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**ECOLOGICAL RISK ASSESSMENT
FOR THE EFFECTS OF FISHING IN THE
WESTERN & CENTRAL PACIFIC OCEAN:
PRODUCTIVITY-SUSCEPTIBILITY ANALYSIS**

WCPFC-SC3-EB SWG/WP-1

Paper prepared by

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1. Background & Introduction

The First Regular Session of the WCPFC Scientific Committee (SC1) endorsed the suggestion (Molony 2005, Kirby et al. 2005) that Ecological Risk Assessment (ERA) be carried out for the WCPFC Convention Area. SPC-OFP undertook a preliminary ERA (Kirby & Molony 2006) based on the CSIRO/AFMA approach (Hobday et al. 2006). These results were presented to the Second Regular Session of the WCPFC Scientific Committee (SC2), who called for the continuation of this work. In December 2006 the Commission approved its budget for 2007 and a collaborative proposal to carry out the ERA work was then developed between SPC-OFP and CSIRO, Australia. This included the intention to hold an ERA Research Planning Workshop involving technical experts and relevant NGOs, and to prepare a 3 yr ERA Research Plan for submission to SC3. This proposal was subject to peer review and the WCPFC Secretariat gave their approval in March 2008. The analysis presented here is therefore a work-in-progress and there remains room for improvement in data quality/quantity and the resolution and complexity of the analyses. Nonetheless, what is presented illustrates the utility of Ecological Risk Assessment (ERA) in supporting the Ecosystem Approach to Fisheries (EAFM) and in assisting CCMs and the SC to meet their obligations under the WCPFC Convention.

The CSIRO/AFMA approach to ERA is hierarchical (Levels 1, 2 & 3; Hobday et al. 2005): Level 1 is based on stakeholder workshops, and is designed to identify hazards to species and systems and to carry out a Scale-Intensity-Consequence Analysis (SICA). Level 2 is based on the biological characteristics of species caught in the fishery concerned, and the degree of interaction between that fishery and those species. This has been called Productivity-Susceptibility Analysis (PSA) and is the approach and level at which the ERA for the WCPFC Convention Area has so far been carried out. At this level, individual species are assigned risk scores relative to each other, resulting in a risk ranking along each of the two axes used (productivity, susceptibility) and as the distance from the origin of the graph. It is important to emphasise both the relative nature of these scores, such that they are valid only for the particular PSA carried out, and the fact that this is a risk assessment *for the effects of fishing* and not an estimate of extinction risk due to the sum of all risks experienced by any particular species (i.e. trophic interactions,

environmental variability, climate change, fishing, habitat destruction, pollution, etc.). Estimates of population status for any single species result from analyses at Level 3, which may take the form of a classical stock assessment. ERA as a process then, is designed to engage stakeholders, identify those species at most risk from fishing activities, and ultimately to provide population assessments for those species. It is therefore a useful process for prioritisation of fisheries research and conservation/management action.

2. Updates since SC2

A new database for life history data was made available for analysis, through a collaborative agreement between SPC-OFP and CSIRO, Australia. This has allowed refinement of the indices used in the Productivity-Susceptibility Analyses (PSAs).

Productivity: as well as the age-based metrics used previously, it has also been possible to use population parameters such as natural mortality, as well as the growth parameters k and length-at-infinity.

Susceptibility: Vertical overlap index between species habitat (max. & min. depth) and longline gear (max. depth) was calculated, as well as the length- and condition-at-capture metrics and percentage retained, used previously.

The following 3 PSAs were carried out for 2 fishery categories (deep & shallow longline)

- PSA 1 for **all species** observed caught (number of species: N=233)
- PSA 2 for **all fish species** observed caught (N=190)
- PSA 3 for **species of special interest** (SSIs: birds, mammals, reptiles, sharks) (N=99)

Spatial overlap plots have been updated to the period 2002-2006 for longline effort, observer effort, and observed encounters of birds, mammals, reptiles, and sharks.

PSAs have not been carried out for purse seine fisheries, as the observer data do not include the same attributes used in the PSAs for longline (condition, fate) – nevertheless, purse seine fisheries are likely to have some impact on non-target associated and dependent species, so a summary plot reproduced from Langley et al. (2006) is provided, to illustrate the degree of bycatch in the different set types. Further work will be carried out on purse seine fisheries in the course of the project.

3. Spatial overlap between species distributions and longline fishing effort

The updated database includes both minimum and maximum depth as well as global distribution for 94% of species observed caught. This enables the degree of overlap between fishing effort and species distribution to be calculated and included in PSAs.

$$\text{Vertical Overlap Index} = \frac{[\text{maximum hook depth} - \text{minimum species depth}]}{[\text{maximum species depth} - \text{minimum species depth}]}$$

For this year the degree of overlap has been calculated in the vertical dimension. A similar index for the degree of overlap in the horizontal dimensions (see Fig, XX) has not yet been calculated, but will be included in future analyses.

Overlap indices are simple metrics serving a similar purpose to habitat standardisation of catch rates in stock assessments for tunas (Bigelow et al. 2005). The statistical approach now favoured (Maunder et al. 2006) may be useful for PSAs, although the lack of species identification for non-target species on commercial logsheets would be a limiting factor.

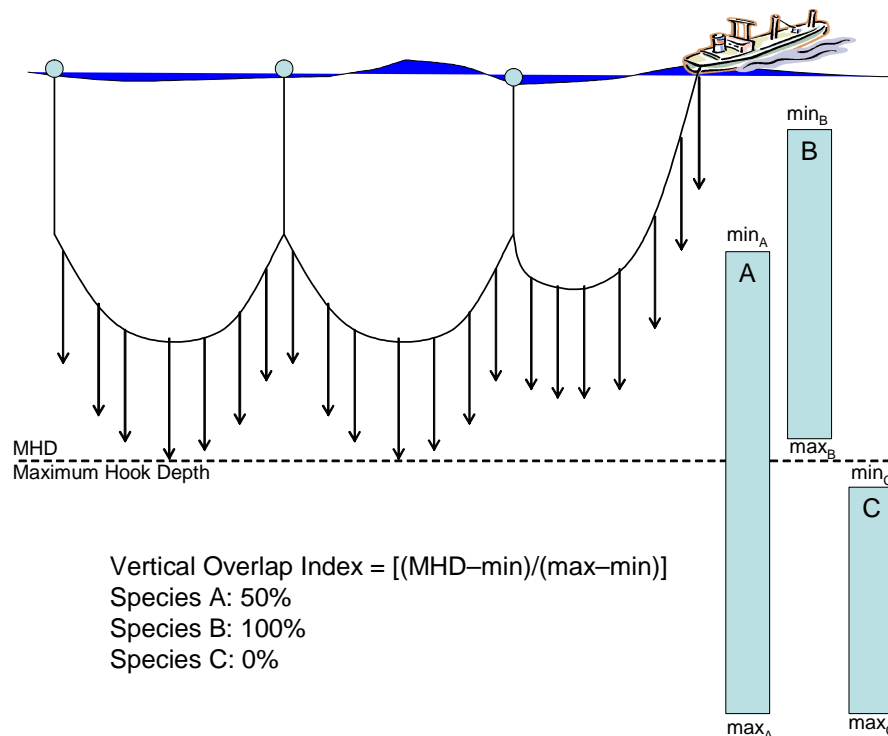


Fig. 1. Sketch to illustrate how the Vertical Overlap Index is calculated from the minimum and maximum depths defining the species' depth range and the maximum hook depth for shallow and deep longline

4. Indicators for Susceptibility

PSA 1: all species, age-based

Exposure: Vertical Overlap Index
Sensitivity: Condition \times Retained*

PSA 2: fish (bony fish & sharks, rays, dogfish), length- and age-based

Exposure: Vertical Overlap Index
Sensitivity: Condition \times Retained*
Length-at-capture / maximum length; L_{LL}/L_{max}

PSA 3: Species of special interest (birds, mammals, turtles, sharks), age-based plus reproductive output

Exposure: Vertical Overlap Index
Sensitivity: Condition \times Retained*

5. Indicators for Productivity

PSA 1: all species, age-based

Reproductive strategy (1–5: 1: teleosts; 2: sharks; 3: turtles; 4: birds; 5: mammals)
Age-at-maturity / Maximum age; A_{mat} / A_{max}
Maximum age; A_{max}

PSA 2: fish (bony fish & sharks, rays, dogfish), length- and age-based

Natural mortality, M
Von Bertalanffy growth coefficient; k
Von Bertalanffy length-at-infinity; L_{inf}
Age-at-maturity / Maximum age; A_{mat} / A_{max}

PSA 3: Species of special interest (birds, mammals, turtles, sharks), age-based plus reproductive output

Age-at-maturity / Maximum age; A_{mat} / A_{max}
Maximum age; A_{max}
Litter size \times Reproductive frequency (yr^{-1})

*including those categorised by observers as “DFR: discarded, fins removed”

6. Substitution of parameters

The database available for this analysis includes 73 attributes for 233 species. Many of these attributes are minimum, maximum and average values that are sexually disaggregated, so potentially 6 measurements of the same parameter for each species. Of course, not all these values are known, so we aggregated the analysis for the two sexes and used all the parameter values to derive a single value for each attribute for each species. Even this was not sufficient to obtain parameter values for every species, so average values were calculated for species groups (Table 1) and substituted for a number of species (Table 2). The sex aggregation and parameter substitution are necessary in order to include as many species as possible, which is the general aim of the Level 2 PSA. It must therefore be noted that there is an inherent trade-off between accuracy and precision in these analyses, and that for any finer scale analysis by area/fishery/sex it will be necessary to substitute average parameters for those that are area/fishery/sex specific but so far unquantified. Life history parameters may be largely independent of the area/fishery, though they can vary by sex, but length-at-capture, vertical/horizontal overlap index, condition and fate will vary by area/fishery and this variability may not be well described. Further work will attempt analyses at finer resolutions (including for individual CCMs) and identify the resolutions appropriate to the quality of the input data.

7. Results

Results are presented in Figs. 1–3 and Table 3. In the figures, risk scores are plotted along the two axes (x : productivity; y : susceptibility) such that the higher the score, the bigger the risk. Scores have been scaled on both axes such that the minimum value is zero and the maximum value is one. The assignment of risk categories HIGH, MEDIUM and LOW (Table 1) is such that MEDIUM encompasses all values in the range: $\text{mean} \pm 1\text{SD}$, and HIGH and LOW risk categories are values above and below this range, respectively.

PSAs 1 & 2 flag albatrosses as HIGH risk in both deep and shallow longline fisheries, which serves as a basic sanity check for the method (although Shy Albatross (DCU) ranks MEDIUM for deep longline in PSA 3). Petrels tend to rank as HIGH risk in PSA 1 and

HIGH or MEDIUM risk in PSA 3. With such low productivity, being so long lived, being susceptible to both longline configurations at the surface, and being not able to survive hooking and immersion, it is no surprise that these species rank highly. What is missing in the method, however, is an index of horizontal overlap between species distributions and fishing effort, which in the case of albatrosses and petrels shows two things: firstly, that the degree of overlap is only a small percentage of the total fishery distribution, and secondly that this overlap is a significant proportion (41%) of the global breeding distribution (Birdlife Int 2006). Future PSAs need to incorporate both aspects, as the first aspect limits the generality of the results and the second may underestimate risk.

Turtles generally rank as HIGH risk in PSA 1 (relative to all species) and MEDIUM risk in PSA 2 (relative to other SSIs only). The exception is the leatherback turtle (LTB), which ranks as LOW and MEDIUM risk in PSA 1 and LOW risk in PSA 3; this apparently anomalous result, given the general concern about the population status of leatherbacks based on nesting beach surveys, is not actually surprising when the input data to the PSA are considered: leatherbacks have a lower age at maturity than other turtles; they occupy deeper habitat; and they are generally alive when caught and are subsequently discarded. This is a good example of how PSAs may identify relative risk posed by a particular fishery, rather than estimate population status or quantify the relative role of fishing in general compared to other sources of mortality.

Most of the rays rank as HIGH risk in PSA 2 if not in PSAs 1 or 3, where the other SSIs rank as higher risk. Several shark species rank as HIGH risk in PSA 1. They tend to be alive when caught (ca. 70%) though often their fins are retained and only ca. 30% are discarded alive and intact. Despite scoring as HIGH risk on productivity, most of the sharks do not subsequently rank as HIGH risk in general in PSAs 2 & 3. In PSA 2 this is probably because sharks are generally caught as juveniles. Many of the species that do rank as HIGH risk in PSA 2 are teleosts that have the highest scores for susceptibility, being generally caught near their maximum size and not surviving the experience. Notable teleosts that rank as HIGH risk in PSA 1 include blue marlin (BUM), frigate mackerel (FRI), longtail tuna (LOT), spanish mackerel (COM) and sailfish (SFA). In all PSAs, the principal market species of tuna – albacore (ALB), bigeye (BET), skipjack (SKJ) and yellowfin (YFT) – are scored as being at MEDIUM risk.

8. Sources of error and uncertainty

The first source of error and uncertainty is the database of biological parameters. These data were obtained from public domain databases such as *Fishbase* (www.fishbase.org), from the peer-reviewed and grey literature and from expert opinion. They therefore vary greatly in quality, in terms of sample sizes and sampling strategy more generally. It is not obvious whether different length metrics (total length, fork length) have been used consistently between the biological data and the observer data. Classifications by observers of CONDITION are largely subjective (here we have used both categories DEAD and DYING) and do not account for post-release mortality (i.e. of those classed as ALIVE). Species identification skill by observers is variable and may be poor, and we have not used data recorded for species groups, though this may actually be informative, e.g. in generating some of the average values used for substitution (Tables 1 & 2).

9. Conclusions

The PSAs generally capture what we would expect for the different species groups, and the formulation of the risk scores along each of the two axis (productivity, susceptibility) does lead to some obvious results in terms of the high risk experienced by long-lived, air-breathing species with low reproductive output. However, there are some surprises, such as for the leatherback turtle, and some obvious omissions, such as the horizontal habitat overlap with fishing effort, that serve to illustrate the limits of the analyses as presently formulated. The results should therefore be seen as indicative rather than conclusive. There is a need for closer screening of input parameters along both axes, finer scale analyses by area/fishery, and sensitivity analyses for some of the necessary assumptions. These aspects will all be addressed in the course of the ERA project, given the endorsement of the Scientific Committee and ongoing support of the WCPFC.

References

The database used for these analyses contains 816 references to primary sources and for obvious reasons these are not included here. The database itself will be made available on the WCPFC website so that the interested reader can look up the parameter values used here and check their sources. The following is a list of literature cited in this paper.

Bigelow KA (2005) Incorporation of other oceanographic factors into CPUE standardizations. Working Paper ME-WP2, 1st Regular Session of the WCPFC Scientific Committee, Nouméa.

Birdlife Int (2006) Distribution of albatrosses and petrels in the WCPFC Convention Area and overlap with WCPFC longline fishing effort. NGO Paper, 2nd Regular Session of the WCPFC Scientific Committee, Manila, 7 - 18 August 2006.

Hobday AJ, Smith A, Webb H, Daley R, Wayte S, Bulman C, Dowdney J, Williams A, Sporcic M, Dambacher J, Fuller M, Walker T (2006) Ecological risk assessment for the effects of fishing: methodology. Working Paper EB-WP14, 2nd Regular Session of the WCPFC Scientific Committee, Manila, 7 - 18 August 2006.

Kirby DS, Allain V, Molony B (2005) Potential ecosystem indicators for the WCPO. Working Paper EB-WP5, 1st Regular Session of the WCPFC Scientific Committee, Nouméa.

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Langley A, Williams P, Hampton J (2006) The Western and Central Pacific tuna fishery: 2005 overview and status of stocks. Tuna Fisheries Assessment Report No. 7, Secretariat of the Pacific Community, Nouméa

Maunder MN, Hinton MG, Bigelow KA, Langley AD (2006) Developing indices of abundance using habitat data in a statistical framework. *Bulletin of Marine Science* 79:545–559

Molony B (2005) Estimates of the mortality of non-target species with an initial focus on seabirds, turtles and sharks. Working Paper EB-WP1, 1st Regular Session of the WCPFC Scientific Committee, Nouméa.

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Table 1. Average values for species groups used when species-specific parameters were not available

	Bony fish	Sharks, Rays & Dogfish	Mammals	Birds	Turtles
LIFE SPAN: (A_{\max} , YRS)	15	30	34	40	66
AGE AT MATURITY: (A_{mat} , YRS)	4	14	10	7	26
AGE RATIO: (A_{mat}/A_{\max})	0.27	0.46	0.30	0.17	0.39
CONDITION: (% <i>DEAD</i>)	0.52	0.32	Dolphins: 0.67 Whales: 0.43	1.00	0.21
FATE: (% <i>RETAINED</i>)	0.31	0.70	1.00	0.00	0.95
LONGLINE LENGTH / MAXIMUM LENGTH (L_{LL} / L_{\max})	0.75	Sharks: 0.50 Rays: 0.68 Dogfish: 0.71	NA	NA	NA
NATURAL MORTALITY: (M)	0.61	Sharks & Rays: 0.19 Dogfish: 0.09	NA	NA	NA
GROWTH COEFFICIENT k	0.52	Sharks: 0.17 Rays: 0.13 Dogfish: 0.08	NA	NA	NA
LENGTH AT INFINITY L_{INF} , cm	116	Sharks: 325 Rays: 83 Dogfish: 110	NA	NA	NA
LITTER SIZE	NA	Sharks: 21 Dogfish: 11	1	1	100
REPRODUCTIVE FREQUENCY (YR^{-1})	NA	0.65	0.25	Petrels: 1 Albatrosses: 0.75	2.2

Table 2. Number of species for which average parameter values were used.
 Cap: where length-at-capture is greater than maximum recorded length in the database,
 the ratio was capped at 1.0

Total N=233	Bony fish N=133	Sharks, Rays & Dogfish N=58	Mammals N=16	Birds N=19	Turtles N=6
A_{\max}	33	13	1	1	1
A_{mat}/A_{\max}	41	8	0	0	1
%DEAD	36	16	0	0	1
%RETAINED	2	4	0	0	0
L_{LL} / L_{\max}	Cap: 46 Avg: 37	Cap: 7 Avg: 15	NA	NA	NA
M	45	20	NA	NA	NA
k	28	13	NA	NA	NA
L_{INF}	25	16	NA	NA	NA
LITTER SIZE	NA	8	0	0	0
FREQUENCY	NA	34	5	2	1

Fig. 1. PSA 1: all species

Susceptibility: vertical overlap index, condition \times fate

Productivity: $A_{\text{mat}}/A_{\text{max}}$, A_{max} , reproductive strategy

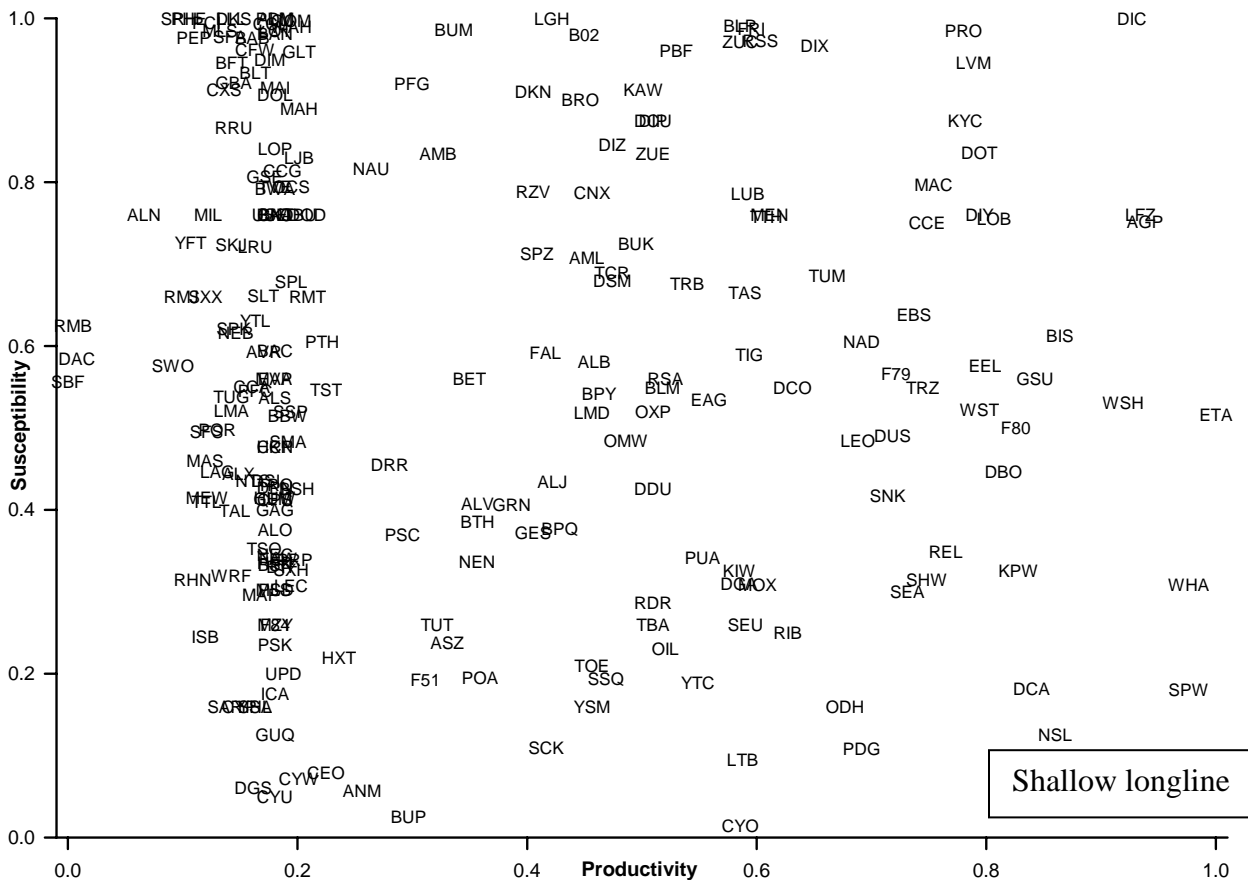
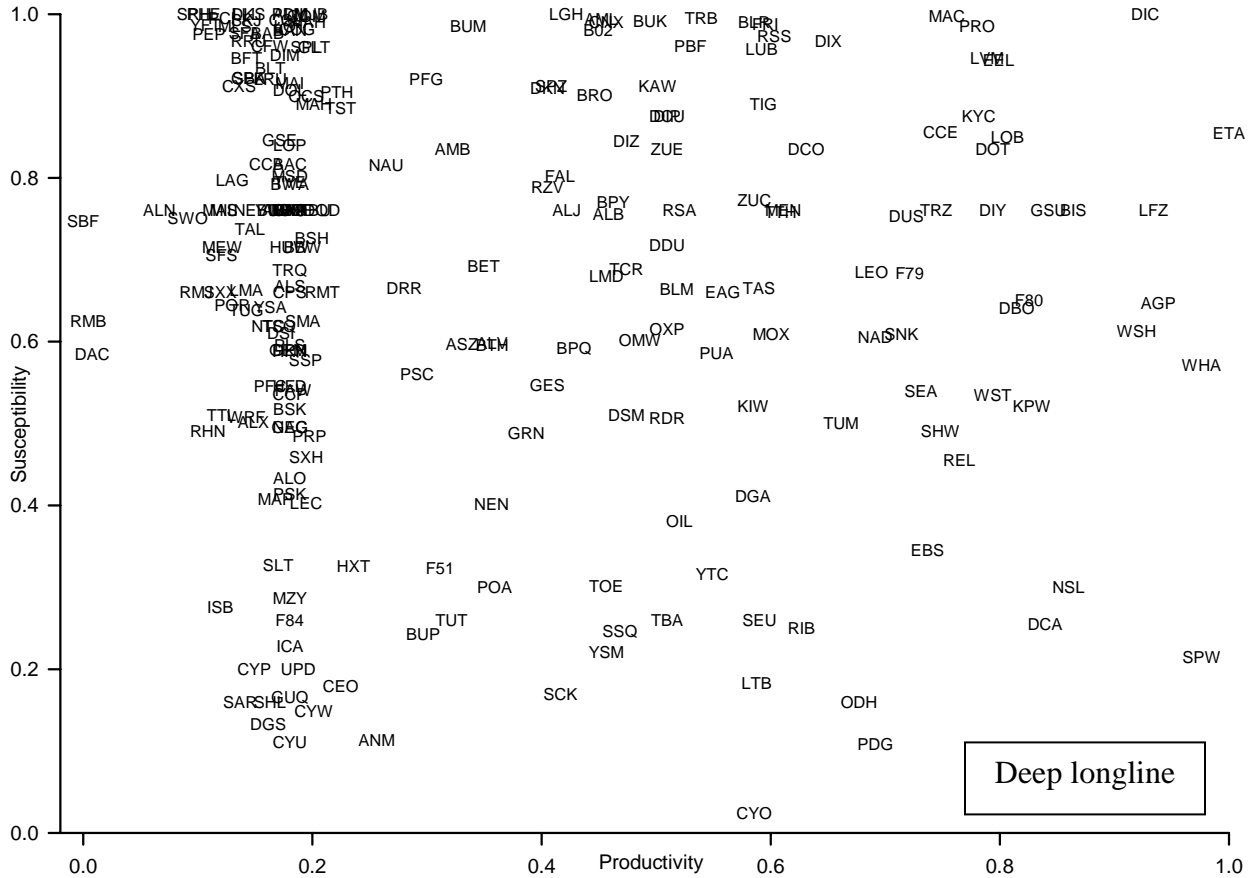


Fig. 2. PSA 2: all fish species

Susceptibility: vertical overlap index, condition \times fate, L_{LL}/L_{max}

Productivity: A_{mat}/A_{max} , M , k , L_{inf}

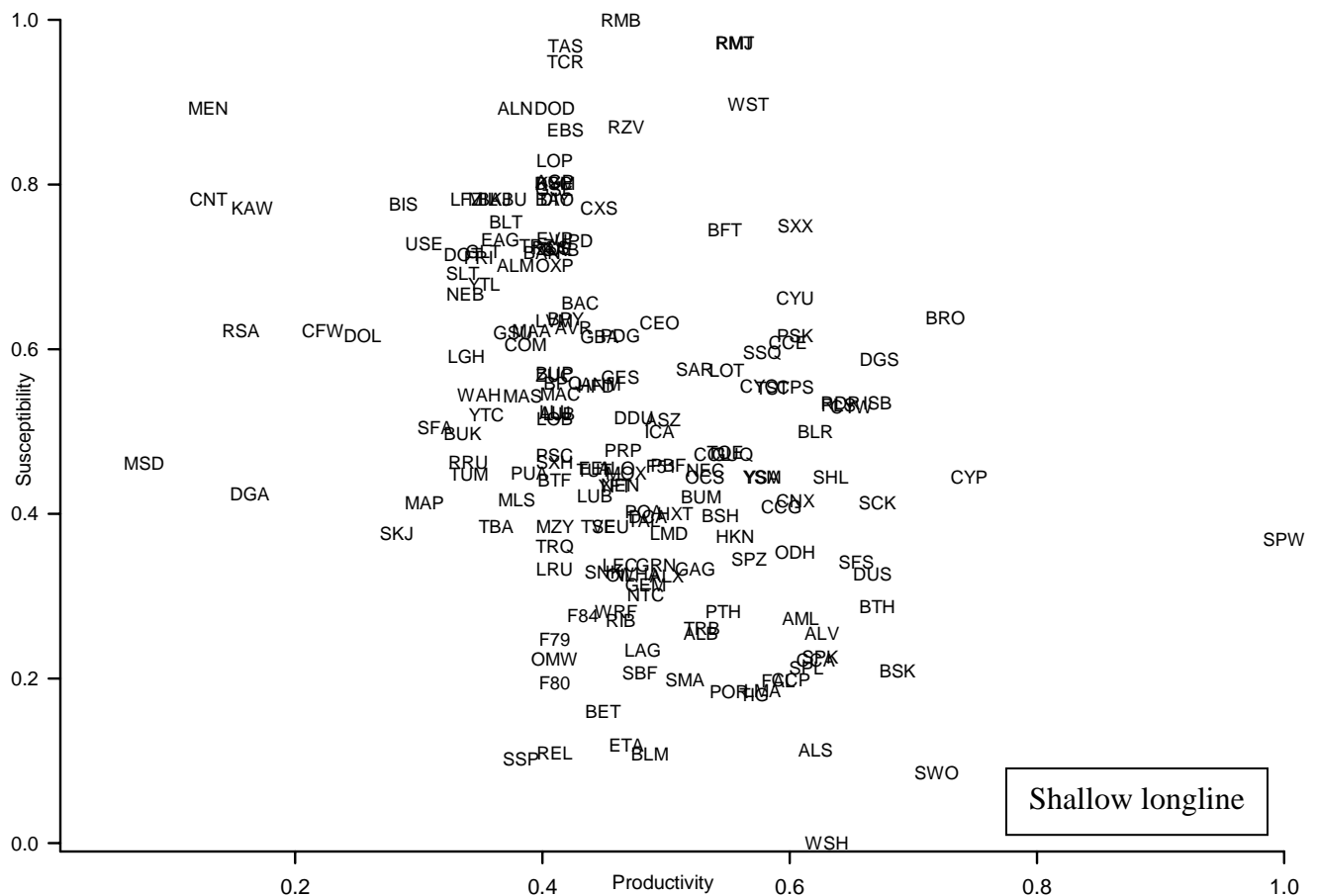
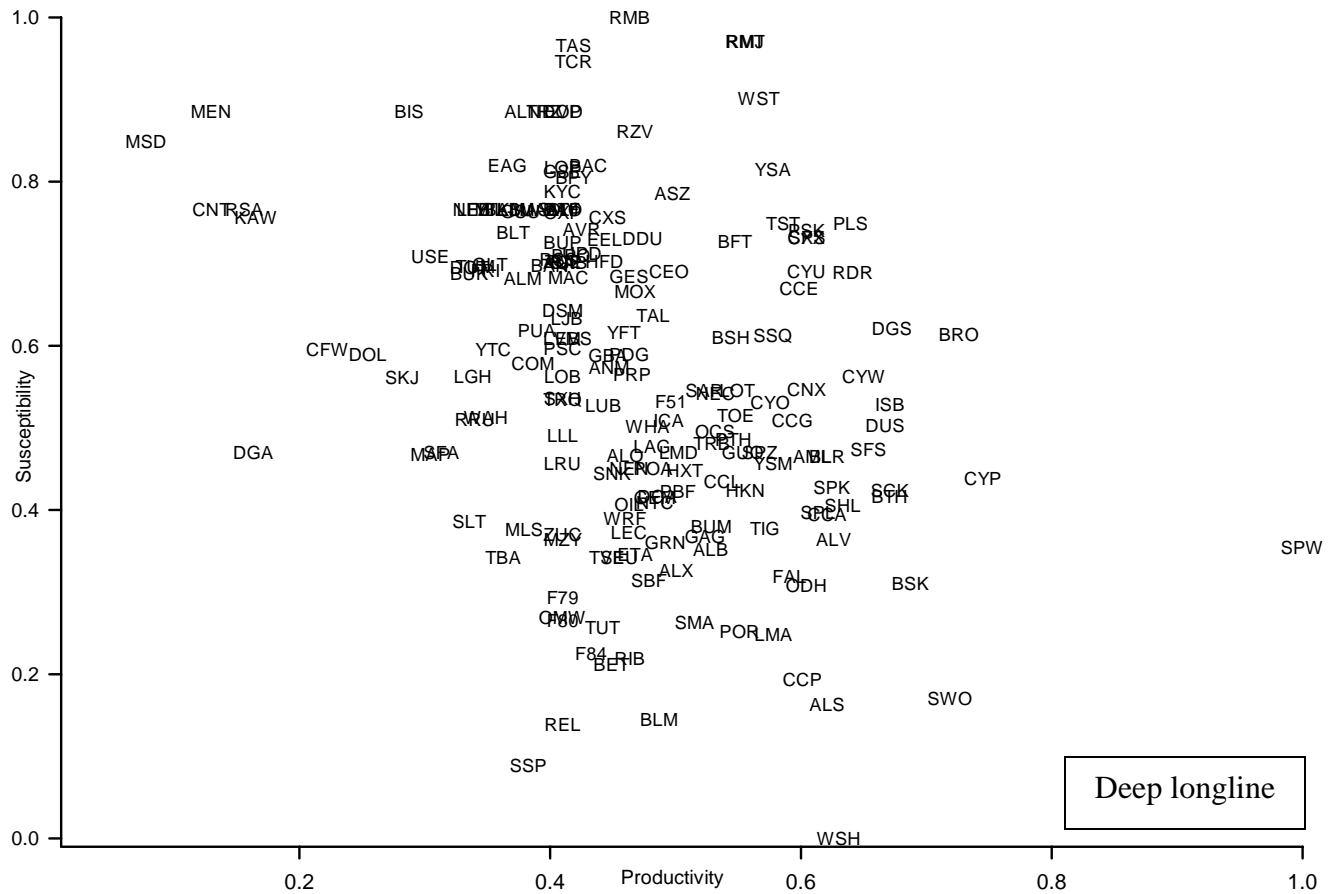
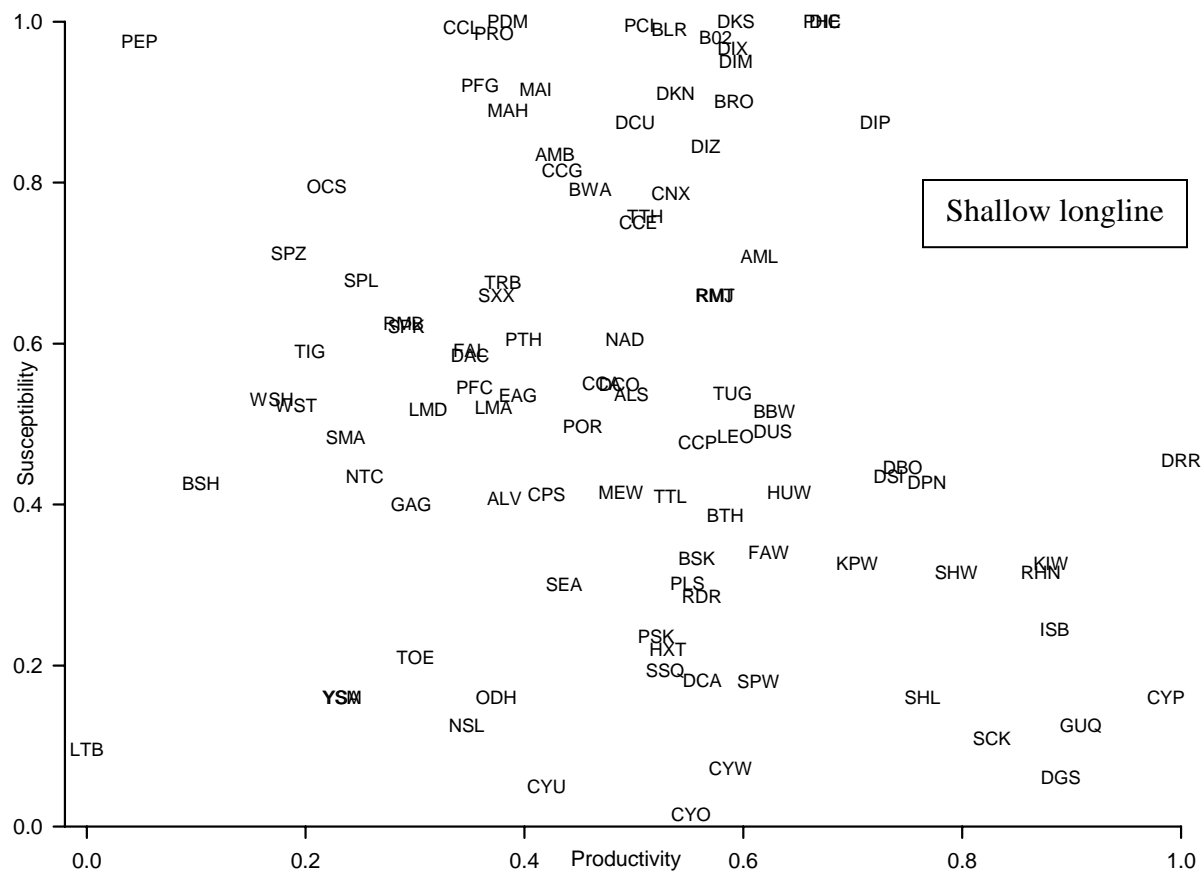
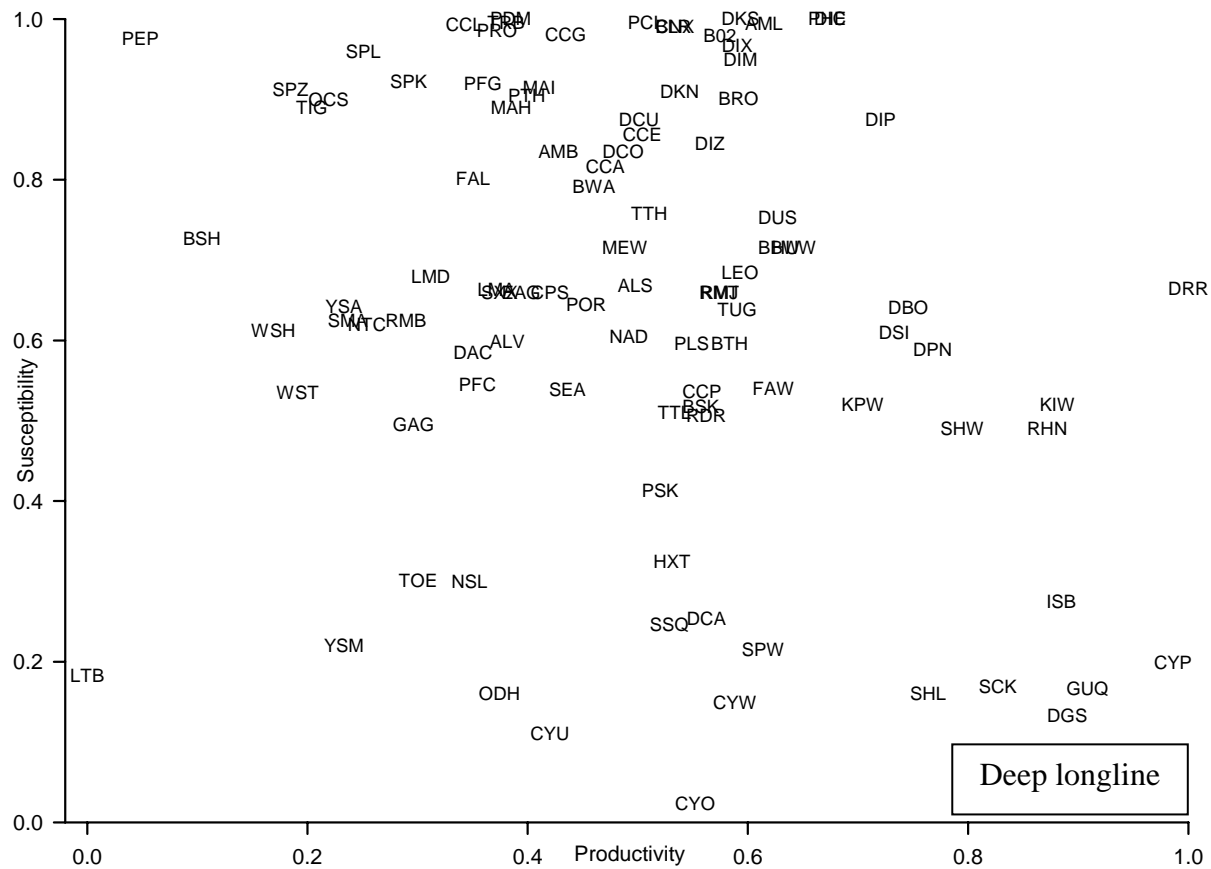


Fig. 3. PSA 3: sharks & rays, birds, mammals, reptiles

Susceptibility: vertical overlap index, condition \times fate

Productivity: $A_{\text{mat}}/A_{\text{max}}$, A_{max} , annual reproductive output



[illegible]

					PSA 1					PSA 2						PSA 3		
CODE	SCIENTIFIC_NAME	COMMON_NAME	DEEP_SUSC	SHALLOW_SUSC	PRODUCTIVITY	DEEP_RISK	SHALLOW_RISK	DEEP_SUSC	SHALLOW_SUSC	PRODUCTIVITY	DEEP_RISK	SHALLOW_RISK	DEEP_SUSC	SHALLOW_SUSC	PRODUCTIVITY	DEEP_RISK	SHALLOW_RISK	
PEP	<i>Pelamis platurus</i>	yellow-bellied seasnake	HIGH	HIGH	MEDIUM	MEDIUM	HIGH						HIGH	HIGH	LOW	MEDIUM	HIGH	
PFC	<i>Puffinus carneipes</i>	Flesh-footed Shearwater	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
PFG	<i>Puffinus griseus</i>	Sooty Shearwater	MEDIUM	HIGH	MEDIUM	HIGH	HIGH						HIGH	HIGH	MEDIUM	MEDIUM	HIGH	
PHE	<i>Phoebastria palpebrata</i>	Light-mantled Albatross	HIGH	HIGH	HIGH	HIGH	HIGH						HIGH	HIGH	MEDIUM	HIGH	HIGH	
PLS	<i>Dasyatis violacea</i>	Pelagic Stingray	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
POA	<i>Brama brama</i>	Ray's Bream	LOW	LOW	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
POR	<i>Lamna nasus</i>	Porbeagle shark	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
PRO	<i>Procellaria aequinoctialis</i>	White-chinned Petrel	HIGH	HIGH	MEDIUM	HIGH	HIGH				LOW	LOW	HIGH	HIGH	MEDIUM	HIGH	HIGH	
PRP	<i>Promethichthys prometheus</i>	ROUDI ESCOLAR	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
PSC	<i>Psenes cyanophrys</i>	MAN-O-WAR FISH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
PSK	<i>Pseudocarcharias kamoharui</i>	Crocodile Shark	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	
PTH	<i>Alopias pelagicus</i>	Pelagic Thresher	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
PUA	<i>Sphoeroides pachygaster</i>	balloonfish	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
RDR	<i>Dasyatis brevicaudata</i>	smooth stingray	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
REL	<i>Regalecus glesne</i>	oarfish ("king of herrings")	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
RHN	<i>Physeter macrocephalus</i>	SPERM WHALE	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	
RIB	<i>Mora moro</i>	Ribaldo	LOW	LOW	LOW	LOW	LOW											
RMB	<i>Manta birostris</i>	Manta Ray	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	
RMJ	<i>Mobula japanica</i>	MANTA RAY	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
RMT	<i>Mobula tarapacana</i>	CHILEAN DEVIL RAY	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
RRU	<i>Elegatis bipinnulata</i>	rainbow runner	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
RSA	<i>Decapterus macarellus</i>	MACKEREL SCAD / SABA	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM						
RSS	<i>Rhadosargus sarba</i>	Bream Silver/Tarwhine	HIGH	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM						
RZV	<i>Ranzania laevis</i>	SLENDER SUNFISH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH						
SAR	<i>Sarotherodon galilaeus galilaeus</i>	SAROTHERODON GALILAEUS	LOW	LOW	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
SBF	<i>Thunnus maccoyii</i>	Southern Bluefin Tuna	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM						
SCK	<i>Dalatias licha</i>	Black Shark	LOW	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	LOW	LOW	HIGH	MEDIUM	MEDIUM	
SEA	<i>Arctocephalus forsteri</i>	New Zealand Fur-seal	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM						MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
SEU	<i>Seriola caerulea</i>	White Trevalla	LOW	LOW	MEDIUM	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
SFA	<i>Istiophorus platypterus</i>	Sailfish	HIGH	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM						
SFS	<i>Lepidopus caudatus</i>	Southern Frostfish	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM						
SHL	<i>Etmopterus baxteri</i>	rough deep-sea shark	LOW	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	LOW	LOW	HIGH	MEDIUM	MEDIUM	
SHW	<i>Globicephala macrorhynchus</i>	Short-finned Pilot Whale	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM						MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	
SKJ	<i>Katsuwonus pelamis</i>	Skipjack Tuna	HIGH	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM						
SLT	<i>Alliothunnus fallai</i>	Slender Tuna	LOW	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM						
SMA	<i>Isurus oxyrinchus</i>	Shortfinned Mako or Blue Pointer	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	
SNK	<i>Thyrssites atun</i>	Barracouta	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM				
SPK	<i>Sphyrna mokarran</i>	Great Hammerhead	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	LOW	MEDIUM	MEDIUM	
SPL	<i>Sphyrna lewini</i>	Scalloped Hammerhead	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	LOW	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	LOW	MEDIUM	MEDIUM	
SPW	<i>Rhincodon typus</i>	whale shark	LOW	LOW	HIGH	MEDIUM	MEDIUM	LOW	MEDIUM	HIGH	HIGH	HIGH	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	
SPZ	<i>Sphyrna zygaena</i>	smooth hammerhead	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	
SRH	<i>Spratelloides gracilis</i>	SILVER SPRAT / SILVER-STRIPPED ROUND HERRING	HIGH	HIGH	MEDIUM	MEDIUM	HIGH											
SSP	<i>Tetrapturus angustirostris</i>	Short Bill Spearfish	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM						
SSQ	<i>Scymnodon squamulosus</i>	VELVET DOGFISH	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	
SWO	<i>Xiphias gladius</i>	Broad Billed Swordfish	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	HIGH	MEDIUM	MEDIUM						
SXH	<i>Scombrotoxa heterolepis</i>	BLACK MACKEREL	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
SXX	<i>Stegostoma fasciatum</i>	Zebra Shark	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
TAL	<i>Taractichthys longipinnis</i>	Long finned Bream (pomfret)	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
TAS	<i>Taractes asper</i>	FLATHEAD POMFRET	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH						
TBA	<i>Trachinotus bailloni</i>	Black-Spotted Dart	LOW	LOW	MEDIUM	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
TCR	<i>Taractes rubescens</i>	DAGGER POMFRET	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH						
TIG	<i>Galeocerdo cuvier</i>	Tiger Shark	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	
TOE	<i>Torpedo fairchildi</i>	ELECTRIC RAY	LOW	LOW	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	LOW	LOW	
TRB	<i>Triaknodon obesus</i>	Whitetip Reef Shark	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	
TRQ	<i>Trachipterus trachipterus</i>	DEALFISH / RIBBON FISH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
TRZ	<i>Pseudocaranx dentex</i>	Silver Trevally	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	MEDIUM						
TSQ	<i>Nototodarus sloanii</i>	flying squid	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW				LOW	LOW						
TST	<i>Taractichthys steindachneri</i>	SICKLE POMFRET / MONCHONG	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM						
TTH	<i>Eretmochelys imbricata</i>	Hawksbill turtle	MEDIUM	MEDIUM	HIGH	HIGH	HIGH						MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
TTL	<i>Caretta caretta</i>	Loggerhead	MEDIUM	MEDIUM	HIGH	HIGH	HIGH						MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
TUG	<i>Chelonia mydas</i>	Green turtle	MEDIUM	MEDIUM	HIGH	HIGH	HIGH						MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	
TUM	<i>Atule mate</i>	[a trevally]	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
TUT	<i>Tubbia tasmanica</i>	Rudderfish, Tasmanian rudderfish	LOW	LOW	MEDIUM	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
TVE	<i>Pteraclis velifera</i>	SPOTTED FANFISH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
UPD	<i>Pleuroscopus pseudodorsalis</i>	blue stargazer	LOW	LOW	MEDIUM	LOW	LOW	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM						
USE	<i>Uraspis secunda</i>	COTTONMOUTH JACK	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	LOW	MEDIUM	MEDIUM						
WAH	<i>Acanthocybium solandri</i>	Wahoo	HIGH	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
WHA	<i>Polyprion oxygeneios</i>	Hapuku	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
WRF	<i>Polyprion americanus</i>	Bass groper	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM						
WSH	<i>Carcharodon carcharias</i>	white shark	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	MEDIUM	MEDIUM	
WST	<i>Dasyatis akajei</i>	WHIP STINGRAY	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	
YFT	<i>Thunnus albacares</i>	Yellowfin Tuna	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
YSA	<i>Scymnodalatias albicauda</i>	Sherwoods dogfish	MEDIUM	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	LOW	
YSM	<i>Scymnodon macracanthus</i>	ROUGHSKIN DOGFISH	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	LOW	LOW	LOW	LOW	LOW	
YTL	<i>Seriola lalandi</i>	Yellowtail Kingfish	LOW	LOW	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
YTC	<i>Seriola Rivoliana</i>	Almaco jack	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
ZUC	<i>Zu cristatus</i>	SCALLOPED RIBBONFISH	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM						
ZUE	<i>Zu elongatus</i>	DEALFISH (SCALLOPED)	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM						

Fig. 4. Spatial distribution of (a) longline and (b) observer effort, and encounters with (c) sharks, (d) marine mammals, (e) birds, and (f) turtles, for the period 2002-2006

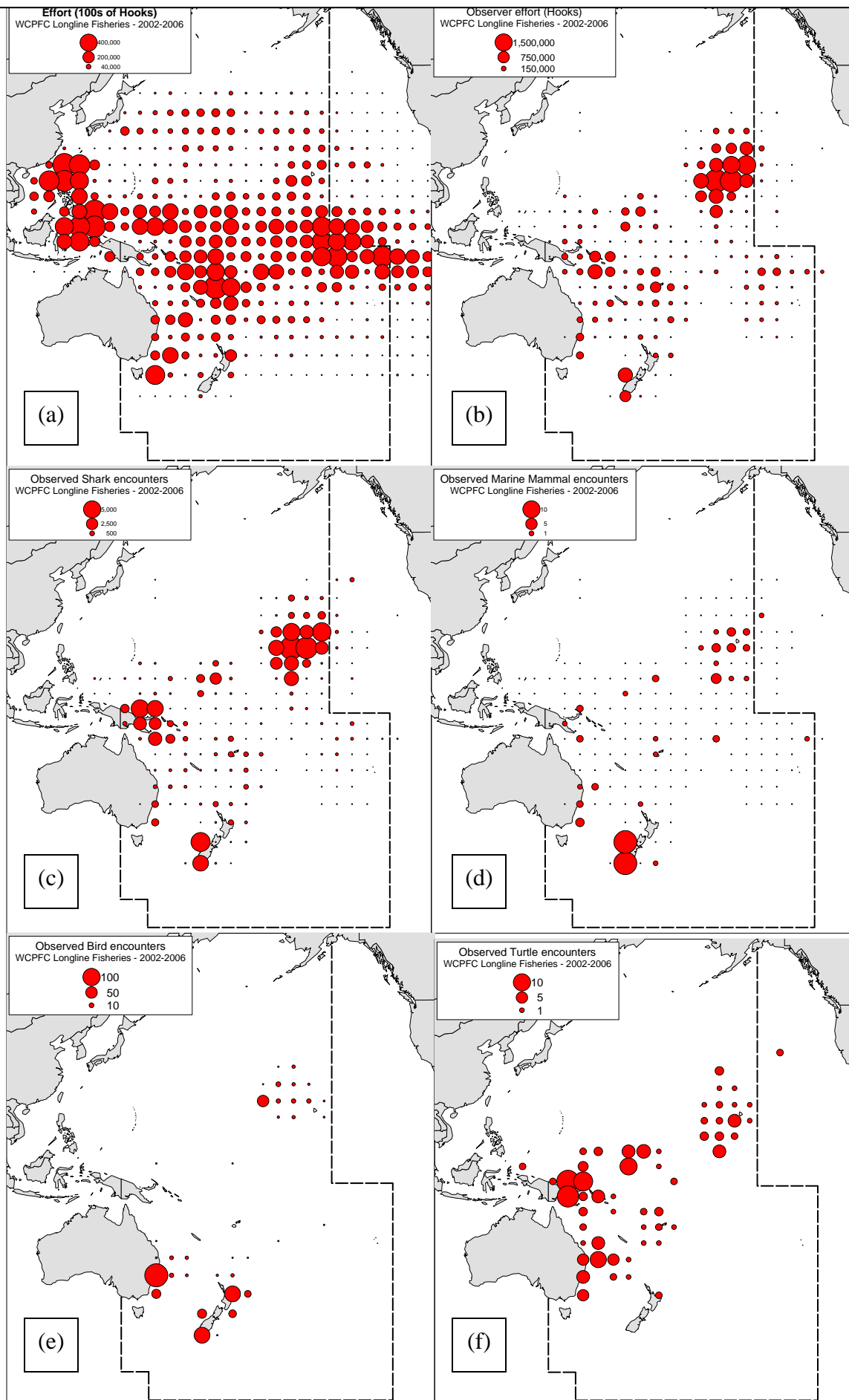


Fig. 5. Proportion of purse seine catch by species / species group and set type. (a) unassociated sets, (b) log sets, (c) drifting FADs, (d) anchored FADs

