sea chondrichthyans

Sharks, rays, chimaerids (ghost sharks) that live most of their life below 200 m depth.

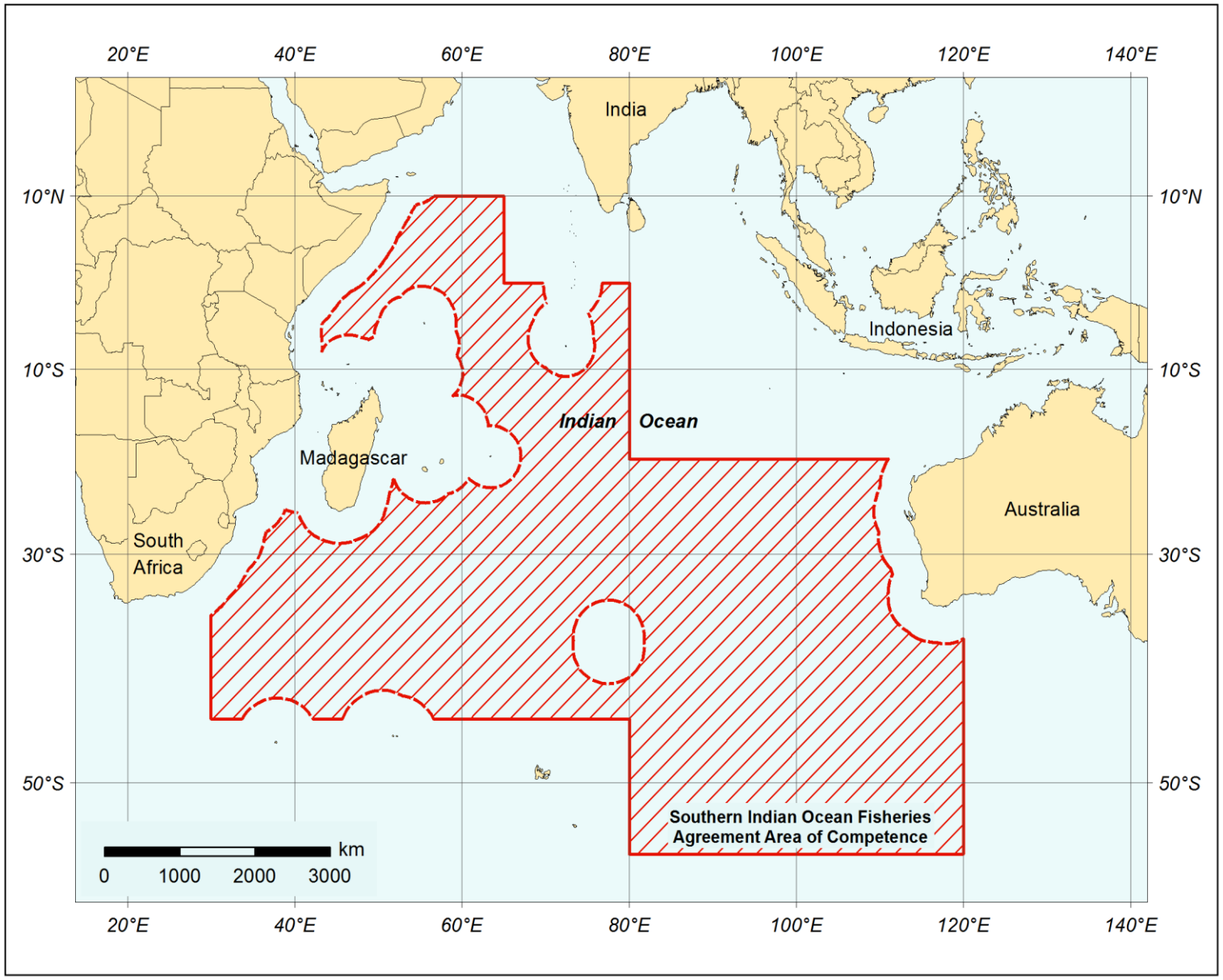


Birdbeak Dogfish- *Deania calcea*

Giant stingaree-*Plesiobatus daviesi*



Narrownose chimaera- *Harriotta raleighana*



The deep sea chondrichthyans species list:

Distribution

likely to occur within SIOFA Competence Area

&

Depth Range

occur at depths used by fishing gears

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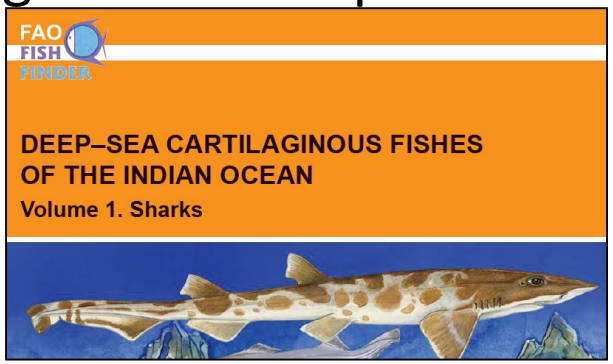
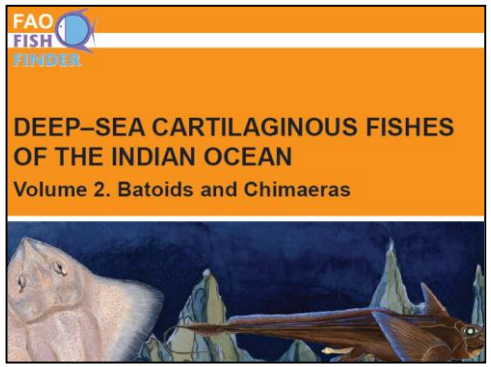
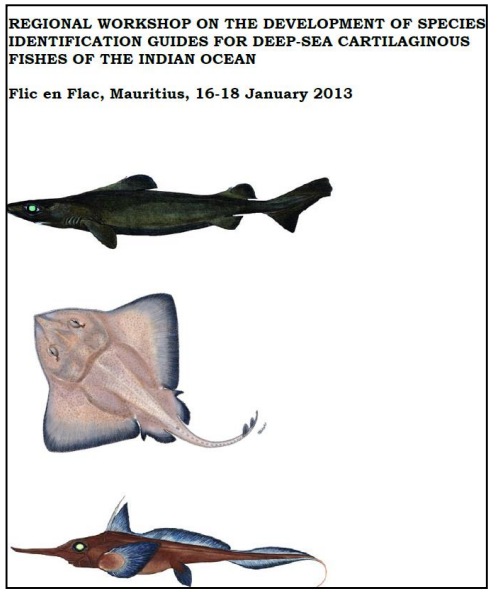
Generating the species list

- SIOFA list of shark species captured (website, shark codes data and some photos supplied)

- FAO guides to deep-sea cartilaginous fishes of Indian Ocean:







- Global shark and ray species guide books:

  Ebert et al. 2013 Sharks of the world. A fully illustrated guide.

  Last et al. 2016 Rays of the World.

- Recent published literature on new species in the region

Species included

- 101 species occurring in and likely to interact with fisheries in SIOFA

- Sharks 76%,
- batoids 15%
- chimaeras 9%

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Productivity attributes

- Maximum size
- Size at maturity
- Maximum age
- Age at maturity

- Fecundity (number of pups born per year)
- Reproductive strategy (Live bearer -pups or egg cases)
- Trophic level (level in the food web)

Additional attributes

- Growth rate- von Bertalanffy
- Rate of population increase
- Size at birth

Source of attributes data

- FAO guides, published literature on deepwater chondrichthyans- for each attribute the literature used was cited

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Other information

Distribution

1. Wide – across a number of oceans and distributed widely among the oceans
2. Intermediate - across a number of oceans but with smaller ranges within each ocean
3. Restricted - only in one ocean and with small range in that ocean

Depth range for a species

Role in fishery

- Bycatch (caught and unknown if retained or discarded)
- Byproduct (caught and retained)
- Discard (caught and returned to sea)

Proxy and missing data

- Some species do not have all this attribute data
- Where any data was missing, such as maximum age- used ‘proxy’ data from another species that was closest (and noted in the analysis that this was proxy data):

  ✓Taxonomically- same genus or family

  ✓Depth range most similar

  ✓Size of the animal most similar

- Documented all sources and reasons for using proxy data in ‘comments column’
- If no data at all for that genus or family it was classed as ‘missing data’

Risk categorisation for productivity attributes

Attribute	Low productivity (high risk)	Medium productivity (medium risk)	High productivity (low risk)
P1. Average age at maturity	>15 years	5–15 years	<5 years
P2. Average maximum age	>25 years	10–25 years	<10 years
P3. Fecundity	<10 pups/egg cases per year	10-20 pups/egg cases per year	>20 pups/egg cases per year
P4. Average maximum size (rescaled for deepwater sharks)	>200 cm	70-200 cm	<70 cm
P5. Average size at maturity (rescaled for deepwater sharks)	>150 cm	40-150 cm	<40 cm
P6. Reproductive strategy	Live bearer	Egg case layer	Broadcast spawner (teleosts)
P7. Trophic level	>3.25	2.75–3.25	<2.75

Risk categorisation for susceptibility attributes

Attribute	Low susceptibility (low risk)	Medium susceptibility (medium risk)	High susceptibility (high risk)
S1. Availability	<10% horizontal overlap	10-30% horizontal overlap	>30% horizontal overlap
S2. Encounterability	Low vertical overlap with fishing gear (<10%) based on middle 90% of the gear range	Medium vertical overlap with fishing gear (10-30%) based on middle 90% of the gear range	High vertical overlap with fishing gear (>30%) based on middle 90% of the gear range
S3. Selectivity (scores vary by gear type)	Demersal and midwater trawl: 0-15 cm; > 500 cm in length Line: 0-40 cm; >500 cm in length Gillnet: 0-70 cm; >140 cm in length	Demersal and midwater trawl: 15-30 cm; 400-500 cm in length Line: 40-80 cm; 200-500 cm in length Gillnet: 70-80 cm; 130-140 cm in length	Demersal and midwater trawl: 30-400 cm in length Line: 80-200 cm in length Gillnet: 80-130 cm in length
S4. Post-capture mortality (scores may vary by fishery and gear type)	Evidence of post capture release and survival	Bycatch species (discarded)	Target or byproduct species

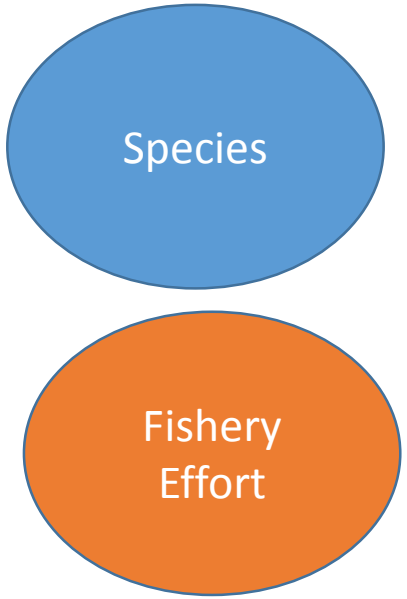
Susceptibility 1 (availability)

- Used % overlap of species distributions with fishing effort mapped at 20-minute mesh block for each gear
- PSA and SAFE methods assume homogenous distribution of species across their ranges
  - Need habitat models to improve on this assumption

Availability scoring when “no overlap”

PSA

- If fish and effort don’t overlap (-1)
- Availability gets Low (1)
- Species still shows up in PSA



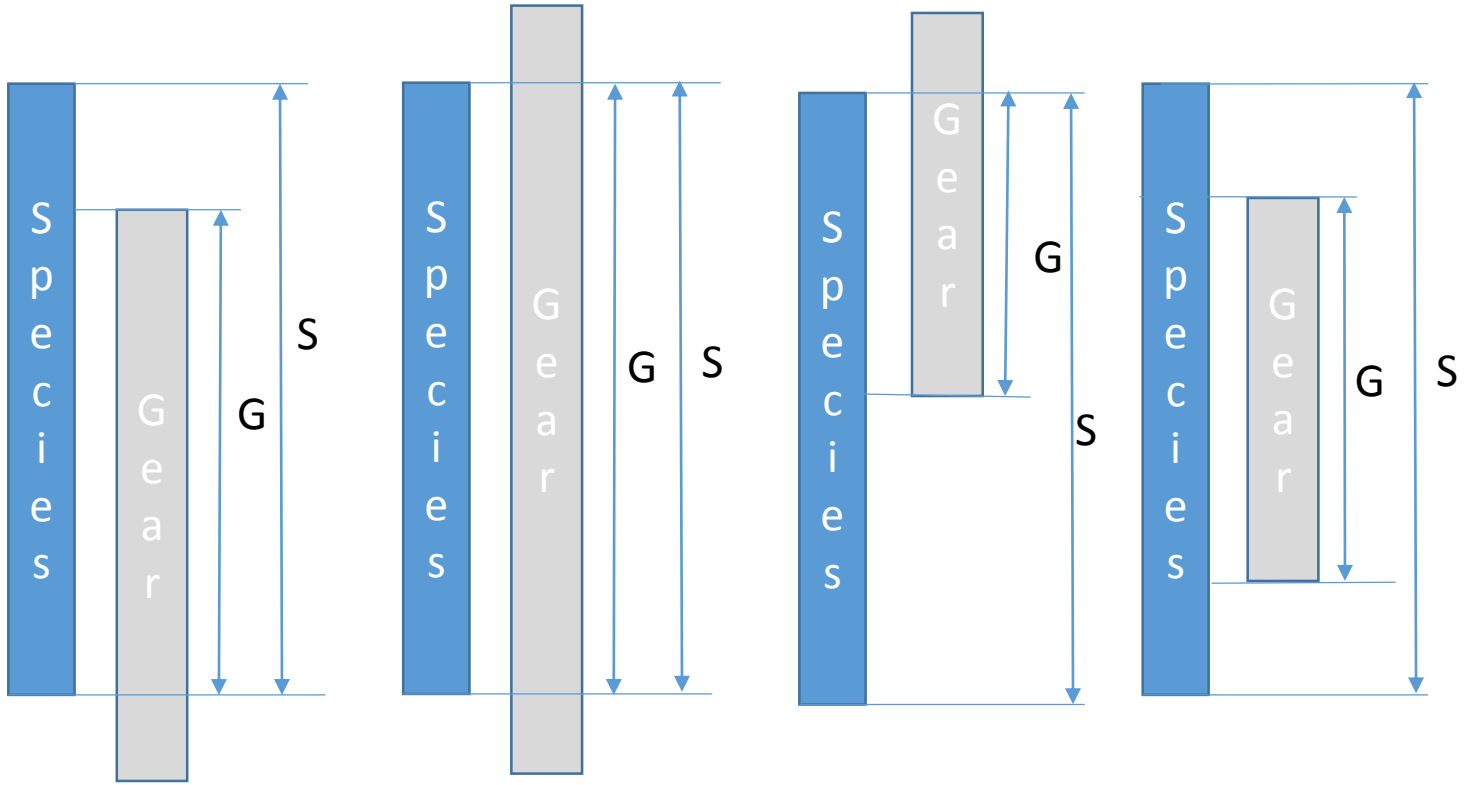
SAFE

- If fish and effort don’t overlap (-1)
- Availability gets 0
- F gets true “0”
- Species does not show up in SAFE

SIO PSA - Encounterability (Method 3)

Depth overlap is 'continuous'

- depth range of fish (min and max)
- depth range of fishing gear (middle 90% of records)
- Calculate % overlap
- Scale, Consistent with "availability"



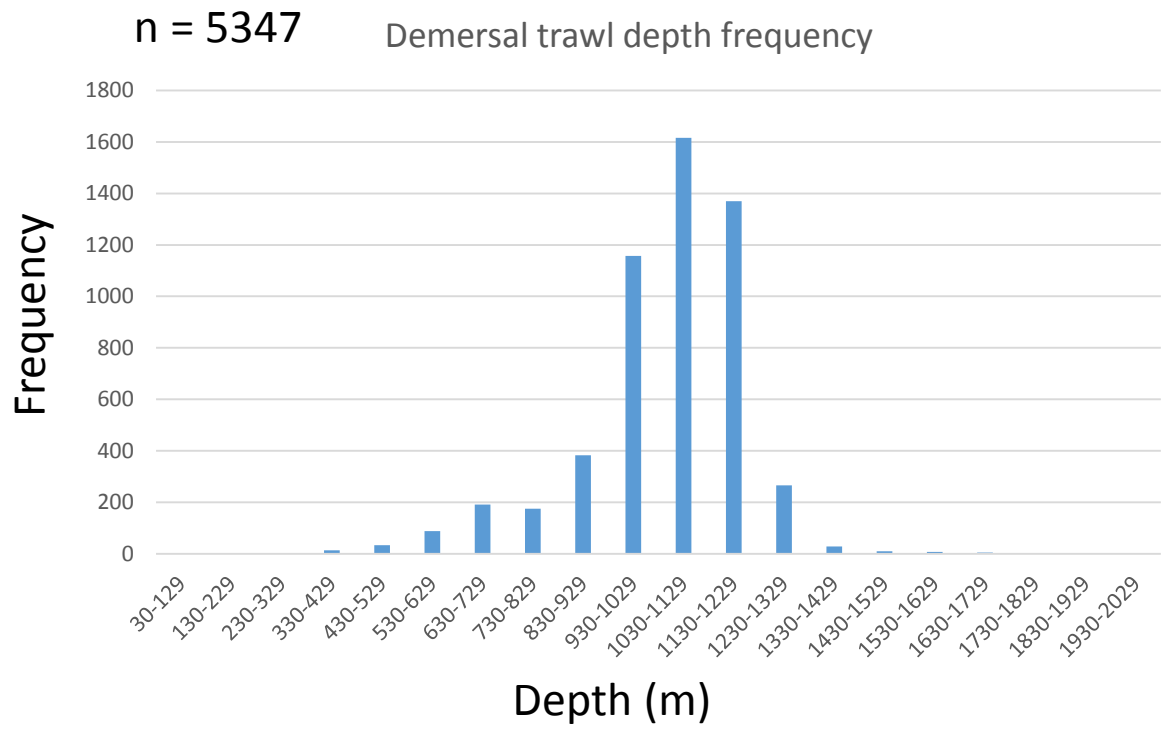
E=G/S
E<0.1, low, score of 1
0.1>E>0.3, medium score, continuous between 1 and 3
E>0.3, high, score of 3

SIO PSA - Encounterability (Method 3)

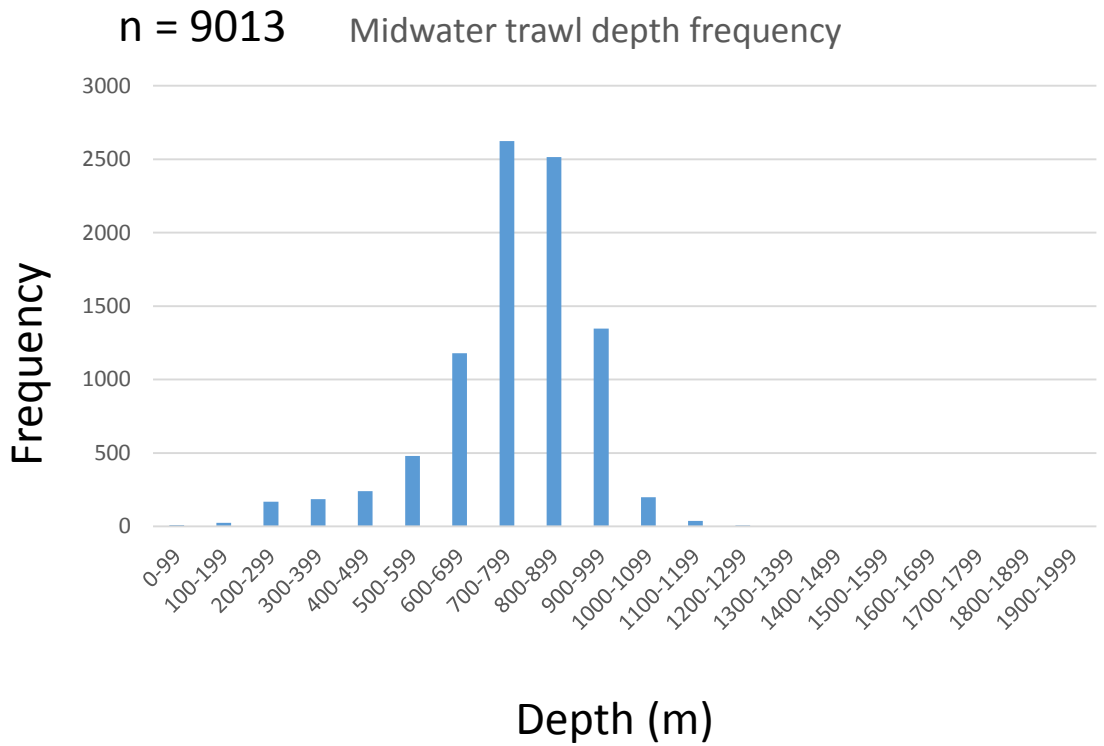
- Used middle 90% of depth records available
- Outliers consequently discarded

Gear	Fishery ID	Depth Min (m)	Depth Max (m)
Demersal Trawl	96	700	1235
Midwater Trawl	97	430	970
Demersal Longline	98	597	1716
Gillnet	110	810	1390

Encounterability – demersal trawl

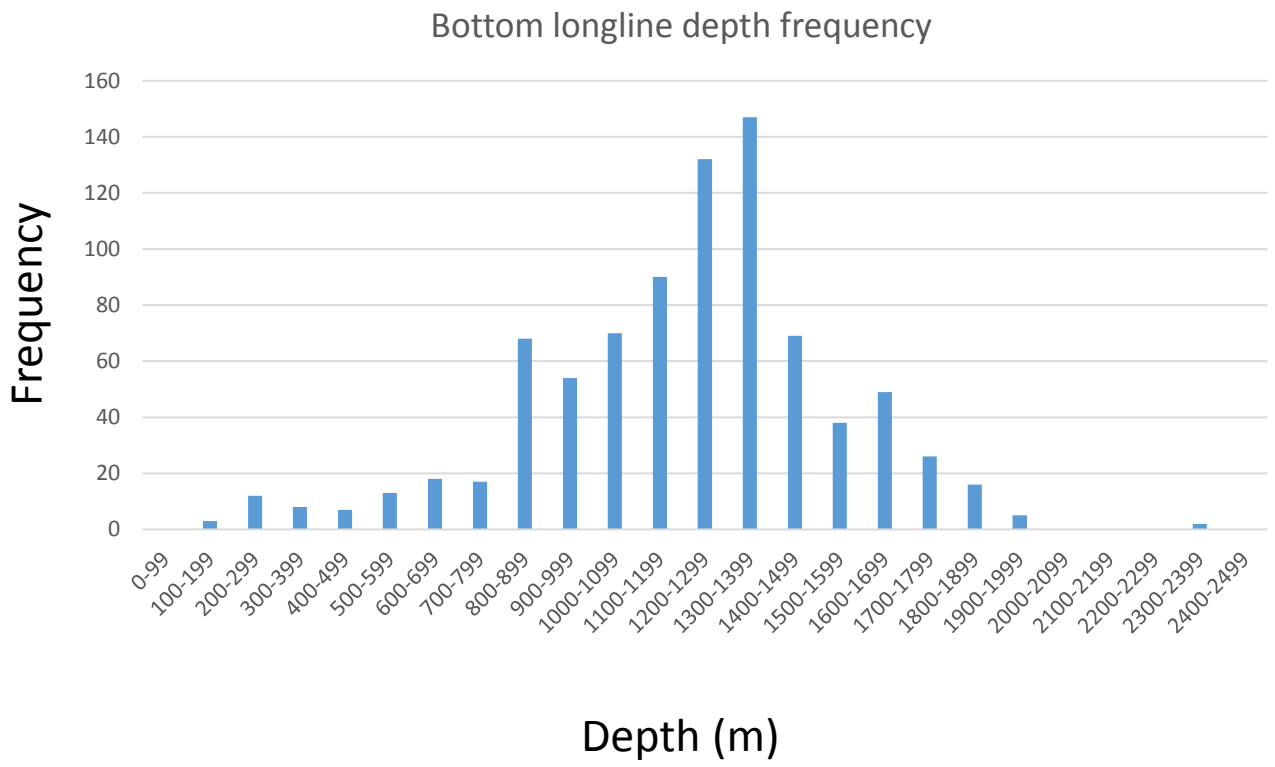


Encounterability – midwater trawl

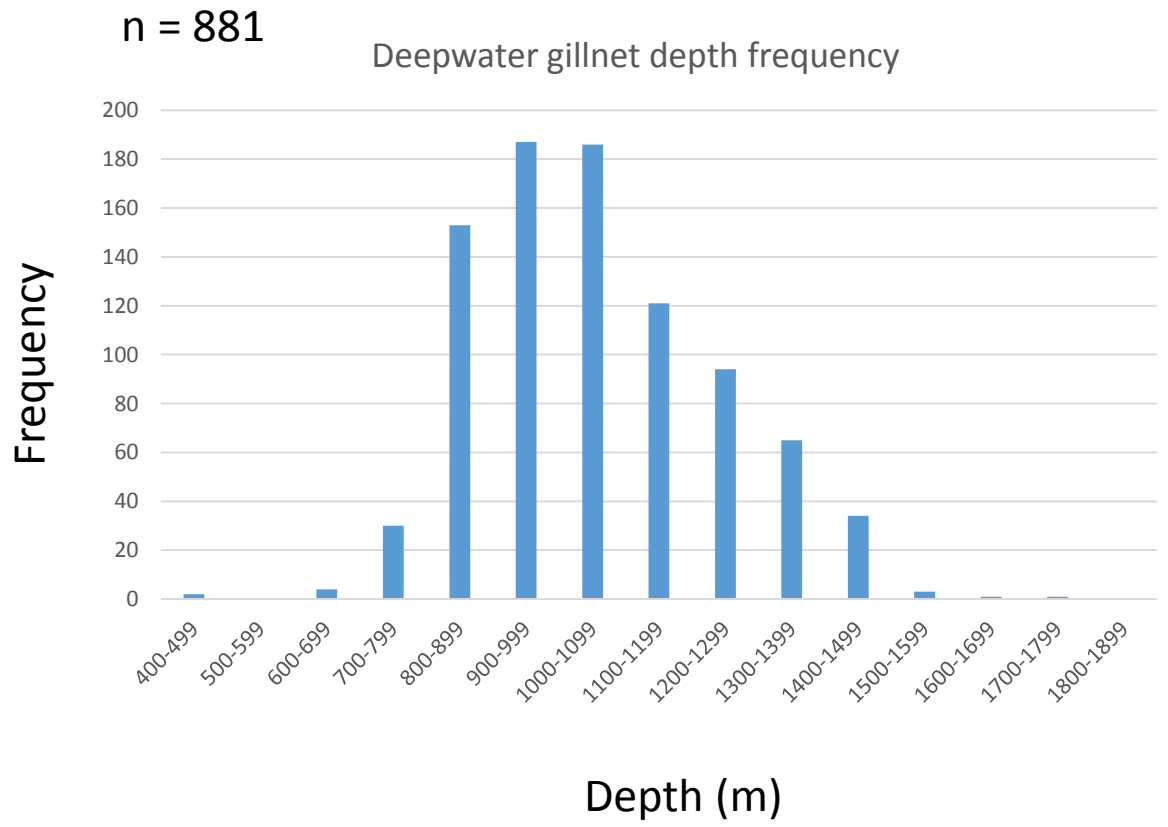


Encounterability – bottom longline

n = 844



Encounterability - gillnet



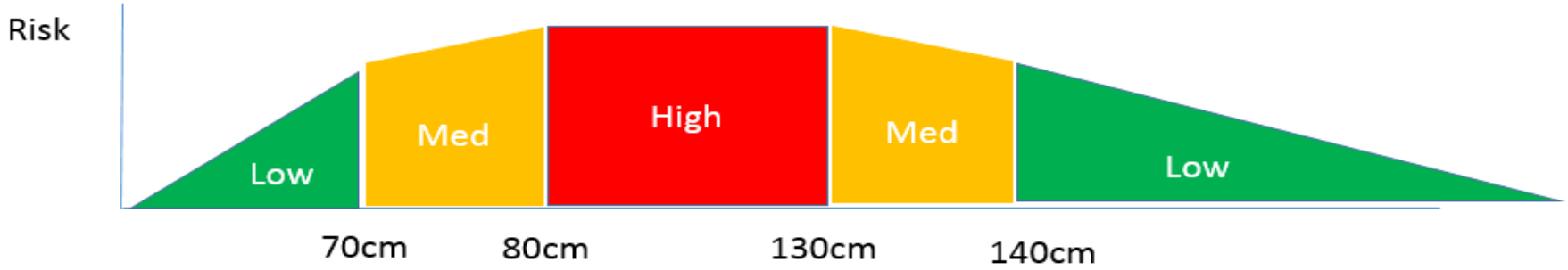
Susceptibility 3 (Selectivity)

- Size-dependent, varies by gear, assumed to be the same for sharks, batoids and chimaeras

Trawl

Line

Gillnet



Susceptibility 4 (Post Capture Mortality)

- Target = high risk (3)
- Byproduct = high risk (3)
- Bycatch = taxa/fishery dependent (medium risk 2)
- Protected species = taxa dependent (air breathing etc.)

Spatial data – fishing effort

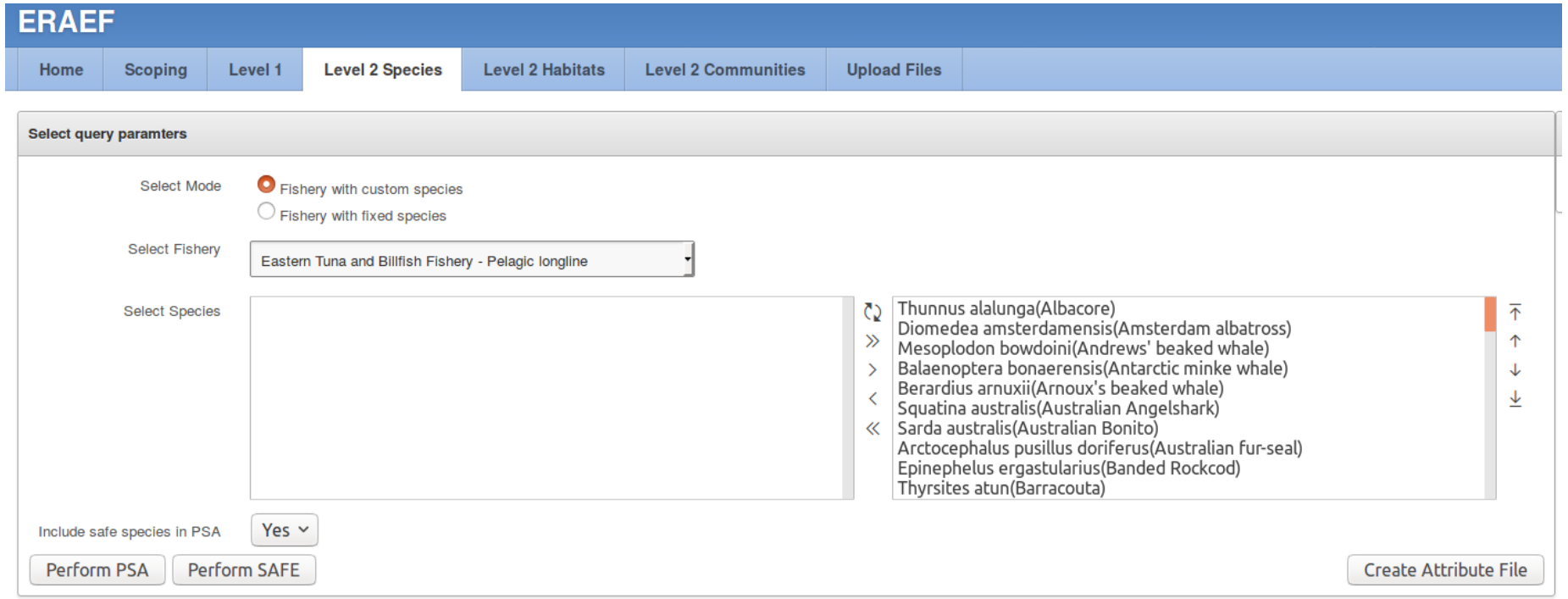
- Fishing effort all gears – 2011-2016 – Australia, Cook Islands (2 vessels, missing 1), EU, Japan, hoping to get France Overseas Territories and Korea data soon
- 20-minute mesh created using lat/longs
- Defined ‘fished area’ as all mesh blocks with at least one fishing operation
- Assumption that fishing has occurred across the entire block – precautionary

Spatial data – species distribution maps

- 71 species maps from FAO Geonetwork database
- 21 from IUCN Red List
- Various sources in published literature for *B. bachi, B. tenuicephalus, E. alphus, C. willwatchi, C. didierae, C. buccanigella*
- Reason for sources – ease of access and comprehensiveness of holdings
- Results could vary depending on data source and type used

PSA and SAFE results

http://www.marine.csiro.au/apex/f?p=127



Proposed next steps

- Finalise assumptions and outputs – ERAWG/SC engagement required
- Draft SC paper (December 2017)
- Review by SIOFA ERAWG/SC (January 2018)
- Paper submission (February 2018)
- Presentation to SIOFA SC3 and formulation of MoP advice (March 2018)
- Peer-reviewed publication (2018)
  - Consider for broader ERA of southern hemisphere chondrichthyans
- Extend methods to other SIOFA bycatch species?