



The Ecosystem Approach to Fisheries

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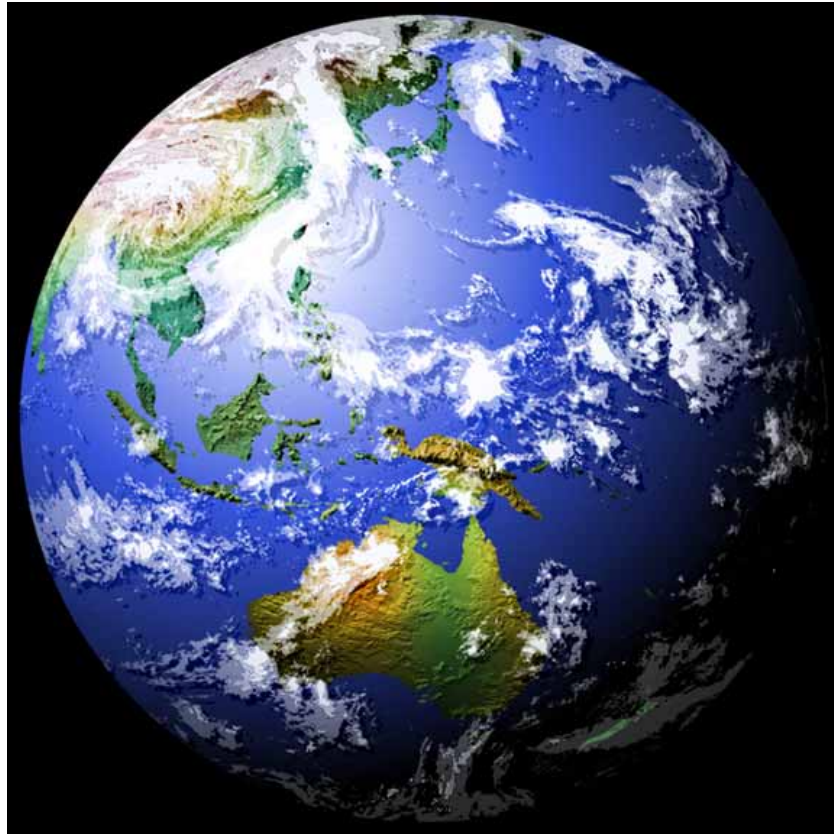
The Ecosystem Approach to Fisheries

Outline

- Marine ecosystems, our use of them, the challenges to sustainable use, and the need for change
- What change is needed?
 - The goals and approach
 - Ecosystem Based Management (EBM)
 - Ecosystem Based Fisheries Management (EBFM)
 - Ecosystem Approach to Fisheries (EAF)
 - The management system
 - The scientific input
- Some tools and example applications



The oceans, life and humans – the blue planet



Oceans have supported life for millions of years and human activities for thousands of years

- Produced the original oxygen for the atmosphere
- The main control of atmospheric composition and climate
- Central to chemical cycles
- Home to by far the most species and biodiversity
- Contain the planet's largest habitats



The oceans, life and humans – our use of the ocean



Humans have used the oceans for thousands of years to enormous benefit

- food – from algae to whales
- materials – from mangroves and salt to corals and shells
- transport – for trade, exploration and conquest
- recreation
- inspiration

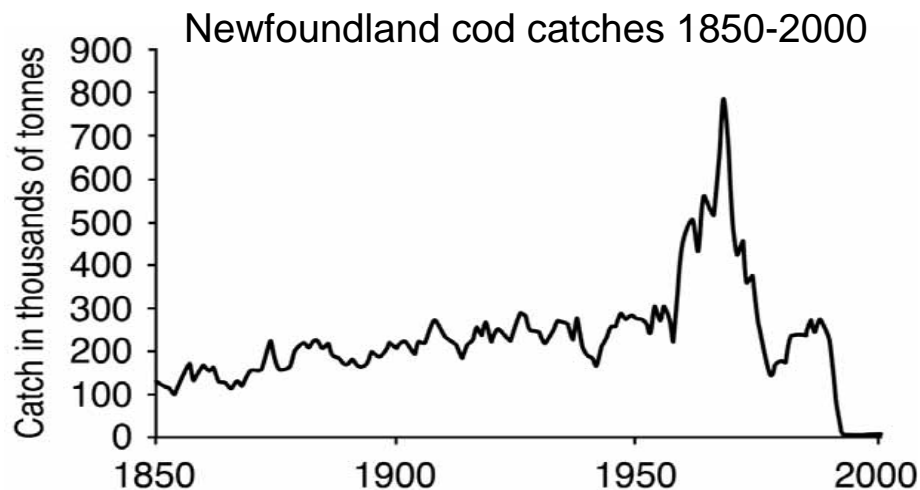




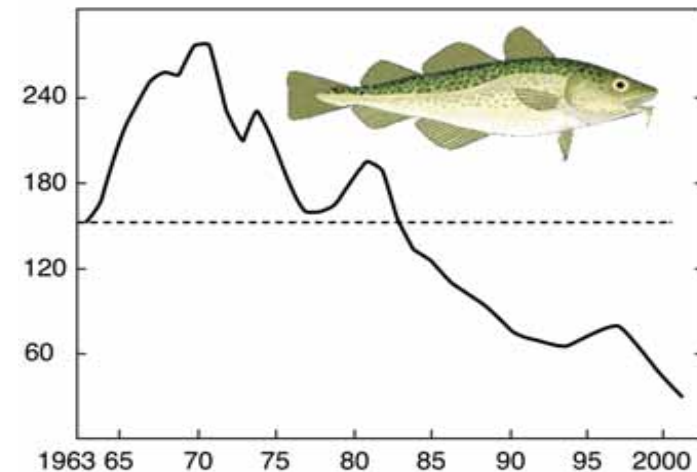
What is going on beneath the surface?

Too many overfished stocks

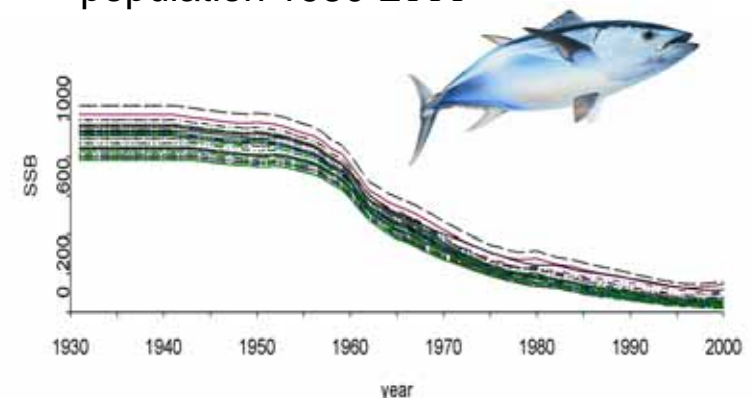
- 25% of world stocks are overfished
- some grossly overfished – populations reduced to less than 15% of unfished abundance
- some that have provided sustainable catches for hundreds of years previously
- many with serious social and economic consequences to human communities



North Sea cod breeding population 1963-2000



Southern Bluefin Tuna breeding population 1930-2000



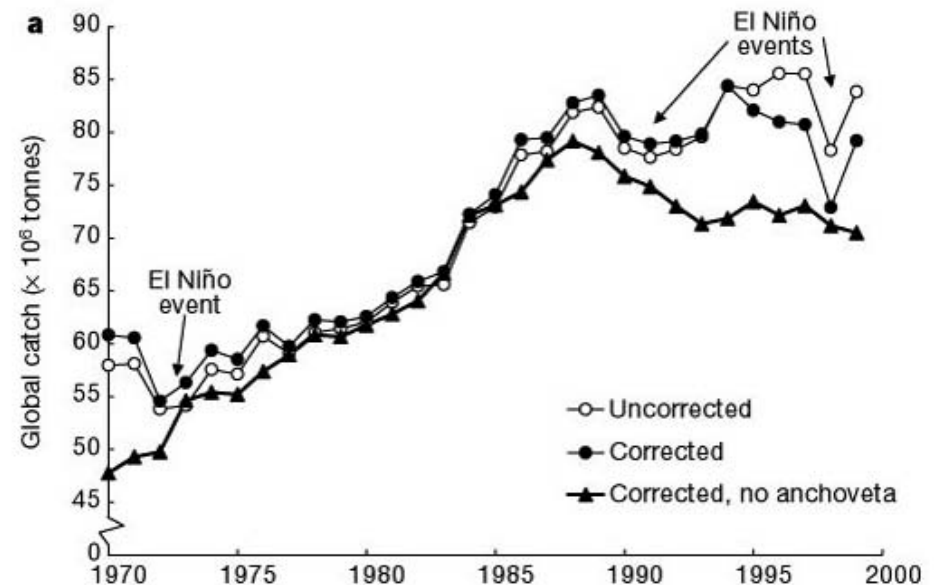


What is going on beneath the surface?

Global catches stable or declining

Despite

- fishing in more places in the sea
- fishing more species
- fishing further down the food web (e.g. more small species)
- retaining more of what was discarded
- fishing with more efficient and effective technology.





What is going on beneath the surface?

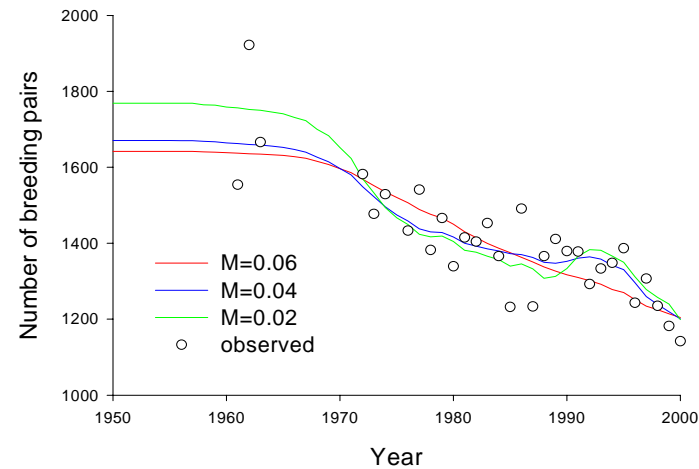
Many threatened and extinct marine “icon” species

Many species of marine mammals, seabirds and turtles are threatened.

The main causes

- direct harvest
- by-catch
- habitat loss and introduced species
- contaminants and pollutants

South Georgia Wandering albatross



Extinct . . .





What is going on beneath the surface?

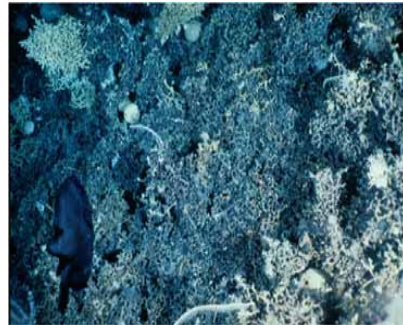
Coastal and seabed habitat modification

Cities, industry and marinas in coastal habitats

Development from 1937



Seabed impacts of trawling



Coral habitat on untrawled and trawled seamounts

Coastal sedimentation



Before dredging and the 100 km sediment plume during dredging



What is going on beneath the surface?

Nutrient and contaminant pollution from the land

Increasing amounts of nutrients and contaminants from the land and coast

- heavy metals, pathogens, synthetic organic chemicals

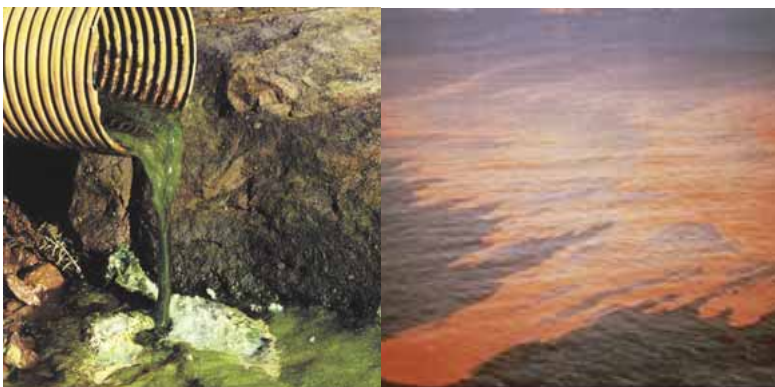
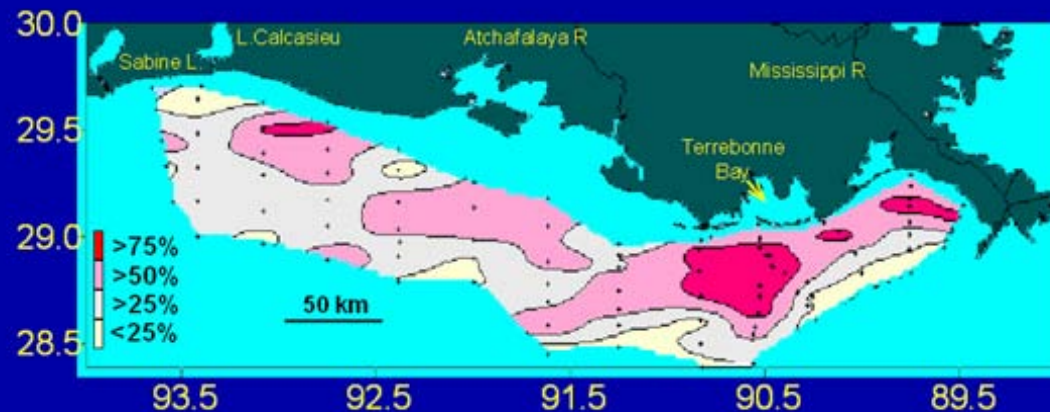
⇒ algal blooms, bio-fouling, poisoning, disrupted reproduction

⇒ major ecosystem changes

- Black Sea, Gulf of Mexico oxygen depletion
- Switching N to P limitation of oceanic phytoplankton?

Mississippi River discharge into Gulf of Mexico

Bottom-Water Hypoxia Frequency of Mid-Summer Occurrence 1985 - 1999



What is going on beneath the surface? Introduced marine species

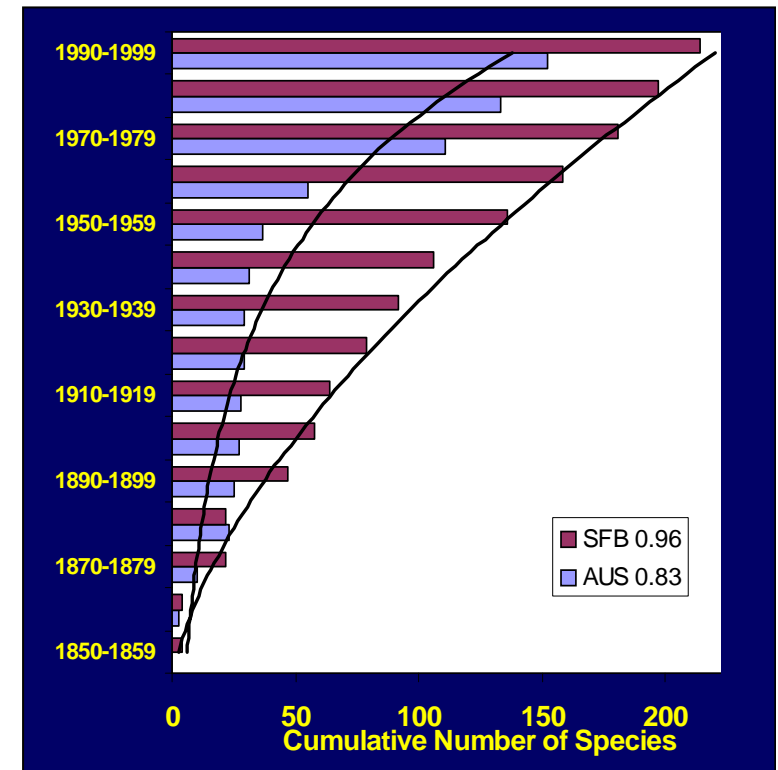


Increasing number of marine species introductions between ecosystems mainly due to

- shipping
- aquaculture
- aquarium releases



Number of species in two coastal systems – Australia and USA





What is going on beneath the surface?

Climate change

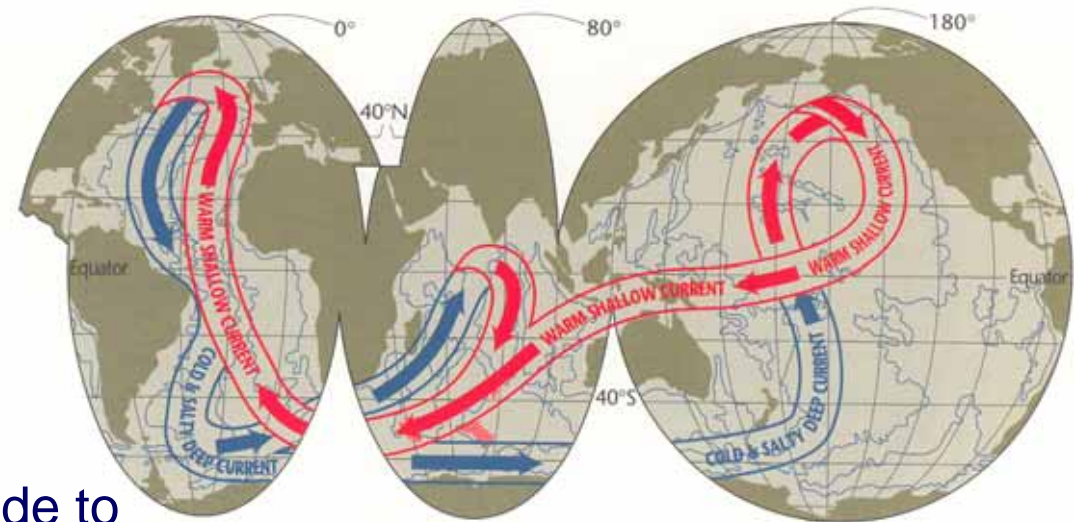
Profound change is predicted over the next few human generations

- whole current systems strengthened or stopped
- reduced oxygenation of the deep and middle-depth oceans
- changed species distributions
- changed ecosystems

The past will not be a good guide to the future as these things happen

- they are starting to happen, it is a question of how far they go

⇒ sustainable use with changing ecological processes
(ie non-stationarity)





What is going on beneath the surface?

The present situation

Growth in the human population, economic affluence and technology in the past about 60 years has hugely extended our use and impacts on ocean ecosystems

In that short period we have developed and demonstrated the capacity to fundamentally change marine ecosystems

- locally and globally

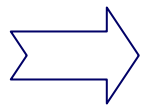
We must change the way we use and manage the oceans if we are to achieve the goals of sustainable development



What is going on beneath the surface?

Sustainable Development - a reminder

- "Sustainable development is ... a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as the present needs."
(Brundtland Report 1986)



- Provides inter-generational equity
- Maintain options and reversibility on human generation time scales
- Addresses long-term not just short-term needs and issues

The current extent and pattern of marine and coastal development
is not sustainable



What is going on beneath the surface?

The future

What we do in the next 20 years will determine what is possible in the following about 100 years

- multiple pressures and impacts, not just fisheries
- species introductions and serious climate change are effectively irreversible and are best avoided
- other uses and impacts are reversible and potentially manageable
 - few marine extinctions
 - depleted species have been recovered
 - degraded habitats and water quality have been recovered
 - but recoveries are relatively few and have taken serious management measures



What is going on beneath the surface?

Sustainability – what will it take?

Social awareness and commitment to a sustainable future

- recognition and acceptance that we have a problem
- reflected in goals, frameworks, agreements and institutions
- Being less greedy and prepared to leave more for other species, future human generations and a fully functional ecosystem
- Transparent and participatory decision-making
- Anticipatory and precautionary decision-making
- Decision-making that emphasises long-term outcomes and benefits, not just short term
- Clear limits and standards for sustainable impacts and use
- Regulators with appropriate input and/or output controls
- Regulators capable of making and implementing decisions
- Managing safely within our understanding
 - recognise uncertainties and their effects
 - manage uses within limits despite uncertainties



Sustainability – what will it take?

Many of the changes needed relate to the management system

Science is only a part of what is needed, although it is important

The principles, goals and frameworks

- EBM, EBFM, EAF

The management system

1. structure, transparency and participation in decision-making
2. precaution
3. sustainability standards
4. management instruments

Science support

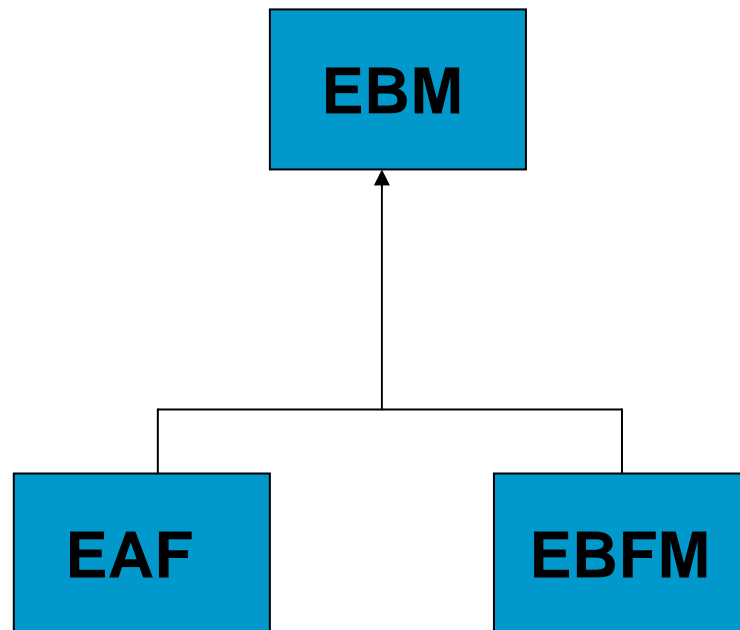
- Success despite uncertainty
- Ecological Risk Assessment and Management Strategy Evaluation



Principles, goals and frameworks of approach

Ecosystem Based Management (EBM), Ecosystem Based Fishery Management (EBFM), Ecosystem Approach to Fisheries (EAF)

Re-discovering and making more explicit Sustainable Development



Two ways of going about it

Ecosystem Based Management

- sets goals and intentions for Sustainable Development of regional ecosystems
- balancing all uses of ecosystem
- delivered through Integrated Oceans Management or Multiple Use Management
- 'manage people not ecosystems'

Ecosystem Approach to Fisheries (EAF) and Ecosystem Based Fisheries Management (EBFM)

- sets goals and intentions for Sustainable Development of fisheries
- fisheries contribution to EBM
- other industry sectors need to make similar contributions to EBM



Principles, goals and frameworks of approach

Ecosystem Based Fishery Management (EBFM)

“EBFM is a new direction for fishery management, essentially reversing the order of management priorities to start with the ecosystem rather than the target species”

Pikitch et al 2004

Sustain healthy marine ecosystems and the fisheries they support

1. avoid degradation of ecosystems
2. minimise the risk of irreversible change
3. obtain socioeconomic benefits without compromising the ecosystem
4. generate knowledge to understand the consequences of human actions
 - Where knowledge is insufficient adopt precautionary management measures that favour the ecosystem



Principles, goals and frameworks of approach

Ecosystem Based Fishery Management (EBFM)

- Apply to fisheries individually and the combination of all fisheries in an ecosystem
- Consider and account for the impacts of non-fishery activities
- Address key ecosystem components
 - ecosystem structure and processes
 - trophic interactions and dependencies
 - habitats
 - protected and endangered species
 - non-target species (by-catch = retained by-product and discards)
 - target species
- Develop and use
 - shared vision and objectives among stakeholders
 - standards, reference points and control rules analogous to single species decision criteria
 - adaptive management and precaution
 - ocean zoning, specifying the type and level of allowable human activity



Principles, goals and frameworks of approach

Ecosystem Based Fishery Management (EBFM)

“EBFM can be implemented in systems with different levels of information”

- data poor situations..... “natural history and general knowledge to develop precautionary set-asides or safety margins for catch and area of access.”
- moderate amounts of data..... “effective single species management with the addition precautionary measures for unknown ecosystem components” “address all ecosystem components”
- future development of “ecosystem-based reference points and measures of system status for more comprehensive EBFM”
 - more comprehensive use of ecological principles and models foreshadowed by Mangel and Levin 2005
 - EBFM, like Sustainable Development, is a journey or a directed change



Principles, goals and frameworks of approach

Ecosystem Approach to Fisheries (EAF)

Developed by FAO (2003) to:

- bridge target stock oriented fishery management and the emerging ecosystem-based approaches
- more explicitly recognize the interdependence between human well-being and ecosystem well-being
- recognise that rigorously target stock oriented management would solve many current fisheries problems
- implement many prior agreements in the 1995 FAO Code of Conduct for Responsible Fishing



Principles, goals and frameworks of approach

Ecosystem Approach to Fisheries (EAF)

As for EBFM:

Address key ecosystem elements:

- retained species (target and by-product)
- non-retained by-catch
- habitats
- ecosystem structure and processes

Develop and use:

- stakeholder consultation and participation
- operational (measurable) objectives, indicators and reference points for the ecosystem elements
- decision rules for the management measures
- planned adaptive management



Principles, goals and frameworks of approach

The practicality

EAF and the initial stages of EBFM are much the same

- the approaches will develop and evolve
- as will observational and analytic capability
- but implementation can and must begin with the information currently available

Many activities and observations are already in place so marginal increase in management cost relatively low

- better integration, analysis, decision tools, data management
- some prioritized and targeted extra observations
- strengthened and extended reference points and control rules
- increased use of spatial management

Increased precaution in decision making is necessary

- more ecosystem components considered and understanding of them is weak
- more active balancing of catch, management cost and risk
- usually lower fishing mortalities



Sustainability – what will it take?

Implementing EAF/EBFM

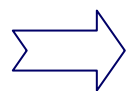
With those EAF/EBFM goals and context, how do we move forward?

The management system

1. structure, transparency and participation in decision-making
2. precaution
3. management instruments

Science support

- Success despite uncertainty
- Ecological Risk Assessment and Management Strategy Evaluation



Together developing sustainability standards

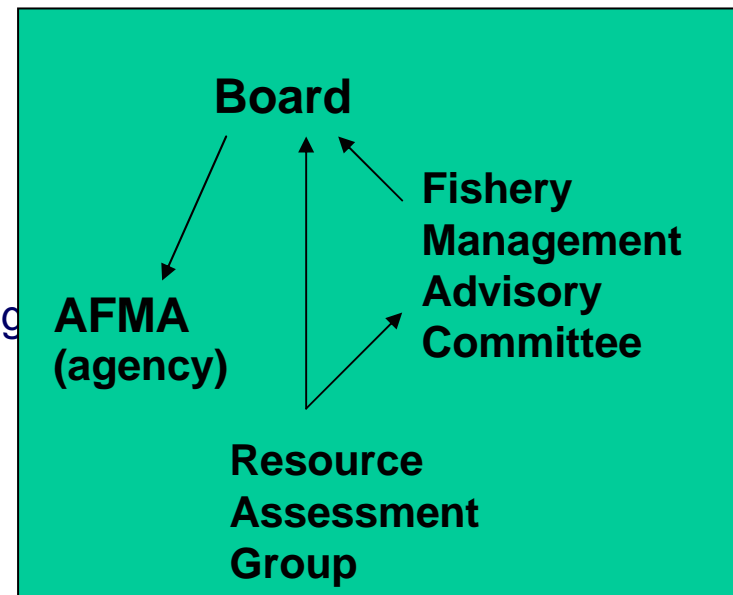
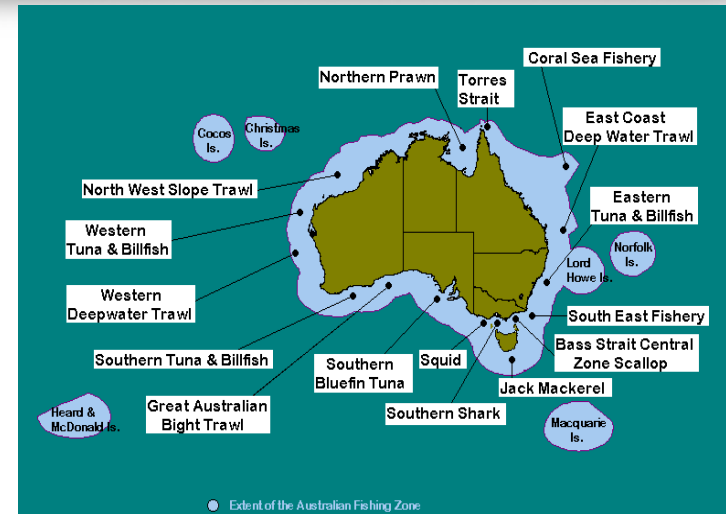


Sustainability – what will it take?

The management system

1. Structure, transparency and participation in decision-making

- The one I know best
- Australian Fisheries Management Authority
 - federal Statutory Authority for day-to-day management at arms length from politics
 - objectives of ecological sustainability and economic efficiency
- An expertise based Board
 - expertise in fishing industry, natural resource management, marine science, business
 - no more than 2 of 5 Directors directly involved with the fishing industry
- A partnership approach
 - industry, scientific, conservation, and recreational fishing interests on advisory committees
- Science provided independently from AMFA and reported directly to Board
- Sustainability audit by Environment Dept



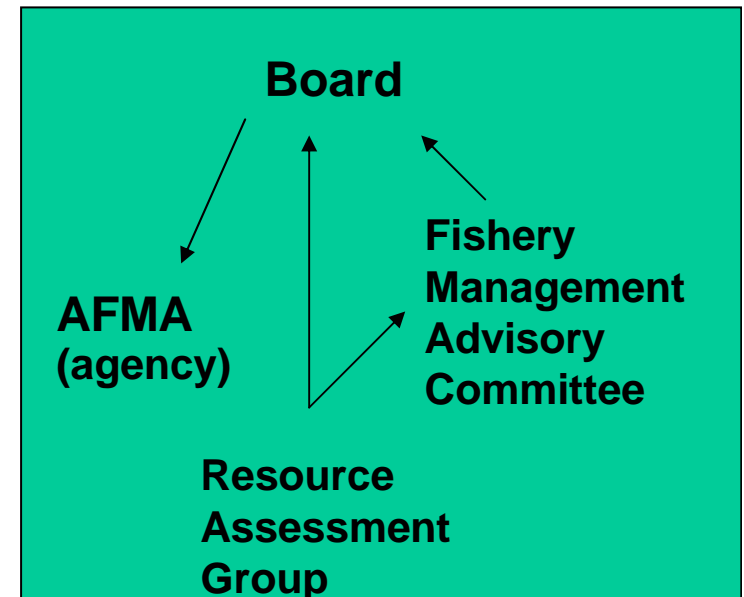


Sustainability – what will it take? The management system

1. Structure, transparency and participation in decision-making

The wide stakeholder participation and cross-group communication is critical

- a Board member attends MACs
 - lead scientist from RAG is MAC member
 - industry on RAGs, MACs, Board
 - conservation interests on RAGs, MACs, and Board Environment Committee
- finding and owning best outcomes
 - management strategy evaluation
 - ecological risk assessment
 - balancing strengths and weaknesses of ‘top-down’ and ‘bottom-up’
 - setting frameworks and parameters vs cost effective solutions and implementation
 - more formal co-management is a goal





Sustainability – what will it take?

The management system

2. precaution in decision-making

- This is the topic where we all have much remaining to do
- Guidance from FAO Guidelines (1995) mainly remains a ‘light on the hill’
 - consider needs of future generations and avoid potentially irreversible changes
 - where impact is uncertain priority should be given to preserving the stock
 - corrective measures should achieve their purpose in less than 2-3 decades
 - prior identification of undesirable outcomes and measures to avoid them
 - prior authorization of all fishing activities
 - harvesting capacity commensurate with sustainable yields
 - management plans incorporating the above for each fishery
- Fishery management systems without this are **anti-precautionary**



Sustainability – what will it take?

The management system

2. precaution in decision-making

A common feature in the 10 fishery management success cases identified by Hilborn et al (2003):

- The fisheries “use lower exploitation rates that deliberately do not attempt to maximize biological yield”.

- Western Australian lobster
- Tasmanian (Aust) abalone
- NZ Hoki
- NZ lobster
- NZ orange roughy
- US/Can Pacific halibut
- Bering Sea (US) Pacific cod
- Alaska salmon
- Bering Sea (US) pollock
- Falkland squid (UK)



Sustainability – what will it take?

The management system

2. precaution in decision-making

For the Australian Fisheries Management Authority:

Practical implementation through Ecological Risk Assessment (ERA) and Management Strategy Evaluation (MSE) applications

- What constitutes high, medium or low risk?
 - How to score risk in the absence of data?
 - How robust must the management strategy be to uncertainty?
 - how certain that it will achieve desired outcomes
 - how certain that it will avoid undesired outcomes
-
- initial choices made by Resource Assessment Groups
 - reviewed and commented on by the Management Advisory Committees
 - final approval and operational standards through the Board



Sustainability – what will it take?

The management system

3. regulators have and use appropriate management tools

Management tools to provide

- Equitable allocation and reallocation, effective management control, align economic incentives with sustainability
- There is no ‘silver bullet’ and a mix is necessary
- Beware of the interest group with a single solution
 - be it property rights, new technology, ‘designer ecosystems’, economic rationalism, market incentives, or marine reserves

The range of management tools are well known



Sustainability – what will it take?

The management system

3. regulators have and use appropriate management tools

- Input and/or output controls
 - participants, effort, gear, area, species, catch
 - ‘open access’ is known to fail
 - match catching capacity to ecological capacity
- Individual transferability to avoid the ‘race to fish’ and provide property-right incentives
 - effort, area, quota
 - combine strengths and weaknesses of ‘top-down’ and ‘bottom-up’ approaches
- Marine Protected Areas (reserves)
 - primarily for biodiversity, conservation, wilderness value
 - a fishery management tool of last resort?



Sustainability – what will it take?

Scientific support

Science can

- Increase understanding
 - Help deal with lack of understanding
 - Need for management success despite uncertainty
 - the pressing immediate issue
1. **Ecological Risk Assessment** to identify and prioritize risks
 - what risk and focus
 2. **Management Strategy Evaluation** to design and test adaptive management strategies
 - strategies with a high chance of success



Sustainability – what will it take?

Scientific support

1. Ecological Risk Assessment (ERA)

Framework and methods developed by Hobday, Smith, Stobutzki and others for Australian Federally managed fisheries

- Applied to 14 fisheries, 25 sub-fisheries, 1,400 species
- Mostly 'data poor' by US, Canadian or ICES standards

Address components of EAF/EBFM

- target species
- by-product and by-catch species
- protected, endangered and threatened (PET) species
- habitats
- ecological communities (including food-webs)



Sustainability – what will it take?

Scientific support Ecological Risk Assessment (ERA)

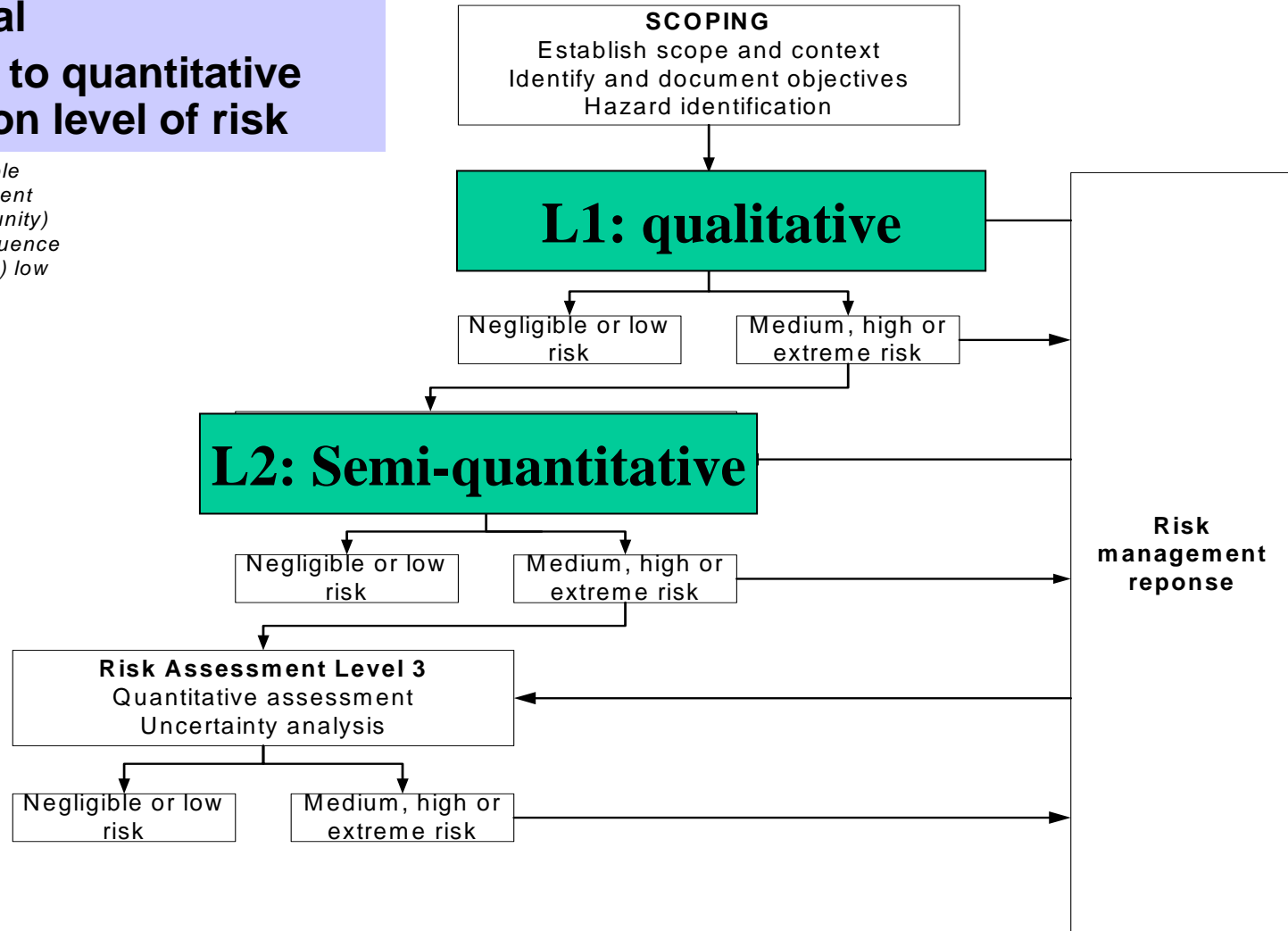
ERA Framework

- hierarchical
- qualitative to quantitative depending on level of risk

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





Sustainability – what will it take?

Scientific support Ecological Risk Assessment (ERA)

ERA Level 1 - qualitative

Scale ~> Impact ~> Consequence Analysis (SICA)

Identify 'units of analysis' for each ecosystem component (target species, bycatch species, PET species, habitats, communities)

For each fishing activity and 'unit of analysis':

- temporal and spatial scale and overlap of activity and unit
- impact of activity through credible scenarios \Rightarrow impact score & certainty
- select consequence score based on worst case for most vulnerable unit to each activity

Risk \approx consequence

- Exposure-Effects approach rather than Likelihood-Consequence

Extensive default tables of consequence scores

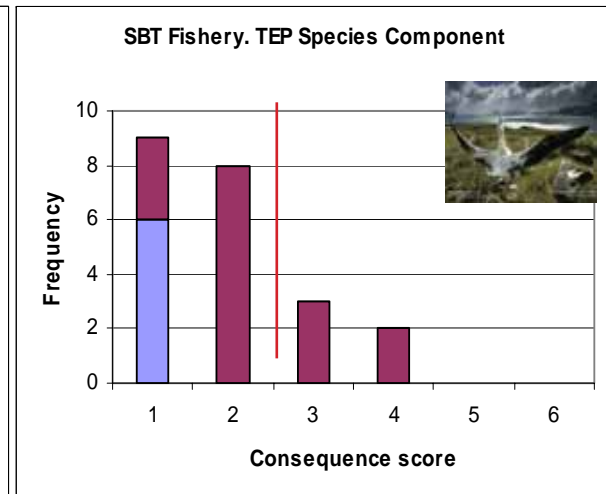
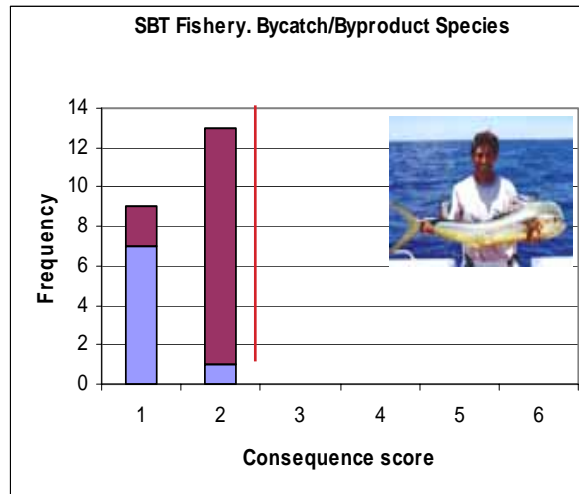
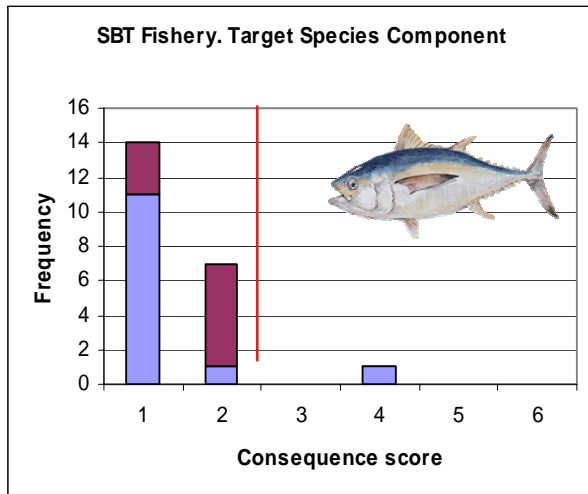
- for 'units of analysis' and impact scores
- a standard for operational precaution from qualitative analysis



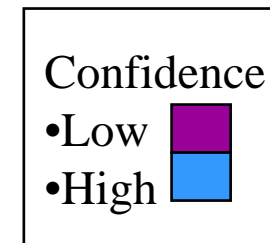
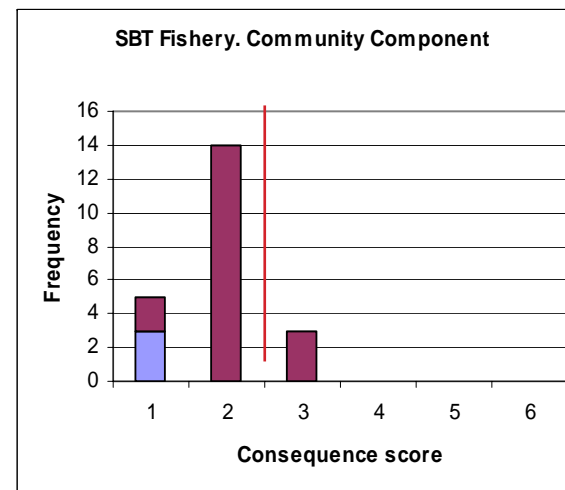
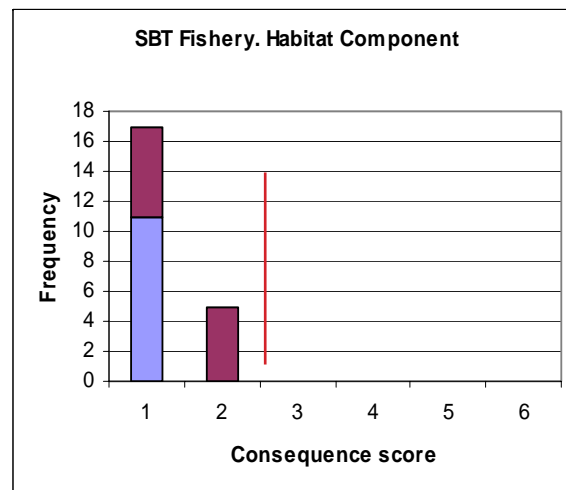
Sustainability – what will it take?

Scientific support Ecological Risk Assessment (ERA)

Level 1 ERA – example for a tuna fishery



- For each component
- risk for each unit of analysis
- Threshold risk level defined



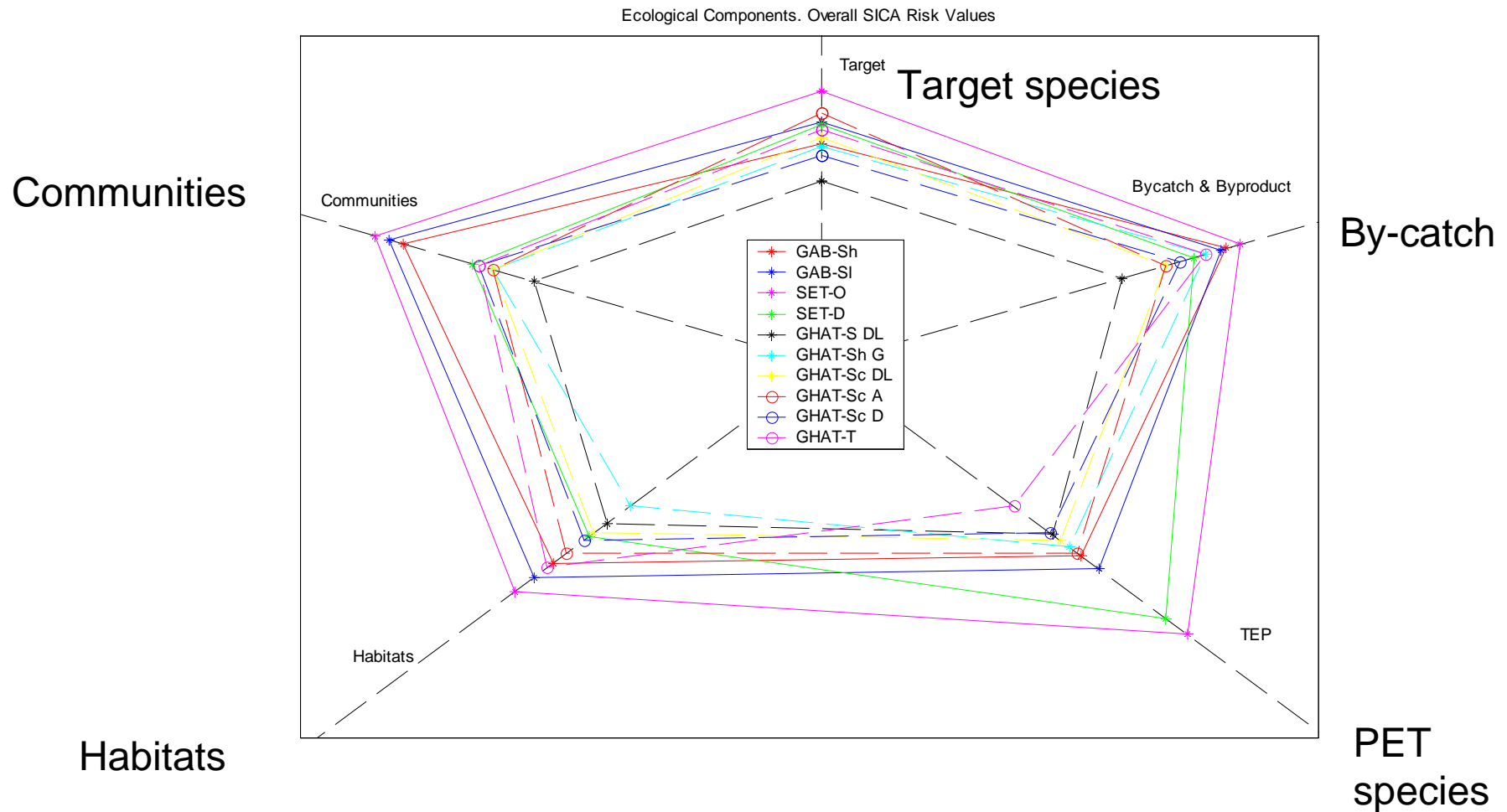


Sustainability – what will it take?

Scientific support

Ecological Risk Assessment (ERA)

Level 1 ERA – comparing several fisheries by risk to components





Sustainability – what will it take?

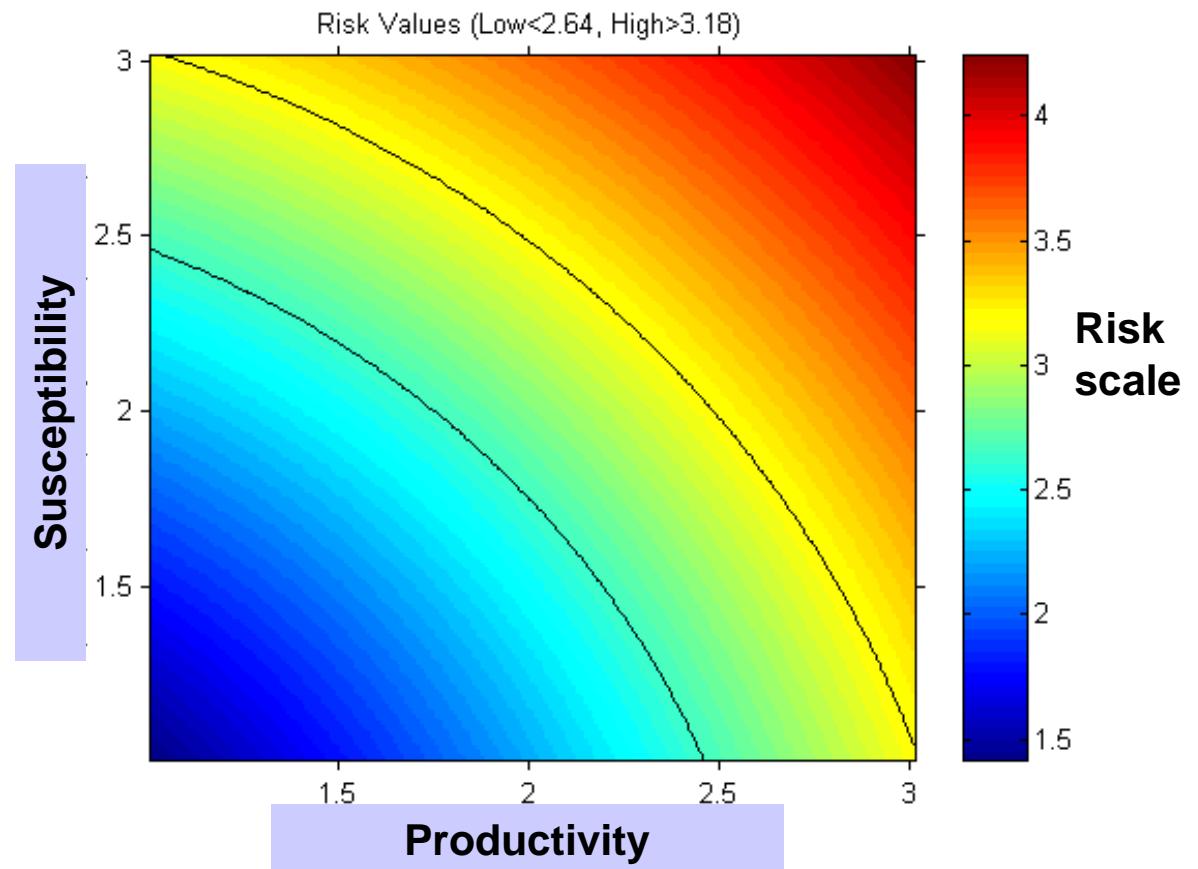
Scientific support Ecological Risk Assessment (ERA)

ERA Level 2 – semi-qualitative

Productivity-Susceptibility Analysis (PSA)

Risk to an ecological unit depends on two characteristics:

- **susceptibility** or “exposure” to the fishing activity
- **productivity** giving the rate of recover after depletion or damage by the fishing activity





Sustainability – what will it take?

Scientific support Ecological Risk Assessment (ERA)

ERA Level 2 – Productivity-Susceptibility Analysis (PSA)

For each fishing activity and unit of each ecosystem component

- standardised score for productivity and susceptibility (H,M,L)
 - mix of empirical, statistical, sub-model analysis for scores
 - life history, recovery time, food-web attributes and +/- models
 - missing values for a unit are scored at the most pessimistic level
-
- Database of attributes for productivity and susceptibility
 - ~1600 species, ~100 habitats, ~20 communities
 - based on existing data
 - Tables for productivity and susceptibility scores (risk) in different situations
 - a standard for operational precaution from qualitative analysis

Habitat types for Southeast Australia

Igneous rock with large epifauna (3 types)
Sedimentary rock with large epifauna (11 types)

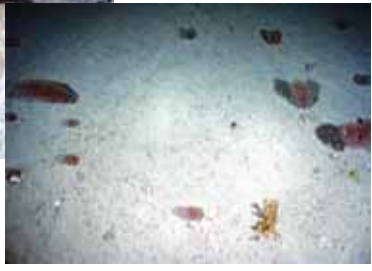
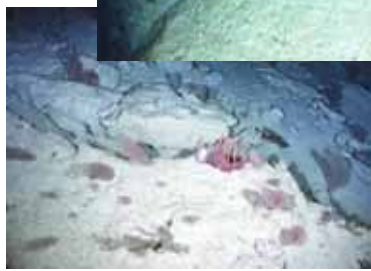
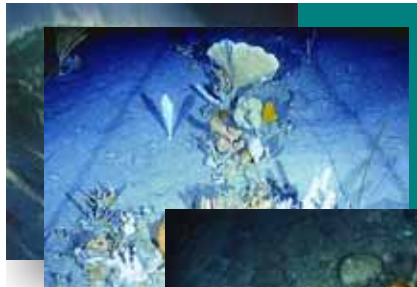
Boulders supporting crinoids; coarse sediments supporting octocorals (5 types)

101 habitat types as 'units of analysis'

Sediments, variously current/ wave rippled/ bioturbated supporting large epifauna (sponges, octocorals, crinoids) (19 types)

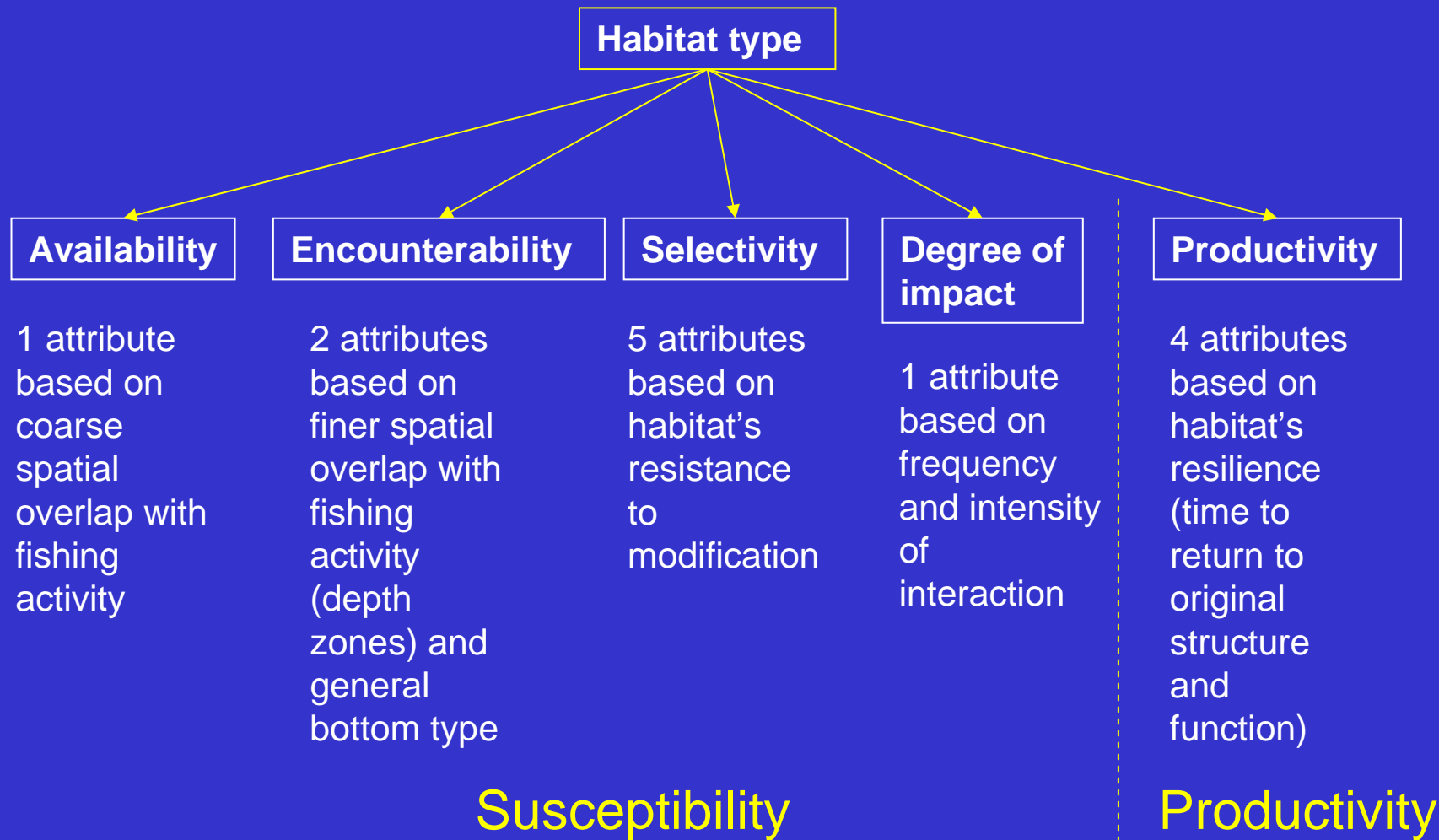
Sediments, various morphology/ supporting small/ encrusting/ mobile epifauna (58 types)

Inner shelf sediments supporting small/ encrusting epifauna (5 types)





Level 2 (PSA): attributes for assessment of susceptibility and productivity for habitats



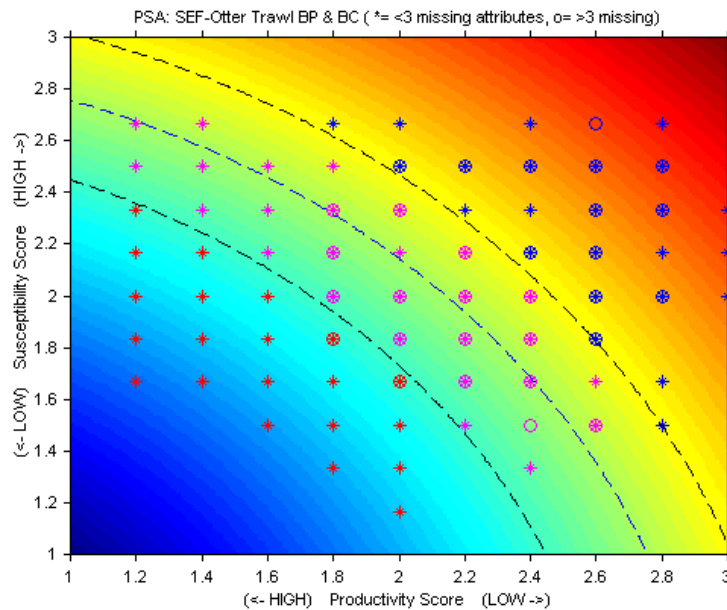


Sustainability – what will it take?

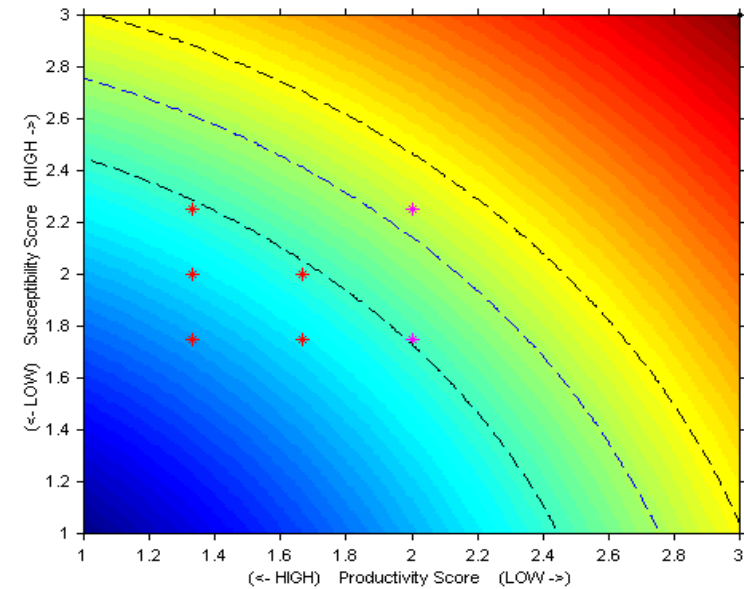
Scientific support

1. Ecological Risk Assessment (ERA)

ERA Level 2 – Productivity-Susceptibility Analysis (PSA)



360 by-catch
species in SE trawl
fishery



7 habitat types in Bass
Strait scallop dredge
fishery



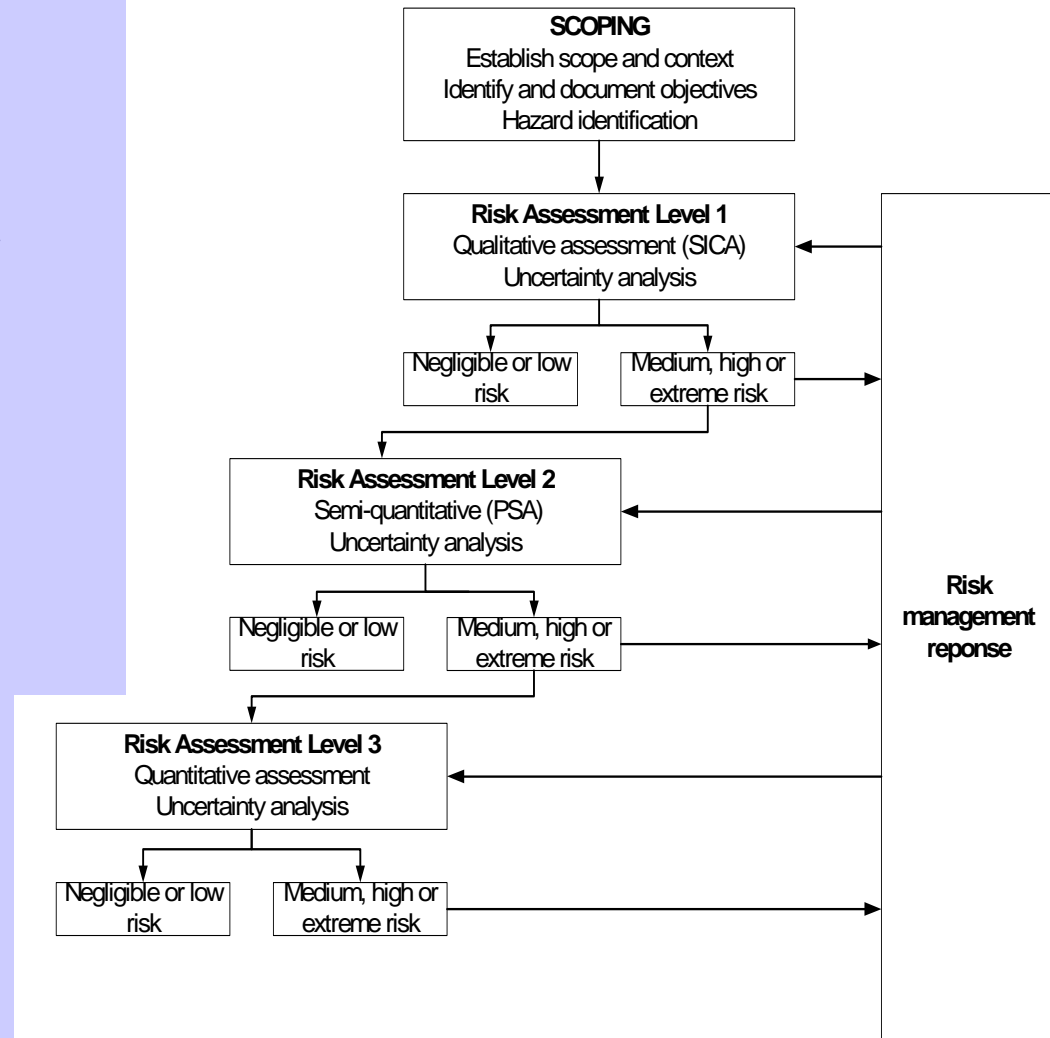
Sustainability – what will it take?

Scientific support

1. Ecological Risk Assessment (ERA)

Used to:

- Identify and prioritise fishery management responses
 - by-catch action plans, recovery plans, target species and fishery management plans, time/area access
- Prioritise fisheries R&D
- Standards for risk assessment and risk management
 - tables of consequence (L1), resilience (L2), risk thresholds, modified reference points (L3)
- Support external reviews
 - environment audit under conservation legislation





Sustainability – what will it take?

Scientific support

2. Management Strategy Evaluation (MSE)

MSE is a way to scientifically design and test operational management strategies

- risk management strategies from the ERA framework

It uses and builds on methodology and approaches developed since 1970s by several groups

- Adaptive management (Holling, Walters, Hilborn et al)
- Management Procedures (International Whaling Commission, Cooke, de la Mare, Butterworth et al)

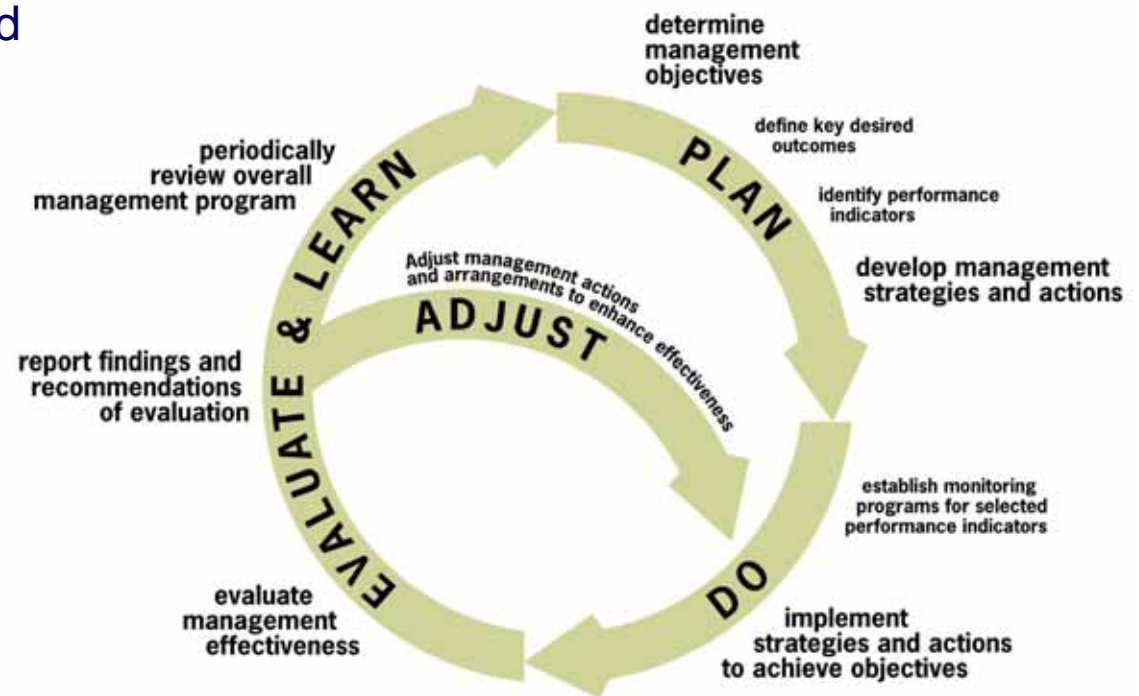


So what is a management strategy and how can it be scientifically tested?

The adaptive management cycle is used widely

- from business cash-flow to natural resource management
- continuous improvement and ISO 9000/14000 management systems

- Measurable objectives and performance measures
- Monitor
- Evaluate performance
- Adjust management measures in light of performance
- Periodically re-evaluate the overall strategy



Planned adaptive management cf reactive management



Scientific design and testing of management strategies

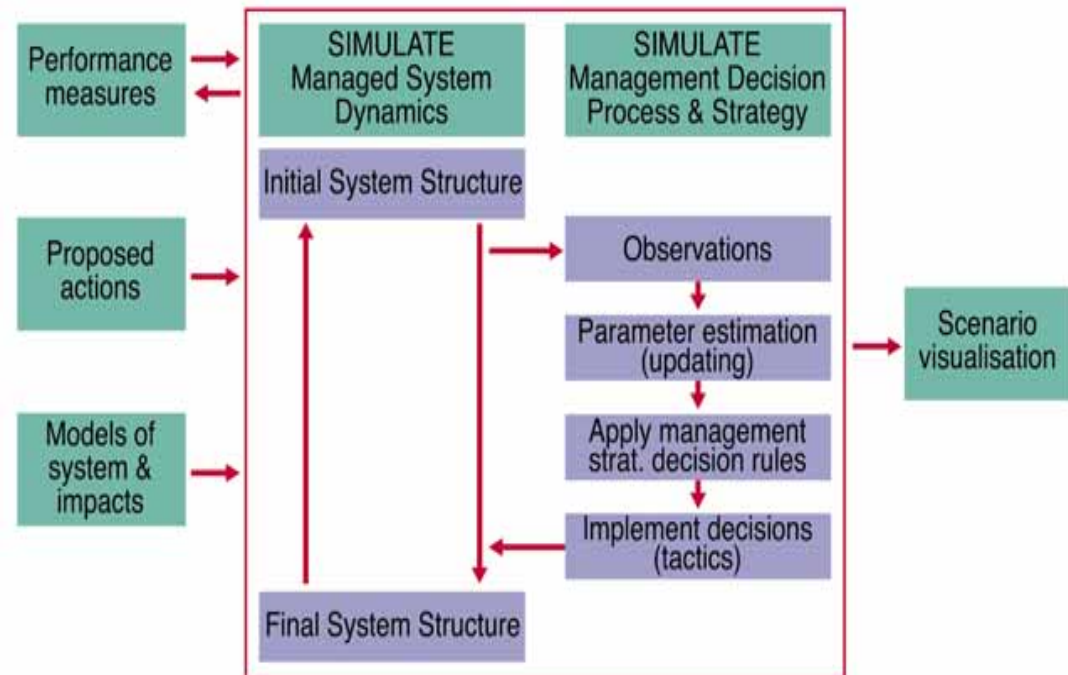
Select performance measures

- ecological, economic, social

Computer simulation of

- range of models for the managed system
 - uncertainty in understanding
- monitoring
 - errors in observations
- assessment
- management decision
- management implementation
 - errors in implementation

General Framework for Monitoring/Management Strategy Evaluation



Test options for any element of the strategy, including performance of the overall strategy in delivering on objectives



Scientific design of management strategies

– the power of the monitoring and decision feedback loop

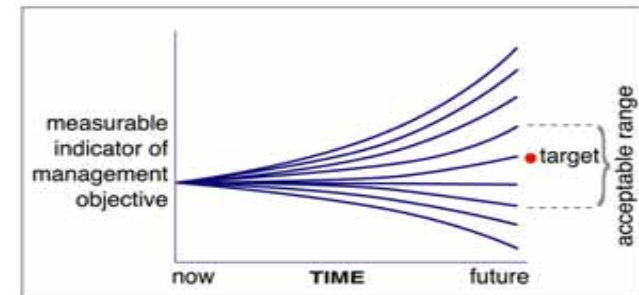
What to monitor and how to respond

- ⇒ design of monitoring and feedback decision rule
- ⇒ greater certainty of management outcome despite uncertainty in prediction

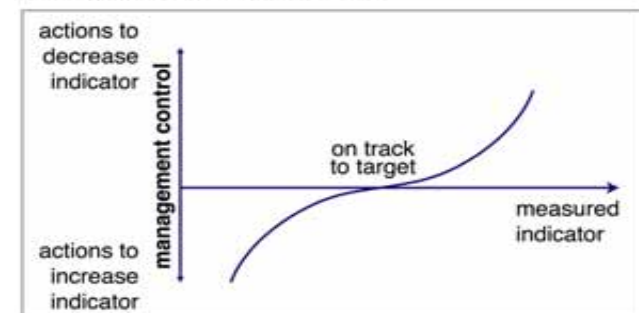
Identify uncertainties that greatly affect performance

- ⇒ target research effort

Predictions

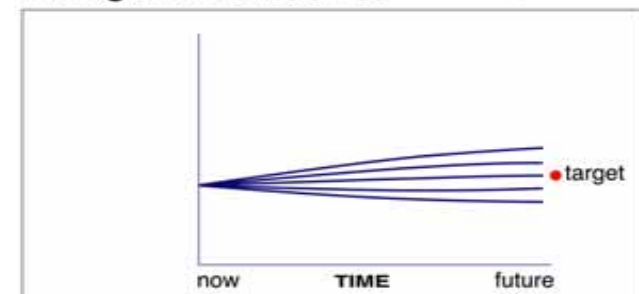


Feedback decision rule



AND

Management outcomes





Scientific support

2. Management Strategy Evaluation (MSE)

Examples of MSE testing for some EAF objectives

Target species

- Numerous single species
- quantitative for S. African hake, Macquarie Is toothfish, Iceland cod
- qualitative for multi-species multi-gear fishery (Smith et al this conference)

Spatial zoning of fishing to protect seabed habitats from trawling

- The North West Shelf of Australia

By-catch limits to achieve protection and recovery

- Potential Biological Removals (PBR) limit for the US Marine Mammal Protection Act

Catch limits for prey species that account for predator needs

- Krill through CCAMLR; Iceland cod-shrimp-caplin

Ecological indicators and assessment models for food-webs for use in ecosystem management

- Various systems by Fulton, Smith and Punt

Cumulative impacts of multiple-use of ecosystems

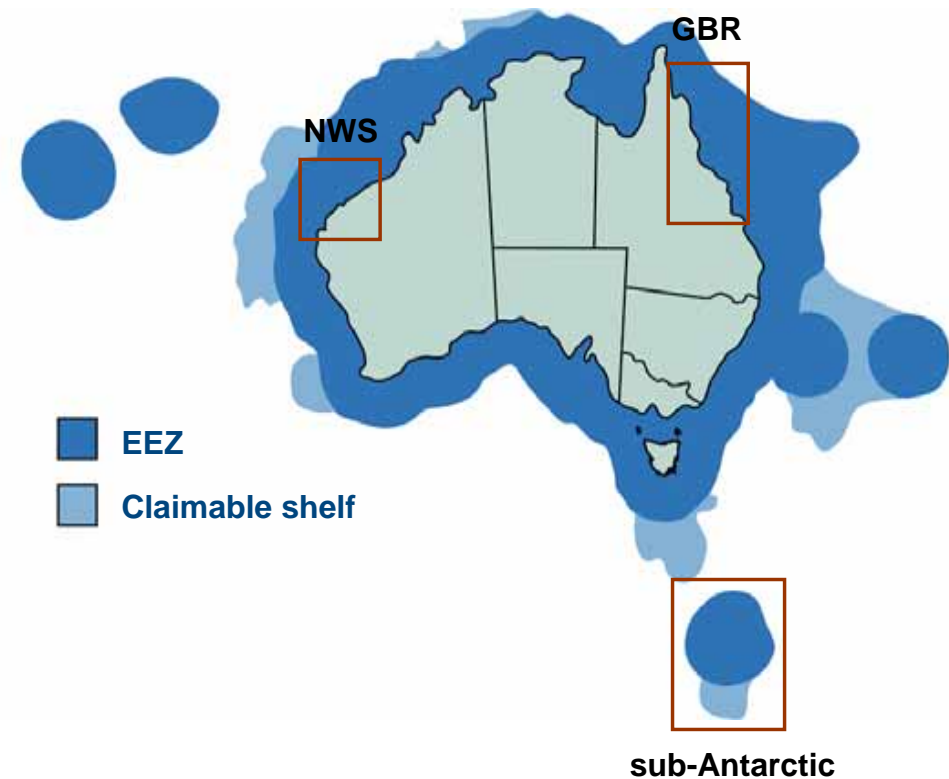
- North West Shelf of Australia



Some Australian example applications of the management system and scientific support

Measuring the effects of line fishing on a coral reef ecosystem
- The Great Barrier Reef

Meeting exploitation and conservation goals in an area with high conservation value
- Subantarctic island and marine ecosystems





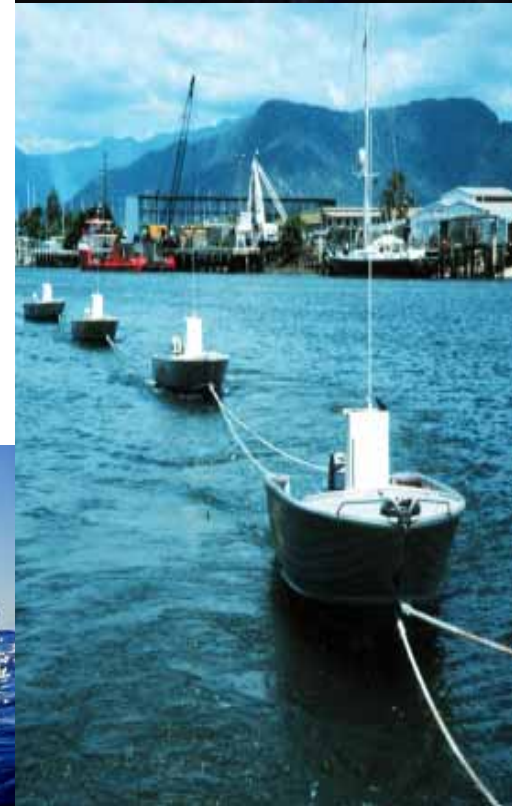
Measuring the effects of line fishing on the Great Barrier Reef



There is a large commercial line fishery on the GBR giving rise to concern about:

- Sustainability of the target species
- Broader ecological effects such as disrupted food-chains

Management strategies to detect fishing effects were designed and tested using a detailed biophysical model





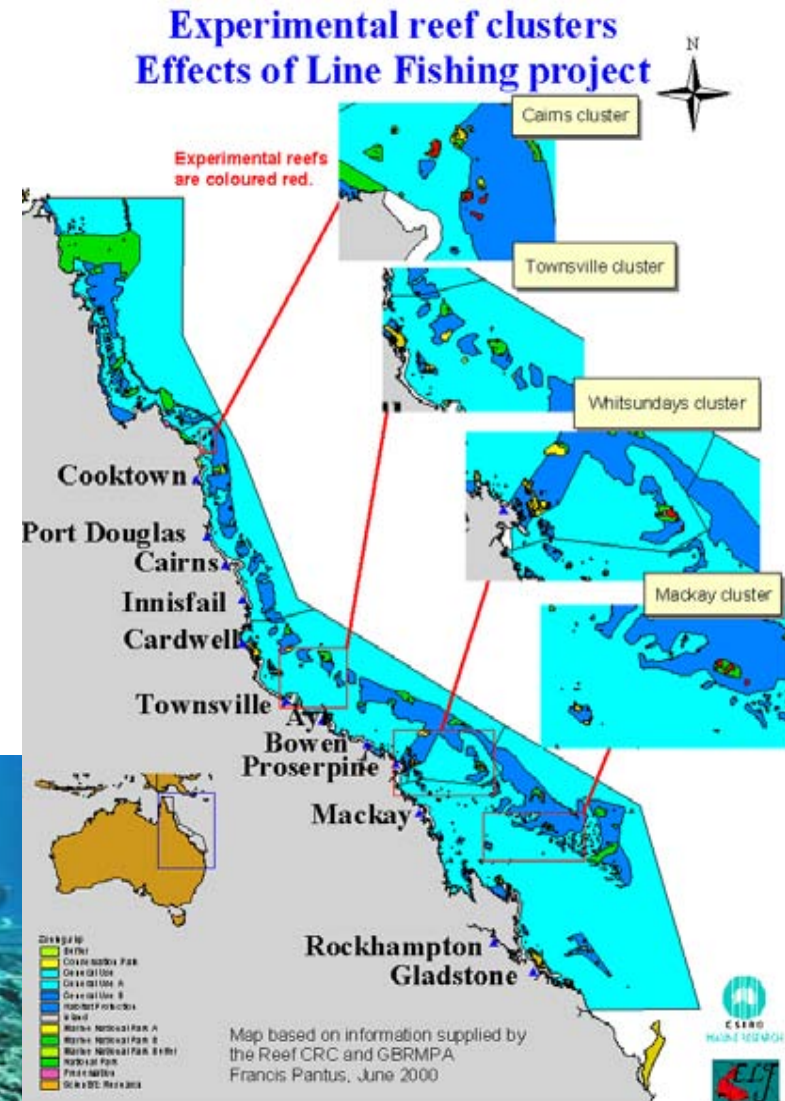
Measuring the effects of line fishing on the Great Barrier Reef


A management experiment was adopted using

- 24 reefs in 4 clusters
- Open areas, closed areas, and exchange of these treatments
- scientific monitoring

It has shown

- the target species are sustainably harvested
- no effect on prey species or biodiversity





Meeting exploitation and conservation goals in an area with high conservation value – Macquarie Island



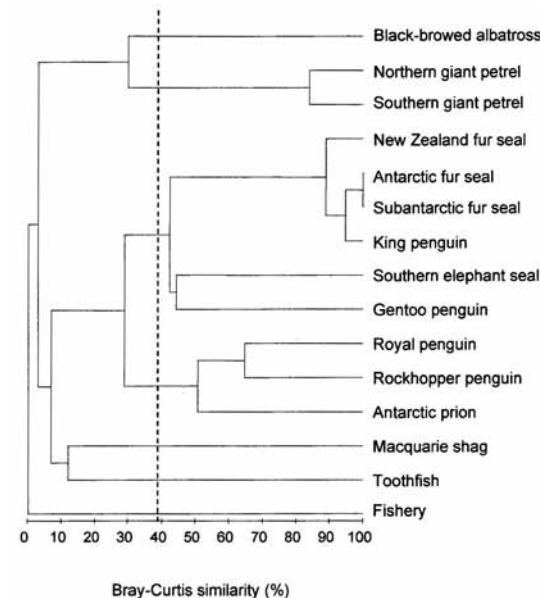
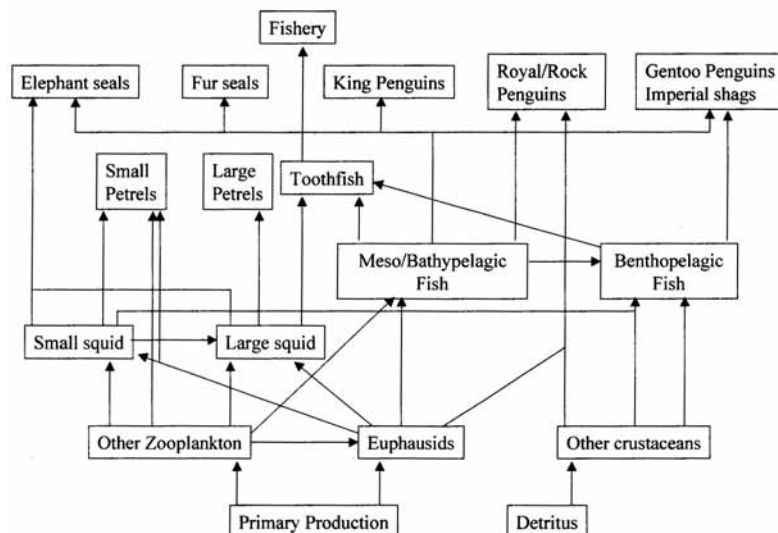
- Development of toothfish fishery
- Large populations of seals, sea lions, penguins, albatross and other sea birds
- Concern about seabed habitats, by-catch, food-web disruption





Research program and management strategy evaluation (3y)

- Map seabed habitats
- Map wildlife foraging areas
- Food-webs (many) and dietary overlaps
- By-catch mitigation and monitoring program
- Model testing of environmental and fishery management strategies

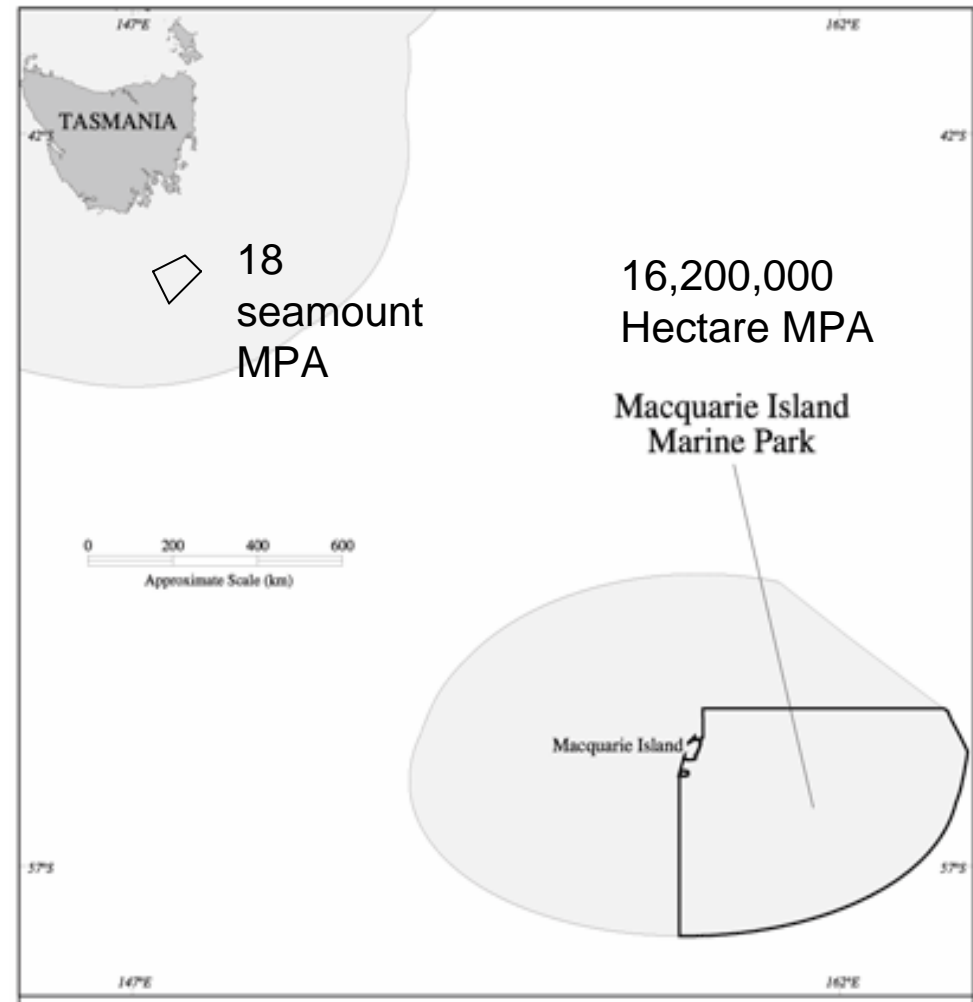
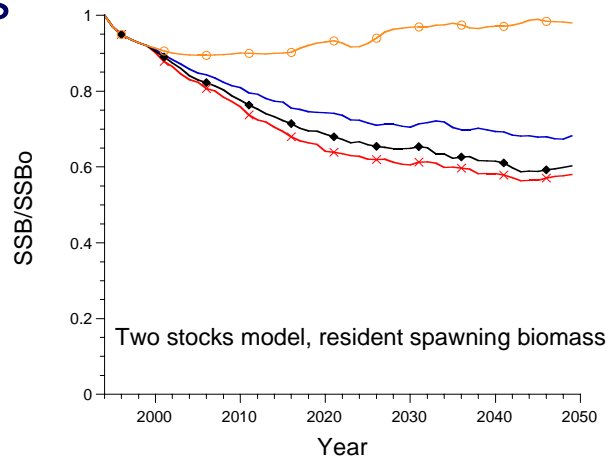




Strategy adopted at Macquarie Island

- By-catch mitigation and observer monitoring
- Large Marine Protected Area in main wildlife foraging area
- Toothfish tagging and monitoring program with agreed decision rules for setting annual catch for individual transferable quotas

Tested method for determining catch





What is going on beneath the surface? The future

The oceans can continue to be:

- a source of enormous wealth, enjoyment and benefit to people
- a key part of the planet's life support system

But they are at serious risk.

Achieving a sustainable future will require:

- Engaging societies to build strong commitment to an ecologically sustainable future
- Reforming institutions as necessary to be participatory, anticipatory, precautionary, use measurable sustainability standards, be willing and able to act decisively, and take a long-term view
- Make use of scientific risk assessment, scientific testing of management strategies to inform some difficult choices
- Fully use existing data; risk based priorities for new data
- EAF/EBFM is a pathway in this



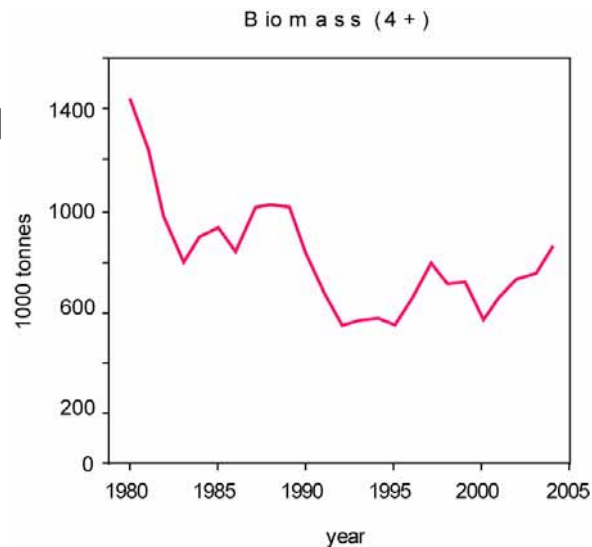
Can we do EAF/EBFM?

Of course we can, with

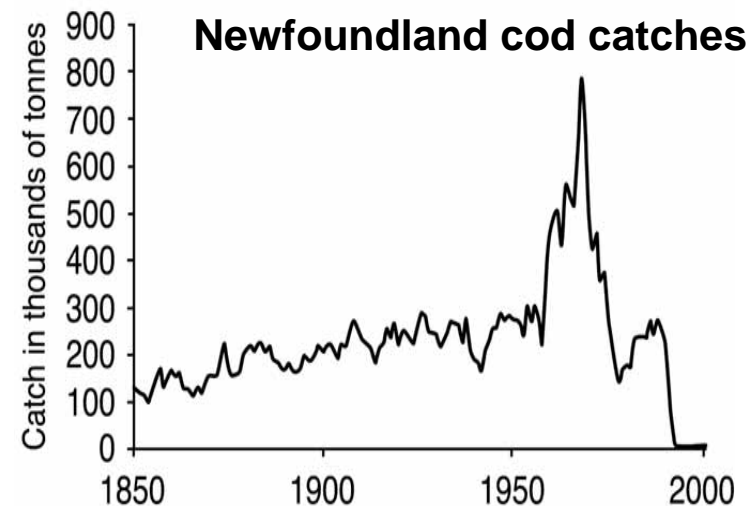
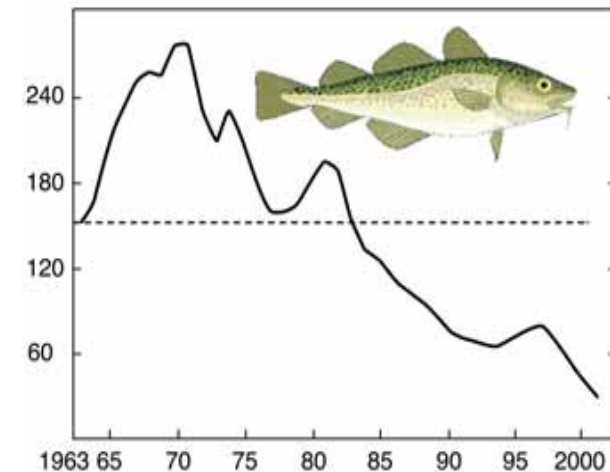
- Society informed and committed to sustainability.
- Regulators with the appropriate management tools and prepared to act for long-term benefit and recognizing ecological dependencies
- Use scientifically tested adaptive management strategies

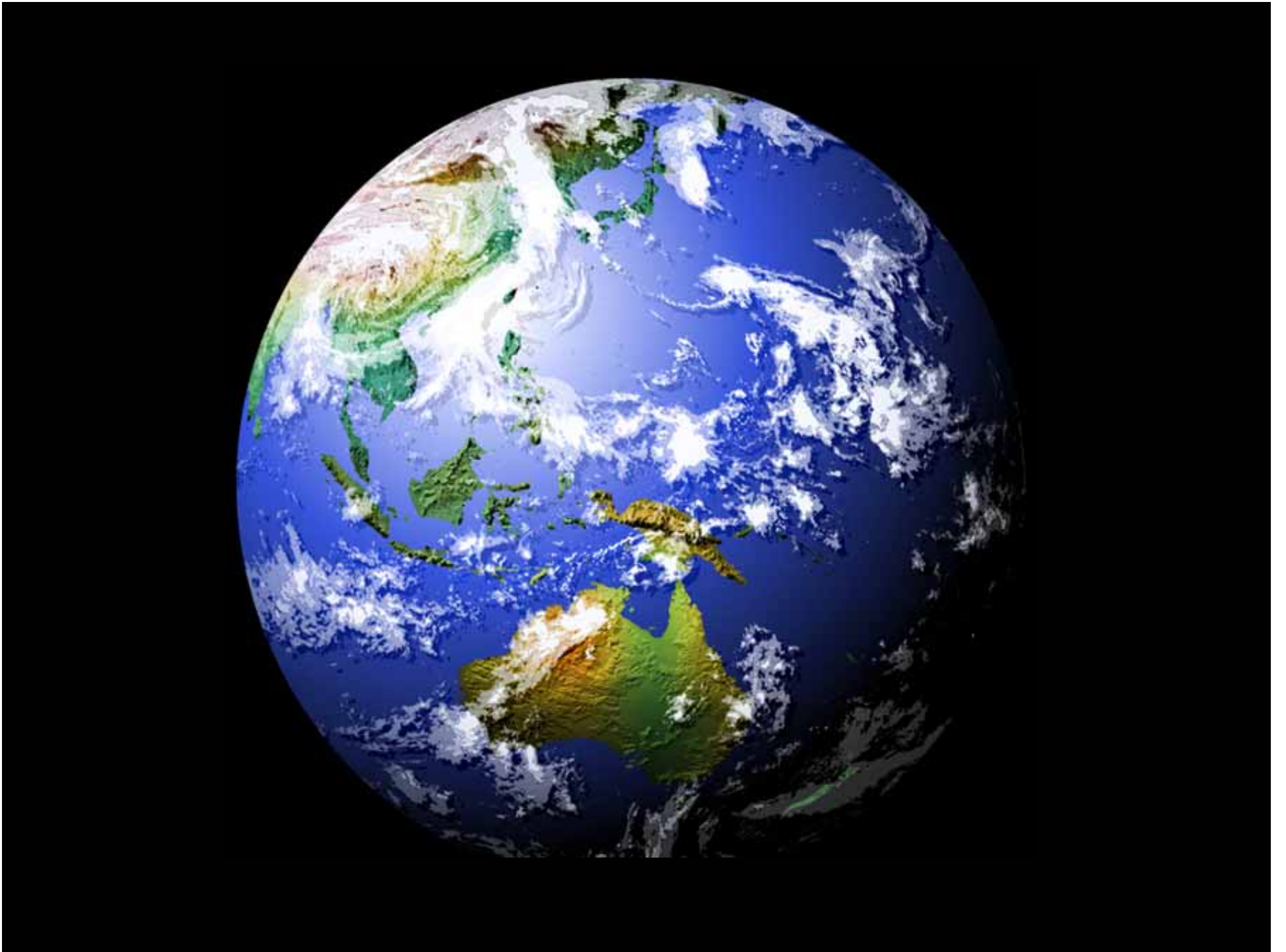
Spot the difference this makes

Iceland cod



North Sea cod spawners







Sustainability – what will it take?

Scientific and Management - development of operational standards

Detailed default ERA tables for consequence (Level 1) and productivity/resilience (Level 2)

Treatment of missing data and threshold risk levels

Modified reference points for Level 3 risk management strategies

	Target reference points	Limit reference points
Target and bycatch spp		MSY biomass
PET species	F as small as possible	'Potential Biological Removal' catch
Major prey spp		0.5 MSY biomass
habitats	Examples in protected sites	Less than 0.5 modified
Food webs	FIB index not decreasing; examples in protected sites	
biodiversity	No loss spawning sites; small change in Ne & selection differential; protected sites	PET criteria; Ne reduced by less than 0.5; selection differential no more than ?



The management system

3. Operational standards and limits for sustainability

Some possible Reference Points for Ecologically Sustainability

	Target	Limit
Target and by-catch species		<ul style="list-style-type: none">• Mortality or biomass for MSY• Equivalent limits for data limited fisheries
Endangered and protected species	<ul style="list-style-type: none">• Fishing mortality as close to zero as possible	<ul style="list-style-type: none">• Potential Biological Removal level of mortality
Significant prey species		<ul style="list-style-type: none">• Biomass not less than halfway between MSY and unfished levels
Food-web	<ul style="list-style-type: none">• Foodweb in balance (FIB) index not decreasing• Viable and representative food-web undisturbed in protected areas: reference sites	



The management system

3. Operational standards and limits for sustainability

Some possible Reference Points for Ecologically Sustainability

	Target	Limit
Biodiversity	<ul style="list-style-type: none"> • No loss of spawning areas or local extinctions. • Low selective differential • Small reduction in effective spawning population. • Viable and representative biodiversity undisturbed in protected areas: reference sites 	<ul style="list-style-type: none"> • No extinctions or stocks below genetically viable levels • Effective spawning population not less than half unfished level
Habitats		<ul style="list-style-type: none"> • Not less than half of habitat area present when unfished
Reversibility		<ul style="list-style-type: none"> • Reversible in human generation time (20y) • Overfished stocks recovered in 10y or 1 fish generation time if greatly different
Effects of non-fishery uses	<ul style="list-style-type: none"> • Combined fishery and non-fishery uses meet the above 	<ul style="list-style-type: none"> • Combined fishery and non-fishery uses meet the above