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ECOLOGICAL RISK ASSESSMENT (ERA) FOR THE EFFECTS OF FISHING IN THE WESTERN & CENTRAL PACIFIC OCEAN: RESEARCH PLANNING WORKSHOP REPORT AND DRAFT RESEARCH PLAN

WCPFC-SC3-EB SWG/WP-3

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*The authors and SPC-OFP take full responsibility for the views expressed in this paper. Nonetheless, it draws heavily from the expert opinion of those who attended our ERA Research Planning Workshop. We are very grateful for their contributions, we absolve them of any responsibility for this report and research plan, yet we hope that it does reflect what they also think is the way forward in implementing ERA in support of an Ecosystem Approach to Fisheries in the WCPFC Convention Area. A list of workshop participants is provided within this document and we reiterate our thanks to all of them for sharing their experiences and ideas.

The Contracting Parties to this Convention

…,

Mindful that effective conservation and management measures require the application of the **precautionary approach** and the **best scientific information available**,

Conscious of the need to avoid adverse impacts on the marine environment, preserve biodiversity, maintain integrity of marine ecosystems and **minimize the risk** of long-term or irreversible effects of fishing operations,

…

Article 2
Objective

The objective of this Convention is to ensure, through effective management, the **long-term conservation and sustainable use** of highly migratory fish stocks in the western and central Pacific Ocean in accordance with the 1982 [UN] Convention [on the Law of the Sea] and the [1995 UN Fish Stocks] Agreement.

Article 3
Area of application

…

3. This Convention applies to **all stocks of highly migratory fish** within the Convention Area except sauries. Conservation and management measures under this Convention shall be applied throughout the range of the stocks, or to specific areas within the Convention Area, as determined by the Commission.

Article 5
Principles and measures for conservation and management

…

(d) **assess the impacts of fishing**, other human activities and environmental factors **on target stocks, non-target species, and species belonging to the same ecosystem or dependent upon or associated with the target stocks**;

(e) **adopt measures to minimize** waste, discards, catch by lost or abandoned gear, pollution originating from fishing vessels, **catch of non-target species, both fish and non-fish species**, (hereinafter referred to as non-target species) and **impacts on associated or dependent species, in particular endangered species**...

(f) **protect biodiversity** in the marine environment;

…

Verbatim extracts from the 'Convention On The Conservation And Management Of Highly Migratory Fish Stocks In The Western And Central Pacific Ocean', hereafter referred to as 'the Convention'.

PART 1: ECOLOGICAL RISK ASSESSMENT (ERA) RESEARCH PLANNING WORKSHOP REPORT

1. Introduction

The First Regular Session of the WCPFC Scientific Committee endorsed the recommendation (Molony 2005, Kirby et al. 2005) that Ecological Risk Assessment be carried out as a means to assess bycatch issues in 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). The SC2 final report recorded that:

> 187. The Scientific Committee endorsed the Ecological Risk Assessment exercise in general, and the PSA in particular, as an appropriate way to assist the Commission in prioritizing species for management action or further research. There was agreement to further refine the PSA risk assessment approach and to encourage members to further develop this approach.
>
> 188. The Commission should develop a dedicated shark research programme to support stock assessment of shark species that rank highly in the Ecological Risk Assessment, in cooperation with other RFMOs. Alternative methods of analysis other than stock assessment should also be explored.
>
> 189. The Commission should develop long-term data collection, monitoring and research programmes dedicated to all species identified as higher risk in the productivity–susceptibility analysis.

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, to prepare a 3 yr ERA Research Plan for submission to SC3. The ERA Research Planning Workshop was convened by SPC-OFP and hosted by the US Western Pacific Regional Fisheries Management Council in Honolulu from 6 to 9 August 2007. The purpose of the workshop was to advise SPC-OFP in drawing up a research plan to develop risk assessment methodologies for the WCPFC Convention Area, to consider the appropriate scales/units of analysis and the interface between ERA and traditional fisheries scientific methods such as stock assessment. Any work of this nature is bound to draw on and have implications for fisheries monitoring activity that has been underway for some years, and this was discussed in the workshop.

Participants from various agencies, NGOs and Universities were invited to attend on the basis of their technical competence and prior experience of ecological risk assessment. In addition to invited participants, a few interested colleagues based in Honolulu attended for part of the time. A list of workshop participants is provided in Table 1. Representation was not sought from each CCM, due to the technical nature of the workshop. The Ecosystem and Bycatch Specialist Working Group (EBSWG) is the representative body for consideration of this workshop report and research plan, and both the EBSWG and the SC plenary should play an active role in the ERA process as it develops.

ERA is a practical way for the WCPFC to meet its obligations towards non-target species. To be most useful, ERA methodologies must be easily applied, they should utilise available data and identify significant data gaps, they must be cost effective and they need to identify appropriate spatial scales, considering fishing patterns, ecological and jurisdictional boundaries. They must also be transparent, comparable and transferable, and embedded in fisheries management systems.

Table 1. Participants at the ERA Research Planning Workshop

Name	Institution	Location
David Kirby (co-Chair)	Oceanic Fisheries Programme Secretariat of the Pacific Community (SPC-OFP)	Noumea, New Caledonia
Alistair Hobday (co-Chair)	Pelagic Fisheries and Ecosystems CSIRO Marine & Atmospheric Research	Hobart, Australia
Brett Molony (Rapporteur)	Oceanic Fisheries Programme Secretariat of the Pacific Community (SPC-OFP)	Noumea, New Caledonia
Don Bromhead	Oceanic Fisheries Programme Secretariat of the Pacific Community (SPC-OFP)	Noumea, New Caledonia
John Hampton	Oceanic Fisheries Programme Secretariat of the Pacific Community (SPC-OFP)	Noumea, New Caledonia
Simon Nicol	Oceanic Fisheries Programme Secretariat of the Pacific Community (SPC-OFP)	Noumea, New Caledonia
Peter Williams	Oceanic Fisheries Programme Secretariat of the Pacific Community (SPC-OFP)	Noumea, New Caledonia
Barry Baker	Agreement for the Conservation of Albatrosses and Petrels (ACAP)	Hobart, Australia
Keith Bigelow	WCPFC Scientific Committee (Vice-Chair) & NOAA Fisheries, US Government	Honolulu, Hawaii
Paul Dalzell	Western Pacific Regional Fisheries Management Council, US Government	Honolulu, Hawaii
Jon van Dyke	University of Hawaii	Honolulu, Hawaii
Marcia Hamilton	Western Pacific Regional Fisheries Management Council, US Government	Honolulu, Hawaii
Mark Maunder	Inter-American Tropical Tuna Commission (IATTC)	La Jolla, California
Selina Heppell	Oregon State University	Corvallis, Oregon
Lorraine Hitch	Worldwide Fund for Nature (WWF)	Canberra, Australia
Pierre Kleiber	NOAA Fisheries, US Government	Honolulu, Hawaii
Dae Yeon Moon	WCPFC Scientific Committee (Chair) & Korean Government	Seoul, Korea
John Sibert	Pelagic Fisheries Research Program	Honolulu, Hawaii
Ilona Stobutzki	Bureau of Rural Sciences, Australian Government	Canberra, Australia
Samasoni Sauni	Forum Fisheries Agency (FFA)	Honiara, Solomon Islands
Sung Kwon Soh	WCPFC Secretariat	Pohnpei, Federated States of Micronesia
William Walsh	Pelagic Fisheries Research Program	Honolulu, Hawaii
Susan Waugh	Birdlife International	Wellington, New Zealand

2. Hierarchical approach to Ecological Risk Assessment

Beddington et al. (2007) recognise that 'Given the problems that most authorities have in deriving reliable quantitative assessments of their stocks of major commercial importance, the large numbers of small, commercially unimportant stocks present in most areas, usually as bycatch, cannot realistically be assessed.' They go on to state that 'Under a comprehensive ecosystem approach, risk assessment methodologies should be used to identify those bycatch species in need of special measures', and cite the paper presented by Kirby & Molony (2006) to SC2 in support of this assertion. The WCPFC is therefore in a good position by comparison with other RFMOs and indeed many national fisheries management bodies, in taking a strategic rather than a reactive approach to its legal obligations to non-target highly migratory species and associated/dependent species.

ERA is designed to engage stakeholders, to consider the risk posed by fishing to all species captured or interacting with a fishery, to identify opportunities for management intervention and to provide population assessments for species at most risk. It is a pragmatic process for prioritisation of research and conservation/management action. The Australian CSIRO/AFMA approach to ERA is hierarchical (Fig. 1.; Hobday et al. 2006):

Level 1 is based on stakeholder workshops, and is designed to identify hazards to species and systems and to assign risk scores based on the expert opinion of participants. Management action may follow or further research may be carried out at the next level.

Level 2 is based on the biological characteristics of species caught in the fishery and the degree of interaction between that fishery and those species. The main method used is Productivity-Susceptibility Analysis (PSA). Risk scores are calculated for each species relative to one another along each of the two axes used (productivity, susceptibility) and as the Euclidean distance from the origin of the graph. It is important to emphasise both the relative nature of risk scores at Level 2 and the fact the result is a risk assessment *for the effects of fishing* and not an estimate of stock status or extinction risk due to the sum of all risks (i.e. trophic interactions, environmental variability, climate change, fishing, habitat destruction, pollution, etc.). Analysis at Level 2 can identify species at relatively high risk, for which management measures or further research are required.

Level 3 seeks to quantify all risks as components of mortality and to provide an estimate of stock status. This already happens for stocks of target species but it is unrealistic to expect such assessments – which are time consuming and expensive – to be carried out for all species, hence the value in the hierarchical approach.

It is important to recognise that management responses can follow from analyses at any level and need not wait for highly robust estimates of stock status from a Level 3 analysis. WCPFC has already passed Conservation & Management Measures and/or Resolutions on seabirds, turtles, sharks and other non-target fish species under the WCPFC Rules of Procedure. ERA provides a more structured but less formal process through which issues may be prioritised, considering the cost of management vs. the cost of further research, while still taking into account the best available science.

The hierarchical approach for ERA adopted in Australia could be adapted to the broader WCPFC context after due consideration of where responsibilities lie and how it relates to existing activities, structures and processes (Table 2). The WCPFC is an international body comprised of its members and those members retain the right and responsibility to carry out analyses of fisheries and fishing impacts within their zones. But some fisheries operate across several zones and/or high seas so regional scale analyses are appropriate. SPC-OFP as science provider to WCPFC is capable of carrying out those analyses but CCMs may also wish to apply an ERA framework within their zones, which may help in comparative analysis and the quantification of cumulative risk from different fisheries.

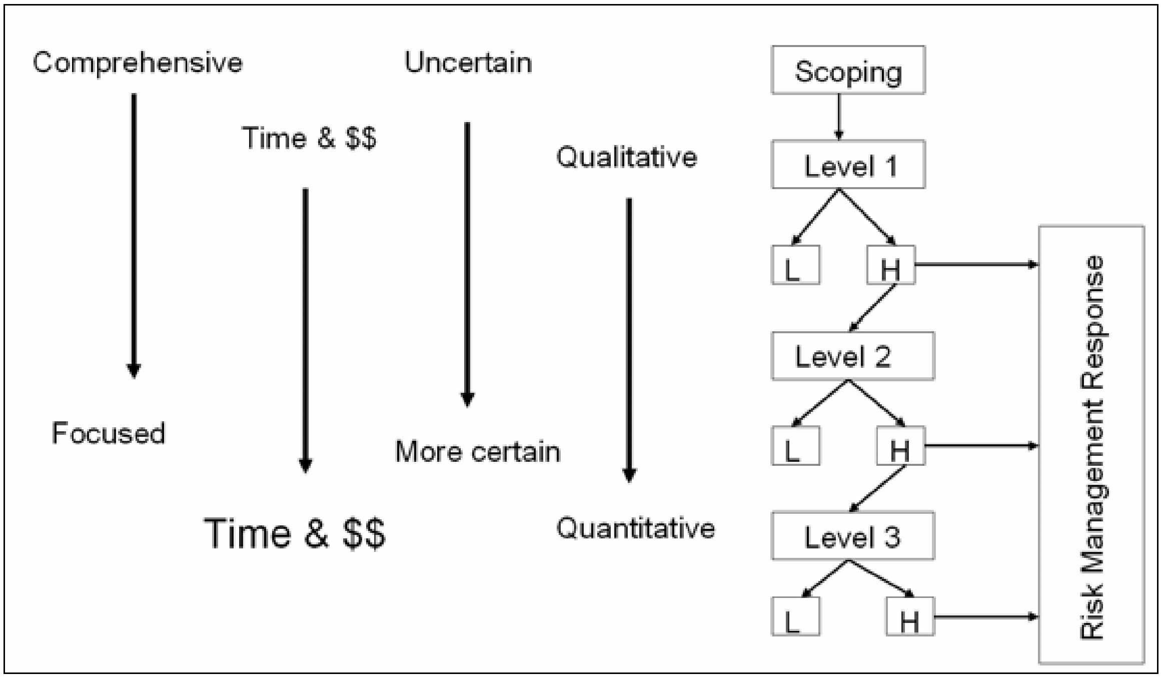


Figure 1. Rationale for a hierarchical approach to Ecological Risk Assessment

Table 2. Framework for Ecological Risk Assessment for WCPFC Convention Area

		WCPFC	CCMs	
LEVEL 1	WHAT:	**Hazard Identification & Qualitative Risk Ranking**		MANAGEMENT RESPONSE
	WHO:	Ecosystem & Bycatch SWG	Government agencies & stakeholders	
LEVEL 2	WHAT:	**Relative Risk Ranking using Semi-Quantitative Indicators**		
	WHO:	Science provider and/or others	Government agencies, NGOs, academics	
LEVEL 3	WHAT:	**Absolute Risk Quantification using stock assessment or equivalent**		
	WHO:	Science provider and/or others	Government agencies, NGOs, academics	

3. The management context around ecological risk assessment

The 'Convention On The Conservation And Management Of Highly Migratory Fish Stocks In The Western And Central Pacific Ocean' assigns *de jure* responsibility to the WCPFC for the effective conservation and management of **highly migratory fish species** (excluding sauries) listed under Annex 1 of the 1982 UN Convention on the Law of the Sea (UNCLOS) and occurring in the Convention area. In addition to obligations concerning target and non-target highly migratory fish species, UNCLOS and the Convention confer obligations to 'assess the impacts of fishing' and to 'minimise impacts' upon 'associated and dependent species'.

According to the FAO Fisheries Glossary (http://www.fao.org/fi/glossary/ – discussed in Itano & Kirby 2006) *associated species* are those species that (i) prey upon the target species, (ii) are preyed on by it, (iii) compete with it for food, living space, etc; or (iv) **co-occur in the same fishing area and are exploited or accidentally taken in the same fishery or fisheries**. This last definition is commonly called 'bycatch' or 'by-product' if it has some economic value. A list of associated species **observed caught** in WCPO tuna fisheries, thus meeting criteria (iv) above, is given in Kirby & Hobday 2007 (SC3-EB-SWG-WP1; note that under present levels of observer coverage this list may not be exhaustive). *Dependent species* are generally species within the food chain (e.g. a predator) which depend heavily on others (e.g. a prey species) for their maintenance.

The list of UNCLOS Annex 1 highly migratory species occurring in the Convention Area is provided in Table 3. Annex 1 marine mammals are the responsibility of the WCPFC through its obligations to non-target species. Marine birds and turtles are not presently listed under UNCLOS Annex 1. Nonetheless, the WCPFC has obligations to these species as non-target associated and dependent species, and it also has the authority to add them to the list of HMS. The management responsibility is therefore for multiple species rather than just for target species. An ecosystem approach to fisheries management is not specifically mentioned in the Convention, although most of its aspirational if not operational aspects are included (i.e. minimise bycatch, maintain ecological integrity, preserve biodiversity, take into account environmental effects on target/limit reference points, etc.).

The WCPFC Convention is not the only international law applicable to WCPO tuna fisheries. The 1979 Convention on Migratory Species of Wild Animals (CMS) promotes the development of cooperative agreements addressing specific species and habitats. An example is the Agreement on the Conservation of Albatrosses and Petrels (ACAP), which is an observer to the WCPFC. ACAP entered into force in 2004 and was designed explicitly because of the threat caused by longline fishing operations. At the Eighth CMS Conference in 2005 a recommendation was adopted calling for the development of a global conservation instrument for migratory sharks. A meeting to 'Identify and Elaborate an Option for International Cooperation on Migratory Sharks under the Convention on Migratory Species' is due to take place in Seychelles in December 2007.

Table 3. Highly Migratory Species (UNCLOS Annex 1) in the WCPFC Convention Area, as recorded in the SPC-OFP Observer Database

1)	*Acanthocybium solandri*	WAHOO
2)	*Alopias pelagicus*	PELAGIC THRESHER
3)	*Alopias superciliosus*	BIGEYE THRESHER
4)	*Alopias vulpinus*	THRESHER
5)	*Auxis rochei*	BULLET TUNA
6)	*Auxis thazard*	FRIGATE TUNA
7)	*Brama australis*	SOUTHERN RAYS BREAM
8)	*Brama brama*	RAY'S BREAM / ATLANTIC POMFRET
9)	*Brama japonica*	PACIFIC POMFRET
10)	*Carcharhinus albimarginatus*	SILVERTIP SHARK
11)	*Carcharhinus altimus*	BIGNOSE SHARK
12)	*Carcharhinus amblyrhynchos*	GREY REEF SHARK
13)	*Carcharhinus brachyurus*	BRONZE WHALER SHARK
14)	*Carcharhinus falciformis*	SILKY SHARK
15)	*Carcharhinus galapagensis*	GALAPAGOS SHARK
16)	*Carcharhinus leucas*	BULL SHARK
17)	*Carcharhinus limbatus*	BLACKTIP SHARK
18)	*Carcharhinus longimanus*	OCEANIC WHITETIP SHARK
19)	*Carcharhinus melanopterus*	BLACKTIP REEF SHARK
20)	*Carcharhinus obscurus*	DUSKY SHARK
21)	*Carcharhinus plumbeus*	SANDBAR SHARK
22)	*Carcharodon carcharias*	GREAT WHITE SHARK
23)	*Cetorhinus maximus*	BASKING SHARK
24)	*Coryphaena equiselis*	POMPANO DOLPHINFISH
25)	*Coryphaena hippurus*	MAHI MAHI / DOLPHINFISH / DORADO
26)	*Delphinus delphis*	COMMON DOLPHIN
27)	*Eumegistus illustris*	BRILLIANT POMFRET
28)	*Euthynnus affinis*	KAWAKAWA
29)	*Galeocerdo cuvier*	TIGER SHARK
30)	*Galeorhinus galeus*	SCHOOL SHARK
31)	*Globicephala macrorhynchus*	SHORT-FINNED PILOT WHALE
32)	*Grampus griseus*	RISSO'S DOLPHIN
33)	*Istiophorus platypterus*	SAILFISH (INDO-PACIFIC)
34)	*Isurus oxyrhinchus*	SHORT FINNED MAKO
35)	*Isurus paucus*	LONG FINNED MAKO
36)	*Katsuwonus pelamis*	SKIPJACK
37)	*Lagenorhynchus obscurus*	DUSKY DOLPHIN
38)	*Lamna ditropis*	SALMON SHARK
39)	*Lamna nasus*	PORBEAGLE SHARK
40)	*Makaira indica*	BLACK MARLIN
41)	*Makaira nigricans*	BLUE MARLIN
42)	*Megaptera novaeangliae*	HUMPBACK WHALE
43)	*Nasolamia velox*	WHITENOSE SHARK
44)	*Orcinus orca*	KILLER WHALE
45)	*Prionace glauca*	BLUE SHARK
46)	*Pteraclis velifera*	SPOTTED FANFISH
47)	*Pterycombus petersii*	PRICKLY FANFISH
48)	*Rhincodon typus*	WHALE SHARK
49)	*Sphyrna lewini*	SCALLOPED HAMMERHEAD
50)	*Sphyrna mokarran*	GREAT HAMMERHEAD
51)	*Sphyrna zygaena*	SMOOTH HAMMERHEAD
52)	*Stenella attenuata*	DOLPHIN, SPOTTED
53)	*Stenella longirostris*	SPINNER DOLPHIN
54)	*Taractes asper*	FLATHEAD POMFRET
55)	*Taractes rubescens*	DAGGER POMFRET
56)	*Taractichthys longipinnis*	BIG-SCALED POMFRET
57)	*Taractichthys steindachneri*	SICKLE POMFRET / MONCHONG
58)	*Tetrapturus angustirostris*	SHORT-BILLED SPEARFISH
59)	*Tetrapturus audax*	STRIPED MARLIN
60)	*Thunnus alalunga*	ALBACORE
61)	*Thunnus albacares*	YELLOWFIN
62)	*Thunnus maccoyii*	SOUTHERN BLUEFIN TUNA
63)	*Thunnus obesus*	BIGEYE
64)	*Thunnus orientalis*	PACIFIC BLUEFIN TUNA
65)	*Triaenodon obesus*	WHITETIP REEF SHARK
66)	*Tursiops truncatus*	BOTTLENOSE DOLPHIN
67)	*Xiphias gladius*	SWORDFISH

The Kobe joint meeting of tuna fisheries RFMOs in January 2007 identified the following as part of their joint course of action:

- Development of data collection, stock assessment and appropriate management of shark fisheries under the competence of tuna RFMOs
- Implementation of the precautionary approach and an ecosystem-based approach to fisheries management, including improved data collection on incidental by-catch and non-target species
- establishment of measures to minimize the adverse effect of fishing for highly migratory fish species on ecologically related species, particularly sea turtles, seabirds and sharks

Finally, the Informal Consultations of State Parties to the 1995 UN Fish Stocks Agreement in April 2007 identified – as one of the criteria for reviewing the performance of RFMOs – the extent to which the RFMO has adopted conservation and management measures to ensure long-term sustainability for both target stocks and non-target species.

It is clear therefore that there are strong obligations upon the WCPFC and its constituent CCMs to develop and implement a precautionary, ecosystem-based approach to fisheries management (Jon van Dyke pers. comm.). ERA can help identity the degree of precaution required for particular fisheries and species, and may also identify where better monitoring is required. It can provide a strategic alternative to reactive management, which often results in ad hoc solutions to bycatch problems, and if adopted as an iterative process it may become adaptive and responsive to new information.

4. Stakeholder engagement and perceived risk (Level 1)

The first level of analysis under the CSIRO/AFMA framework is based on stakeholder consultations. This process is being pursued by some FFA member countries through their Ecosystem Approach to Fisheries Management (EAFM; see FFA 2007, SC3-EB-IP-11) following the Fletcher (2005) model. The scope of the meeting is discussed and defined, hazards identified and risk scores derived either by a *likelihood* × *consequence* analysis or a *scale* × *intensity* × *consequence* analysis (SICA). SICA is the preferred approach in cases where likelihood can be assumed to be high. Both approaches originate in other risk assessment/management contexts (e.g. epidemiology, insurance, or disaster planning) and follow procedures defined by the International Standards Organisation.

One of the purposes of analysis at this level is to engage stakeholders and to attempt consensus building with regard to ecological risk assessment. In the absence of consensus, divergent views may be accounted for either in supporting documentation or as a frequency distribution of responses. However, while some perceptions may be well informed and highly accurate, others may not be and there is not necessarily any weighting of the opinions of those involved according to their levels of knowledge and experience. This applies to scientists reaching beyond the limits of their expertise, as much as it does to anyone else involved in the process. These issues were discussed in the ERA workshop and it was suggested that some post hoc analysis of workshop outcomes might be undertaken, especially with regard to the estimation of risk scores. Stakeholders representing divergent perspectives might both be objective in identifying hazards but the estimation of risk could simply follow their preconceptions or vested interests.

Another aspect concerning stakeholder engagement is the question of ‘who are the stakeholders?’ It is possible to generate pre-determined outcomes by poor selection of workshop participants. The right stakeholder mix does depends on the intended outcomes (there is no point inviting participants with absolutely no interest or relevant expertise) but it should not predetermine them. This is an example of where political will and integrity are crucial to the process working. Good governance is a pre-requisite and workshops must be free of political interference. Stakeholders might include fisheries officers, industry and NGO representatives and indigenous peoples (where relevant), artisanal fishers, officials from other government departments (environment, conservation, finance, trade, etc.). The presence of qualified scientists may reducs the chances of decisions being made on the basis of lack of knowledge or misunderstanding.

Stakeholders may also include representatives from neighbouring countries, in the case of ERA/EAFM workshops for species targeting highly migratory species, and in this age of instant global communication it must be acknowledged that stakeholders may be a long way away yet still hold strong and influential views. An example of this is the support from the US mainland for designating the North-West Hawaiian Islands as a Marine National Monument, expressed by email petitions, when the people were not resident or engaged in the resource management process already taking place in the state of Hawaii.

Any process designed to engage stakeholders must account for and seek to minimise ‘stakeholder fatigue’, i.e. it must recognise people’s other commitments and not give them the impression that their time will be wasted. The workshop should be conducted using ‘plain English’ (or rather the common language of its participants) and well defined and agreed terms, in order to minimise ‘linguistic uncertainty’, i.e. when participants have a different understanding of the same terminology (see Itano & Kirby 2006).

Level 1 workshops are a good point at which the ERA/EAFM process may take into account economic and social ‘risks’ etc., and explore the trade-offs between ecological obligations under the Convention, and economic aspects such as ‘optimal utilisation’. Workshop settings can explicitly consider these trade-offs, which is the approach taken by the FFA. An alternative is to conduct an analytical exercise of Management Strategy Evaluation (MSE), where harvest strategies are defined in a modelling context, and different goals and trade-offs can be explored in the model. The importance of that type of work is recognised here and is the subject of separate consideration by SC3.

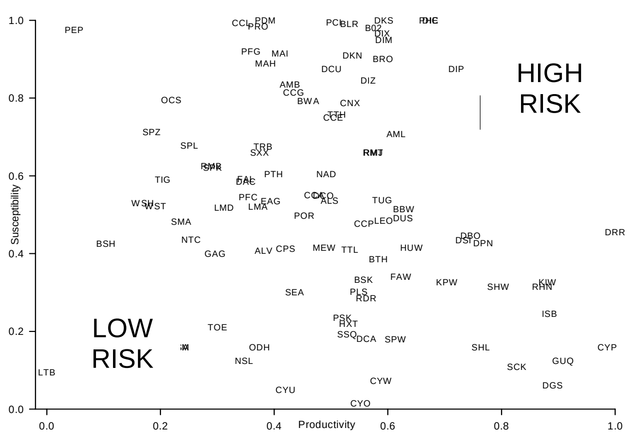
Level 1 type analyses have tended to be carried out at the national or sub-national scale. This is not always the case and the Commission for the Conservation of Antarctic living Marine Resources (CCAMLR) has implemented a system for ecological risk assessment (Susan Waugh pers. comm.) based upon expert opinion in a workshop setting, specifically the Working Group on Incidental Mortality Associated with Fishing (IMAF). Through a workshop process, CCAMLR statistical areas were assigned risk scores and different mitigation measures are required in each area. This approach undertook the full set of steps in ERA, including identifying objectives, analysing risk, management of the risk and monitoring and evaluation of the implementation and efficacy of measures. The CCAMLR experience was recognised as being efficient and adaptive, and has been highly effective at reducing risk to vulnerable species rapidly, while maximising fishing opportunities. The ERA workshop discussed the utility of developing such a system through the WCPFC Ecosystem & Bycatch SWG and this will be discussed further.

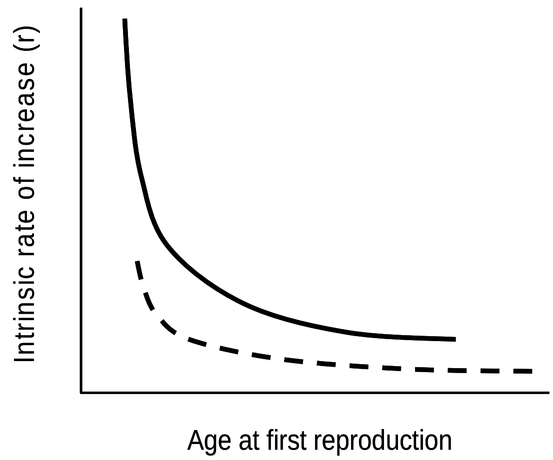
5. Productivity-Susceptibility Analysis (PSAs) and other indicator-based measures of apparent relative risk (Level 2)

Analyses at Level 2 follow the same approach to population dynamics as single species stock assessments, except that instead of solving the differential equation,

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

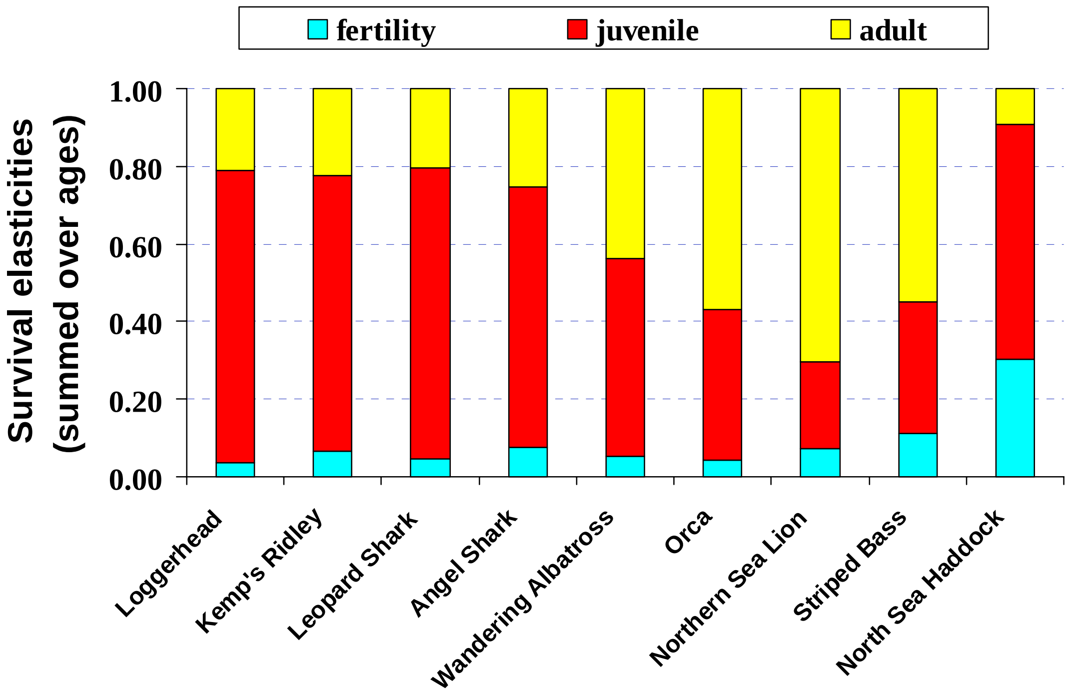
indicators are used for the parameters *r* and *q*, which determine the relative magnitude of the population growth (i.e. productivity) and mortality (i.e. susceptibility) terms in the equation above, and these are plotted against each other. The use of indicators means that a range of species can be compared simultaneously, relative to one another, without requiring an estimate of biomass *B* for any of them. For particular species of interest (e.g. target species) this is no substitute for a stock assessment, but it is very useful as a means to compare a large number of species using measurable and commonly available data. These Productivity-Susceptibility Analyses (PSAs) Analyses result in a 2-dimensional plot of productivity on the *x*-axis and susceptibility on the *y*-axis. An example from this year's updated PSAs for the WCPO (Kirby & Hobday 2007) is given below left:





PSAs depend on life history parameters to define the productivity index. There is a general relationship between age-at-maturity and population growth rate (Selina Heppell pers. comm.: above right). The position of the curve may vary for different species groups but the shape is usually the same. This makes age-at-maturity a good indicator to include on the productivity axis. Other indicators include the ratio of age-at-maturity to maximum age and maximum age itself, with delayed maturity and long lifespan scoring higher risk due to lower lifetime reproductive output. Similar metrics can be used for length, though these are less robust on the productivity axis as maximum length can be reached by some species well before they reach their maximum age. However, length metrics are often useful due to the availability of data by comparison with age metrics.

It is also possible to use length-at-capture on the susceptibility axis, as the ratio of length-at-capture against length-at-maturity or maximum length, i.e. to determine whether the species is being caught mostly as young juveniles or breeding adults. Once this has been determined, the ratio can be scored for risk depending on the importance of the different life history stages. This can be calculated from elasticity analysis (Heppell et al. 1999), which identifies the relative importance of the different life history stages to population growth. It also identifies at what stage management measures will be most efficient.



Reproductive value assessment is a related method used to value individuals of different age- or stage-classes, based on their current and future reproductive potential, and to determines the number of 'adult equivalents' taken in different fisheries.

The condition and fate of species caught is a direct measure of susceptibility that is often recorded by scientific observers. This allows calculation of indicators for whether particular species are more or less likely to survive the experience. The classification of condition is subjective on the part of the observer and there may also be post-release mortality of individuals that are apparently alive. Data on post-release mortality is lacking for most species but can easily be incorporated into the PSA framework, as apporpriate. In any case, the response in relative risk scores to variations in post-release mortality can be assessed in the absence of data. Other susceptibility indicators include: the extent of habitat overlap in both vertical and horizontal dimensions, and the vulnerability to fishing gear that results. A simple vertical overlap index has been calculated for the PSAs presented this year (Kirby & Hobday 2007), which was possible as maximum and minimum depth ranges were available for almost all species observed caught. However, we know from the experience of stock assessments for tunas that the degree of vertical habitat overlap is not necessarily the same thing as vulnerability to longline fishing gear. The log sheet data used to standardise fishing effort for tunas may not be much use for non-target species but observer data may prove useful in this regard.

In the horizontal dimension, the available data for most species are not so precise. This highlights the importance of tagging and tracking data to determine the degree of overlap of species' range with fishing effort. Data were presented at the ERA workshop showing tracking data from the BirdLife Global Procellariiform Tracking Database (Barry Baker pers. comm.). The WCPFC area includes 41% of the global breeding distribution of albatrosses and petrels, and that albatross distribution is concentrated north of 20ºN and south of 30ºS. Some species spend a significant proportion (>40%) of their time in high seas areas, including the Tasman Sea and areas north of the Hawaiian Islands. Several species have ranges that span the tropical Pacific. , though few tracking data are yet available for these species. However, data from Sooty Shearwaters indicate that this species crosses the central Pacific quickly, and that little time is spent foraging (Shaffer et al. 2006), suggesting they may have low susceptibility to fishing during this time. This is an example where use of tracking data can be used to obtain a better measure of susceptibility: in this case, the range of the sooty shearwater would indicate high horizontal overlap in tropical regions, but the tracking data and dive depth data indicate little horizontal and vertical overlap. Further spatio-temporal considerations are important for seabirds, marine mammals and for fish with confined spawning grounds. Bycatch during breeding periods in these areas would likely have a big impact on population growth, and spatio-temporal metrics can take this into account.

The importance of spatial scale and the degree of overlap with and vulnerability to fishing effort illustrates the importance of the ensuring that the Regional Observer Programme has coverage across the whole range of fishing effort. Ultimately the WCPFC needs to carry out or at least collaborate with multi-species tagging programmes such as TOPP (Tagging of Pacific Predators; http://topp.org/topp_predators).

The ERA workshop participants discussed the application of PSAs to risk assessment in Australian fisheries (Ilona Stobutski pers. comm.) and to the WCPO (Kirby & Hobday 2007). A total of 32 fisheries in Australia have been assessed and advice provided to Management Advisory Committees. The main utility from a scientific perspective has been in identifying those bycatch species for which the Level 2 PSA is sufficient, those for which data are sufficient to do a Level 3 analysis, those for which data are limited. The main utility from a management perspective has been the identification of species that are potentially at risk and initiating discussions on how to address these.

The quality of PSAs, in terms of the likelihood that the resultant risk scores approximate reality, depends greatly upon the degree to which the life histories of the constituent species are known (for *productivity*) and on the quality of the observer data used (for *susceptibility*). ERA workshop participants discussed the Hawaii longline fishery observer program, where considerable in depth analysis and validation of logsheets against observer data and auctions has been carried out (William Walsh pers. comm.). There are at least three sources of uncertainty in the observer data or its use: observational error, referring to the inherent difficulty of data collection; analytical error, referring to several characteristic biases; and comparability, referring to consistency of procedures and protocols within and between agencies and to the levels of detail in observer and logbook data. The principal observational difficulties consist of counting large numbers of bycatch species, such as blue sharks, at the same time as trying to accurately record target species, and the difficulties of identifying certain sharks with congeners in the catch (e.g. *Carcharhinus*, *Alopias* & *Isurus* spp.). Newly hired observers apparently make the greatest number of species misidentifications, and tend to report rare or unusual sharks in the process. The consequence is that the apparent biodiversity of shark bycatch may be artificially inflated. In formulating a species list for an observer program it is therefore important that it be based on local knowledge. For billfishes, total numbers reported are consistent among datasets but the species composition varies greatly, with up to 50% under/over-reporting due to misidentification of species. There may also be misreporting, such as finning and discarding of sharks but recording them on logsheets as 'released'. Errors in observer data tend to be inversely proportional to price and the peak season for error is during periods of high catches of target species.

The ERA workshop participants discussed the issue of quantifying and communicating the degree of uncertainty in PSAs. Various methods are available to flag missing or poor qulity data and also to use ranges of plausible values in the analysis. Some weaknesses of the PSA approach were acknowledged, including the lack of scaling by fishing effort and biomass. Fishing effort may indeed be incorporated as a way of comparing the relative risk posed by different fisheries but it was recognised that if biomass estimates are available you have already carried out some kind of Level 3 analysis and there is not necessarily any need to refer back to Level 2. Further enhancements are proposed to the PSA methodology in the ERA Research Plan detailed in Part 2 of this paper.

6. Assessment models for single species population dynamics and their suitability for non-target associated & dependent species (Level 3)

Stock assessments are routinely carried out for the principal market species of tuna (albacore, bigeye, skipjack, yellowfin) and have also been carried out for other target species such as swordfish (Kolody et al. 2006) and striped marlin (Langley et al. 2007). In some cases the models used for stock assessments of target species may also be used for non-target species. A stock assessment for blue shark in the North Pacific has recently been conducted (Pierre Kleiber pers. comm.) but unfortunately this was not available for presentation at SC3. Due to the limited degree to which log sheets record non-target species, only a limited number of species may be assessable using standard stock assessment software (e.g. MULTIFAN-CL, CASAL, SS2) and – generally speaking – the uncertainty around the assessment results is likely to be worse than for target species. The most productive species tend to generate the most data and present assessments are carried out on relatively highly productive (though highly susceptible) species. Carrying out future assessments simply because data is available will not target research effort at species likely to be at greatest risk of adverse effects from fishing, though there may be other reasons why a species is chosen for assessment. A Level 2 approach (i.e. PSA) can therefore assist in the process of prioritising species for conventional assessment where it is possible to assess them. Where it is not, alternative analytical methods must be applied or management measures based on the best available science at this stage.

MULTIFAN-CL (MFCL) is a general assessment model, though it has been designed for tunas. It has a flexible structure in terms of the underlying population dynamics and also in the types and structures of input data. That flexibility is key to whether MFCL could be used to craft models appropriate to non-target species. An obvious difficulty is the volume of data that MFCL requires. Although the basic population dynamics encoded in MFCL is common to most species, including non-target species, the harvest sub-model might need to be re-crafted to deal with situations where there are significant anthropogenic effects on the population resulting from processes that differ from fishing. Likewise, provision may need to be made to incorporate abundance indices based on observations other than CPUE, such as nest counts, in cases where detailed records of catch by the fishery are unavailable or where fishing effort cannot be defined in such a way that CPUE is a good abundance index. The main advantage is that MFCL incorporates tagging data. CASAL is more general and has been used for assessing stock status for both target and non-target species. SS2 is an alternative that is commonly used in the USA. Most of these models fit indices of abundance and are in principle flexible about what this index is; however, they are still designed for fish, with Beverton-Holt or Ricker type stock-recruitment relationships. Other models must be considered for other species and a general model for all species caught in fisheries could be developed.

Integrated analysis is a modelling method used to combine and compare information in a common framework (Mark Maunder pers. comm.) and the stock assessment methods discussed above are examples of integrated analyses as applied to fish. Mathematics is used to connect the information together. Statistics is used to measure the reliability of the data. Scientific understanding is used to constrain how the information is combined. Experience is used to fill in information gaps, interpret data and results, and guide information collection and research. Several applications were used to illustrate the advantages and limitations of integrated analysis. The waved albatross application illustrated the use of integrated analysis to identifying errors in the model and inconsistencies among data and model assumptions. The African penguin application illustrated how integrated analysis helps focus the analysis on population processes even if data is not available for those processes. The eastern spotted dolphin application illustrated how integrated analysis is used to determining support for alternative hypotheses. The New Zealand sea lion applications illustrated how integrated analysis can be used to investigate different management strategies and associated tradeoffs, and how it can deal with complex observation models. The yellow-eye penguin and black-footed albatross applications illustrated how lack of data (e.g. bycatch estimates) and poorly designed data collection are the main problem with analyzing protected species.

An advantage of integrated analysis is that it addresses the whole problem, not just elements of the issue. It forces the modeller to be explicit about assumptions and to consider what processes are important. It helps determine whether data are consistent and provides a formal way of comparing the influence of different parts of the life cycle. Integrated analysis identifies where data is lacking and is an excellent tool for generating alternative hypotheses and identifying areas for further research. Other advantages of integrated analysis are that it is possible to identify errors in models, to compare consistency of the data with the model to model trade-offs among fisheries management policies and to represent uncertainties. However, integrated analysis takes a lot of time and information, which is lacking for most species at the level of detail required. This is often because data collection was not designed to address management decisions, data holders are unwilling to provide data, or data is not in a format ready for users. For now, WCPFC should draw widely on sources for stock or population assessment of non-target species, e.g. birds/whale researchers may have stock status information for these species. In return, WCPFC must ensure that fine-scale data is available for analysis as necessary. The challenge is then to determine what are the fisheries impacts on those species.

Potential Biological Removal (PBR) is a method used in marine mammal management to determine a maximum number of animals that can be removed from a population without causing population decline. This method is useful for setting thresholds of take (that is also cumulative across all human-induced mortality) which can trigger consultation or management action if exceeded. Data requirements are estimates of maximum population growth rate, stock status (endangered, threatened, vulnerable) and population size. For population size, uncertainty is incorporated by using a lower confidence limit, which encourages better data collection. The analysis can be modified to be region- or stock-specific. There may be, however, a tendency to use PBR as a target rather than a limit.

Population viability analysis (PVA) is a method of stochastic simulation modelling used to evaluate extinction risk or risk of decline, based on year to year variance in population size or vital rates (survival, fertility, recruitment). PVAs vary in their level of complexity and data requirements. The simplest PVA – diffusion approximation – relies on estimates of population trend and variance in a time series. The analysis provides an analytical estimate of the proportion of simulations that will drop below a pre-set threshold in a pre-set time frame. More complex PVAs use an age-structured model and require age-specific vital rate estimates, their variances, and covariances. Removals due to fishing can be subtracted directly in simulations and models can incorporate density dependence.

7. Pelagic ecosystem variability and change: ecosystem indicators and risk-based methods for understanding long-term environmental change

The ability to discern environmental effects from fisheries impacts on target and non-target stocks and on ecosystems is essential to building confidence in the best available science and deciding on appropriate conservation and management measures. There is interaction between climate/ecosystem variability and change, and the risk of adverse effects from fishing: natural variability affects species distributions and habitat overlap with effort in both vertical and horizontal dimensions – it therefore imposes changes in susceptibility; it also affects recruitment, so has the potential to impose changes in productivity. These effects may occur at various time and space scales. This can be handled in a PSA and a starting point would be to carry out PSAs under different El Niño/La Niño phases. It is important to recognise however, that the strongest modes of climate/ecosystem variability do not necessarily produce the strongest effects on biological components of ecosystems (David Kirby pers. obs.) and it is therefore better to be able to directly identify how climate variability/change may affect attributes that are considered along one or other of the PSA axes.

The effect of climate/ecosystem variability and change, particularly on recruitment, may also be incorporated into the calculation of MSY-based reference points in stock assessments (Mark Maunder pers. comm.). MSY, as an equilibrium based reference point, is usually calculated over the duration of the fishery, with present fishing effort and biomass being compared to that at MSY to determine whether the stock is experiencing overfishing or is in an overfished state respectively. In a fluctuating environment however, MSY over shorter periods is variable and failure to account for this can lead to overfishing during low recruitment regimes. Alternatively, recruitment variability may be explicitly incorporated into the calculation of reference points and a ‘dynamic MSY’ calculated, allowing for more timely monitoring of stock status and fishing mortality.

The ERA workshop focussed mainly on species rather than habitats or communities, in recognition of the multi-species management obligations under the Convention. The scope of the ERA project however, can also encompass species groups and trophic interactions. This would address the obligations under the Convention with regard to ‘dependent species’ and the requirement to ‘maintain the integrity of marine ecosystems’. Separate project proposals have been submitted to WCPFC and elsewhere to develop ecosystem models for the WCPFC Convention Area and the outputs of those models can be incorporated into a risk assessment framework. In themselves, they are Level 3 analyses for the ecosystem but the relative importance of constituent species or species groups in determining ecosystem structure and function is an output of ecosystem models and this index of ‘keystoneness’ could be incorporated into a multidimensional PSA.

There are international, multidisciplinary projects presently underway (TOPP, referred to above, and the GLOBEC project CLIOTOP: Climate Impacts on Oceanic Top Predators) to understand the interrelationship between climate/ecosystem variability and change and the spatial population dynamics of oceanic top predators. The ERA project should keep involved in those projects, drawing from and incorporating the information they generate.

8. Summary remarks

Participants at the ERA workshop generally agreed that it had been a very worthwhile exercise and that a lot of ground had been covered in a constructive way. It was important to have specialists from different disciplines (seabirds, sharks, turtles, stock assessment, oceanography, etc.) as there was a synergy of ideas. There was recognition that we are being proactive and strategic in this work and that the lessons learned should be transferable among CCMs within the Convention Area (including FFA members undertaking EAFM) as well as to other RFMOs.

Outcomes in this first meeting were more to do with methodology and tools but there is a fundamental need to identify what we know, what we don't know and what we can't know. There was general enthusiasm to have future technical meetings, which could work through example risk assessments at whatever level they have been carried out. This would help to determine how far assessments for particular species groups and areas can progress, and whether the level of information needed is too great to progress further.

Open issues remain around how best to maintain transparency and efficiency, and when, where and how to engage stakeholders. Good communication, using consistent terminology in plain English, is vital between all levels and among all participants in an ERA. The challenge affecting many CCMs is the integration between national level activities and regional assessments. This includes integration across SPC, FFA and WCPFC activities in the provision of technical assistance and capacity building, so as to add value, avoid duplication, and to ensure that there is consistency and agreement in the scientific advice provided. Sub-regional scales of analysis will need to be carefully identified according to data availability and fisheries characteristics and the CCMs concerned must be identified and involved in the analysis.

All participants recognised that the effectiveness of the ERA exercise for the WCPFC will depend on the willingness of the EBSWG, SC and WCPFC to adopt a risk-based framework in its decision-making with regard to mitigation measures for non-target highly migratory species and associated/dependent species, though this may be an outcome rather than a pre-requisite of the ERA research project. Adopting or establishing best practice in fisheries monitoring and analysis must be a general goal of the SC and the ERA can have a significant role in this. With this goal in mind, the main output of this workshop is this workshop report and the research plan in Part 2.

References:

Beddington JR, Agnew DJ, Clark CW (2007) Current problems in the management of marine fisheries. Science 316:1713–1716

FFA (2007) Update on the application of the ecosystem-based approach to managing tuna fisheries amongst FFA member countries and territory in the WCPO: specific to lessons from stakeholder consultations in countries. Working Paper EB-IP-11, 3rd Regular Session of the WCPFC Scientific Committee, Honolulu.

Fletcher WJ (2005) The application of qualitative risk assessment methodology to prioritize issues for fisheries management. ICES Journal of Marine Science 62:1576–1587

Heppell S, Crowder LB, Menzel TR (1999) Life table analysis of long-lived marine species with implications for conservation and management. American Fisheries Society Symposium 23:137–148

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.

Itano D, Kirby D (2006) Standardized fishery terms to facilitate the communication within Scientific Committee and with the WCPFC. Working Paper FT-WP-5, 2nd Regular Session of the WCPFC Scientific Committee, Manila.

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.

Kirby DS, Moloney B (2006) An ecological risk assessment for species caught in WCPO longline and purse seine fisheries. Working Paper EB-WP1, 2nd Regular Session of the WCPFC Scientific Committee, Manila.

Kirby DS, Hobday A (2007) Ecological Risk Assessment for species caught in the WCPO tuna fishery: updated Productivity-Susceptibility Analysis. Working Paper EB-WP-1, 3rd Regular Session of the WCPFC Scientific Committee, Honolulu.

Kolody D, Campbell R, Davies N (2006) Multifan-CL Stock Assessment for South-West Pacific Broadbill Swordfish 1952-2004. Working Paper ME-WP-3. 2nd Regular Session of the WCPFC Scientific Committee, Manila

Lodge MW, Anderson D, Løbach T, Munro G, Sainsbury K, Willock A (2007) Recommended best practices for regional fisheries management organizations. Royal Institute of International Affairs, Chatham House, London

Langley A, Molony B, Bromhead D, Yokawa K, Wise B (2007) Stock assessment of striped marlin (*Tetrapturus audax*) in the southwest Pacific Ocean.. Working Paper SA-WP-6, 3rd Regular Session of the WCPFC Scientific Committee, Honolulu.

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.

Shaffer SA et al. (2006) Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. PNAS 103:12799–12802

PART 2: ERA RESEARCH PLAN

A high-level review of the performance of Regional Fisheries Management Organisations (RFMOs) has recently been carried out by the Royal Institute of International Affairs, at Chatham House, London, with the aim of defining a model RFMO (Lodge et al. 2007). In their report the panel calls for 'risk-based impact assessment of the effect of fishing activities on non-target species, followed by explicit analytical assessments and/or action when risk is determined to be high'. This is consistent with the proposed research plan.

The WCPFC is not bound to follow a hierarchical approach but for the reasons discussed above it is a good model to follow. A first consideration is the extent to which Level 1 analyses are applicable in a regional international context, and this is discussed below.

At Level 2 there is a need to identify appropriate spatial scales for analysis and this must be guided by the extent of any particular fishery and the availability of data. Furthermore, some CCMs (e.g. Australia) already have well developed ERA processes in place and others (e.g. FFA countries) are beginning to implement them. The activities of this ERA project for the WCPFC must complement these activities, by learning from and supporting them and not duplicating effort.

At Level 3, detailed species-specific analyses must account for all sources of mortality, not just fishing, in order to clearly quantify stock status and tolerable fishing mortality.

In carrying out fishery based analyses for the WCPFC there must be an emphasis on **comparability**, so that any particular fishery may compare its impacts with that of other fisheries and cumulative impacts may be quantified. A second necessary quality of the analyses we propose is **transferability**, so that inferences may reasonably be made from the study area into areas that are fished but neither monitored nor assessed.

High-level output:

Identification of highly migratory species and associated/dependent species that are at relatively high risk of adverse effects due to fishing, for consideration by the SC in terms of further research or management responses.

Research outputs:

(1) Level 1 analyses for WCPFC Convention Area or particular sub-regions, carried out through sessions of the EBSWG at future Scientific Committee meetings.

(2) Enhanced Productivity-Susceptibility Analyses (PSAs) that are comparable, transferable and for which uncertainty has been quantified explicitly and appropriately.

(3) Identification of highly migratory species, or associated/dependent species, that are at high apparent risk and are assessable at Level 3 using existing data sources and models.

(4) Identification of fisheries monitoring requirements (i.e. data quality and quantity) in order to generate sufficient data for other high-risk species to be assessable at Level 3.

(5) Scientific support for SIDS in implementing Level 1 analyses at the national level, as requested by the countries/territories concerned and in collaboration with FFA.

(6) Identification and evaluation of bycatch mitigation measures.

(1) Level 1 analyses for WCPFC Convention Area or particular sub-regions, carried out through sessions of the EBSWG at future Scientific Committee meetings

Future meetings of the EBSWG could adopt a workshop-type format for at least part of the session and go through the qualitative risk assessment process (Level 1), considering the state of knowledge and uncertainty around species and species groups for different areas and scales around the WCPFC Convention Area. This is the process followed in the CCAMLR ERA for seabirds and is common across most ERA processes, including setting objectives, risk assessment, identification of risk management measures, monitoring and review. The Ecosystem Approach to Fisheries Management (EAFM) is a management process and as ERA supports EAFM there is a need to consider the implications for procedural aspects of the EBSWG, the SC and WCPFC.

The WCPFC has established due process, including the Scientific Committee and its Specialist Working Groups. Ad hoc working groups have been established by the SC and SPC-OFP has convened its own scientific workshops. Given practical constraints, it might not be productive to suggest yet another round of meetings. However, other Commissions spend considerably more time discussing bycatch issues than the 1 day presently allotted to the EBSWG and so long as the time is used efficiently it could be possible to carry out a Level 1 type analysis for the Convention Area.

An alternative that may work more efficiently is for this year's ERA Research Planning Workshop participants to meet again prior to future SC meetings as an ERA Technical Advisory Group, to work through some analyses at all Levels 1–3 and identify species at risk, species that can be subject to more detailed analysis at Level 3, and data gaps constraining our ability to generate scientific advice.

(2) Enhanced Productivity-Susceptibility Analyses (PSAs) that are comparable, transferable and for which uncertainty has been quantified and communicated

The PSAs presented to SC3 are indicative of the kind of outputs that the analysis can provide. However, there are various ways in which to improve the underlying analysis so that the SC can have confidence to proceed to conservation and management measures or further research based on the results. Some of the necessary enhancements are discussed in Kirby & Hobday (2007) and in the workshop report in Part 1 of this paper.

It is necessary to carry out further quality control of the input data, so that biological characteristics are accurately defined where known, and so that average values are used appropriately. The inclusion of attributes in the formulation of risk scores along each axis needs to be investigated so that no more/less are used than will minimise the uncertainty.

The results of elasticity analysis should be incorporated into the susceptibility axis, to better assess whether the stage at which the fishery impacts a species is likely to be a high/low risk. Reproductive value assessment may also be used to determine relative impacts of different fisheries.

Better spatial indicators for vertical, horizontal and temporal dimensions must also be incorporated on the susceptibility axis, and access arrangements developed to enable habitat utilisation data for seabirds and other species groups to be incorporated into assessments at an appropriate scale and level of detail. The potential impacts of climate change on habitat overlap with fisheries can also be explored.

Fisheries need to better defined and characterised so that fishery specific risk scores can be better assigned. These need to be comparable and transferable, so that cumulative impacts can be assessed and inference drawn on fisheries operating in unmonitored areas.

Fishing effort may be included as a multiplier on the susceptibility axis or as a third dimension to allow comparison among fisheries. IUCN Red List status (critically endangered >> least concern) may also be used in 'weighting' the final risk scores, although assessments are unlikely to be available for most species.

The incorporation of higher dimensionality into the PSAs should be explored. Although difficult to visualise, an extension of the Pythagoras theorem used to calculate Euclidean distance and overall risk score for the two axes in the PSA (productivity, susceptibility) will give the distance between two points in multi-dimensional space. This allows other important attributes unrelated to productivity or susceptibility to be included. For example, a multi-dimensional analysis for the effects of fishing on ocean ecosystems could be carried out, incorporating an index of keystoneness (i.e. the importance of that species in determining ecosystem structure and function) as another dimension. This addresses the obligation to assess and minimise impacts upon 'dependent' as well as 'associated' species under the Convention.

In addition to PSAs, a range of indicator-based methods will be explored for inferring risk of adverse effects due to fishing. Where data are available these will include shifts in length/age distributions and species range, which may be inferred from presence/absence, ratio estimates of target species catch composition (e.g. skipjack:bigeye in purse seine) and associations with bycatch composition.

It may be possible to make comparisons within taxa using Level 3 analyses for a particular species as a way to infer stock status for others, e.g. use results from blue shark stock assessment to give insight into the status of other sharks by comparison of attributes that make other species are more/less risk. By using such reference species in comparison to species groups based on life history characteristics and elasticity analyses (i.e. not necessarily family based) it may be possible to look at trend analyses for a much broader range of species. This may be more meaningful than the analysis of CPUE trends for bycatch, which may be misleading as we expect CPUE to be higher as populations recover and lower as gear becomes more selective.

The quantification and communication of uncertainty is as important in PSAs as it is in any other scientific analysis, so that stakeholders and decision makers understand the extent of the knowledge base available to them and to what degree the 'facts' are known, unknown and unknowable. It is important to not lose data during an analysis, especially on data poor species etc. Therefore categories are not used if you can use continuous numbers and the full range of values for attributes can be used and not just the averages. In an ERA context supporting the precautionary principle, the extremes are what management is aiming to avoid, so explicitly identifying uncertainties in information provides opportunities to evaluate, document and communicate these possibilities. Methods such as bootstrapping, Bayesian networks and fuzzy number methods are tools that can assist with evaluating and interpreting the influence of uncertainty on risk scoring. Moreover both Bayesian networks and fuzzy number methods may help with communicating the uncertainty around the risk classification.

The results of enhanced PSAs will lead to the identification of highly migratory species and associated/dependent species that are at relatively high apparent risk. This will inform decision making by the SC in terms of further research or management responses.

(3) Identification of highly migratory species, or associated/dependent species, that are at high apparent risk and are assessable at Level 3 using existing data sources and models

After carrying out PSAs at Level 2 and identifying species of concern, the next stage is either to implement immediate management measures, to carry out more detailed analysis at Level 3 if data are available or to start collecting the necessary data to allow such analysis. In anticipation of this, it is useful to start to identify species for which data availability is likely to be sufficient for Level 3 analysis while doing the PSAs. This will also identify those species for which data are limited and level 3 analysis is not presently possible. For these species, the best that might be done is a stochastic simulation analysis or estimation of potential biological removal (PBR).

(4) Identification of fisheries monitoring requirements in order to generate sufficient data for other high-risk species to be assessable at Level 3.

There is a general need to consider the fisheries monitoring requirements needed to allow detailed assessment of a range of species deemed to be high risk from Level 2 PSAs. Sharks are rarely reported to species level on logsheets, some CCMs only report target species on logsheets and nothing else, but we have seen in the ERA workshop that correcting logbooks with observer data can result in increases or decreases in catch rates of 50% and can also halve the standard deviation. There is therefore a need for better long-term fleet-wide monitoring, as well as enhanced observer coverage generally and observer programmes with a finite life span for specific tasks. SPC-OFP will produce a paper for the SPC-FFA Data Collection Committee in December 2007 and for the Statistics SWG at SC4 on fisheries monitoring requirements for ERA.

(5) Scientific support for SIDS in implementing Level 1 analyses at the national level, as requested by the countries/territories concerned and in collaboration with FFA

Research aspects of the ERA are likely to be efficiently handled at large spatial scales (e.g. estimating some of the components of productivity and susceptibility for individual species, such as biological characteristics and species distribution). However, individual countries, including SIDS, are likely to apply ERA at the national level of jurisdiction (i.e. EEZs). It is therefore important to support such processes with appropriate scientific and technical information in a standardised format. This will allow consistent scientific advice to be supplied at a range of spatio-temporal scales.

In the first instance, the provision of scientific advice on ERA to SIDS will be similar in form to that for the outcomes of regional stock assessments. Stock status for tuna species in the WCPO is provided, with specific scientific advice then tailored to individual countries, depending on their location within the stock assessment model region. Regional scale PSAs are precautionary, by including all species observed caught in the WCPFC Convention Area. At the national level, regional scale results may be discussed and species eliminated if they are known not to occur in that zone. Attention can then be focussed on those species that should be of more concern. Risk scores therefore will not change, but the list of species may be reduced.

In addition to interpreting regional results at national scales, if observer data are sufficient for that zone it will be possible to carry out national scale analyses and to determine risk scores at the country level, which may be lower/higher than the risk determined at the regional level. These will also be important in understanding the cumulative effects of fishing on particular species at a range of spatial scales. Sub-regional analyses, comprised of PSAs for neighbouring countries and high-seas areas, may be most informative, especially where observer data are good enough to link to logsheets and port-sampling.

The mechanism for providing this scientific support may be through the National Tuna Fisheries Status Reports (NTFSRs) that SPC-OFP routinely produce for SPC Island Members, and this could be integrated with the FFA EAFM, where both the country and the agencies desire such collaboration. It is essential that the ERA process support and enhance the EAFM process at the appropriate levels, to avoid duplication and confusion. Non-FFA member countries must also have access to similar advice and information but CCMs with the data and capacity to carry out their own ERAs are encouraged to do so.

(6) Identification and evaluation of bycatch mitigation measures

This is the interface between ERA as a research exercise and a decision making tool. This paper has detailed how ERA is not just a technical exercise but how it can assist management in identifying and prioritising species for further research or immediate conservation and management measures and in evaluating the effects of those measures. As questions move beyond the ecology and into what could be done to reduce risk, consideration must be given to what is practicable and efficient to implement, what is the easiest thing to change, and what management intervention will have the greatest positive impact per dollar spent. The communication of uncertainty is again crucial in the identification and evaluation of mitigation measures, so that they might be effective.

For this kind of analysis a decision tree approach may be a better graphical tool than a multidimensional PSA and it may incorporate results from all levels of analysis. The analysis may initially be for research purposes but there are procedural considerations and implications, for example, which is the appropriate SWG for presentation of results such as a shark stock assessment (presumably the stock assessment SWG) but mitigation recommendations will come from the EBWG. There is a need to ensure that the relationship among SWGs is well defined in order to be effective and to link the scientific output of the ERA to the identification and evaluation of bycatch mitigation measures.

Ultimately the SC and WCPFC may wish to formalise its procedures into operational control rules linked to the scientific outputs of the ERA. There needs to be further dialogue about this among scientists and managers in the WCPFC context. However, this should not delay the management process if issues obviously require immediate action.

Similarly, there are many research aspects to be addressed regardless of whether or not SC formalises its approach to information coming from ERA. The impacts of mitigation measures such as changes in hook type, leaders, set type, and spatial closures, may be assessed at Level 2 as they directly affect the attributes that are input to the susceptibility axis. Risk scores may be calculated with/without the mitigation measure, and the resulting or expected effects will be apparent in the PSA plots.

There is a general need to monitor and evaluate the inputs to ERA and the effects of mitigation measures. In some case there will be a need to update information on a regular basis, either because research fields are advancing rapidly (e.g. knowledge of at sea distributions from tracking data) or the species affected are of considerable concern. In other fields and for other species, progress is much slower or input variables are not expected to change, e.g. a 2–5 yearly review of demographic data may be sufficient.

A new web-based bycatch database is being developed by SPC-OFP for the WCPFC and it will include the attributes used in the ERA as well as information on mitigation measures. This will be maintained during the course of the project, with information updated as it becomes available.

Appendix 1. Ecological Risk Assessment (ERA) Workshop Agenda

Monday 6 August

09h30: Meet at Western Pacific Regional Fisheries Mangement Council offices,

10h00: Welcome and introduction to workshop aims, participants etc. [David Kirby]

10h15: *Opening address: Paul Dalzell, Senior Scientist, Western Pacific Regional Fisheries Management Council, Hawaii*

Session 1. The management context around ecological risk assessment

10h30: Keynote speech: Jon van Dyke, Professor of International Law, University of Hawaii.

"Fisheries management obligations for non-target species under international law"

Discussion on the degree to which non-target associated and dependent species should be the subject of commission related research and conservation & management measures

11h30: Keynote speech: Alistair Hobday, CSIRO Marine Research, Australia

"The need for risk-based methods in ecosystem-based fisheries management"

Discussion on what 'risk' is and how ecological risk assessment helps with the implementation of the ecosystem approach to fisheries mangement and application of the precautionary principle

12h30: Lunch

Session 2. Perceived Risk: Stakeholder workshops and scale-intensity-consequence analysis (SICA)

14h00: Keynote speech: Samasoni Sauni, FFA

"Application of the Ecosystem-Based Approach to Tuna Fisheries Management in the WCPO: lessons from stakeholder workshops in FFA Member countries"

Discussion on stakeholder engagement, hazard identification and risk scoring in workshop settings; how effective are these forums and what is the science base needed?

15h30: Afternoon tea

Discussion continues

17h30: Close

Tuesday 7 August

Session 3. Apparent Relative Risk: Productivity-Susceptibility Analysis (PSA) and other indicator-based methods for comparative analysis

09h00: Keynote speech: Ilona Stobutzki, BRS, Australia
"Experiences with productivity-susceptibility analysis (PSA) in Australia"

Discussion on the use of PSAs in a national management context

10h30: Coffee

11h00: Keynote speech: David Kirby, SPC-OFP
"Updated productivity-susceptibility analysis for the western & central Pacific"

Discussion on the use of PSAs in the WCPFC context

12h30: Lunch

14h00: Keynote speech: Selina Heppell, Oregon State University
"Elasticity analysis, potential biological removal, reproductive value assessment, and diffusion approximation for extinction risk"

Discussion on applicability of these methods to the WCPFC context

15h30: Afternoon tea

16h00 Keynote speech: Barry Baker, ACAP
"Spatial overlap between seabirds and fishing effort"

Discussion on how to include spatial metrics in relative risk assessments

17h00 Keynote speech: Susan Waugh, Birdlife International
"CCAMLR seabird assessment"

Discussion on seabird-specific assessments, relevance and transferability to WCPFC

18h00: Close

Wednesday 8 August

Session 4. Absolute Risk: Assessment models for single species population dynamics and their suitability for non-target associated & dependent species

09h00: Keynote speech: Pierre Kleiber, NOAA Fisheries

"MULTIFAN-CL stock assessment software: potential applications and limitations for the assessment of billfish, sharks and other species"

Discussion on what other species may be amenable to population/stock assessment using MULTIFAN-Cl

10h30: Coffee

11h00: Keynote speech: Mark Maunder, IATTC

"Integrated modelling of protected species: advantages and limitations"

Discussion on what other species may be amenable to population/stock assessment using integrated models and other existing modelling approaches; in what cases will it be necessary to develop and apply other approaches?

12h30: Lunch

Session 5. Capturing uncertainty in ecological risk assessments

14h00: Keynote speech: Bill Walsh, NOAA Fisheries

"Potential pitfalls in the analysis of fishery observer data"

Discussion on how to reduce uncertainty in risk assessments using observer data

15h30: Afternoon tea

16h00: Keynote speech: Simon Nicol, SPC-OFP

"Capturing uncertainty in ecological risk assessments: synthesis & summary"

Discussion on how to identiy, quantify and communicate uncertainty in risk assessments

17h30: Close

Thursday 9 August

Session 6. Pelagic ecosystem variability and change: ecosystem indicators and risk-based methods for understanding long-term environmental change

09h00: Keynote speech: David Kirby

"Regime shifts and recruitment in WCPO tuna fisheries: multivariate methods for classifying variability and detecting change"

Discussion on deriving ocean ecosystem indicators

10h30: Coffee

11h00: Keynote speech: Mark Maunder

"Capturing climate change in biological reference points: recruitment variability and dynamic MSY"

Discussion on capturing recruitment variability in stock projections and developing risk-based analyses of climate change scenarios

Closing address: John Hampton, Oceanic Fisheries Programme Manager, Secretariat of the Pacific Community

12h30: Lunch
