Ecosystem-based resource assessments for sustainable fisheries

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- **Resource assessment and fisheries management**
- **Ecosystem-based fisheries assessment approaches**

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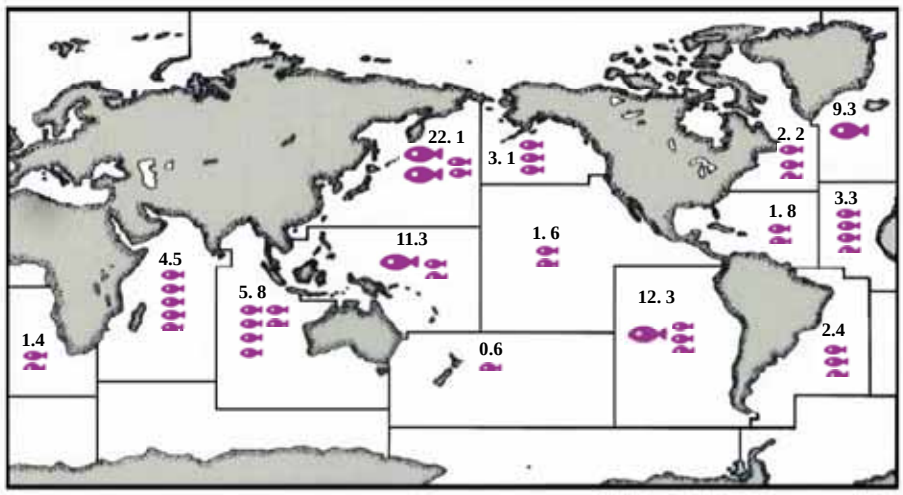
  3. **EBFA approach**

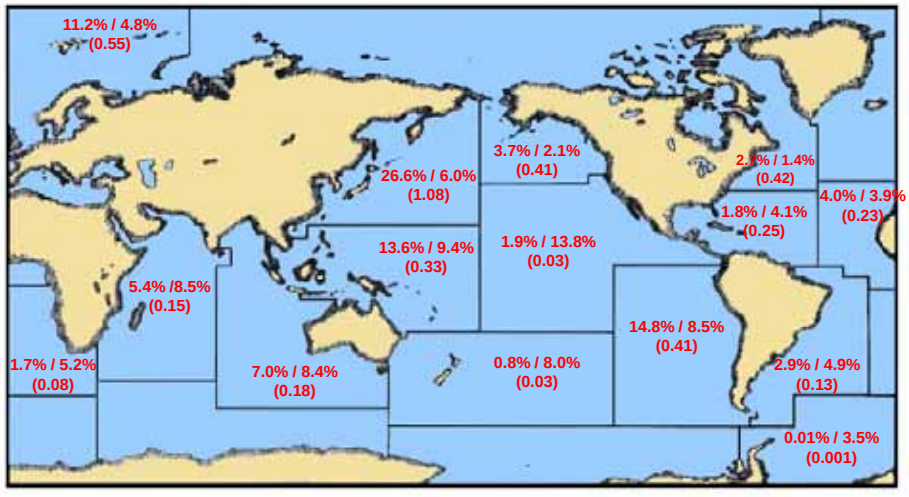
Catch by FAO marine fishing area

Total catch (in 2006) = 83.1 million tons



Proportion of catch to area by FAO area

( ) : catch per unit area (mt/km^2)

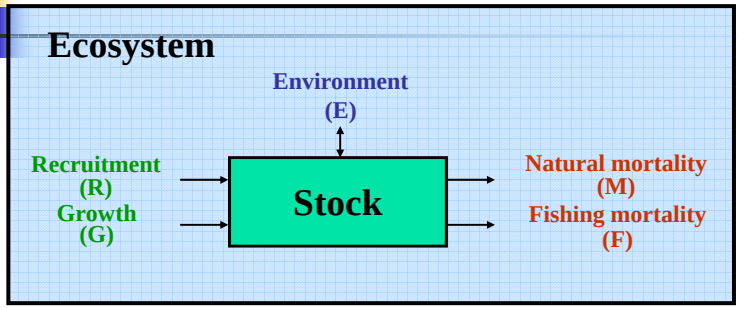


Status of World Fisheries

- Reductions in traditional fishing grounds due to the EEZ regime
- Depletion of fisheries resources in quantity and quality
- Deterioration of coastal ecosystems due to pollution

-> Necessary to develop tools and system for managing fisheries resources by a environmentally sound and sustainable way : Ecosystem-based fisheries management

Typical Population-based Approach



Population parameters

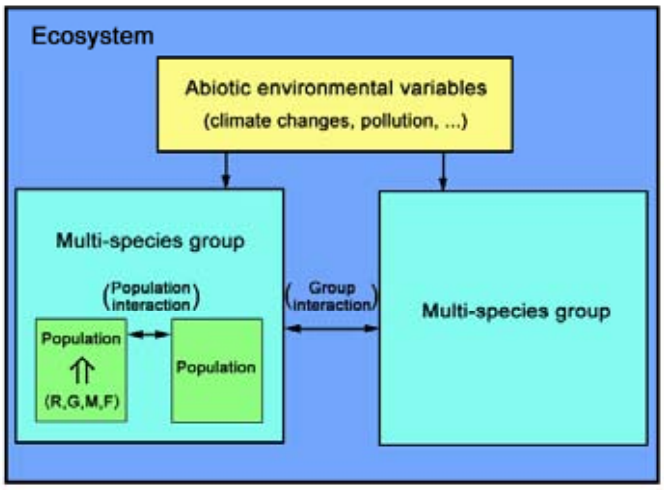
1. Recruitment (R)
2. Growth (G)
3. Natural mortality (M)
4. Fishing mortality (F)

Typical Fisheries Management

- Mostly indirect control devices
- TAC-based management
- Community-based self-management
- Enhancement by artificial reefs, releasing fries and juveniles, and seaweed beds
- Marine ranching
- Buy-back program to reduce fishing vessels

* Operated separately, not systematically

Interactions of Organisms with Biotic and Abiotic Environments in a Marine Ecosystem



R denotes recruitment, G, growth, M, natural mortality, and F, fishing mortality.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Study Group on Ecosystem-based management science and its application to the North Pacific
Acronym: EBMSG
Parent Committees: MEQ, FIS
Co-Chairman: Glen Jamieson <JamiesonG@pac.dfo-mpo.gc.ca>
Co-Chairman: Chang-Ik Zhang <cizhang@pknu.ac.kr>
Mailing List (EBMSG Members only)
Terms of reference:
1. Review and describe existing and anticipated ecosystem-based management initiatives in PICES member nations and the scientific bases for them;
2. Identify emerging scientific issues related to the implementation of ecosystem-based management;
3. Develop recommendations for a Working Group to focus on one or more issues identified in (2) above;
4. Report the results to the parent Committees (FIS and MEQ) at PICES XIII.
Products
Product Type
2004


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Working Group on Ecosystem-based management science and its application to the North Pacific (Oct. 2004 -)
Acronym: WG-19
Parent Committees: MEQ, FIS
Co-Chairman: Glen Jamieson <JamiesonG@pac.dfo-mpo.gc.ca>
Co-Chairman: Chang-Ik Zhang <cizhang@pknu.ac.kr>
Co-Chairman: Patricia Livingston <Pat.Livingston@noaa.gov>
Mailing List (WGEBM Members only)
Terms of reference:
1. Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem based management objectives of each country.
2. Describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Identify key information gaps and research and implementation challenges.
3. Evaluate the indicators from the 2004 Symposium on "Quantitative Ecosystem Indicators for Fisheries Management" for usefulness and application to the North Pacific.
4. Review existing definitions of "eco-regions" and identify criteria that could be used for defining ecological boundaries relevant to PICES.

Why ecosystem-based fisheries management?

- Shortcomings of a single species management

  - Limited management: only focus on sustainability explicitly

- Reykjavik Declaration (2002), FAO (2003): stressed implementation of ecosystem approach to fisheries (EAF)
- WSSD (2002): encouraged the application of the ecosystem-based approach of fisheries by 2010

Spectrum of Ecosystem-based Management Approaches (Modified from Sainsbury)

Traditional fishery management	Ecosystem-based fishery management	Ecosystem-based multi-sector management
✓ target species ✓ single species or multi-species	✓ start with the target species ✓ add issues of ecosystem impact on fishery resources	✓ integrated management ✓ multiple use management

EBFA approach

Definitions of Ecosystem and Ecosystem-based Management

'**Ecosystem**' is 'the spatial unit and its organisms and natural processes that is being studied or managed.'

'**Ecosystem-based management'** is 'a strategic approach to managing human activities that seeks to ensure the coexistence of healthy, fully functioning ecosystems and human communities'

Principles of Ecosystem (NMFS EPAP 1999)

1. The ability to predict ecosystem behavior is limited.

2. Ecosystems have real thresholds and limits which, when exceeded, can affect major system restructuring.

3. Once thresholds and limits have been exceeded, changes can be irreversible.

4. Diversity is important to ecosystem functioning.

5. Multiple time scales interact within and among ecosystems.

6. Components of ecosystems are linked.

7. Ecosystem boundaries are open.

8. Ecosystems change with time.

Steele and Collie in *THE SEA* (2004)

It is becoming clear that we **cannot manage entire ecosystems**; we can **only regulate first-order impacts** without being able to predict second-order consequences...

Ecosystem-based Management Goals

- Maintain system **sustainability**
- Maintain **biodiversity** consistent with natural processes
- Protect and restore **habitats** of fish and prey
- Maintain **social and economic benefits**

Ecosystem-based Fisheries Assessment Approaches

- **ERAEF by Australia**
- **MSC's FAM**
- **EBFA approach**

Ecological Risk Assessment for the Effects of Fishing (ERAEF)

Risk assessment is one way of evaluating sustainability

ERAEF Approach

5 ecological "components" evaluated (= ecosystem)

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

Outline of approach: ERAEF

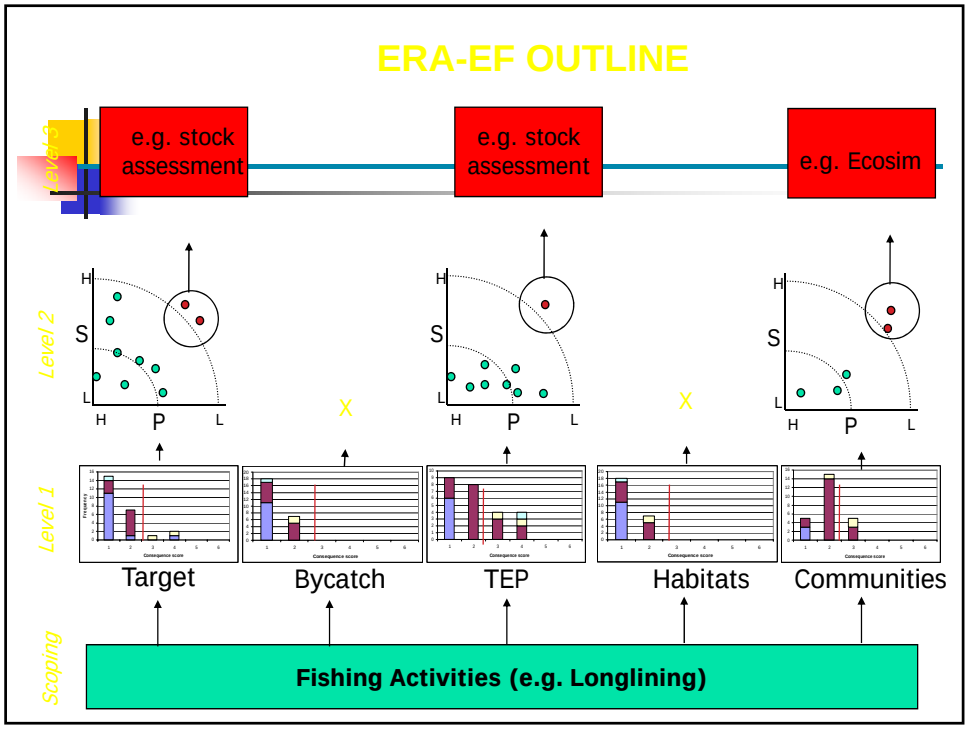
Hierarchical approach:

- 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

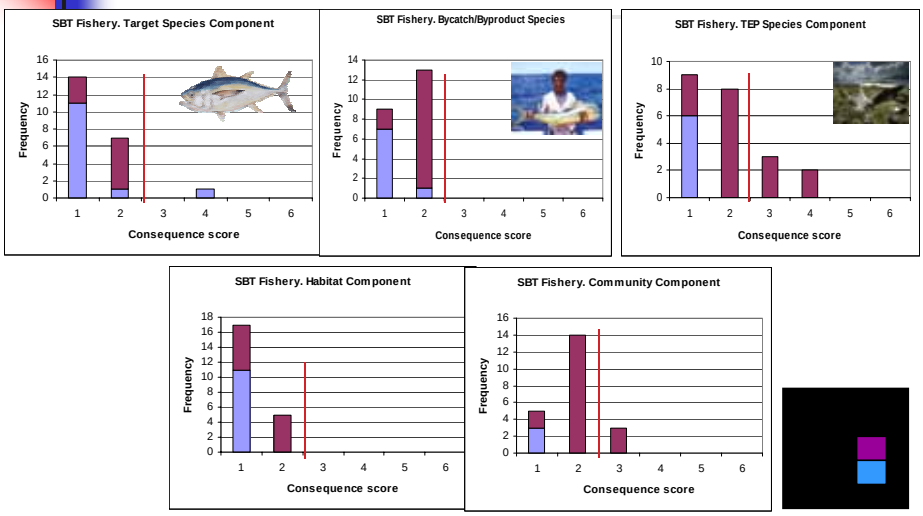
Proceed to subsequent level depending on estimated risk at current level

ERAEF Method Development

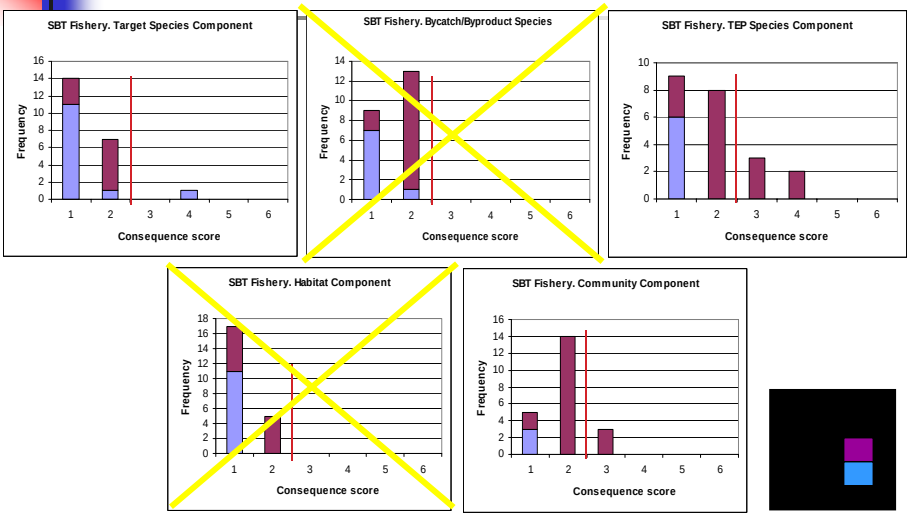
- Level 1; SICA
- Level 2: PSA
- Level 3; Stock assessment, Eco-family



Level 1 – All components

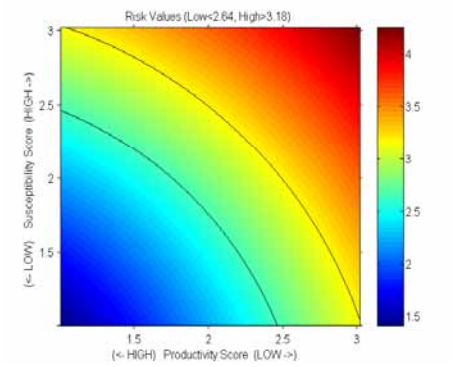


Level 1 – All components



Level 2 (PSA) Progress

- Axis 1: Productivity Attributes (additive)
- Axis 2: Susceptibility Attributes (multiplicative)



Level 2 PSA is "semi-quantitative"

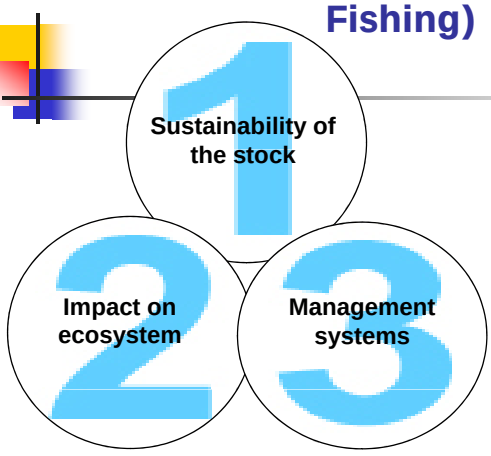
$$\frac{dB}{dt} = rB(1-\frac{B}{K}) - qEB$$

- 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"
- B=species, habitats, communities

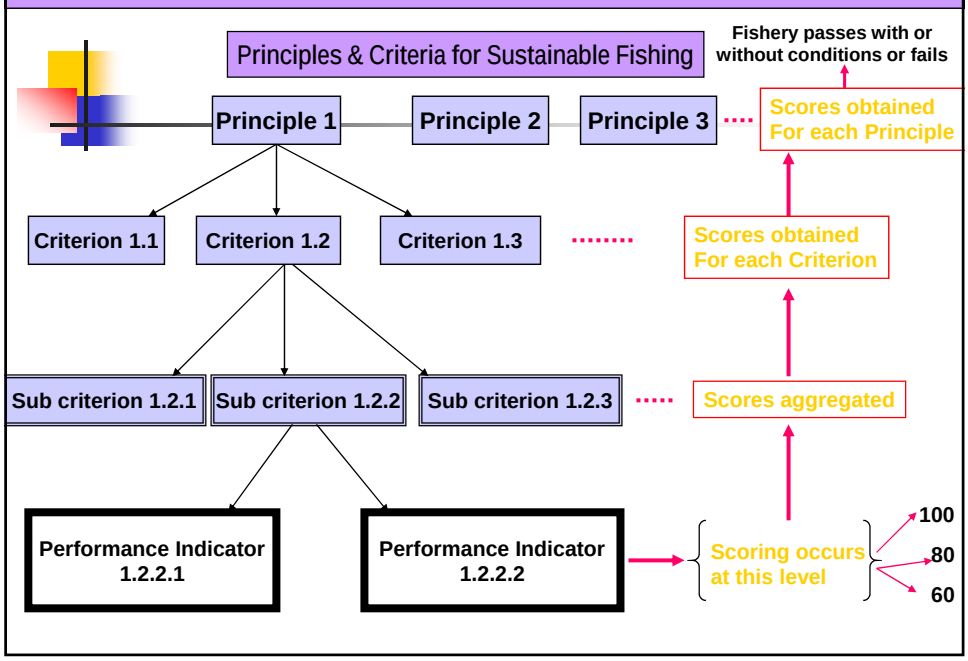
The Marine Stewardship Council

The MSC Standard*
(Principles and Criteria for Sustainable Fishing)



* based on international guides for standard setting and founded on the FAO Code of Conduct for Responsible Fisheries

Assessment Hierarchy



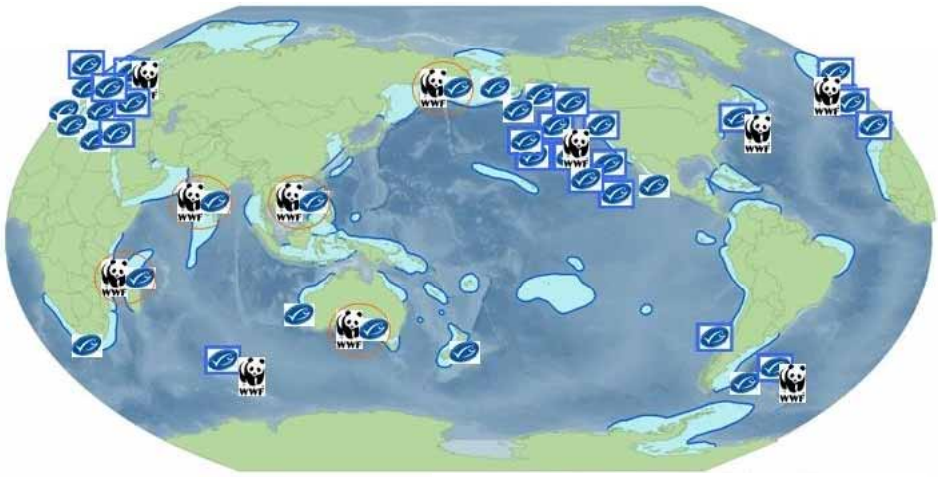
Passing the Standard

- Each performance indicator must score ≥ 60 (minimum pass, sustainable performance)
- Each Principle must achieve an aggregate score of ≥ 80 (best practice)
- For any indicator scoring from ≥ 60 to < 80, fishery client must agree to meet conditions to achieve specified outcomes over a defined period of time

Certifications and Assessments

around the world

WWF partnerships



MARINE STEWARDSHIP COUNCIL ©

The best environmental choice in seafood **www.msc.org**

Ecosystem-based Fisheries Assessment (EBFA) approach (Zhang et al. in prep)

Considerations for EBFA approach (Zhang et al. in prep)

- Not revolutionary, but evolutionary approach
- Capable of being applied w/ available information
- Precautionary, and environmentally sound
- Simple and pragmatic

Elements of the EBFA approach

- Two-tier assessment system
- Management objectives, indicators and reference points
- Risk indices and management status indices

2 tier assessment system

Tier	Method	Level of information
Tier 1	Quantitative analysis	High
Tier 2	Semi-quantitative or qualitative analysis	Low

Management Objectives of EBFAA

- **Maintain system sustainability**
- **Maintain biodiversity consistent with natural processes**
- **Protect and restore habitats of fish and prey**

Selecting Indicators

1. Ease of understanding by users

2. Susceptibility to influence thru management of human activities

3. Measurability using existing data or currently monitored information

- Selection of indicators was based on FAO (2000), MSC (Marine Stewardship Council, 2005) method, and ERA (Ecological Risk Assessment) from Australia (2005)

Identification of indicators : Sustainability

Attribute	Indicator	
	Tier 1 (8)	Tier 2 (12)
Biomass	- Biomass or CPUE	- CPUE
Fishing intensity	- Fishing mortality or Catch	- Restricted access - Fishery monitoring and sampling - Fishing method - Precautionary approach and sensitivity of stock assessment
Size at first capture	- Size at first capture	- Size at entry
Habitat size	- Habitat size	
Community structure	- FIB index	
Reproductive potential	- FRP index	
Productivity	- Total production of ecosystem	
Life history characteristics		- Maximum age or age at maturity - Adult habitat overlap with juvenile
Management		- Management plan for fishery - Management of IUU fishery
Recovery		- Recovery plan and period for depleted stocks
Genetic structure	- No. of spawning populations	- Population structure

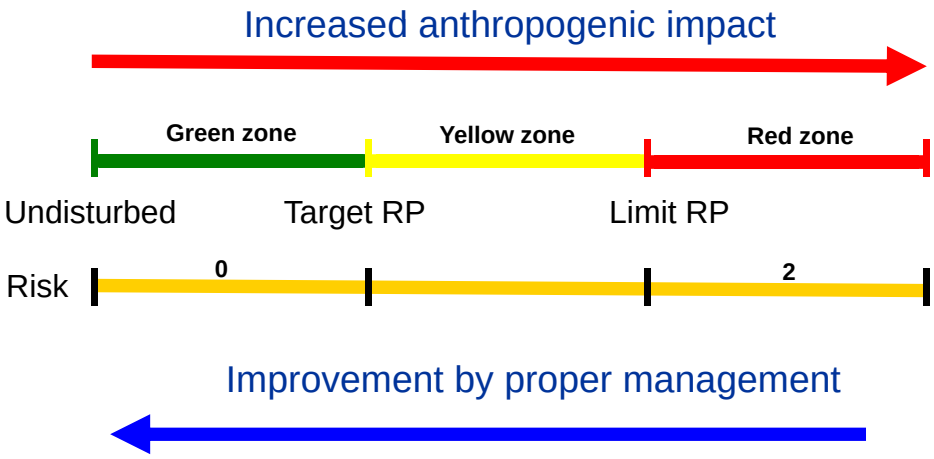
Tier 1 (Quantitative analysis)

Sustainability

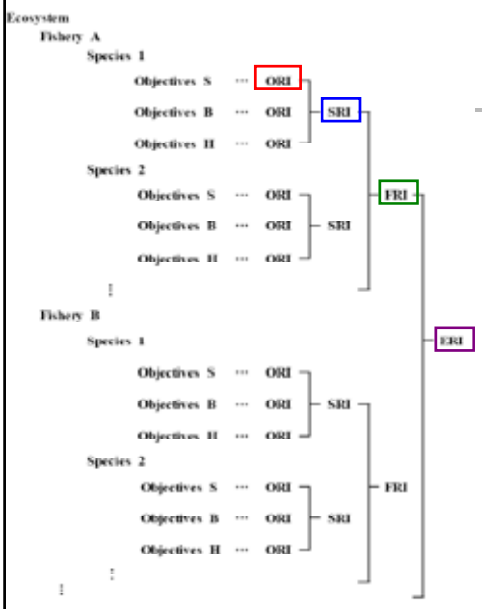
Attribute	Indicator	Reference points		
		Target (0)	Between (0 - 2)	Limit (2)
Biomass	Biomass (B)	$B \geq B_{40\%}$	$B_{40\%} > B \geq B_{35\%}$	$B < B_{35\%}$
	or CPUE (U)	$U \geq U_{ABC}$	$U_{ABC} > U \geq U_{limit}$ [1]	$U < U_{limit}$
Fishing intensity	Fishing mortality (F)	$F \leq F_{40\%}$(or $F_{0.1}$)	$F_{40\%}$ (or $F_{0.1}$) $< F \leq F_{MSY}$	$F > F_{MSY}$
	or Catch (C)	$C \leq ABC$	$ABC < C \leq MSY$	$C > MSY$
Size at first capture	Age at first capture (t)	$t \geq t_{target}$	$t_{target} > t \geq t_{limit}$ [2]	$t < t_{limit}$
Habitat size	Habitat size (H)	$H \geq H_{target}$	$H_{target} > H \geq H_{limit}$ [3]	$H < H_{limit}$
Community structure	FIB index	$FIB \geq FIB_{target}$	$FIB_{target} > FIB \geq FIB_{limit}$ [4]	$FIB < FIB_{limit}$
Reproductive potential	FRP index	$FRP \geq FRP_{target}$	$FRP_{target} > FRP \geq FRP_{limit}$ [5]	$FRP < FRP_{limit}$
Productivity	Total production of ecosystem (P)	$P \geq P_{target}$	$P_{target} > P \geq P_{limit}$ [6]	$P < P_{limit}$
Genetic structure	No. of spawning populations (SP)	$SP \geq SP_{target}$	$SP_{target} > SP \geq SP_{limit}$ [7]	$SP < SP_{limit}$

[1] U_{limit} : U_{ABC} – SD, U_{ABC} was estimated from stock assessment.
[2] t_{limit} : $0.5t_{target}$, t_{target} was optimal age at first capture from Beverton-Holt yield per recruit analysis.
[3] H_{limit} : H_{target} – 2SD, H_{target} was mean plus one standard deviation of habitat size from 1990 to 2006.
[4] FIB_{limit} : FIB_{target} – 2SD, FIB_{target} was mean plus one standard deviation of FIB indices from 1990 to 2006.
[5] FRP_{limit} : FRP_{target} – 2SD, FRP_{target} was mean plus one standard deviation of FRP indices from 1990 to 2006.
[6] P_{limit} : $0.5_{Ptarget}$,
[7] SP_{limit} : $0.5SP_{target1}$

Reference Points (RP) and Risks



Nested risk indices of EBFA



$$ORI = \frac{\sum_{i=1}^{n} I_i W_i}{\sum_{i=1}^{n} W_i}$$

I_i : Score of indicator i
W_i : Weighting factor of indicator i
n : Number of indicators

$$SRI = \lambda_S ORI_S + \lambda_B ORI_B + \lambda_H ORI_H$$

λ_S λ_H : Weighting value for objectives $\sum \lambda = 1.0$
ORI_S : Sustainability risk index
ORI_B : Biodiversity risk index
ORI_H : Habitat risk index

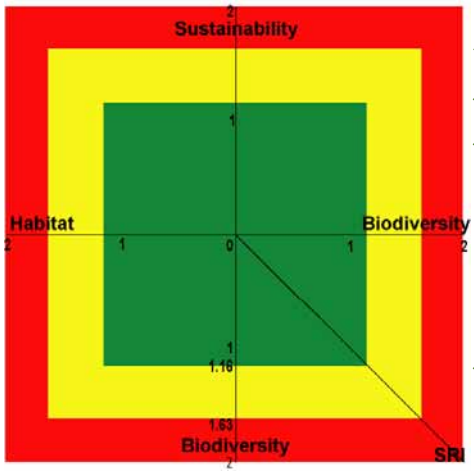
$$FRI = \frac{\sum B_i SRI_i}{\sum B_i}$$

B_i : Biomass or biomass index of species i

$$ERI = \frac{\sum C_i FRI_i}{\sum C_i}$$

C_i : Catch of fishery

Risk Assessment Diagram: examining indices to determine areas in needs of management action



- Each ORI has score from 0 to 2
- Diagonal bisecting line shows SRI value
- Each colored zone with boundary values of 1.16 and 1.63
  - has same area --> same probability for points to be in each zone
  - represents degree of safety in ecosystem
- Red and yellow zones require corrective management plans to move to green zone

Management status indices

$$MI_O = \frac{ORI_t - ORI_{t+i}}{ORI_t} \times 100$$

$$MI_S = \frac{SRI_t - SRI_{t+i}}{SRI_t} \times 100$$

$$MI_F = \frac{FRI_t - FRI_{t+i}}{FRI_t} \times 100$$

$$MI_E = \frac{ERI_t - ERI_{t+i}}{ERI_t} \times 100$$

- Management improvement can be examined by Wilcoxon non-parametic test for differences in risk indices.

Steps for EBFA approach

1. Identifying ecosystem and fisheries

   eg., EBS, trawl fishery and longline fishery

2. Identifying species based on tier system

   Tier 1 : 9 species such as walleye pollock

   Tier 2 : 28 species such as POP

3. Identifying indicators

   Indicators for each management objectives

Steps for EBFA approach (cont.)

4. Setting reference points
5. Scoring risks

   Using continuous and discrete methods

6. Calculating ORI, SRI and FRI, and plotting risk diagrams
7. Calculating MIs to compare

Assessing indicators using reference points

Example _ Sustainability_Biomass (Tier 1)

Objectives	Attribute	Indicator	Reference points			Weight
			Target (0)	Limit (1)	Beyond Limit (2)	
Sustainability	Biomass	Biomass (B)	$B \geq B_{40\%}$	$B_{40\%} > B \geq B_{35\%}$	$B < B_{35\%}$	***

In Tongyeong marine ranch

Jacopever rockfish : $B_{40\%}$: 527.6mt

$B_{35\%}$: 461.62mt

Biomass in 1998 : 110mt-Beyond limit, Risk score: 2

Biomass in 2006 : 833mt-Target, Risk score: 0

Result of tier 1 assessment

Jacopever rockfish

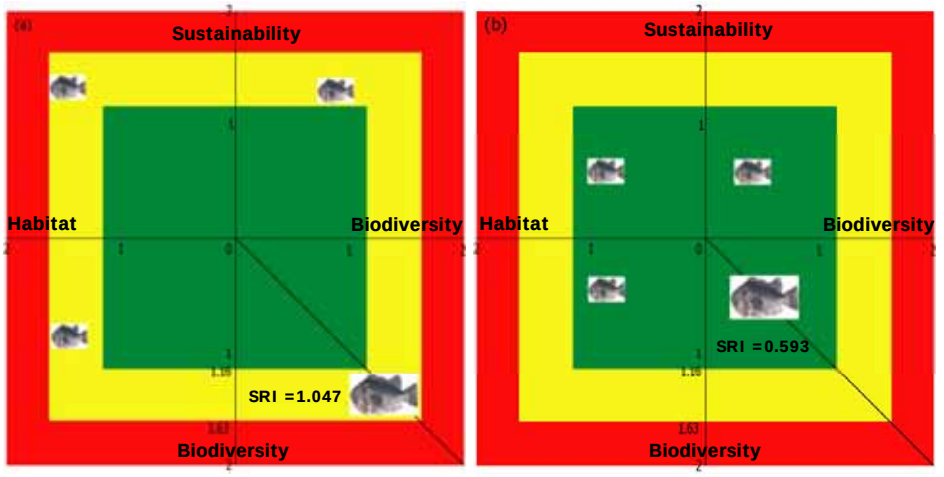
Objectives	ORI (Zone)		MI	Significance
	1998	2006		
Sustainability	1.333(Yellow)	0.583(Green)	56.25	*
Biodiversity	1.571(Yellow)	0.857(Green)	45.45	**
Habitat	1.375(Yellow)	0.375(Green)	72.73	*
SRI	1.407(Yellow)	0.593(Green)	57.89	**

*** : denotes a significant difference at α = 0.05 level**

**** : denotes a significant difference at α = 0.01 level**

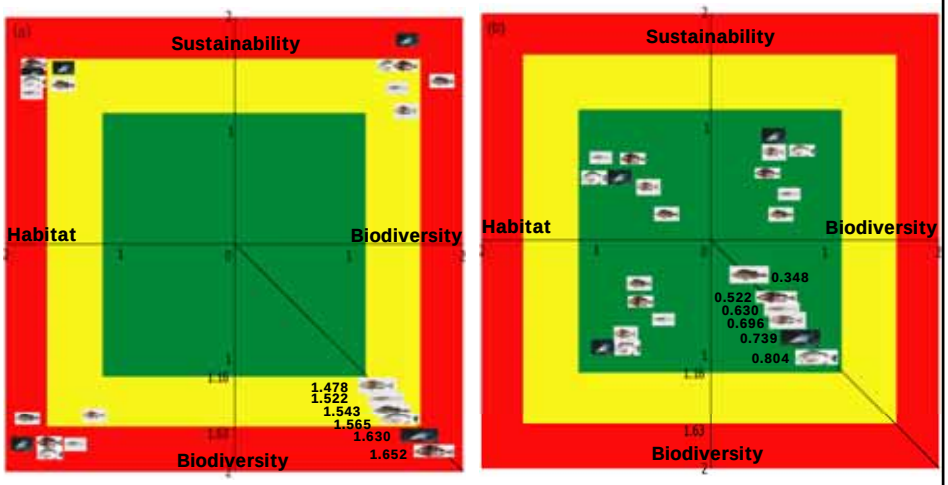
NS : denotes non-significant

ORI diagram for Jacopever rockfish by Tier 1 assessment



1998 2006

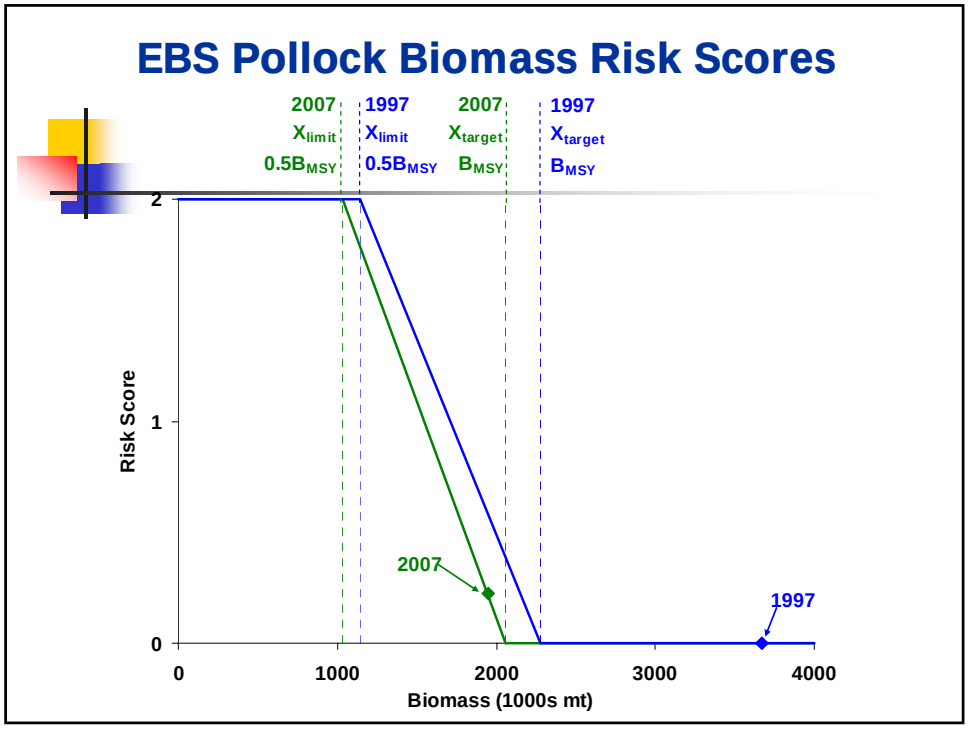
ORI diagram for by-catch species by Tier 2 assessment

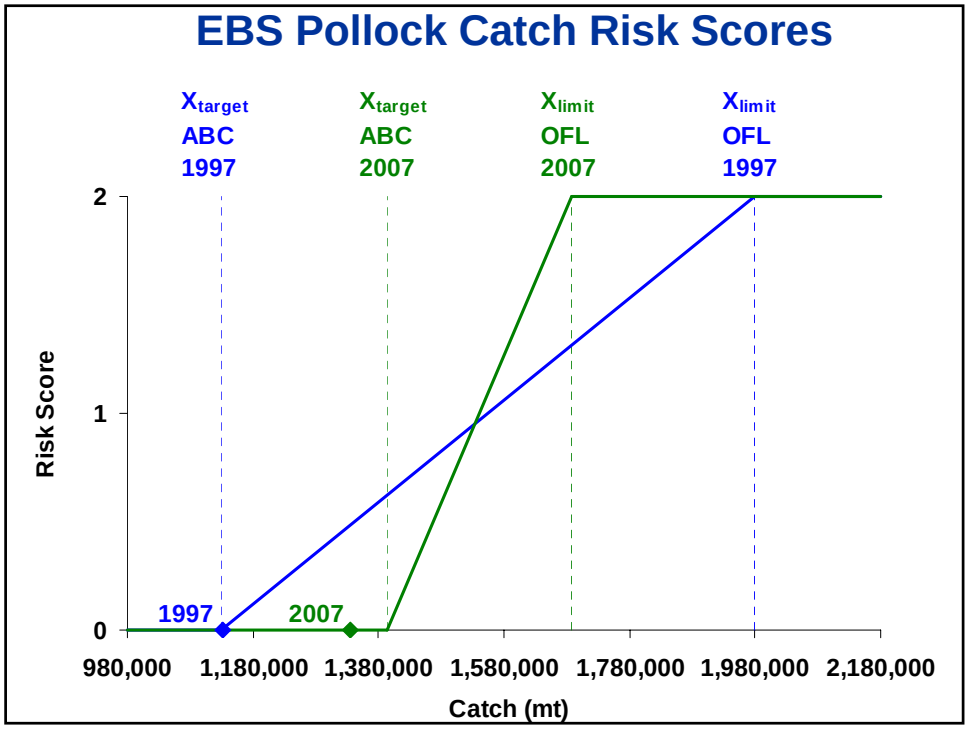


Black rockfish Red sea bream Common seabass

Black seabream Yellow tail Rock bream

1998 2006


EBS Pollock Biomass Risk Scores
2007
X_{limit}
$0.5B_{MSY}$
1997
X_{limit}
$0.5B_{MSY}$
2007
X_{target}
B_{MSY}
1997
X_{target}
B_{MSY}
Risk Score
2
1
0
2007
1997
0
1000
2000
3000
4000
Biomass (1000s mt)


EBS Pollock Catch Risk Scores
X_{target}
ABC
1997
X_{target}
ABC
2007
X_{limit}
OFL
2007
X_{limit}
OFL
1997
Risk Score
2
1
0
1997
2007
980,000
1,180,000
1,380,000
1,580,000
1,780,000
1,980,000
2,180,000
Catch (mt)

Discussion and Conclusion

- Integrated holistic approaches such as ERAEF, MSC Approach, EBFA, are useful to assess species and fisheries concerned
- Further comprehensive studies on indicators and reference points required
- Socio-economic status should be explicitly included

Thank you!