Assessing impacts of climate changes on fisheries: An EAF perspective

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Outline

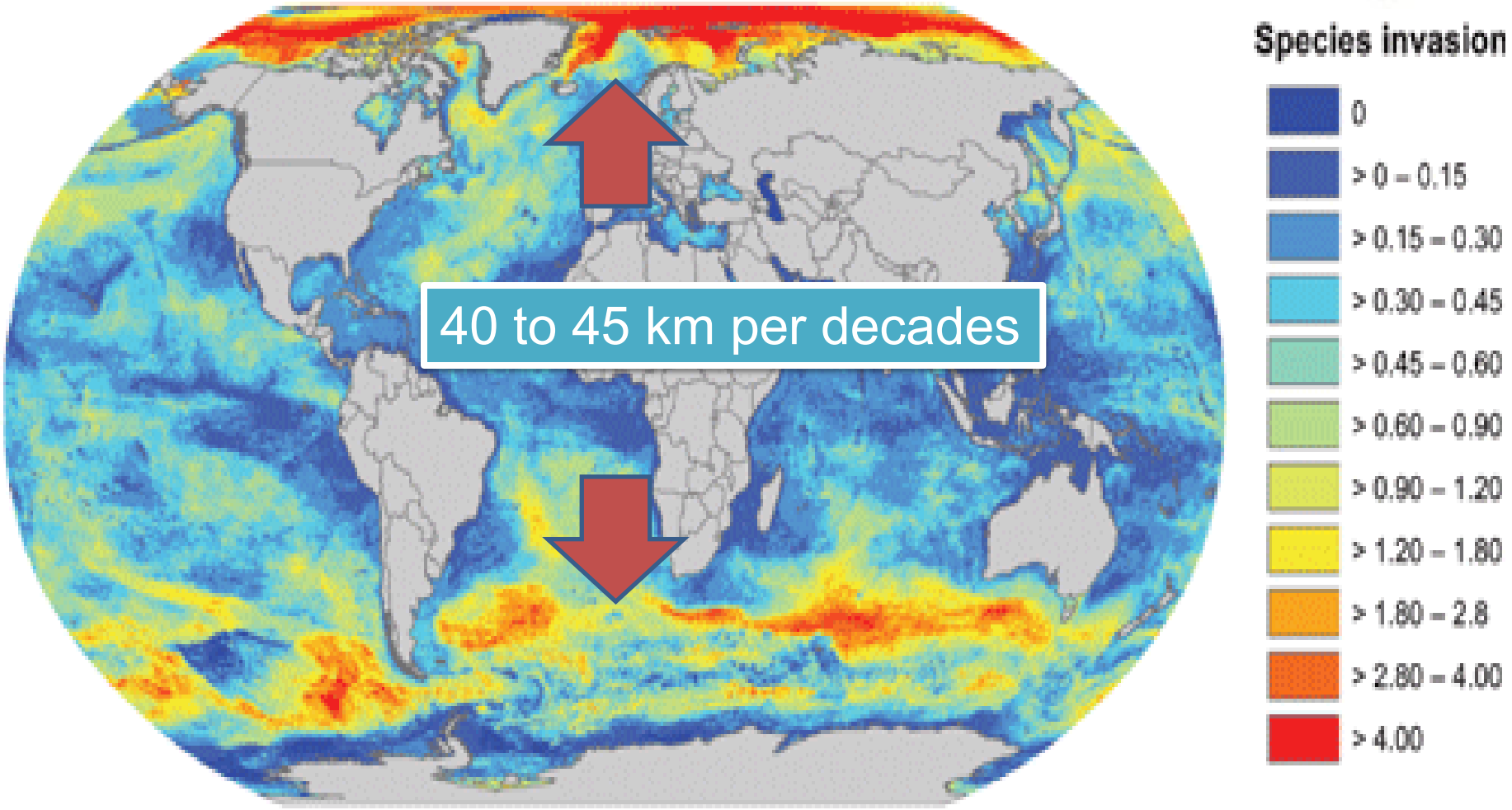
- Impacts of climate changes on fish and fisheries
- IFRAME approach as an EAF
- Application of the approach
- Management implications under changing climate condition

Examples of potential impacts of climate changes (Revised from UNEP (2007))

State changes	Mediating environmental/ ecosystem impacts	Human well-being impacts		
		Human health	Food security	Socio-economy
Sea surface temperature ⬆	Trophic structure and food web ⟺	Food safety ⬇	Fishery species distribution ⟺ Aquaculture production ⬇	Profits ⬇ Costs ⬆
	Coral Bleaching ⬆	Disruption of utility services ⬆	Artisanal fishers ⟺	Risk in fisheries and agriculture ⬆
	Sea-level rise ⬆		Aquaculture facilities ⟺	
	Trophical storm and hurricane frequency and intensity ⬆		Aquaculture damage ⬆	

Fish migrating to cooler waters

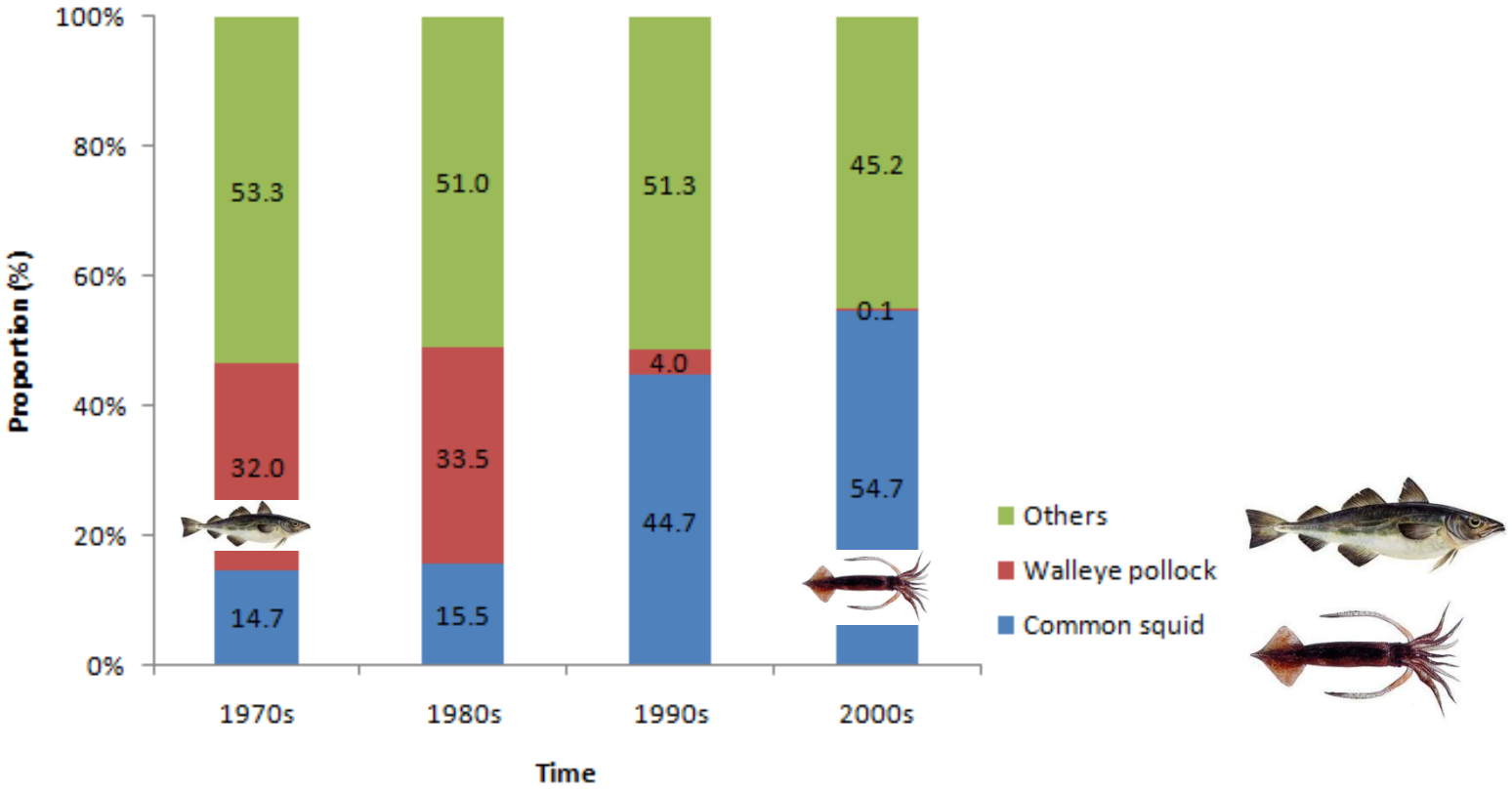
(IPCC SRES A1B scenario)



By 2050 large numbers of marine species (1,066 spp.) will migrate towards cooler waters – specifically the Arctic and Southern Ocean – at an average rate of 40 to 45 km per decades (Cheung et al. 2009).

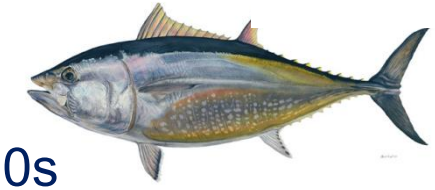
Impacts of climate changes

An example of catch proportions in Korean waters of the Japan/East Sea : shifts in dominant species

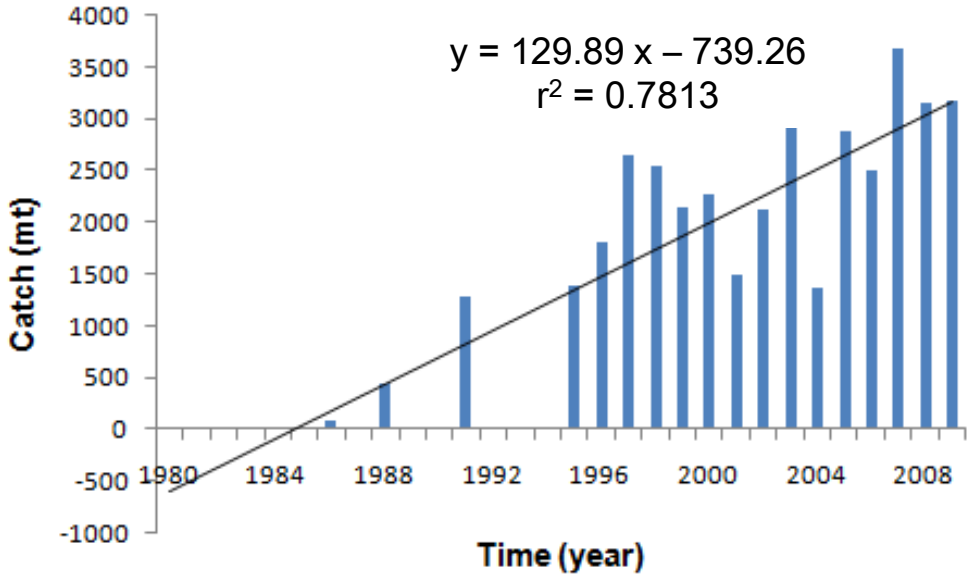


Impacts of climate changes

Catch of bluefin tuna in Korea



- ✓ Continuous increase since mid-1980s



Studies on impacts of climate changes

- Biodiversity : Roessig et al. (2004), Harley et al. (2006), Munday et al. (2008), ….
- Species richness : Hiddink and Hofsted (2008), ….
- Productivity of fish populations : Zhang et al. (1999), Hollowed et al. (2009), ….
- Distribution of fish populations : Park et al. (2000), Nye et al. (2009), Cheung et al. (2009), ….

But, still limited knowledge and poor understandings on the relevant mechanisms of key ecological processes !!!

Why ecosystem-based fisheries management?

- Shortcomings of a single species management

  - lead to over-fishing in many areas

    (77% fully-, over-fished: FAO (2005))

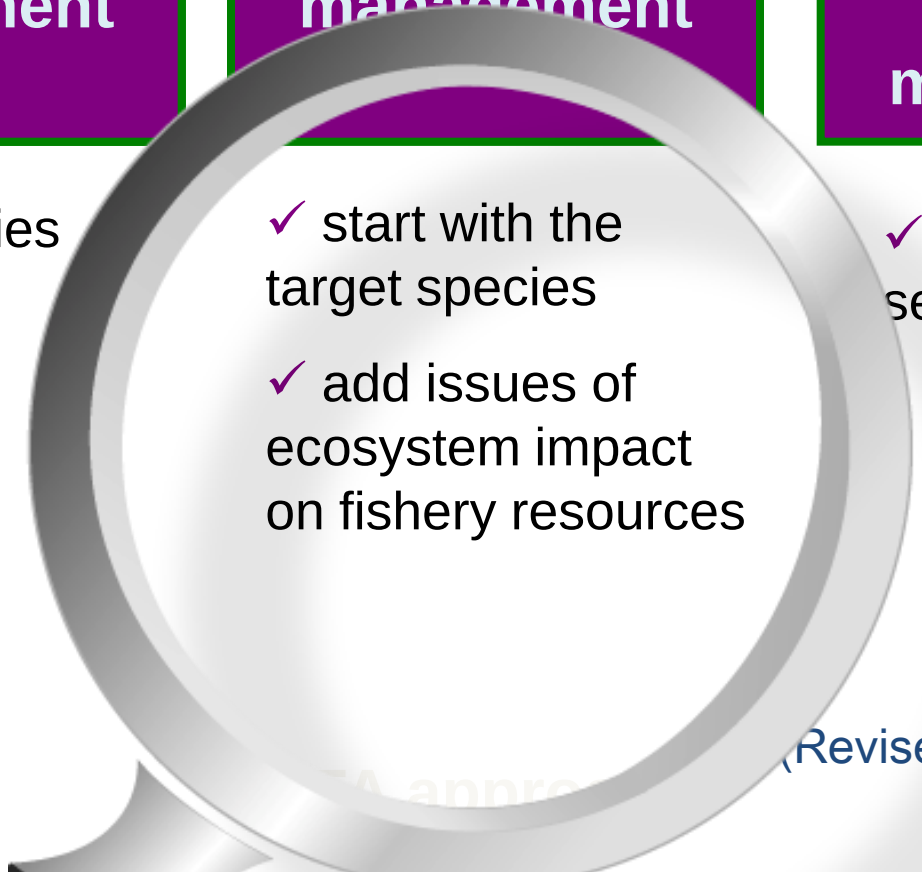
- Limited management only on sustainability

  - ignoring habitat quality, biodiversity and socio-economic benefits

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

Spectrum of Ecosystem-based Management Approaches

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

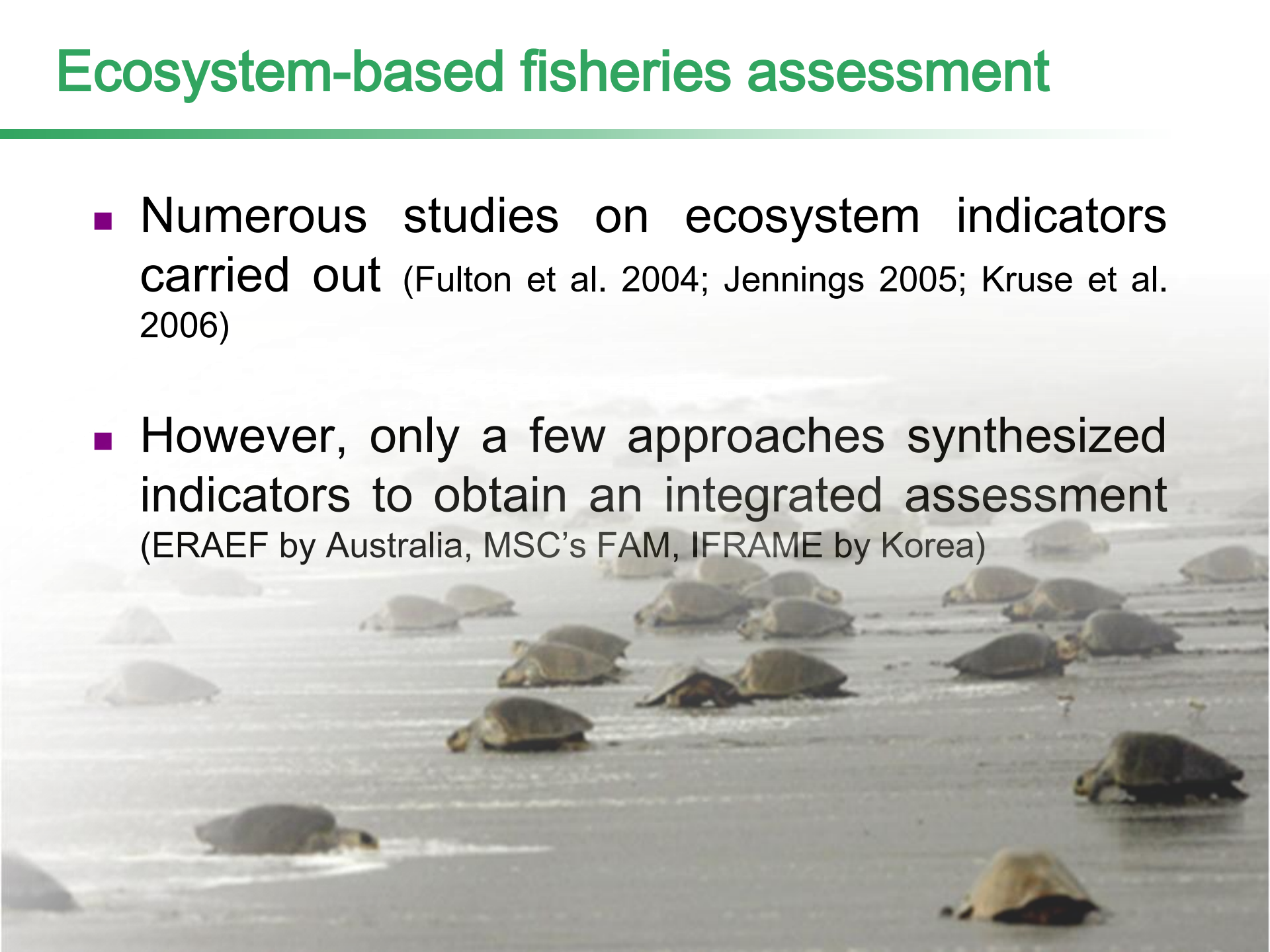


(Revised from Sainsbury)

Ecosystem-based fisheries assessment

- Numerous studies on ecosystem indicators carried out (Fulton et al. 2004; Jennings 2005; Kruse et al. 2006)

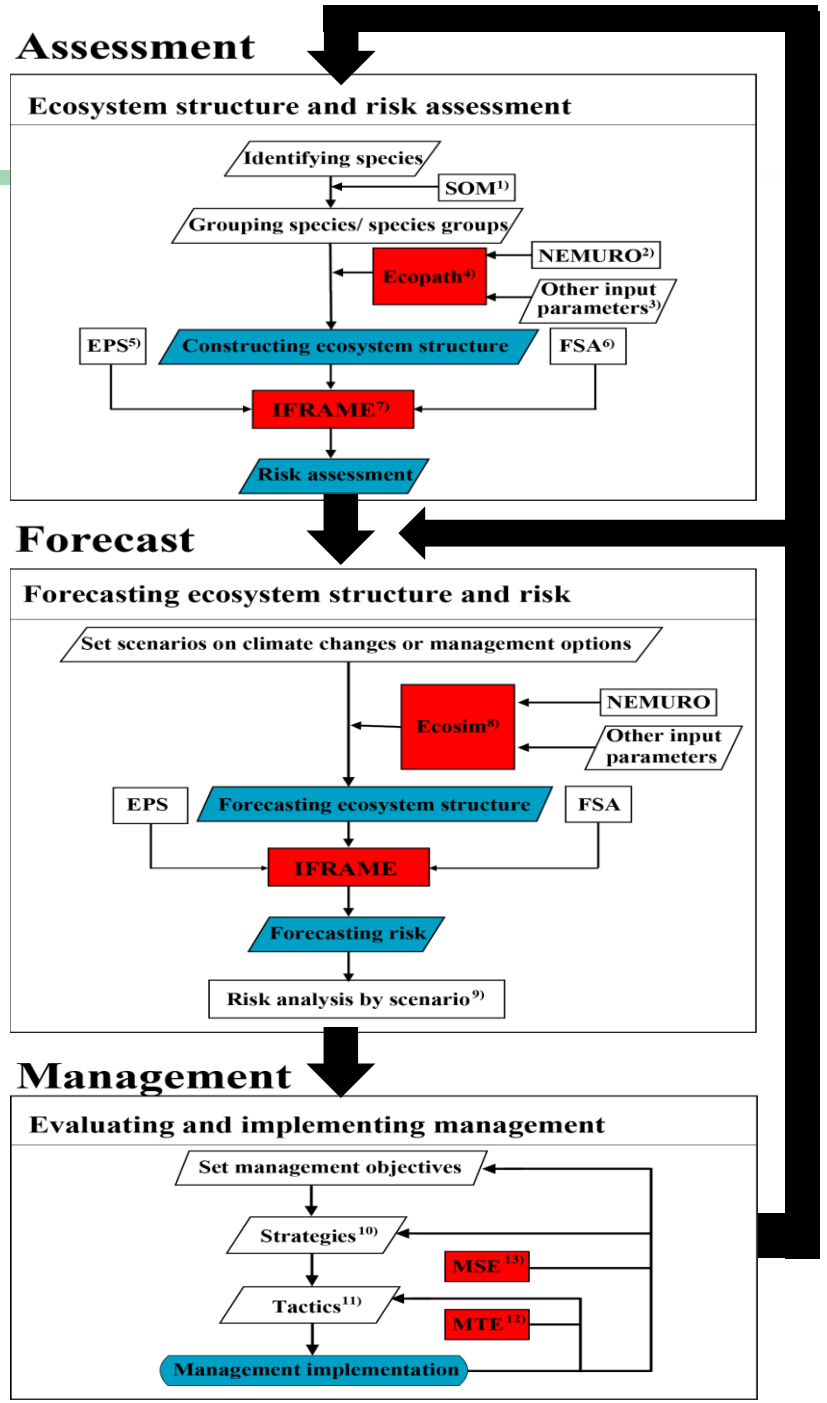
- However, only a few approaches synthesized indicators to obtain an integrated assessment (ERAEF by Australia, MSC's FAM, IFRAME by Korea)



IFRAME

Integrated **F**isheries **R**isk **A**nalysis **M**ethod for **E**cosystems :

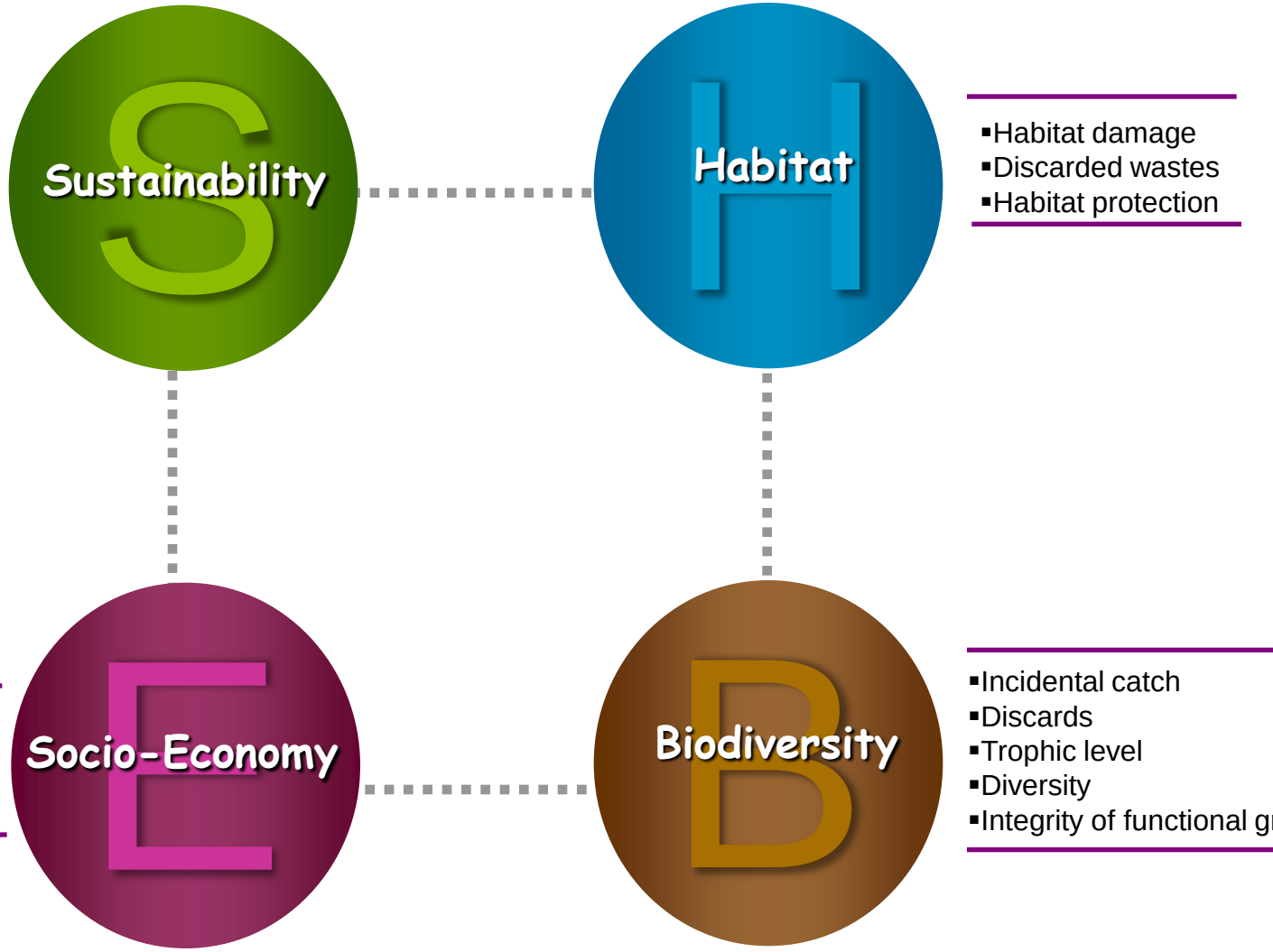
in the developing stages



IFRAME: 2 tier system

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

Management objectives, attributes & indicators



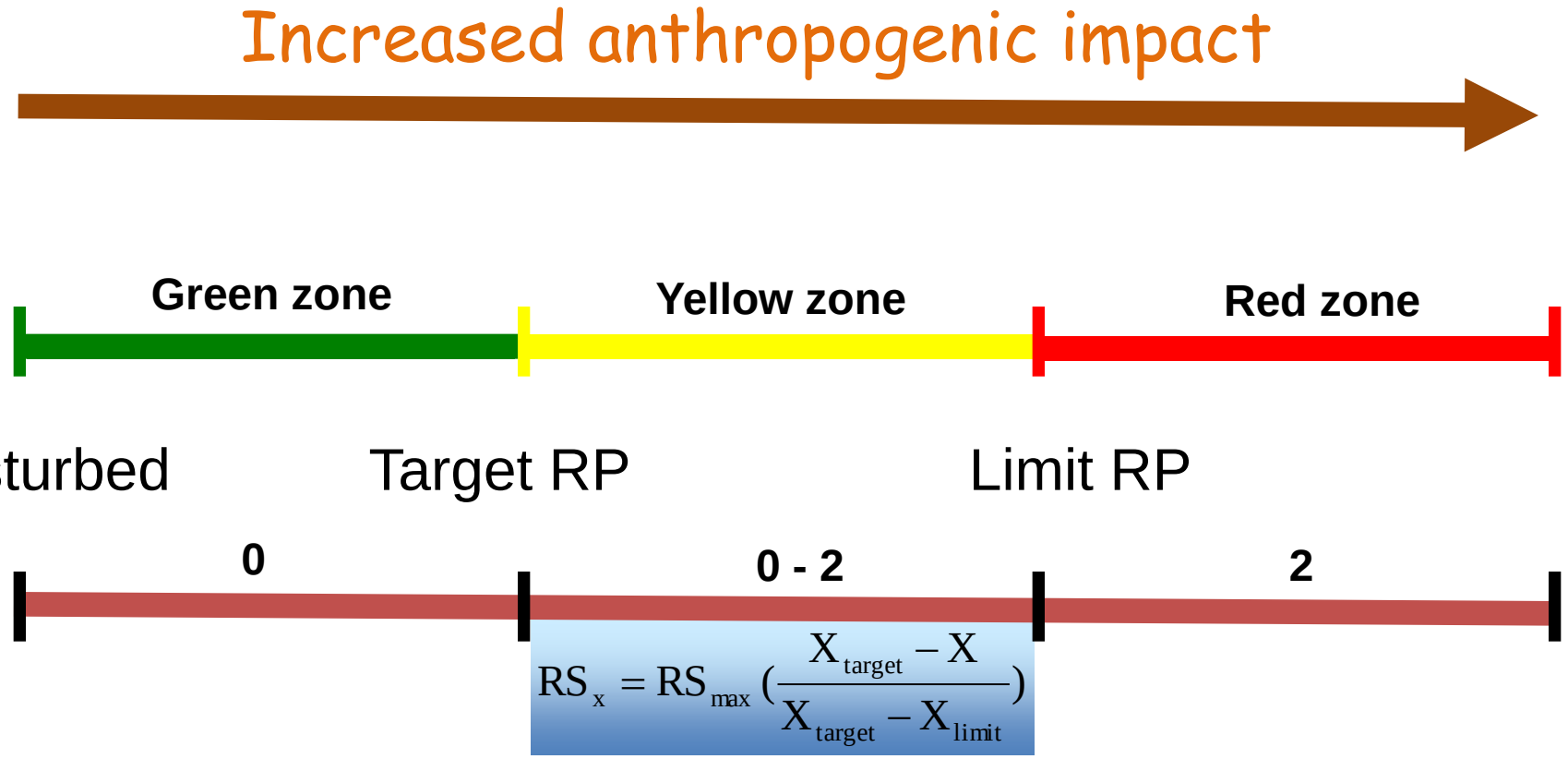
- Biomass
- Fishing intensity
- Size/age at first capture
- Habitat size
- Community structure

- Habitat damage
- Discarded wastes
- Habitat protection

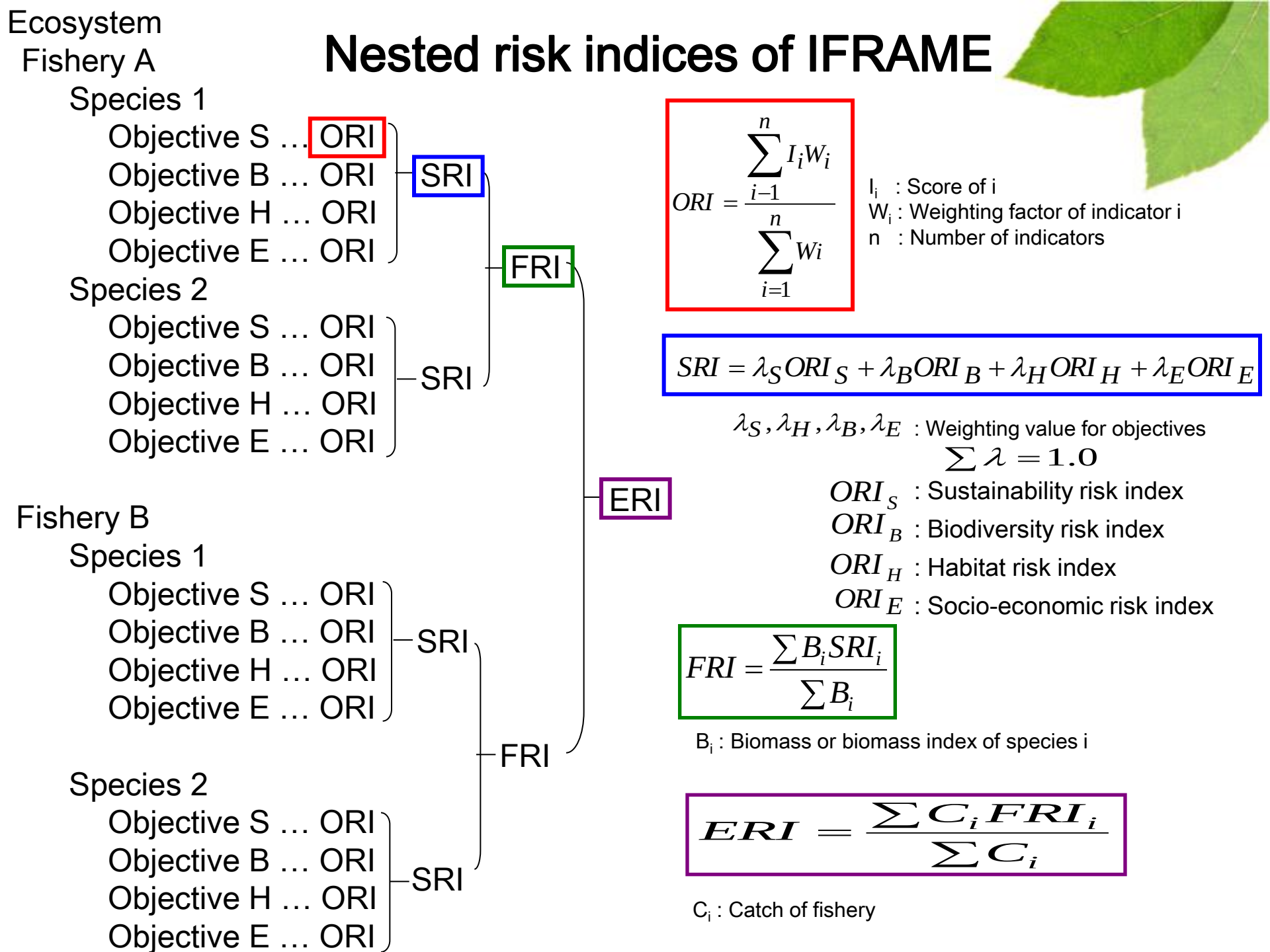
- Economic production
- Revenue
- Market
- Employment

- Incidental catch
- Discards
- Trophic level
- Diversity
- Integrity of functional group

Reference points and Risks



Nested risk indices of IFRAME



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

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

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

$\lambda_S, \lambda_H, \lambda_B, \lambda_E$: Weighting value for objectives

$$\sum \lambda = 1.0$$

ORI_S : Sustainability risk index
ORI_B : Biodiversity risk index
ORI_H : Habitat risk index
ORI_E : Socio-economic risk index

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

B_i : Biomass or biomass index of species i

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

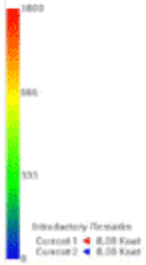
C_i : Catch of fishery

Application to the Korean large purse seine fishery (Preliminary)

- Korean large purse seine fishery

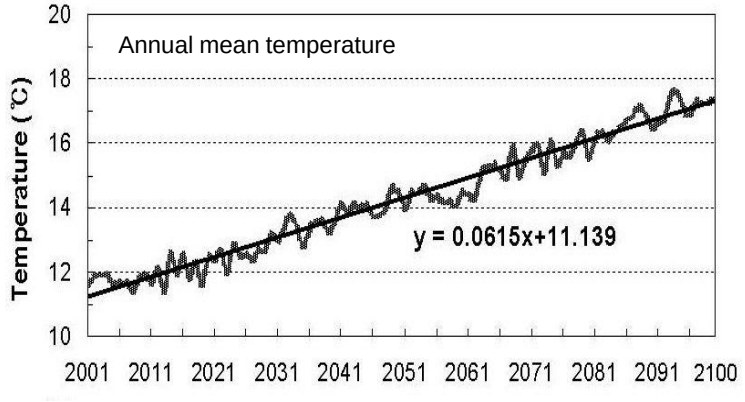
  - Main species: chub mackerel (*Scomber japonicus*)
  - Bycatch species: bluefin tuna, horse mackerel, Spanish mackerel, squids, etc.
  - Annual catch : around 250,000 mt

- Catch and CPUE data
  - 30'x30' blocks
  - 1980-2008 (29 years)



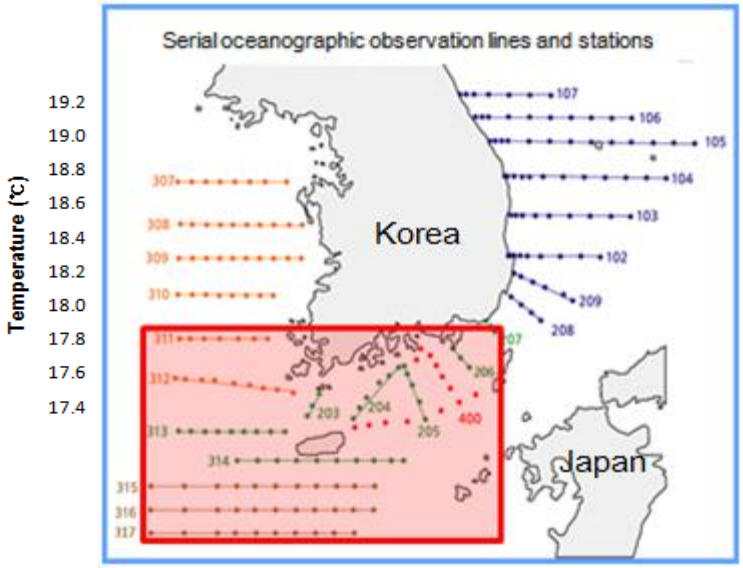
Warming of fishing ground

- IPCC SRES A2 scenario
  (Kim et al., 2007)
  - Increasing rate: 0.062℃/year



- SST in northern East China Sea
  - Main fishing ground of the Korean large purse seine
  - Warming rate of SST: 0.086℃/year

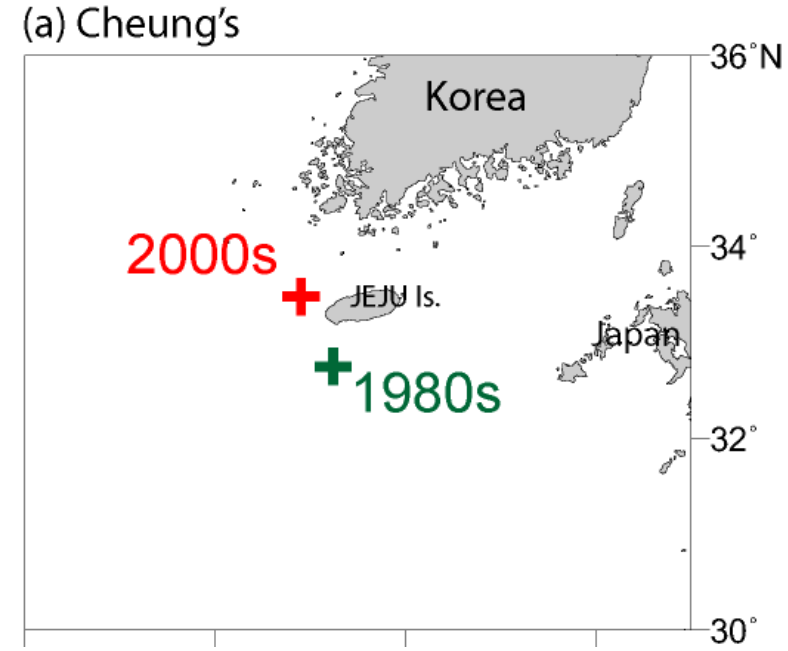
  (higher than 0.062℃/year of IPCC rate)

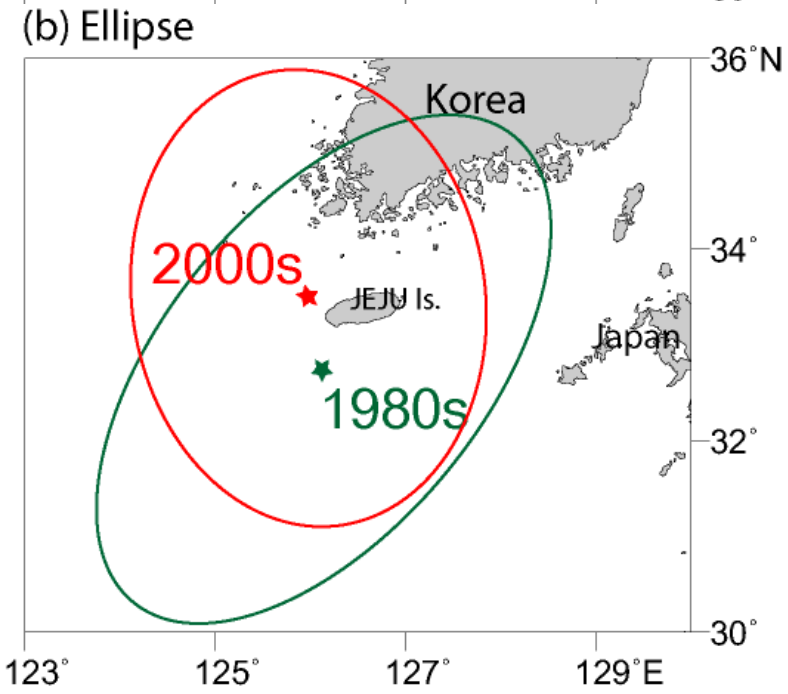


Methods

- Predictions for habitat areas
  - Warming rate of 0.06℃/year (SST)
  - Reference year 2008, predicted habitat areas for 2033, 2058, 2083, and 2108

- Predictions for biomass and risk indices
  - Using SOM, NEMURO, ECOPATH with ECOSIM
  - Predicting biomass altering F-values ranging from zero to 2.0xF_{ABC}, based on the changes in habitat areas of chub mackerel due to warming
  - IFRAME, Tier 1 for chub mackerel

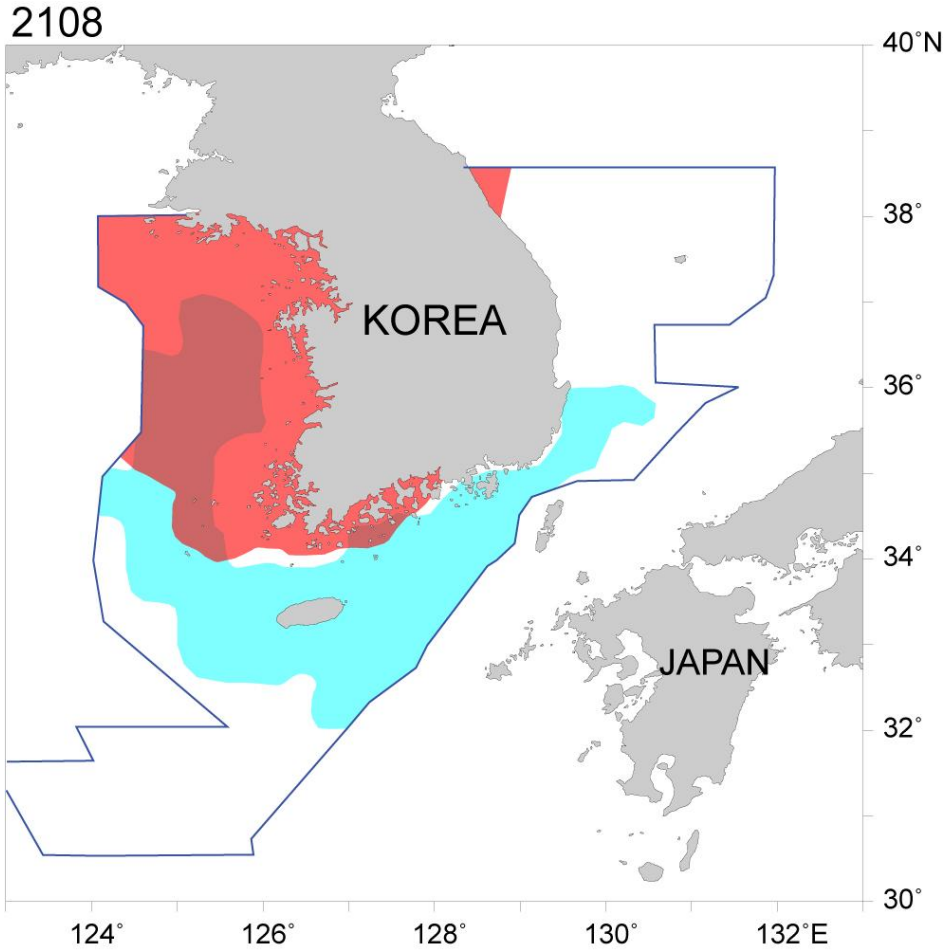




Changes in fishing grounds of chub mackerel

- Northward movements of fishing grounds for1980s-2000s (19 years):
- Cheung's method
  - 81.5km northward movement
  - 42.9km/decade
- Equal-frequency ellipse method
  - 81.2km northward movement
  - 42.7km/decade
- Fish movement rate similar with Cheung et al.(2009)'s prediction of 40-45km/ decade

Prediction of habitat areas of chub mackerel

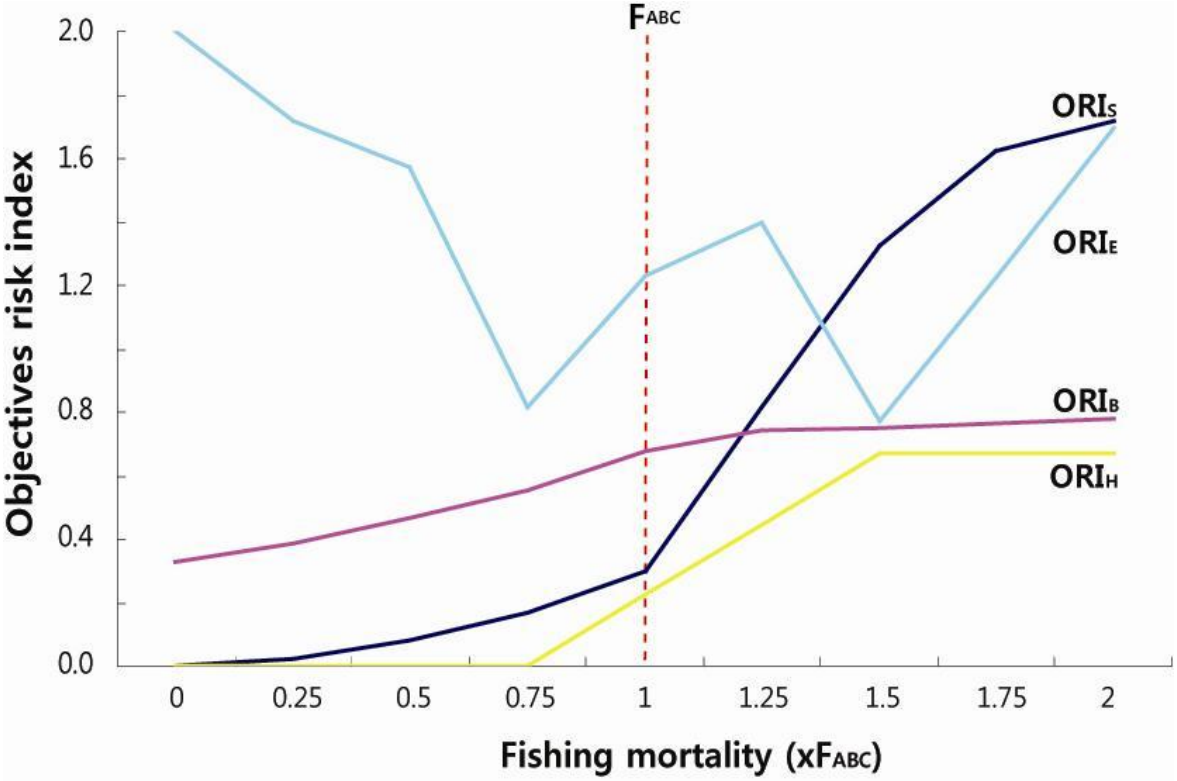


- SST range: 14.4-22.5℃
- Faster northward movement in the Japan/East Sea than that in the Yellow Sea
- The main habitat area of chub mackerel will be outside of the South Korean EFZ in Japan/East Sea in 2108

Sustainability	Biodiversity	Habitat	Socio-economic benefit
Biomass (B)	**Bycatch rate (BC/C)**	Critical habitat damage rate (DH/H)	**Landings**
Fishing mortality (F)	**Discards rate (D/C)**	**Pollution rate of spawning and nursery ground (PG/G)**	**Revenue (per vessel or person, etc.)**
Age (or length) at first capture (t or L)	**Mean trophic level of the community (TL_c)**	**Lost fishing gear (frequency, FR)**	**Return on Investment (ROI)**
Habitat size (H)	**Diversity index (DI)**	**Discarded wastes (DW)**	**% ratio of landing to total supply**
Mean trophic level in catch(TL)	**Pelagic sp./ Benthic sp. (P/B)**		Employment rate
Rate of mature fish (MR)			
Slope of size spectra			

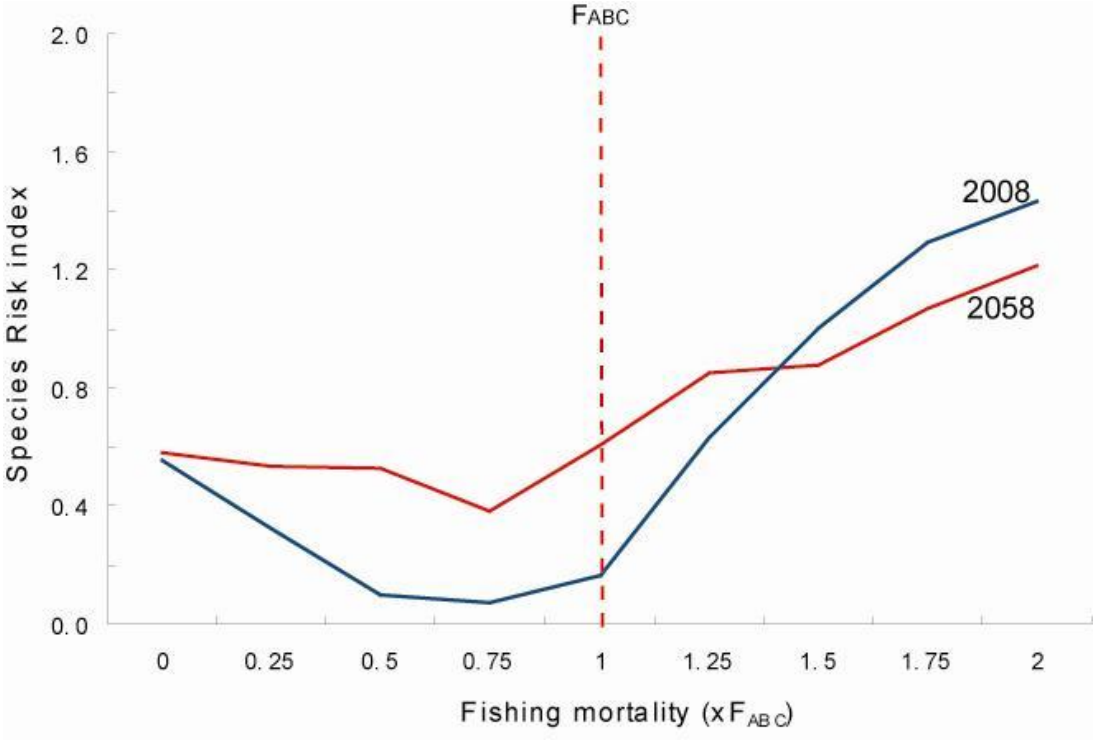
A total of 16 indicators used for IFRAME (Revised from Zhang et al., 2010)

ORIs of chub mackerel for 2058



- Sustainability: risk index began to increase as F increased from $0.25F_{ABC}$
- Biodiversity and Habitat : risk index increased moderately as F increased
- Socio-economy: W-shaped risk indices lower at $0.75F_{ABC}$ and $1.5F_{ABC}$

Species Risk Indices of chub mackerel



- SRI for 2058 : higher than that of 2008 from zero F to $1.25F_{ABC}$
- SRI: lowest with $0.75F_{ABC}$ in 2008 and 2058
- Fishing with population-based F_{ABC} level will cause ecological overfishing, suggesting to reduce the F level to $0.75F_{ABC}$

IFRAME is still in the developing stages

- Preliminary results indicate that this approach has potential as a tool for forecasting risk indices of objectives, species and fisheries.
- However, it is still far from practical applications due to lack of knowledge for assessing risks of a number of indicators.
- Especially, specific ecological process studies on the indicators and reference points under a changing climate are required.

Management implications from the preliminary analysis

Management Objectives	Strategies	Tactics
Sustainability	- Increasing biomass - Reducing fishing capacity - Maintaining community structure	- TAC reduction (by $0.75F_{ABC}$) - Reducing number of licenses or permits - Limiting number of trips and/or fishing days - Developing new fishing gears and methods
Habitat	- Preventing habitat damage - Restricting discarded wastes	- Establishing marine protected area (MPA) - Modifying closed season and areas - Restricting use of harmful fishing gears - Adopting temporary fishing recession - Modifying stock enhancement programs
Biodiversity	- Preventing incidental catches and discards - Preserving diversity and trophic level	
Socio-economy	- Increasing revenues - Maintaining viable production - Supporting employment	- Enhancing community-based management - Government supports due to shifted fisheries - Predicting supply and demand of shifted fish species - Predicting employment due to shifted fisheries - Strengthening international cooperation for EAF management

Legal systems and relevant policies in fisheries management under climate changes : A Korean case

	Two major acts for fisheries legal systems and policies ("**Fishery Resources Management Act**" and "**Marine Ecosystem Conservation and Management Act**")
Objectives	To establish a comprehensive plan for fisheries resources and ecosystem management, and to contribute to a sustainable fisheries and marine ecosystems
Contents	- Conducting assessment of fisheries resources every year
	- Establishing a master plan for fisheries management every 5 years and for ecosystem conservation and management every 10 years
	- Building up an institutional foundation for self-management of fisheries resources
	- Embracing international regulations and encouraging international cooperation
	- Using eco-friendly fishing gears and methods
	- Applying a precautionary approach
	- Stipulating management of habitats and ecological environments
Limitations	- Lack of scientific data and research for EAF
	- No clear explicit provisions on EAF and climate changes

Suggested policies and measures responding climate changes

	Current management	EAF management
Goal	Managing and rebuilding species	Managing and protecting species, fisheries and their ecosystems responding to climate changes
Objective	Sustainability of species itself	Sustainability, habitat quality, biodiversity, socio-economic benefits, responding to climate changes
Information	Scientific research and fishery data	Scientific research, fishery data, non-scientific knowledge and information from fishers and other stakeholders
Bodies	Central and local governments	Central and local governments, and all relevant stakeholders including fishers, by establishing Fishery Management Councils
Flexibility	Restricted	Flexible
Range of areas	Areas within one nation's EEZ	Areas within and beyond one nation's EEZ, cooperating with neighboring nations, possibly by establishing a Regional Management Body
Period	Short-term	Short-term, and mid- and long-terms as well

Thank you very much!