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# Ecological Risk Assessment for Effects of Fishing

METHODOLOGY

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## Preface

This document, *Ecological Risk Assessment for the Effects of Fishing: Methodology*, is one of three in the ERAEF series. This document outlines, in detail, the steps to completing a case study for a fishery. The individual case study results are then reported using the document *ERAEF Case Study Report Fishery Name*. The rationale and theoretical development of the methodology, together with a summary of the project and results for all the fisheries assessed, is covered in the third document: *ERAEF Stage 2 Final Report (June 2006)*. The ERAEF methodology has seen continual refinement and extension since project began in 2001, and this methodology document supersedes all other methodology documents produced by the ERAEF project.

There are three sections to this document; a short overview of the ERAEF methodology (Section 1), the detailed methodological steps to complete the results (Section 2) that should be read in conjunction with *ERAEF Case Study Report Fishery Name*, and a summary and interpretation of results (Section 3). It is possible to read the overview in the first section, skip the second section of detailed methods, and then read the third section. If additional detail is required, the second section can be visited. Within the second section, there are three types of content: (i) instructions to authors of a fishery assessment, (ii) methods for undertaking the assessment, and (iii) pro-formas and examples of output from de-identified case studies. These are identified in **different ways** to allow quick recognition of the content and relevance to the task at hand. The organisation of this document reflects that used in the *ERAEF Case Study Reports*. The same section headers and numbering scheme, and figure and table numbers are used to allow easy reference between the two documents.



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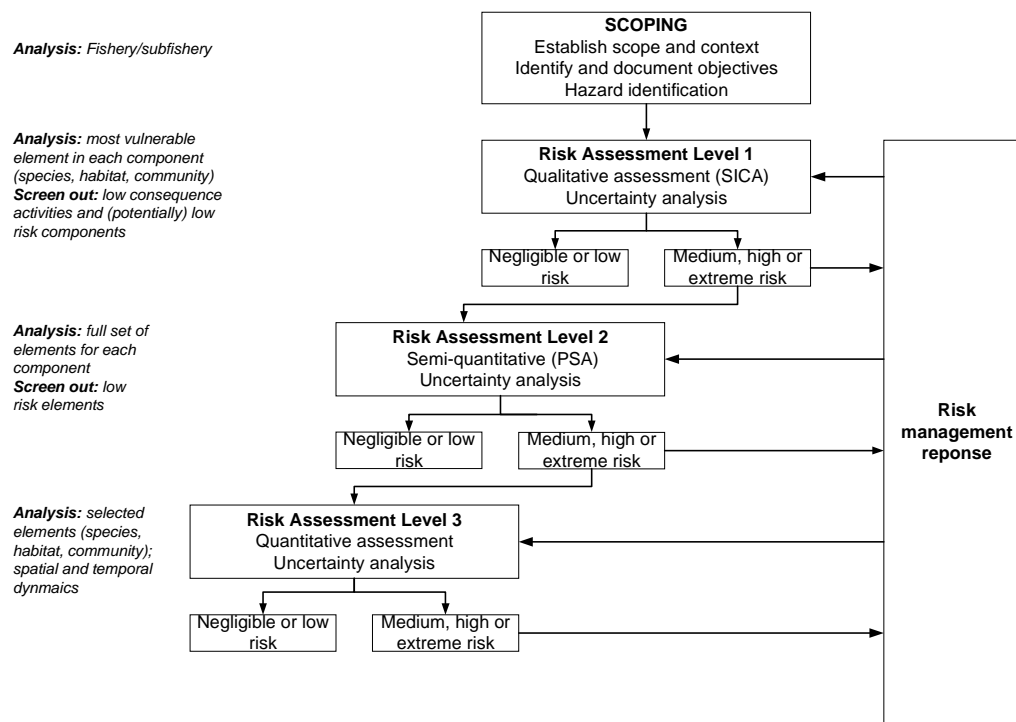
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## 1. Overview

### Ecological Risk Assessment for the Effects of Fishing (ERAEF) Framework

#### *The Hierarchical Approach*

The Ecological Risk Assessment for the Effects of Fishing (ERAEF) framework involves a hierarchical approach that moves from a comprehensive but largely qualitative analysis of risk at Level 1, through a more focused and semi-quantitative approach at Level 2, to a highly focused and fully quantitative “model-based” approach at Level 3 (**Figure 1**). This approach is efficient because many potential risks are screened out at Level 1, so that the more intensive and quantitative analyses at Level 2 (and ultimately at Level 3) are limited to a subset of the higher risk activities associated with fishing. It also leads to rapid identification of high-risk activities, which in turn can lead to immediate remedial action (risk management response). The ERAEF approach is also precautionary, in the sense that risks will be scored high in the absence of information, evidence or logical argument to the contrary.



**Figure 1. Overview of ERAEF showing focus of analysis for each level at the left in italics.**

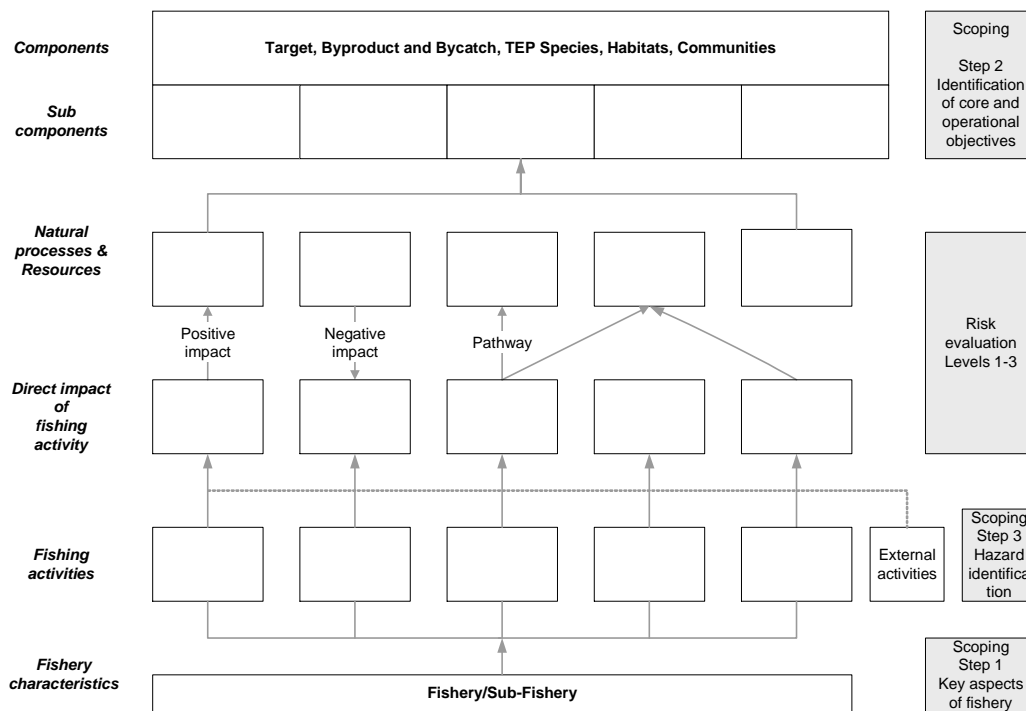
#### *Conceptual Model*

The approach makes use of a general conceptual model of how fishing impacts on ecological systems, which is used as the basis for the risk assessment evaluations at each level of analysis (Levels 1-3). For the ERAEF approach, five general ecological

components are evaluated, corresponding to five areas of focus in evaluating impacts of fishing for strategic assessment under EPBC legislation. The five *components* are:

- Target species
- By-product and by-catch species
- Threatened, endangered and protected species (TEP species)
- Habitats
- Ecological communities

This conceptual model (**Figure 2**) progresses from *fishery characteristics* of the fishery or sub-fishery, → *fishing activities* associated with fishing and *external activities*, which may impact the five ecological components (target, byproduct and bycatch species, TEP species, habitats, and communities); → *effects of fishing and external activities* which are the direct impacts of fishing and external activities; → *natural processes and resources* that are affected by the impacts of fishing and external activities; → *sub-components* which are affected by impacts to natural processes and resources; → *components*, which are affected by impacts to the sub-components. Impacts to the sub-components and components in turn affect achievement of management objectives.



**Figure 2.** Generic conceptual model used in ERAEF.

The external activities that may impact the fishery objectives are also identified at the Scoping stage and evaluated at Level 1. This provides information on the additional impacts on the ecological components being evaluated, even though management of the external activities is outside the scope of management for that fishery.

The assessment of risk at each level takes into account current management strategies and arrangements. A crucial process in the risk assessment framework is to document the rationale behind assessments and decisions at each step in the analysis. The decision to proceed to subsequent levels depends on

- Estimated risk at the previous level
- Availability of data to proceed to the next level
- Management response (e.g. if the risk is high but immediate changes to management regulations or fishing practices will reduce the risk, then analysis at the next level may be unnecessary).

### ***ERAEF stakeholder engagement process***

A recognized part of conventional risk assessment is the involvement of stakeholders involved in the activities being assessed. Stakeholders can make an important contribution by providing expert judgment, fishery-specific and ecological knowledge, and process and outcome ownership. The ERAEF method also relies on stakeholder involvement at each stage in the process, as outlined below. Stakeholder interactions are recorded.

### ***Scoping***

In the first instance, scoping is based on review of existing documents and information, with much of it collected and completed to a draft stage prior to full stakeholder involvement. This provides all the stakeholders with information on the relevant background issues. Three key outputs are required from the scoping, each requiring stakeholder input.

1. Identification of units of analysis (species, habitats and communities) potentially impacted by fishery activities (section 2.2.2; Scoping Documents S2A, S2B and S2C).
2. Selection of objectives (section 2.2.3; Scoping Document S3) is a challenging part of the assessment, because these are often poorly defined, particularly with regard to the habitat and communities components. Stakeholder involvement is necessary to agree on the set of objectives that the risks will be evaluated against. A set of preliminary objectives relevant to the sub-components is selected by the drafting authors, and then presented to the stakeholders for modification. An agreed set of objectives is then used in the Level 1 SICA analysis. The agreement of the fishery management advisory body (e.g. the MAC, which contains representatives from industry, management, science, policy and conservation) is considered to represent agreement by the stakeholders at large.
3. Selection of activities (hazards) (section 2.2.4; Scoping Document S4) that occur in the sub-fishery is made using a checklist of potential activities provided. The checklist was developed following extensive review, and allows repeatability between fisheries. Additional activities raised by the stakeholders can be included in this checklist (and would feed back into the original checklist). The background information and consultation with the stakeholders is used to finalize the set of activities. Many activities will be self-evident (e.g. fishing, which obviously occurs), but for others, expert or anecdotal evidence may be required.

**Level 1. SICA (Scale, Intensity, Consequence Analysis)**

The SICA analysis evaluates the risk to ecological components resulting from the stakeholder-agreed set of activities. Evaluation of the temporal and spatial scale, intensity, sub-component, unit of analysis, and credible scenario (consequence for a sub-component) can be undertaken in a workshop situation, or prepared ahead by the draft case study author and debated at the stakeholder meeting. Because of the number of activities (up to 24) in each of five components (resulting in up to 120 SICA elements), preparation before involving the full set of stakeholders may allow time and attention to be focused on the uncertain or controversial or high risk elements. The rationale for each SICA element must be documented and this may represent a challenge in the workshop situation. Documenting the rationale ahead of time for the straw-man scenarios is crucial to allow the workshop debate to focus on the right portions of the logical progression that resulted in the consequence score.

SICA elements are scored on a scale of 1 to 6 (negligible to extreme) using a “plausible worst case” approach (see ERAEF Methods Document for details). Level 1 analysis potentially result in the elimination of activities (hazards) and in some cases whole components. Any SICA element that scores 2 or less is documented, but not considered further for analysis or management response.

**Level 2. PSA (Productivity Susceptibility Analysis)**

The semi-quantitative nature of this analysis tier should reduce but not eliminate the need for stakeholder involvement. In particular, transparency about the assessment will lead to greater confidence in the results. The components that were identified to be at moderate or greater risk (SICA score > 2) at Level 1 are examined at Level 2. The units of analysis at Level 2 are the agreed set of species, habitat types or communities in each component identified during the scoping stage. A comprehensive set of attributes that are proxies for productivity and susceptibility have been identified during the ERAEF project. Where information is missing, the default assumption is that risk will be set high. Details of the PSA method are described in the accompanying ERAEF Methods Document. Stakeholders can provide input and suggestions on appropriate attributes, including novel ones, for evaluating risk in the specific fishery. The attribute values for many of the units (e.g. age at maturity, depth range, mean trophic level) can be obtained from published literature and other resources (e.g. scientific experts) without full stakeholder involvement. This is a consultation of the published scientific literature. Further stakeholder input is required when the preliminary gathering of attribute values is completed. In particular, where information is missing, expert opinion can be used to derive the most reasonable conservative estimate. For example, if the species attribute values for annual fecundity have been categorized as low, medium and high on the set [ $<5$ , 5-500,  $>500$ ], estimates for species with no data can still be made. Estimated fecundity of a species such as a broadcast-spawning fish with unknown fecundity, is still likely greater than the cutoff for the high fecundity categorization ( $>500$ ). Susceptibility attribute estimates, such as “fraction alive when landed”, can also be made based on input from experts such as scientific observers. The final PSA is completed by scientists because access to computing resources, databases, and programming skills is required. Feedback to stakeholders regarding comments received during the preliminary PSA

consultations is considered crucial. The final results are then presented to the stakeholder group before decisions regarding Level 3 are made. The stakeholder group may also decide on priorities for analysis at Level 3.

### **Level 3**

This stage of the risk assessment is fully-quantitative and relies on in-depth scientific studies on the units identified as at medium or greater risk in the Level 2 PSA. It will be both time and data-intensive. Individual stakeholders are engaged as required in a more intensive and directed fashion. Results are presented to the stakeholder group and feedback incorporated, but live modification is not considered likely.

### **Conclusion and final risk assessment report**

The conclusion of the stakeholder consultation process will result in a final risk assessment report for the individual fishery according to the ERAEF methods. It is envisaged that the completed assessment will be adopted by the fishery management group and used by AFMA for a range of management purposes, including to address the requirements of the EPBC Act as evaluated by Department of the Environment and Heritage.

### **Subsequent risk assessment iterations for a fishery**

The frequency at which each fishery must revise and update the risk assessment is not fully prescribed. As new information arises or management changes occur, the risks can be reevaluated, and documented as before. The fishery management group or AFMA may take ownership of this process, or scientific consultants may be engaged. In any case the ERAEF should again be based on the input of the full set of stakeholders and reviewed by independent experts familiar with the process.

Each fishery case study will be revised at least every four years or as required by Strategic Assessment. However, to ensure that actions in the intervening period do not unduly increase ecological risk, each year certain criteria will be considered. At the end of each year, the following trigger questions should be considered by the MAC for each sub-fishery.

- Has there been a change in the spatial distribution of effort of more than 50% compared to the average distribution over the previous four years?
  - Has there been a change in effort in the fishery of more than 50% compared to the four year average (e.g. number of boats in the fishery)?
  - Has there been an expansion of a new gear type or configuration such that a new sub-fishery might be defined?
- Responses to these questions should be tabled at the relevant fishery MAC each year and appear on the MAC calendar and work program. If the answer to any of these trigger questions is yes, then the sub-fishery should be reevaluated.

## 2. Methodology

The focus of analysis is the fishery as identified by the responsible management authority. The assessment area is defined by the fishery management jurisdiction within the AFZ. The fishery may also be divided into sub-fisheries on the basis of fishing method and/or spatial coverage. These sub-fisheries should be clearly identified and described during the scoping stage. Portions of the scoping and analysis at Level 1 and beyond, is specific to a particular sub-fishery. The fishery is a group of people carrying out certain activities as defined under a management plan. Depending on the jurisdiction, the fishery/sub-fishery may include any combination of commercial, recreational, and/or indigenous fishers.

Section 2 outlines the ERA methods for each level scoping, Level 1 and Level 2, together with instructions, proforma documents and examples required to complete an ERA as follows:

- Executive summary
- Stakeholder engagement (2.1)
- Scoping (2.2)
- Level 1 Scale, Intensity and Consequence Analysis (2.3)
- Level 2 Productivity and Susceptibility Analysis (2.4)
- Level 3 review of research work done at this level (2.5)

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## Executive Summary: an example of an assessment

Fishery: Southern and Eastern Scalefish and Shark Fishery (SESSF)  
Sub-Fishery: otter trawl component of Commonwealth Trawl Sector

### Assessment Method

This assessment of the ecological impacts of the otter trawl fishery was undertaken using the ERAEF method version 9.2. ERAEF stands for “Ecological Risk Assessment for Effect of Fishing”, and was developed jointly by CSIRO Marine and Atmospheric Research, and the Australian Fisheries Management Authority. ERAEF provides a hierarchical framework for a comprehensive assessment of the ecological risks arising from fishing, with impacts assessed against five ecological components – target species; by-product and by-catch species; threatened, endangered and protected (TEP) species; habitats; and (ecological) communities.

ERAEF proceeds through four stages of analysis: scoping; an expert judgement based Level 1 analysis (SICA – Scale Intensity Consequence Analysis); an empirically based Level 2 analysis (PSA – Productivity Susceptibility Analysis); and a model based Level 3 analysis. This hierarchical approach provides a cost-efficient way of screening hazards, with increasing time and attention paid only to those hazards that are not eliminated at lower levels in the analysis. Risk management responses may be identified at any level in the analysis.

Application of the ERAEF methods to a fishery can be thought of as a set of screening or prioritization steps that work towards a full quantitative ecological risk assessment. At the start of the process, all components are assumed to be at high risk. Each step, or Level, potentially screens out issues that are of low concern. The Scoping stage screens out activities that do not occur in the fishery. Level 1 screens out activities that are judged to have low impact, and potentially screens out whole ecological components as well. Level 2 is a screening or prioritization process for individual species, habitats and communities at risk from direct impacts of fishing. The Level 2 methods do not provide absolute measures of risk. Instead they combine information on productivity and exposure to fishing to assess potential risk – the term used at Level 2 is risk. Because of the precautionary approach to uncertainty, there will be more false positives than false negatives at Level 2, and the list of high risk species or habitats should not be interpreted as all being at high risk from fishing. Level 2 is a screening process to identify species or habitats that require further investigation. Some of these may require only a little further investigation to identify them as a false positive; for some of them managers and industry may decide to implement a management response; others will require further analysis using Level 3 methods, which do assess absolute levels of risk.

This assessment of the SESSF otter trawl fishery includes the following:

- Scoping
- Level 1 results for all components
- Level 2 results for the three species components, and for habitats

Level 3 assessments (quantitative stock assessments) have been undertaken for a number of the target species, but are not formally part of the ERA and are not reported here.

### **Fishery Description**

Gear:	Otter trawl (minimum 90mm cod-end)
Area:	Barrenjoey Point (Sydney) to Cape Jervis (Adelaide)
Depth range:	20 to 1300m
Fleet size:	100 vessels (76 active in 2005)
Effort:	Approximately 40,000 shots per year
Landings:	19,065 t in 2005
Discard rate:	Quota species 8%; non-quota species 68% (2003)
Main target species:	flathead, morwong, redfish, ling, blue grenadier, orange roughy
Management:	Quota management system for 34 species/stocks
Observer program:	ISMP program operating since mid 1990s

### **Ecological Units Assessed**

Target species:	28
By-product species:	95
Discard Species:	276
TEP species:	201
Habitats:	158
Communities:	33

### **Level 1 Results**

No ecological components were eliminated at Level 1 (there was at least one risk score of 3 – moderate – or above for each component).

A number of hazards (fishing activities) were eliminated at Level 1 (risk scores 1 or 2). Those remaining included:

- Fishing (direct and indirect impacts on all 5 ecological components)
- Gear loss (impact on TEP species)
- Translocation of species (impact on habitats)
- Discarding catch (impact on TEP species)
- Navigation/steaming (impact on target species)
- Activity/presence on water (impact on target species and communities)
- Fishing through physical disturbance (impact on habitats and communities)

Significant external hazards included other fisheries in the region, coastal development, and other extractive activities.

Risks rated as major or above (risk scores 4 or 5) were all related to direct or indirect impacts from primary fishing operations. Severe impacts (risk score 5) were confined to habitats and byproduct/bycatch species.

Impacts from fishing on all species components and on habitats were assessed in more detail at Level 2.

## **Level 2 Results**

### Species

There were 600 species assessed at Level 2 using the PSA analysis. Of these, 159 were assessed to be at high risk, including 15 target species, 39 by-product species, 99 by-catch species, and 6 TEP species. By taxa, the high risk species comprised 58 chondrichthyans (sharks and rays), 96 teleosts (boney fishes), 4 marine birds, and 1 marine mammal. Of the 600 species assessed at Level 2, expert over rides were used on 166 species. Of the 159 species assessed to be at high risk, 4 had more than 3 missing attributes.

All the target species are managed through the quota system, and the recent introduction of strict harvest strategies for this group should provide the foundation for ongoing sustainability of catches into the future. Of the 6 TEP species assessed to be at high risk, the four birds are at high due to lack of information. The single marine mammal at high risk (Australian fur seal) has low productivity and high susceptibility. It is captured by the fishery, but its overall population has increased in recent years (Stewardson and Knuckey (2005)). The single TEP teleost at high risk is the spiny pipehorse, which is occasionally found entangled in fishing gear (40 observations in 2004).

The main ecological sustainability issue for species appears to be a number of teleost and chondrichthyan species taken as by-product and by-catch in the fishery. In general, the chondrichthyan species are at high risk because of low productivity, and the teleost species because of high exposure to fishing (high proportion of range within the fishery, live in habitats that are likely to encounter the gear, and are the right size to be selected by the fishery).

### Habitats

158 habitats were assessed at Level 2 using the habitat PSA analysis. Habitat types were classified based on substratum, geomorphology, and dominant fauna, using photographic data. Of the 158 habitat types, 46 were assessed to be at high risk, 58 medium, and 54 low. Of the high risk habitats, none were found on the inner shelf (0-100m), 18 were on the outer shelf (100-200m), 12 were on the upper slope (200-700m), and 16 were on the mid slope (700-1500m). These depth categories are somewhat different from those used for species.

High risk mid slope habitats include several categories of hard bottom (but still accessible to trawl gear) with delicate epifauna consisting of octocorals, crinoids, small sponges, and sedentary animals. There are also several types of soft bottom habitat that support large, erect or delicate epifauna. Habitats of seamount and canyon features occur at this depth zone.

High risk habitats on the upper slope also include several hard bottom types, in this case dominated by large sponges not seen on the mid slope. There are also several soft bottom habitats based on bryozoan communities which are restricted to a narrow zone near the shelf break. Habitats of canyon features occur at this depth zone.

High risk habitats on the outer shelf include soft sediment seabed types interspersed with harder bottom supporting large sponges, mixed epifauna, and the bryozoan communities at the shelf break.

### Communities

The community component was not assessed at Level 2 for the otter trawl sub-fishery, but should be considered in future assessments when the methods to do this are fully developed.

### **Summary**

Two key issues emerge from the ERAEF analysis of the SESSF otter trawl fishery. Both are related to direct impacts from fishing, one on certain vulnerable benthic habitats, and the other on a suite of byproduct and bycatch species not currently managed directly through the quota management system. For both these components, there are species or habitats at risk across a broad range of depths, from the outer shelf to the lower slope (with some inner shelf species also at risk).

### **Managing identified risks**

Using the results of the ecological risk assessment, the next steps for each fishery will be to consider and implement appropriate management responses to address these risks. To ensure a consistent process for responding to the ERA outcomes, AFMA has developed an Ecological Risk Management (ERM) framework.

## **2.1 Stakeholder Engagement**

### **2.1 Proforma: Summary Document SD1. Summary of stakeholder involvement for fishery [INSERT FISHERY NAME]**

Case study stage	Type of stakeholder interaction	Date of stakeholder interaction	Composition of stakeholder group (names or roles)	Summary of outcome
Scoping	Phone calls and email		<i>e.g. AFMA fishery manager, AFMA logbook manager</i>	<i>e.g. Information considered sufficient to move to Level 1</i>
	Review by fishers		<i>e.g. Executive Officer of fishery distributed to fishers</i>	<i>e.g. April 24, feedback on preferred objectives was provided Hazards agreed on.</i>
Level 1 (SICA)	Workshop		<i>e.g. MAC (managers,</i>	<i>e.g. Debated the credible scenarios, and required</i>

Case study stage	Type of stakeholder interaction	Date of stakeholder interaction	Composition of stakeholder group (names or roles)	Summary of outcome
			<i>fishers, science, environment)</i>	<i>explanation of the consequence scoring</i>
	Workshop		<i>e.g. MAC (managers, fishers, science, environment)</i>	<i>e.g. Agreed that Level 1 is acceptable</i>
Level 2 (PSA)	Email		<i>e.g. Fred Expert</i>	<i>e.g. Supplied estimates of age at maturity for 64 shark species without published ages</i>
	Workshop		<i>e.g. MAC (managers, fishers, science, environment)</i>	<i>E.g. Contributed expert judgments on missing attributes. Agreed that Level 2 is acceptable</i>

## 2.2 Scoping

The aim in the Scoping stage is to develop a profile of the fishery being assessed. This provides information needed to complete Levels 1 and 2 and at stakeholder meetings. The focus of analysis is the fishery, which may be divided into sub-fisheries on the basis of fishing method and/or spatial coverage. Scoping involves six steps:

- Step 1 Documenting the general fishery characteristics (2.2.1)
- Step 2 Generating “unit of analysis” lists (species, habitat types, communities) (2.2.2)
- Step 3 Selection of objectives (2.2.3)
- Step 4 Hazard identification (2.2.4)
- Step 5 Bibliography (2.2.5)
- Step 6 Decision rules to move to Level 1 (2.2.6)

Instructions: Scoping documents to be completed are:

- Step 1 General Fishery Characteristics - Scoping document S1
- Step 2 Unit list (target, byproduct/bycatch, TEP, habitats, communities) Scoping document S2
- Step 3 Identification of Objectives - Scoping document S3
- Step 4 Hazard identification – Scoping document S4
- Step 5 Bibliography

### 2.2.1 General Fishery Characteristics (Step 1).

The general fishery characteristics document provides a reference for discussions and clarification of analysis for Levels 1 and 2 at stakeholder meetings.

The information used to complete this step may come from a range of documents as listed below and any other relevant background documents. The level and range of information available will vary. Some fisheries/sub-fisheries will have a wide range of reliable information, whereas others may have limited information.

Key documents can be found on the AFMA web page at [www.afma.gov.au](http://www.afma.gov.au) and include the following:

- Assessment Report
- Management Plan
- Management Regulations
- Management Plan and Regulation Guidelines
- AFMA At a glance web page  
[http://www.afma.gov.au/fisheries/etbf/at\\_a\\_glance.php](http://www.afma.gov.au/fisheries/etbf/at_a_glance.php)
- Bycatch Action Plans
- Data Summary Reports (logbook and observer)

Other publications that may provided information include

- BRS Fishery Status Reports
- Strategic Plans

Information may also be obtained from:

- Experts and other key people

Once the above information has been obtained the following proforma document can be completed.

#### Scoping Document S1 General Fishery Characteristics

Fishery Name:

Date of assessment:

Assessor:

<i>General Fishery Characteristics</i>	
<b>Fishery Name</b>	
<b>Sub-fisheries</b>	<i>Identify sub-fisheries on the basis of fishing method/area.</i>
<b>Sub-fisheries assessed</b>	<i>The sub-fisheries to be assessed on the basis of fishing method/area in this report.</i>
<b>Start date/history</b>	<i>Provide an indication of the length of time the fishery has been operating.</i>
<b>Geographic extent of fishery</b>	<i>The geographic extent of the managed area of the fishery. Maps of the managed area and distribution of fishing effort should be included in the detailed description below, or appended to the end of this table.</i>
<b>Regions or Zones within the fishery</b>	<i>Any regions or zones used within the fishery for management purposes and the reason for these zones if known</i>
<b>Fishing season</b>	<i>What time of year does fishing in each sub-fishery occur?</i>
<b>Target species and stock status</b>	<i>Species targeted and where known stock status.</i>
<b>Bait Collection and usage</b>	<i>Identify bait species and source of bait used in the subfishery. Describe methods of setting bait and trends in bait usage.</i>
<b>Current entitlements</b>	<i>The number of current entitlements in the fishery. Note latent entitlements. Licences/permits/boats and number active.</i>
<b>Current and recent TACs, quota trends by method</b>	<i>The most recent catch quota levels in the fishery by fishing method (sub-fishery). Summary of the recent quota levels in the fishery by fishing method (sub-fishery). In table form</i>
<b>Current and recent fishery effort trends by method</b>	<i>The most recent estimate of effort levels in the fishery by fishing method (sub-fishery). Summary of the recent effort trends in the fishery by fishing method (sub-fishery). In table form</i>
<b>Current and recent fishery catch trends by method</b>	<i>The most recent estimate of catch levels in the fishery by fishing method (sub-fishery) (total and/or by target species). Summary of the recent catch trends in the fishery by fishing method (sub-fishery). In table form</i>
<b>Current and recent value of fishery (\$)</b>	<i>Note current and recent value trends by sub-fishery. In table form</i>
<b>Relationship with other fisheries</b>	<i>Commercial and recreational, state, national and international fisheries List other fisheries operating in the same region any interactions</i>
<i>Gear</i>	
<b>Fishing gear and methods</b>	<i>Description of the methods and gear in the fishery, average number days at sea per trip.</i>
<b>Fishing gear restrictions</b>	<i>Any restrictions on gear</i>
<b>Selectivity of gear and fishing methods</b>	<i>Description of the selectivity of the sub-fishery methods</i>
<b>Spatial gear zone set</b>	<i>Description where gear set i.e. continental shelf, shelf break, continental slope (range nautical miles from shore)</i>
<b>Depth range gear set</b>	<i>Depth range gear set at in metres</i>
<b>How gear set</b>	<i>Description how set, pelagic in water column, benthic set (weighted) on seabed</i>
<b>Area of gear impact per set or shot</b>	<i>Description of area impacted by gear per set (square metres)</i>

<b>Capacity of gear</b>	<i>Description number hooks per set, net size weight per trawl shot</i>
<b>Effort per annum all boats</b>	<i>Description effort per annum of all boats in fishery by shots or sets and hooks, d for all boats</i>
<b>Lost gear and ghost fishing</b>	<i>Description of how gear is lost, whether lost gear is retrieved, and what happens to gear that is not retrieve, and impacts of ghost fishing</i>
<i>Issues</i>	
<b>Target species issues</b>	<i>List any issues, including biological information such as spawning season and spawning location, major uncertainties about biology</i>
<b>Byproduct and bycatch issues and interactions</b>	<i>List any issues, as for the target species above</i>
<b>TEP issues and interactions</b>	<i>List any issues. This section should consider all TEP species groups: marine mammals, chondrichthyans (sharks, rays etc.), marine reptiles, seabirds, teleosts (bony fishes), include any key spawning/breeding/aggregation locations that might overlap with the fishery/sub-fishery.</i>
<b>Habitat issues and interactions</b>	<i>List any issues for any of the habitat units identified in <b>Scoping Document S1.2</b>. This should include reference to any protected, threatened or listed habitats</i>
<b>Community issues and interactions</b>	<i>List any issues for any of the community units identified in <b>Scoping Document S1.2</b>.</i>
<b>Discarding</b>	<i>Summary of discarding practices by sub-fishery, including bycatch, juveniles of target species, high-grading, processing at sea.</i>
<i>Management: planned and those implemented</i>	
<b>Management Objectives</b>	<i>The management objectives from the most recent management plan</i>
<b>Fishery management plan</b>	<i>Is there a fisheries management plan is it in the planning stage or implemented what are the key features</i>
<b>Input controls</b>	<i>Summary of any input controls in the fishery, e.g. limited entry, area restrictions (zoning), vessel size restrictions and gear restrictions. Primarily focused on target species as other species are addressed below.</i>
<b>Output controls</b>	<i>Summary of any output controls in the fishery, e.g. quotas. Effort days at sea. Primarily focused on target species as other species are addressed below.</i>
<b>Technical measures</b>	<i>Summary of any technical measures in the fishery, e.g. size limits, bans on females, closed areas or seasons. Gear mesh size, mitigation measures such as TEDs. Primarily focused on target species as other species are addressed below.</i>
<b>Regulations</b>	<i>Regulations regarding species (bycatch and byproduct, TEP), habitat, and communities; Marpol and pollution; rules regarding activities at sea such as discarding offal and/or processing at sea.</i>
<b>Initiatives and strategies</b>	<i>BAPs; TEDs; industry codes of conduct, MPAs, Reserves</i>
<b>Enabling processes</b>	<i>Monitoring (logbooks, observer data, scientific surveys); assessment (stock assessments); performance indicators (decision rules, processes, compliance; education; consultation process</i>
<b>Other initiatives or agreements</b>	<i>State, national or international conventions or agreements that impact on the management of the fishery/sub-fishery being evaluated.</i>
<b>Data</b>	
Logbook data	<i>Verified logbook data; data summaries describe programme</i>
Observer data	<i>Objective observer programme; describe parameters, how many years run; coverage – random or full coverage; comments on interactions with species; observer training, species identification, and length of service; data summaries</i>
Other data	<i>Studies, surveys</i>

### 2.2.2 Unit of Analysis Lists (Step 2)

There are three categories of units; species, habitats and communities.

Establish which units of analysis should be considered for a particular sub fishery. Units of Analysis form the basis of the Level 1: Scale Intensity and Consequence Analysis (SICA) and Level 2: Productivity and Susceptibility Analysis (PSA). These lists are presented to stakeholders for verification.

The methods of identifying unit of analysis for the species, habitats and communities are outlined below:

*Identification of Units: Species (Target, Byproduct/Bycatch, TEP)*

Identification of species units (target, bycatch/byproduct and TEP species) potentially impacted by fishery activities is part of the scoping process. Identification of target, bycatch and byproduct species impacted in the fishery is often possible through existing data and reports. Potentially impacted TEP species are often poorly documented, perhaps as not all interactions result in death; thus, a wide variety of sources and experts should be consulted to generate potential species. Expert judgment and anecdotal evidence is also used to compile this preliminary species list. Stakeholders are then consulted, individually and at fishery management meetings, on the preliminary list and additions and deletions made, with rationale recorded for the particular decisions. Each species identified during the scoping is added to the ERAEF database used to run the Level 2 analyses. A CAAB code (Code for Australian Aquatic Biota) is required to input the information. The CAAB codes for each species may be found at <http://www.marine.csiro.au/caab/>

Target species [sub-fishery]

List the target species of the sub- fishery. This list is obtained by reviewing all available fishery literature, including logbooks, observer reports and discussions with stakeholders. Target species are as agreed by the fishery.

Byproduct species [sub-fishery]

List the byproduct species of the sub- fishery. Byproduct refers to any part of the catch which is kept or sold by the fisher but which is not a target species. This list is obtained by reviewing all available fishery literature, including logbooks, observer reports and discussions with stakeholders.

Discard species [sub-fishery]

List the discard (bycatch) species (excluding TEP species) of the sub-fishery. Bycatch as defined in the Commonwealth Policy on Fisheries Bycatch 2000 refers to:

- that part of a fisher's catch which is returned to the sea either because it has no commercial value or because regulations preclude it being retained; and
- that part of the 'catch' that does not reach the deck but is affected by interaction with the fishing gear

However, in the ERAEF method, the part of the target or byproduct catch that is discarded is included in the assessment of the target or byproduct species. The list of bycatch species is obtained by reviewing all available fishery literature, including logbooks, observer reports and discussions with stakeholders.

### TEP species [sub-fishery]

List the TEP species that occur in the area of the sub-fishery. Highlight species that are known to interact directly with the fishery. TEP species are those species listed as Threatened, Endangered or Protected under the EPBC Act.

TEP species are often poorly listed by fisheries due to low frequency of direct interaction. Both direct (capture) and indirect (e.g. food source captured) interaction are considered in the ERAEF approach. A list of TEP species has been generated for each fishery and is included in the PSA workbook species list. This list has been generated using the DEH Search Tool from DEH home page <http://www.deh.gov.au/>

For each fishery, the list of TEP species is compiled by reviewing all available fishery literature. Species considered to have potential to interact with fishery (based on geographic range & proven/perceived susceptibility to the fishing gear/methods and examples from other similar fisheries across the globe) should also be included.

### *Identification of Units: Habitats*

The Ecological Risk Assessment for the Effects of Fishing (ERAEF) addresses habitat as one of five components of the ecosystem. Habitat defined simply is the “place where an organism lives” (Bax et al.1999). Habitat not only represents the fundamental ecological unit in which species interact, but is the matrix that supports an essential range of ecological processes which sustain ecosystem health. The loss or impairment of habitat integrity therefore results in direct impacts to species, communities and ecosystem structure and function (Bax & Williams 2001, Bax et al.1999).

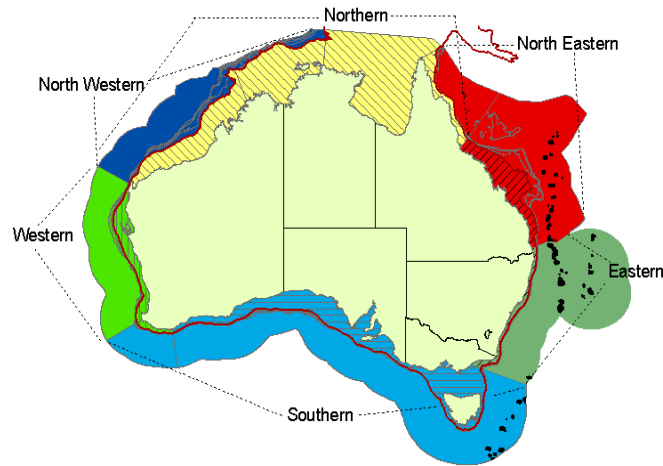
Pelagic habitat is typically the water-column and defined on the basis of Pelagic Regionalisation (Commonwealth of Australia, 2005), and ERAEF Community Component definitions (ERAEF Methodology, 2006). Data on the types and distributions of benthic habitat in Australia’s Commonwealth fisheries are generally sparse. As a result, this methodology has been applied to the classification system derived for South Eastern Habitat data<sup>1</sup> and formulated around image data availability and project requirements including delivery timelines. The ERAEF methodology is designed to assess habitat risk to a range of activities associated with fishing. Its objective is to create a broad assessment which can be applied generically to the great variety of habitats occurring within Commonwealth fishery areas that extend from tropical to sub-Antarctic water masses over 115° of longitude and 46° of latitude. The basic unit is a habitat type, defined as either pelagic (encompassing the water-column), or benthic (the seafloor structure including its attached invertebrate fauna).

Scoping involves identifying the habitat units (‘types’) occurring within the jurisdictional boundary of the (sub) fishery. The pelagic habitats considered are as delineated by the pelagic boundaries described for the ERAEF Communities Component (**Figure 3**). These are adapted from the Bioregionalisation project which

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<sup>1</sup> Habitat data acknowledgements: CMAR video surveys from Southeastern Australia (1994- 2001), Great Australian Bight (SS200001, SS200507, SS200510), A. Williams, B. Barker, F. Althaus.

defines pelagic provinces based on oceanographic properties in relation to their depth and proximity to land, and underlying water masses (**Table 1**).



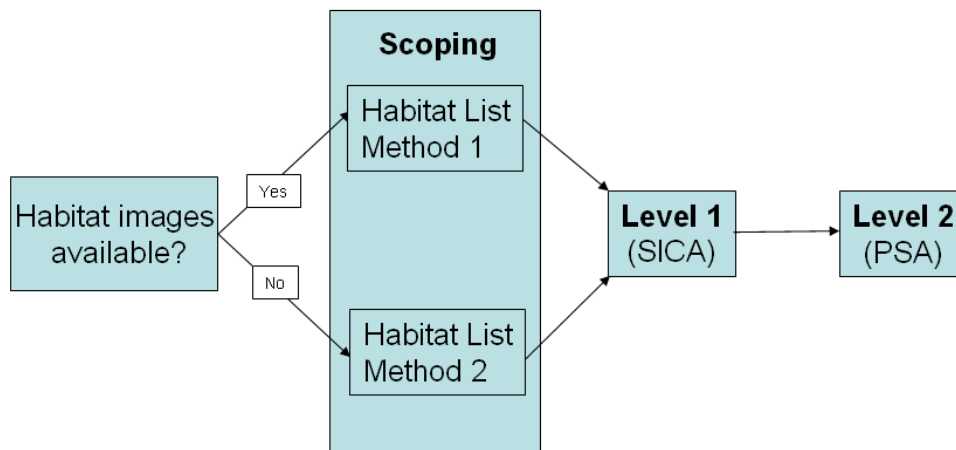
**Figure 3. Boundaries of Australian pelagic provinces including communities, defined by region and depth (Bulman et al., unpublished).**

**Table 1. Australian pelagic provinces and communities used in ERAEF.**

Pelagic Province	Community	Depth range	
Eastern	Coastal pelagic	0	200
	Oceanic (1)	0	600
	Oceanic (2)	>600	depth at EEZ
	Seamount oceanic (1)	0	600
	Seamount oceanic (2)	> 600	
Southern	Coastal pelagic Tas	0	200
	Coastal pelagic GAB	0	200
	Oceanic (1)	0	200
	Oceanic (2)	200	600
	Oceanic (3)	>600	depth at EEZ
	Seamount oceanic (1)	0	200
	Seamount oceanic (2)	200	600
	Seamount oceanic (3)	>600	
Western	Coastal pelagic	0	200
	Oceanic (1)	0	400
	Oceanic (2)	>400	depth at EEZ
Northern	Coastal NWS	0	200
	Coastal Bonaparte	0	200
	Coastal Arafura	0	200
	Coastal Gulf	0	200
	Coastal East Cape York	0	200
Northwestern	Oceanic (1)	0	800
	Oceanic (2)	>800	depth at EEZ
Northeastern	Coastal	0	200
	Oceanic (1)	0	600
	Oceanic (2)	>600	depth at EEZ
	Plateau (1)	0	600
	Plateau (2)	>600	depth at EEZ

Pelagic Province	Community	Depth range	
	Seamount oceanic (1)	0	600
	Seamount oceanic (2)	>600	depth at EEZ
Heard/McDonald Islands	Heard Plateau	0	1000
	Oceanic (1)	0	1000
	Oceanic (2)	>1000	depth at EEZ
Macquarie Island	Coastal	0	250
	Oceanic (1)	0	1600
	Oceanic (2)	>1600	depth at EEZ

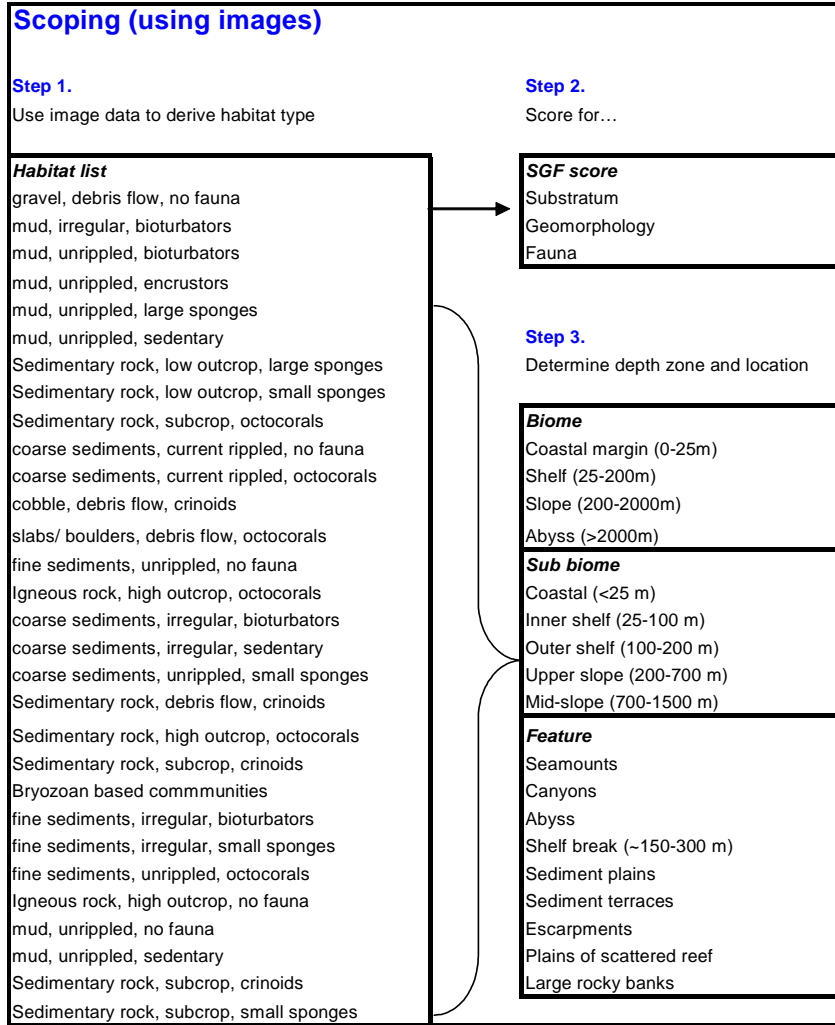
Identifying benthic habitat types that occur within Australia's Exclusive Economic Zone has proved challenging due to the dispersed and variable nature of habitat data generally. Whatever data does exist varies in type, scale, quality and consistency, and perhaps most importantly, accessibility. To date two methods exist that direct the construction of habitat scoping lists, Scoping Method 1: requires image data, or Scoping Method 2: no image data (**Figure 4**). The method used in the absence of image data is precautionary, and may contain habitat types that can be eliminated from consideration as additional data becomes available.



**Figure 4. Generating the list of habitat types (units of analysis) for the ERAEF habitat component depends on the availability of images. Two methods are thus possible for the Scoping stage. Thereafter, the same process is applied.**

#### Method 1 for identifying habitat types

The preferred methodology (Habitat Scoping Method 1) is constructed around digital image data from various (CSIRO) video surveys which have provided a wide range of information for temperate Australian seafloor habitats, and underpinned the development of the methodology (**Figure 5**).



**Figure 5. Habitat Scoping Method 1: used to derive a list of habitats when images of habitat type are available (Habitat list at Step 1 is a representative example only). Steps 1-3 outline information required.**

To divide a continuous benthos into discrete habitat types requires a classification scheme. Currently there is no universally accepted benthic classification scheme, although some provide terminology or structures that are widely used (e.g. Greene et al. 1999, Roff & Taylor 2000, Kostylev et al. 2001). For most fisheries, Scoping Method 1 can be applied (Figure 5). This requires a representative sample of still images that have been extracted from video taken within the fishery area, and matching data acquired from the images using the habitat classification scheme of Kloser et al. (2000) adapted by Althaus and Barker (unpublished 2005) (**Table 2**).

**Table 2. SGF Scoring Categories: Substratum (S), Geomorphology (G), Fauna (F). Each category describes a gradient of classes, recognised in temperate southeastern waters. Where it has been apparent that these do not adequately describe habitats found in western, northern, northeastern or sub-antarctic waters, categories have been expanded to accommodate additional data. Note: only attached invertebrates are considered within habitat, therefore the faunal class for mobile species (8) is excluded here. Mobile benthic species are considered within the community component (modified from Althaus and Barker, unpublished 2005).**

SUBSTRATUM			GEOMORPHOLOGY			FAUNA		
code	NAME (hardness)	DESCRIPTION	code	NAME	DESCRIPTION	code	NAME	DESCRIPTION
0	Mud (soft)  (approx. <0.1 mm)	Very fine mud sediments. At times it is difficult to discern between what could be mud and the next level of this field (fine sediments). Mud has a silt-like, soft appearance and may appear flat or irregular in topography. Easily stirred up with contact, significantly contributes to turbidity	0	Unrippled/Flat	The seafloor sediment topography is generally flat with no significant sign of rippling due to currents, wave action or intensive bioturbation	0	No fauna	No apparent epifauna or infauna
1	Fine sediments (soft)  (approx 0.1-1 mm)	Sediments still appear to be very fine but with a slightly coarser appearance than mud. This may mean a mixed composition of mud and slightly larger clasts (fine sands), but with the appearance of being more stable (less likely to be swept away by moderate currents or existing in a high energy, wave affected area).	1	Current rippled/directed scour	Sediment rippling in the topography due to currents. The pattern of rippling can be uniform continuous waves or of stippled irregular pattern throughout. Current rippled also applies for areas where the sediments have been scoured around the edges of consolidated substratum. In the case of regular continuous current ripples, the profile of the topography is such that it appears as though the lee side of the mound is steeper than that of the side facing the direction of the current.	1	Large/erect sponges	Large and/or erect sponges dominate aggregated epifauna. Often associated with hard bottom, on either subcropping or outcropping rock, consolidated sediments or substantial exposed patches of "hard" substrata.  (solitary large sponges included in this category)
2	Coarse sediments (soft)  (approx 1-4 mm)	Sediments consist of, or contain a significant proportion of larger clasts than that of the fine sediments. These clasts may	2	Wave rippled	Topography showing signs of rippling due to wave base action. The forward and back wave action causes these ripples to be similar in profile	2	Small/low sponges	Small or low & encrusting sponges dominate potentially mixed fauna. Associated with "hard" substrata. Also includes the small, low

SUBSTRATUM			GEOMORPHOLOGY			FAUNA		
code	NAME (hardness)	DESCRIPTION	code	NAME	DESCRIPTION	code	NAME	DESCRIPTION
		range from a coarse sand matrix through to larger fragments of shell/ biogenic debris distributed throughout finer sediments.			on both sides of the ripple.			standing sponges sometimes seen on apparently "soft" substratum.  (solitary small sponges included in this category)
3	Gravel/pebble (hard)  (approx 4-60 mm)	Substratum consists of sediments that include of a significant proportion of larger clasts. These clasts may be biogenic in origin i.e. larger dead shell/ bryozoan/ coral debris or larger clasts of a terrigenous origin. The gravel/pebble class provides points for attachment of faunas i.e. small encrusting sponges and bryozoans. There are times that this class is extrapolated to areas with a generally finer substratum class but with sometimes subtle, just discernible attached communities in the imagery – evidence for hardness.	3	Irregular	The topography is highly irregular with no regular patterning suggestive of currents or wave action. Mounds and depressions consistently across the seafloor are considered to be due to heavy bioturbation or, in some areas, structure created by bryozoan thickets.	3	Mixed faunal community	Mixed, attached, invertebrate community of diverse composition and morphology. Characteristically dominated by large or erect species. Includes all taxa, typically, octocorals, bryozoans, large compound/colonial ascidia, sponges, other hard corals, sponges, and encrusting forms.
4	Cobble/boulder/slab (hard)  (approx 60 mm – 3 m)	Observed clasts are larger in dimension than that of gravel/pebble. A broad range of clast sizes ranging from a clast of about cricket ball size to that of a clast of the approximate size of a small car. 'Slabs' are flat boulders of friable sedimentary rock.	4	Debris flow /rubble banks	There is evidence of larger substratum clasts (gravel/pebble, cobble/boulder) existing in flows or banks. The area is characterized by a large number of these clasts being visible in the area. At times the exposed edges of the flow or bank provide an insight into what probably is occurring in the vicinity	4	Crinoids	Stalked crinoids dominate the faunal composition of the habitat. They tend to be associated with hard substratum for attachment, typically sedimentary slabs or boulders. Filter feeders that inhabit areas with relatively high currents, in a distinct depth range.  (solitary stalked crinoids also included in this class)

SUBSTRATUM			GEOMORPHOLOGY			FAUNA		
code	NAME (hardness)	DESCRIPTION	code	NAME	DESCRIPTION	code	NAME	DESCRIPTION
5	Igneous/ Metamorphic Rock (>3 m)	Consolidated substratum that is more extensive than boulders. This class is used where hard e.g. granite, dolerite or volcanic rock is observed. The geomorphology of the general area is taken into consideration based on other observations.	5	Subcrop	Applies where either consolidated substratum (rock) is protruding from surrounding sediments, or where there are signs of consolidated substratum underlying a sediment veneer. Often appears as intermittent protrusions of this "hard" substratum and areas in between covered with finer sediments. Extrapolation of this class is applied in areas where it is considered that the underlying subcrop prevails, generally with larger attached faunas evident.	5	Octocorals  (gorgonians, seawhips, soft corals)	Octocorals dominate potentially mixed fauna. Commonly, seawhips on soft grounds, Gorgonians and soft corals tending to be associated with "hard" bottom e.g. outcropping or subcropping rock/ biogenic base. Dominants in relatively shallow zones in warmer waters, and in cool temperate waters, in deeper waters (200- 1500m) e.g gold corals.  (solitary octocorals also scored 5)
6	Sedimentary Rock (>3m)	Consolidated substratum that is more extensive than boulders. This class is used where e.g. sandstones, mudstones, and limestones are observed. The geomorphology of the general area is taken into consideration based on other observations, however, where rock type is unclear, this class becomes the default.	6	Low Outcrop  (no holes or cracks)	Low relief outcrops (less than 1 m in height) without any holes and cracks. This class is distinguished by a protrusion of consolidated substrate forming either a sheer edge or undercut, or without an appreciable undercut. Slabs are included under 6.	6	Low encrustings	Mixed small/ low encrusting invertebrate community. Fauna includes the bryozoa, ascidiacea, noncoralline algae, tube worms and other molluscs attached via abyssal threads. This category also includes unique Bryozoan communities, typically from the shelf-break (150-300m).
7	Biogenic	Consolidated substratum that is more extensive than boulders. This class is used where substratum of biogenic calcium carbonate (limestone) is observed e.g Depositions of skeletal material forming coral reef base or biogenic sediments as irregular sized debris. The	7	Low Outcrop  (with holes and cracks)	Low relief outcrops (less than 1 m in height) with holes and cracks. This class is distinguished by a protrusion of consolidated substrate forming either a sheer edge with holes and cracks and undercuts.	7	Solitary / sedentary	Solitary sedentary/ sessile epifauna (i.e. individuals). Examples include seapens, ascidians, other taxa.  NOT sponges, crinoids or other octocorals (they are scored as above)

SUBSTRATUM			GEOMORPHOLOGY			FAUNA		
code	NAME (hardness)	DESCRIPTION	code	NAME	DESCRIPTION	code	NAME	DESCRIPTION
		fauna and geomorphology of the general area is taken into consideration based on other observations.						
X	Not described	Specifically associated with Bryozoan Communities. Substratum unidentified, however are based on 'soft' sediments around the shelf break.	8	High Outcrop (no holes or cracks)	High relief outcrops (more than 1 m in height) without any holes and cracks. Distinguished by a protrusion of consolidated substrate forming either a sheer edge or undercut, or without an appreciable undercut.	9	Bioturbators	Distinct infaunal bioturbators that are discerned by the burrows and tracks over and in "soft" sediments. Somewhat of a default class used where there are "soft" sediments exhibiting a "highly irregular" morphology, indicating the presence of significant infaunal bioturbator communities.
			9	High Outcrop (with holes and cracks)	High relief outcrops (more than 1 m in height) with holes and cracks. Distinguished by a protrusion of consolidated substrate forming a sheer edge or undercut with holes and cracks.	SG	Seagrass Communities	Includes all seagrass species, as a distinction from other alga. . Important habitat as nursery grounds for fish and crustacea, and grazing for threatened species e.g. dugongs.  This is the only algal group considered due to the overlap of both the NPF and TSF with this type of habitat. No other Commonwealth fisheries extend into coastal margin depths where macroalgae may be the dominant faunal taxa.
			X	Not described	Specifically associated with Bryozoan Communities. Geomorphology unidentified, however is based on 'soft' sediments around the shelf	HC	Hard Corals	Hard corals dominate potentially mixed fauna. Typically associated with "hard" bottom e.g. outcropping or subcropping

SUBSTRATUM			GEOMORPHOLOGY			FAUNA		
code	NAME (hardness)	DESCRIPTION	code	NAME	DESCRIPTION break.	code	NAME	DESCRIPTION
								rock/ biogenic base (e.g. dead corals). Dominant taxa in warmer waters. In cool temperate waters, scleractinia are included in the mixed faunal community category  (solitary hard corals also scored 5)
						BV	Bivalve beds	Bivalves communities attached to the substratum by abyssal threads. Identified as significant faunal group in the Gulf of Carpentaria and Torres Strait.

This classification enables three relevant attributes of benthic habitat to be scored for substratum (sediment type), geomorphology (seafloor topography) and fauna (dominant faunal group). The resulting combination generates a list of habitat units or ‘types’ per fishery area e.g. ‘Habitat type X; Sedimentary rock + subcrop + octocorals’, based on the definition that includes the seafloor structure and its attached invertebrate fauna. Although the distributions of habitat types are not mapped at fine scales prior to Level 3 of the ERAEF, the detailed information is ‘nested’ within coarser scales of distribution that enable key characteristics to be inferred. For example, habitat types are located within broad zones of biological distribution – biomes and sub-biomes (defined off temperate Australia by a series of depth zones), as well as prominent geological features, such as submarine canyons and seamounts (**Figure 5**). The features listed in Habitat Scoping Method 1 are discerned from real-time video and acoustic validation.

### Method 2 for identifying habitat types

In regions and fisheries where image data does not exist, or is unable to be used, an alternative approach to the derivation of habitat types is applied. The alternative (Habitat Scoping Method 2) is based primarily on geophysical data and GIS mapping (**Figure 6**). Fishery boundaries

(AFMA 2006) and effort are mapped over bathymetry (at the sub-biomic depth ranges specified in Figure 1), and Geomorphic units (Harris et al. 2003). In future, where available, biological and geophysical survey data (e.g. Heap et al. 2005), and catch/ bycatch data (Logbooks and Observer) can be included. Detail from this mapping provides some understanding of the substratum, geomorphology and fauna, which enables a list of potentially available habitat types to be inferred. This step may be limited to the resolution of habitat types as hard or soft grounds, or include all habitat types that fall into these categories effectively generating a precautionary list of available habitats. The intention is to apply the alternative step only to fisheries lacking visual material, and where it is utilized details of the Method 2 will appear in those case studies.

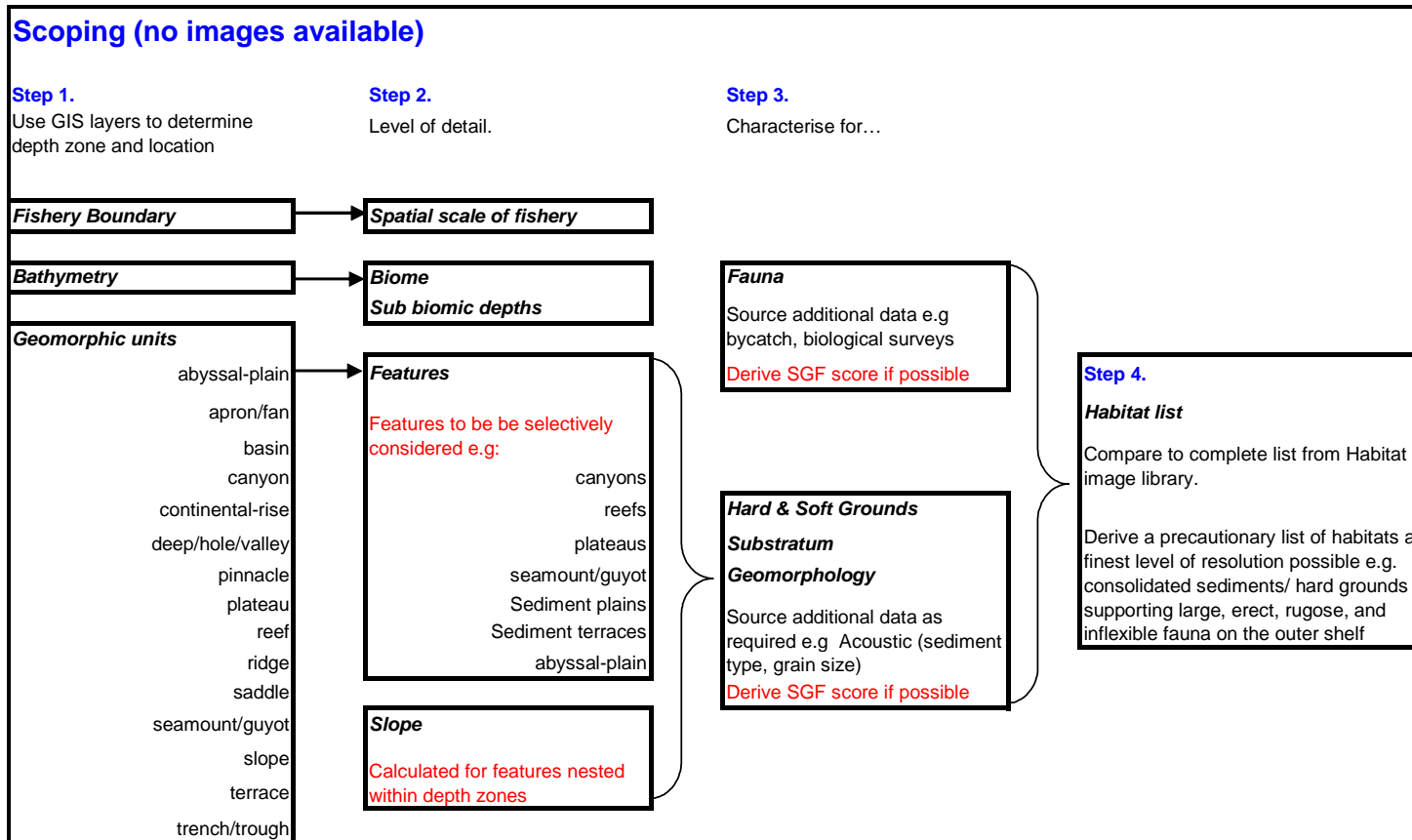


Figure 6. Habitat Scoping Method 2: used in the absence of habitat image data. Steps 1-4 outline information utilised to generate a Habitat list.

### *Identification of Units: Communities*

There can be many interpretations of community from very large-scale, ocean basin species assemblages to the small-scale, such as assemblages of a single taxon or small-scale habitat associations such as infaunal invertebrate communities. Therefore, it was necessary to be clear that, in the ERAEF context, communities on the Australian and sub-Antarctic islands continental shelves and slopes were defined as the species assemblage that occupy the large-scale provinces and biomes generally identified by the bio-regionalisation projects. These projects used fish species' distributions in determining the boundaries of the provinces and therefore have an underlying biotic basis well-suited to our purposes.

Community biota are classified as all mobile fauna, vertebrate or invertebrate, but not including sessile organisms such as coral that are largely structural and therefore classified as habitat. In most cases, the generated community lists will comprise largely vertebrate species because information is more readily available for them. The species lists for the communities assessed in the present ERAEF process were compiled initially from searching the CAAB database (Rees *et al.* 2005) by string locators for the "community province" and depth zone. However, these lists were representative of only demersal or demersally-caught fish species and so we collated information from other sources such as the TEP and target species lists of the sub-fishery and various literature sources to complete the lists. However, the resulting lists are not necessarily comprehensive and validation by experts in the region is desirable.

### Define community boundaries

#### Demersal Communities

The demersal communities boundaries are based on the IMCRA boundaries for the inshore 0-200 m, and on the slope and outer shelf bioregionalisation for the slope >200 m (IMCRA Technical Group 1998, Last *et al.* 2005 respectively) although there is some overlap between the two schema on the outer shelf. Specifically, there are nine core provinces and eight biotones on the shelf—biotones are transition zones between the provinces—which are based on the classification of demersal fish species richness and diversity. This classification was ideal for our purposes and consequently we defined 17 "provinces" based largely on the IMCRA scheme (**Table 3, Figure 7a**). Offshore, the provinces were similar in geographic boundary to the inshore provinces (**Table 3**) but were also depth-stratified into several alternating strata of "core" and "transition" depth zones (Last *et al.* 2005). In defining community depth boundaries on the slope, we subsumed the "transition" depth zones into the "core" depth zones by redefining the depth boundary as the midpoint depth between the "core" zones i.e. the midpoint of the "transition" zone. This resulted in five major depth strata 110-250m, 250-565m, 565-820m, 820-1100m and >1100m in addition to the inner shelf 0-110m that could usually be defined in each province and that constituted a community. In addition to the shelf and slope communities, seamount, reef and plateau communities, also similarly depth stratified, were identified in several provinces. For the bioregionalisation projects, the distributions of about half the Australian fish species were recorded as "string data" that describes their distribution in a single-dimension only. The string data points are used here to locate the positions of the boundaries between the major biomes (see **Table 3**).

In the sub-Antarctic islands, a complete bioregionalisation was not available. Definitions of demersal communities around Heard & McDonald Islands were based on Meyer *et al.* 2000 who defined biophysical units based on benthic assemblages and physical oceanography (**Figure 8a**). At Macquarie Island, demersal communities were largely defined using only water mass information (**Figure 9a**) (Condie *et al.* 2003; Lyne and Hayes 2004). The steepness of the slope around Macquarie Island obviated the need to stratify the slope into any more than two major strata.

### Pelagic Communities

The pelagic communities were based on both the outcomes of the Pelagic Bioregionalisation project that defines broader biomes based on oceanographic properties, and the underlying water masses that exist in oceans around Australia (Fig 2b)(Condie *et al.* 2003; Lyne and Hayes 2004). Those provinces defined are Western, Southern, Eastern and Northern. The pelagic communities overlay the demersal communities. The coastal pelagic communities (0–200 m) overlay the inner and outer shelf demersal communities in all provinces. Offshore, there is one epipelagic community, oceanic (1), in each of the six Australian provinces but the maximum depth in each province varies between 200 and 800 m according to the water masses. A mesopelagic community, oceanic (2), has also been defined for each of the provinces. A third offshore/oceanic community, oceanic (3), has been defined in the Southern province where the underlying Antarctic Intermediate water mass (north of 50°S) impinges on the slope. Seamount and reef pelagic communities that overlay the corresponding demersal features have also been defined to allow identification of potentially vulnerable communities. Although they are likely to have similar species composition to their surrounding pelagic communities, distribution and abundance of particular species might differ.

The pelagic communities at both Heard and McDonald and Macquarie Islands were based on the supposition of the dominant water masses (Condie *et al.* 2003; Lyne and Hayes 2004). Around Heard/McDonald Is (**Figure 3b**), a pelagic zone (0-1000 m) overlies the Heard Plateau, including the Western Banks and Shell Bank complex and the deeper trough areas. This equates to the Antarctic Surface Water and the upper Circumpolar Deep Water (Meyer *et al.* 2000). Surrounding the Plateau are the oceanic layers (0-1000 m – a continuation of the previous two water masses-and >1000 m). The major oceanographic feature influencing this region is the southern branch of the Polar Front, which passes south of the island. This front diverges from the main front and flows northwards through the trough between the Heard Plateau and Shell Bank. Deeper currents apparently move in the opposite direction up the slope. Macquarie Island lies between the Subantarctic Front to the north and Polar Front to the south. At Macquarie Island (Fig 4b), the coastal zone (0-250 m) overlays the shelf, and two oceanic zones (0-1600 m and >1600m) surround the shelf area.

**Table 3. Geographical and depth descriptions of (a) demersal and (b) pelagic communities within Australian territorial waters. The string positions are geographical locators used in bioregionalisation projects to describe location along the Australian coastline (-1 is the point on the EEZ boundary which is actually further north from the string point 0).**

(a) Demersal communities

Demersal Province	Biome (=Community)	String start	String stop	Depth start	Depth stop
Cape Province	Outer Shelf	-1	12	110	250
	Upper Slope	-1	12	250	565
	Mid–Upper Slope	-1	12	565	820
	Mid Slope	-1	12	820	1100
	Lower slope/Abyssal	-1	12	>1100	depth at EEZ
	Seamount	-1	12	0	110
	Seamount	-1	12	110	250
	Seamount	-1	12	250	565
	Seamount	-1	12	565	820
	Seamount	-1	12	820	1100
North Eastern Transition	Inner shelf	281	14	0	110
	Inner shelf reef	281	14	0	110
	Outer Shelf	12	20	110	250
	Upper Slope	12	20	250	565
	Mid–Upper Slope	12	20	565	820
	Mid Slope	12	20	820	1100
	Lower slope/Abyssal	12	20	>1100	depth at EEZ
North Eastern Province	Inner shelf	14	39	0	110
	Inner shelf reef	14	39	0	110
	Outer Shelf	20	39	110	250
	Upper Slope	20	39	250	565
	Mid–Upper Slope	20	39	565	820
	Mid Slope	20	39	820	1100
	Lower slope/Abyssal	20	39	>1100	depth at EEZ
	Plateau	20	39	0	110
	Plateau	20	39	110	250
	Plateau	20	39	250	565
	Plateau	20	39	565	820
	Plateau	20	39	820	1100
	Seamount	20	39	0	110
	Seamount	20	39	110	250
	Seamount	20	39	250	565
Seamount	20	39	565	820	
Seamount	20	39	820	1100	
Seamount	20	39	>1100	depth at EEZ	
Central Eastern Transition	Inner shelf	39	58	0	110
	Outer Shelf	39	53	110	250
	Upper Slope	39	53	250	565
	Mid–Upper Slope	39	53	565	820
	Mid Slope	39	53	820	1100
	Lower slope/Abyssal	39	53	>1100	depth at EEZ
	Seamount	39	53	0	110
	Seamount	39	53	110	250
	Seamount	39	53	250	565
	Seamount	39	53	565	820
	Seamount	39	53	820	1100
	Seamount	39	53	>1100	depth at EEZ
Central Eastern Province	Inner shelf	58	68	0	110
	Outer Shelf	53	70	110	250
	Upper Slope	53	70	250	565
	Mid–Upper Slope	53	70	565	820
	Mid Slope	53	70	820	1100

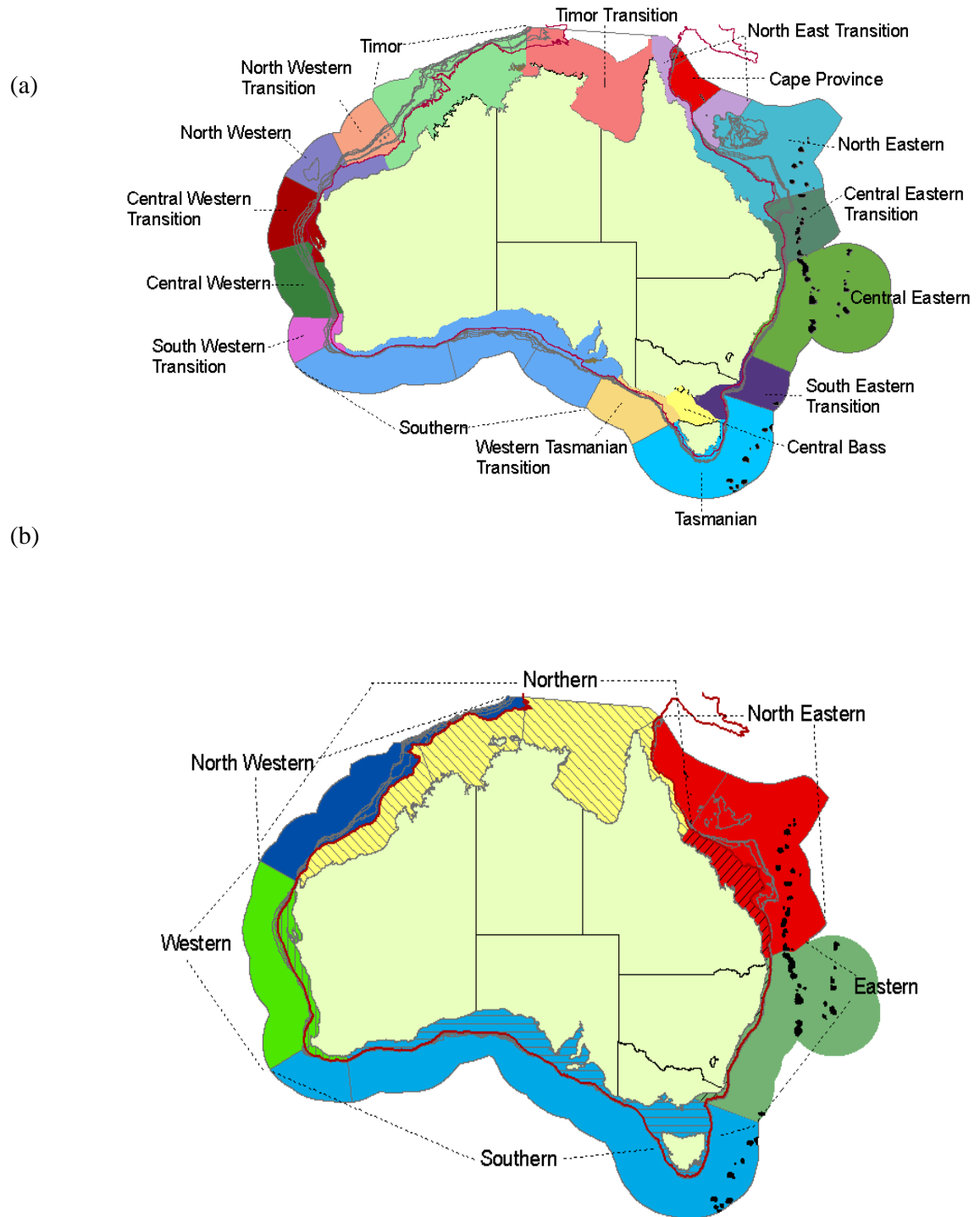
Demersal Province	Biome (=Community)	String start	String stop	Depth start	Depth stop
	Lower slope/Abyssal	53	70	>1100	depth at EEZ
	Seamount	53	70	0	110
	Seamount	53	70	110	250
	Seamount	53	70	250	565
	Seamount	53	70	565	820
	Seamount	53	70	820	1100
	Seamount	53	70	>1100	depth at EEZ
South Eastern Transition	Inner shelf	68	85	0	110
	Outer Shelf	70	80	110	250
	Upper Slope	70	80	250	565
	Mid–Upper Slope	70	80	565	820
	Mid Slope	70	80	820	1100
	Lower slope/Abyssal	70	80	>1100	depth at EEZ
	Seamount	70	80	>1100	depth at EEZ
Central Bass	Inner shelf			0	110
Tasmanian Province	Inner shelf	85	103	0	110
	Outer Shelf	80	103	110	250
	Upper Slope	80	103	250	565
	Mid–Upper Slope	80	103	565	820
	Mid Slope	80	103	820	1100
	Lower slope/Abyssal	80	103	>1100	depth at EEZ
	Seamount	80	103	565	820
	Seamount	80	103	820	1100
	Seamount	80	103	>1100	depth at EEZ
Western Tasmanian Transition	Inner shelf	103	116	0	110
	Outer Shelf	103	118	110	250
	Upper Slope	103	118	250	565
	Mid–Upper Slope	103	118	565	820
	Mid Slope	103	118	820	1100
	Lower slope/Abyssal	103	118	>1100	depth at EEZ
Southern Province	Inner shelf Eyre	116	131	0	110
	Inner shelf Eucla	131	148	0	110
	Inner shelf South West Coast	148	167	0	110
	Outer Shelf	118	170	110	250
	Upper Slope	118	170	250	565
	Mid–Upper Slope	118	170	565	820
	Mid Slope	118	170	820	1100
	Lower slope/Abyssal	118	170	>1100	depth at EEZ
South Western Transition	Inner shelf	167	176	0	110
	Outer Shelf	170	175	110	250
	Upper Slope	170	175	250	565
	Mid–Upper Slope	170	175	565	820
	Mid Slope	170	175	820	1100
	Lower slope/Abyssal	170	175	>1100	depth at EEZ
Central Western Province	Inner shelf	176	186	0	110
	Outer Shelf	175	190	110	250
	Upper Slope	175	190	250	565
	Mid–Upper Slope	175	190	565	820
	Mid Slope	175	190	820	1100
	Lower slope/Abyssal	175	190	>1100	depth at EEZ
Central Western Transition	Inner shelf	186	202	0	110
	Outer Shelf	190	200	110	250
	Upper Slope	190	200	250	565
	Mid–Upper Slope	190	200	565	820
	Mid Slope	190	200	820	1100
	Lower slope/Abyssal	190	200	>1100	depth at EEZ
North Western Province	Inner shelf	202	215	0	110
	Outer Shelf	200	208	110	250

Demersal Province	Biome (=Community)	String start	String stop	Depth start	Depth stop
	Upper Slope	200	208	250	565
	Mid–Upper Slope	200	208	565	820
	Mid Slope	200	208	820	1100
	Lower slope/Abyssal	200	208	>1100	depth at EEZ
	Plateau	200	208	820	1100
North Western Transition	Outer Shelf	208	218	110	250
	Upper Slope	208	218	250	565
	Mid–Upper Slope	208	218	565	820
	Mid Slope	208	218	820	1100
	Lower slope/Abyssal	208	218	>1100	depth at EEZ
	Reef	208	218	0	110
	Reef	208	218	110	250
Timor Province	Inner shelf	215	252	0	110
	Outer Shelf	218	252	110	250
	Upper Slope	218	252	250	565
	Mid–Upper Slope	218	252	565	820
	Mid Slope	218	252	820	1100
	Lower slope/Abyssal	218	252	>1100	depth at EEZ
Timor Transition	Inner shelf Arafura	252	270	0	110
	Inner shelf Groote	270	272	0	110
	Inner shelf Cape York	272	281	0	110
	Inner Shelf Gulf	270	281	0	110
Heard/McDonald Islands	Shelf (Territorial Seas)			0	100
	Outer Heard Plateau			100	500
	Inner Heard Plateau			100	500
	Shell Bank			100	500
	Western Banks			200	500
	Shell Bank Deep			>1000	
	North Eastern Plateau			500	1000
	North Eastern Trough			500	1000
	South Eastern Trough			500	1000
	Western Trough			500	1000
	Southern upper slope			500	1000
	Lower slope/Abyssal			>1000	depth at EEZ
Macquarie Island	Shelf			0	250
	Upper-mid slope			250	1000
	Lower slope/Abyssal			>1000	depth at EEZ

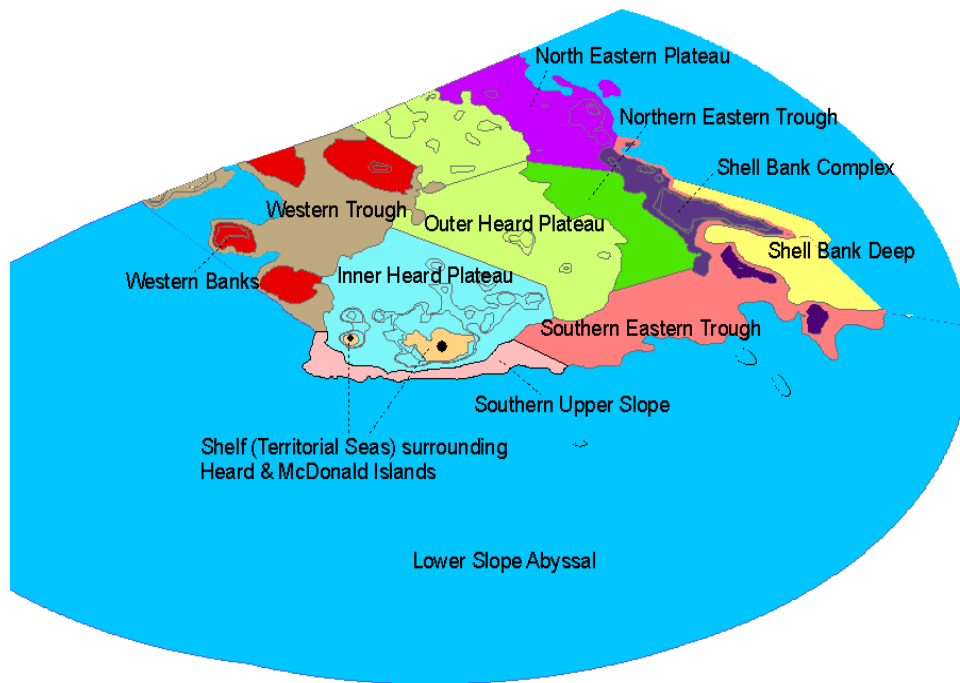
## (b) Pelagic communities

Pelagic Province					
Eastern	Coastal pelagic	53	80	0	200
	Oceanic (1)	53	80	0	600
	Oceanic (2)	53	80	>600	depth at EEZ
	Seamount oceanic (1)	53	80	0	600
	Seamount oceanic (2)	53	80	> 600	
Southern	Coastal pelagic Tas	80	116	0	200
	Coastal pelagic GAB	116	162	0	200
	Oceanic (1)	80	170	0	200
	Oceanic (2)	80	170	200	600
	Oceanic (3)	80	170	>600	depth at EEZ
	Seamount oceanic (1)	80	170	0	200
	Seamount oceanic (2)	80	170	200	600
	Seamount oceanic (3)	80	170	>600	
Western	Coastal pelagic	162	200	0	200
	Oceanic (1)	170		0	400
	Oceanic (2)	170	200	>400	depth at EEZ
Northern	Coastal NWS	200	238	0	200

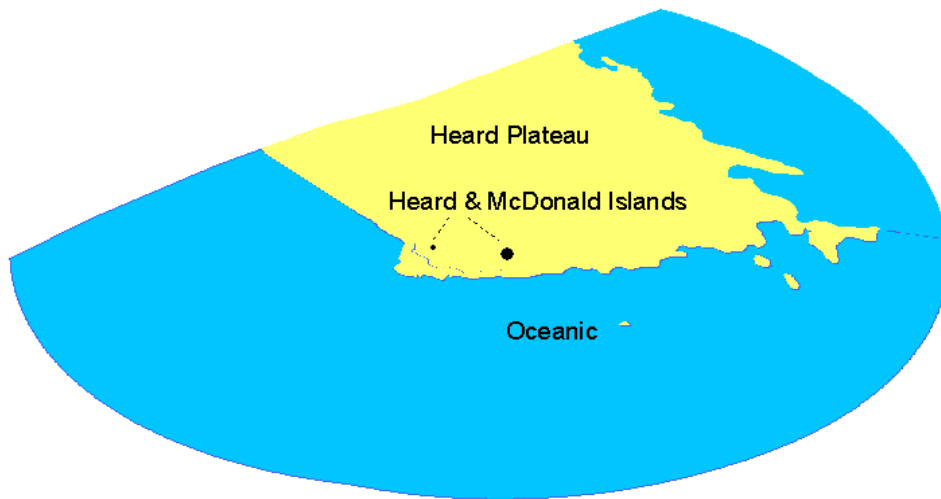
Pelagic Province					
	Coastal Bonaparte	238	256	0	200
	Coastal Arafura	256	270	0	200
	Coastal Gulf	270	281	0	200
	Coastal East Cape York	281	18	0	200
Northwestern	Oceanic (1)	200	238	0	800
	Oceanic (2)	200	238	>800	depth at EEZ
Northeastern	Coastal	18	53	0	200
	Oceanic (1)	0	53	0	600
	Oceanic (2)	0	53	>600	depth at EEZ
	Plateau (1)	0	53	0	600
	Plateau (2)	0	53	>600	depth at EEZ
	Seamount oceanic (1)	0	53	0	600
	Seamount oceanic (2)	0	53	>600	depth at EEZ
Heard/McDonald Islands	Heard Plateau	n/a	n/a	0	1000
	Oceanic (1)	n/a	n/a	0	1000
	Oceanic (2)	n/a	n/a	>1000	depth at EEZ
Macquarie Island	Coastal	n/a	n/a	0	250
	Oceanic (1)	n/a	n/a	0	1600
	Oceanic (2)	n/a	n/a	>1600	depth at EEZ



**Fig 7. a) Demersal communities around mainland Australia based on bioregionalisation schema. Some inshore (0-110 m) communities comprise more than one community e.g. Timor Transition comprises 4 distinct communities. b) Australian pelagic provinces. Hatched areas indicate coastal epipelagic zones overlying the shelf. Offshore (oceanic) provinces comprise two or more overlapping pelagic zones as indicated in Table 1. Seamounts (black) and plateaux (light green) are illustrated in their demersal or pelagic provinces.**

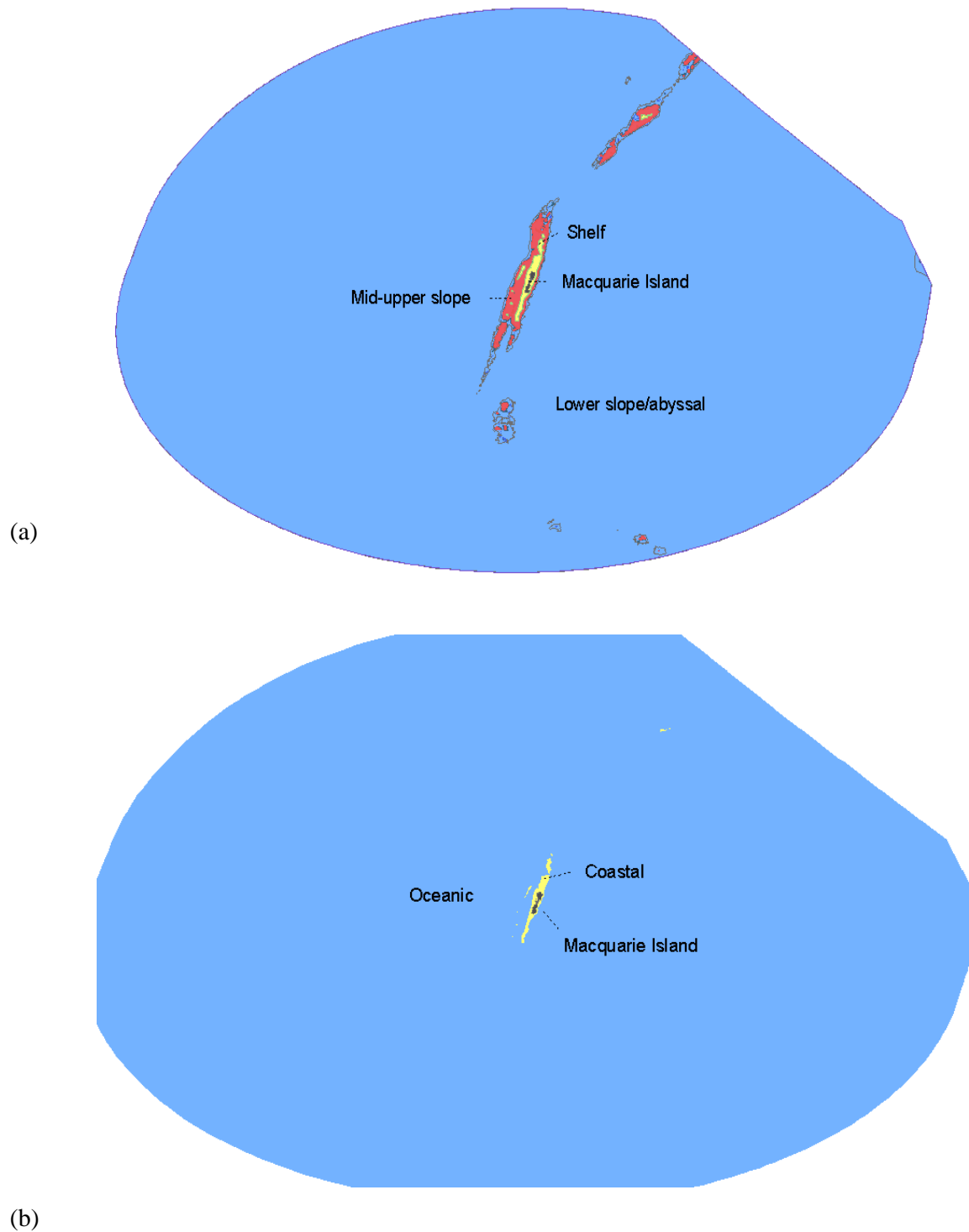


(a)



(b)

**Figure 8. a) Demersal communities and b) pelagic communities from Heard and McDonald Islands based largely on Meyer *et al.* (2000) and Condie *et al.* (2003). Oceanic province comprises two strata (0-1000 m and >1100 m).**



**Figure 9. (a) Demersal and (b) pelagic communities around Macquarie Island based on bioregionalisation schema (Condie *et al.* 2003; Last *et al.* 2005). The pelagic oceanic province comprises two strata (0-1600 m and >1600 m).**

## Units of analysis lists

The units of analysis for the sub-fishery are listed by component:

- Species Components (target, byproduct/discards and TEP components). [Scoping document S2A Species]
- Habitat Component: habitat types. [Scoping document S2B Habitats]
- Community Component: community types. [Scoping document S2C Communities]

### Ecological Units Assessed

Target species:	X
By-product and bycatch species:	X and X respectively
TEP species:	X
Habitats:	X (X benthic, X pelagic)
Communities:	X (X demersal, X pelagic)

### Scoping Document S2A Species

Each species identified during the scoping is added to the ERAEF database used to run the Level 2 analyses. A CAAB code (Code for Australian Aquatic Biota) is required to input the information. The CAAB codes for each species may be found at <http://www.marine.csiro.au/caab/>

Target species: [*Fishery name*]

List the target species of the sub- fishery. This list is obtained by reviewing all available fishery literature, including logbooks, observer reports and discussions with stakeholders. Target species are as agreed by the fishery.

Species Number	Taxa	Family name	Scientific name	Common Name	CAAB code
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Byproduct species [Fishery name]

List the byproduct species of the sub- fishery. Byproduct refers to any part of the catch which is kept or sold by the fisher but which is not a target species. This list is obtained by reviewing all available fishery literature, including logbooks, observer reports and discussions with stakeholders.

Species Number	Taxa	Family name	Scientific name	Common Name	CAAB code
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Discard species [Fishery name]

List the discard (bycatch) species (excluding TEP species) of the sub-fishery. Bycatch as defined in the Commonwealth Policy on Fisheries Bycatch 2000 refers to:

- that part of a fisher's catch which is returned to the sea either because it has no commercial value or because regulations preclude it being retained; and
- that part of the 'catch' that does not reach the deck but is affected by interaction with the fishing gear

However, in the ERAEF method, the part of the target or byproduct catch that is discarded is included in the assessment of the target or byproduct species. The list of bycatch species is obtained by reviewing all available fishery literature, including logbooks, observer reports and discussions with stakeholders.

Species Number	Taxa	Family name	Scientific name	Common Name	CAAB code
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TEP species [fishery name]

List the TEP species that occur in the area of the sub-fishery. Highlight species that are known to interact directly with the fishery. TEP species are those species listed as Threatened, Endangered or Protected under the EPBC Act.

TEP species are often poorly listed by fisheries due to low frequency of direct interaction. Both direct (capture) and indirect (e.g. food source captured) interaction are considered in the ERAEF approach. A list of TEP species has been generated for each fishery and is included in the PSA workbook species list. This list has been generated using the DEH Search Tool from DEH home page <http://www.deh.gov.au/>

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For each fishery, the list of TEP species is compiled by reviewing all available fishery literature. Species considered to have potential to interact with fishery (based on geographic range & proven/perceived susceptibility to the fishing gear/methods and examples from other similar fisheries across the globe) should also be included.

Species Number	Taxa	Family name	Scientific name	Common Name	CAAB code
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**Scoping Document S2B1. Benthic Habitats**

Risk assessment for benthic habitats considers both the seafloor structure and its attached invertebrate fauna. Because data on the types and distributions of benthic habitat in Australia’s Commonwealth fisheries are generally sparse, and because there is no universally accepted benthic classification scheme, the ERAEF methodology has used the most widely available type of data – seabed imagery – classified in a similar manner to that used in bioregionalisation and deep seabed mapping in Australian Commonwealth waters. Using this imagery, benthic habitats are classified based on an SGF score, using sediment, geomorphology, and fauna. Where seabed imagery is not available, a second method (Method 2) is used to develop an inferred list of potential habitat types for the fishery. For details of both methods, see Hobday et al (2006).

A list of the benthic habitats for the [fishery: sub-fishery]. Shading denotes habitats occurring within the jurisdictional boundary of the sub-fishery that are not subject to effort from [method].

ERAEF record No.	ERAEF Habitat Number	Sub-biome	Feature	Habitat type	SGF Score	Depth (m)	Image available	Reference image location
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**Scoping Document S2B2. Pelagic Habitats**

A list of the pelagic habitats for the [fishery: sub-fishery]. Shading denotes habitats occurring within the jurisdictional boundary of the subfishery that are not subject to effort from [method].

ERAEF Habitat Number	Pelagic Habitat type	Depth (m)	Comments	Reference
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	Cape	North Eastern Transition	North Eastern	Central Eastern Transition	Central Eastern	South Eastern Transition	Central Bass	Tasmanian	Western Tas Transition	Southern	South Western Transition	Central Western	Central Western Transition	North Western	North Western Transition	Timor	Timor Transition	Heard & McDonald Is	Macquarie Is
Demersal community																			
Plateau 0 – 110m																			
Plateau 110- 250m <sup>4</sup>																			
Plateau 250 – 565m <sup>4</sup>																			
Plateau 565 – 820m <sup>5</sup>																			
Plateau 820 – 1100m <sup>5</sup>																			

<sup>1</sup> Four inner shelf communities occur in the Timor Transition (Arafura, Groote, Cape York and Gulf of Carpentaria) and three inner shelf communities occur in the Southern (Eyre, Eucla and South West Coast). At Macquarie Is: <sup>2</sup>inner & outer shelves (0-250m), and <sup>3</sup>upper and midslope communities combined (250-1000m). At Heard/McDonald Is: <sup>4</sup>outer and upper slope plateau communities combined to form four communities: Shell Bank, inner and outer Heard Plateau (100-500m) and Western Banks (200-500m), <sup>5</sup>mid and upper plateau communities combined into 3 trough, southern slope and North Eastern plateau communities (500-1000m), and <sup>6</sup> 3 groups at Heard Is: Deep Shell Bank (>1000m), Southern and North East Lower slope/abyssal, <sup>7</sup>Great Barrier Reef in the North Eastern Province and Transition and <sup>8</sup> Rowley Shoals in North Western Transition.

## Scoping Document S2C2. Pelagic Communities

Pelagic communities that overlie the demersal communities in which fishing activity occurs in the fishery (x). Shaded cells indicate all communities that exist in the province.

Pelagic community	Northeastern	Eastern	Southern	Western	Northern	Northwestern	Heard and McDonald Is <sup>2</sup>	Macquarie Is
Coastal pelagic 0-200m <sup>1,2</sup>								
Oceanic (1) 0 – 600m								
Oceanic (2) >600m								
Seamount oceanic (1) 0 – 600m								
Seamount oceanic (2) 600–3000m								
Oceanic (1) 0 – 200m								
Oceanic (2) 200-600m								
Oceanic (3) >600m								
Seamount oceanic (1) 0 – 200m								
Seamount oceanic (2) 200 – 600m								
Seamount oceanic (3) 600–3000m								
Oceanic (1) 0-400m								
Oceanic (2) >400m								
Oceanic (1) 0-800m								
Oceanic (2) >800m								
Plateau (1) 0-600m								
Plateau (2) >600m								
Heard Plateau 0-1000m <sup>3</sup>								
Oceanic (1) 0-1000m								
Oceanic (2) >1000m								
Oceanic (1) 0-1600m								
Oceanic (2) >1600m								

<sup>1</sup> Northern Province has five coastal pelagic zones (NWS, Bonaparte, Arafura, Gulf and East Cape York) and Southern Province has two zones (Tas, GAB). <sup>2</sup> At Macquarie Is: coastal pelagic zone to 250m. <sup>3</sup> At Heard and McDonald Is: coastal pelagic zone broadened to cover entire plateau to maximum of 1000m.

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### **2.2.3 Identification of Objectives for Components and Sub-components (Step 3)**

Objectives must be identified for each sub-fishery, for each of the five ecological components (target, byproduct and bycatch species, TEP species, habitats, and communities). Management objectives need to be identified for each component (core objectives) and sub-component (operational objectives), with the latter expressed as limits to acceptable change (what is “acceptable” needs to be defined in each case). Core objectives (also called endpoints) identify what you are trying to achieve. Operational objectives (or measurement endpoints) are objectives stated in ways that can be measured. It is important to identify objectives that managers, the fishing industry, and other stakeholders can agree on, and that scientists can quantify and assess. The identified objectives are used as part of the Level SICA analysis (step 6).

The method for identifying objectives is described and outlined next. Objectives are identified for each sub-fishery for the five ecological components (target, bycatch/byproduct, TEP, habitats, and communities) and sub-components, and are clearly documented. It is important to identify objectives that managers, the fishing industry, and other stakeholders can agree on, and that scientists can quantify and assess. The criteria for selecting ecological operational objectives for risk assessment are that they:

- be biologically relevant;
- have an unambiguous operational definition;
- be accessible to prediction and measurement; and
- that the quantities they relate to be exposed to the hazards.

For fisheries that have completed ESD reports, use can be made of the operational objectives stated in those reports.

The sub-components for each component type are shown in the examples below.

Component	Target species					
Sub components	Population size	Geographic range	Genetic structure	Age/size/sex structure	Reproductive capacity	Behaviour movement

Component	Byproduct or Bycatch species					
Sub components	Population size	Genetic structure	Genetic structure	Age/size/sex structure	Reproductive capacity	Behaviour movement

Component	TEP species						
Sub components	Population size	Genetic structure	Genetic structure	Age/size/sex structure	Reproductive capacity	Behaviour movement	Interactions with the fishery

Component	Habitat				
Sub components	Substrate quality	Water quality	Air quality	Habitat types	Habitat structure and function

Component	Community				
Sub components	Species composition	Functional group composition	Distribution of community	Trophic/size structure	Bio and geochemical cycles

Each 'operational objective' is matched to example indicators. **Scoping Document S3** provides suggested examples of operational objectives and indicators. Where operational objectives are already agreed for a fishery (Existing Management Objectives), those should be used (e.g. Strategic Assessment Reports). The objectives

need not be exactly specified, with regard to numbers or fractions of removal/impact, but should indicate that an impact in the sub-component is of concern/interest to the sub-fishery. The rationale for including or discarding an operational objective is a crucial part of the table and must explain why the particular objective has or has not been selected for in the (sub) fishery. Only the operational objectives selected for inclusion in the (sub) fishery are used for Level 1 analysis (**Level 1 SICA Document L1.1**).

**Scoping Document S3 Components and Sub-components Identification of Objectives**

*Table (Note: Operational objectives that are eliminated should be shaded out and a rationale provided as for the retained operational objectives)*

Component	Core Objective	Sub-component	Example Operational Objectives	Example Indicators	Rationale
	"What is the general goal?"	As shown in sub-component model diagrams at the beginning of this section.	"What you are specifically trying to achieve"	"What you are going to use to measure performance"	Rationale flagged as 'EMO' where Existing Management Objective in place, or 'AMO' where there is an existing AFMA Management Objective in place for other Commonwealth fisheries (assumed that squid fishery will fall into line).
Target Species	Avoid recruitment failure of the target species  Avoid negative consequences for species or population sub-components	1. Population size	1.1 No trend in biomass 1.2 Maintain biomass above a specified level 1.3 Maintain catch at specified level 1.4 Species do not approach extinction or become extinct	Biomass, numbers, density, CPUE, yield	1.1 add in rationale for each objective 1.2 1.3 1.4

Component	Core Objective	Sub-component	Example Operational Objectives	Example Indicators	Rationale
		2. Geographic range	2.1 Geographic range of the population, in terms of size and continuity does not change outside acceptable bounds	Presence of population across the GAB	2.1
		3. Genetic structure	3.1 Genetic diversity does not change outside acceptable bounds	Frequency of genotypes in the population, effective population size ( $N_e$ ), number of spawning units	3.1
		4. Age/size/sex structure	4.1 Age/size/sex structure does not change outside acceptable bounds (e.g. more than X% from reference structure)	Biomass, numbers or relative proportion in age/size/sex classes Biomass of spawners Mean size, sex ratio	4.1
		5. Reproductive Capacity	5.1 Fecundity of the population does not change outside acceptable bounds (e.g. more than X% of reference population fecundity) 2 Recruitment to the population does not change outside acceptable bounds	Egg production of population Abundance of recruits	5.1 5.2
		6. Behaviour /Movement	6.1 Behaviour and movement patterns of the population do not change outside acceptable bounds	Presence of population across space, movement patterns within the population (e.g. attraction to bait, lights)	6.1

Component	Core Objective	Sub-component	Example Operational Objectives	Example Indicators	Rationale
Byproduct and Bycatch	Avoid recruitment failure of the byproduct and bycatch species  Avoid negative consequences for species or population sub-components	1. Population size	1.1 No trend in biomass 1.2 Species do not approach extinction or become extinct 1.3 Maintain biomass above a specified level 1.4 Maintain catch at specified level	Biomass, numbers, density, CPUE, yield	1.1 1.2 1.3 1.4
		2. Geographic range	2.1 Geographic range of the population, in terms of size and continuity does not change outside acceptable bounds	Presence of population across space	2.1
		3. Genetic structure	3.1 Genetic diversity does not change outside acceptable bounds	Frequency of genotypes in the population, effective population size ( $N_e$ ), number of spawning units	3.1
		4. Age/size/sex structure	4.1 Age/size/sex structure does not change outside acceptable bounds (e.g. more than X% from reference structure)	Biomass, numbers or relative proportion in age/size/sex classes Biomass of spawners Mean size, sex ratio	4.1

Component	Core Objective	Sub-component	Example Operational Objectives	Example Indicators	Rationale
		5 Reproductive Capacity	5.1 Fecundity of the population does not change outside acceptable bounds (e.g. more than X% of reference population fecundity) Recruitment to the population does not change outside acceptable bounds	Egg production of population Abundance of recruits	5.1
		6. Behaviour /Movement	6.1 Behaviour and movement patterns of the population do not change outside acceptable bounds	Presence of population across space, movement patterns within the population (e.g. attraction to bait, lights)	6.1
TEP species	Avoid recruitment failure of TEP species  Avoid negative consequences for TEP species or population sub-components  Avoid negative impacts on the population from fishing	1. Population size	1.1 Species do not further approach extinction or become extinct 1.2 No trend in biomass 1.3 Maintain biomass above a specified level 1.4 Maintain catch at specified level	Biomass, numbers, density, CPUE, yield	1.1 1.2 1.3 1.4
		2. Geographic range	2.1 Geographic range of the population, in terms of size and continuity does not change outside acceptable bounds	Presence of population across space, i.e. the GAB	2.1

Component	Core Objective	Sub-component	Example Operational Objectives	Example Indicators	Rationale
		3. Genetic structure	3.1 Genetic diversity does not change outside acceptable bounds	Frequency of genotypes in the population, effective population size ( $N_e$ ), number of spawning units	3.1
		4. Age/size/sex structure	4.1 Age/size/sex structure does not change outside acceptable bounds (e.g. more than X% from reference structure)	Biomass, numbers or relative proportion in age/size/sex classes Biomass of spawners Mean size, sex ratio	4.1
		5. Reproductive Capacity	5.1 Fecundity of the population does not change outside acceptable bounds (e.g. more than X% of reference population fecundity) Recruitment to the population does not change outside acceptable bounds	Egg production of population Abundance of recruits	5.1
		6. Behaviour/Movement	6.1 Behaviour and movement patterns of the population do not change outside acceptable bounds	Presence of population across space, movement patterns within the population (e.g. attraction to bait, lights)	6.1
		7. Interactions with fishery	7.1 Survival after interactions is maximised 7.2 Interactions do not affect the viability of the population or its ability to recover	Survival rate of species after interactions Number of interactions, biomass or numbers in population	7.1 7.2

Component	Core Objective	Sub-component	Example Operational Objectives	Example Indicators	Rationale
Habitats	Avoid negative impacts on the quality of the environment  Avoid reduction in the amount and quality of habitat	1. Water quality	1.1 Water quality does not change outside acceptable bounds	Water chemistry, noise levels, debris levels, turbidity levels, pollutant concentrations, light pollution from artificial light	1.1
		2. Air quality	2.1 Air quality does not change outside acceptable bounds	Air chemistry, noise levels, visual pollution, pollutant concentrations, light pollution from artificial light	2.1
		3. Substrate quality	3.1 Sediment quality does not change outside acceptable bounds	Sediment chemistry, stability, particle size, debris, pollutant concentrations	3.1
		4. Habitat types	4.1 Relative abundance of habitat types does not vary outside acceptable bounds	Extent and area of habitat types, % cover, spatial pattern, landscape scale	4.1
		5. Habitat structure and function	5.1 Size, shape and condition of habitat types does not vary outside acceptable bounds	Size structure, species composition and morphology of biotic habitats	5.1
Communities	Avoid negative impacts on the composition/function/distribution/structure of the community	1. Species composition	1.1 Species composition of communities does not vary outside acceptable bounds	Species presence/absence, species numbers or biomass (relative or absolute) Richness Diversity indices Evenness indices	1.1
		2. Functional group composition	2.1 Functional group composition does not change outside acceptable bounds	Number of functional groups, species per functional group (e.g. autotrophs, filter feeders, herbivores, omnivores, carnivores)	2.1

Component	Core Objective	Sub-component	Example Operational Objectives	Example Indicators	Rationale
		3. Distribution of the community	3.1 Community range does not vary outside acceptable bounds	Geographic range of the community, continuity of range, patchiness	3.1
		4. Trophic/size structure	4.1 Community size spectra/trophic structure does not vary outside acceptable bounds	Size spectra of the community Number of octaves, Biomass/number in each size class Mean trophic level Number of trophic levels	4.1
		5. Bio- and geo-chemical cycles	5.1 Cycles do not vary outside acceptable bounds	Indicators of cycles, salinity, carbon, nitrogen, phosphorus flux	5.1

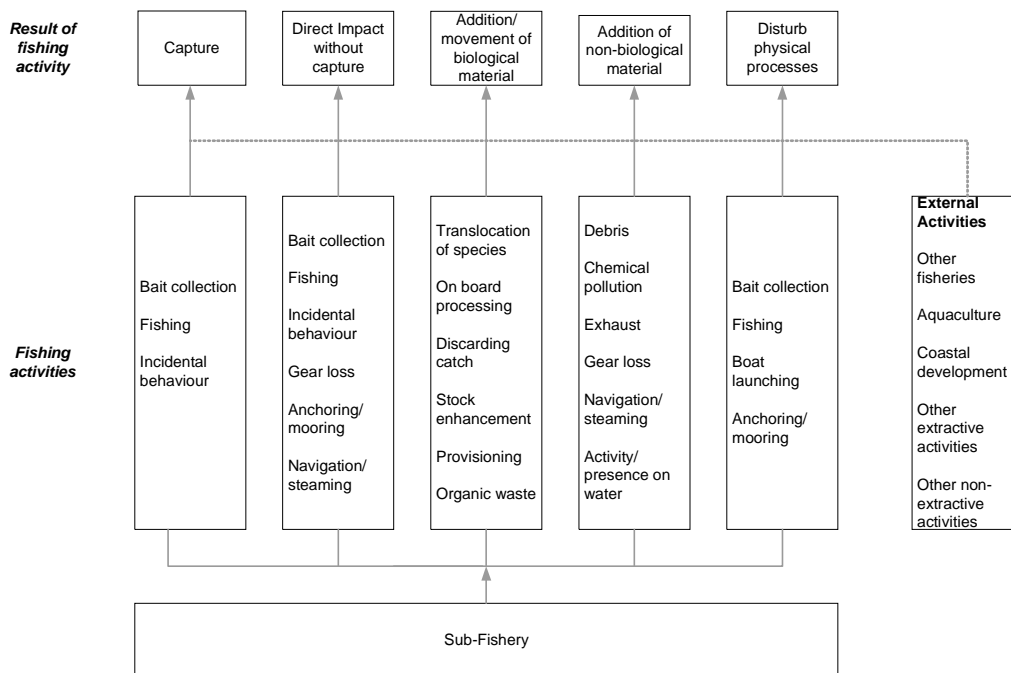
### 2.2.4 Hazard Identification (Step 4)

Hazards are the activities undertaken in the process of fishing, and any external activities, which have the potential to lead to harm.

The effects of fishery/sub-fishery specific hazards are identified under the following categories:

- capture
- direct impact without capture
- addition/movement of biological material
- addition of non biological material
- disturbance of physical processes
- external hazards

These categories are subdivided into fishing activities (of the fishery being evaluated) and external activities (including other fisheries) as shown in **Figure 10** below:



**Figure 10. Schematic diagram of fishery/sub-fishery specific hazards subdivided into fishing activities and external activities.**

These fishing and external activities are scored on a presence/absence basis for each fishery/sub-fishery. An activity is scored as a zero if it does not occur and as a one if it does occur. The rationale for the scoring is also documented in detail and must include if/how the activity occurs and how the hazard may impact on organisms/habitat.

#### Scoping Document S4. Hazard Identification Scoring Sheet

This proforma table is completed once for each sub-fishery. **Table 4** provides a set of examples of fishing activities for the effects of fishing to be used as a guide to assist in scoring the hazards.

Fishery Name:

Sub-fishery Name:

Date completed:

Direct impact of Fishing	<i>Fishing Activity</i>	Score (0/1)	Documentation of Rationale
Capture	Bait collection		
	Fishing		
	Incidental behaviour		
Direct impact without capture	Bait collection		
	Fishing		
	Incidental behaviour		
	Gear loss		
	Anchoring/ mooring		
	Navigation/steaming		
Addition/ movement of biological material	Translocation of species (boat launching, reballasting)		
	On board processing		
	Discarding catch		
	Stock enhancement		
	Provisioning		
	Organic waste disposal		
Addition of non-biological material	Debris		
	Chemical pollution		
	Exhaust		
	Gear loss		
	Navigation/ steaming		
	Activity/ presence on water		
Disturb physical processes	Bait collection		
	Fishing		
	Boat launching		
	Anchoring/ mooring		
	Navigation/ steaming		
External Hazards (specify the particular example within each activity area)	Other capture fishery methods		
	Aquaculture		
	Coastal development		
	Other extractive activities		
	Other non-extractive activities		
	Other anthropogenic activities		

**Table 4. Examples of fishing activities. (Modified from Fletcher et al. 2002)**

Direct Impact of Fishing	Fishing Activity	Examples of Activities Include
Capture		Activities that result in the capture or removal of organisms. This includes cryptic mortality due to organisms being caught but dropping out prior to the gear's retrieval (i.e. They are caught but not landed)
	Bait collection	Capture of organisms due to bait gear deployment, retrieval and bait fishing. This includes organisms caught but not landed.
	Fishing	Capture of organisms due to gear deployment, retrieval and actual fishing. This includes organisms caught but not landed.
	Incidental behaviour	Capture of organisms due to crew behaviour incidental to primary fishing activities, possible in the crew's down time; e.g. crew may line or spear fish while anchored, or perform other harvesting activities, including any land-based harvesting that occurs when crew are camping in their down time.
Direct impact, without capture		This includes any activities that may result in direct impacts (damage or mortality) to organisms without actual capture.
	Bait collection	Direct impacts (damage or mortality) to organisms due to interactions (excluding capture) with bait gear during deployment, retrieval and bait fishing. This includes: damage/mortality to organisms through contact with the gear that doesn't result in capture, e.g. Damage/mortality to benthic species by gear moving over them, organisms that hit nets but aren't caught.
	Fishing	Direct impacts (damage or mortality) to organisms due to interactions (excluding capture) with fishing gear during deployment, retrieval and fishing. This includes: damage/mortality to organisms through contact with the gear that doesn't result in capture, e.g. Damage/mortality to benthic species by gear moving over them, organisms that hit nets but are not caught.
	Incidental behaviour	Direct impacts (damage or mortality) without capture, to organisms due to behaviour incidental to primary fishing activities, possibly in the crew's down time; e.g. the use of firearms on scavenging species, damage/mortality to organisms through contact with the gear that the crew use to fish during their down time. This does not include impacts on predator species of removing their prey through fishing.
	Gear loss	Direct impacts (damage or mortality), without capture on organisms due to gear that has been lost from the fishing boat. This includes damage/mortality to species when the lost gear contacts them or if species swallow the lost gear.
	Anchoring/ mooring	Direct impact (damage or mortality) that occurs and when anchoring or mooring. This includes damage/mortality due to physical contact of the anchor, chain or rope with organisms, e.g. An anchor damaging live coral.
	Navigation/ steaming	Direct impact (damage or mortality) without capture may occur while vessels are navigating or steaming. This includes collisions with marine organisms or birds.
Addition/ movement of biological material		Any activities that result in the addition or movement of biological material to the ecosystem of the fishery.
	Translocation of species (boat movements, reballasting)	The translocation and introduction of species to the area of the fishery, through transportation of any life stage. This transport can occur through movement on boat hulls or in ballast water as boats move throughout the fishery or from outside areas into the fishery.

Direct Impact of Fishing	Fishing Activity	Examples of Activities Include
	On board processing	The discarding of unwanted sections of target after on board processing introduces or moves biological material, e.g. heading and gutting, retaining fins but discarding trunks.
	Discarding catch	The discarding of unwanted organisms from the catch can introduce or move biological material. This includes individuals of target and byproduct species due to damage (e.g. shark or marine mammal predation), size, high grading and catch limits. Also includes discarding of all non-retained bycatch species. This also includes discarding of catch resulting from incidental fishing by the crew. The discards could be alive or dead.
	Stock enhancement	The addition of larvae, juveniles or adults to the fishery or ecosystem to increase the stock or catches.
	Provisioning	The use of bait or berley in the fishery.
	Organic waste disposal	The disposal of organic wastes (e.g. food scraps, sewage) from the boats.
Addition of non-biological material		Any activities that result in non-biological material being added to the ecosystem of the fishery, this includes physical debris, chemicals (in the air and water), lost gear, noise and visual stimuli.
	Debris	Non-biological material may be introduced in the form of debris from fishing vessels or mother ships. This includes debris from the fishing process: e.g. cardboard thrown over from bait boxes, straps and netting bags lost. Debris from non-fishing activities can also contribute to this e.g. Crew rubbish – discarding or food scraps, plastics or other rubbish. Discarding at sea is regulated by MARPOL, which forbids the discarding of plastics.
	Chemical pollution	Chemicals can be introduced to water, sediment and atmosphere through: oil spills, detergents other cleaning agents, any chemicals used during processing or fishing activities.
	Exhaust	Exhaust can be introduced to the atmosphere and water through operation of fishing vessels
	Gear loss	The loss of gear will result in the addition of non-biological material, this includes hooks, line, sinkers, nets, otter boards, light sticks, buoys etc.
	Navigation /steaming	The navigation and steaming of vessels will introduce noise and visual stimuli into the environment. Boat collisions and/or sinking of vessels. Echo-sounding may introduce noise that may disrupt some species (e.g. whales, orange roughy)
	Activity /presence on water	The activity or presence of fishing vessels on the water will noise and visual stimuli into the environment.
Disturb physical processes		Any activities that will disturb physical processes, particularly processes related to water movement or sediment and hard substrate (e.g. boulders, rocky reef) processes.
	Bait collection	Bait collection may disturb physical processes if the gear contacts seafloor-disturbing sediment, or if the gear disrupts water flow patterns.
	Fishing	Fishing activities may disturb physical processes if the gear contacts seafloor-disturbing sediment, or if the gear disrupts water flow patterns.

Direct Impact of Fishing	Fishing Activity	Examples of Activities Include
	Boat launching	Boat launching may disturb physical processes, particularly in the intertidal regions, if dredging is required, or the boats are dragged across substrate. This would also include foreshore impacts where fishers drive along beaches to reach fishing locations and launch boats. Impacts of boat launching that occurs within established marinas are outside the scope of this assessment.
	Anchoring /mooring	Anchoring/mooring may affect the physical processes in the area that anchors and anchor chains contact the seafloor.
	Navigation /steaming	Navigation /steaming may affect the physical processes on the benthos and the pelagic by turbulent action of propellers or wake formation.
External hazards		Any outside activities that will result in an impact on the component in the same location and period that the fishery operates. The particular activity as well as the mechanism for external hazards should be specified.
	Other capture fishery methods	Take or habitat impact by other commercial, indigenous or recreational fisheries operating in the same region as the fishery under examination
	Aquaculture	Capture of feed species for aquaculture. Impacts of cages on the benthos in the region
	Coastal development	Sewage discharge, ocean dumping, agricultural runoff
	Other extractive activities	Oil and gas pipelines, drilling, seismic activity
	Other non-extractive activities	Defense, shipping lanes, dumping of munitions, submarine cables
	Other anthropogenic activities	Recreational activities, such as scuba diving leading to coral damage, power boats colliding with whales, dugongs, turtles. Shipping, oil spills

**2.2.5 Bibliography (Step 5)**

All references used in the scoping assessment are to be included in the References section in the ERA Results Report.

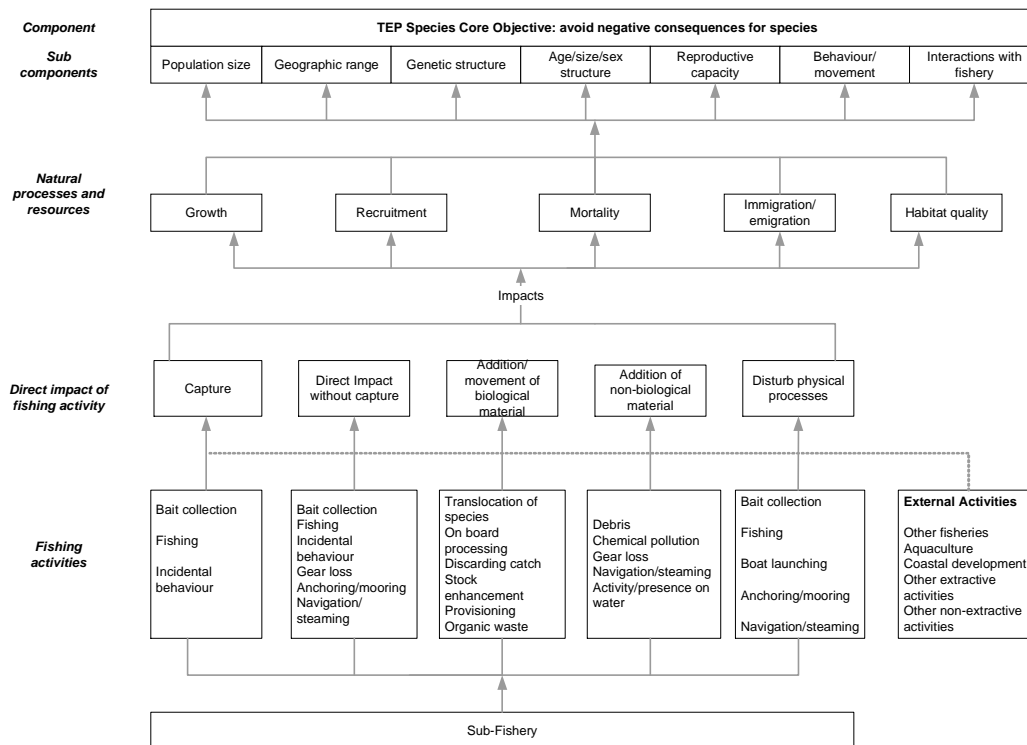
**2.2.6 Decision rules to move to Level 1(Step 6)**

Any hazards that are identified at Step 4 Hazard Identification as occurring in the fishery are carried forward for analysis at Level 1.

### 2.3 Level 1 Scale, Intensity and Consequence Analysis (SICA)

Level 1 aims to identify which hazards lead to a significant impact on any species, habitat or community. Analysis at Level 1 is for whole components (target; bycatch and byproduct; TEP species; habitat; and communities), not individual sub-components. Since Level 1 is used mainly as a rapid screening tool, a “worst case” approach is used to ensure that elements screened out as low risk (either activities or components) are genuinely low risk. Analysis at Level 1 for each component is accomplished by considering the most vulnerable sub-component and the most vulnerable unit of analysis (e.g. most vulnerable species, habitat type or community). This is known as credible scenario evaluation (Richard Stocklosa e-systems Pty Ltd, March 2003) Review of CSIRO Risk Assessment Methodology: ecological risk assessment for the effects of fishing in conventional risk assessment. In addition, where judgments about risk are uncertain, the highest level of risk that is still regarded as plausible is chosen. For this reason, the measures of risk produced at Level 1 cannot be regarded as absolute.

The conceptual model is completed for each component by linking the *effects of fishing and external activities* (these are the direct impacts of fishing and external activities identified at the scoping stage) to *natural processes and resources* (that are affected by the direct impacts); and in turn linking these to the *sub-components* (which are affected by impacts to natural processes and resources) and *components* (impacts, which are affected by impacts to the sub-components), which may impact on the achievement of the management objectives (core and operational) from **Scoping Document S3**. An example of a completed conceptual model for the TEP species is shown in **Figure 11**.



**Figure 11.** Example of completed conceptual model for the TEP species.

At Level 1 each fishery/sub-fishery is assessed using a scale, intensity and consequence analysis (SICA). SICA is applied to the component as a whole by choosing the most vulnerable sub-component (linked to an operational objective) and most vulnerable unit of analysis. The rationale for these choices must be documented in detail. These steps are outlined below. Scale, intensity, and consequence analysis (SICA) consists of the following thirteen steps for each activity and component for each (sub) fishery. The first ten steps are performed for each activity and component, and correspond to the columns of the SICA table. The final three steps summarise the results for each component.

- Step 1: Record the hazard identification score (absence (0) presence (1) scores) identified at step 3 at the scoping level (Scoping Document S3) onto the SICA table (2.3.1)
- Step 2: Score spatial scale of the activity (2.3.2)
- Step 3: Score temporal scale of the activity (2.3.3)
- Step 4: Choose the sub-component most likely to be affected by activity (2.3.4)
- Step 5: Choose the most vulnerable unit of analysis for the component e.g. species, habitat type or community assemblage (2.3.5)
- Step 6: Select the most appropriate operational objective (2.3.6)
- Step 7: Score the intensity of the activity for that sub-component (2.3.7)
- Step 8: Score the consequence resulting from the intensity for that sub component (2.3.8)
- Step 9: Record confidence/uncertainty for the consequence scores (2.3.9)
- Step 10: Document rationale for each of the above steps (2.3.10)
- Step 11: Summary of SICA results (2.3.11)
- Step 12: Evaluation/discussion of Level (2.3.12)
- Step 13: Components to be examined at Level 2 (2.3.13)

Level 1 documents to be completed are:

- SICA tables for species (target, byproduct and bycatch, TEP), habitat and community components
- Summary of SICA results

### SICA Habitat-specific issues

The Scale, Intensity and Consequence Analysis involves a qualitative comparison of only those habitat types known to occur within the area of effort of the sub-fishery. This step identifies the ‘Unit of Analysis’ or the habitat type considered most vulnerable to a particular fishing-related activity, specific to that sub-fishery. The risk of habitats differs according to gear types used by the different fisheries, the intensity and frequency of effort, location, feature type and depth fished. These ‘most’ vulnerable types are then scored according to the Tables as described for the other components.

Changes have been made to the Description of Consequences Table (**Table 5**), to accommodate the potential variation in recovery times of both sub-components ‘Habitat Types’ and ‘Habitat structure and function’. The supporting rationales are described in detail under each consequence score for that sub-component. It is important to note that even at a relatively low level of intensity some habitats may demonstrate a high

consequence score for some gears e.g. seamount habitats at mid-slope depths. Even at low intensity, vulnerable seamount habitats supporting slow-growing, long-lived and complex faunal communities may be substantially impacted by one encounter, which may require recovery times of decades.

The instructions for completing the SICA analysis are outlined below.

### **2.3.1 Record the hazard identification score (absence (0) presence (1) scores) identified at step 3 in the scoping level onto the SICA Document (Step 1)**

Record the hazard identification score absence (0) presence (1) identified at Step 3 at the scoping level onto the SICA sheet. A separate sheet will be required for each component (target, bycatch and byproduct, and TEP species, habitat, and communities). Only those activities that scored a 1 (presence) will be analysed at Level 1

### **2.3.2 Score spatial scale of activity (Step 2)**

The greatest spatial extent must be used for determining the spatial scale score for each identified hazard. For example, if fishing (e.g. capture by longline) takes place within an area of 200 nm by 300 nm, then the spatial scale is scored as 4. The score is then recorded onto the SICA Document and the rationale documented.

#### **Spatial scale score of activity**

<1 nm:	1-10 nm:	10-100 nm:	100-500 nm:	500-1000 nm:	>1000 nm:
1	2	3	4	5	6

Maps and graphs may be used to supplement the information (e.g. sketches of the distribution of the activity relative to the distribution of the component) and additional notes describing the nature of the activity should be provided. The spatial scale score at Step 2 is not used directly, but the analysis is used in making judgments about level of intensity at Step. Obviously, two activities can score the same with regard to spatial scale, but the intensity of each can differ vastly. The reasons for the score are recorded in the rationale column of the SICA spreadsheet.

### **2.3.3 Score temporal scale of activity (Step 3)**

The highest frequency must be used for determining the temporal scale score for each identified hazard. If the fishing activity occurs daily, the temporal scale is scored as 6. If oil spillage occurs about once per year, then the temporal scale of that hazard scores a 3. The score is then recorded onto the SICA Document and the rationale documented.

#### **Temporal scale score of activity**

Decadal (1 day every 10 years or so)	Every several years (1 day every several years)	Annual (1-100 days per year)	Quarterly (100-200 days per year)	Weekly (200-300 days per year)	Daily (300-365 days per year)
1	2	3	4	5	6

It may be more logical for some activities to consider the aggregate number of days that an activity occurs. For example, if the activity “fishing” was undertaken by 10 boats during the same 150 days of the year, the score is 3. If the same 10 boats each spend 30 non-overlapping days fishing, the temporal scale of the activity is a sum of 300 days, indicating that a score of 6 is appropriate. In the case where the activity occurs over many days, but only every 10 years, the number of days by the number of years in the cycle is used to determine the score. For example, 100 days of an activity every 10 years averages to 10 days every year, so that a score of 3 is appropriate.

The temporal scale score at Step 3 is not used directly, but the analysis is used in making judgments about level of intensity at Step 7. Obviously, two activities can score the same with regard to temporal scale, but the intensity of each can differ vastly. The reasons for the score are recorded in the rationale column.

#### ***2.3.4 Choose the sub-component most likely to be affected by activity (Step 4)***

The most vulnerable sub-component must be used for analysis of each identified hazard. This selection must be made on the basis of expected highest potential risk for each ‘direct impact of fishing’ and ‘fishing activity’ combination, and recorded in the ‘sub-component’ column of the SICA Document. The justification is recorded in the rationale column.

#### ***2.3.5 Choose the unit of analysis most likely to be affected by activity and to have highest consequence score (Step 5)***

The most vulnerable ‘unit of analysis’ (i.e. most vulnerable species, habitat type or community) must be used for analysis of each identified hazard. The species, habitats, or communities (depending on which component is being analysed) are selected from **Scoping Document S2 (A – C)**. This selection must be made on the basis of expected highest potential risk for each ‘direct impact of fishing’ and ‘fishing activity’ combination, and recorded in the ‘unit of analysis’ column of the SICA Document. The justification is recorded in the rationale column.

#### ***2.3.6 Select the most appropriate operational objective (Step 6)***

To provide linkage between the SICA consequence score and the management objectives, the most appropriate operational objective for each sub-component is chosen. The most relevant operational objective code from **Scoping Document S3** is recorded in the ‘operational objective’ column in the SICA document. Note that SICA can only be performed on operational objectives agreed as important for the (sub) fishery during scoping and contained in **Scoping Document S3**. If the SICA process identifies reasons to include sub-components or operational objectives that were previously not included/eliminated then these sub-components or operational objectives must be re-instated.

#### ***2.3.7 Score the intensity of the activity for the component (Step 7)***

The score for intensity of an activity considers the direct impacts in line with the categories shown in the conceptual model (**Figure 11**) (capture, direct impact without capture, addition/movement of biological material, addition of non-biological material, disturbance to physical processes, external hazards). The intensity of the activity is

judged based on the scale of the activity, its nature and extent. Activities are scored as per intensity scores below.

**Intensity score of activity** (Modified from Fletcher et al. 2002)

Level	Score	Description
Negligible	1	remote likelihood of detection at any spatial or temporal scale
Minor	2	occurs rarely or in few restricted locations and detectability even at these scales is rare
Moderate	3	moderate at broader spatial scale, or severe but local
Major	4	severe and occurs reasonably often at broad spatial scale
Severe	5	occasional but very severe and localized or less severe but widespread and frequent
Catastrophic	6	local to regional severity or continual and widespread

This score is then recorded on the **Level 1 (SICA) Document** and the rationale documented.

**2.3.8 Score the consequence of intensity for that component (Step 8)**

The consequence of the activity is a measure of the likelihood of not achieving the operational objective for the selected sub-component and unit of analysis. It considers the flow on effects of the direct impacts from Step 7 for the relevant indicator (e.g. decline in biomass below the selected threshold due to direct capture). Activities are scored as per consequence scores below. A more detailed description of the consequences at each level for each component (target, bycatch and byproduct, TEP species, habitats, and communities) is provided as a guide for scoring the consequences of the activities in the description of consequences table (see **Table 5** below).

**Consequence score for ERAEF activities** (Modified from Fletcher et al. 2002).

Level	Score	Description
Negligible	1	Impact unlikely to be detectable at the scale of the stock/habitat/community
Minor	2	Minimal impact on stock/habitat/community structure or dynamics
Moderate	3	Maximum impact that still meets an objective (e.g. sustainable level of impact such as full exploitation rate for a target species).
Major	4	Wider and longer term impacts (e.g. long-term decline in CPUE)
Severe	5	Very serious impacts now occurring, with relatively long time period likely to be needed to restore to an acceptable level (e.g. serious decline in spawning biomass limiting population increase).
Intolerable	6	Widespread and permanent/irreversible damage or loss will occur-unlikely to ever be fixed (e.g. extinction)

The score should be based on existing information and/or the expertise of the risk assessment group. The rationale for assigning each consequence score must be documented. The conceptual model may be used to link impact to consequence by showing the pathway that was considered. In the absence of agreement or information, the highest score (worst case scenario) considered plausible is applied to the activity.

### **2.3.9 Record confidence/uncertainty for the consequence scores (Step 9)**

The information used at this level is qualitative and each step is based on expert (fishers, managers, conservationists, scientists) judgment. The confidence rating for the consequence score is rated as 1 (low confidence) or 2 (high confidence) for the activity/component. The score is recorded on the SICA Document and the rationale documented. The confidence will reflect the levels of uncertainty for each score at steps 2, 3, 7 and 8.

**Description of Confidence scores for Consequences. The confidence score appropriate to the rationale is used, and documented on the SICA Document.**

Confidence	Score	Rationale for the confidence score
Low	1	Data exists, but is considered poor or conflicting No data exists Disagreement between experts
High	2	Data exists and is considered sound Consensus between experts Consequence is constrained by logical consideration

### **2.3.10 Document rationale for each of the above steps (Step 10)**

The rationale forms a logical pathway to the consequence score. It is provided for each choice at each step of the SICA analysis.

**Table 5A. Target Species. Description of consequences for each component and each sub-component. Use table as a guide for scoring the level of consequence for target species (Modified from Fletcher et al. 2002).**

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
<b>Population size</b>	<b>1. Population size</b> Insignificant change to population size/growth rate (r). Unlikely to be detectable against background variability for this population.	<b>1. Population size</b> Possible detectable change in size/growth rate (r) but minimal impact on population size and none on dynamics.	<b>1. Population size</b> Full exploitation rate but long-term recruitment dynamics not adversely damaged.	<b>1. Population size</b> Affecting recruitment state of stocks and/or their capacity to increase	<b>1. Population size</b> Likely to cause local extinctions if continued in longer term	<b>1. Population size</b> Local extinctions are imminent/immediate
<b>Geographic range</b>	<b>2. Geographic range</b> No detectable change in geographic range. Unlikely to be detectable against background variability for this population.	<b>2. Geographic range</b> Possible detectable change in geographic range but minimal impact on population range and none on dynamics, change in geographic range up to 5 % of original.	<b>2. Geographic range</b> Change in geographic range up to 10 % of original.	<b>2. Geographic range</b> Change in geographic range up to 25 % of original.	<b>2. Geographic range</b> Change in geographic range up to 50 % of original.	<b>2. Geographic range</b> Change in geographic range > 50 % of original.
<b>Genetic structure</b>	<b>3. Genetic structure</b> No detectable change in genetic structure. Unlikely to be detectable against background variability for this population.	<b>3. Genetic structure</b> Possible detectable change in genetic structure. Any change in frequency of genotypes, effective population size or number of spawning units up to 5%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units up to 10%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units up to 25%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units, change up to 50%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units > 50%.
<b>Age/size/sex structure</b>	<b>4. Age/size/sex structure</b> No detectable change in	<b>4. Age/size/sex structure</b> Possible detectable	<b>4. Age/size/sex structure</b> Impact on population	<b>4. Age/size/sex structure</b> Long-term	<b>4. Age/size/sex structure</b> Long-term	<b>4. Age/size/sex structure</b> Long-term recruitment dynamics

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
	age/size/sex structure. Unlikely to be detectable against background variability for this population.	change in age/size/sex structure but minimal impact on population dynamics.	dynamics at maximum sustainable level, long-term recruitment dynamics not adversely affected.	recruitment dynamics adversely affected. Time to recover to original structure up to 5 generations free from impact.	recruitment dynamics adversely affected. Time to recover to original structure up to 10 generations free from impact.	adversely affected. Time to recover to original structure > 100 generations free from impact.
<b>Reproductive capacity</b>	<b>5. Reproductive capacity</b> No detectable change in reproductive capacity. Unlikely to be detectable against background variability for this population.	<b>5. Reproductive capacity</b> Possible detectable change in reproductive capacity but minimal impact on population dynamics.	<b>5. Reproductive capacity</b> Impact on population dynamics at maximum sustainable level, long-term recruitment dynamics not adversely affected.	<b>5. Reproductive capacity</b> Change in reproductive capacity adversely affecting long-term recruitment dynamics. Time to recovery up to 5 generations free from impact.	<b>5. Reproductive capacity</b> Change in reproductive capacity adversely affecting long-term recruitment dynamics. Time to recovery up to 10 generations free from impact.	<b>5. Reproductive capacity</b> Change in reproductive capacity adversely affecting long-term recruitment dynamics. Time to recovery > 100 generations free from impact.
<b>Behaviour/movement</b>	<b>6. Behaviour/movement</b> No detectable change in behaviour/movement. Unlikely to be detectable against background variability for this population. Time taken to recover to pre-disturbed state on the scale of hours.	<b>6. Behaviour/movement</b> Possible detectable change in behaviour/movement but minimal impact on population dynamics. Time to return to original behaviour/movement on the scale of days to weeks.	<b>6. Behaviour/movement</b> Detectable change in behaviour/movement with the potential for some impact on population dynamics. Time to return to original behaviour/movement on the scale of weeks to months.	<b>6. Behaviour/movement</b> Change in behaviour/movement with impacts on population dynamics. Time to return to original behaviour/movement on the scale of months to years.	<b>6. Behaviour/movement</b> Change in behaviour/movement with impacts on population dynamics. Time to return to original behaviour/movement on the scale of years to decades.	<b>6. Behaviour/movement</b> Change to behaviour/movement. Population does not return to original behaviour/movement.

**Table 5B. Bycatch and Byproduct species. Description of consequences for each component and each sub-component. Use table as a guide for scoring the level of consequence for bycatch/byproduct species (Modified from Fletcher et al. 2002).**

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
<b>Population size</b>	<p><b>1. Population size</b> Insignificant change to population size/growth rate (r). Unlikely to be detectable against background variability for this population.</p>	<p><b>1. Population size</b> Possible detectable change in size/growth rate (r) but minimal impact on population size and none on dynamics.</p>	<p><b>1. Population size</b> No information is available on the relative area or susceptibility to capture/ impact or on the risk of life history traits of this type of species Susceptibility to capture is suspected to be less than 50% and species do not have vulnerable life history traits. For species with vulnerable life history traits to stay in this category susceptibility to capture must be less than 25%.</p>	<p><b>1. Population size</b> Relative state of capture/susceptibility suspected/known to be greater than 50% and species should be examined explicitly.</p>	<p><b>1. Population size</b> Likely to cause local extinctions if continued in longer term</p>	<p><b>1. Population size</b> Local extinctions are imminent/immediate</p>
<b>Geographic range</b>	<p><b>2. Geographic range</b> No detectable change in geographic range. Unlikely to be detectable against background variability for this</p>	<p><b>2. Geographic range</b> Possible detectable change in geographic range but minimal impact on population range and none on dynamics, change in</p>	<p><b>2. Geographic range</b> Change in geographic range up to 10 % of original.</p>	<p><b>2. Geographic range</b> Change in geographic range up to 25 % of original.</p>	<p><b>2. Geographic range</b> Change in geographic range up to 50 % of original.</p>	<p><b>2. Geographic range</b> Change in geographic range &gt; 50 % of original.</p>

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
	population.	geographic range up to 5 % of original.				
<b>Genetic structure</b>	<b>3. Genetic structure</b> No detectable change in genetic structure. Unlikely to be detectable against background variability for this population.	<b>3. Genetic structure</b> Possible detectable change in genetic structure. Any change in frequency of genotypes, effective population size or number of spawning units up to 5%.	<b>3. Genetic structure</b> Detectable change in genetic structure. Change in frequency of genotypes, effective population size or number of spawning units up to 10%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units up to 25%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units up to 50%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units > 50%.
<b>Age/size/sex structure</b>	<b>4. Age/size/sex structure</b> No detectable change in age/size/sex structure. Unlikely to be detectable against background variability for this population.	<b>4. Age/size/sex structure</b> Possible detectable change in age/size/sex structure but minimal impact on population dynamics.	<b>4. Age/size/sex structure</b> Detectable change in age/size/sex structure. Impact on population dynamics at maximum sustainable level, long-term recruitment dynamics not adversely damaged.	<b>4. Age/size/sex structure</b> Long-term recruitment dynamics adversely affected. Time to recover to original structure up to 5 generations free from impact.	<b>4. Age/size/sex structure</b> Long-term recruitment dynamics adversely affected. Time to recover to original structure up to 10 generations free from impact.	<b>4. Age/size/sex structure</b> Long-term recruitment dynamics adversely affected. Time to recover to original structure > 100 generations free from impact.
<b>Reproductive capacity</b>	<b>5. Reproductive capacity</b> No detectable change in reproductive capacity. Unlikely to be detectable against background variability for this population.	<b>5. Reproductive capacity</b> Possible detectable change in reproductive capacity but minimal impact on population dynamics.	<b>5. Reproductive capacity</b> Detectable change in reproductive capacity, impact on population dynamics at maximum sustainable level, long-term recruitment dynamics not	<b>5. Reproductive capacity</b> Change in reproductive capacity adversely affecting long-term recruitment dynamics. Time to recovery up to 5 generations free from impact.	<b>5. Reproductive capacity</b> Change in reproductive capacity adversely affecting long-term recruitment dynamics. Time to recovery up to 10 generations free from impact.	<b>5. Reproductive capacity</b> Change in reproductive capacity adversely affecting long-term recruitment dynamics. Time to recovery > 100 generations free from impact.

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
			adversely damaged.			
<b>Behaviour/movement</b>	<b>6. Behaviour/movement</b> No detectable change in behaviour/movement. Unlikely to be detectable against background variability for this population. Time taken to recover to pre-disturbed state on the scale of hours.	<b>6. Behaviour/movement</b> Possible detectable change in behaviour/movement but minimal impact on population dynamics. Time to return to original behaviour/movement on the scale of days to weeks.	<b>6. Behaviour/movement</b> Detectable change in behaviour/movement with the potential for some impact on population dynamics. Time to return to original behaviour/movement on the scale of weeks to months.	<b>6. Behaviour/movement</b> Change in behaviour/movement with impacts on population dynamics. Time to return to original behaviour/movement on the scale of months to years	<b>6. Behaviour/movement</b> Change in behaviour/movement with impacts on population dynamics. Time to return to original behaviour/movement on the scale of years to decades.	<b>6. Behaviour/movement</b> Change to behaviour/movement. Population does not return to original behaviour/movement.

**Table 5C. TEP species. Description of consequences for each component and each sub-component. Use table as a guide for scoring the level of consequence for TEP species (Modified from Fletcher et al. 2002).**

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
<b>Population size</b>	<b>1. Population size</b> Almost none are killed.	<b>1. Population size</b> Insignificant change to population size/growth rate (r). Unlikely to be detectable against background variability for this population.	<b>1. Population size.</b> State of reduction on the rate of increase are at the maximum acceptable level. Possible detectable change in size/growth rate (r) but minimal impact on population size and none on dynamics of TEP species.	<b>1. Population size</b> Affecting recruitment state of stocks or their capacity to increase.	<b>1. Population size</b> Local extinctions are imminent/immediate	<b>1. Population size</b> Global extinctions are imminent/immediate
<b>Geographic range</b>	<b>2. Geographic range</b> No interactions leading to impact on geographic range.	<b>2. Geographic range</b> No detectable change in geographic range. Unlikely to be detectable against background variability for this population.	<b>2. Geographic range</b> Possible detectable change in geographic range but minimal impact on population range and none on dynamics. Change in geographic range up to 5 % of original.	<b>2. Geographic range</b> Change in geographic range up to 10% of original.	<b>2. Geographic range</b> Change in geographic range up to 25% of original.	<b>2. Geographic range</b> Change in geographic range up to 25% of original.
<b>Genetic structure</b>	<b>3. Genetic structure</b> No interactions leading to impact on genetic structure.	<b>3. Genetic structure</b> No detectable change in genetic structure. Unlikely to be detectable against background variability for this population.	<b>3. Genetic structure</b> Possible detectable change in genetic structure but minimal impact at population level. Any change in frequency of genotypes, effective population size or	<b>3. Genetic structure</b> Moderate change in genetic structure. Change in frequency of genotypes, effective population size or number of spawning units up to 10%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units up to 25%.	<b>3. Genetic structure</b> Change in frequency of genotypes, effective population size or number of spawning units up to 25%.

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
			number of spawning units up to 5%.			
<b>Age/size/sex structure</b>	<b>4. Age/size/sex structure</b> No interactions leading to change in age/size/sex structure.	<b>4. Age/size/sex structure</b> No detectable change in age/size/sex structure. Unlikely to be detectable against background variability for this population.	<b>4. Age/size/sex structure</b> Possible detectable change in age/size/sex structure but minimal impact on population dynamics.	<b>4. Age/size/sex structure</b> Detectable change in age/size/sex structure. Impact on population dynamics at maximum sustainable level, long-term recruitment dynamics not adversely damaged.	<b>4. Age/size/sex structure</b> Severe change in age/size/sex structure. Impact adversely affecting population dynamics. Time to recover to original structure up to 5 generations free from impact	<b>4. Age/size/sex structure</b> Impact adversely affecting population dynamics. Time to recover to original structure > 10 generations free from impact
<b>Reproductive capacity</b>	<b>5. Reproductive capacity</b> No interactions resulting in change to reproductive capacity.	<b>5. Reproductive capacity</b> No detectable change in reproductive capacity. Unlikely to be detectable against background variability for this population.	<b>5. Reproductive capacity</b> Possible detectable change in reproductive capacity but minimal impact on population dynamics.	<b>5. Reproductive capacity</b> Detectable change in reproductive capacity, impact on population dynamics at maximum sustainable level, long-term recruitment dynamics not adversely damaged.	<b>5. Reproductive capacity</b> Change in reproductive capacity, impact adversely affecting recruitment dynamics. Time to recover to original structure up to 5 generations free from impact	<b>5. Reproductive capacity</b> Change in reproductive capacity, impact adversely affecting recruitment dynamics. Time to recover to original structure > 10 generations free from impact
<b>Behaviour/movement</b>	<b>6. Behaviour/movement</b> No interactions resulting in change to behaviour/movement.	<b>6. Behaviour/movement</b> No detectable change in behaviour/movement. Time to return to original behaviour/movement on the scale of hours.	<b>6. Behaviour/movement</b> Possible detectable change in behaviour/movement but minimal impact on population dynamics. Time to return to	<b>6. Behaviour/movement</b> Detectable change in behaviour/movement with the potential for some impact on population dynamics. Time to return to	<b>6. Behaviour/movement</b> Change in behaviour/movement, impact adversely affecting population dynamics. Time to return to original behaviour/	<b>6. Behaviour/movement</b> Change in behaviour/movement. Impact adversely affecting population dynamics. Time to return to original behaviour/

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
			original behaviour/ movement on the scale of days to weeks	original behaviour/ movement on the scale of weeks to months	movement on the scale of months to years.	movement on the scale of years to decades.
<b>Interaction with fishery</b>	<b>7. Interactions with fishery</b> No interactions with fishery.	<b>7. Interactions with fishery</b> Few interactions and involving up to 5% of population.	<b>7. Interactions with fishery</b> Moderate level of interactions with fishery involving up to 10 % of population.	<b>7. Interactions with fishery</b> Major interactions with fishery, involving up to 25% of population.	<b>7. Interactions with fishery</b> Frequent interactions involving ~ 50% of population.	<b>7. Interactions with fishery</b> Frequent interactions involving the entire known population negatively affecting the viability of the population.

**Table 5D. Habitats. Description of consequences for each component and each sub-component. Use table as a guide for scoring the level of consequence for habitats. Note that for sub-components Habitat types and Habitat structure and function, time to recover from impact scales differ from substrate, water and air. Rationale: structural elements operate on greater timeframes to return to pre-disturbance states (Modified from Fletcher et al. 2002).**

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
<b>Substrate quality</b>	<p><b>1. Substrate quality</b> Reduction in the productivity (similar to the intrinsic rate of increase for species) on the substrate from the activity is unlikely to be detectable. Time taken to recover to pre-disturbed state on the scale of hours.</p>	<p><b>1. Substrate quality</b> Detectable impact on substrate quality. At small spatial scale time taken to recover to pre-disturbed state on the scale of days to weeks, at larger spatial scales recovery time of hours to days.</p>	<p><b>1. Substrate quality</b> More widespread effects on the dynamics of substrate quality but the state are still considered acceptable given the percent area affected, the types of impact occurring and the recovery capacity of the substrate. For impacts on non-fragile substrates this may be for up to 50% of habitat affected, but for more fragile habitats, e.g. reef substrate, to stay in this category the % area affected needs to be smaller up to 25%.</p>	<p><b>1. Substrate quality</b> The level of reduction of internal dynamics of habitats may be larger than is sensible to ensure that the habitat will not be able to recover adequately, or it will cause strong downstream effects from loss of function. Time to recover from local impact on the scale of months to years, at larger spatial scales recovery time of weeks to months.</p>	<p><b>1. Substrate quality</b> Severe impact on substrate quality with 50 - 90% of the habitat affected or removed by the activity which may seriously endanger its long-term survival and result in changes to ecosystem function. Recovery period measured in years to decades.</p>	<p><b>1. Substrate quality</b> The dynamics of the entire habitat is in danger of being changed in a major way, or &gt; 90% of habitat destroyed.</p>
<b>Water quality</b>	<p><b>2. Water quality</b> No direct impact on water quality. Impact unlikely to be detectable. Time taken to recover to pre-disturbed state on</p>	<p><b>2. Water quality</b> Detectable impact on water quality. Time to recover from local impact on the scale of days to weeks, at larger spatial scales</p>	<p><b>2. Water quality</b> Moderate impact on water quality. Time to recover from local impact on the scale of weeks to months, at larger spatial scales</p>	<p><b>2. Water quality</b> Time to recover from local impact on the scale of months to years, at larger spatial scales recovery time of weeks to months.</p>	<p><b>2. Water quality</b> Impact on water quality with 50 - 90% of the habitat affected or removed by the activity which may seriously endanger its</p>	<p><b>2. Water quality</b> The dynamics of the entire habitat is in danger of being changed in a major way, or &gt; 90% of habitat destroyed.</p>

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
	the scale of hours.	recovery time of hours to days.	recovery time of days to weeks.		long-term survival and result in changes to ecosystem function. Recovery period measured in years to decades.	
<b>Air quality</b>	<b>3. Air quality</b> No direct impact on air quality. Impact unlikely to be detectable. Time taken to recover to pre-disturbed state on the scale of hours.	<b>3. Air quality</b> Detectable impact on air quality. Time to recover from local impact on the scale of days to weeks, at larger spatial scales recovery time of hours to days.	<b>3. Air quality</b> Detectable impact on air quality. Time to recover from local impact on the scale of weeks to months, at larger spatial scales recovery time of days to weeks.	<b>3. Air quality</b> Time to recover from local impact on the scale of months to years, at larger spatial scales recovery time of weeks to months.	<b>3. Air quality</b> Impact on air quality with 50 - 90% of the habitat affected or removed by the activity .which may seriously endanger its long-term survival and result in changes to ecosystem function. Recovery period measured in years to decades.	<b>3. Air quality</b> The dynamics of the entire habitat is in danger of being changed in a major way, or > 90% of habitat destroyed.
<b>Habitat types</b>	<b>4. Habitat types</b> No direct impact on habitat types. Impact unlikely to be detectable. Time taken to recover to pre-disturbed state on the scale of hours to days.	<b>4. Habitat types</b> Detectable impact on distribution of habitat types. Time to recover from local impact on the scale of days to weeks, at larger spatial scales recovery time of days to months.	<b>4. Habitat types</b> Impact reduces distribution of habitat types. Time to recover from local impact on the scale of weeks to months, at larger spatial scales recovery time of months to < one year.	<b>4. Habitat types</b> The reduction of habitat type areal extent may threaten ability to recover adequately, or cause strong downstream effects in habitat distribution and extent. Time to recover from impact on the scale of > one year to < decadal	<b>4. Habitat types</b> Impact on relative abundance of habitat types resulting in severe changes to ecosystem function. Recovery period likely to be > decadal	<b>4. Habitat types</b> The dynamics of the entire habitat is in danger of being changed in a catastrophic way. The distribution of habitat types has been shifted away from original spatial pattern. If reversible, will require a long-term recovery period, on

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
				timeframes.		the scale of decades to centuries.
<b>Habitat structure and function</b>	<p><b>5. Habitat structure and function</b> No detectable change to the internal dynamics of habitat or populations of species making up the habitat. Time taken to recover to pre-disturbed state on the scale of hours to days.</p>	<p><b>5. Habitat structure and function</b> Detectable impact on habitat structure and function. Time to recover from impact on the scale of days to months, regardless of spatial scale</p>	<p><b>5. Habitat structure and function</b> Impact reduces habitat structure and function. For impacts on non-fragile habitat structure this may be for up to 50% of habitat affected, but for more fragile habitats, to stay in this category the % area affected needs to be smaller up to 20%. Time to recover from local impact on the scale of months to &lt; one year, at larger spatial scales recovery time of months to &lt; one year.</p>	<p><b>5. Habitat structure and function</b> The level of reduction of internal dynamics of habitat may threaten ability to recover adequately, or it will cause strong downstream effects from loss of function. For impacts on non-fragile habitats this may be for up to 50% of habitat affected, but for more fragile habitats, to stay in this category the % area affected up to 25%. Time to recover from impact on the scale of &gt; one year to &lt; decadal timeframes.</p>	<p><b>5. Habitat structure and function</b> Impact on habitat function resulting from severe changes to internal dynamics of habitats. Time to recover from impact likely to be &gt; decadal.</p>	<p><b>5. Habitat structure and function</b> The dynamics of the entire habitat is in danger of being changed in a catastrophic way which may not be reversible. Habitat losses occur. Some elements may remain but will require a long-term recovery period, on the scale of decades to centuries.</p>



Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
	Interactions which affect the distribution of communities unlikely to be detectable against natural variation.	Possible detectable change in geographic range of communities but minimal impact on community dynamics change in geographic range up to 5 % of original.	Detectable change in geographic range of communities with some impact on community dynamics Change in geographic range up to 10 % of original.	Geographic range of communities, ecosystem function altered measurably and some functional groups are locally missing/declining/increasing outside of historical range. Change in geographic range for up to 25 % of the species. Recovery period measured in months to years.	Change in geographic range of communities, ecosystem function altered and some functional groups are currently missing and new groups are present. Change in geographic range for up to 50 % of species including keystone species. Recovery period measured in years to decades.	Change in geographic range of communities, ecosystem function collapsed. Change in geographic range for >90% of species including keystone species. Recovery period measured in decades to centuries.
Trophic/size structure	4. Trophic/size structure Interactions which affect the internal dynamics unlikely to be detectable against natural variation.	4. Trophic/size structure Change in mean trophic level, biomass/ number in each size class up to 5%.	4. Trophic/size structure Changes in mean trophic level, biomass/ number in each size class up to 10%.	4. Trophic/size structure Changes in mean trophic level. Ecosystem function altered measurably and some function or components are locally missing/declining/increasing outside of historical range and/or allowed/facilitated new species to appear. Recovery period measured in years to decades.	4. Trophic/size structure Changes in mean trophic level. Ecosystem function severely altered and some function or components are missing and new groups present. Recovery period measured in years to decades.	4. Trophic/size structure Ecosystem function catastrophically altered as a result of changes in mean trophic level, total collapse of ecosystem processes. Recovery period measured in decades to centuries.
Bio-geochemical cycles	5. Bio- and geochemical cycles Interactions which	5. Bio- and geochemical cycles Only minor changes	5. Bio- and geochemical cycles Changes in relative	5. Bio- and geochemical cycles Changes in relative	5. Bio- and geochemical cycles Changes in relative	5. Bio- and geochemical cycles Ecosystem function

Sub-component	Score/level					
	1 Negligible	2 Minor	3 Moderate	4 Major	5 Severe	6 Intolerable
	affect bio- & geochemical cycling unlikely to be detectable against natural variation.	in relative abundance of other constituents leading to minimal changes to bio- & geochemical cycling up to 5%.	abundance of other constituents leading to minimal changes to bio- & geochemical cycling, up to 10%.	abundance of constituents leading to major changes to bio- & geochemical cycling, up to 25%.	abundance of constituents leading to Severe changes to bio- & geochemical cycling. Recovery period measured in years to decades.	catastrophically altered as a result of community changes affecting bio- and geo- chemical cycles, total collapse of ecosystem processes. Recovery period measured in decades to centuries.





### 2.3.11 Summary of SICA results (step 11)

The proforma report below provides a summary table (**Level 1 (SICA) Document L1.6**) of consequence scores for all activity/component combinations showing those that scored 3 or above for consequence, and differentiating those that did so with high confidence (in bold). \*Tony I suspect in reality just those score 3 get bolded \*

#### Level 1 (SICA) Document L1.6. Summary table of consequence scores for all activity/component combinations.

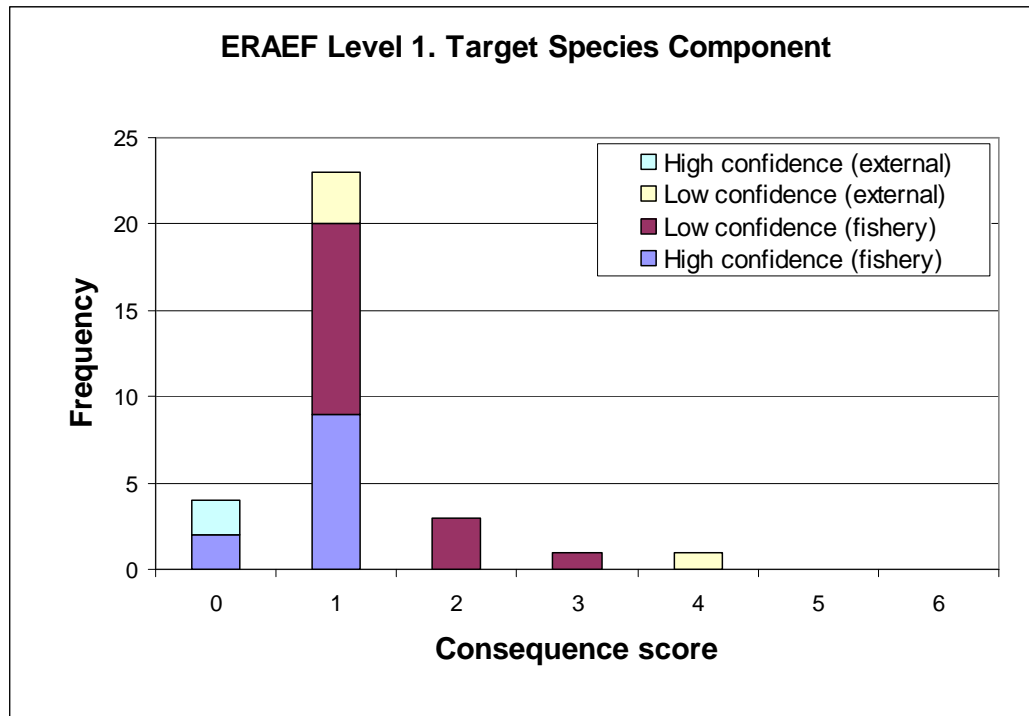
Direct impact	Activity	Target species	Byproduct and bycatch species	TEP species	Habitats	Communities	
Capture	Bait collection						
	Fishing						
	Incidental behaviour						
Direct impact without capture	Bait collection						
	Fishing						
	Incidental behaviour						
	Gear loss						
	Anchoring/mooring						
Addition/movement of biological material	Navigation/steaming						
	Translocation of species						
	On board processing						
	Discarding catch						
	Stock enhancement						
	Provisioning						
	Organic waste disposal						
	Addition of non-biological material	Debris					
		Chemical pollution					
		Exhaust					
Gear loss							
Navigation/steaming							
Disturb physical processes	Activity/presence on water						
	Bait collection						
	Fishing						
	Boat launching						
	Anchoring/mooring						
External hazards	Navigation/steaming						
	Other fisheries						

Note: external hazards are not considered at Level 2 in the PSA analysis

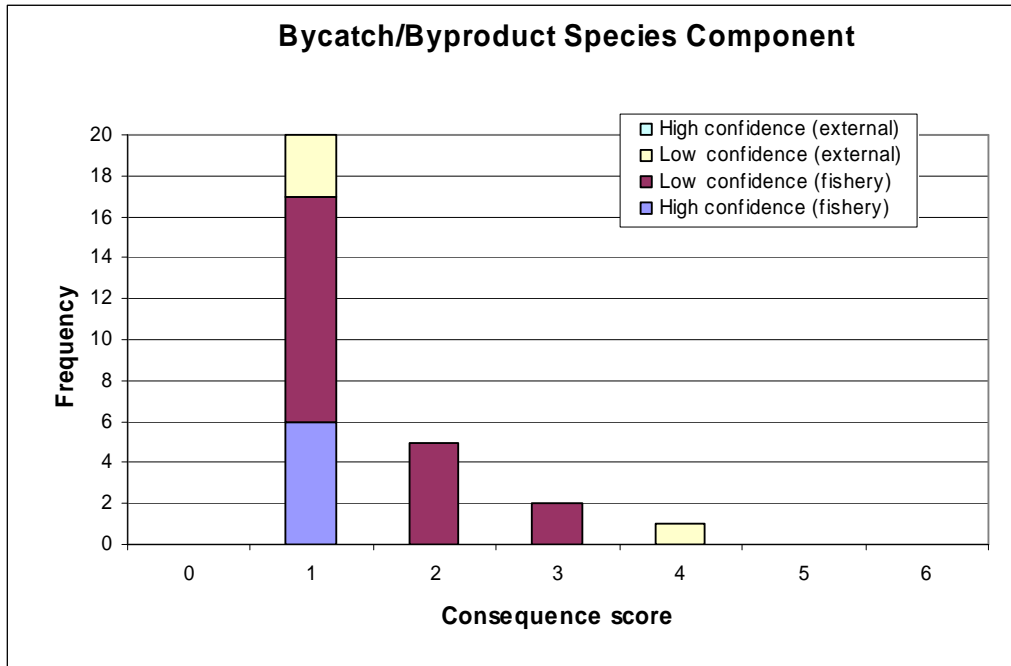
Direct impact	Activity	Target species	Byproduct and bycatch species	TEP species	Habitats	Communities
(specify the particular example within each activity area)						
	Aquaculture					
	Coastal development					
	Other extractive activities					
	Other non extractive activities					
	Other anthropogenic activities					

Individual plots of the SICA consequence scores for each component are generated in the SICA spreadsheets and included within the fishery report. Examples are shown below.

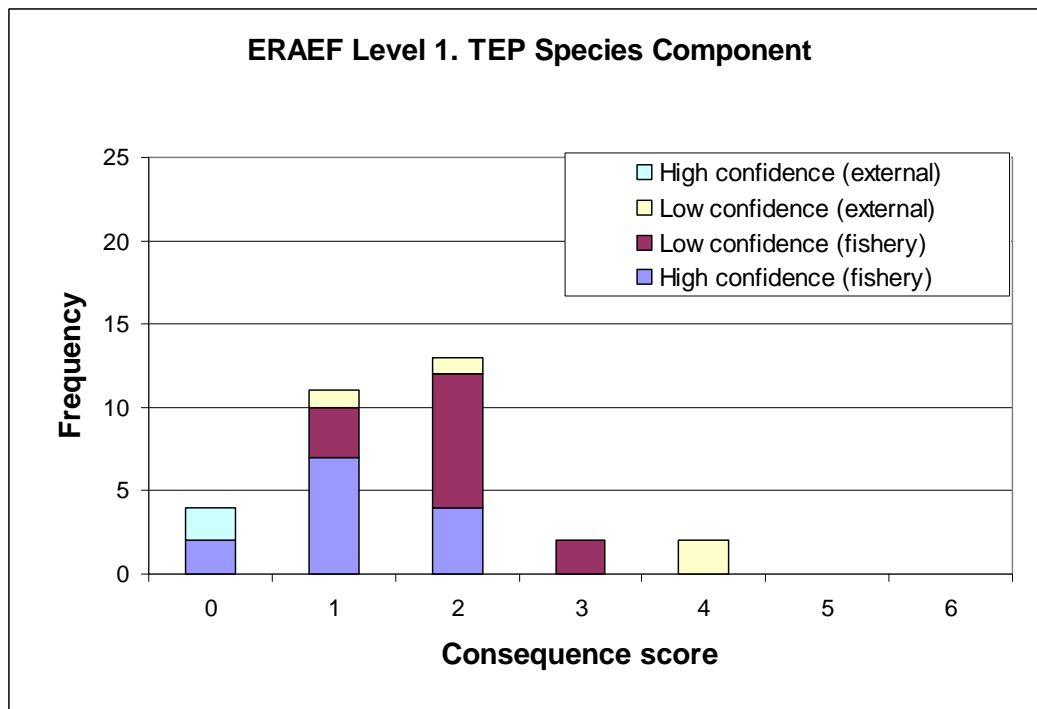
Target species: Frequency of consequence score differentiated between high and low confidence.



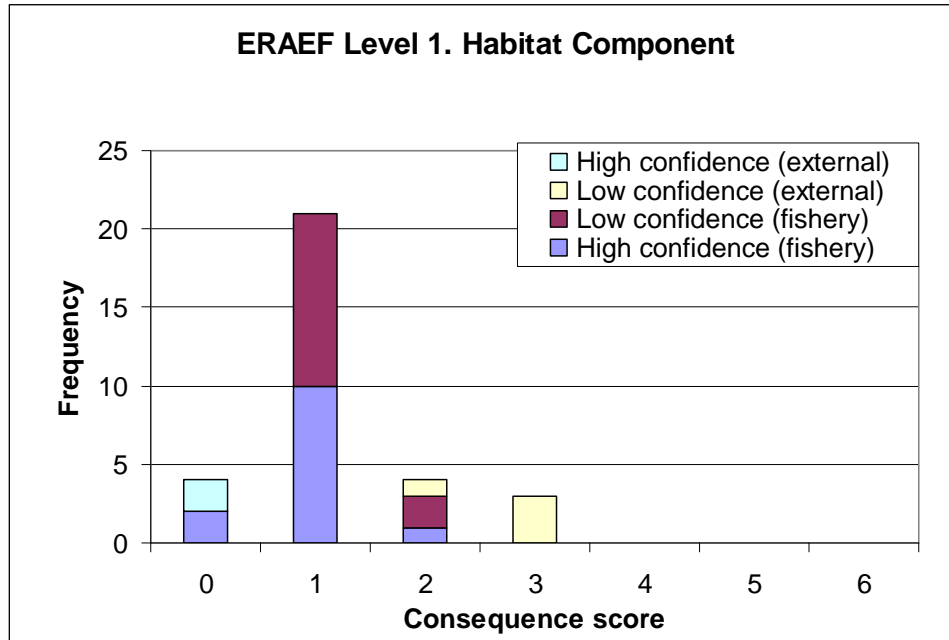
Byproduct and bycatch species: Frequency of consequence score differentiated between high and low confidence



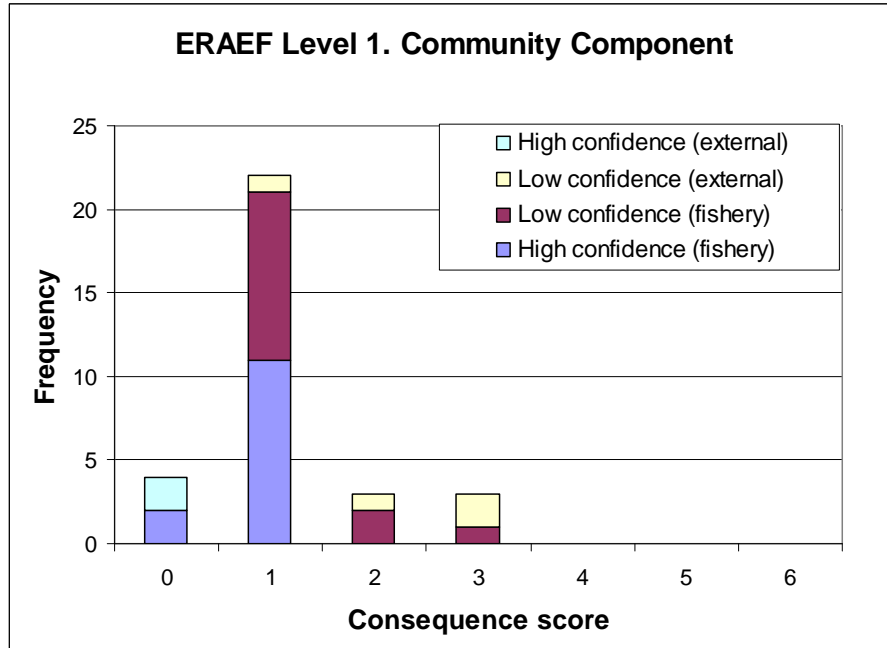
TEP species: Frequency of consequence score differentiated between high and low confidence (SICA excel workbook)



Habitats: Frequency of consequence score differentiated between high and low confidence



Communities: Frequency of consequence score differentiated between high and low confidence (SICA excel workbook)



### **2.3.12 Evaluation/discussion of Level 1 (step 12)**

This section should provide a brief discussion of the results of the Level 1 analysis. This should summarise:

- Which components had scores 3 or above
- Which hazards were NOT eliminated
- Any significant external hazards and their likely importance relative to impacts from the sub-fishery under analysis
- Provide some detailed discussion of any elements that scored 4 or above
- Discuss key uncertainties (especially those resulting in scores of 4 or above)
- Provide an overview of how the analysis “makes sense”

Example below

No components were eliminated at Level 1 (at least one score of 3 or above for each component).

Most hazards were eliminated as low risk. For the XXXX fishery, those remaining included:

- Direct impact of capture by fishing (all components)
- Direct impact without capture (habitats and communities)
- Activity/presence on water (TEP)
- Physical disturbance from fishing (habitats and communities)

Of these hazards the only ones assessed as “major” (Risk score 4) were the direct impacts of fishing on target species and on habitats. There were no hazards assessed at risk score 5 or above associated with the XXXX fishery.

Hazards from external impacts included other fisheries (adjoining YYYY fishery targeting same species), aquaculture (possibly affecting inshore nursery areas), and extractive (oil and gas exploration) and non-extractive (shipping) activities.

### **2.3.13 Components to be examined at Level 2 (step 13)**

As a result of the preliminary SICA analysis, the components that are to be examined at Level 2 are those with any consequence scores of 3 or above. These components are:

- *List them*

The SICA has removed some components from further analysis, as these are judged to be impacted with low consequence by the set of activities considered. Those components excluded are

- *List them*

## 2.4 Level 2 Productivity and Susceptibility Analysis (PSA)

When the risk of an activity at Level 1 (SICA) on a component is moderate or higher and no planned management interventions that would remove this risk are identified, an assessment is required at Level 2. The PSA approach is a method of assessment which allows all units within any of the ecological components to be effectively and comprehensively screened for risk. The units of analysis are the complete set of species habitats or communities identified at the scoping stage. The PSA results in sections 2.4.2 and 2.4.3 of this report measure risk from direct impacts of fishing only, which in all assessments to date has been the hazard with the greatest risks identified at Level 1. Future iterations of the methodology will include PSAs modified to measure the risk due to other activities, such as gear loss.

The PSA approach is based on the assumption that the risk to an ecological component will depend on two characteristics of the component units: (1) the extent of the impact due to the fishing activity, which will be determined by the susceptibility of the unit to the fishing activities (Susceptibility) and (2) the productivity of the unit (Productivity), which will determine the rate at which the unit can recover after potential depletion or damage by the fishing. It is important to note that the PSA analysis essentially measures potential for risk (hereafter noted as risk). A measure of absolute risk requires some direct measure of abundance or mortality rate for the unit in question, and this information is generally lacking at Level 2.

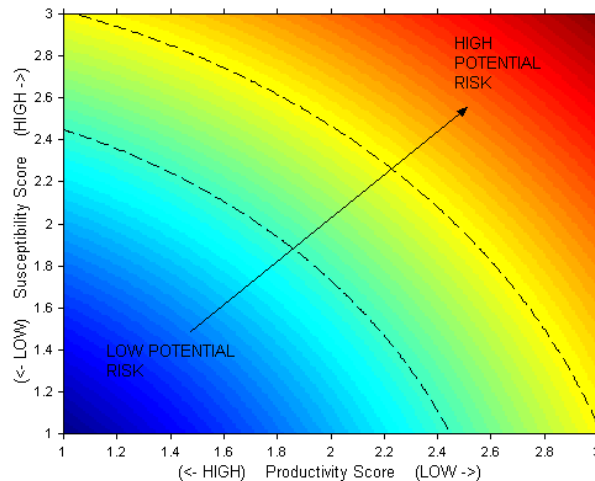
The PSA approach examines attributes of each unit that contribute to or reflect its productivity or susceptibility to provide a relative measure of risk to the unit. The following section describes how this approach is applied to the different components in the analysis. Full details of the methods are described in Hobday et al. (2006).

### Species

The following Table outlines the seven attributes that are averaged to measure productivity, and the four aspects that are multiplied to measure susceptibility for all the species components.

	<b>Attribute</b>
Productivity	Average age at maturity
	Average size at maturity
	Average maximum age
	Average maximum size
	Fecundity
	Reproductive strategy
	Trophic level
Susceptibility	Availability considers overlap of fishing effort with a species distribution
	Encounterability considers the likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species (based on two attributes: adult habitat and bathymetry)
	Selectivity considers the potential of the gear to capture or retain species
	Post capture mortality considers the condition and subsequent survival of a species that is captured and released (or discarded)

During the Level 2 assessment, each unit of analysis within the ecological component (species, habitat, or community) is scored for risk with regard to attributes in these two classes and the output graphed to produce a PSA plot (**Figure 13**).



**Figure 13.** The axes on which risk to the ecological units is plotted. The x-axis includes attributes that influence the productivity of a unit, or its ability to recover after impact from fishing. The y-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. The combination of susceptibility and productivity determines the relative risk to a unit, i.e. units with high susceptibility and low productivity are at highest risk, while units with low susceptibility and high productivity are at lowest risk. The contour lines divide regions of equal risk and group units of similar risk levels.

### ***The Level 2 PSA Excel workbook (species and habitats)***

The PSA for species components (habitat and community components are similar) is completed using an Excel workbook has a number of linked worksheets as follows:

- Instructions worksheet: details on how to complete the PSA
- Deleted Units worksheet: list of units excluded from the PSA, for species this is usually due to insufficient taxonomic resolution, or duplication of species.
- Attributes worksheet: download from ERAEF database containing the raw information on the attributes of each species, habitat, or community type.
- Attributes statistics worksheet: gives statistics on attribute information and is used as a guide to the availability of information for undertaking the PSA.
- Susceptibility stock proxies worksheet: contains the table used to determine if a correction to the Availability score for a species is needed based on the risk that stock structure exists in the species being considered.
- Susceptibility coding, category, score worksheet: contains tables that assist the scoring of units in the susceptibility worksheet
- Susceptibility worksheet: used to score the susceptibility axis of the PSA
- Productivity worksheet: used to score the productivity axis of the PSA
- Ranking worksheet: used to calculate the overall risk scores based on the Productivity and Susceptibility scores.
- PSA graphs: shows the distribution of the PSA scores for the component(s).

- Summary of Productivity, Susceptibility rankings worksheet, sorted by component and taxa groups to allow ease of interpretation.

There are seven steps for the PSA undertaken for each component brought forward from Level 1 analysis.

- Step 1 Identify the units excluded from analysis and document the reason for exclusion (2.4.1)
- Step 2 Score units for productivity (2.4.2)
- Step 3 Score units for susceptibility (2.4.3)
- Step 4 Plot individual units of analysis onto a PSA Plot (2.4.4)
- Step 5 Ranking of overall risk to each unit (2.4.5)
- Step 6 Evaluation of the PSA analysis (2.4.6)
- Step 7 Decision rules to move from Level 2 to Level 3 (2.4.7)

Level 2 documents to be completed are:

- Table of units excluded from analysis (step 1)
- PSA summary of results by components (steps 2 and 3)
- PSA results summary of stakeholder discussions
- PSA plot of units of analysis (step 4 generated by PSA workbook)
- PSA Uncertainty analysis of overall ranking (step 5 generated by PSA workbook)
- PSA evaluation (step 6 generated by PSA workbook)



### **2.4.2 and 2.4.3 Level 2 PSA (steps 2 and 3)**

#### **Level 2 PSA Methodology: Species Components (Target, Byproduct/Bycatch, TEP)**

It is important to note that these risk values are mostly determined by “intrinsic” properties of the [unit] (productivity), and while the relative fishery interactions are measured through the susceptibility attributes, assessment of the actual impact of the sub-fishery on the [units] is not made. This distinction was made at Level 2, because for many [units], information is absent. In addition to the difficulty of obtaining information, inclusion of an “impact” attribute such as “fraction of the population killed/habitat destroyed” would reduce the importance of such information in assessing risk. In the limited cases when such information is available, it is possible to assess true ecological risk of the sub-fishery on the particular [unit]. Inclusion of such an attribute within the PSA would reduce its importance by  $\sim 1/n$ , where  $n$  is the total number of attributes. When this information is included outside the PSA, it has a much more powerful effect in deciding if the high-risk [unit] is ultimately at high or low risk from the sub-fishery.

Thus, the impact of the fishery on the high-risk [units] identified through the PSA should be assessed at Level 3 of the ERAEF, however, examination at Level 3 may not be necessary if alternative information exists. This possibility is explained in the ERAEF Methods (Hobday et al., 2004). The advantage of Level 2 is that it allows the low-risk [units] to be excluded from such intensive and expensive analysis. This simplification and attempt to use data-poor techniques might still result in problems, for example, a [unit] with low susceptibility and high productivity would be ranked in the low-risk category, and excluded from further ERAEF analysis. If, however, only a limited number/area of the [units] remained, ensuring that the sub-fishery would not impact those remaining [units] might be extremely important. The converse is also true; a [units] might have been ranked high with regard to susceptibility and low with regard to productivity (high risk), and yet the fishery might only capture one individual from a population of several million every year. Thus, the Level 2 PSA is intended to quickly screen low from high-risk [units], such that research and management efforts can be directed where most needed.

The high and moderate risk units identified in each component in this PSA should be considered at Level 3, or evaluated with regard to alternative management strategies, as outlined in Hobday et al (2004). We recommend that high-risk units with high uncertainty (a high number of missing attributes) should be the priority and focus in additional data collection efforts before committing to a Level 3 risk analysis for such units.

#### **Methods: Score species for productivity**

The level of fishing impact a unit of analysis (e.g. species, habitat type, or species assemblage) can sustain will depend on the inherent productivity of the unit. The productivity determines how rapidly a unit can recover from depletion or impact due to fishing. For example, the productivity of a unit such as a species or population is

determined by species attributes such as longevity, growth rate, fecundity, recruitment and natural mortality. The productivity of a unit such as a “habitat type” is determined by habitat attributes such as connectivity and regeneration rates. For community units, the productivity might be determined by the diversity or size of the members. While units have inherent productivity, fishing can also affect productivity of the unit depending on the size of reduction in the unit and the temporal stage of the unit dynamics when the impact occurs (e.g. the life stage of a species taken by a fishery). The attributes used to provide an index of the productivity of species in the [fishery: sub-fishery] are recorded in Level 2 PSA Excel Workbook Productivity worksheet. The attributes used to score productivity for the three species components are:

- Average age at maturity
- Average max age
- Fecundity:
- Average max size
- Average size at Maturity
- Reproductive strategy
- Trophic level (fishbase)

### **Methods: Score species for susceptibility**

This section describes the methodology for scoring susceptibility in the species components of the PSA. Susceptibility is estimated as the product of four independent aspects; Availability, Encounterability, Selectivity and Post-capture Mortality (PCM). The treatment of these aspects has been tailored to utilize original datasets (e.g. FishBase), and incorporate additional information, such as outputs from the BIOREG Project (Lyne et al., 2005), and additional information compiled by the ERAEF team specifically for TEP species. The calculations are carried out within the excel workbooks developed for the PSA analysis.

The level of fishing impact that a unit of analysis can sustain depends on its risk or susceptibility to capture or damage by the sub-fishery activities. For example, the susceptibility of a unit such as a species is determined by species attributes such as habitat overlap with the fishery, depth in the water column, and feeding method. The susceptibility of a unit such as “habitat type” is determined by abiotic habitat attributes such as grain size and heterogeneity and the fishing method. The susceptibility of the community units is determined by functional group redundancy, or trophic level diversity. The attributes used to provide an index of the susceptibility of species in the [fishery: sub-fishery] are described below and recorded in the Excel PSA worksheet.

### **Susceptibility Aspect 1: Availability**

Availability considers overlap of the fishing effort with a species distribution. Where a fishery overlaps a large proportion of a species range the risk is high because the species has no refuge, and the potential for impact is high.

#### Availability scoring

Availability is scored in the PSA spreadsheet using one of two methods based on available data.

### 1. Default option for scoring availability

For species without detailed geographic distributional information, availability is scored based on broad categories, reflecting the potential for the fishery to cause impact to the species in question:

- Globally distributed – low risk,
- Southern Hemisphere – medium risk, or
- Australian endemic – high risk.

In application, this method is typically applied to species that are data poor, as well as highly migratory fishes such as tunas.

If this default method is used, the potential for multiple stocks must be considered. Multiple stocks may lead to an increased risk with relation to fishery impacts. For Australian fisheries, the impact on a widely distributed species is likely to be low. However even a restricted local fishery can present high risks to an individual stock or colony. For example, the Australian sea lion has a number of genetically distinct colonies across the south coast of Australia. For some species, multiple stocks have been identified in previous studies. These stocks are given separate consideration from the start of the PSA analysis e.g. eastern and western grey nurse sharks. For many data poor species where stock structure has not been studied, the likelihood of separate stocks is assessed using stock structure proxies (**Table 6**). The main factor considered when using the stock structure proxies are barriers to dispersal, rather than ability to disperse. Most marine species have the ability to disperse, either as adults or as larvae, or both but barriers to dispersal vary between species.

**Table 6. Stock likelihood scores and rationale types for reviewing availability risk scores for species without detailed distributional maps. Examples are in italic. Coding is automatically completed in the PSA workbook**

<b>Rationale: Type of barrier to dispersal</b>	<b>Score = Low risk (L)</b> (low chance of local stocks)	<b>Score = Medium risk (M)</b> (medium chance of local stocks)	<b>Score = High risk (H)</b> (high risk of local stocks)
<b>Rationale 1. Geographic barriers</b>	<b>1L</b> <i>Deep sea species &gt;650 m: Semi-global water mass - Antarctic bottom water. Some depth barriers, too shallow:</i>	<b>1M</b> <i>Pelagic and upper slope: Depth and water temperature barriers -mode water.</i>	<b>1H</b> <i>Restricted to estuaries and or embayments on the shelf: Combination of lat, long, depth, coastal, water temperature barriers</i>
<b>Rational 2. Temporal barriers</b>	<b>2L</b> <i>No seasonal peaks in feeding, mating, spawning.</i>	<b>2M</b> <i>Some seasonal peaks but breeding not restricted to a particular season. E.g. batch spawning teleosts, some dogfishes</i>	<b>2H</b> <i>Species forms breeding colonies or breeding aggregations. Fishing is permitted at or near breeding or feeding aggregations</i>
<b>Rationale 3. Ecological barriers (habitat requirements or feeding)</b>	<b>3L</b> <i>Occupiable habitat is dispersed through a species range. E.g. pelagic species such as skipjack tuna</i>	<b>3M</b> <i>Bycatch species has a preference for a particular type of habitat but habitat occurs across 50% or the range of a fishery. Habitat is different to the habitat of the target species and therefore not targeted</i>	<b>3H</b> <i>Occupiable habitat is restricted by food availability or bottom topography (reefs, canyons etc). Fishing occurs at or near restricted habitat</i>
<b>Rationale 4. Behavioral barriers</b>	<b>4L</b> <i>No behavior. E.g. algae</i>	<b>4M</b> <i>No social behaviour e.g. sunfish</i>	<b>4H</b> <i>Sea lion returns to birth place to breed and rear young. Birds remain near rookery to rear chicks. Migrating populations targeted by</i>

<b>Rationale: Type of barrier to dispersal</b>	<b>Score = Low risk (L)</b> (low chance of local stocks)	<b>Score = Medium risk (M)</b> (medium chance of local stocks)	<b>Score = High risk (H)</b> (high risk of local stocks)
			<i>fishing activity</i>
<b>Rationale 5. Early life history barriers</b>	<b>5L</b>	<b>5M</b>	<b>5H</b>
	<i>Larvae pelagic and dispersed easily, is dispersed in space and time.</i>	<i>Few restrictions to dispersal. E.g. larvae pelagic, but adults only spawn in the Sargasso Sea.</i>	<i>Fry spawned in same river as parent. River mouth is fished annually</i>

For species where the default availability method is used, the likelihood of multiple stocks must be considered. Any species that initially scored as medium or low, based on its distribution category is re-evaluated using the Stock Structure Proxies Table (**Table 6**). Any medium risk species need to be checked against high risk characteristics. For example, the gannet is a bird distributed throughout the southern hemisphere so its default availability score would be medium risk. However, the gannet forms distinct breeding colonies in the Furneaux group of Bass Strait Islands. This is a behavioural barrier to dispersal. It is highly likely that this species forms separate populations and the availability risk score is adjusted to high. Similarly any species with a low default availability score needs to be checked against the medium and high risk characteristics in the stock structure proxy table. For example both skipjack tuna and beaked whales have global distributions and would initially rank as low risk. Skipjack tuna do not have any medium or high risk characteristics and would remain low risk. On the other hand, some globally distributed beaked whales have seasonal peaks in breeding but are not restricted to a particular geographic area to breed. The availability risk scores for these whales would be elevated from low to medium. If a species is likely to have stocks based on more than one rationale, then the highest score is used.

#### Scoring stock structure proxies

These stock likelihood proxies have been scored for all TEP species and fish species that do not have BIOREG maps (invertebrates have not been scored to date) and loaded into the ERAF database. These proxy scores are provided with fishery-specific attribute data downloads from the database. If the stock structure proxy is unavailable, then availability defaults to high.

#### *2. Availability scores for species with distribution maps*

For species with good distribution maps, availability is scored using detailed mapping analysis: the amount of overlap between fishing effort and species distribution. The distribution of a species is defined by BIOREG maps (demersal fishes) or DEH distributional information (TEP species). Only distribution within EEZ waters and the jurisdictional boundary of each fishery is considered. The effort mapping is based on logbook data and is restricted to the last four years of fishing.

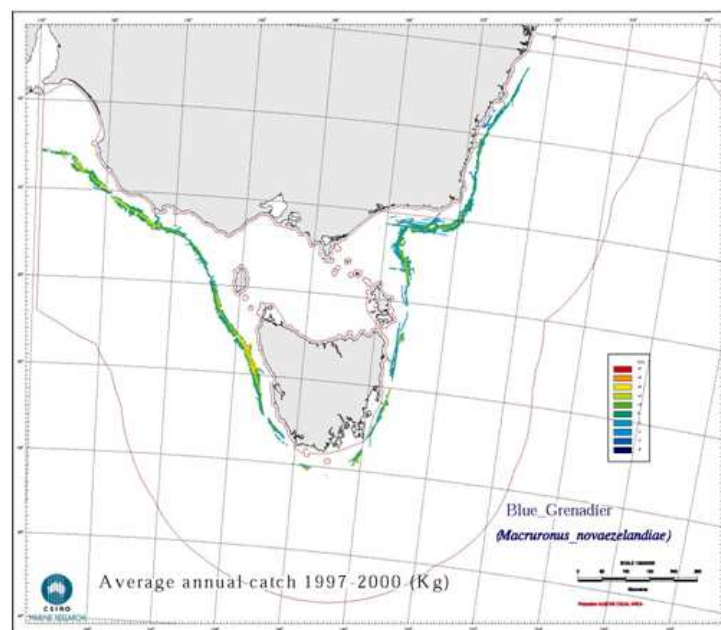
Availability = distributional range in Australia (km<sup>2</sup>)/fraction of the species distribution where current effort occurs.

This analysis is performed for each mapped species using mapping software and is repeated for each fishery. Results from the analysis are then loaded into the database as the fishery-dependant coding for availability. These results are then downloaded to PSA workbooks for each fishery and availability is scored automatically using the following cut-offs:

<10% overlap	Low risk
10 – 30% overlap	Medium risk
>30% overlap	High risk

These cutoffs were set in a precautionary manner. In the longer term it may be possible to establish different cutoffs for dispersed, aggregating and migratory species. For example, east coast orange roughly aggregate to spawn on two seamounts, St Helens Hill and St. Patricks Head. Targeting these seasonal aggregations has resulted in overfished status for this stock, even though effort on these seamounts covers less than 1% of the species distribution. Conversely fishing across 40% of the range of periwinkles is unlikely to pose an ecological risk. Unfortunately it was beyond the resources of the current project to set a range of cutoffs based on taxa risk. This is difficult, as the ecology of most species examined is poorly known, however, this remains an area for future validation attempts.

Where possible, the full geographic range of demersal fishes and have been refined to reflect core range (where say, 90% of individuals of a species occur). Ranges are refined to core ranges using bathymetric distribution. The bathymetric contours of the preferred depth of a species are projected onto a 2-dimensional regional map (**Figure 14**). In the example below, blue grenadier is reported to occur from 50 m – 1000 m but most adults occur from 300–600 m (Daley *et al.* 1997). This method of refining to core ranges is important in estimating availability of demersal upper-slope fish and invertebrates, such as blue grenadier and king crabs. For example the upper-slope is very steep, and averages only 8 km wide around southern Australia. Fishing upper-slope stocks can be highly targeted. The core distribution method accounts for this pattern (**Figure 15**).



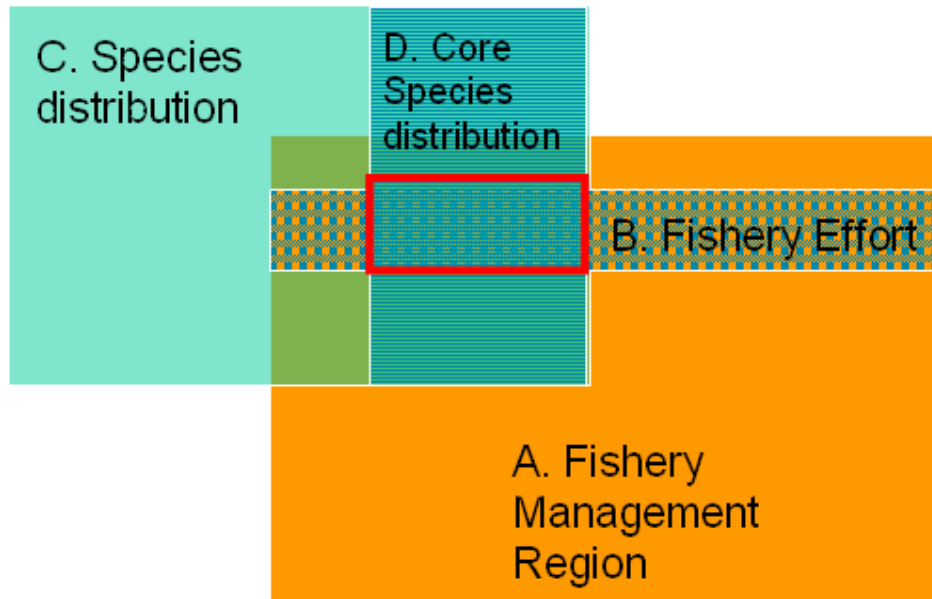
**Figure 14. Example mapping of the distribution of catch for a species.**

Principal bathymetric distributions were obtained from text-books (Gomon *et al.* 1994, Daley *et. al* 1997, Yearsley *et al.* 1999) or from observer data calculated as follows: mean average depth where a species was recorded  $\pm 1$  standard deviation. Observer data was only used to define core ranges when the entire bathymetric range of a species lies within the range of the observer program. This is to ensure that the core range obtained is constrained by the distribution of the species rather than the distribution of the observer program, which could otherwise lead to a circular argument. This constraint also prevents over-representing the availability of inshore species, such as bream, which occur mainly in state waters outside the range of observer data.

Overall, the scoring rule for availability is as follows:

**If** there is a calculated fishing effort and species distribution overlap value (this may be further refined by the use of bathymetry data for demersal fish) then use overlap calculation (**Figure 15**).

**Otherwise** use global distribution score and adjust for stock structure proxy. If the stock structure proxy cannot be scored, then availability defaults to high.



**Figure 15. Schematic of the availability calculation. A. The core species distribution (D) overlap with effort (B) is marked by the red square**

#### *Overrides for availability and special consideration of TEP species*

In fisheries that have observer programs, with observers that have been trained to identify seabirds and marine mammals, observer input may be used to adjust availability scores for these TEP species. If an observer can demonstrate that they can identify say a blue whale, but he has only seen one during say, 10 years experience on SEF Trawl grounds, then availability is scored low. If the observer can identify cape petrels and sees them between 33% and 66% of days spent on the fishing grounds then availability

then availability is medium etc. Unless there are independent field observations during commercial operations it is not appropriate to use manual over-ride for availability. Observer data should be verified in face to face observer meetings to ensure that the observer is qualified to identify the species concerned.

### **Susceptibility Aspect 2: Encounterability**

Encounterability considers the likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species.

#### Encounterability Scoring

The main component of encounterability considered for each species is its adult habitat. This habitat is also checked to determine if it lies within a bathymetric zone where fishing is permitted.

#### *Habitat encounterability (fishery-dependent)*

The habitat of each species was initially coded using FishBase information (e.g. sand, mud, rock or reef). Scoring tables were developed for each fishery but some FishBase habitats were ambiguous and difficult to score, e.g. wide ranging and island. The habitat codes were subsequently simplified and better linked to encounterability of the gear (**Table 7**). Species are divided into benthic (bottom) species, water column (pelagic) species and air column species (birds, mammals, reptiles). Benthic species are further divided into hard bottom (e.g. rock/reef) species and soft bottom (e.g. sand/mud) species. Species that occur in the water column are further divided into benthopelagic (bottom third of the water column) mesopelagic (middle third of the water column) and epipelagic (upper third of the water column). Species that occur in poorly known parts of the deep ocean (700–3,000 m), where the water column is poorly defined, may be scored bathypelagic. Some species occur in more than one habitat and a number of habitat codes will be assigned. For these species, the risk score is initially set for the worst case code. The risk score may be reduced after consultation and review but only if appropriate. For example, orange roughy are targeted using demersal trawls. This species occurs on hard bottom (medium encounterability risk for trawl) and also in the bottom third of the water column/benthopelagic (high encounterability risk). Initially the risk score is set at high. The score is then reviewed at industry meetings. For example skippers have been able to fly the net just off the bottom and capture orange roughy in aggregations over pinnacles. Therefore the risk score is not altered.

Where possible, the original habitat information was used to code the new habitat categories (**Table 7**) but for some species additional searches of FishBase and text-books were made (Gomon *et al.* 1994, Daley *et al.* 1997, Yearsley *et al.* 1999). All air breathers are initially scored high risk because the consequences of encountering the fishing gear are higher –they could drown before capture and cannot escape the gear (see also observer over-rides below). These species can also encounter the fishing gear during deployment and retrieval.

#### *Bathymetry check*

The bathymetry check is used to check the encounterability risk score for false positives (species scored high, but should be lower). The bathymetric range of a species is

categorised based on demersal provinces (**Table 8**). Bathymetry check coding is completed in the ERAF database and scoring occurs automatically in the PSA workbook. However, for the purposes of manual review, the bathymetry check is explained below.

A species may be vulnerable to a particular gear type due to a common position within the water column or on a common bottom type—high potential risk. However if the species occurs outside the bathymetric range of a fishery the actual risk is low. This type of false positives is often related to the fishery regulations, jurisdictional boundaries of fisheries or imprecise logbook data. For example, bottom set gillnets have, in the past, been highly effective at capturing gulper sharks in the Southern Shark Fishery on hard bottom in 300–600 m of water. So based on the gear type and habitat, the potential encounterability risk for gulper sharks in this fishery would be high. However, regulations no longer permit the use of gillnets deeper than 200 m. Therefore the actual encounterability risk is low. A different type of problem occurs in the Auto-longline Sector of the GHATF. Some early logbook data presented capture locations in 30 mile grids. If that effort were analysed, it could only be resolved to a scale of 30 miles. Potentially, fishing location errors at the scale of 30 miles would suggest that this sector overlaps with the distribution of many species of seahorses. In reality the auto-longline sector is restricted to waters deeper than 300 m and there is no species of seahorse that lives that deep in Australian waters. Therefore the actual encounterability risk is low.

Scoring rule for encounterability as follows:

For non-TEP species encounterability is calculated automatically in the PSA work sheet using the minimum of the habitat and bathymetry risk scores.

#### Special consideration of sub-Antarctic fisheries

The simple system of habitat scoring used in the ERAF applies well to most demersal and pelagic fisheries around the Australian continent but, in the Antarctic and sub-Antarctic waters, the relationship between the water column, the ocean floor and habitat distribution is more complicated. Complicating factors include surface ice and deep ocean trenches. Powerful circumpolar currents create strong upwellings and regions of seasonal high productivity around the continent, near sub-Antarctic islands and well offshore. A number of commercial species are bathypelagic with poorly understood ecology. Fishing boats and gear are highly specialised. For these reasons, habitat risk scores for sub-Antarctic fisheries should be carefully reviewed taking into account the characteristics of the fishing gear described in the scoping documents for these fisheries.

#### *Over-rides for encounterability and special consideration of TEP species*

Habitat for marine birds, reptiles and mammals is epipelagic/air. All species are potentially encountered during deployment and retrieval of either demersal or pelagic gear. These species are vulnerable to drowning before capture. The default encounterability score for these groups is high. Actual encounterability for birds depends, in part, on mitigation measures which may or may not be effective. In fisheries that have observer programs, encounterability scores may be reduced. For example, if an observer sees pilot whales every day he/she observes auto-longline fishing but the pilot whales never approach the gear or take fish off the hooks, then availability is high but encounterability is over-ridden to low. Similarly, if an observer had seen dark-browed

albatross while shooting hooks on >2/3 days then availability is high. If, however the observer has never seen a dark-browed albatross on a hook then encounterability is low. For fisheries without independent field observations during commercial fishing e.g. observer programs, there are no over-rides of the ERAF methodology.

**Table 7. Habitat codes and scores for evaluating the encounterability risk for a species. A check to determine that the fishing gear examined can operate in the same habitat where the species lives. For example scores for two gear types automatically scored in the PSA spreadsheet.**

Habitat name	Habitat Definition	Habitat Code	Encounterability risk scores Example Fishery 1: Otter trawl gear	Encounterability risk scores Example fishery 2: Tuna longline gear
Hard Bottom	Rocks, reefs etc.	HB	M	L
Soft Bottom	Sands, muds etc.	SB	H	L
Epipelagic	Top third of the water column, near the surface	EP	L	H
Mesopelagic	Middle third of the water column	MP	L	L
Benthopelagic	Bottom third of the water column, near the bottom	BP	H	L
Bathypelagic	Deepwater, 700–3000 m	BBP	H	L
Air column	Birds, mammals, reptiles	AIR	H	H

**Table 8. Bathymetry codes and scores for checking the encounterability risk for a species. A check to determine if fishing is permitted and practical within the bottom depth range of the species examined. Example scores for two fisheries are provided.**

Province name	Province depth range (m)	Province code	Example Fishery 1. Auto-longline Fishery score for bathymetry check (Permitted in upper slope provinces 300–800 m only)	Example Fishery 1. Southern Shark Fishery score for bathymetry check (Permitted only in inner-shelf province < 80 m)
Inner Shelf	0-110	1	L	H
Outer Shelf	110-250	2	L	L
Upper Slope	250-565	3	H	L
Mid-Upper Slope	565-820	4	H	L
Mid Slope	820-1100	5	L	L
Lower slope/Abyssal	1100-3000	6	L	L

### Susceptibility Aspect 3: Selectivity

For species that do encounter fishing gear, selectivity considers the potential of gear to capture or retain the species.

#### Selectivity Scoring

The ideal way to determine selectivity would be conduct field experiments and gather species-specific data on selectivity for every fishery gear. For some fishery types these experiments normally use nets with commercial size mesh as well as smaller and/or larger mesh. The alternative mesh sizes provide data on fish that escape commercial nets, as well as retained. Unfortunately there are only a few fisheries that have undertaken this type of experiments. These include the Southeast Trawl fishery and the Southern Shark Fishery (Bax and Knuckey 1996, Walker *et al.* 2005).

Selectivity of nets is affected by a number of factors including length, overall shape, fin spines, swimming speed relative to tow speed of the gear etc. Among these attributes, only length is available for most of the thousands of species covered in the ERAF database. Where available, size at maturity is used rather than maximum size. Size at maturity is more typical of the individuals in a population whereas very few individuals reach maximum size for the species. For species where size at maturity is not available, maximum size is used.

Selectivity of hooks is defined by typical weights of the species caught relative to the breaking strain of the snood and the gaffing method used in the fishery.

Scoring rules for selectivity are as follows:

Risk categories for selectivity are defined by cut-offs which are set by the fishery case study leaders for each gear type

For nets, first establish mesh size. Enter the mesh size on the 'Susceptibility coding, category, score worksheet in cell B85. The PSA workbook then automatically calculates size cut-offs for different risk categories:

<mesh size=low risk

1-2 times mesh size=medium risk

> 2 times mesh size =high risk (based on Knuckey 1996);

for species 4-5 m = medium risk, and

species over 5 m = low risk

The appropriate size measurement (size at maturity or maximum size) is determined automatically. Species are then coded and scored automatically for selectivity based on their size. For most groups, when the size at maturity is double the mesh size the risk of being selected is high. The upper size cut-off is used to eliminate large species. Basking sharks up to 5 m long have been captured in trawl nets and gill nets but the risk of capturing such large animals is low.

For hook fisheries, body weight cut-offs are determined from observer data. These weight cut-offs are converted to size cut-offs using length weight relationships where available.

*Overrides for selectivity of long thin species*

It has been suggested that shape be considered when scoring selectivity. On face value one might assume that long thin species such as squid and seasnakes could escape nets more easily than boxfishes of similar total length. However, in the early 1990's Australian trawlers caught over 80,000 sea snakes (Milton 2000). Similarly arrow squid are taken in high numbers in the SET and the GABT. More than 1,900 tonnes were taken from 2001-2004 and in some years the trawl-caught squid catch has been higher than the catch from the directed jig fishery. This suggests that for moving trawl nets at least, selectivity over-rides are not appropriate. By contrast it seems intuitive that a sea-snake would be likely to escape a stationary gill net. If supporting data could be obtained then such an override for changing a risk category may be appropriate. There are no overrides without supporting data, in line with use of the precautionary principle in the ERAEF.

### Special consideration of the Southern Shark Fishery

This fishery is a special case. Even though it has not had an official observer program, detailed field observations have been undertaken on commercial boats and selectivity experiments have been completed on a species specific basis for chondrichthyans and teleosts. For this fishery, published papers have been used to provide selectivity overrides (Walker *et al.* 2005)

#### *Overrides for selectivity and special consideration of TEP species*

Potentially marine mammals, birds and reptiles can be selected if they encounter fishing gear. These species are likely to be scored high selectivity risk based on their size. However, other biological attributes and fishery restrictions may reduce these risks. Observer data and face to face observer meetings should be used to review selectivity risk scores. Scores should only be overridden based on supporting data from independent observer programs or observer notes on wildlife interactions. For example, in the Autolongline sector of the GHAT, observer records show seahorses and plankton feeders are not caught on hooks. It is hardly surprising that plankton feeding sharks and whales are not attracted to bait. Likewise seahorses have tiny mouths which could never take a hook. Selectivity risk for these species in hook fisheries is overridden to low. In the same fishery killer whales eat blue eye off longlines, but often leave a fishes jaws and part of its head on the hook. Killer whales are not captured by this gear (Ross Daley field observations on commercial vessels 2005). Selectivity experiments suggest that selectivity of hooks for most invertebrates is low (Walker *et al.* 2005). Molluscs such as bailer shells, scallops etc. have low selectivity in hook fisheries.

#### **Susceptibility Aspect 4: Post Capture Mortality (PCM)**

Post capture mortality evaluates the case that, if captured, a species would be released in condition that would permit subsequent survival. The PCM of a species is affected by its biology and fishing practices. Biological factors limit the potential of a species to be captured alive. These biological factors can be assessed using expert judgement. For example, sharks with spiracles, such as Port Jackson sharks can breathe without swimming and can survive on deck for many hours if captured alive (Terry Walker personal communication, Ross Daley field observations 2005). The impact of fishing practices on PCM is more difficult to evaluate and independent field observations are needed. Handling practices vary between fisheries. The most important considerations are the time taken to clear discards from the deck. In the absence of expert judgement and independent field observations the default value for the PCM of all species is high. Scoring rule for PCM is as follows:

All species considered dead on capture = high PCM risk, unless there are observer data or other verified field observations made during commercial fishing operations.

#### *Override scores for PCM*

Observer meetings will be important for evaluating PCM. Where observers can verify that fishers regularly release 2/3 of individuals of a given species alive during normal fishing operations then the PCM risk is low. For the Southern Shark Fishery, data is available from Field experiments (Walker *et al.* 2005).

### **Level 2 PSA Methodology: Habitat Component**

The PSA methodology is structured around a set of attributes that describe the intrinsic risk (susceptibility) and resilience (productivity) of each particular habitat type to impacts of the different fishing gears (**Figure 16**). Attributes are derived from images, expert opinion and scientific literature and reflect the definition of habitat as the seafloor and attached fauna. In all cases the concept behind the attribute is explained, as well as the rationale for its inclusion. These are followed by the apportioned ranks, which may be derived in three ways; from the attribute table itself (e.g. Availability calculated by GIS mapping), in some cases from associated Lookup Tables to be consulted for gear specific scores, where necessary these are located beneath the related attribute, other attribute scores are derived from the SGF score attributed to each habitat type as listed within **Scoping Document S2A**. An attempt has been made to automate attribute scoring based entirely upon SGF scores, but for some attributes visualization of the image or knowledge of the wider terrain as seen in video has been critical to appropriate scoring, meaning some reliance on manual scoring. Where this has been the case, expert opinion has supported the scoring.

Representative images and corresponding habitat data will be linked within the ERAEF database to enable visualization of habitat types by fishery, attribute, aspect of risk, or risk ranking.

<b>Level 2 PSA: Habitat attributes</b>	
<p><b>A Productivity</b></p> <ul style="list-style-type: none"> <li><b>A1</b> Regeneration of fauna</li> <li><b>A2</b> Natural disturbance</li> </ul>	<p><b>B Susceptibility</b></p> <ul style="list-style-type: none"> <li><b>B1 Availability</b> <ul style="list-style-type: none"> <li><b>B1.1</b> General depth range (Biome)</li> </ul> </li> <li><b>B2 Encounterability</b> <ul style="list-style-type: none"> <li><b>B2.1</b> Depth zone and feature type</li> <li><b>B2.2</b> Ruggedness</li> <li><b>B2.3</b> Level of disturbance</li> </ul> </li> <li><b>B3 Selectivity</b> <ul style="list-style-type: none"> <li><b>B3.1</b> Removability/ mortality of fauna/ flora</li> <li><b>B3.2</b> Areal extent</li> <li><b>B3.3</b> Removability of substratum</li> <li><b>B3.4</b> Substratum hardness</li> <li><b>B3.5</b> Seabed slope</li> </ul> </li> </ul>

**Figure 16. Habitat attributes used to score productivity and susceptibility in the PSA. The codes beside each attribute are used in the following sections to link tables.**

**Step 1. Identify the habitat types excluded from analysis and document the reason for exclusion.**

#### **Step 2. Score productivity of habitat type**

Two attributes are used to estimate this aspect of habitat risk. Habitat productivity is defined here as the capacity for habitat to regenerate and return to a pre-disturbance state following the effects of fishing disturbance.

Productivity is scored according to a rank: (1) indicating the most productive, (2) the intermediate state or (3), the least productive state.

**Productivity Attribute A1: Regeneration of fauna**

In many cases, the age, growth and regeneration rates of sessile invertebrate species is not known, however, where some data exists this has been applied to the taxa (faunal group). Depth is regarded as a proxy for productivity i.e. habitats in deeper waters take longer to recover than those in shallow waters (<60m) which tend to be adapted to highly disturbed zones. It is important to recognize however, that there will be variation within groups (**Table 9** and **Table 10**).

**Table 9. Description of Productivity Attribute A1: Regeneration of Fauna**

				Productivity Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Productivity</b>	Regeneration of fauna	Accumulation/ recovery of fauna	Fauna have different intrinsic growth and reproductive rates, which are also variable in different conditions of temperature, nutrients, and productivity.	Annual. See <b>Regeneration of Fauna Lookup Table</b>	< Decadal. See <b>Regeneration of Fauna Lookup Table</b>	> Decadal. See <b>Regeneration of Fauna Lookup Table</b>
<b>Description and decision rules</b>				Productivity Ranks		
<p><b>Non-automated category.</b> Assessment requires data on age/ growth/ recolonisation of fauna/ flora. Data for Australian fishery regions will not be available in most cases, and so reference to comparative data from studies elsewhere is necessary. To some extent depth can be used as a general surrogate for accumulation and recovery time (deeper=longer) and this relationship is reflected in the data from other studies. Here, ranks aim to split fauna with regeneration times that are annual (1), &lt; decadal (2) and &gt; decadal (3), but see Regeneration look up table for cross-reference between depth and faunal group. <b>Decision rules:</b> all fauna (other than encrusting) in continental slope depths = rank 3. A precautionary approach if no information available for group/ area in question is that large bodied, cold water (temperate) animals = rank 3. # score shelf break as for upper slope.## NPF and TSF considered independently.</p>				<p><b>See Regeneration of Fauna Lookup table (Table 10)</b></p>		

**Table 10. Lookup Table for scoring Productivity Attribute A1: Regeneration of Fauna**

Ranks	No fauna/ Bioturbators	Small sponges/ Low encrustings/ BV	Large Sponges	Ascidians/ bryozoans	NPF and TSF only Seagrass Communities/ mixed faunal communities/ Hard Corals	Crinoids/ Solitary/ Mixed Communiites/ H & S corals
Coastal Margin	1	1	1	1	2	1
Inner shelf	1	1	2	2	2	2
Outer shelf	1	1	3	2	-	3
Upper slope	1	1	3	3	-	3
Mid-slope	1	2	3	3	-	3

**Productivity Attribute A2. Natural disturbance**

The natural disturbance regime that is assumed to occur at specific depth zones is scored as an attribute (**Table 11** and **Table 12**).

**Table 11. Description of Productivity Attribute A2: Natural disturbance**

				Productivity Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Productivity</b>	Natural disturbance	Level of natural disturbance affects intrinsic ability to recover	Frequently disturbed communities adapted to recover from disturbance	Regular or severe natural disturbance	Irregular or moderate natural disturbance	No natural disturbance
<b>Description and decision rules</b>				Productivity Ranks		
<p><b>Non-automated category.</b> Natural disturbance is considered primarily in the context of water currents, but other issues such as temperature fluctuations (e.g. coral bleaching) and predation may be relevant. The major features of water currents are tidal movements, wave base (depth limit of wind-driven wave action ~60 m), swell base (depth limit of storm-driven swell influence ~120 m) and local currents. Some general patterns are recognized, e.g. tidal flow models and depth related patterns, but expert judgment is also important. <i>Details</i> of current strengths, direction and regularity of disturbances and their influence on fauna rarely documented.</p> <p><b>Decision rules:</b> only coastal and shallow inner shelf (surf zone to 60 m) and highly tidal or strong current-prone areas are eligible for rank = 1, but quiescent shallow areas (&lt;60 m) should rank higher. Deep inner shelf and outer shelf (60-200 m) eligible for rank = 2. All continental slope depths (&gt; 200 m) = rank 3.</p>				<p><b>See Natural Disturbance Lookup Table (Table 12)</b></p>		

**Table 12. Lookup Table for scoring Productivity Attribute A2: Natural Disturbance**

Disturbance description	Depths	Rank
Regular or severe natural disturbance	60m	1
Irregular or moderate natural disturbance	60-200m	2
No natural disturbance	>200m	3

Other significant processes that contribute to habitat productivity that were not used due to either lack of data or the difficulty of devising a ranking include:

- **Habitat Connectivity.** The concept behind this attribute is that replenishment by recruitment is variable. Recruitment rates are affected by several features of habitat connectivity e.g. proximity, habitat abundance, climate, oceanographics, which spatially and temporally influence habitat propagule settlement and recruitment dynamics. Ideally recruitment data would be used if available, or habitat rarity as a % of total study area, may be applied as a surrogate.
- **Regeneration time of the substratum.** Replacement times of substrata are variable as different substrata have different intrinsic accumulation rates and rely on different processes; however in every case accumulation will require extended geological timeframes, which cannot be ranked reasonably. Possible categories of consideration are biogenic consolidated substrata, biogenic sediments and other sediments
- **Chain of habitats.** Although this attribute may be more important for mobile species, it is worth consideration as it is largely unclear to what degree mobile species play a role in maintenance of habitats. Some good examples of ecosystem engineers and keystone species exist, but not specifically in relation to ‘chains of habitats’. Habitat fragmentation is the greatest risk of unregulated area access, and little habitat monitoring. Some habitats may be very patchy and isolated in space, e.g. seamounts. Adequate biodiversity protection may require a network of habitats to maintain these links.

### **Step 3. Score habitat type for susceptibility**

Habitat susceptibility to fishing is the product of three independent aspects: ‘Availability’, ‘Encounterability’ and ‘Selectivity’. Aspects may be characterized by one or more attributes. The Post Capture Mortality aspect of susceptibility considered in the species component is not applied to habitats due to little data.

#### **Susceptibility Aspect B1. Availability**

One attribute is used to score availability.

##### **Susceptibility Attribute B1.1. General depth range of habitat**

This attribute estimates the spatial overlap of the sub-fishery with the habitat at the largest scale considered within the jurisdictional boundary of the sub-fishery (the biome), measured as a proportion of the total known habitat area. This attribute can be well quantified for all Australian Commonwealth fisheries using published bathymetry data and the AFMA management boundaries. This attribute is scored for each habitat type using **Table 13**.

**Table 13. Description of Susceptibility Attribute B1.1: General depth range of habitat**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Availability</b>	General depth range of habitat (Biome)	Spatial overlap of sub-fishery with habitat defined at biomic scale	Habitat occurs within the management area	Sub-fishery overlap with habitat distribution at biomic scale is small (<10% habitat)	Sub-fishery overlap with habitat distribution at biomic scale is 10-50% habitat	Sub-fishery overlaps majority of habitat at biomic scale (>50% habitat)
<b>Description and decision rules</b>				Susceptibility Ranks		
This attribute estimates the spatial overlap of the subfishery with habitat defined at the 'biomic' scale - the primary subdivision of the marine benthic realm into coastal margin (<25 m), continental shelf (25-200 m), continental slope (200-2,000 m) and abyss (>2,000m). Overlap is estimated as the % overlap of the sub-fishery area with the habitat distribution defined by biomes, where the boundary of the area analysed for overlap is the sub-fishery area, e.g. SET, GHAT, GAB, NPF.				<b>GIS analysis to compare map of fishery with biomes</b>		

**Susceptibility Aspect B2. Encounterability**

Three attributes describe the proportion of the habitat available to the sub-fishery that is actually encountered by the sub-fishery (as determined by effort mapping). The first two attributes (B2.1 and B2.2) describe known features of habitat at scales relevant to fishing operations. To use either implies some knowledge of habitat location, extent and geomorphology, which may not be known in detail however, bathymetry data, general descriptions and expert knowledge, and knowledge of gear operational depths (derived from logbooks and catch data) should be available in most cases. The third attribute relevant to encounterability (B2.3) attempts to describe the level of disturbance generated by the gear footprint characteristic of different gear types.

**Susceptibility Attribute B2.1. Depth zone and feature type**

It is essential to know the depth zone, and preferable to know something of the horizontal distribution of the habitat type within depth zones. If horizontal distribution is not known, a precautionary approach is to consider fishing effort in entire depth zones (sub-biomes). This attribute is scored for each habitat type using **Table 14**.

**Table 14. Description of Susceptibility Attribute B2.1: Depth zone and feature type**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Encounterability</b>	Depth zone and feature type	Habitat encountered at the depth and location at which fishing activity occurs	Fishing takes place where habitat occurs	Low overlap of fishing and habitat distribution (<10%)	Moderate overlap of fishing and habitat distribution (10-50%)	Majority of fishing overlaps habitat distribution (>50%)
<b>Description and decision rules</b>				Susceptibility Ranks		
This attribute estimates the % of the habitat fished. Habitat remains coarsely resolved - into primary depth zones (sub-biomes) within biomes. From a Commonwealth fisheries perspective this differentiates the inner and outer shelf, upper and mid-slope. In this attribute, fishing effort defines the fished area. Effort is mapped at the scale for which 'good' data is available - in space and time, i.e. using latitude/ longitudes in preference to ½ degree grids, and aggregated data from 2001-2004, and also for all years for which good records exist to capture historical detail. For special cases, feature type may also be important to avoid under estimation and will need to be assessed in isolation, e.g. seamounts and canyons form small fractions of the slope, but are specifically targeted. Decision rule: seamounts, canyons, bioherms and other features known a priori to be special or highly vulnerable, or are foci for intensive fishing effort, are ranked as high risk (3). If there is clearly no overlap with certain depth zones or features, then no further scoring is necessary for those depth zones or features. Overlap is estimated as the % overlap of fishing effort with the habitat distribution defined by sub-biomes, where the boundary of the area analysed for overlap is the sub-fishery area, e.g. SET, GHAT, GAB.				<b>GIS analysis to compare distribution of fishing effort with habitat distribution</b>		

**Susceptibility Attribute B2.2. Ruggedness (Fractal dimension and slope of substratum)**

Ruggedness is based on the concept that the relief, rugosity, hardness, and slope of the substratum influence access by different gears e.g. banks of hard rocks ('reefs') vs flows/ accumulations of loose rocks or sedimentary bedforms ('hard grounds') vs plains/ terraces of fine gravel/sand/muds ('soft grounds') (**Table 15**). A lookup table has been designed against which to consider the different fishing methods (**Table 16**). Information on seafloor relief is provided by the Geomorphology score given to each habitat type at the scoping stage, and from consideration of slope angle of the habitat type under consideration. The image of the habitat type must also be consulted in some cases. Slope is difficult to assess from still images and is therefore generally derived from video or expert opinion. Geomorphology category indicates which column to refer to in the Ruggedness Lookup Table (**Table 16**) depending on the sub-fishery being assessed.

**Table 15. Description of Susceptibility Attribute B2.2: Ruggedness**

Aspect	Attribute	Concept	Rationale	Susceptibility Ranks		
				1	2	3
<b>Encounterability</b>	Ruggedness (fractal dimension of substratum and seabed slope)	Relief, rugosity, hardness and seabed slope influence accessibility to different sub-fisheries	Rugged substratum is less accessible to mobile gears. Steeply sloping seabed is less accessible to mobile gears	High relief (>1.0 m), rugged surface structure (cracks, crevices, overhangs, large boulders, rock walls); > 10 degrees slope.	Low relief (<1.0 m), rough surface structure (rubble, small boulders, rock edges); 1-10 degrees slope.	No relief, smooth simple surface structure (mounds, undulations, ripples); < 1 degree slope.
<b>Description and decision rules</b>				Susceptibility Ranks		
Semi-automated category using 'Geomorphology' score from images				<b>See ruggedness lookup table (Table 16) for gear-specific rank</b>		
Geomorphology categories: 8 - 9 -- Column 1		Automated				
Geomorphology categories: 4 - 7-- Column 2		This category highly variable: expert check each case				
Geomorphology categories: 0 – 3, X -- Column 3		Automated				

**Table 16. Lookup Table for scoring Susceptibility Attribute B2.2: Ruggedness**

Ranks for ruggedness (fractal dimension of substratum and seabed slope)		Column 1	Column 2	Column 3
		High relief (>1.0 m), rugged surface structure (cracks, crevices, overhangs, large boulders, rock walls)	Low relief (<1.0 m), rough surface structure (rubble, small boulders, rock edges)	No relief, smooth simple surface structure (mounds, undulations, ripples)
Fishery	Method	> 10 degrees slope	1-10 degrees slope	< 1 degree slope
BSS	Dredge	1	1	3
CSF	Hand Collection: Aquarium	3	3	1
CSF	Trap (finfish/ crab)	2	3	3
CSF	Demersal Longline	2	3	3
CSF	Trawl	1	2	3
CSF	Autolongline	2	3	3
CSF	Other line: trot, set, drop, hand	2	3	3
GAB	Shelf and Slope Trawl	1	2	3

GHAT	Shark Gillnet	2	3	3
GHAT	Scale Autolongline	2	3	3
HIMI	Demersal Trawl	1	2	3
HIMI	Midwater Trawl	1	2	3
MIF	Demersal Trawl	1	2	3
SET	Otter Trawl	1	2	3
SET	Danish Seine	1	1	3
NWS	Deepwater Trawl	1	2	3
WDW	Deepwater Trawl	1	2	3
NPF	Prawn Trawl	1	1	3
TSF	Prawn Trawl	1	1	3
TSF	Hand Collection: Lobster	3	3	1

### Susceptibility Attribute B2.3. Level of disturbance

This attribute measures the number of encounters required to produce impact on benthic habitats (**Table 17**). The gear size, weight and mobility influences the relative disturbance of each gear type, reflected on the seafloor as a gear footprint.

**Table 17. Description of Susceptibility Attribute B2.3: Level of disturbance**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Encounterability</b>	Level of disturbance	Gear footprint and intensity of encounters	Degree of impact is determined by the frequency and intensity of encounters (inc. size, weight and mobility of individual gears)	Many encounters needed to cause impact	Several encounters needed to cause impact	Single encounter causes high impact
<b>Description and decision rules</b>				Susceptibility Ranks		
<p><b>Non-automated category.</b> This is a complex attribute to score because it requires some understanding of several issues: the removability of faunal/ floral types by different gear configurations (described in "Removability/ mortality of fauna/ flora"), consideration of substratum hardness and removability, as well as knowledge of gear footprint, and a fine scale analysis of effort distribution. Expert judgment needs to be applied to the range of possible interactions and a precautionary approach taken.</p>				<p><b>See Level of Disturbance lookup table for gear-specific rank (Table 18)</b></p>		

**Table 18. Lookup Table for scoring Susceptibility Attribute B2.3: Level of Disturbance**

Ranks for Level of Disturbance		Many encounters needed to cause impact	Several encounters needed to cause impact	Single encounter causes high impact	General characteristics of gear determining ranks			
Fishery	Method				Size	Weight	Mobility	Footprint
HIMI	Demersal Trawl			3	Large	Heavy	High	Large
HIMI	Midwater Trawl			3	Large	Heavy	High	Large
MIF	Demersal Trawl			3	Large	Heavy	High	Large
GAB	Shelf and Slope Trawl			3	Large	Heavy	High	Large
SET	Otter Trawl			3	Large	Heavy	High	Large
NWS	Northwest Slope Trawl			3	Large	Heavy	High	Large
CSF	Trawl			3	Large	Heavy	High	Large
WDW	Western Deepwater Trawl			3	Large	Heavy	High	Large
NPF	Otter Trawl			3	Large	Heavy	High	Large
TSF	Otter Trawl			3	Large	Heavy	High	Large
SET	Danish Seine		2		Large	Intermediate	Intermediate	Intermediate
GHAT	Scale Autolongline		2		Large	Intermediate	Low	Intermediate
CSF	Autolongline		2		Large	Intermediate	Low	Intermediate
GHAT	Shark Gillnet		2		Intermediate	Intermediate	Low	Intermediate
CSF	Demersal Longline		2		Intermediate	Intermediate	Low	Intermediate
BSS	Dredge			3	Small	Heavy	High	Intermediate
CSF	Other line: trot, set, drop, hand	1			Small	Intermediate	Low	Intermediate
CSF	Hand Collection: Aquarium	1			Small	Light	High	Small
CSF	Trap (finfish/ crab)	1			Small	Light	Low	Small
TSF	Hand Collection: Lobster	1			Small	Light	High	Small

**Susceptibility Aspect B3. Selectivity**

Five attributes of habitat describe its intrinsic susceptibility to fishing gears, dependent upon gear selectivity. Fauna and substratum are assessed separately because the elements contributing to selectivity risk differ.

### Susceptibility Attribute B3.1. Removability/ mortality of flora/ fauna

The size, height, robustness, flexibility and structural complexity of the attached invertebrate fauna will influence whether it will be removed or killed by interaction with fishing gears. Generally, large, erect, rugose, inflexible and delicate forms living on the seabed (epifauna) are most vulnerable, compared to small, low, encrusting, flexible, robust or deep burrowing forms (infauna), which are least vulnerable. Faunal scores are derived from the Fauna score given to each habitat type at the scoping stage (Scoping habitats: **Table 2**). Faunal categories indicate which column to consider in the Removability of Fauna/ Flora Lookup Table (**Table 20**). **Table 20** outlines the relative risk associated with ‘form’ depending on the fishing method, and demonstrates how risk to selectivity by bottom-contact gears is variable.

**Table 19. Description of Susceptibility Attribute B3.1: Removability/ mortality of flora/ fauna**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Selectivity</b>	Removability/ mortality of fauna/ flora	Removal/ mortality of structure forming epifauna/ flora (inc. bioturbating infauna)	Erect, large, rugose, inflexible, delicate epifauna and flora, and large or delicate and shallow burrowing infauna (at depths impacted by mobile gears) are preferentially removed or damaged.	Low, robust or small (<5 cm), smooth or flexible types, OR robust or deep burrowing types.	Erect or medium sized (but < 30 cm), moderately rugose or inflexible, OR moderately robust or shallow burrowing types.	Tall, delicate or large (> 30 cm high), rugose or inflexible, OR delicate or shallow burrowing types.
<b>Description and decision rules</b>						
This is a complex attribute to score for reasons of high diversity in types of fauna and flora present, and non-standardized gear within a sub-fishery. For example, within demersal trawl the range of factors that influence removability include footrope weight, use of chains, roller/ bobbin size, bridle configuration, door weight. The range of possible interactions needs to be considered and a conservative approach taken. Note 'footprint' and 'intensity' covered elsewhere. This attribute is questioning whether mortality occurs if the interaction happens?						
<b>Semi-automated category using 'Fauna' score from images</b>				Susceptibility Ranks		
Fauna Categories: 0, 6, 9 -- Column 1		Category 6 may vary with gear type; expert check in each case		See Removability of Fauna/Flora lookup table for gear-specific rank (Table 20)		
Fauna Categories: 2, 8, BV -- Column 2		Category 2 may vary with gear type; expert check in each case				
Fauna Categories: 1, 3, 4, 5, 7, SG, HC -- Column 3		Automated				

**Table 20. Lookup Table for scoring of Susceptibility Attribute B3.1: Removability of Fauna/Flora**

Ranks for Removability / mortality of Fauna/ Flora		Column 1	Column 2	Column 3
		Low, robust or small (<5 cm), smooth or flexible types, OR robust or deep burrowing types	Erect or medium sized (but < 30 cm), moderately rugose or inflexible, OR moderately robust or shallow burrowing types	Tall, delicate or large (> 30 cm high), rugose or inflexible, OR delicate or shallow burrowing types.
Fishery	Method			
BSS	Dredge	3	3	3
CSF	Hand Collection: Aquarium	1	1	1
CSF	Trap (finfish/ crab)	1	2	2
CSF	Demersal Longline	1	2	2
CSF	Trawl	1	2	3
CSF	Autolongline	1	1	3
CSF	Other line: trot, set, drop, hand	1	1	2
GAB	Shelf and Slope Trawl	1	2	3
GHAT	Shark Gillnet	1	2	3
GHAT	Scale Autolongline	1	1	3
HIMI	Demersal Trawl	1	2	3
HIMI	Midwater Trawl	1	2	3
MIF	Demersal Trawl	1	2	3
SET	Otter Trawl	1	2	3
SET	Danish Seine	1	2	3
TSF	Otter Trawl	1	2	3
TSF	Hand Collection: Lobster	1	1	1
NWS	Northwest Slope Trawl	1	2	3
WDW	Western Deepwater Trawl	1	2	3
NPF	Otter Trawl	1	2	3

### Susceptibility Attribute B3.2. Areal extent

This attribute estimates the areal extent of hard and soft grounds as a proportion of the sub-fishery area, stratified by depth (**Table 21** and **Table 22**). Hard grounds occur in patches within large sediment plains, tend to increase habitat complexity and typically provide attachment surfaces for fauna, and consequently act as surrogates for faunal distribution. Hard grounds are generally less common than soft sediments, and may be rare at some depths i.e. upper and mid slope in the southeast of Australia (rank 3 indicates high risk of risk to interactions with fishing gears). Rare habitats may contain rare species, and demonstrate a reduced capacity to recover. There needs to be some regional consideration of this attribute. Most often the extent and distribution of habitat types defined at this scale is not known, so these ranks have been determined by estimates of hard versus soft grounds provided by fishers for some areas, and acoustic surveys and scientific mapping also for some areas. Information to score this attribute is contained within the Habitat database 'Substratum Hardness' attribute, and can be scored from sediment size derived from the Substratum score given to the habitat at the scoping stage (Scoping habitats: **Table 2**).

**Table 21. Description of Susceptibility Attribute B3.2: Areal Extent**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Selectivity</b>	Areal extent	How much of each habitat is present	Effective degree of impact greater in rarer habitats: rarer habitats may maintain rarer species.	Common (> 10%) within the sub-fishery.	Moderately common (1-10%) within the sub-fishery.	Rare (<1%) within the sub-fishery.
<b>Description and decision rules</b>				Susceptibility Ranks		
This attribute will frequently be difficult to estimate because the finer scale distribution of habitats is usually not known - but in cases where a rare habitat is known and mapped it is important to incorporate this into the scoring, otherwise use the lookup table based upon expert opinion. The attribute is related to the 'Depth zone and feature type' attribute used in Encounterability, but will permit finer scale evaluation in cases where mapping has been completed. Note also, there is an element of Productivity covered too, since rarer habitats may have less capacity to recover, i.e. be less resilient. This attribute estimates the % of the habitat type with a depth zone (sub-biome).				<b>See Areal Extent lookup table for rank (Table 22)</b>		

**Table 22. Lookup Table for scoring of Susceptibility Attribute B3.2: Areal Extent**

Ranks	Hard substratum	Soft substratum	Gravel substratum
Coastal Margin (<25m)	2	1	2
Inner shelf (25-100m)	2	1	2
Outer shelf (100-200m)	3	1	2
Upper slope (200-700m)	3	1	2
Mid-slope (700-1500m)	3	1	2

**Susceptibility Attribute B3.3 & B3.4. Removability of substratum & Substratum hardness**

Substratum hardness and clast size influences gear access, degree of impact, residual effect, and importantly, the structure of the sessile invertebrate community present (**Table 23**). Substratum type will strongly influence whether or not the seabed will be degraded by contact of fishing gears, e.g. hard rocky bottom is intrinsically more resistant to impact, and prevents the use of certain gears, whereas, softer sedimentary or weathered rock is more susceptible being broken up, and intermediate sized components, such as boulders that form attachment sites for sessile animals, can be permanently removed. Sediment bottom types are less resistant, but are more resilient to impact. They accumulate relatively rapidly, and are ‘re-worked’ by burrowing animals that turn over the sediment and create surface structures such as mounts and pits that are used by other seabed surface dwellers. To score Removability of substratum, use the Substratum score from habitat scoping (Scoping habitats: **Table 2**), and refer as directed to the appropriate column in the associated lookup table (**Table 24**). To score Substratum Hardness (Attribute B 3.4) use the Substratum score from habitat scoping (Scoping habitats: **Table 2**).

**Table 23. Description of Susceptibility Attribute B3.3: Removability of Substratum**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Selectivity</b>	Removability of substratum	Certain size classes can be removed	Intermediate sized clasts (~6 cm to 3 m) that form attachment sites for sessile fauna can be permanently removed	Immovable (bedrock and boulders >3 m). See <b>Removability of substratum</b> lookup table for gear specific rank	< 6 cm (transferable). See <b>Removability of substratum</b> lookup table for gear specific rank	6 cm to 3 m (removable). See <b>Removability of substratum</b> lookup table for gear specific rank
<b>Description and decision rules</b>						
Checks are particularly important for friable hard bottom such as when sedimentary rocks are present as soft ledges or slab boulders in canyon heads. Removable substratum includes the dead biogenic matrix formed by stony and deepwater reef-building corals.						
<b>Semi-automated category using Substratum score from images</b>				Susceptibility Ranks		
Categories 5 and 6 -- column 1		check image +/- expert opinion in each case		<b>See Removability of Substratum lookup table for gear specific rank (Table 24)</b>		
Categories 0 - 3 (mud, fine and coarse sediments, gravel/ pebble), X -- column 2		Automated				
Category 4 (cobble/ boulder/ slab) -- column 3		check image +/- expert opinion in each case				

**Table 24. Lookup Table for scoring of Susceptibility Attribute B3.3: Removability of Substratum**

		Column 1	Column 2	Column 3
<b>Ranks for Removability of substratum</b>		Immovable (bedrock and boulders >3 m)	< 6 cm (transferable)	6 cm to 3 m (removable)
Fishery	Method			
BSS	Dredge	1	2	3
CSF	Hand Collection: Aquarium	1	1	2
CSF	Trap (finfish/ crab)	1	1	1
CSF	Demersal Longline	1	1	1
CSF	Trawl	1	2	3
CSF	Autolongline	1	1	1
CSF	Other line: trot, set, drop, hand	1	1	1
GAB	Shelf and Slope Trawl	1	2	3
GHAT	Shark Gillnet	1	1	1
GHAT	Scale Autolongline	1	1	1
HIMI	Demersal Trawl	1	2	3
HIMI	Midwater Trawl	1	2	3
MIF	Demersal Trawl	1	2	3
SET	Otter Trawl	1	2	3
SET	Danish Seine	1	2	3
TSF	Otter Trawl	1	2	3
TSF	Hand Collection: Lobster	1	1	1
NWS	Northwest Slope Trawl	1	2	3
WDW	Western Deepwater Trawl	1	2	3
NPF	Otter Trawl	1	2	3

**Table 25. Description of Susceptibility Attribute B3.4: Substratum hardness**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Selectivity</b>	Substratum hardness	Composition of substrata	Harder substratum is intrinsically more resistant	Hard (igneous or indurated) lithotypes	Soft (sedimentary or weathered) lithotypes	Sediments
<b>Description and decision rules</b>						
<b>Automated category using Substratum score from images</b>				Susceptibility Ranks		
Category 5 (igneous/ metamorphic rock)			Automated	1		
Category 4, 6, 7 (sedimentary rock, cobble/ boulder/ slab, biogenic substrata)			Automated	2		
Categories: 0 – 3, X (mud, fine sediments , coarse sediments, gravel/ pebble)			Automated	3		

**Susceptibility Attribute B3.5. Seabed slope**

Some fisheries target steep grounds that occur on the Continental slope, seamounts, plateaus and canyons. Fishing impact may be greater on steep slopes because gravity (or latent energy transfer) assists in moving habitat structures such as boulders downhill once they are dislodged, and faunal densities are often greater (**Table 26**). This attribute assesses the relative risk of impact to known features as they are represented within primary depth zones (those of greater slope rank higher) (**Table 27**).

**Table 26. Description of Susceptibility Attribute B3.5: Seabed slope**

				Susceptibility Ranks		
Aspect	Attribute	Concept	Rationale	1	2	3
<b>Selectivity</b>	Seabed slope	Mobility of substrata once dislodged; generally higher levels of structural fauna	Gravity or latent energy transfer assists movement of habitat structures e.g. turbidity flows, larger clasts. Greater density of filter feeding animals found where currents move up and down slopes.	See <b>Slope</b> lookup table for rank	See <b>Slope</b> lookup table for rank	See <b>Slope</b> lookup table for rank
<b>Description and decision rules</b>				Susceptibility Ranks		
This attribute can be applied at the habitat scale of depth zone (sub-biome) or feature. Many habitats of the upper slope are relatively steep compared to the shelf; many habitats of canyons are relatively steep compared to adjacent plains and terraces. Numerically, if data are available, ranks should be split at 1 degree, 1-10 degrees, >10 degrees. <b>Decision rule:</b> canyons and seamounts = rank 3; upper slope, rank =2, unless the substratum is identified as rocky bank when rank =1. Where a feature does not appear within a sub-biome it is indicated by a dash.				<b>See Slope lookup table for rank (Table 27)</b>		

**Table 27. Lookup Table for scoring of Susceptibility Attribute B3.5: Seabed slope**

<b>Ranks</b>	<b>Plains</b>	<b>Terraces</b>	<b>Canyons</b>	<b>Seamounts / Bioherms</b>	<b>Rocky banks/ Fringing reefs</b>
Coastal Margin	1	--	--	<b>3 (Bioherms)</b>	<b>1</b>
Inner shelf	1	--	--	<b>3 (Bioherms)</b>	<b>1</b>
Outer shelf	1	<b>2</b>	<b>3</b>	--	<b>1</b>
Upper slope	--	<b>2</b>	<b>3</b>	<b>3 (seamounts)</b>	<b>1</b>
Mid-slope	1	1	<b>3</b>	<b>3 (seamounts)</b>	<b>1</b>

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**Level 2 PSA Methodology: Community Component**

The objective of the community assessments is to identify whether a community is at potential risk from fishing through significant changes to properties such as species composition, structure and function, and distribution. This is a daunting task at best in data rich analyses, and elsewhere potentially overwhelming. Most commonly there is information on a subset of species in a community, as when research has focused on the predators and prey of a species of commercial importance, thus supporting the definition of a “relevant subsystem”. Where a more complete picture of membership is known there is justification for a “full” description of the system, recognizing that seldom are all species in a community or environment fully known. Therefore three general kinds of techniques could be applied, depending on the level of knowledge of trophodynamics in the system: topological analyses, qualitative models, and quantitative models. The first two techniques are suitable for the level 2 semi-quantitative approach whereas the last technique is a level 3 approach.

Some of the community metrics widespread in community ecology are measures of the systems’ resilience or stability. They measure the ability of the system to maintain its integrity while being perturbed and to return to its previous state. However, many of these attributes can only be derived from quantitative analyses, and are therefore unsuitable for use at this level. Some are derived from both productivity and susceptibility aspects of an ecosystem or community and therefore difficult to map into either productivity or susceptibility streams in the current PSA analysis method which has been developed and applied to the individual species. While we acknowledge that modification to our rationale may be necessary in the future, we have taken the view that any attributes that are intrinsic to the community’s ability to maintain itself such as growth, or stability, the attributes are deemed “productivity” but if related to exploitation or removal then they are deemed “susceptibility”.

The ramifications of potential perturbations in a community will be dependent on the connectedness of the species and their ability to influence the other species. We used qualitative techniques of response to perturbation and topological analyses to derive metrics such as key players, error sensitivity that here we considered to be productivity attributes. Identifying the high risk species from the PSA analyses for species provided a starting point for these qualitative analyses. More quantitative susceptibility measures such as the number of species that are fished or at high risk logically places a functional group at risk of loss of function, and if severe, the whole community may be at risk.

Cumulative effects on species from all fisheries have not been addressed in these assessments, but remain an important risk for a community. While a species might be caught in many fisheries, the overall catch rate might be relatively low. If the population biomass is small or the species represent a significant proportion of a functional group the impact could be severe. Alternatively, if its biomass is large or it represents a very small portion of a functional group the impact might be small. Whilst we do not address this problem in this stage, we developed several fishery-specific spatial metrics, such as the % overlap of the fishery with the community assessed and the proportion of the total catch per species caught by sub-fishery within that community to derive proxy susceptibility attributes for the community. This last attribute might be integral to determining cumulative effects in the future.

The following table (Table 1) is a list of all attributes identified as being relatively simple to calculate within the bounds of the semi-quantitative method, i.e. do not require explicit quantitative data such as required for ecosystem modelling or stock assessments. Some attributes will require knowledge of the community members and some build on individual risk ratings from species PSA analyses. The rankings of high, medium and low follow the rationale for species. For some attributes, e.g. topological analyses and diversity measures, rankings have not been determined or are arbitrary until we have results from more community analyses to determine an appropriate range.

### Species compilations

All communities around Australia were populated initially with species from the CAAB distribution database. Subsequently we modified lists using information from various sources and in particular the South East Transition lists derived their species composition from: the sub fishery species lists including the threatened and endangered species, a local ecosystem study (Bax & Williams 2000, 2001, Bulman et al. 2000, Bulman et al. 2001 and FRDC trophic modelling project (2002/028) in progress, Williams & Bax 2001), and literature.

Species were first extracted from the CAAB database but only about half of the species in CAAB have associated distributional (string data). Therefore additional species were added by comparing with the sub fishery lists, the trophic modelling project and the SEF ecosystem study species. Considerable cross-checking was required since our communities were mostly smaller than the area of the sub fisheries and distributions of some fishery species were sometimes restricted to areas not within our community. Marine mammal and bird distributions are likely to be inaccurate as the sources were often inconsistent. Species composition and distributional data for invertebrates was unavailable for this analysis. Invertebrates were restricted to those which were primarily of fishery interest and those which were mobile. Sessile or attached invertebrates (including infauna) are dealt with in the Habitat analyses.

Pelagic community species lists were the most difficult to compile as there was no base distributional data available in CAAB. Species were obtained initially from relevant sub-fisheries such as the SBT or skipjack tuna fisheries. Some species were added from information on FishBase. Most information was obtained from studies on midwater fishes and tunas (Young and Blaber 1986, Young and Davis 1990, 1992, Young et al. 2001, Williams & Koslow 1997). These lists are likely to be incomplete and will need some expert verification.

Table 1. Community attributes calculated for PSA analysis.

Property	Component		Attribute	Rationale	Aspect	High	Med	Low
Productivity	Life-history	1	Mean growth rate ( $H_0$ : high, more productive)	High mean growth rate of community members means higher productivity.	Productivity			
		2	Mean length at maturity (Jennings et al., Fig 12.10). ( $H_0$ : low, more productive)	Low mean length at maturity would suggest species higher growth rates and therefore more productive.				
	Diversity/Species Composition	1	Species richness (S) ( $H_0$ : high richness, more resilience)	Higher species richness means higher productivity or higher resilience to perturbation. Could indicate also redundancy in functional groups.		<50	50-300	>300
		2	Taxonomic distinctness (presence/absence data) $\Delta^+$ ( $H_0$ : high richness, more resilient)	Low phylogenetic biodiversity indicates significant impact or higher risk of loss of biodiversity from impact. This index is independent of sample size. Can be monitored for loss of $\Delta^+$ from impact (of fishing)				
	Trophic structure	1	Mean trophic level ( $H_0$ : low, can also indicate change)	Low mean trophic level would indicate species probably of smaller size and higher growth rates.				
		2	% of functional groups with total number of members per group > 5 or 10 ( $H_0$ : more groups, less susceptible)	Redundancy guards against impact.		<30	30-50	>50
		3	Number of top predators (n predators <2) ( $H_0$ : high number, more stable)	High number of top predators means productive system supporting them, therefore not significantly impacted.		<3	3-10	>10
		4	Attack sensitivity ( $H_0$ : low AS, high resilience to impact)	Calculated from topological analysis see Appendix 2				
		5	Error sensitivity ( $H_0$ : low ES, high resilience)	Calculated from topological analysis see Appendix 2				
		6	Key players ( $H_0$ : high value, high risk)	Calculated from mean of influence and fragmentation dominator tree analysis metrics see Appendix 2.				
7		Number of high risk species which eat high risk prey	The more high risk predators relying on high risk prey lessens the resilience to effects of perturbation					
Susceptibility	Trophic structure	1	% of functional groups fished (total all gear types) ( $H_0$ : higher the number more susceptible the	If high number of functional groups is fished, then community structure and diversity at risk.	Selectivity	>50	30-50	<30

Property	Component	Attribute	Rationale	Aspect	High	Med	Low
		community is)					
		2 % of functional groups with high proportion of species fished i.e. >50% species (H <sub>0</sub> : high % means community structure susceptible)	If high number of functional groups have more than half species membership fished, then community structure and diversity susceptible.	Selectivity	>50	30-50	<30
		3 % of mean functional group risk rating (H <sub>0</sub> : higher; higher risk)	If species within functional groups have high risk ratings then functional group is at risk.	Selectivity	>30	5-30	<5
	Fishery specific	1 % jurisdictional overlap of fishery with community (H <sub>0</sub> : high overlap, more vulnerable)	High overlap, more of community available, high risk	Availability	>65	30-65	<30
		2 % actual effort overlap of effort in fishery with community (H <sub>0</sub> : high overlap, more vulnerable)	High effort overlap, more of community available, high risk	Encounterability	>50	10-50	<10
		3 Mean trophic level of catch from sub fishery (H <sub>0</sub> : lower trophic level, higher risk)	Monitor; can be calculated directly from catch stats	Selectivity	<3	3-3.5	>3.5
		4 % of functional groups fished by sub fishery/gear (H <sub>0</sub> : higher the number more susceptible the community is)	If high number of functional groups is fished, then community structure and diversity at risk.	Selectivity	>50	30-50	<30
		5 Number of trophic levels captured by gear (H <sub>0</sub> : more trophic levels, less discriminating, higher susceptibility of community)	If a gear is indiscriminate in selectivity of fishes and trophic levels, then community is more susceptible to impact	Selectivity	>3.0	2.0-3.0	1
		6 % sub fishery catch of total catch overall all gear types (H <sub>0</sub> : high proportion of total catch, more impact of fishery on community)	High proportions of sub-fishery catch of total catch considered to indicate high selectivity therefore risk from sub fishery. Could also be a proportion of cumulative risk in future iterations	Selectivity	>50	10-50	<10
		7 % of fished species with high PCM from species PSA (H <sub>0</sub> : higher number, higher risk)	If high proportion of species have high Post-capture mortality, risk to community is higher	Post-capture mortality	>60	30-60	<30

# Generic Food Web

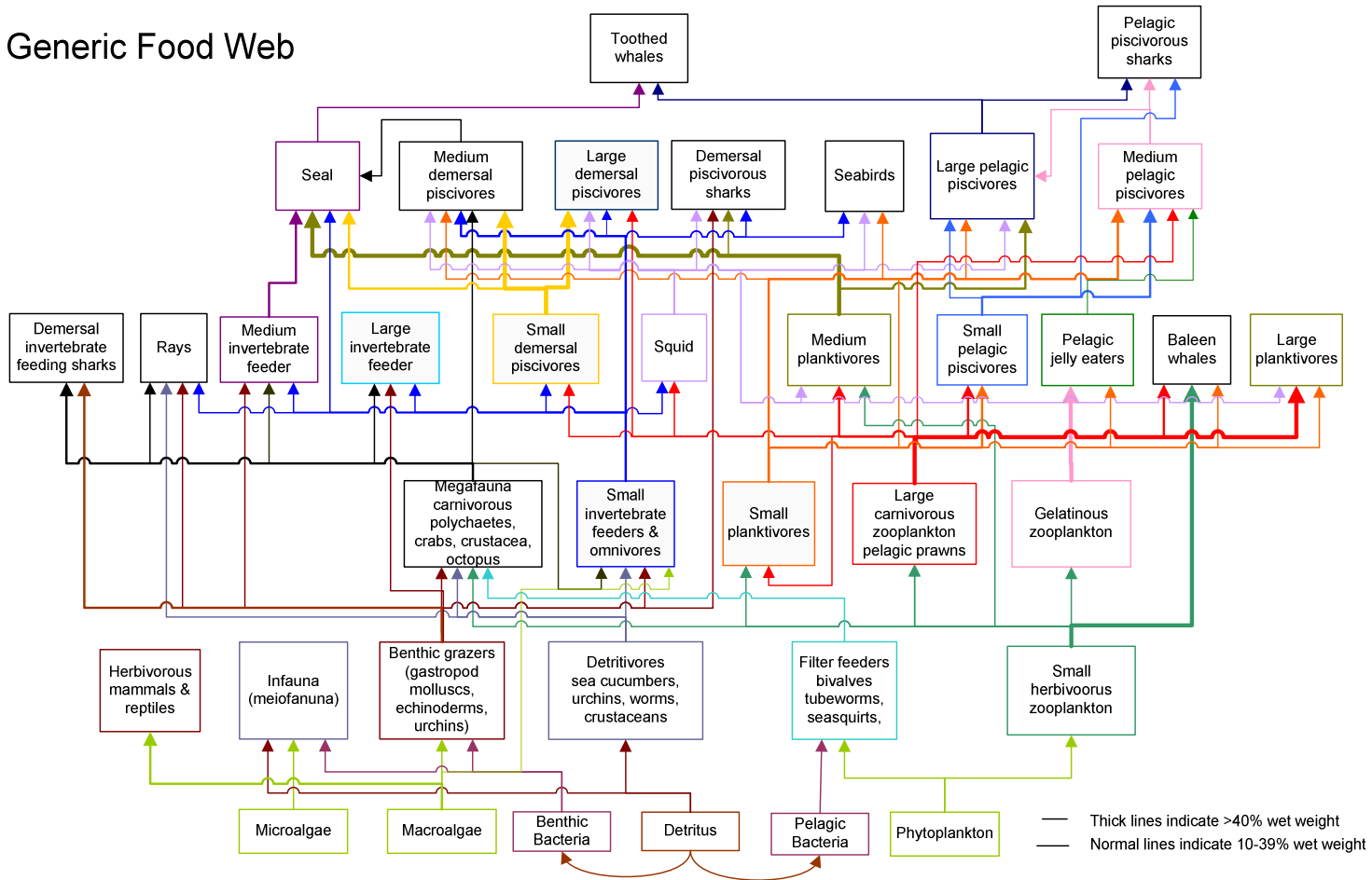


Fig 1. A generic food web for use in ERAEF community analyses.

### Trophic structure

A generic food web structure was decided upon in order to organise the community into functional groups for derivation of some metrics (Fig 1). The generic structure is based around several ecosystem models: the Eastern Bass Strait model developed for the South East Fishery region from southern NSW to Wilson's Promontory in Victoria (Bulman *et al.* 2002, 2006), the Atlantis model developed for the South East region (Fulton *et al.* 2004), the North West Shelf model (Bulman 2006) and the West Florida Shelf model (Okey & Mahmoudi 2002). This approach assumes dietary information is available for most of the "indicator" species so that they are allocated into appropriate trophic groups. Decisions regarding single species groupings will need to be made in each community around Australia. Therefore, each community trophic structure will be based largely on a generic approach but will be individualised to accommodate the relevant commercially or ecologically significant species. By individualising each community food web structure, they will not be directly comparable. However, identifying the high risk species, which will most often include the target species, is necessary for the qualitative and quantitative food-web analyses. However, it will also result in some of the metrics being high risk because of the single-species state of the group, rather than a "diluted" risk result if the targeted species were subsumed in an aggregate group.

For this case study, we chose the South Eastern Transition biotone communities, in which the 110-250m community was identified in the SE Otter trawl fishery as the most vulnerable community (Fig 2). In all, there six communities associated with the continental shelf and slope. The Eastern pelagic province overlays this biotone, and the associated depth zones are the coastal (0-200 m), epipelagic (0- 600 m) and mesopelagic (> 600 m) zones.

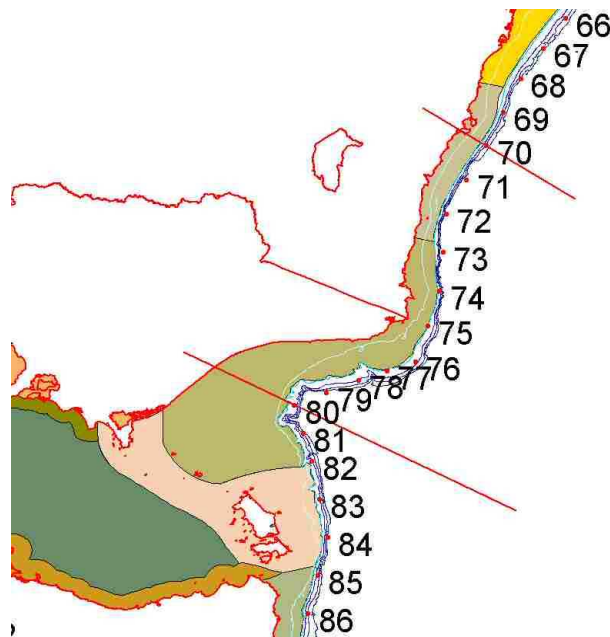


Fig 2. The South Eastern Transition boundaries (points 70 & 80) for offshore communities and the mesoscale communities (corresponding to those between points 69 to 85 and shown shaded tan) within the South Eastern Biotone for shelf communities.

### ***Productivity attributes***

#### Semi-quantitative

Measures of growth & reproductive productivity were derived as the average of the mean growth rate and mean length at maturity of all the individual fish species of the community. These measures were collected in the ERA database (CSIRO) for those species which were identified from the fishery, however the community was broader than that fished therefore data for the additional species was collated initially from the FishBase database (Froese and Pauly 2005). Ideally, this data would be inspected for appropriateness of the values and we would search for data from local stocks.

Taxonomic diversity was measured using the taxonomic diversity routines in Primer (Clarke and Warwick 2001). These measures were first applied to communities to explain large-scale patterns in species distribution and disturbance and because of disadvantages of the basic species richness (S) index, which we also provide. It assumes that taxonomic diversity relates to ecological diversity crucial to maintaining ecosystem stability during disturbance. We used an index which uses presence/absence data only and is suitable for our methodology. Only the fish community was tested because we considered that this was the only group in which we had reasonable confidence about the species composition. The average taxonomic distinctness ( $\Delta^+$ ) is the average taxonomic distance between species  $i$  to every other species, summed over all species. This measure is probably a useful tool for monitoring for loss of diversity particularly for lightly-exploited communities. For the south-east, however, where exploitation has been evident for nearly a century, disturbance is already high and therefore evidence of further loss of diversity is uncertain. Comparison with other communities will provide further information about the range of values and consequent rankings.

Other attributes that we consider as productivity attributes are the mean trophic level of the community. Ideally this measure would be weighted using biomass but in its absence a non-weighted value was used. The number of top predators is a measure of how productive the system is that supports them, therefore a higher number means more productive and less impact is likely. A related attribute is the number of species in the functional groups because the larger number of species in a functional group guards means a certain amount of redundancy and thus the community is resilient to loss of species. Using a generic structure that is consistent across all communities for this attribute and others reliant on structure, will provide a range of values, for ranking.

#### Qualitative analyses

##### *From single- to multi-species analysis of risk*

The underlying basis for our level 2 community analyse can be derived from the same principles supporting single species analyses at level 1. Here we show how the basic attributes used to rank productivity and susceptibility of a single species lead to mathematical formulations describing the dynamics of multi-species systems. This will lead us to two complimentary aspects of ecosystem theory: system stability and perturbation response.

Using the basic formulation of logistic growth

$$\frac{dN_i}{dt} = r_i N_i \left( 1 - \frac{N_i}{K_i} \right) - C_i \quad (1)$$

the change  $d$  in the population abundance  $N$  of species  $i$  over time  $t$  is a function of its per capita growth rate  $r$  and the ratio of its own population level to a certain carry capacity  $K$ , the latter of which is set by the level of resources and habitat available in the environment. The population growth rate  $r$  is the sum of all births and deaths of a population (*i.e.*  $r$  = per capita rate of birth minus per capita rate of death), and thus in, this parameter makes intrinsic to this single species formulation all resources that benefit and all hazards that befall the population. In multi-species equations the individual rates of birth and death are detailed according to their biological or physical source. Also included is  $C$  a constant rate of fishery harvest.

Left to itself, a population undergoing logistic growth will rise from a low level of relative abundance to a final equilibrium level  $K$ . Graphing this rise over time produces the sigmoid curve of figure 2. We may read into these curves the rationale supporting our level 1 analysis. When we try to describe attributes of productivity we are pointing towards features distinguishing a relatively fast rise in abundance from a slow rise, and a relatively high carrying capacity from a low one.

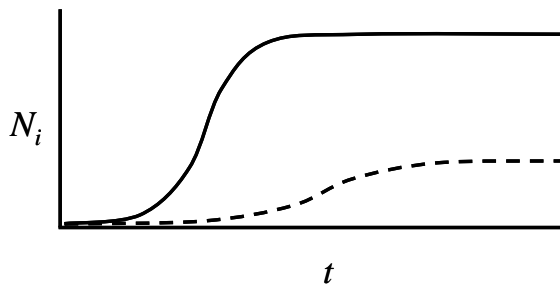


Figure 2. General sigmoid curves for logistic population growth. Dashed-line describes, relative to solid-line, a population with a slower growth rate and lower carrying capacity.

When we take into account the susceptibility of a population to effects of fishing we are concerned about whether a population can sustain and recovery from the extra source of mortality imposed by a fishery harvest. In a simplistic manner, this too can be understood through the formulation of logistic growth. Here we examine the change in the growth rate of population in relation to a change in abundance through the use of partial derivatives. Taking the partial derivative of equation (1) with respect to  $N_i$ , we have

$$\left. \frac{\partial \left( \frac{dN_i}{dt} \right)}{\partial N_i} \right|_* = -\frac{r_i N_i}{K_i} + \frac{C_i}{N_i} \quad (2)$$

which describes change in a population's per capita growth rate due to a change in its abundance. Note that this is evaluated in reference to equilibrium conditions (as denoted by the asterisk). Ignoring for now the effects of fishing and considering only the first term on the right side, equation (2) tells us that under logistic growth a change in the population level away from equilibrium will be countered by an equal change in

the growth rate in the opposite direction equal to  $-r_i N_i / K_i$ . Hence any deviation away from carrying capacity (which in the absence of fishing is merely the carrying capacity  $K$ ), either positive or negative, will be opposed so that the system will return to its equilibrium level. This, in effect, demonstrates negative feedback and thus defines the stability properties of the population. Considering the effects of a constant rate of harvest  $C$ , equation (2) shows that the tendency of a return to equilibrium can be weakened or reversed by the term  $C_i / N_i$ , the level of harvest in relation to the population size. This term, which is positive in sign, introduces positive or destabilizing feedback into the dynamics of the population. When this positive term becomes greater than the negative one, then the population will decline to extinction. Taken in total the right side of equation (2) lays down the attributes required assessing the susceptibility of a population to harvest in terms of population growth rate, abundance, carrying capacity and rate of harvest. This equation, of course, is in the terms of a single-species, and expanding to a multi-species formulation requires that we specify the sources of birth and death for each species in a community, as in the general form of the Lotka-Volterra equations<sup>2</sup>

$$\frac{dN_i}{dt} = N_i \left( \sum_{j=1}^n \alpha_{ij} N_j - k_i \right) - C_i. \quad (3)$$

where there are  $n$  equations, and with  $\alpha_{ij}$  signifying per capita density-dependent interaction terms, and  $k_i$  the density independent parameters (such as immigration and emigration). The  $\alpha_{ij}$  terms can portray all possible interactions between species, such as predator-prey (with a +, - pair of interaction signs), direct competition (-, -), mutualism (+, +), commensalism (0, +), amensalism (0, -), or neutral interactions (0, 0). Interactions between species can also be conveniently portrayed as a signed digraph. For instance, the signed digraph in figure 3 represents a three species food chain with predator-prey relationships, and self-regulation for each species.

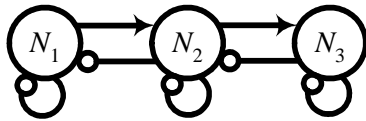


Figure 3. Signed digraph of three species community. Large circles are population variables, and direct interactions between species, here predator and prey, are shown as links ending in an arrow, for a positive effect, or small circle, for a negative effect. A link connecting a species to itself denotes self regulation.

There is a direct correspondence between the linkages portrayed in signed digraphs the partial derivatives from a set of Lotka–Volterra equations. For the three species system of figure 3, there are nine partial derivatives—one each for the three species with respect to themselves, and six for each species with respect to each other. These then give us the community (or Jacobian) matrix for the system

<sup>2</sup> This presentation has adopted a Lotka–Volterra formulation to illustrate analyses of community dynamics, however an equivalent presentation could proceed via a formulation based on input-output or compartment flow models.

$$\mathbf{A} = \frac{\partial \left( \frac{dN_i}{dt} \right)}{\partial N_i} \Big|_* = \begin{bmatrix} -\alpha_{1,1}N_1 + \frac{C_1}{N_1} & -\alpha_{1,2}N_1 & 0 \\ \alpha_{2,1}N_2 & -\alpha_{2,2}N_2 + \frac{C_2}{N_2} & -\alpha_{2,3}N_2 \\ 0 & \alpha_{3,2}N_3 & -\alpha_{3,3}N_3 + \frac{C_3}{N_3} \end{bmatrix}. \quad (4)$$

Note the similarity between the diagonal elements of this matrix and the terms on the right side of the single species model in equation (2). While the diagonal  $\alpha_{ii}$  terms in equation (4) would appear equivalent to  $r_i/K_i$  within equation (2), they are in fact not. In the single-species model  $r_i$  accounted for all sources of birth and death, but in the multi-species model these attributes are divided among the other species. For instance, reading along the second row of this community matrix, one sees that species two derives a positive influence, or births, from eating species one ( $+\alpha_{2,1}$ ), has a negative self-effect from intraspecific interactions ( $-\alpha_{2,2}$ ), a positive self-effect from harvest ( $+C_2/N_2$ ), and finally a negative influence from species three via predation losses ( $-\alpha_{2,3}$ ).

#### *Perturbation response and system stability*

In determining the risk of a community to effects of fishing we are concerned with two aspects of ecosystem dynamics: response to perturbation and system stability. We will briefly describe the basic analyses involved, data requirements, and methodological options for different levels of knowledge of the system. In predicting the effects of a perturbation, we are concerned with new equilibrium levels that populations will move towards after one or more species in the system are impacted by a change in a parameter controlling a rate of growth. While the community matrix details all direct effects between species, the ultimate effects of a perturbation are transmitted to many, if not all species in a community. These effects can be assessed through the adjoint of the community matrix. The adjoint matrix details the feedback cycles produced from a perturbation, and can be used to predict change in species abundances. Methods for interpreting adjoint matrix analyses are discussed in Dambacher *et al.* (2002, 2003a).

For example, the adjoint matrix for the three species system described by figure 3 and equation (4) is

adjoint(-A) =

$$\begin{bmatrix} \left( \alpha_{2,2}N_2 - \frac{C_2}{N_2} \right) \left( \alpha_{3,3}N_3 - \frac{C_3}{N_3} \right) + \alpha_{2,3}N_2\alpha_{3,2}N_3 & -\alpha_{1,2}N_1 \left( \alpha_{3,3}N_3 - \frac{C_3}{N_3} \right) & \alpha_{1,2}N_1\alpha_{2,3}N_2 \\ \alpha_{2,1}N_2 \left( \alpha_{3,3}N_3 - \frac{C_3}{N_3} \right) & \left( \alpha_{1,1}N_1 - \frac{C_1}{N_1} \right) \left( \alpha_{3,3}N_3 - \frac{C_3}{N_3} \right) & - \left( \alpha_{1,1}N_1 - \frac{C_1}{N_1} \right) \alpha_{2,3}N_2 \\ \alpha_{2,1}N_2\alpha_{3,2}N_3 & \left( \alpha_{1,1}N_1 - \frac{C_1}{N_1} \right) \alpha_{3,2}N_3 & \left( \alpha_{1,1}N_1 - \frac{C_1}{N_1} \right) \left( \alpha_{2,2}N_2 - \frac{C_2}{N_2} \right) + \alpha_{1,2}N_1\alpha_{2,1}N_2 \end{bmatrix} \quad (5)$$

Effects of a perturbation are read down the column of the species through which a disturbance is directly acting. For instance, in reading down the third column, decreasing the harvest rate of species three will cause an increase in the abundance of species one, via feedback cycle  $\alpha_{1,2}N_1\alpha_{2,3}N_2$ , and a decrease in the abundance of species two via feedback cycle  $-\left( \alpha_{1,1}N_1 - C_1/N_1 \right) \alpha_{2,3}N_2$ . Note the response of species

three is determined by no linkage or interaction associated with itself. Rather, to know the fate of that population one must know or have measured most of the parameters regulating all other species in the community. It is this sort of complexity and demand for community interaction data that makes precise quantitative analyses of communities so difficult and rare. There are, however, qualitative means by which ecosystem models can be analysed (Dambacher et. al. 2002, 2003a). In either quantitative or qualitative analyses of perturbation response, we can attribute risk for a whole community based on the summed expectation of change in abundance for all populations in the system. Risk at a community level can be based on assessing whether species predicted to have a relatively large decrease in abundance due to a perturbation also have elevated levels of risk assigned from level 1 analyses.

Mathematical determinations of community stability involve analysis of the values and balance of system feedback cycles, and also proceed from the community matrix  $A$ . Here we are concerned if population levels can remain close to either fixed values or values that oscillate regularly according to the internal dynamics of the system. The ‘closeness’ defines a ‘local’ attractor or equilibrium of the system. A system’s stability depends on the signs of its eigenvalues ( $\lambda$ ), which are the roots of the characteristic equation formed by the equality

$$|A - \lambda I| = 0 \quad (6)$$

where  $I$  is the identity matrix and ‘ $| \quad |$ ’ denotes the matrix determinant. The resulting characteristic polynomial is of the form

$$a_0 \lambda^n + a_1 \lambda^{n-1} + a_2 \lambda^{n-2} + \dots + a_n = 0. \quad (7)$$

A system can be stable if and only if all eigenvalues of  $A$  have negative real parts

$$\text{Re } \lambda_i (A) < 0 \quad i = 1, 2, 3, \dots, n \quad (8)$$

(Lyapunov [1892] 1992). Stable systems are able to maintain equilibrium around a local attractor and are buffered against species extinction, while unstable systems are likely to diverge from former equilibria and suffer species loss.

If all elements of  $A$  are known or measured, one can proceed directly through a quantitative analysis. Typically, however, quantification of the elements of  $A$  is incomplete or imprecise, while the sign of the elements are well known, as in the information contained in the signed digraph of figure 3. In this latter situation one can proceed via qualitative analyses to assess the stability of a system (May 1974, Dambacher et. al. 2003b). For example, in figure 3 (a), a four variable system is conditionally stable, and all species can coexist when interaction strengths are within a limited region of parameter space. We consider two scenarios whereby a species is severely reduced or eliminated, effectively leaving a three variable system. Removal of  $N_4$  in figure 3(b) leads to a neutrally stable system where  $N_2$  and  $N_3$  are no longer controlled by a common predator. The most efficient consumer of  $N_1$  will overwhelm the other consumer, ultimately leading to extinction of the latter and a two variable system. Here  $N_4$  effectively acts as a keystone predator, whereby its removal causes subsequent extinctions in the system. In figure 3 (c) removal of basal resource variable  $N_1$  leaves a system entirely unstable and no species may persist.

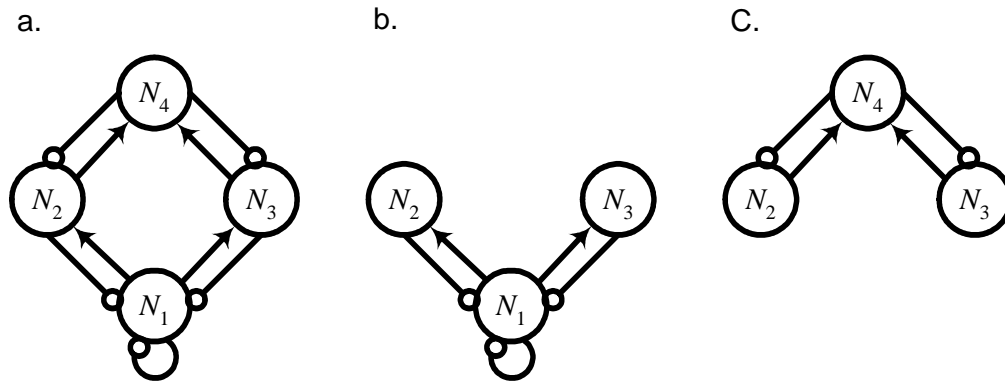


Figure 3. Signed digraph of a) system that can be conditionally stable, and two possible systems resulting from b) removal of  $N_4$ , which can only be neutrally stable and where  $N_2$  or  $N_3$  will likely perish, and c) removal of species  $N_1$  leaving a completely unstable system where no species can persist.

*Topological analyses*

Allesina and Bodini (2004) introduced the notion of dominator trees for analysis of extinction risk in ecological communities. Originally developed for optimization of computer programming and code generation for flow networks (Lengauer and Tarjan 1979, Georgiadis and Tarjan. 2004), the concept of a dominator tree is extended to ecological systems by identifying structural dependencies among species that are critical for resource flow through a food web. One species dominates another if it is a singular source of resource flow within a network, with the presumption that its removal would precipitate downstream extinctions of other species that can gain resources through no other source. In figure 4, there is non-redundant resource flow to species **c**, **d**, and **e** via species **a**. Thus species **a** is a dominant of these three species and its removal would cause their demise. Removal of species **b**, **c**, **d**, **e**, or **f** would not completely eliminate resource flow to any other species.

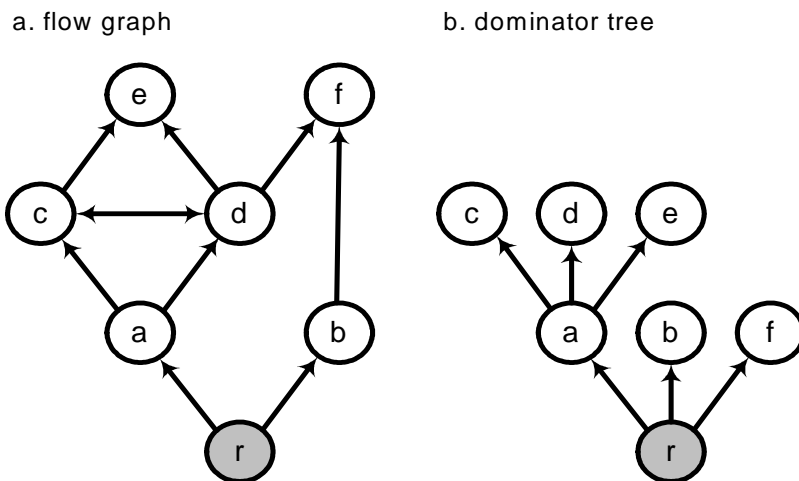


Figure 4. a) Flow graph of example ecosystem, where system resources **r** flow into and through basal species **a** and **b** and then on to other variables. b) Dominator tree of same

system showing serial dependencies within flow graph. Adapted from Allesina and Bodini (2004).

The risk of the entire system to secondary extinctions can be assessed through the measure of “error sensitivity”

$$ES = \sum_{i \neq r} \frac{|dom(i)| - 1}{(N - 1)^2} \quad (9)$$

and the maximum impact of the removal of particular species can be assessed through the measure of “attack sensitivity” (Allesina and Bodini 2004)

$$AS = \max \left\{ \frac{|dom(i)| - 1}{N - 1} \right\} \forall i \neq r. \quad (10)$$

Dominator trees that are configured as a linear chain will have a greatest possible value of error sensitivity of 0.5, as in figure 5a, and those with a star-like configuration will have a minimum value equal to  $1/(N-1)$ , as in figure 5b. Values of attack sensitivity can range between 0 and 1. Low values of ES and AS denote systems least prone to secondary extinctions. We will employ a modified version of equation (10) to assess the mean attack sensitivity for  $m$  number of species  $j$ , that are deemed to have high risk in level 1 analyses

$$AS^{\text{mean high risk}} = \frac{\sum_{j=1}^m \max \left\{ \frac{|dom(i)| - 1}{N - 1} \right\} \forall i \neq r}{m} \quad (11)$$

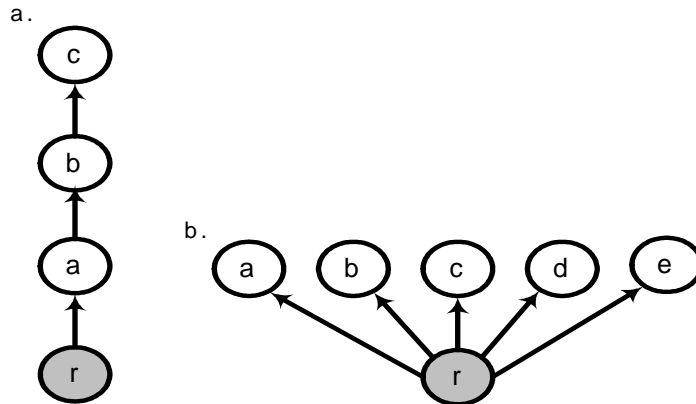
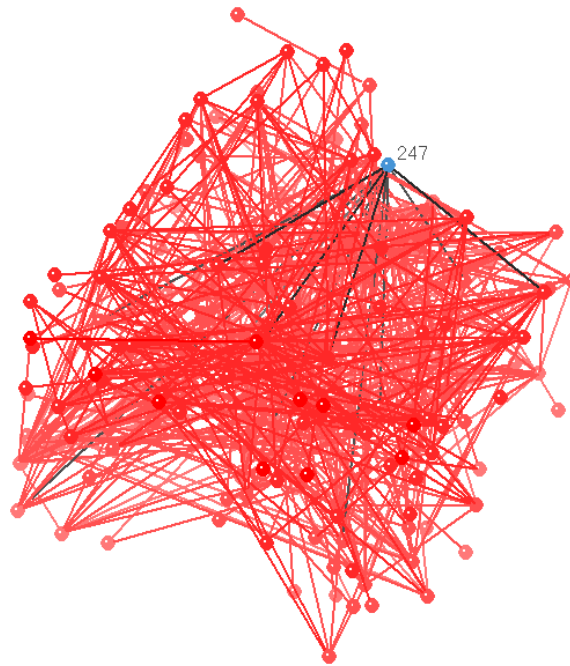


Figure 5. Dominator trees illustrating the full range of extinction susceptibility, where in a) there is maximum risk with a probability of 0.5 for secondary extinction upon removal of any one species, and in b) there is zero risk of secondary extinction. Adapted from Allesina and Bodini (2004).

Our final metric for qualitative risk analysis is that of defining “key players” (Borgatti 2003) in a community, which can be defined by two different criteria. A key player can be a node that, when removed, causes the greatest possible fragmentation to the network (Fig 6a). Alternately, a key player can be identified as the node through which the greatest number of other nodes can be reached or influenced within a given path length (Fig. 6b). In figure 7, which is based on a food web of 189 demersal species from the SE Australian shelf, jackass morwong (*Nemadactylus macropterus*) is, by the influence method, a key player that reaches 98% of all other species within a path



a.



b.

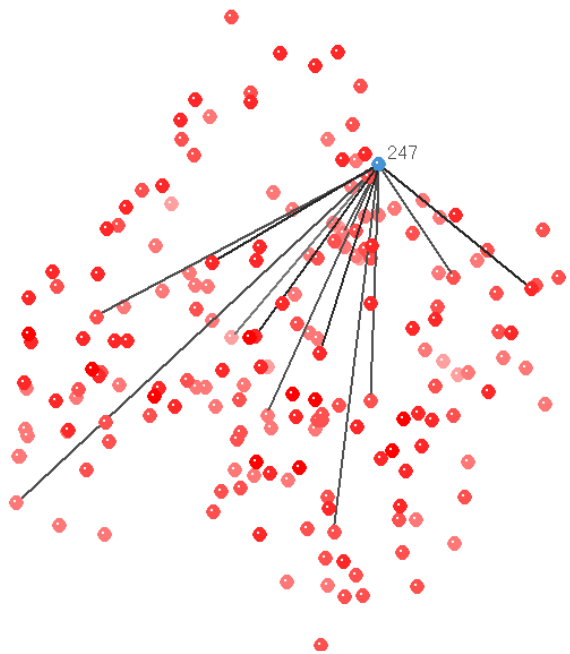


Figure 7. Key player analysis of SE Australian shelf demersal food web. Jackass morwong (no. 247) reached 98% of all other species in network within path length of 3 links. All trophic links are shown in a) and only those directly connected to key player are shown in b).

***Susceptibility attributes***

Susceptibility metrics, *sensu* the ERAEF method, refer to measures relating to removals or exploitation of species in the community. The metrics we derived were tentatively assigned to the four aspects of susceptibility used in the species level PSA - availability, encounterability, selectivity and post-capture mortality. For example, the % overlap (by area) of each community by the sub-fishery determined for both demersal and pelagic provinces/biotones, were considered availability aspects. However, the refinement of this metric, the actual area of each community fished, or the overlap of the effort, was considered an encounterability aspect. This metric was determined from the number of shots in each one km<sup>2</sup> grids recorded in the available commercial logbooks. This was more difficult to determine for the sub-fisheries that reported in half-degree grids only as it was too coarse for our analysis. In our example, the jurisdictional boundary of the South East Shark and Scalefish Fishery (SESSF) overlaps the South East Transition 110-250m community by 100% thus the availability of the community to fishing was deemed high. The encounterability aspect, the % overlap of the actual effort with the community, based on 2001-2004 commercial logbook data (Fig 8), was 99.6% and also ranked high. The encounterabilities of nearly all the adjacent communities by the otter trawl sub-fishery were also high in this province.

Several attributes were considered to be selectivity aspects. They were based on the proportions of species fished of the community, the mean trophic level of the catch and number of trophic levels caught within the community by the gear. We used community-specific catch data and knowledge of the trophic structure of the community to determine them. We also derived selectivity metrics based on the individual species risk scores from the species PSA analyses. Many of the species identified in the community composition were not identified as being caught by the fishery so their PSA scores had not been calculated. For those species, we calculated risk scores in the same way as for the fishery-related species. We then used these scores to identify and rank functional groups with high risk species, based on the rationale that if they comprise of many high risk species they are at risk of disruption of function, leading to similar disruption of the community.

Similarly, we used the post capture-mortality scores from the species PSAs to derive a community level post-capture mortality score. For species not caught in the fishery post-capture mortality is not an issue, however, the usual pre-cautionary practice of scoring high in the absence of data was used.

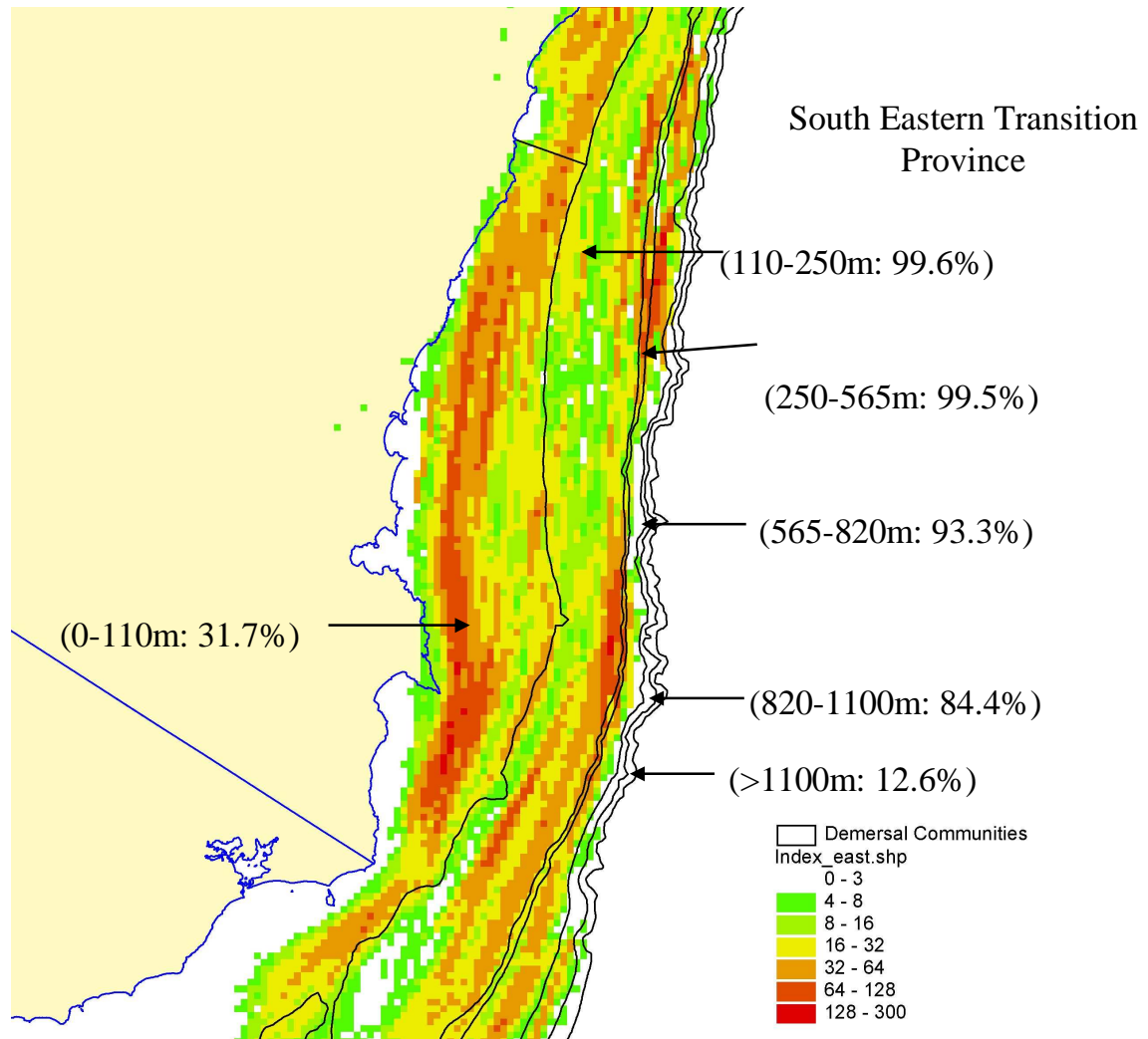


Fig 8. Map of the communities and effort intensities (number of shots in 2004) in the South Eastern Transition Province. Numbers in parentheses refer to the % overlap of the South East Trawl (SET) otter trawl sub-fishery and each demersal community. Note that the contours shown and effort do not map exactly due to low precision of matching co-ordinates.

#### Results for the South East Transition 110-250m community

As mentioned in previous sections, we used the assessment of the otter trawl subfishery of the SESSF as a case study. From the Level 1 community SICA analysis, the South Eastern Transition 110-250m community was identified as the most vulnerable unit of analysis for many of the fishing hazards. This community lies within a region of the fishery that has been well-studied over many years. Therefore, we have arguably the best data sets with which to trial the community level 2 approach. For as many attributes as possible we derived scores for this community. While this data set is good particularly for fish and some other higher vertebrates, the data for invertebrates are sparse, therefore, our analysis focused only on fish.

The quantitative metrics were calculated for all fish species in the community composition list (Table 2). Qualitative and taxonomic analyses are still in progress.

Table 2. Preliminary attributes of South East Transition 110-250m community.

	Aspect	Attribute	Value	Potential Risk Ranking
Productivity	Life-history	Mean growth	2.60	
		Mean length at maturity	38.10	
	Diversity/Species Composition	Species richness (S)	334	M
		Taxonomic distinctness $\Delta^+$	44.5	
	Trophic structure	Mean trophic level	3.19	
		Number of top predators	24	
		% of functional groups with total number of members per group > say 5 or 10	0.41	M
		Attack sensitivity	.025	L
		Error sensitivity	.01	L
		Key players: influence & fragmentation	Y	M
Number of high risk species which eat high risk prey		1	L	
Susceptibility	Trophic structure	% of functional groups fished (total all gear types)	1.00	H
		% of functional groups with high proportion of species fished i.e. >50% species	0.59	H
		% of mean functional group risk rating	0.53	H
	Fishery specific	% jurisdictional overlap of fishery with community	1.00	H
		% actual effort overlap of effort in fishery with community	0.99	H
		Mean trophic level of catch from sub fishery (Ho: lower trophic level, higher risk)	3.37	M
		% of functional groups fished by sub fishery/gear	0.7	H
		Number of trophic levels captured by gear	2.13	M
		% sub fishery catch of total catch overall all gear types	0.40	M
		% of fished species with high PCM from species PSA	1.00	H

### **2.4.2 and 2.4.3 Level 2 PSA (steps 2 and 3)**

#### *Summary of Species PSA results*

The results in the Tables below provide details of the PSA assessments for each species, separated by role in the fishery, and by taxa where appropriate. These assessments are limited to direct impacts from fishing, and the operational objective is to avoid over-exploitation due to fishing, either as over-fishing or becoming over-fished. The risk scores and categories (high, medium or low) reflect potential rather than actual risk using the Level 2 (PSA) method. For species assessed at Level 2, no account is taken of the level of catch, the size of the population, or the likely exploitation rate. To assess actual risk for any species requires a Level 3 assessment which does account for these factors. However, recent fishing effort distributions are considered when calculating the availability attribute for the Level 2 analysis, whereas the entire jurisdictional range of the fishery is considered at Level 1.

The PSA analyses do not fully take account of management actions already in place in the fishery that may mitigate for high risk species. Some management actions or strategies, however, can be accounted for in the analysis where they exist. These include spatial management that limits the range of the fishery (affecting availability), gear limits that affect the size of animals that are captured (selectivity), and handling practices that may affect the survival of species after capture (post capture mortality). Management strategies that are not reflected in the PSA scores include limits to fishing effort, use of catch limits (such as TACs), and some other controls such as seasonal closures.

It should be noted that the PSA method is likely to generate more false positives for high risk (species assessed to be high risk when they are actually low risk) than false negatives (species assessed to be low risk when they are actually high risk). This is due to the precautionary approach to uncertainty adopted in the PSA method, whereby attributes are set at high risk levels in the absence of information. It also arises from the nature of the PSA method assessing potential rather than actual risk, as discussed above. Thus some species will be assessed at high risk because they have low productivity and are exposed to the fishery, even though they are rarely if ever caught and are relatively abundant.

In the PSA Tables below, the “Comments” column is used to provide information on one or more of the following aspects of the analysis for each species: use of overrides to alter susceptibility scores (for example based on use of observer data, or taking account of specific management measures or mitigation); data or information sources or limitations; and information that supports the overall scores. The use of over-rides is explained more fully in Hobday et al (2007).

The PSA Tables also report on “missing information” (the number of attributes with missing data that therefore score at the highest risk level by default). There are seven attributes used to score productivity and four aspects (availability, encounterability, selectivity and post capture mortality) used to score susceptibility (though encounterability is the average of two attributes). An attribute or aspect is scored as missing if there are no data available to score it, and it has defaulted to high risk for this reason. For some species, attributes may be scored on information from related species or other supplementary information, and even though this information is indirect and less reliable than if species specific information was available, this is not scored as a missing attribute.

There are differences between analyses for TEP species and the other species components. In particular, target, by-product and by-catch species are included on the basis that they are known to be caught by the fishery (in some cases only very rarely). However TEP species are included in the analysis on the basis that they occur in the area of the fishery, whether or not there has ever been an interaction with the fishery recorded. For this reason there may be a higher proportion of false positives for high vulnerability for TEP species, unless there is a robust observer program that can verify that species do not interact with the gear.

Observer data and observer expert knowledge are important sources of information in the PSA analyses, particularly for the bycatch and TEP components. **There is no observer program currently in place for this fishery. {OR} The level of observer data for this fishery is regarded as [high, medium, low].** {Go on to briefly justify this on the basis of level of observer coverage, length of time in place, availability of data, adequacy of taxonomic resolution, etc – see details in Scoping section. This may need a group discussion first to be consistent across fisheries}.

A summary of the species considered at Level 2 is presented below, sorted by component, by taxa within components, and then by the overall risk score [high (>3.18), medium (2.64-3.18), low<2.64)].

This summary is generated from the PSA workbook and presented in the ERA results report as per proforma table below.

ERA species ID	Scientific name	Common name	average logbook catch (kg) 2001-04	Missing > 3 attributes (Y/N)	Number of missing productivity attributes (out of 7)	Number of missing susceptibility attributes (out of 5)	Productivity (additive) 1 - low , 3 - high	Susceptibility (mult) 1 - low , 3 - high	Overall risk 4.24 - high 1.41 - low ,	Override used?	PSA risk category	Comments
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*Summary of Habitat PSA results*

A summary of the habitats considered at Level 2 is presented below, and is sorted by the overall risk score (high, medium, low), by sub-biome, and by SGF score (Habitat type). These are sorted by role in fishery, taxa and 2D P& S category by high, medium and low.

Record #	ERA habitat #	Sub-biome	Feature	Habitat Name	SGF Score	n missing attributes	Productivity score (Average)	Susceptibility score (Multiplicative)	Overall risk value (P&Sm)	Overall risk score (2D multiplicative)	Risk ranking override	Rationale
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*Summary of Community PSA results*

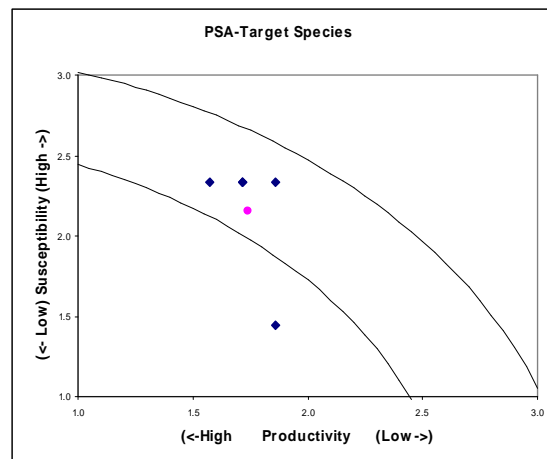
Similar summaries will be presented for the Level 2 community results. Communities not evaluated as methods not complete.

#### 2.4.4 PSA Plot for individual units of analysis (Step 4)

The average productivity and susceptibility scores for each unit of analysis (e.g. for each species) are then used to place the individual units of analysis on 2D plots (as below). The relative position of the units on the plot will determine relative risk at the unit level as per PSA plot below. The overall risk value for a unit is the Euclidean distance from the origin of the graph. Units that fall in the upper third of the PSA plots are deemed to be at high risk. Units with a PSA score in the middle are at medium risk, while units in the lower third are at low risk with regard to the productivity and susceptibility attributes. The divisions between these risk categories are based on dividing the area of the PSA plots into equal thirds. If all productivity and susceptibility scores (scale 1-3) are assumed to be equally likely, then  $1/3^{\text{rd}}$  of the Euclidean overall risk values will be greater than 3.18 (high risk),  $1/3^{\text{rd}}$  will be between 3.18 and 2.64 (medium risk), and  $1/3^{\text{rd}}$  will be lower than 2.64 (low risk).

Paste plots here, as in the example below, for the components that were examined at Level 2. These results are generated in the PSA workbook in the ranking worksheet.

##### PSA plot for target species



##### PSA plot for byproduct species

##### PSA plot for discards/bycatch species

##### PSA plot for TEP species

##### PSA plot for habitats

##### PSA plot for communities

The overall risk value for each unit is the Euclidean distance from the origin to the location of the species on the PSA plot. The units are then divided into three risk categories, high, medium and low, according to the risk values (**Figure 17**). The cut-offs for each category are thirds of the total distribution of all possible risk values (**Figure 17**).

**Figure 17.** Overall risk values in the PSA plot. Left panel. Colour map of the distribution of the euclidean overall risk values. Right panel. The PSA plot contoured to show the low risk (blue), medium risk (orange) and high risk (red) values.

The PSA output allows identification and prioritization (via ranking the overall risk scores) of the units (e.g. species, habitat types, communities) at greatest risk to fishing activities. This prioritization means units with the lowest inherent productivity or highest susceptibility, which can only sustain the lowest level of impact, can be examined in detail. The overall risk to an individual unit will depend on the level of impact as well its productivity and susceptibility.

#### **2.4.5 Uncertainty analysis ranking of overall risk (Step 5)**

The final PSA result for a species is obtained by ranking overall risk value resulting from scoring the productivity and susceptibility attributes. Uncertainty in the PSA results can arise when there is imprecise, incorrect or missing data, where an average for a higher taxonomic unit was used (e.g. average genera value for species units), or because an inappropriate attribute was included. The number of missing attributes, and hence conservative scores, is tallied for each unit of analysis. Units with missing scores will have a more conservative overall risk value than those species with fewer missing attributes, as the highest score for the attribute is used in the absence of data. Gathering the information to allow the attribute to be scored may reduce the overall risk value. Identification of high-risk units with missing attribute information should translate into prioritisation of additional research (an alternative strategy).

A second measure of uncertainty is due to the selection of the attributes. The influence of particular attributes on the final result for a unit of analysis (e.g. a habitat unit) can be quantified with an uncertainty analysis, using a Monte Carlo resampling technique. A set of productivity and susceptibility scores for each unit is calculated by removing one of the productivity or susceptibility attributes at a time, until all attribute combinations have been used. The variation (standard deviation) in the productivity and susceptibility scores is a measure of the uncertainty in the overall PSA score. If the uncertainty analysis shows that the unit would be treated differently with regard to risk, it should be the subject of more study.

The validity of the ranking can also be examined by comparing the results with those from other data sources or modelling approaches that have already been undertaken in specific fisheries. For example, the PSA results of the individual species (target, byproduct and bycatch and TEP) can be compared against catch rates for any species or against completed stock assessments. These comparisons will show whether the PSA ranking agrees with these other sources of information or more rigorous approaches.

The following analysis is based on statistical information generated in the PSA workbook under the following headings for both species and habitats:

- Availability of information
- Correlation between attributes
- Productivity and susceptibility risk values
- Overall risk values

Profroma text and tables as well as examples of results under each of the above headings are outlined below and form part of the ERA results report under this section.

**Availability of information**

The ability to score each species based on information on each attribute [varied/did not vary] between the attributes (as per summary below). With regard to the productivity attributes, [least known productivity attribute] was missing in [X]% of [units], and so the most conservative score was used, while information on [best known productivity attribute] could be found or calculated for [Y% of units]. The current method of scoring the susceptibility attributes provides a value for each attribute for each species – some of these are based on good information, whereas others are merely sensible default values.

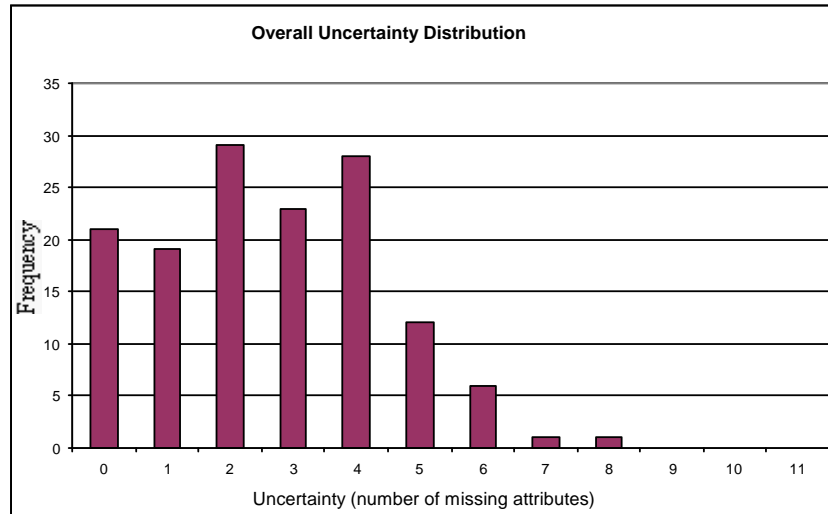
**Summary of the success of obtaining information on the set of productivity and susceptibility attributes for the species. Where information on an attribute was missing the highest score was used in the PSA.**

Results from PSA workbook ranking worksheet (species only).

Productivity Attributes	Average age at maturity	Average max age	Fecundity	Average max size	Average size at Maturity	Reproductive strategy	Trophic level (fishbase)
Total species scores for attribute							
n species scores with attribute unknown, (conservative score used)							
% unknown information							
Susceptibility Attributes	Availability	Encounter ability	Habitat	Selectivity	PCM		
		Bathymetry overlap					
Total species scores for attribute							
n species scores with attribute unknown, (conservative score used)							
% unknown information							

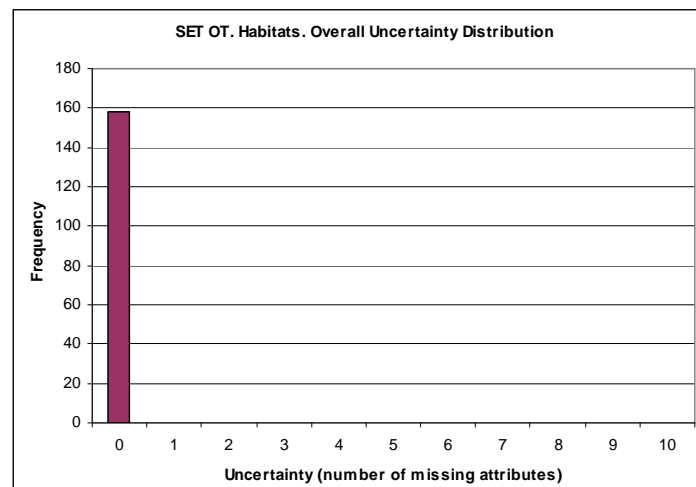
Each species considered in the analysis had information for an average of [A, (B%)] productivity attributes and [C (D%)] susceptibility attributes. This meant that, on average, conservative scores were used for less than [E%] of the attributes for a single species. [Units] had missing information for between [F and G] of the combined [H] productivity and susceptibility attributes.

Results Overall uncertainty distribution in PSA workbook ranking graphs worksheet  
 Paste Species uncertainty distribution histogram here (example below)



**Species: Overall uncertainty distribution - frequency of missing information for the combined productivity and susceptibility attributes**

Habitats: Eleven attributes were used in the habitat PSA. All attributes were scored according to Habitat attribute tables 9-27 (ERAEF Methodology). Only attributes that could be ranked were utilized and therefore there are no missing attributes. [example below]



**Habitats: Overall uncertainty distribution- frequency of missing information for the combined productivity and susceptibility attributes**

### Correlation between attributes

In situations where attributes are strongly correlated only one of them should be included in the final PSA (Stobutzki et al., 2001).

Species component: The attributes selected for productivity and susceptibility [were/were not] strongly correlated (as per correlation matrix below for Productivity and susceptibility). The strongest productivity attribute correlation was between [attribute J and attribute K], while the strongest susceptibility correlation was between [attribute L and attribute M]. This correlation analysis suggests that each attribute

[was/was not] “measuring” a different aspect of the [unit] characteristics and [all/not all] attributes were suitable for inclusion in the PSA.

**Correlation matrix for the species productivity attributes. The correlation (r) is based on the scores within each attribute pair. Results from PSA workbook ranking graphs worksheet.**

	Age at maturity	Max age	Fecundity	Max size	Min size at maturity	Reproductive strategy	Trophic level
Age at maturity	X						
Max age		X					
Fecundity			X				
Max size				X			
Min size at maturity					X		
Reproductive strategy						X	
Trophic level							X

**Correlation matrix for the four species susceptibility attributes. The correlation (r) is based on the scores within each attribute pair. Results from PSA workbook ranking graphs worksheet.**

	Availability	Encounterability	Selectivity	Post-capture mortality
Availability	X			
Encounterability		X		
Selectivity			X	
Post-capture mortality				X

Habitat Component: The attributes selected for productivity and susceptibility [were/not] strongly correlated (as per correlation matrix below for productivity and susceptibility). There was [X] correlation between the productivity attributes Regeneration of Fauna and Natural disturbance ( $r = [x]$ ). The susceptibility correlation could not be calculated between the Availability and any other aspect, because there was no variation in the Availability score. There [was/X] correlation between the attributes used to calculate Encounterability and Selectivity. All attributes were suitable for inclusion in the PSA.

**Correlation matrix for the habitat productivity attributes. The correlation (r) is based on the scores within each attribute pair. Results from PSA workbook ranking graphs worksheet.**

Productivity Correlation Matrix	Regeneration of fauna	Natural disturbance
Regeneration of fauna	X	
Natural disturbance	X	X

**Correlation matrix for the three habitat susceptibility attributes. The correlation (r) is based on the scores within each attribute pair. Results from PSA workbook ranking graphs worksheet.**

Susceptibility Correlation Matrix	Availability score	Encounterability score (average)	Selectivity score (average)
Availability score	X		
Encounterability score (average)	X	X	
Selectivity score (average)	X	X	X

Productivity and susceptibility risk values

### Productivity and susceptibility risk values for Species

The average productivity score for all [units] was [X ± Y] (mean ± SD of scores calculated using n-1 attributes) and the mean susceptibility score was [X ± Y] (as per summary of average productivity and susceptibility scores as below). Individual scores are shown in Section 2.4.2 and 2.4.3 Summary of PSA results. The [small/large] variation in the average of the boot-strapped values (using n-1 attributes), indicates the productivity and susceptibility scores [are/are not] robust to elimination of a single attribute. Information for a single attribute [does not/does] have a disproportionately large effect on the productivity and susceptibility scores. Information was missing for an average of [Z] attributes out of [Y] possible for each [unit].

### Productivity and susceptibility risk values for habitats

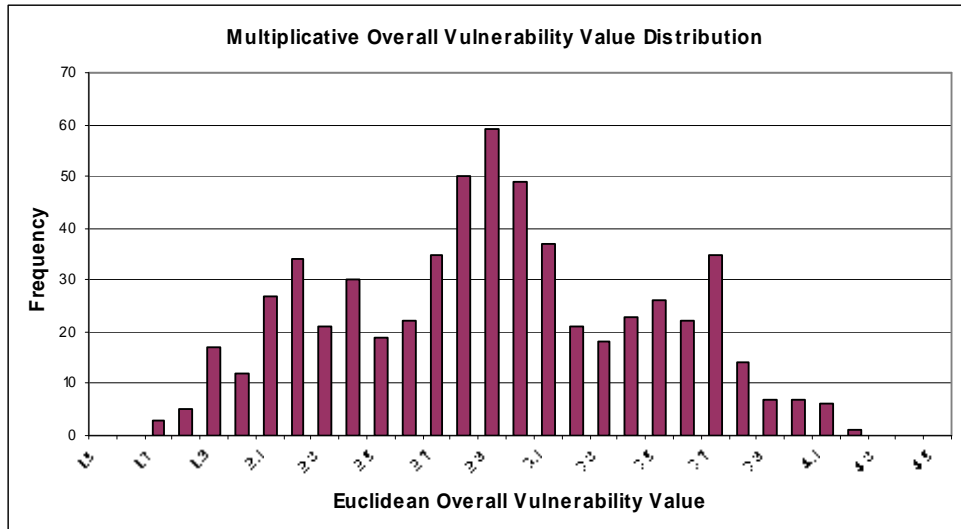
The average productivity score for all habitats was [X ± Y] (mean ± SD of scores calculated using n-1 attributes) and the mean susceptibility score was [X ± Y] (as per summary of average productivity and susceptibility scores as below). Individual scores are shown in Section 2.4.3 Summary of PSA results. The small/large variation in the average of the boot-strapped values (using n-1 attributes), indicates the productivity and susceptibility scores are robust to elimination of a single attribute. Information for a single attribute [does not/does] have a disproportionately large effect on the productivity and susceptibility scores.

## Overall Risk Values

### Overall Risk Values for Species

The overall risk values (euclidean distance on the PSA plot) could fall between 1 and 4.24 (scores of 1&1 and 3&3 for both productivity and susceptibility respectively). The mean observed overall risk score was [X], with a range of [Y – Z]. The actual values for each species are shown in Section 2.4.2 and 2.4.3 Summary of PSA results. A total of [A units, (B%)] were classed as high risk, [B (C%)] were in the moderate risk category, and [D (E%)] as low risk.

Results: Frequency distribution of the overall PSA risk values (Paste frequency distribution histogram from workbook ranking sheet here. Example below)



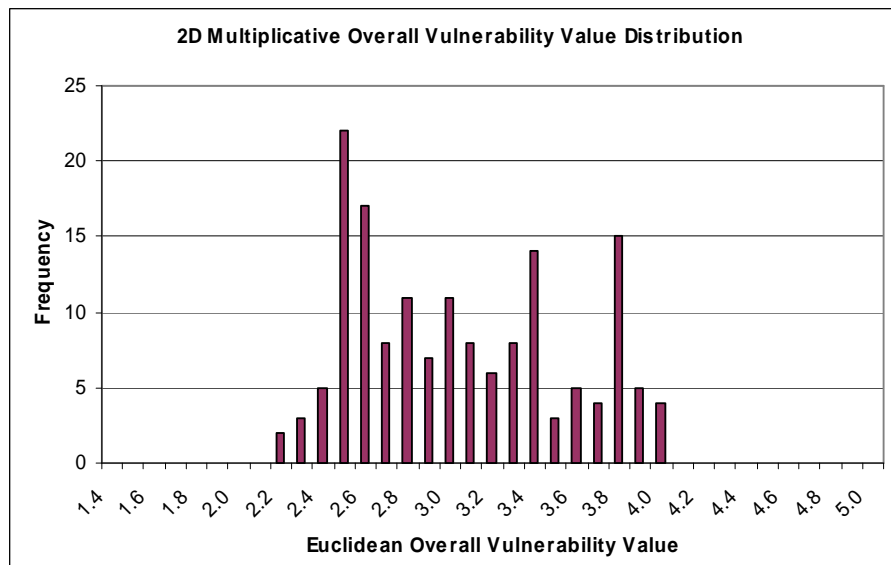
Frequency distribution of the overall risk values generated for the [X units] in the [fishery sub-fishery] PSA.

Overall Risk Values for Habitats

The overall risk values (euclidean distance on the PSA plot) could fall between 1 and 4.24 (scores of 1&1 and 3&3 for both productivity and susceptibility respectively).

The mean observed overall risk score was [X], with a range of [Y- Z].

The actual values for each habitat are shown in Section 2.4.3 Summary of PSA results. A total of [X] units, (%) were classed as high risk, [X] units, (%) were in the medium risk category, and [X] (%) as low risk.

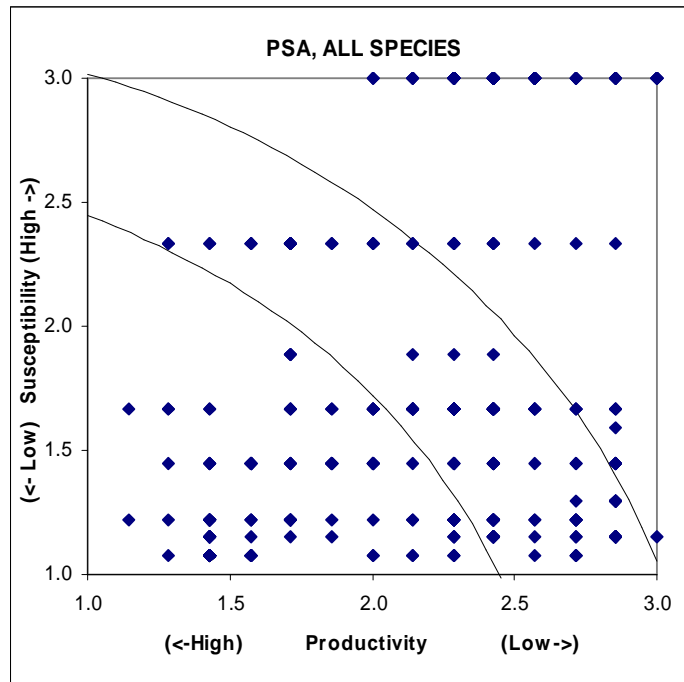


Frequency distribution of the overall risk values generated for the [X] habitat types in the [fishery sub-fishery] PSA.

The distribution of the overall risk values of all species is shown on the PSA plot below. The species are distributed in the [all/lower left/upper right] parts of the plot,

indicating that [both high and low risk units] are potentially impacted in the [fishery sub-fishery].

Results Plot for all species in the sub-fishery PSA risk values (Paste frequency distribution histogram from workbook ranking sheet here. Example below)



PSA plot for all [units] in the [fishery sub-fishery]. Species in the upper right of the plot are at highest risk.

The number of attributes with missing information is of particular interest, because the conservative scoring means these units may be scored at higher risk than if all the information was known. This relationship between the overall risk score and the number of missing attributes shows that an increase in the number of missing attributes (and hence conservative scores used) results in a skew to higher risk values. This suggests that as information becomes available on those attributes, the risk values may decline for some units.

All attributes are treated equally in the PSA, however, information on some attributes may be of low quality. [discuss these attributes, discuss any problems with assembling the data]

#### **2.4.6 Evaluation of the PSA results (Step 6)**

The following analysis is based on statistical information generated in the PSA workbook under the following headings for both species and habitats:

- Statistics
- Discussion

Proforma text and tables as well as examples of results under each of the above headings are outlined below and form part of the ERA results report under this section.

### Species Components: an example

**\*Evaluation example below: update as appropriate. The form is less well prescribed, and so a template for this section is not possible\***

The PSA analysis of the South East Trawl fishery was presented to a SETMAC meeting on 22 November 2005. The PSA methodology has since been reviewed and revised. The following results reflect the revised methodology (as at 19<sup>th</sup> October 2006).

#### Species Component:

The PSA analysis of the South East Trawl fishery was presented to a SETMAC meeting in Melbourne on 22 November 2005. Following discussion at that meeting, some changes were made to the analysis. The changes for individual species are described in detail in Document L2.1. The PSA methodology has since been reviewed and revised. The following results reflect the revised methodology (as at 30 April 2006), as well as the changes for individual species.

#### Overall

A total of 600 species were considered. For most species there was little missing data. The average number of missing attributes was 0.84 out of a possible 12. Of the 600 species assessed at Level 2, expert over rides were used on 166 species. Of the 159 species assessed to be at high risk, 4 had more than 3 missing attributes.

Summary of average productivity, susceptibility and overall risk scores.

Component	Measure	
All species	Number of species	600
	Average of productivity total (range 1-3)	1.94
	Average of susceptibility total (range 1-3)	1.99
	Average of overall risk value (range 1.41-4.24)	2.84
	Average number of missing attributes	0.84
Target species	Number of species	28
	Average of productivity total	1.74
	Average of susceptibility total	2.55
	Average of overall risk value	3.10
	Average number of missing attributes	0.07
Byproduct species	Number of species	95
	Average of productivity total	1.81
	Average of susceptibility total	2.27
	Average of overall risk value	2.95
	Average number of missing attributes	0.47
Discard species	Number of species	276
	Average of productivity total	1.83
	Average of susceptibility total	2.22
	Average of overall risk value	2.91
	Average number of missing attributes	0.97
TEP species	Number of species	201
	Average of productivity total	2.19
	Average of susceptibility total	1.44
	Average of overall risk value	2.66

Component	Measure
	Average number of missing attributes
	0.92

PSA (productivity and susceptibility) risk categories for each species component.

Risk Category	High	Medium	Low	Total
Target species	15	11	2	28
Byproduct species	39	28	28	95
Discard species	99	79	98	276
TEP species	6	121	74	201
Total	159	239	202	600

PSA (productivity and susceptibility) risk categories for each taxon.

Risk Category	High	Medium	Low	Total
Chondrichthyan	58	27	3	88
Invertebrate	0	2	23	25
Marine bird	4	57	18	79
Marine mammal	1	47	1	49
Marine reptile	0	6	1	7
Teleost	96	100	156	352
Total	159	239	202	600

#### Target species

15 target species/stocks are classified as high risk, 11 as medium risk, and 2 as low risk. There was very little missing data.

The following species are classified as high risk: school shark, saw shark, gummy shark (Bass Strait and South Australian stocks), ling, orange roughy (eastern, southern, western and Cascade stocks), blue eye trevalla, blue grenadier, gemfish (east and west), jackass morwong, and mirror dory.

These species are classified as medium risk: elephantfish, redfish, flathead, John dory, blue warehou (east and west), spotted warehou, silver trevally, inshore and offshore ocean perch.

These species are classified as low risk: school whiting and royal red prawn.

These results are generally consistent with more detailed assessments of the target species, with the exceptions of blue warehou and silver trevally which are currently classified as overfished (Caton and McLoughlin 2004). Silver trevally has a medium risk score in this analysis because its productivity is high (therefore scores low) due to its low age and size at maturity, and its susceptibility is medium because a high proportion of its core range within the fishery does not overlap with fishing effort. Much of the silver trevally catch is taken in State waters. Blue warehou has a medium rather than a high risk score because its productivity is high (therefore scores low) due to its relatively short lifespan, and low age and size at maturity. Several species have a

high risk score because a high proportion of their core range is covered by this fishery, leading to a high susceptibility score.

#### Byproduct species

Of the 95 byproduct species, 39 are classified as high risk, 28 as medium risk and 28 as low risk. There was very little missing data.

16 of the high risk species are chondrichthyans, which are classified as high risk due to their low productivity and high susceptibility. Seven of these are likely to be found only in southern Australia; eight are widely distributed, but are temperate species, so could form local stocks in southern Australia; one is a tropical species, so is unlikely to form a local stock in the area of this fishery.

Seven of the high risk chondrichthyans are found over the inner shelf (0-110m), ten over the outer shelf (110-250m), nine over the upper slope (250-565m), four over the mid-upper slope (565-820m), three over the mid-slope (820-1100m), and two over the lower slope (1100-3000m). Most of the species occur over more than one of these bathymetric zones (which explains why the numbers in the previous sentence don't add to the total number of high risk chondrichthyans).

The other 23 high risk species are teleosts that have a high proportion of their core range covered by this fishery, and therefore have scored as highly susceptible. Two of these are likely to be found only in southern Australia; 20 are more widely distributed, but are temperate species, so could form local stocks in southern Australia; one is a tropical species, so is unlikely to form a local stock in the area of this fishery.

Nine of the high risk teleosts are found over the inner shelf (0-110m), 12 over the outer shelf (110-250m), 17 over the upper slope (250-565m), 11 over the mid-upper slope (565-820m), seven over the mid-slope (820-1100m), and none over the lower slope (1100-3000m).

#### Discard species

Of the 276 discard species, 99 are classified as high risk, 79 as medium risk and 98 as low risk. Of all the species components, discards had the highest proportion of missing attributes, with an average of almost one attribute missing.

More than a third of the high risk bycatch species are chondrichthyans with low productivity and high susceptibility. Of the 38 high risk chondrichthyans, 14 of these are likely to be found only in southern Australia; 21 are more widely distributed, but are temperate species, so could form local stocks in southern Australia; three are tropical species, so are unlikely to form a local stock in the area of this fishery.

16 of the high risk chondrichthyans are found over the inner shelf (0-110m), 20 over the outer shelf (110-250m), 18 over the upper slope (250-565m), 16 over the mid-upper slope (565-820m), 13 over the mid-slope (820-1100m), and one over the lower slope (1100-3000m).

The rest of the high risk discard species are teleosts, and almost all of these score high risk because of high susceptibility. These species all have a high proportion of their

range covered by this fishery, live in habitats where they are likely to be encountered by the gear, and are the right size to be selected by the gear.

Of the 61 high risk teleosts, four of these are likely to be found only in southern Australia; 21 are more widely distributed, but are temperate species, so could form local stocks in southern Australia; seven are tropical species, so are unlikely to form a local stock in the area of this fishery. Six species have missing productivity information, and for four species the distributional information needs checking. 15 species (mostly whiptails) are benthopelagic species that will only be at risk in this fishery if the net is flown off the bottom.

16 of the high risk teleosts are found over the inner shelf (0-110m), 19 over the outer shelf (110-250m), 35 over the upper slope (250-565m), 27 over the mid-upper slope (565-820m), 14 over the mid-slope (820-1100m), and four over the lower slope (1100-3000m).

#### TEP species

Of the 201 TEP species, 6 were classified as high risk, 121 as medium risk and 74 as low risk. Risks for TEP species were lowered considerably by use of observer information, provided in the ISMP report and at an ERAEF workshop held at Queenscliff in August 2005.

All seabirds were assigned a low selectivity, as observer data show that although many birds are observed, only a small percentage of these come into contact with the gear, and of these very few die. Of the 79 marine birds in the analysis, 57 were classified as medium risk and 18 as low risk. Four (Tahiti petrel, long-tailed jaeger, Pacific albatross, and Chatham albatross) were classified as high risk, but this was due to lack of information. These species are similar to others in the analysis: it is highly likely that missing information can be found which would eliminate them from the high risk category.

Of the 49 marine mammals, one was classified as high risk, 47 as medium risk, and one as low risk. The Australian fur seal is at high risk due to its low productivity and high susceptibility. Observer reports show that seals are frequently encountered in the fishery, and do come into contact with the gear. Overall it appears that the total Australian fur seal population has increased in recent years (Stewardson and Knuckey 2005).

Dolphins were assigned a low encounterability, as observers report that although dolphins are seen occasionally bow riding, they do not interact with the gear. Whales were also assigned a low encounterability, as they are not reported as seen by observers. Risk scores were reduced for the larger whale species, due to their being assigned a low selectivity because of their large size.

The three TEP shark species were classified as medium risk as observers report very few interactions as most of these species are inshore. Those that are caught are generally released alive.

For the seven species of marine reptiles, six were classified as medium risk, and one as low risk. Sea snakes were medium risk due to lack of data. Turtles were assigned a low encounterability as observers reported that they are not seen in this fishery – their risk category was medium.

Of the 61 syngnathids, one was classified as high risk, eight were classified as medium risk due to a high overlap with the fishery, and the rest were low risk as they had little or no overlap with the area of the fishery. The spiny pipehorse was classified as high risk. This species is restricted to south-eastern Australia, and has been seen entangled in fishing gear by observers (40 observations in 2004).

### Habitat Component:

The PSA analysis of the habitats of the South East Trawl fishery was presented to a SETMAC meeting on 22 November 2005. The PSA methodology has since been reviewed and revised. The following results reflect the revised methodology (as at 26 April 2006).

### Overall

A total of 158 habitat types were considered. Twenty one attributes were scored for all habitats. About a third of the total species fell into each risk category. Risk Ranking categories have been adjusted following the PSA based on stakeholder feedback and expert opinion. The resulting 2D PSA risk rankings (H, M or L) including overrides are considered in the following discussion. Overrides are made according to the rationales discussed in the evaluation and are included in the table above which lists all habitats assessed in the PSA. Overrides are a category adjustment only, the Productivity and Susceptibility scores could not be adjusted further to automatically override overall risk values.

Summary of average productivity, susceptibility and overall risk scores.

Component	Measure	
All habitats	Number of habitats	158
	Average of productivity total	2.13
	Average of susceptibility total	2.08
	Average of overall risk value (2D)	3.01
	Average number of missing attributes	0

PSA (productivity and susceptibility) risk categories for the habitat component.

Risk Category	High	Moderate	Low	Total
Total Habitats	46	58	54	158

PSA (productivity and susceptibility) risk categories for sub-biome (depth zone) fished (before override adjustment).

2D Risk Score	Coastal Margin	Inner-shelf	Outer-shelf	Upper-slope	Mid-slope	Total habitats
High	0	0	19	15	25	59
Medium	0	5	4	25	11	45
Low	0	23	31	0	0	54
Total	Not in fishery	28	54	40	36	158

PSA (productivity and susceptibility) risk categories for sub-biome fished after Risk Ranking adjustment (stakeholder/expert override).

2D Risk Score	Coastal Margin	Inner-shelf	Outer-shelf	Upper-slope	Mid-slope	Total habitats
High	0	0	18	12	16	46

Medium	0	5	5	28	20	58
Low	0	23	31	0	0	54
Total	Not in fishery	28	54	40	36	158

No inner shelf habitats are classified as high risk, 5 as medium risk, and 23 as low risk. Eighteen outer shelf habitats produce high risk scores, 5 medium and 31 are at low risk. Of the upper slope 12 are classified as high risk, 28 at medium and no upper slope habitats appear at low risk. Habitats at mid-slope depths are either at high risk (16) or at medium risk (20), none are considered low risk.

## Discussion

The broad operating depth range of the sub-fishery, together with the detailed data available to define habitats, results in many different habitat types (158) being identified and assessed. This has the effect of including large numbers of habitat types in each risk category. However, these detailed habitat types can be readily aggregated into a smaller number of general categories for interpretation. This is because many types are similar, differing in only one respect of substratum or geomorphology or dominant fauna, and therefore attracting similar PSA scores and the same risk rankings. For example, one general type will group together the habitats of a depth zone characterized by similar substratum and geomorphology but different large fauna (sponges, crinoids, octocorals or mixed communities).

The distribution of risk values for SET otter trawl is approximately equal: 54 (34%) low, 58 (37%) medium and 46 (29%) high. High risk habitat types were identified on the mid-slope, upper slope and outer shelf types but not on the inner shelf. Medium risk habitats were from these depth zones but also included five types on the inner shelf.

Factors contributing to the high risk ranking of 46 habitats included the relatively high overall level of disturbance of bottom trawling and the large number of continental slope habitats fished – where there is very high overlap of fishing effort on the entire upper slope, and extensive use of the mid-slope where productivity is lowest. There is potentially high removability of epifauna that are large, erect or delicate, particularly where habitats have low ruggedness (low angle and high accessibility) and low resistance (e.g. sediments). In overview,

- 16 high risk mid-slope habitats included several categories of hard bottom which are low-relief, mostly sub-cropping, friable sedimentary rocks or mud stones (present as slabs, boulders or cobbles), and what are probably sediment veneers over hard bottom, with large, erect or delicate epifauna consisting of octocorals, crinoids, small sponges and sedentary animals. Outcropping rocky habitat with low encounterability eliminated many complex and diverse types from the high risk category. Several types of soft bottom habitats are characterized by large, erect or delicate epifauna. Habitats of seamount and canyon features are included in this depth zone.
- 15 high risk habitats on the upper slope also included several low-relief hard bottom habitats, but featured epifauna dominated by large sponges not seen on the mid-slope. Several types of soft bottom habitats are characterized by large, erect or delicate epifauna. The most important of these soft seabed types is

based on bryozoan communities, which are restricted to a narrow zone on the extreme outer shelf and upper reaches of the upper slope. Habitats of canyon features are included in this depth zone.

- 12 high risk outer shelf habitats are mostly soft sediment seabed types, with some rock bottom which is mostly low-relief, sub-cropping sedimentary rocks or cobble. Epifauna is characteristically dominated by large sponges, with sedentary and mixed epifauna dominant in some types. The important bryozoan based epifauna occurs on the extreme outer shelf.

Factors contributing to the medium risk ranking of 58 habitats, as for high risk types, included the relatively high overall level of disturbance of bottom trawling and the large number of continental slope habitats fished – where there is very high overlap of fishing effort on the entire upper slope, and extensive use of the mid-slope where productivity is lowest. High outcrop habitats appear in this category because despite low encounterability by bottom trawling, there is uncertainty about the degree of ruggedness that prevents trawl access using new technology. In overview,

- 18 mid-slope medium risk habitats are mostly soft bottom types characterized by bioturbators (and include no visible fauna). Habitats include several categories of hard bottom which are mostly low-relief, sub-cropping, friable sedimentary rocks (present as slabs or cobbles), and what are probably sediment veneers over hard bottom, with epifauna consisting of small encrusting animals. Categories with no fauna are driven by the low productivity of the mid-slope, and in the case of soft bottom types can probably be eliminated at Level 3. However, in some cases such as seamounts, the fauna of hard bottom habitat types appears to have been removed by trawling. High relief, hard rock is included as medium risk despite it having a low encounterability score. This is a rare feature of the mid-slope, probably only present at seamounts, canyons or large debris flows at the bases of large canyons.
- 28 upper slope medium risk habitats are an equal mix of soft and hard bottom types. Soft types are characterized by small sponges, encrustors and bioturbators, while several types of rock bottom which are mostly low-relief, sub-cropping, friable sedimentary rocks (present as slabs or cobbles), and what are probably sediment veneers over hard bottom, have epifauna consisting of small sponges and encrustors.
- 5 outer shelf medium risk habitat types include outcropping and subcropping rock bottom present as sedimentary rocks or cobble with epifauna dominated by large and small sponges and crinoids.
- 5 inner shelf medium risk habitat types are soft sediment types characterized by large sponges and mixed epifaunal communities.

Fifty four habitat types, all on the continental shelf, score at low risk. This result is driven in large part by its relatively high productivity (compared to the slope) based on a faster regeneration time of fauna, and adaptation of fauna to a greater degree of natural disturbance. There are several other key factors for the inner shelf including a large overall area (151,000 sq km or 60% of the SET between 25 and 1,500 m depth), low overlap by trawl effort (11%), large areas of relatively invulnerable habitat (dynamic, naturally disturbed sediment plains with little emergent fauna), and a

relatively high proportion of unencounterable rocky reef existing as hard, high relief outcrop (areas unquantified but known to be very large, especially in the western half and NE of the fishery). In overview,

- 31 outer shelf low risk habitat types are predominantly soft sediment types with small sponges, encrusting, burrowing or no fauna. A small number (4) of hard bottom types have small sponges, encrusting or no fauna
- 23 inner shelf low risk habitat types are predominantly soft sediment types with a variety of fauna from large sponges to bioturbators. A small number (4) of hard bottom types have large sponges or mixed epifauna.

#### **2.4.7 Decision rules to move from Level 2 to Level 3 (Step 7)**

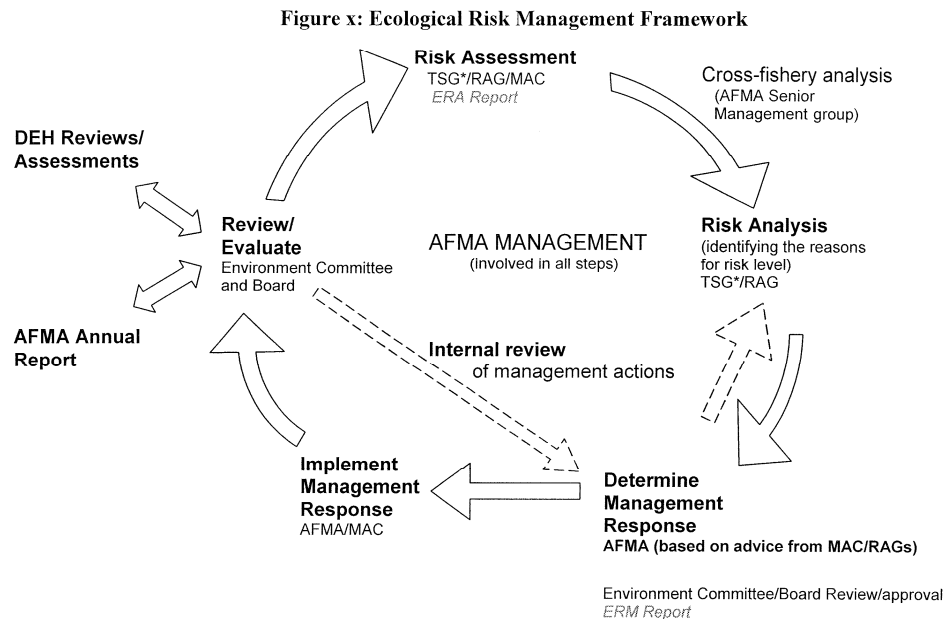
For the PSA overall risk values, units that fall in the upper third (risk value  $> 3.18$ ) and middle third ( $2.64 < \text{risk value} < 3.18$ ) of the PSA plots are deemed to be at high and medium risk respectively. These need to be the focus of further work, either through implementing a management response to address the risk to the vulnerable species or by further examination for risk within the particular ecological component at Level 3. Units at low risk, in the lower third (risk value  $< 2.64$ ), will be deemed not at risk from the sub-fishery and the assessment is concluded for these units.

For example, if in a Level 2 analysis of habitat types, two of seven habitat types were determined to have risk from the sub-fishery, only those two habitat types would be considered at Level 3.

The output from the Level 2 analysis will result in four options:

- The risk of fishing on a unit of analysis within a component (e.g. single species or habitat type) is not high, the rationale is documented, and the impact of the fishing activity on this unit need not be assessed at a higher level unless management or the fishery changes.
- The risk of fishing on a unit is high but management strategies are introduced rapidly that will reduce this risk, this unit need not be assessed further unless the management or the fishery changes.
- The risk of fishing on a unit is high but there is additional information that can be used to determine if Level 3, or even a new management action is required. This information should be sought before action is taken
- The risk of fishing on a unit is high and there are no planned management interventions that would remove this risk, therefore the reasons are documented and the assessment moves to Level 3.

At Level 2 analysis, a fishery can decide to further investigate the risk of fishing to the species via a Level 3 assessment or implement a management response to mitigate the risk. To ensure all fisheries follow a consistent process in responding to the results of the risk assessment, AFMA has developed an ecological risk management framework. The framework (see Figure below) makes use of the existing AFMA management structures to enable the ERAs to become a part of normal fisheries management, including the involvement of fisheries consultative committees. A separate document, the ERM report, will be developed that outlines the reasons why species are at high risk and what actions the fishery will implement to respond to the risks.



\*TSG – Technical Support Group - currently provided by CSIRO.

#### 2.4.8 High/Medium risk categorisation (Step 8)

Following the Level 2 PSA scoring of target, bycatch and byproduct, and TEP species, the high and medium risk species have been divided into five categories that highlight potential reasons for the higher risk scores. These categories should also help identify areas of uncertainty and assist decisions regarding possible management responses for these species. The categories are independent and species are allocated to each category in the order the categories are presented below. Thus, while in principle a species could qualify for both Category 1 and 2, it will only appear in Category 1 because that was scored first. The five categories are programmed into the PSA excel spreadsheets for each fishery according to the following algorithms:

- **Category 1: Missing data** (>3 missing attributes in either *Productivity or Susceptibility estimation*). Rationale: A total of more than 3 missing attributes (out of 12 possible) could lead to a change in risk score if the information became known. This is because where information is missing for an attribute, that attribute is automatically scored as high risk. The choice of 3 attributes was identified using sensitivity analysis.
- **Category 2: Spatial overlap**
  - **2A. Widely distributed** (*More than 80% of the full range of a species is outside the jurisdictional boundary of the fishery*). Rationale: These species may have refuge outside the fishery.
  - **2B. Low overlap** (<20% overlap between effort and the species distribution inside the fishery). Refers to the preferred Availability attribute used to calculate Susceptibility. Rationale: This cutoff (20%) has no strong rationale, other than being a low percentage overlap. Additional

work to determine what threshold might be applicable is required. However, the categories are to be used as a guide for management, and additional effort to decide on cutoffs may be misplaced if the categories are just used as a guide. A similar analysis could be undertaken for the encounterability and selectivity attributes, but there is more information available for availability (overlap) for most species and overlap may be more informative about risk. A subtle change in fishing practice could modify encounterability or selectivity, while to change availability requires a major change in fleet location, which will be easier to detect.

- **Category 3: Low (susceptibility) attribute score** (*One of the susceptibility attribute scores = 1*). Rationale: These species may be scored high risk based on productivity risk alone, even if their susceptibility is very low.
- **Category 4: Spatial uncertainty** (*No detailed distributional data available*) Availability was calculated using less reliable mapping data or distributional categories: Global/Southern Hemisphere/Australia, with stock likelihood overrides where necessary. Rationale: the absence of fine scale catch and species distribution data (e.g. TEP species) means that the substitute attribute (precautionary) was used. Spatial data should be sought.
- **Category 5 Other:** *risk score not affected by 1-4 considered above*

### Categorisation results - High risk species – an example

Of the 58 species classified as high risk in the GABT fishery, 3 had missing data (Category 1), 32 are widely distributed outside the fishery (Category 2A), and 2 had low overlap inside the fishery (Category 2B). There were 21 other high risk species.

High risk Category	Description	Total
Category 1	High risk - Missing data for more than 3 attributes	3
Category 2A	High risk - Widely distributed outside fishery	32
Category 2B	High risk - Low overlap inside fishery	2
Category 3	High risk - One susceptibility attribute scored low	0
Category 4	High risk - Spatial uncertainty	0
Category 5	High risk - other	21
	Total High	58

It is important to stress that this categorization does not imply a down-grading of risk. It is intended as a tool to focus subsequent discussions on risk treatment and identify needs for further data. Sensitivity analysis to the particular cutoffs has not been undertaken in a formal sense, and may not be required, as these categories are intended as guides to focus further consideration of the high risk species. These categories may also indicate the presence of false positives in the high risk species category, but only further analysis or data can determine this.

### 2.5 Level 3

- Review work already done at Level 3 (stock assessment, ecological modelling ect)
- Link back to Level 2 results

At the conclusion of Level 2, a number of units may have been identified as being at high risk because of the activities of the fishery. The options are (i) a management response to reduce the risk, (ii) provision of additional information to justify that the high risk is managed, or (iii) investigation of the high risk unit with a Level 3 approach. Before proceeding to a new Level 3 investigation, suitable existing information to further understand the risks should be identified. The stakeholders for a fishery can assist the Level 3 development by identifying such information; the known information is reported in Table 28 below.

**Table 28. Identification of information regarding high risk units of analysis in sub-fishery name. Example words are added to assist the completion of this table.**

Component and issue	Assessment exists	Action plan exists	Current research underway	Previous research should provide information on this issue
<b>Target Species Component</b>				
Fish Species X	Stock assessment for eastern stocks completed in 2006. status classified as overfished			
Fish Species Y	No	No	No	None known
<b>Byproduct/Bycatch Component</b>				
Shark species Z	No	No	No	This species was investigated in northern Australia, and found to be very rare in deep water, breeding females all come into estuaries, and hence the overlap with the fishery is probably overestimated.
<b>TEP component</b>				
Bird species Z		Bycatch action plan for fishery (2004) describes the measures taken to reduce encounters with this species	Research project FRDC 2003/555 is underway. Goal is to develop a bait that sinks quickly	
<b>Habitat Component</b>				
No high risk unit			Although no high risk units were identified, there is ongoing work to describe the habitat types on the grounds where th	

### 3. General discussion and research implications

The format of content here is less well prescribed, and so a template for this section is not possible

An example is provided for an assessed fishery:

Fishery: Southern and Eastern Scalefish and Shark Fishery (SESSF)  
 Sub-Fishery: otter trawl component of Commonwealth Trawl Sector

The SESSF otter trawl fishery is multi-species fishery that catches over 80 species of commercial value. It operates southward from Barrenjoey Point in NSW, around Victoria and Tasmania and west to Cape Jervis in South Australia, over depths from the inner shelf to the lower slope. The fishing method used is demersal otter trawling.

Twenty species (or species groups) are managed using TACs. The quota species are extremely diverse, ranging from mid-water predators to inshore, mid-shelf and upper slope demersal species. The SESSF trawl fishery is an important component of the Australian fishing industry, taking the largest tonnage and supplying most of the fresh fish for Sydney and Melbourne.

#### 3.1 Level 1

No ecological components were eliminated at Level 1.

A number of hazards (fishing activities) were eliminated at Level 1. Those remaining included:

- Fishing (direct and indirect impacts on all 5 ecological components)
- Gear loss (impact on TEP species)
- Translocation of species (impact on habitats)
- Discarding catch (impact on TEP species)
- Navigation/steaming (impact on target species)
- Activity/presence on water (impact on target species and communities)
- Fishing through physical disturbance (impact on habitats and communities)

Significant external hazards included other fisheries in the region, coastal development, and other extractive activities.

Risks rated as major or above (risk scores 4 or 5) were all related to direct or indirect impacts from primary fishing operations. Severe impacts (risk score 5) were confined to habitats and byproduct/bycatch species.

#### 3.2 Level 2

The two components that Level 1 analyses suggested were at severe risk from fishing were byproduct/bycatch species and habitats. This assessment was confirmed by the Level 2 analyses. Of the 600 species assessed, 159 were found to be at high risk, with 138 of these in the by-product and by-catch categories. 48 of the 158 habitats assessed were also found to be at high risk from trawling.

### **3.2.1 Species at risk**

Of the six TEP species found to be at high risk, four of these (all bird species) had a significant number of missing attributes. A research priority is to undertake a more thorough literature search to reduce this uncertainty, and in all probability eliminate any bird species from the high risk category. Of the remaining two TEP species, seals are known to be caught in significant numbers by trawling, and trials have been conducted to develop seal exclusion devices for use in some parts of the fleet (e.g. blue grenadier factory trawlers). A code of conduct to reduce seal catches has been implemented by SETFIA. Growing seal populations are likely to represent an ongoing challenge to trawl fishermen in avoiding capture of this protected species. Although explicit population models of seals have not been developed, it is very unlikely that current catch levels represent a threat to ecological sustainability of this species. A large number of syngnathid species was assessed at Level 2, but only one species, spiny pipefish, was found to be at potentially high risk. Further analysis of ISMP data should be undertaken to assess the spatial and seasonal characteristics of catches of this species, which may help to suggest possible mitigation measures.

About half the target species were assessed to be at potentially high risk. All these species are currently managed under the quota management system, and quantitative stock assessments (equivalent to Level 3 analyses) are available for a number of these species. Several species are indeed overfished (several orange roughy stocks, eastern gemfish, school shark). Formal harvest strategies for all quota species were implemented in 2005, and application of these strategies should ensure that overfished species recover and that other quota species are not subject to overfishing into the future.

The majority of species judged to be at high risk were either by-product species (39) or discard species (99). A significant number of these within both categories are chondrichthyan (shark and ray) species which generally have low productivity. Some within this group are likely to be false positives, especially those with wide distributions or that are mainly tropical. However there still remain a considerable number of chondrichthyan species that are endemic to southern Australia and that are highly susceptible to capture by trawling. Of the 54 high risk chondrichthyans, 21 are found only in southern Australia, and these should be the focus of further analysis and/or specific management action (see table below). A more detailed risk analysis of chondrichthyan species in southern Australia is being undertaken currently within an FRDC project (FRDC 202/033), and results from this study should be available shortly.

Of the considerable number of teleost species judged to be at high risk, many may be false positives. Almost a half of these are widely distributed and would only be at risk from the otter trawl fishery if they constituted local stocks within the range of the fishery. Further information on stock structure for this group would be valuable in assessing risk. About 15 high risk species are classified as benthopelagic, most of these being whiptails. These could be at risk from mid-water trawling, or where nets are sometimes flown off the bottom as in some orange roughy fishing. A more detailed analysis of which of these species might be vulnerable to this form of fishing would be

valuable. For only six of the 84 high risk teleost species is there a reasonable level of confidence that they could genuinely be at high risk, mainly due to restricted southern distribution and high susceptibility to the gear (see table below). More detailed analysis of logbook and observer data for these species is warranted, as well as a search for any information on relative or absolute abundance from surveys or from catch records from other fisheries in the area.

The high risk chondrichthyan species are found at all depth ranges in the fishery. Allowing that many species are found across several depth categories, the following number of high risk species is found by depth:

Inner shelf (0-110m)	23
Outer shelf (110-250m)	30
Upper slope (250-565m)	27
Mid-upper slope (565-820m)	20
Mid-slope (820-1100m)	16
Lower slope (1100-3000m)	3

As with the chondrichthyans, the high risk teleosts are distributed across all depths fished, with number of species at each depth listed below (the same species can occur at multiple depths):

Inner shelf (0-110m)	25
Outer shelf (110-250m)	31
Upper slope (250-565m)	52
Mid-upper slope (565-820m)	38
Mid-slope (820-1100m)	21
Lower slope (1100-3000m)	4

Closer evaluation of the distribution of high risk by-product and by-catch species has reduced the core set to 21 chondrichthyans and six teleosts, which all have a large overlap in range and depth distribution with the fishery, and are restricted in distribution to southern Australia. This core set is listed in the table below. These species are found at a wide range of depths covering all depths that are fished. Since spatial management (use of seasonal and permanent spatial closures) may be the best way to mitigate risks for many of these species, a more detailed analysis of the spatial and seasonal distribution of catches (based on logbook, ISMP, and survey data) would be very worthwhile. Study of habitat associations of high risk species may also be informative for selection of mitigation measures, and may indicate natural spatial refuges from trawling (and hence lower levels of risk). However consideration needs to be given to risk from other fishing methods in such analyses. Proposed MPAs in south eastern Australia will also provide refuges for at least some species, though the coverage at some depth ranges of these MPAs may be inadequate for a range of high risk species.

In considering spatial management for protection of high risk species, a key concern is the mobility of species and their movement into and out of protected areas (be they natural refuges or areas closed to fishing by MPAs or fishery closures). A current FRDC proposal aims to examine this important issue.

Finally, much of the uncertainty in translating species identified by Level 2 analyses as potentially high risk into actual risk categories stems from the lack of data on abundance of these species (against which to judge the sustainability of catches). The current proposal to develop a system of fishery independent surveys for the SESSF should take into account the needs for such data for by-product and discard species currently assessed as potentially high risk.

### Priority high risk byproduct and bycatch species

Distribution and depth information for chondrichthyans is from Last and Stevens (1994), unless otherwise noted; and for teleosts it is from Daley et al. al. (1997) and FishBase

Taxa	Scientific name	Common name	role	average logbook catch (kg) 2001-04	Distribution	Core depth range
Chondrichthyan	<i>Centrophorus harrissoni</i>	Harrison's dogfish	BP	0	Probably endemic to eastern Australia – from northern NSW to eastern Tasmania; caught in SE trawl from 1992-1998, now very few left in areas where previously targeted (Daley et. al 1998)	400-800m
Chondrichthyan	<i>Cephaloscyllium laticeps</i>	Draughtboard Shark	BP	808	Inshore on the continental shelf of southern Australia from Jervis Bay (NSW) to Recherche Archipelago (WA)	to 60m
Chondrichthyan	<i>Cephaloscyllium</i> sp. A [in Last & Stevens, 1994]	Whitefin Swell Shark	BP	112	Southeastern Australia from Port Stephens (NSW) to Port Lincoln (SA)	240-550m
Chondrichthyan	<i>Hydrolagus ogilbyi</i>	Ogilbys Ghost Shark	BP	29	Southeastern Australia from Coffs Harbour (NSW) to Beachport (SA)	120-350m
Chondrichthyan	<i>Myliobatis australis</i>	Southern Eagle Ray	BP	9,740	Southern Australia from Moreton Bay (Qld) to Jurien Bay (WA), and possibly NZ	to 85m
Chondrichthyan	<i>Squalus mitsukurii</i>	Green-Eyed Dogfish	BP	17,134	Now thought to be endemic to southern Australia (P.Last pers.comm.)	180-600m
Chondrichthyan	<i>Squatina australis</i>	Australian Angel Shark	BP	59,684	Southern Australia from Sydney to Rottnest Island (WA)	to 130m
Chondrichthyan	<i>Aptychotrema rostrata</i>	shovelnose ray	DI	0	Eastern Australia from Moreton Bay (Qld) to Jervis Bay (NSW)	to 50m
Chondrichthyan	<i>Asymbolus rubiginosus</i>	orange spotted catshark	DI	0	Eastern Australia from Port Macquarie (NSW) to southern NSW	40-79m
Chondrichthyan	<i>Chimaera</i> sp. A [in Last & Stevens, 1994]	southern chimaera	DI	0	Southern Australia from Eden (NSW) to Abrolhos Islands (WA)	300-850m
Chondrichthyan	<i>Dipturus australis</i>	common skate	DI	0	East coast of Australia between Moreton Bay (Qld) and Jervis Bay (NSW)	50-180m

Taxa	Scientific name	Common name	role	average logbook catch (kg) 2001-04	Distribution	Core depth range
Chondrichthyan	<i>Dipturus cerva</i>	white spotted skate	DI	0	Southern Australia from Eden (NSW) to Recherche Archipelago (WA)	20-470m
Chondrichthyan	<i>Dipturus gudgeri</i>	bight skate	DI	0	Southern Australia from Shellharbour (NSW) to Geraldton (WA)	400-550m
Chondrichthyan	<i>Dipturus</i> sp. B	grey skate	DI	0	Southeastern Australia from Jervis Bay (NSW) to Eucla (WA)	450-600m
Chondrichthyan	<i>Dipturus whitleyi</i>	whitley's (melbourne) skate	DI	0	Southeastern Australia from Wollongong (NSW) to Albany (WA)	to 170m
Chondrichthyan	<i>Galeus boardmani</i>	sawtail shark	DI	0	From Noosa (Qld) to Carnarvon (WA)	150-640m
Chondrichthyan	<i>Notoraja</i> sp. A [in Last & Stevens, 1994]	blue skate	DI	0	Southern Australia from northern NSW to Perth	840-1120m
Chondrichthyan	<i>Pavoraja nitida</i>	peacock skate	DI	0	Southeastern Australia from Newcastle (NSW) to Eyre (WA)	30-390m
Chondrichthyan	<i>Torpedo macneilli</i>	electric ray	DI	0	Widespread Australian endemic – Swain Reefs (Qld) to Port Hedland (WA)	90-750m
Chondrichthyan	<i>Urolophus bucculentus</i>	sandy-backed stingaree	DI	0	Endemic to Australia	100-230m
Chondrichthyan	<i>Urolophus viridis</i>	green-backed stingaree	DI	0	Southeastern Australia from Stradbroke Island (Qld) to Portland (Vic)	80-180m
Teleost	<i>Cyttus australis</i>	Silver dory	BP	23,493	Southern Australia WA to NSW	10-350m
Teleost	<i>Dannevigia tusca</i>	Australian Tusk	BP	140	Southern Australia – GAB to Bass Strait	115-400m
Teleost	<i>Chaunax endeavouri</i>	coffinfish	DI	0	Eastern Australia from Newcastle (NSW) to Bay of Fires (Tas)	50-300m
Teleost	<i>Eptatretus longipinnis</i>	hagfish	DI	0	Southern Australia – off Robe and Cape Douglas (SA)	to 40m
Teleost	<i>Maxillicosta whitleyi</i>	whitley's scorpionfish	DI	0	Southeastern Australia from Southport(Qld) to SA	20-140m
Teleost	<i>Psychrolutes marcidus</i>	smooth-head blobfish	DI	0	Southeastern Australia from Broken Bay NSW to around Tasmania	600-1200m

**Residual risk**

As discussed elsewhere in this report (Section 1), the ERAEF methods are both hierarchically structured and precautionary. The Level 1 (SICA) analyses are used to identify potential hazards associated with fishing and which broad components of the ecological system they apply to. The Level 2 (PSA) analyses consider the direct impacts of fishing on individual species and habitats (rather than whole components), but the large numbers of species that need to be assessed and the nature of the information available for most species in the PSA analyses limits these analyses in several important respects. These include that some existing management measures are not directly accounted for, and that no direct account is taken of the level of mortality associated with fishing. Both these factors are taken into account in the ERAEF framework at Level 3, but the analyses reported here stop at Level 2. This means that the risk levels for species must be regarded as identifying potential rather than actual risk, and due to the precautionary assumptions made in the PSA analyses, there will be a tendency to overestimate absolute levels of risk from fishing.

In moving from ERA to ERM, AFMA will focus scarce resources on the highest priority species and habitats (those likely to be most at risk from fishing). To that end, and because Level 3 analyses are not yet available for most species, AFMA (with input from CSIRO and other stakeholders) has developed guidelines to assess “residual risk” for those species identified as being at high potential risk based on the PSA analyses. The residual risk guidelines will be applied on a species by species basis, and include consideration of existing management measures not currently accounted for in the PSA analyses, as well as additional information about the levels of direct mortality. These guidelines will also provide a transparent process for including more precise or missing information into the PSA analysis as it becomes available.

CSIRO and AFMA will continue to work together to include the broad set of management arrangements in Level 2 analyses, and these methods will be incorporated in future developments of the ERAEF framework. CSIRO has also undertaken some preliminary Level 3 analyses for bycatch species for several fisheries, and these or similar methods will also form part of the overall ERAEF framework into the future.

**3.2.2 Habitats at risk**

The Level 2 habitat PSA analyses have highlighted a range of habitat types likely to be at high risk from trawling. These habitat types cover both hard and soft ground (the former still able to be trawled), and generally involve habitats with large, erect and fragile epifauna of various types, as well as lower lying bryozoan beds near the shelf break. High risk habitats have been identified at all depth ranges deeper than 100m.

The best options available for managing (the users of) benthic habitats assessed as high risk are likely to involve regulating access through long-term or permanent spatial closures. These can be gear-specific to acknowledge the highly different levels of risk from different gears, but also need to take account of cumulative effects of different sub-fisheries. Long term or permanent spatial closures acknowledge that habitat protection requires a different response than short term regulation of access, such as seasonal closures to protect spawning stocks.

Initially, the information required for an informed management response includes knowledge of what habitats exist, how much of each type there is, and where they are found. So that goals can be clearly defined, it is also necessary to know whether a habitat is essential to maintaining a part of the fishery ecosystem (is important for commercial species), or has important biodiversity values. The Level 2 analysis provides an evaluation of what habitats exist at a relevant level of detail for risk assessment, some coarse scale information on the “how much” and “where”, and some insights into their value to the fishery and to biodiversity values. However the issue of “how much” and “where” requires further analysis (and over time, further data collection).

Additional information to that used in the risk assessment does exist, and would enable an examination of management options. Primarily this is finer scale information on habitat distribution (how much and where), but information on the role of habitat for ecosystem function (e.g. providing refuge for commercial species) is available in some cases.

A feature not highlighted in the Level 2 assessments is that many high to medium risk habitats are scarce, while low risk habitats can be extensive. This suggests that any spatial closures would need to be carefully located, and, if this is possible, relatively small areas may be effective to protect certain habitat types. For example, the hard bottom habitat types of the mid-slope (a mix of high and medium risk types) are estimated to make up as little as 12% of its total area (~38,000 sq km). Only a proportion of this is encounterable by trawl, providing scope to protect pristine habitats while minimizing the impact on present fishing activities. MPA implementation will also have a strong influence on protecting mid-slope hard bottom habitat types due to the extensive coverage of the cinder cone seamounts off southern Tasmania. In contrast, the relatively large inner shelf (~150,000 sq km) is made up by large areas of low risk, relatively invulnerable habitats (dynamic, naturally disturbed sediment plains with little emergent fauna) which have been used traditionally for trawling, together with considerable areas of hard, high relief rocky outcrop that is too rugged for trawl access.

Hard bottom habitat types of the upper slope (a mix of high and medium risk types) are estimated to make up only about 27% of the total upper slope area – but the upper slope is relatively small (about half the area of the mid-slope at ~19,000 sq km). While not all hard bottom is presently encountered by trawl, the upper slope as a whole is very widely trawled. Present trawl effort overlap is estimated at between 65 and 90% and has expanded recently. The distribution of effort from other sub-fisheries, particularly auto-longline, is extensive and also expanding and indicates the need to consider cumulative overlap and impact across sub-fisheries. This combination of many high to medium risk habitats, high and expanding overlap, and small overall area identifies the upper slope as a high priority for both further analysis and mitigation.

Any consideration of spatial management for habitat protection should also involve an analysis of the extent to which it would or would not help mitigate impacts on high risk species. A key element of this is to examine the ecosystem services provided by complex fishery habitat to commercial species and their prey.

### **3.2.3 Communities at risk**

This component of the methodology not completed for the Level 2 stage

## **3.3 Key Uncertainties / Recommendations for Research and Monitoring**

In assessing risk to byproduct, bycatch and TEP species, it is not possible to assess absolute risk without supplementary information on either abundance or total mortality rates, and such data are not available for the vast majority of such species. However it may be possible to draw inferences from information that may be available for some species, either from catch records of occurrence from other fisheries, from fishery independent survey data, or from examination of trends in CPUE from observer data. Such data should be sought and examined for the high risk species identified in this analysis.

In assessing risk to habitats, similar issues arise. In general we do not have detailed information on the amount of each habitat type present in the area of the fishery, nor of its spatial distribution. However some data and information do exist from which inferences can be drawn, and piecing this together in the form of maps, particularly for those habitats identified as high risk, should be a priority.

Specific recommendations arising from this assessment include:

- Obtain information on missing attributes for the four bird species at high risk.
- Obtain information on location of capture of spiny pipefish.
- Obtain missing information for 10 teleost species at high risk.
- Consider risk of benthic-pelagic species (such as whiptails) in more detail; in particular, consider the location and depth of use of mid-water trawling and the species that may be impacted by this fishing method.
- Examine detailed observer data for the 21 chondrichthyan and six teleost byproduct and bycatch species at high risk and with distributions restricted to southern Australia; collate information on proportion of shots for which each of these species is observed, and if possible weight up data to estimate total catch of each species.
- For the six priority high risk teleost byproduct and bycatch species: search for any information on relative or absolute abundance from surveys or from catch records from other fisheries in the area; perform a detailed analysis of the spatial and seasonal distribution of catches; study habitat associations.
- More detailed assessments have been conducted for a range of chondrichthyan species (FRDC 202/033 Rapid assessment of sustainability for ecological risk of shark and other chondrichthyan by-catch species taken in the SSF, SENTF, SETF and GABTF). In some instance these assessments approach a Level 3 analysis for these species, and should be examined and used to update or override the Level 2 assessments reported in this analysis when this report becomes available.
- The current proposal to develop a system of fishery independent surveys for the SESSF should take into account the need for abundance data for potentially high risk byproduct and bycatch species.

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- Map (to the extent that data allow) spatial distributions of key high risk species and habitats, to identify possible candidate areas for fishery closures (taking into account protection afforded by future MPAs in south-east region).
  - Further targeted research and data collection for determining high risk habitat distribution is required.
  - Examine the ecosystem services provided by complex fishery habitat to commercial species and their prey.

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[add required references here]

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## Glossary of Terms

Assemblage	A subset of the species in the community that can be easily recognized and studied. For example, the set of sharks and rays in a community is the Chondrichthyan assemblage.
Attribute	A general term for a set of properties relating to the productivity or susceptibility of a particular unit of analysis.
Bycatch species	A non-target species captured in a fishery, usually of low value and often discarded (see also Byproduct).
Byproduct species	A non-target species captured in a fishery, but it may have value to the fisher and be retained for sale.
Community Component	A complete set of interacting species. A major area of relevance to fisheries with regard to ecological risk assessment (e.g. target species, bycatch and byproduct species, threatened and endangered species, habitats, and communities).
Component model	A conceptual description of the impacts of fishing activities (hazards) on components and sub-components, linked through the processes and resources that determine the level of a component.
Consequence	The effect of an activity on achieving the operational objective for a sub-component.
Core objective	The overall aim of management for a component.
End point	A term used in risk assessment to denote the object of the assessment; equivalent to component or sub-component in ERAEF
Ecosystem	The spatially explicit association of abiotic and biotic elements within which there is a flow of resources, such as nutrients, biomass or energy (Crooks, 2002).
External factor	Factors other than fishing that affect achievement of operational objectives for components and sub-components.
Fishery method	A technique or set of equipment used to harvest fish in a fishery (e.g. long-lining, purse-seining, trawling).
Fishery	A related set of fish harvesting activities regulated by an authority (e.g. South-East Trawl Fishery).
Habitat	The place where fauna or flora complete all or a portion of their life cycle.
Hazard identification	The identification of activities (hazards) that may impact the components of interest.
Indicator	Used to monitor the effect of an activity on a sub-component. An indicator is something that can be measured, such as biomass or abundance.
Likelihood	The chance that a sub-component will be affected by an activity.

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Operational objective	A measurable objective for a component or sub-component (typically expressed as “the level of X does not fall outside acceptable bounds”)
Precautionary approach	The approach whereby, if there is uncertainty about the outcome of an action, the benefit of the doubt should be given to the biological entity (such as species, habitat or community).
PSA	Productivity-Susceptibility Analysis. Used at Level 2 in the ERAEF methodology.
Scoping	A general step in an ERA or the first step in the ERAEF involving the identification of the fishery history, management, methods, scope and activities.
SICA	Scale, Impact, Consequence Analysis. Used at Level 1 in the ERAEF methodology.
Sub-component	A more detailed aspect of a component. For example, within the target species component, the sub-components include the population size, geographic range, and the age/size/sex structure.
Sub-fishery	A subdivision of the fishery on the basis of the gear or areal extent of the fishery. Ecological risk is assessed separately for each sub-fishery within a fishery.
Sustainability	Ability to be maintained indefinitely
Target species	A species or group of species whose capture is the goal of a fishery, sub-fishery, or fishing operation.
Trophic position	Location of an individual organism or species within a foodweb.
Unit of analysis	The entities for which attributes are scored in the Level 2 analysis. For example, the units of analysis for the Target Species component are individual “species”, while for Habitats, they are “biotypes”, and for Communities the units are “assemblages”.

**Appendix A: General summary of stakeholder feedback**

Date	Format received	Comment from stakeholder	Action/explanation

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## Appendix B: PSA results summary of stakeholder discussions

Level 2 (PSA) Document L2.1. Summary table of stakeholder discussion regarding PSA results.

For example: the following species were discussed at the SETMAC meeting on 22 November 2005 in Melbourne. Selected high risk species were discussed.

TAXA_NAME	SCIENTIFIC_NAME	COMMON_NAME	ROLE IN FISHERY	Comments from SETMAC meeting 22-Nov-2005, and follow-up	Action	Outcome