Ecological risk assessment for fisheries: applications in Australia and in the Marine Stewardship Council

Tony Smith, Alistair Hobday, Shijie Zhou
David Johnson, Keith Sainsbury
Outline

• Background – tools to support EBFM
• ERA and Australian fisheries
• ERAEF – structure and approach
  • SICA
  • PSA
  • SAFE
• Outcomes
• The MSC and its risk based framework
• Concluding comments
Tools to support EBFM
ERA for Australian fisheries

• ERA – ecological risk assessment
• Environmental legislation (1999) required comprehensive assessment of ecological impacts of fishing
• Focus till then mostly on assessment and management of target species
• Both data and methods lacking to assess wider ecological impacts – hence risk based methods
• Developed by CSIRO with major funding and support from the Australian Fisheries Management Authority (AFMA) – 2001-2007
Criteria for ERA design

- Comprehensive
- Scientifically defensible
- Make use of existing data and information
- Precautionary given uncertainty
- Cost effective
- Flexible (apply to all types of fisheries)
- Transparent
- Understandable to stakeholders
- Help inform management response

- No such method exists!
ERAEF

- ERAEF – Ecological risk assessment for effects of fishing
- Key features
  - Hierarchical structure
  - Precautionary approach to uncertainty
  - Applicable to all types of fishery
  - Can deal with variable amounts of data
  - Assess impacts on species, habitats and communities
  - Link to risk management response
  - Assist research prioritisation
ERAEF – hierarchical approach

Levels allow screening & elimination of low risk
  • Initial scoping (whole fishery, all issues)
  • Level 1 – qualitative risk assessment
  • Level 2 – semi-quantitative risk assessment
  • Level 3 – full quantitative risk assessment

Proceed to subsequent level depending on
  • Estimated risk at current level
  • Management response at current level

Document rationale and decisions at each level
**Analysis:** Fishery/subfishery

**Analysis:** most vulnerable element in each component (species, habitat, community)

**Screen out:** low consequence activities and (potentially) low risk components

**Analysis:** full set of elements for each component

**Screen out:** low risk elements

**Analysis:** selected elements (species, habitat, community); spatial and temporal dynamics
ERAEF – what is assessed

5 ecological components evaluated

- Target species
- Byproduct and Bycatch species
- Threatened, Endangered and Protected species (TEP)
- Habitats
- Communities (including food chains)

Ecosystem

TA  BC  TEP  HAB  COMM
ERAEF: Scoping

- General description of the fishery (sub-fisheries)
- Identification of objectives for each component
- Identification of “units of analysis” for each sub-fishery
  - Lists of species, habitats, and communities
- Hazard identification
Units of analysis

Species

Habitats

Communities
Hazard identification

List activities affecting components

- Direct capture or impact
- Discarding
- Translocation
- Disturbance
- Pollution
- Other fisheries
- Other human activities
Level 1: SICA

- SICA – scale, intensity, consequence analysis
- Effect of each activity on each component considered
  - E.g. effect of discarding on sea bird behaviour (TEP)
  - Up to 25 activities X 5 components
- Qualitative (expert based) method
- Plausible worst case approach
- Use of look-up tables to guide analysis
LEVEL 1 (SICA) RATIONALE

DEVELOP SCENARIOS: FOR EACH ACTIVITY AGREE ON THE WORST EFFECT ON ANY OF THE SPECIES IN THE COMPONENT

STAKEHOLDER DIVERSITY IS CRUCIAL TO THIS ASPECT

A SET OF ACTIVITIES

HIGH

LOWEST

HIGHEST

SCORE THE CONSEQUENCE OF THAT WORST SCENARIO

IF WORST IS BELOW THE LINE SO WILL BE ALL OTHERS

IF WORST IS ABOVE THE LINE SO MIGHT BE OTHERS…
Risk Landscape - comprehensive

Risk

Fishery landscape

Risk

Fishery landscape

Risk

Fishery landscape
SICA

- Consequence scores rated 1 (negligible) to 6 (intolerable)
- Key to transparency is clear written justification for each score
- Score > 2 (minor) leads to next level analysis (or guided management response)

Key advantage of SICA
- Comprehensive approach to risk (wide range of hazards considered)
- Rapid elimination of low risk hazards at relatively low cost
Level 1 – All components
Level 1 – All components

- **SBT Fishery. Target Species Component**
- **SBT Fishery. Bycatch/Byproduct Species**
- **SBT Fishery. TEP Species Component**
- **SBT Fishery. Habitat Component**
- **SBT Fishery. Community Component**

Confidence:
- Low
- High
ERAEF Level 2: PSA

**SCOPING**
- Establish scope and context
- Identify and document objectives
- Hazard identification

**Risk Assessment Level 1**
- Qualitative assessment (SICA)
- Uncertainty analysis
- Negligible or low risk
- Medium, high or extreme risk

**Risk Assessment Level 2**
- Semi-quantitative (PSA)
- Uncertainty analysis
- Negligible or low risk
- Medium, high or extreme risk

**Risk Assessment Level 3**
- Quantitative assessment
- Uncertainty analysis
- Negligible or low risk
- Medium, high or extreme risk

**Analysis:**
- Fishery/subfishery
- Most vulnerable element in each component (species, habitat, community)
- Screen out: low consequence activities and (potentially) low risk components
- Analysis: full set of elements for each component
- Screen out: low risk elements
- Analysis: selected elements (species, habitat, community); spatial and temporal dynamics

**Risk management response**
PSA

• Consider impacts on all units of analysis within each component assessed
• E.g. over 250 bycatch species in tropical prawn trawl fishery
• Same form of analysis for each unit (but separate method for species, habitat, community)
• “Semi-quantitative” method of analysis
• Reasonable demands on data (not catch or abundance data)
• Measures potential risk rather than actual risk but still useful for prioritizing
PSA

PSA = Productivity Susceptibility Analysis

Risk to an ecological unit (species, habitat, community) from a given activity will depend on two characteristics of the unit:

• the susceptibility or “exposure” of the unit to the fishing activity (**Susceptibility**) and
• the productivity of the unit which will determine the rate at which the unit can recover after depletion or damage by the fishing activity (**Productivity**)
Productivity Susceptibility Analysis (PSA)
PSA is “semi-quantitative”

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

• Level 3 would solve this equation…e.g. stock assessment

• Cannot do this for all species…time and $

• PSA estimates the “r” and the “q”
  • Use available attributes related to these terms

(B = units in species, habitat or community component)
PSA: susceptibility is multiplicative

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

- Susceptibility = \( q = A \times E \times S \times PM \)
  - A = availability
  - E = encounterability
  - S = selectivity
  - PM = post-capture mortality
Attributes for species components
(TA, BP/DI, TEP)

Productivity attributes

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

Susceptibility attributes

- Availability
  - Overlap with fishery
- Encounterability
  - Water column position
  - Habitat overlap
- Selectivity
  - e.g. Size at maturity
- Post-Capture Mortality
  - e.g. Fate/data
Scoring attributes

- Divide each attribute into low, medium, high risk score
- E.g. age at maturity
  - <5 = high productivity = low risk = score 1
  - 5-15 = medium productivity = medium risk = score 2
  - >15 = low productivity = high risk = score 3
- Productivity risk = average risk score across 7 attributes
Susceptibility

- Availability = spatial overlap of fishery with species
- Encounterability = proportion of available population exposed to the gear
- Selectivity = proportion of animals encountering the gear that are captured
- Post capture mortality = proportion of animals captured that die

- Susceptibility score = product of risk scores $A_xE_xS_xP$
Availability scoring

- Global distribution (endemic = high, SH = med, worldwide = low) (if no distribution maps)
  - Stock likelihood adjustment (table X)

OR

- Score the overlap of core species distribution (D) with core fishing effort (B) (red square)
Encounterability Scoring

1. Score habitat attribute for each unit (species, habitat, community)
2. Generate fishery-specific encounterability score based on gear fishing characteristics
   …if data exists and score is M or H, can check to refine overlap….
3. Check bathymetric range of within the species province for overlap with the bottom depth range for the fishery gear type
4. Refine the risk score for encounterability

**Water Column Position**
- Epipelagic
- Mesopelagic
- Benthopelagic
- Bottom (hard or soft)

**Habitat of species**

**Province bottom depth for species**
- 1. 0–110 m
- 2. 110–250 m
- 3. 250–565 m
- 4. 565–820 m
- 5. 820–1100 m
- 6. > 1100m

**Bottom depth range of gear**
- 500-1000m

**Scoring Example:**
- **Risk: H**
  Bottom species living on soft ground
  Overlap with demersal gear on soft ground is High

**Bathymetry check**

- **Risk: L**
  Depth range for the species is outside the depth range of the fishery: encounterability score is corrected to Low
**Selectivity** is a measure of the proportion of animals encountering the fishing gear that is captured.

Attributes related to selectivity:
- **Size**
- (Morphology)
- (Swimming capability)
### Example of species scoring (1)

<table>
<thead>
<tr>
<th></th>
<th>Shortfinned Mako</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
</tr>
<tr>
<td>Average age at maturity</td>
<td></td>
</tr>
<tr>
<td>Average max age</td>
<td></td>
</tr>
<tr>
<td>Fecundity</td>
<td></td>
</tr>
<tr>
<td>Average max size</td>
<td></td>
</tr>
<tr>
<td>Average size at Maturity</td>
<td></td>
</tr>
<tr>
<td>Reproductive strategy</td>
<td></td>
</tr>
<tr>
<td>Trophic level (fishbase)</td>
<td></td>
</tr>
<tr>
<td>Productivity total (additive)</td>
<td></td>
</tr>
<tr>
<td><strong>Susceptibility</strong></td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td></td>
</tr>
<tr>
<td>Encounterability</td>
<td></td>
</tr>
<tr>
<td>Selectivity</td>
<td></td>
</tr>
<tr>
<td>PCM</td>
<td></td>
</tr>
<tr>
<td>Susceptibility total (multiplicative)</td>
<td></td>
</tr>
<tr>
<td><strong>Overall Risk Value</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Risk Category</strong></td>
<td></td>
</tr>
</tbody>
</table>

Long-line fishery
Byproduct species

[Map of the region with a red box highlighting Lord Howe Island]
### Example of species scoring (1)

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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average age at maturity</td>
<td>6.5</td>
<td>2</td>
</tr>
<tr>
<td>Average max age</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>Fecundity</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Average max size</td>
<td>400</td>
<td>3</td>
</tr>
<tr>
<td>Average size at Maturity</td>
<td>195</td>
<td>2</td>
</tr>
<tr>
<td>Reproductive strategy</td>
<td>DS</td>
<td>2</td>
</tr>
<tr>
<td>Trophic level (fishbase)</td>
<td>3.78</td>
<td>3</td>
</tr>
<tr>
<td><strong>Productivity total (additive)</strong></td>
<td></td>
<td><strong>2.57</strong></td>
</tr>
<tr>
<td><strong>Susceptibility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td>0.0288</td>
<td>1</td>
</tr>
<tr>
<td>Encounterability</td>
<td>1,2, HB, EP, MP</td>
<td>3</td>
</tr>
<tr>
<td>Selectivity</td>
<td>195</td>
<td>3</td>
</tr>
<tr>
<td>PCM</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Susceptibility total (multiplicative)</strong></td>
<td></td>
<td><strong>1.67</strong></td>
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<tr>
<td><strong>Overall Risk Value</strong></td>
<td></td>
<td><strong>3.06</strong></td>
</tr>
<tr>
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<td><strong>Med</strong></td>
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</thead>
<tbody>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
</tr>
<tr>
<td>Average age at maturity</td>
<td>2</td>
</tr>
<tr>
<td>Average max age</td>
<td>3</td>
</tr>
<tr>
<td>Fecundity</td>
<td>3</td>
</tr>
<tr>
<td>Average max size</td>
<td>3</td>
</tr>
<tr>
<td>Average size at Maturity</td>
<td>2</td>
</tr>
<tr>
<td>Reproductive strategy</td>
<td>2</td>
</tr>
<tr>
<td>Trophic level (fishbase)</td>
<td>3</td>
</tr>
<tr>
<td>Productivity total (additive)</td>
<td>2.57</td>
</tr>
<tr>
<td><strong>Susceptibility</strong></td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td>1</td>
</tr>
<tr>
<td>Encounterability</td>
<td>3</td>
</tr>
<tr>
<td>Selectivity</td>
<td>3</td>
</tr>
<tr>
<td>PCM</td>
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<tr>
<td><strong>Risk Category</strong></td>
<td>Med</td>
</tr>
</tbody>
</table>

![Risk Values (Low<2.64, High>3.18)](image)
Bycatch and Byproduct species
(Danish Seine)
### PSA summary (trawl fishery)

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target species</td>
<td>16</td>
<td>8</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>Byproduct species</td>
<td>36</td>
<td>24</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>Bycatch species</td>
<td>129</td>
<td>87</td>
<td>82</td>
<td>298</td>
</tr>
<tr>
<td>TEP species</td>
<td>3</td>
<td>119</td>
<td>72</td>
<td>194</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>184</td>
<td>238</td>
<td>178</td>
<td>600</td>
</tr>
</tbody>
</table>
Example: Species Risk Distributions Across Fisheries

- **Purse-seine**
- **Trawl**
- **Longline**
Level 2 Options
(categorization will guide this)

Current risk (H)

No action

Management action

Additional Analysis Overrides

Go to next Level

PSA change

No change

Rationale provided for a “lower risk” due to expert consideration of management

Management change translates to A, E, S, PCM and rescoring reduces risk score

e.g. additional data, or assess with additional tool, such as PSA 3rd axis, reduces risk score
Non-species components

- Most experience and theory for species
Defining habitats types and lists for each subfishery

“Habitat” includes both biological and physical elements

Each habitat “type” was defined by a unique combination of S, G and F

<table>
<thead>
<tr>
<th>Substratum (S)</th>
<th>Geomorphology (G)</th>
<th>Sessile fauna (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mud (soft)</td>
<td>Unripped/ flat</td>
<td>None</td>
</tr>
<tr>
<td>Fine sediments (soft)</td>
<td>Current rippled/ directed scour</td>
<td>Bioturbators (infauna)</td>
</tr>
<tr>
<td>Coarse sands (soft)</td>
<td>Wave rippled</td>
<td>Mixed low/ encrusters</td>
</tr>
<tr>
<td>Gravel/pebble (hard)</td>
<td>Highly irregular</td>
<td>Small/ low sponges</td>
</tr>
<tr>
<td>Cobble/boulder/slab (hard)</td>
<td>Debris flow/ rubble banks</td>
<td>Solitary erect</td>
</tr>
<tr>
<td>Rock (igneous/ metamorphic)</td>
<td>Subcrop</td>
<td>Stalked crinoids</td>
</tr>
<tr>
<td>Rock (sedimentary)</td>
<td>Low outcrop</td>
<td>Octocorals</td>
</tr>
<tr>
<td>Biogenic</td>
<td>High outcrop</td>
<td>Mixed epifaunal community</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large erect sponges</td>
</tr>
</tbody>
</table>

SGF = coarse sand, wave rippled, infauna

= coarse sand, subcrop, large sponges
### Each type evaluated against 11 attributes of habitat vulnerability

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Attribute</th>
<th>Concept</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>General depth range (biome)</td>
<td>Spatial overlap of subfishery with habitat defined at biomic scale</td>
<td>Habitat occurs within the management area</td>
</tr>
<tr>
<td>Encounterability</td>
<td>Depth zone and feature type</td>
<td>Habitat encountered at the depth and location at which fishing activity occurs</td>
<td>Fishing takes place where habitat occurs</td>
</tr>
<tr>
<td></td>
<td>Ruggedness (fractal dimension of substratum and seabed slope)</td>
<td>Relief, rugosity, hardness and seabed slope influence accessibility to different sub-fisheries</td>
<td>Rugged substratum is less accessible to mobile gears. Steeply sloping seabed is less accessible to mobile gears</td>
</tr>
<tr>
<td></td>
<td>Level of disturbance</td>
<td>Gear footprint and intensity of encounters</td>
<td>Degree of impact is determined by the frequency and intensity of encounters (inc. size, weight and mobility of individual gears)</td>
</tr>
<tr>
<td>Selectivity</td>
<td>Removability/ mortality of fauna/ flora</td>
<td>Removal/ mortality of structure forming epifauna/ flora (inc. bioturbating infauna)</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>Areal extent</td>
<td>How much of each habitat is present</td>
<td>Effective degree of impact greater in rarer habitats: rarer habitats may maintain rarer species.</td>
</tr>
<tr>
<td></td>
<td>Removability of substratum</td>
<td>Certain size classes can be removed</td>
<td>Intermediate sized clasts (~6 cm to 3 m) that form attachment sites for sessile fauna can be permanently removed</td>
</tr>
<tr>
<td></td>
<td>Substratum hardness</td>
<td>Composition of substrata</td>
<td>Harder substratum is intrinsically more resistant</td>
</tr>
<tr>
<td></td>
<td>Seabed slope</td>
<td>Mobility of substrata once dislodged; generally higher levels of structural fauna</td>
<td>Gravity or latent energy transfer assists movement of habitat structures, eg turbidity flows, larger clasts. Greater density of filter feeding animals found where currents move up and down slopes.</td>
</tr>
<tr>
<td>Productivity</td>
<td>Regeneration of fauna</td>
<td>Accumulation/ recovery of fauna</td>
<td>Fauna have different intrinsic growth and reproductive rates which are also variable in different conditions of temperature, nutrients, productivity.</td>
</tr>
<tr>
<td></td>
<td>Natural disturbance</td>
<td>Level of natural disturbance affects intrinsic ability to recover</td>
<td>Frequently disturbed communities adapted to recover from disturbance</td>
</tr>
</tbody>
</table>
Example of risk ranking: substratum removability

Rationale: Intermediate sized clasts (~6 cm to 3 m) can be permanently removed

<table>
<thead>
<tr>
<th>Substratum Type</th>
<th>Removability</th>
<th>Risk rank Bottom trawl</th>
<th>Risk rank Bottom longline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard rocky reef</td>
<td>Immovable</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sediments</td>
<td>Transferable</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sedimentary mudstone boulders</td>
<td>Removable</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Increasing vulnerability
Habitats: PSA outcome (Otter trawl)
Community component

- PSA for communities still under development
- Qualitative modelling of trophic structure
Level 3 – Quantitative

A range of tools exist:

- Stock assessments, PBR for species
- Habitat fragmentation/landscape models
- Eco-family models

- SAFE – quantitative version of PSA for species
SAFE: Spatial overlap
Determining MSM

- **B**<sub>lim</sub>
- **B**<sub>msm</sub>
- **B**<sub>0</sub>
- **F**<sub>lim</sub>
- **F**<sub>crash</sub>
- **F**<sub>msm</sub>

**Labels:**
- Extreme
- Medium
- Low

**Axes:**
- Surplus fishing mortality
- Biomass

**Range:**
- 0 to 200
- 0 to 400

**Variables:**
- Biomass
- Surplus fishing mortality
SAFE analysis for demersal longline

Estimated fishing mortality rate (+90% CI)

Fishing mortality rate causing maximum sustainable fishing mortality (min to max)

* Chondrichthyan
* Teleost
Fishing Activities (e.g. Longlining)

Target Communities
Habitats
Bycatch
TEP
Scoping

e.g. SAFE
e.g. Ecosim

ERAEF OUTLINE
Application to Fisheries

32 fisheries assessed in Australia
• Trawl and demersal
• Pelagic fisheries
• Sub-Antarctic
• Minor – e.g. hand collection

2000 species
200 habitats
50 communities
ERA to ERM

- Step through hierarchy to eliminate low risks
- Remaining issues need management attention
- Develop management responses informed by risk analyses
  - E.g. based on PSA analysis
    - Can’t alter productivity
    - Can alter susceptibility
      - A: spatial closure
      - E: seasonal closure
      - S: gear modification
      - P: improve on-board handling practice
- AFMA moving to comprehensive ERM strategies for all fisheries
Marine Stewardship Council

- International certification for sustainable fisheries
- Three principles
  - Sustainable stocks
  - Sustainable ecosystems
  - Good governance
- Score fisheries against set of performance indicators
  - 60 minimum for certification
  - 80 pass
  - 100 maximum possible score
Marine Stewardship Council

- RBF (risk based framework) available to score P1 and P2 outcomes indicators (status of species, habitats and ecosystems)
- RBF currently incorporates SICA and PSA methods
- Calibration exercise in 2008 to equate SICA (1-6) and PSA (1-4) scores to MSC PI scores (0-100)
- Don’t have to use RBF – available for low information or low value fisheries – but “penalty” for use
Equivalence between “Levels”

Ease of demonstrating “pass” for PI

Data requirement

Value of information

- Level 3. Stock assessment
- Level 2.5. SAFE
- Level 2. PSA
- Level 1. SIRA
- No data

High
Low
Easy
Hard

No data
Level 1. SIRA
Level 2. PSA
Level 2.5. SAFE
Level 3. Stock assessment
Links to management

Data, $ → L1 → L2 → L3

Sustainable

Unsustainable
Effect of missing attributes

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSC score</td>
<td>40</td>
</tr>
<tr>
<td>Number missing</td>
<td>4</td>
</tr>
</tbody>
</table>
ERA - summary

• Designed for data deficient situations
• Make best use of existing information
  • Don’t give up because can’t do quantitative analysis
• Inbuilt “precaution” aimed to prevent abuse
  • SICA – plausible worst case scenario
  • PSA – assumes high risk – evidence to lower risk score
• Hierarchical structure
• Toolbox approach
ERAЕF hierarchical structure

Comprehensive

Focused

Uncertain

Qualitative

Quantitative

Time & $$

More certain

Level 1

H

Level 2

L

H

Level 3

L

H

Risk Management Response
Ecological Risk Assessment for the Effects of Fishing (ERAEF)

Principal investigators:
Alistair Hobday
Tony Smith

Stage 2: Development Team
Cathy Bulman, Ross Daley, Jeff Dambacher, Jo Dowdney, Mike Fuller, Dianne Furlani, Miriana Sporcic, Sally Wayte, Helen Webb, Alan Williams

Stage 2: Case study authors
Above, plus Shane Griffiths, Rob Kenyon, Terry Walker, Ian Knuckey, Clive Turnbull, Darren Dennis, Shijie Zhou

Marine Stewardship Council
Yemi Oluruntuyi, Alice McDonald