Effects of Global Warming on Large Marine Ecosystem Sustainability

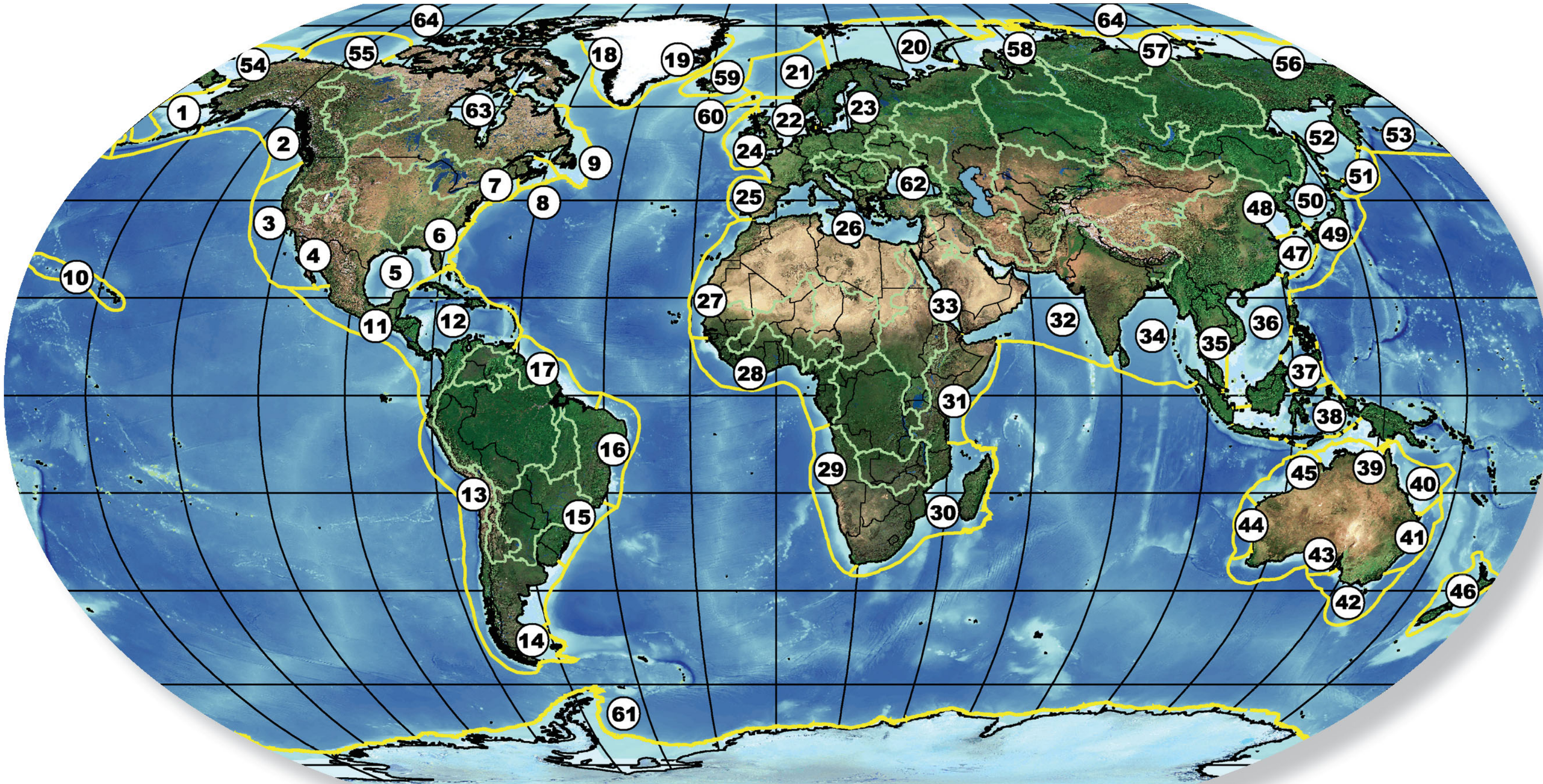
Mainstreaming Responses to Climatic Variability & Change and While Improving Results-Based Management for GEF5

The Fifth GEF Biennial International Waters Conference

Cairns, AUSTRALIA
Session III, Saturday, 24 October 2009

Kenneth Sherman
NOAA, NMFS, NEFSC, Narragansett Laboratory

Large Marine Ecosystems of the World and Linked Watersheds

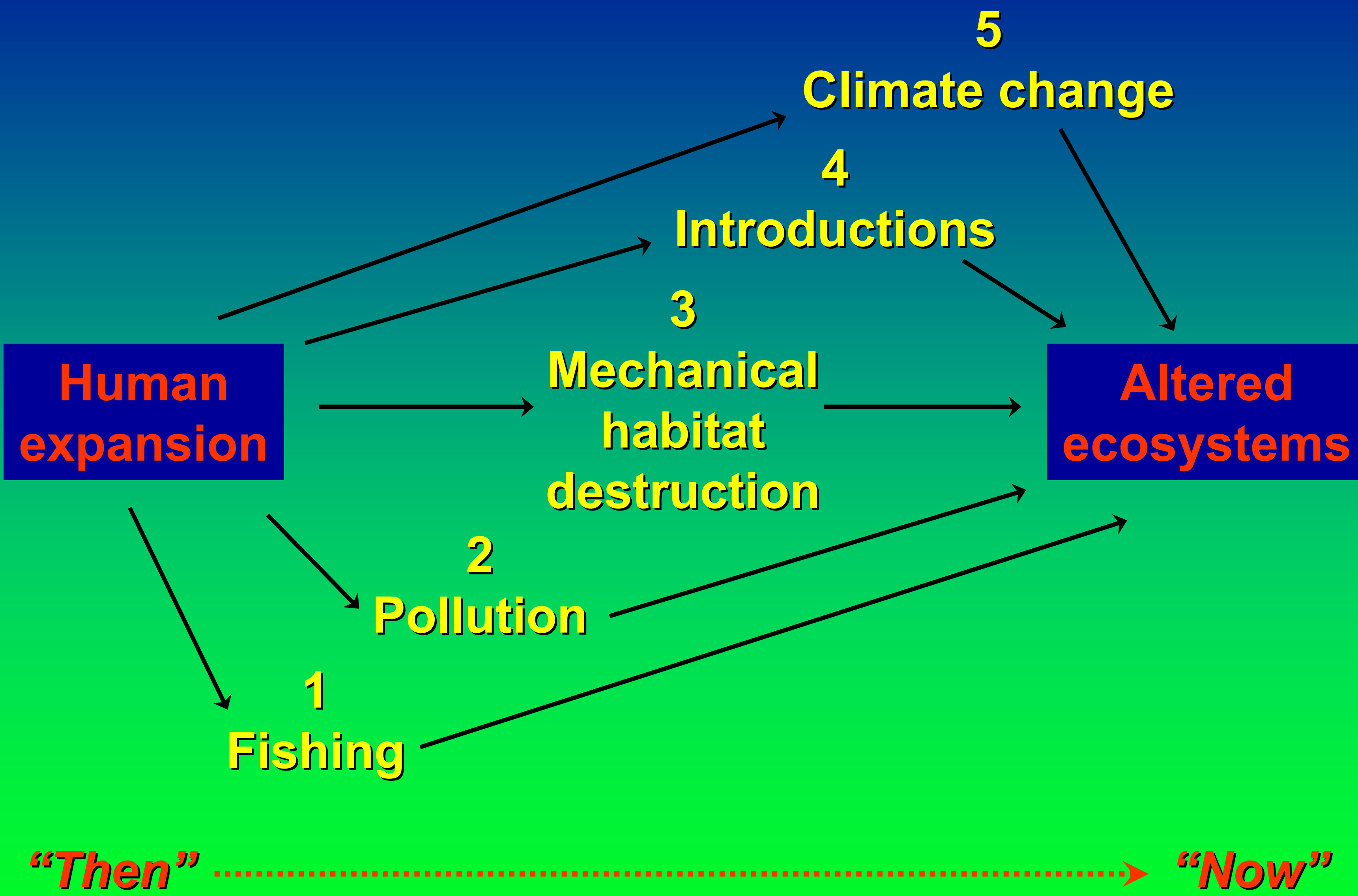


1 East Bering Sea
2 Gulf of Alaska
3 California Current
4 Gulf of California
5 Gulf of Mexico
6 Southeast U.S. Continental Shelf
7 Northeast U.S. Continental Shelf
8 Scotian Shelf
9 Newfoundland-Labrador Shelf
10 Insular Pacific-Hawaiian
11 Pacific Central-American Coastal
12 Caribbean Sea
13 Humboldt Current
14 Patagonian Shelf
15 South Brazil Shelf
16 East Brazil Shelf
17 North Brazil Shelf
18 West Greenland Shelf
19 East Greenland Shelf
20 Barents Sea
21 Norwegian Shelf
22 North Sea
23 Baltic Sea
24 Celtic-Biscay Shelf
25 Iberian Coastal
26 Mediterranean Sea
27 Canary Current
28 Guinea Current
29 Benguela Current
30 Agulhas Current
31 Somali Coastal Current
32 Arabian Sea
33 Red Sea
34 Bay of Bengal
35 Gulf of Thailand
36 South China Sea
37 Sulu-Celebes Sea
38 Indonesian Sea
39 North Australian Shelf
40 Northeast Australian Shelf-Great Barrier Reef
41 East-Central Australian Shelf
42 Southeast Australian Shelf
43 Southwest Australian Shelf
44 West-Central Australian Shelf
45 Northwest Australian Shelf
46 New Zealand Shelf
47 East China Sea
48 Yellow Sea
49 Kuroshio Current
50 Sea of Japan
51 Oyashio Current
52 Okhotsk Sea
53 West Bering Sea
54 Chukchi Sea
55 Beaufort Sea
56 East Siberian Sea
57 Laptev Sea
58 Kara Sea
59 Iceland Shelf
60 Faroe Plateau
61 Antarctic
62 Black Sea
63 Hudson Bay
64 Arctic Ocean

ESTIMATED SOCIOECONOMIC VALUE OF LMEs

Goods and Services Contribute $12.6 Trillion Annually to the Global Economy

Costanza et al. , NATURE, Vol. 287/ 15 May 1997



(from Jackson *et al.*, *Science* vol. 293, 27 July 2001)

The Downward Spiral

Human activities are cumulatively driving the health of the world's oceans down a rapid spiral, and only prompt and wholesale changes will slow or perhaps ultimately reverse the catastrophic problems they are facing.

Jeremy Jackson, Scripps Institution of Oceanography / University of California, San Diego – Scripps News of 13 August 2008

LMEs ARE GLOBAL CENTERS OF EFFORTS TO:

- **REDUCE** coastal pollution
- **RESTORE** damaged habitats
  (Coral reefs, mangroves, sea grasses)
- **RECOVER** depleted fishery stocks
- **ADAPT to climate warming**

SELECTED ECOSYSTEM-RELATED WSSD TARGETS AND PROGRAM OF IMPLEMENTATION (POI), Johannesburg, August 2002

- Land-based Sources of Pollution

  POI – Substantially reduce by 2006
- Ecosystem-based Approach

  POI – Introduce by 2010
- Marine Protected Areas

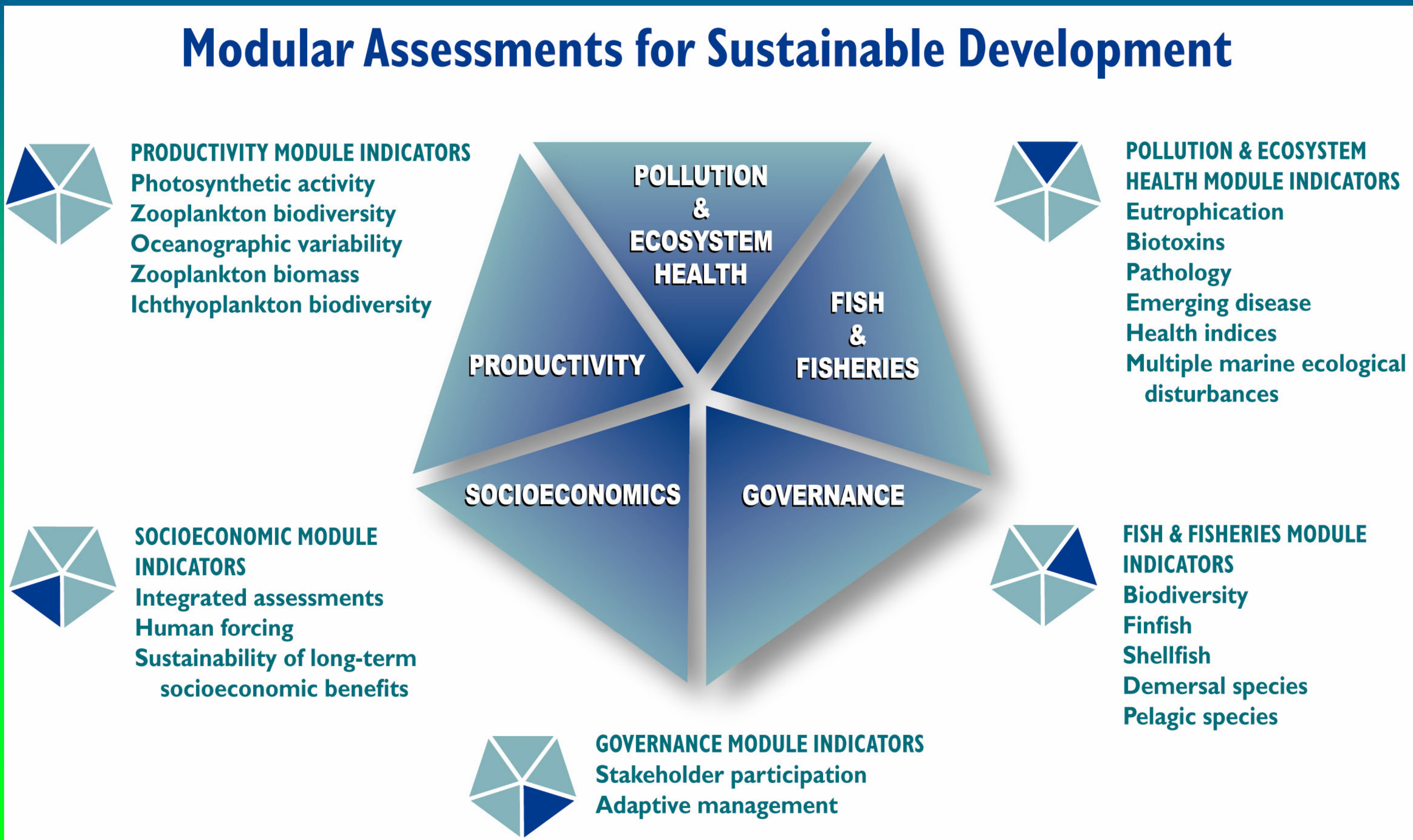
  POI - Designated Network by 2012
- Restoration and Sustainability of Fisheries

  POI – On an urgent basis and where possible to MSY by 2015

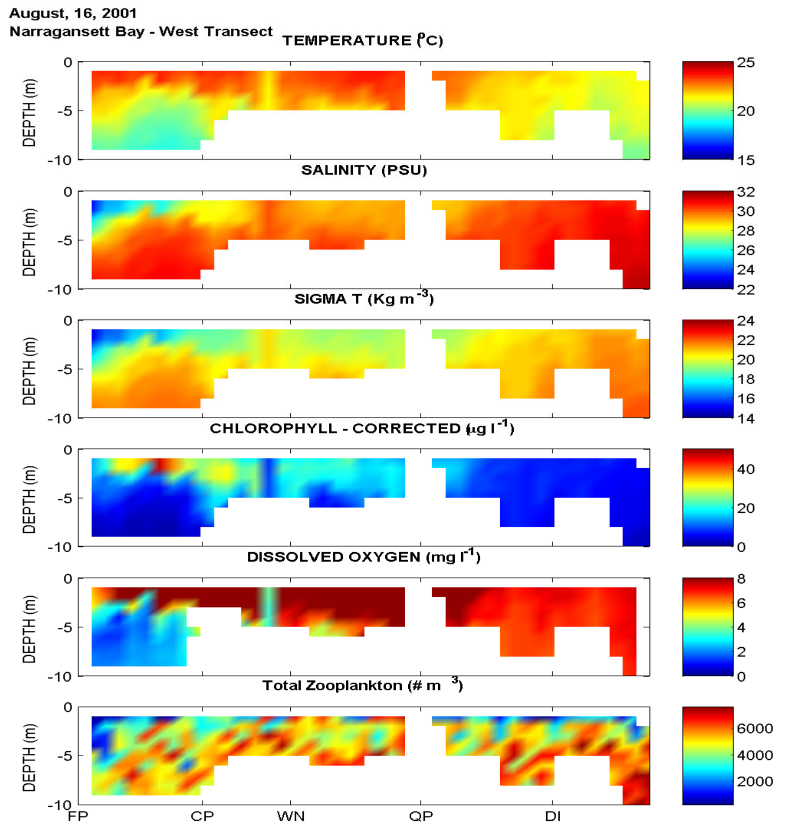
GEF Supported POI Actions

- TDA – SAP Process
- 110 participating countries
- $1.8 billion in start-up financial support by GEF, other donors and participating countries

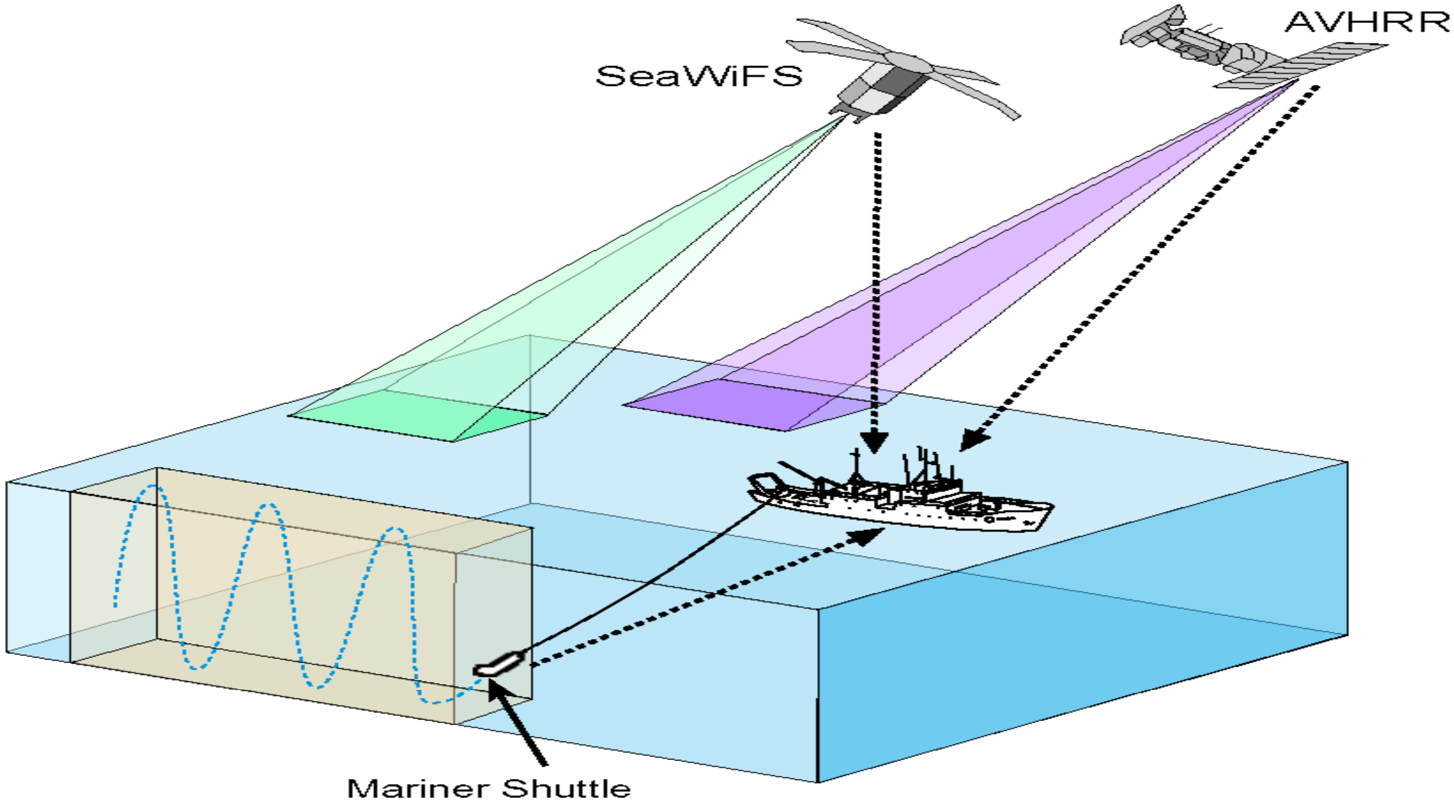
Ecosystem-based Metrics



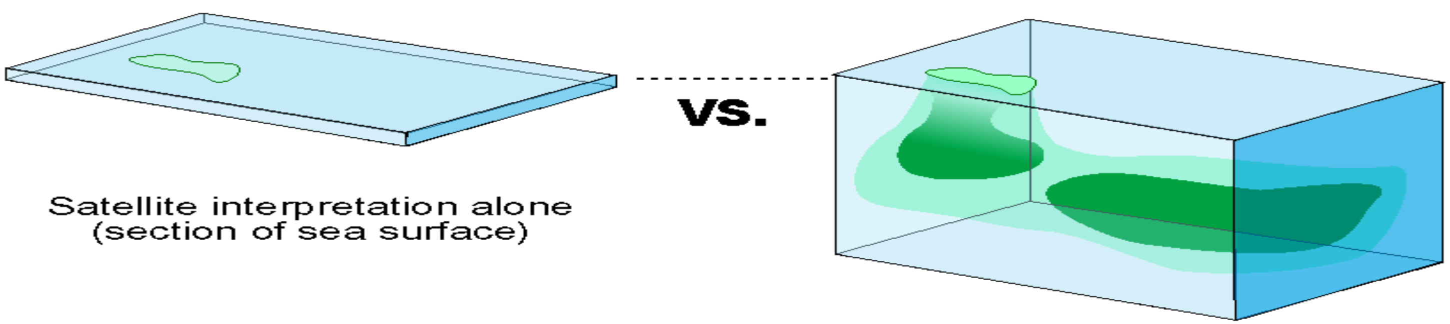
PRODUCTIVITY INDICATORS



An undulating oceanographic recorder (above), towed behind a ship, is used to collect ecological parameters needed to assess the state of the marine ecosystem (left).



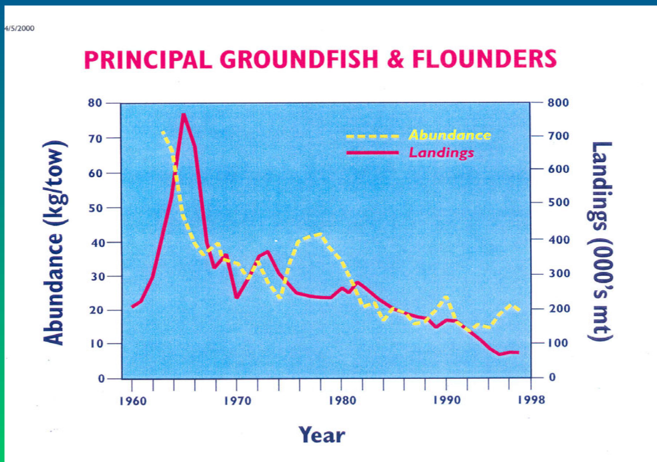
Satellite and in-situ information collected and integrated at sea

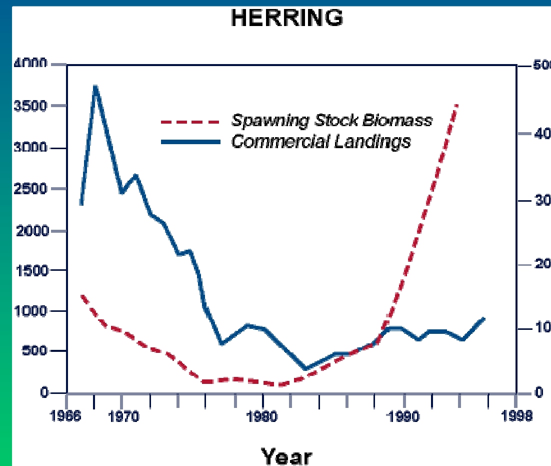


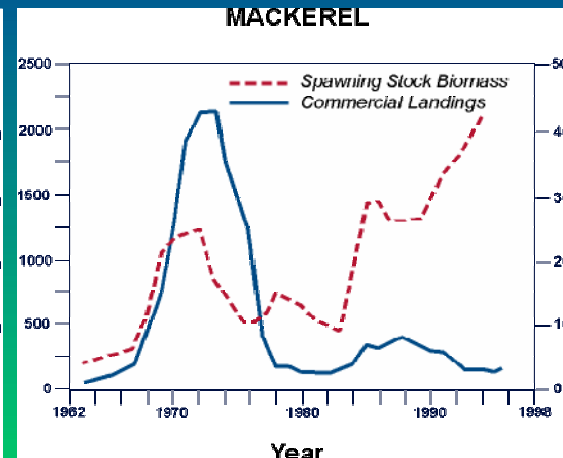
Satellite interpretation alone
(section of sea surface)

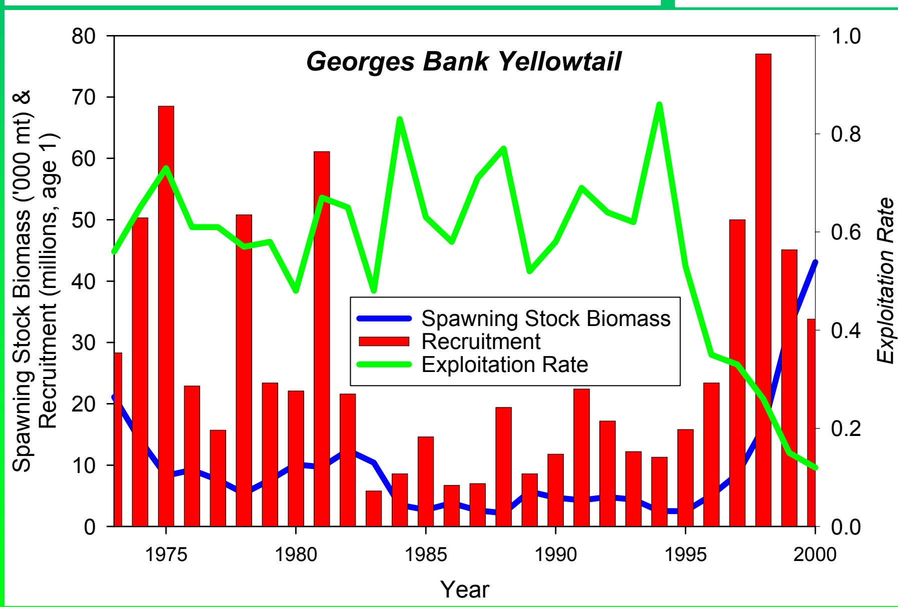
3-D Visualization of Primary Productivity
produced from satellite and in-situ sensors

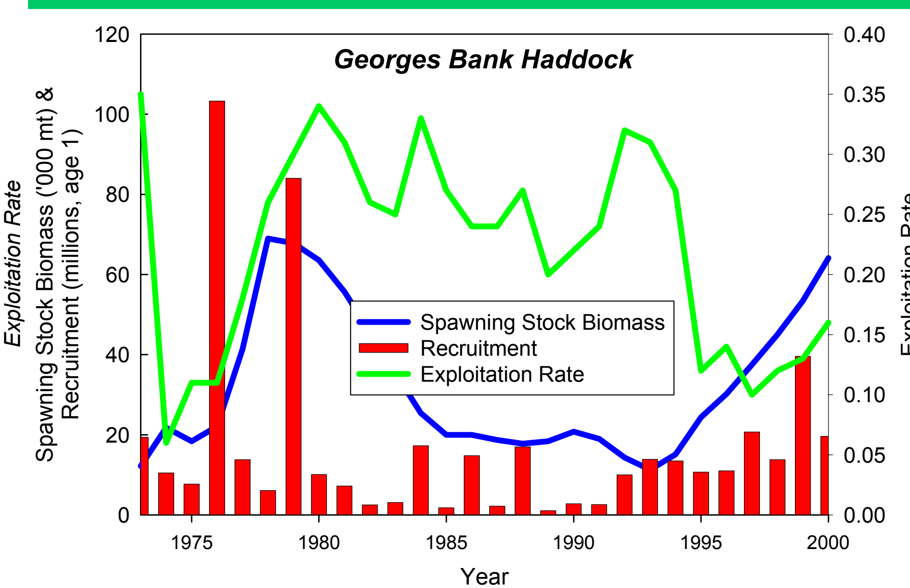
FISH AND FISHERIES INDICATORS











POLLUTION AND ECOSYSTEM HEALTH INDICATORS

Indicators:

Water Clarity
Dissolved Oxygen
Coastal Wetland Loss
Eutrophic Condition
Sediment Contamination
Benthic Index
Fish Tissue Contaminants
Multiple Marine Ecological Disturbances

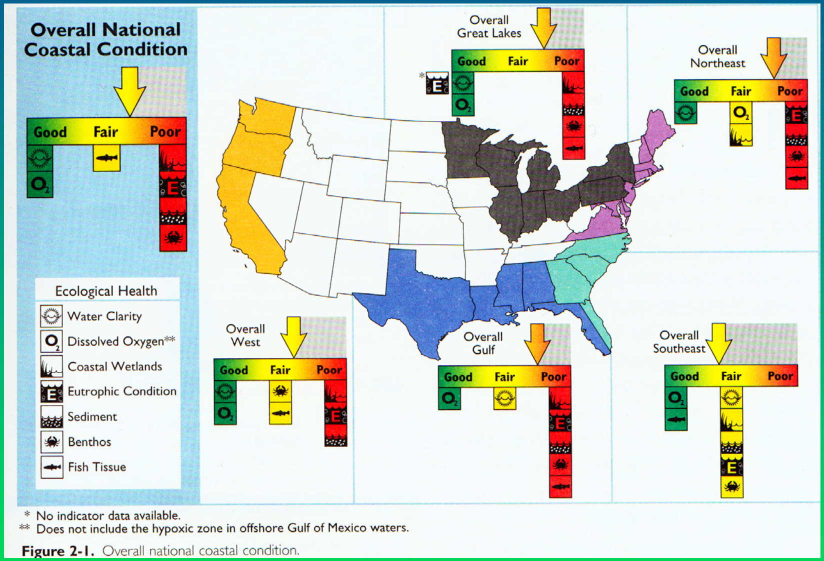
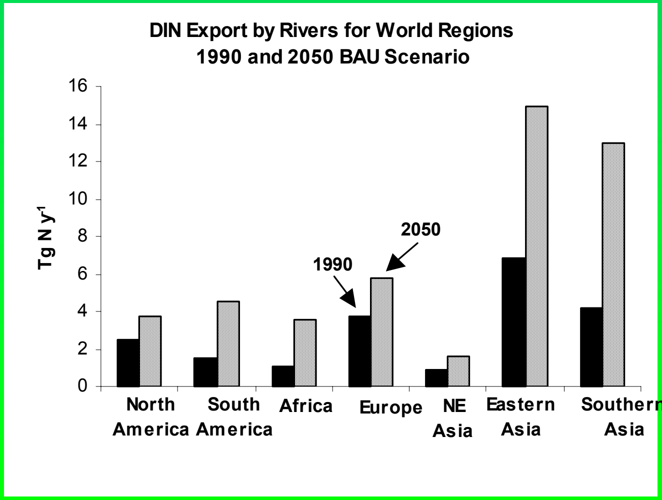


Figure 2-1. Overall national coastal condition.



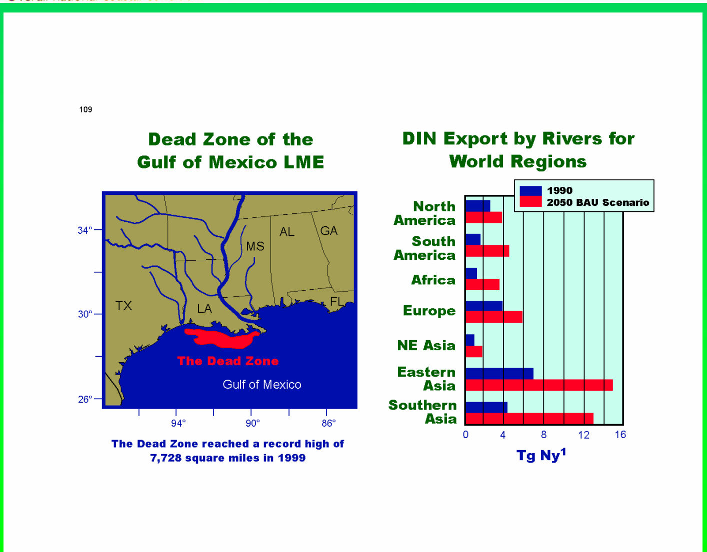
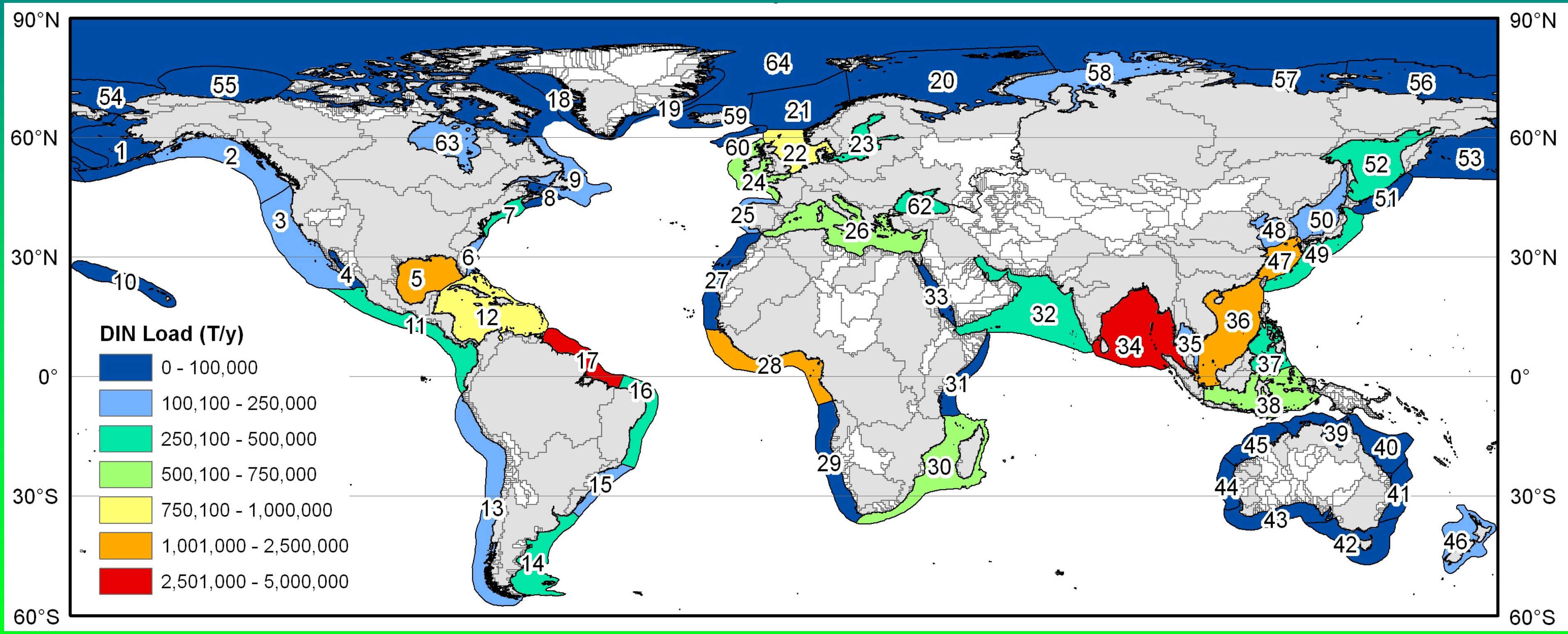
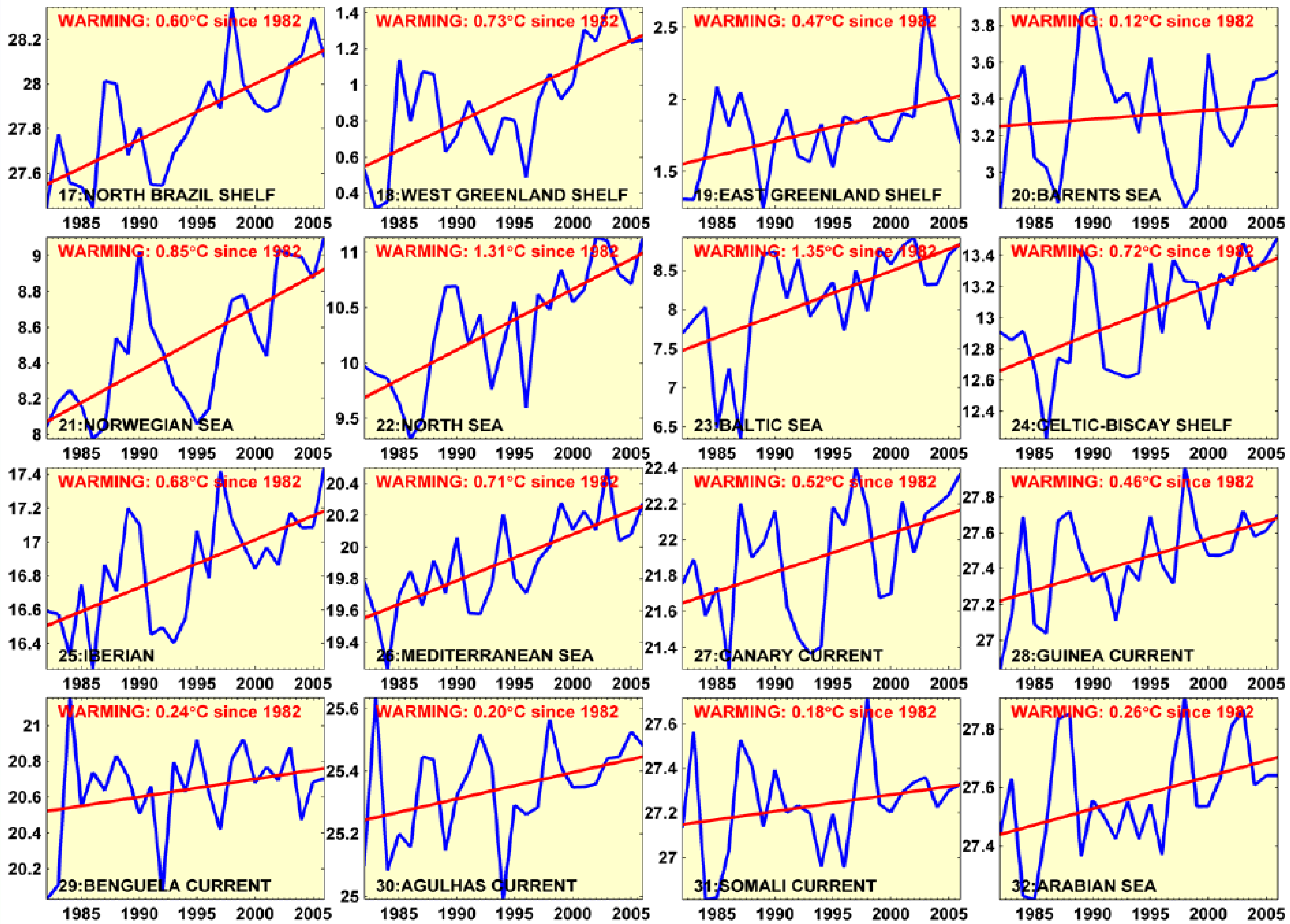


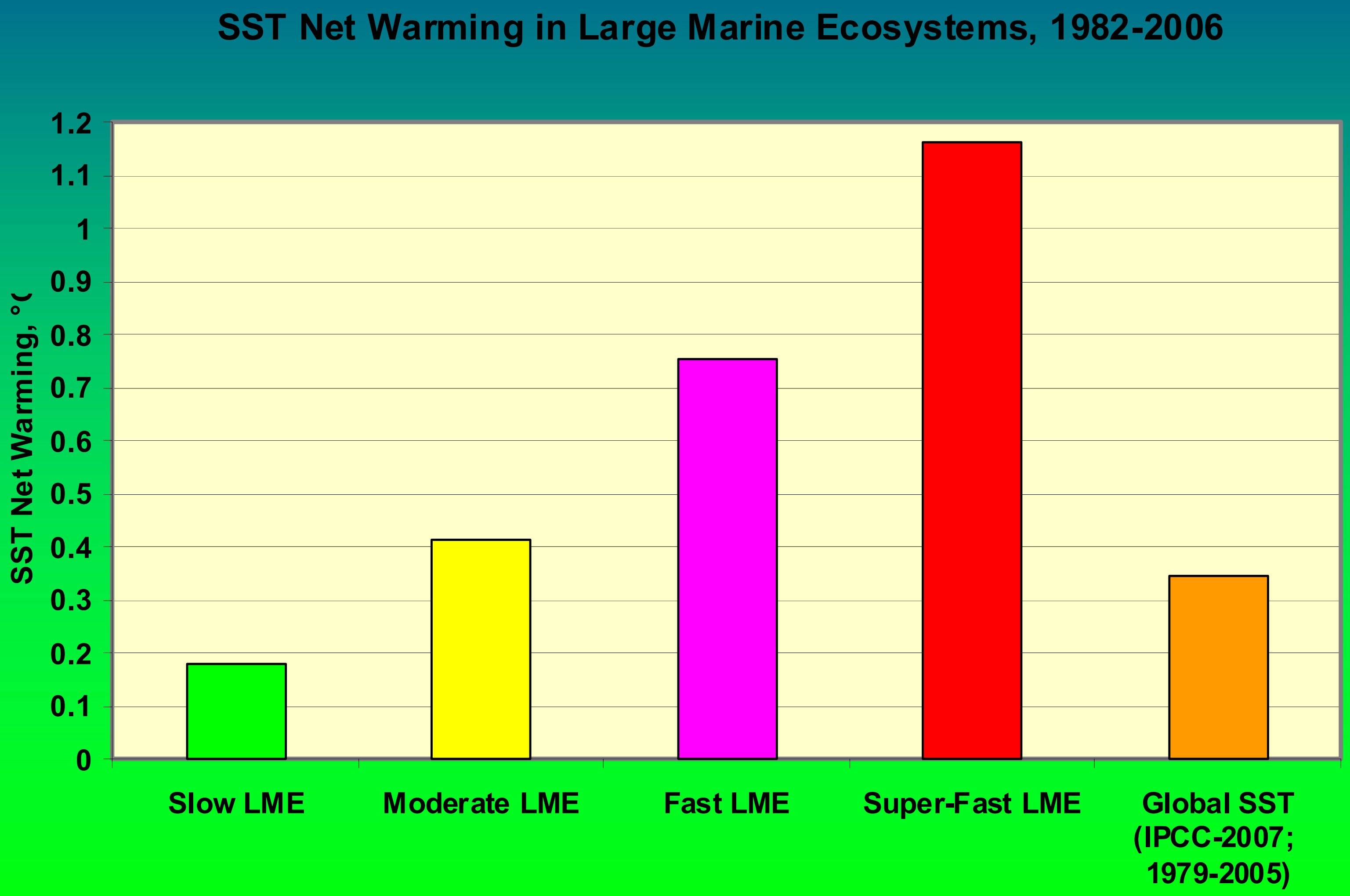
Figure 7. DIN inputs to LMEs from land-based sources predicted by the NEWS DIN model. Watersheds discharging to LMEs are grey; watersheds with zero coastal discharge are white. Units: Tons N/y. See Table 2 for LME identification. (Figure from Lee and Seitzinger 2009).

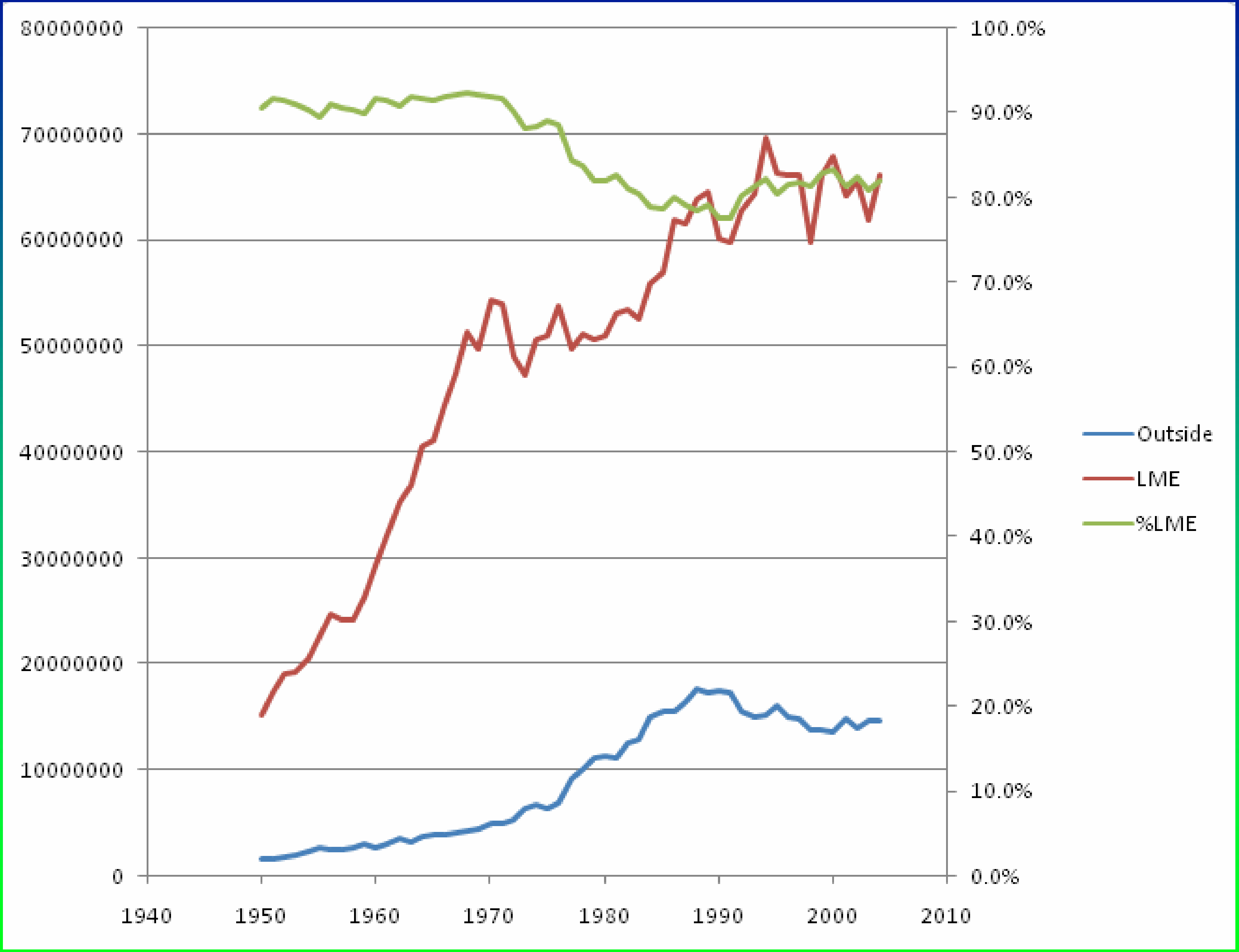




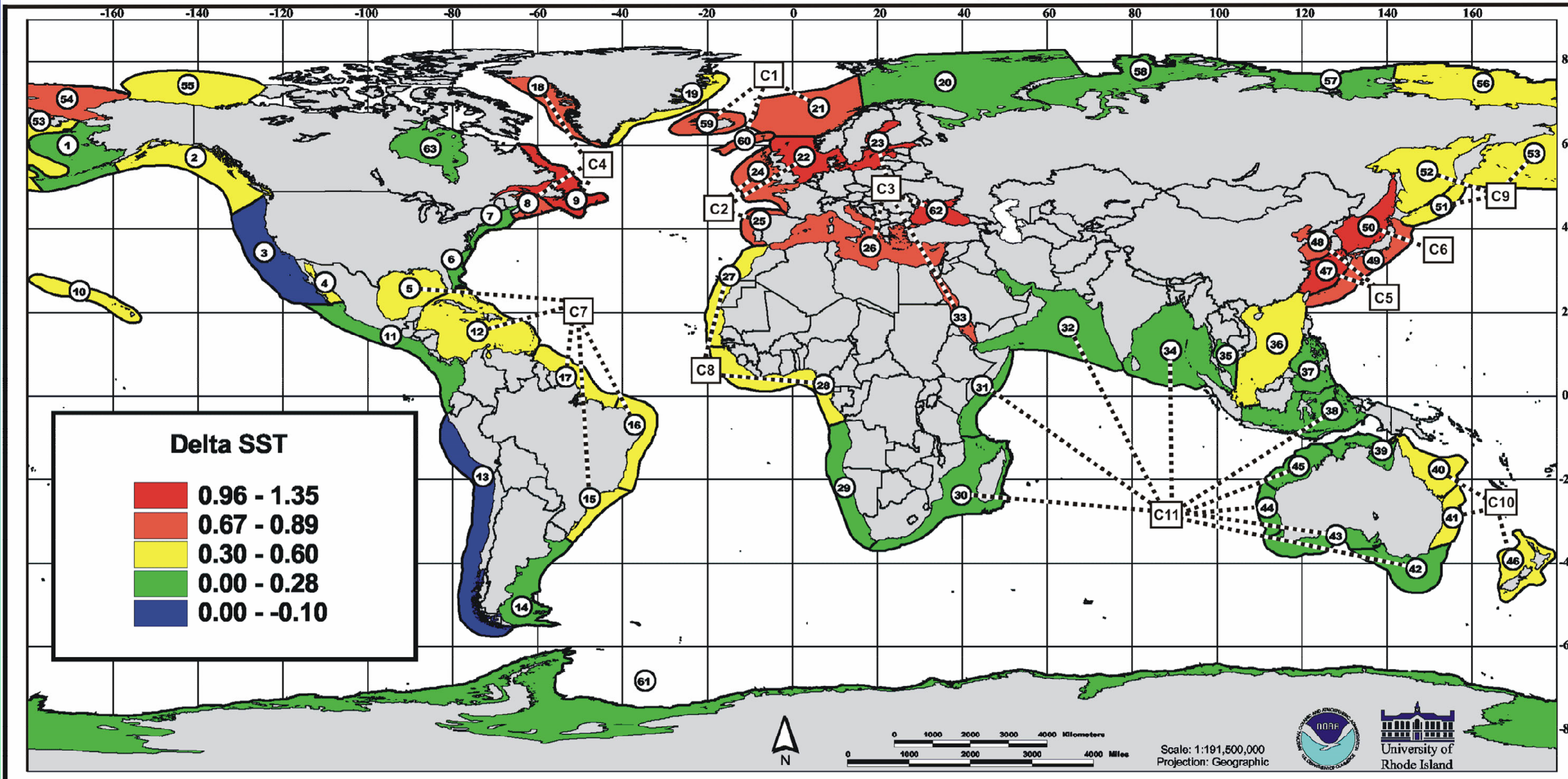
WARMING: 0.60°C since 1982
17:NORTH BRAZIL SHELF
WARMING: 0.73°C since 1982
18:WEST GREENLAND SHELF
WARMING: 0.47°C since 1982
19:EAST GREENLAND SHELF
WARMING: 0.12°C since 1982
20:BARENTS SEA
WARMING: 0.85°C since 1982
21:NORWEGIAN SEA
WARMING: 1.31°C since 1982
22:NORTH SEA
WARMING: 1.35°C since 1982
23:BALTIC SEA
WARMING: 0.72°C since 1982
24:CELTIC-BISCAY SHELF
WARMING: 0.68°C since 1982
25:IBERIAN
WARMING: 0.71°C since 1982
26:MEDITERRANEAN SEA
WARMING: 0.52°C since 1982
27:CANARY CURRENT
WARMING: 0.46°C since 1982
28:GUINEA CURRENT
WARMING: 0.24°C since 1982
29:BENGUELA CURRENT
WARMING: 0.20°C since 1982
30:AGULHAS CURRENT
WARMING: 0.18°C since 1982
31:SOMALI CURRENT
WARMING: 0.26°C since 1982
32:ARABIAN SEA
1985
1990
1995
2000
2005

Climate Warming and Fisheries Biomass Yields





Courtesy of Villy Christensen, UBC, Fisheries Centre



Warming Clusters of LMEs in Relation to SSTs, 1982-2006:

FAST WARMING:

C1 Northern European Cluster; C2 Southern European; C3 Semi-Enclosed European Seas; C4 of the NW Atlantic; C5 Fast Warming East Asian LMEs; C6 Kuroshio Current and Sea of Japan/East Sea LMEs.

MODERATE WARMING:

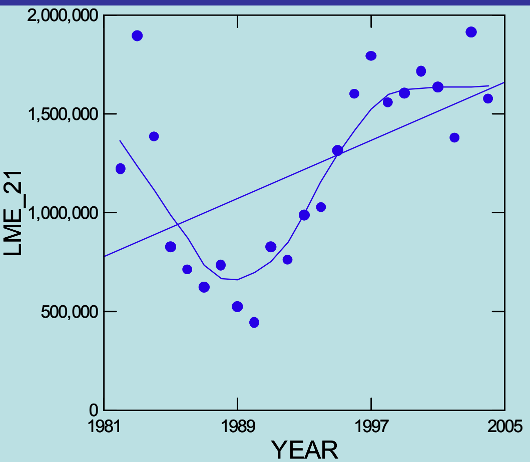
C7 Western Atlantic LMEs; C8 Eastern Atlantic LMEs; C9 NW Pacific LMEs; C10 SW Pacific LMEs. Several Non-Clustered, Moderate Warming LMEs: NE Australia, Insular Pacific Hawaiian, Gulf of Alaska, Gulf of California; South China Sea, East Greenland Shelf;

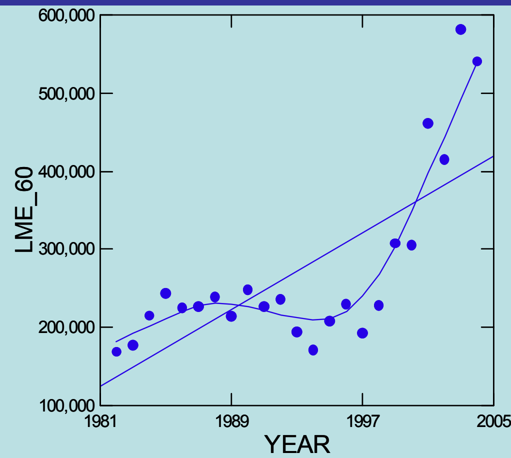
SLOW WARMING:

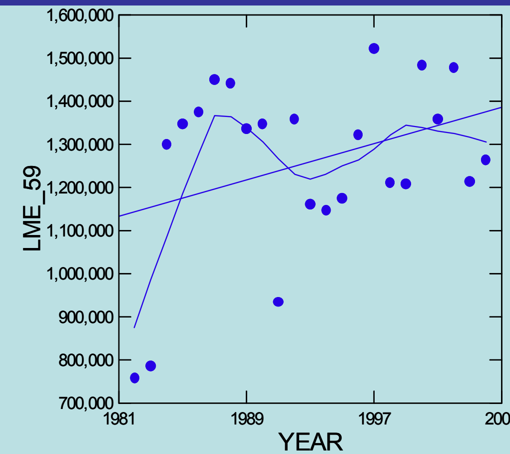
C11 Indian Ocean and Adjacent Waters.

Non-clustered, Slow Warming LMEs include the U.S. Northeast Shelf, the U.S. Southeast Shelf, the Barents Sea, East Bering Sea; Patagonian Shelf, Benguela Current and Pacific Central American Coastal LMEs.

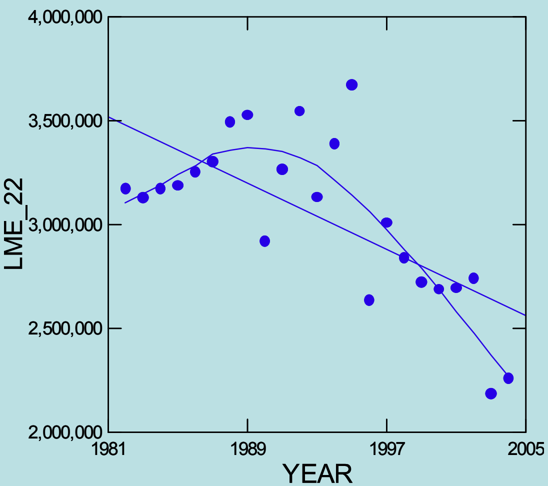
Fisheries biomass yield trends (metric tons) in fast warming cluster 1: Norwegian Sea (LME 21), Faroe Plateau (LME 60), and Iceland Shelf (LME 59).

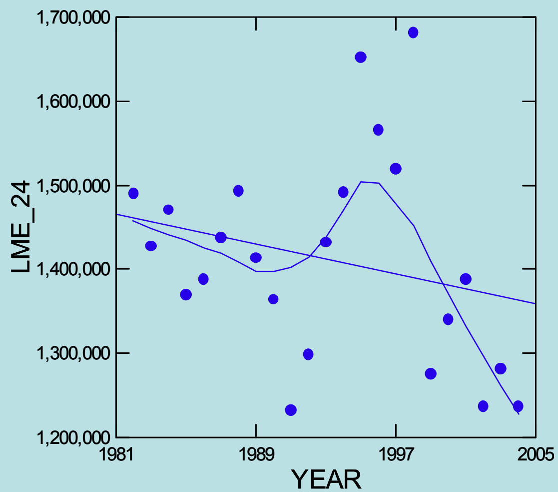


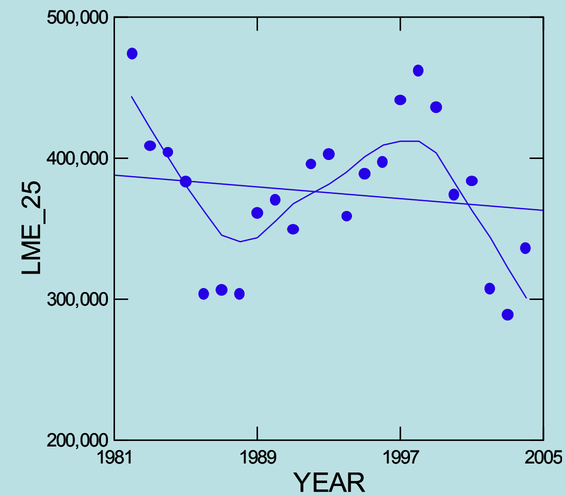


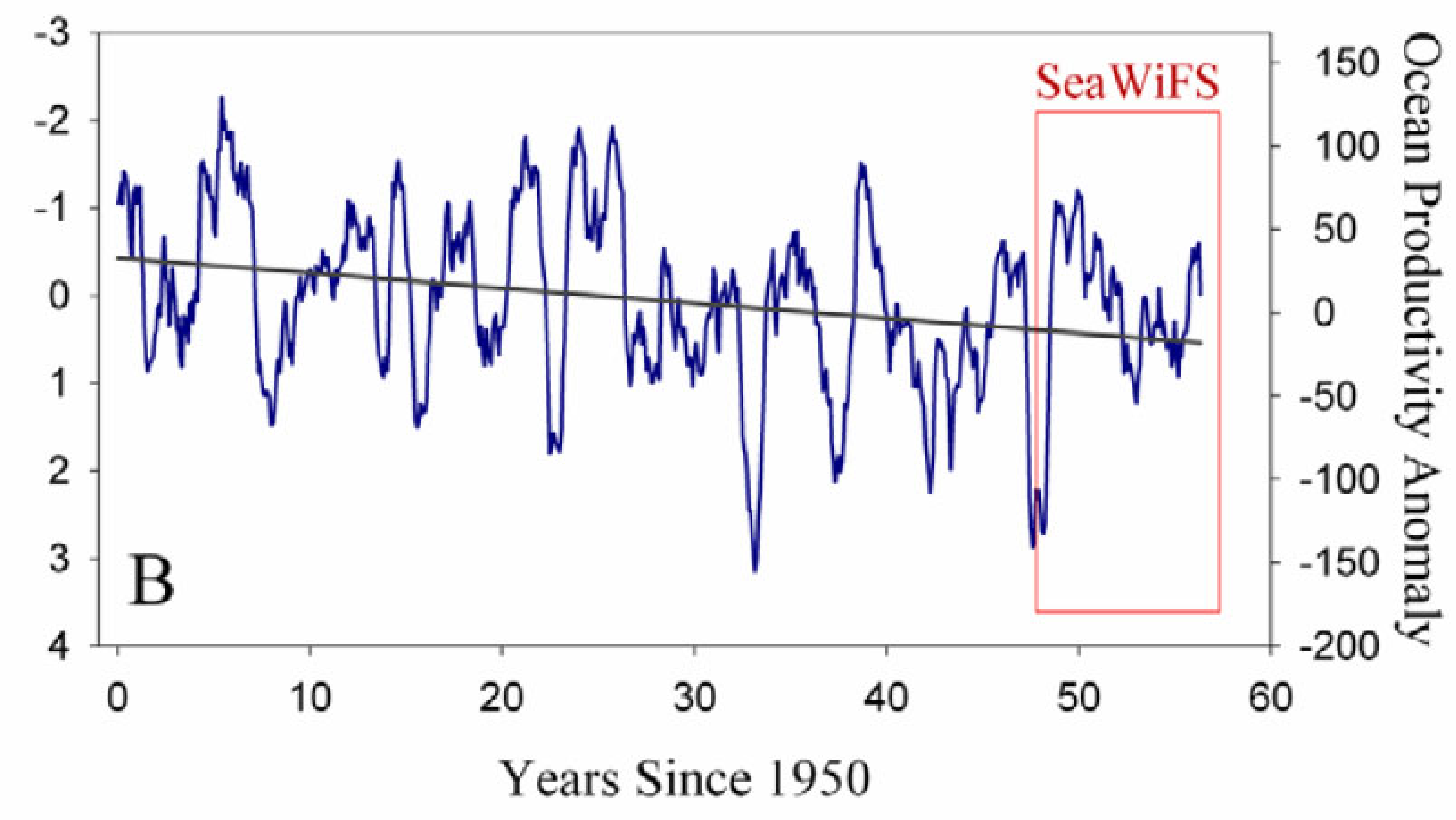


Fisheries biomass yield trends (metric tons) in fast warming cluster 2: North Sea (LME 22), Celtic Biscay (LME 24) and Iberian Coastal (LME 26)



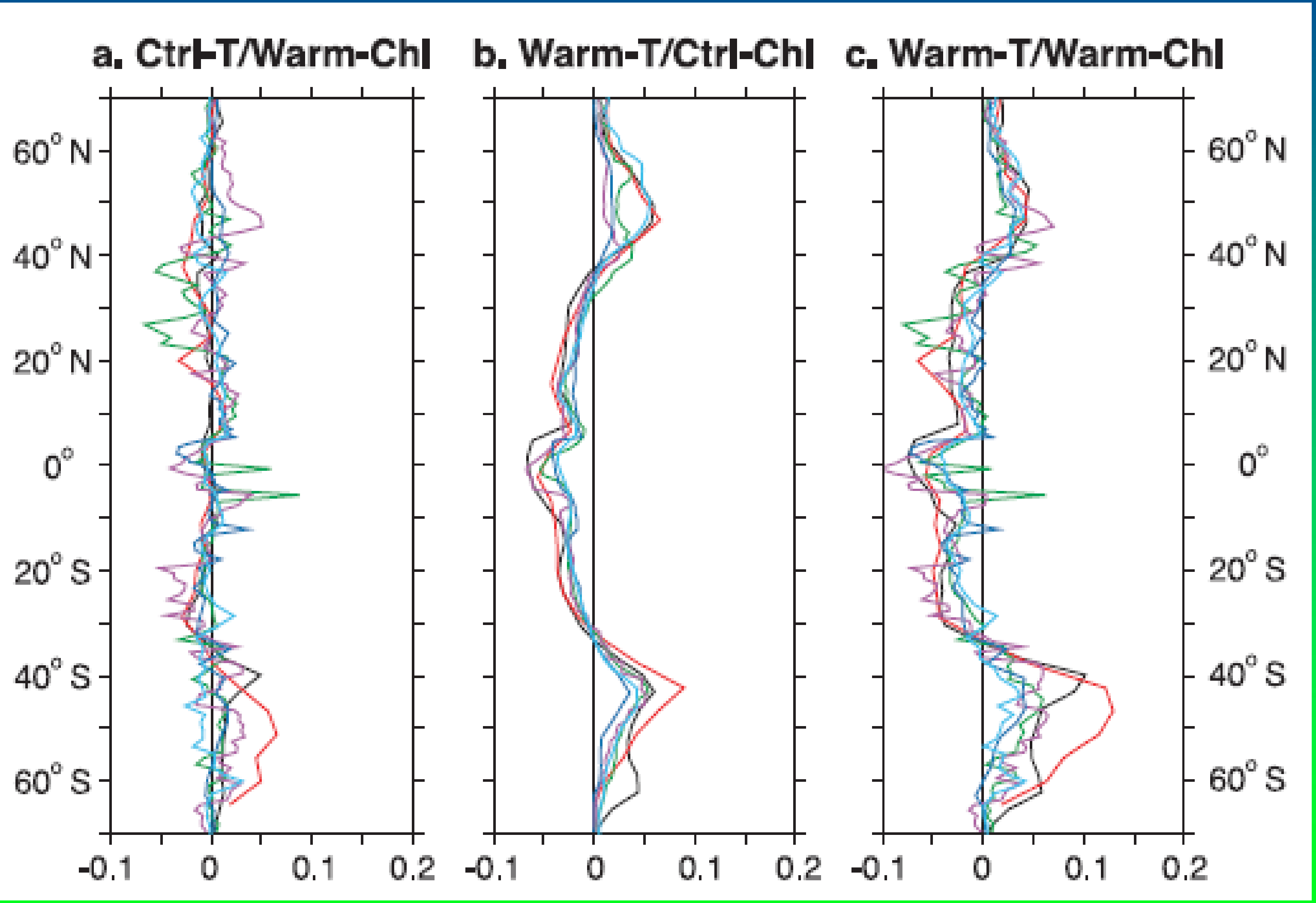






From Behrenfeld et al. 2007

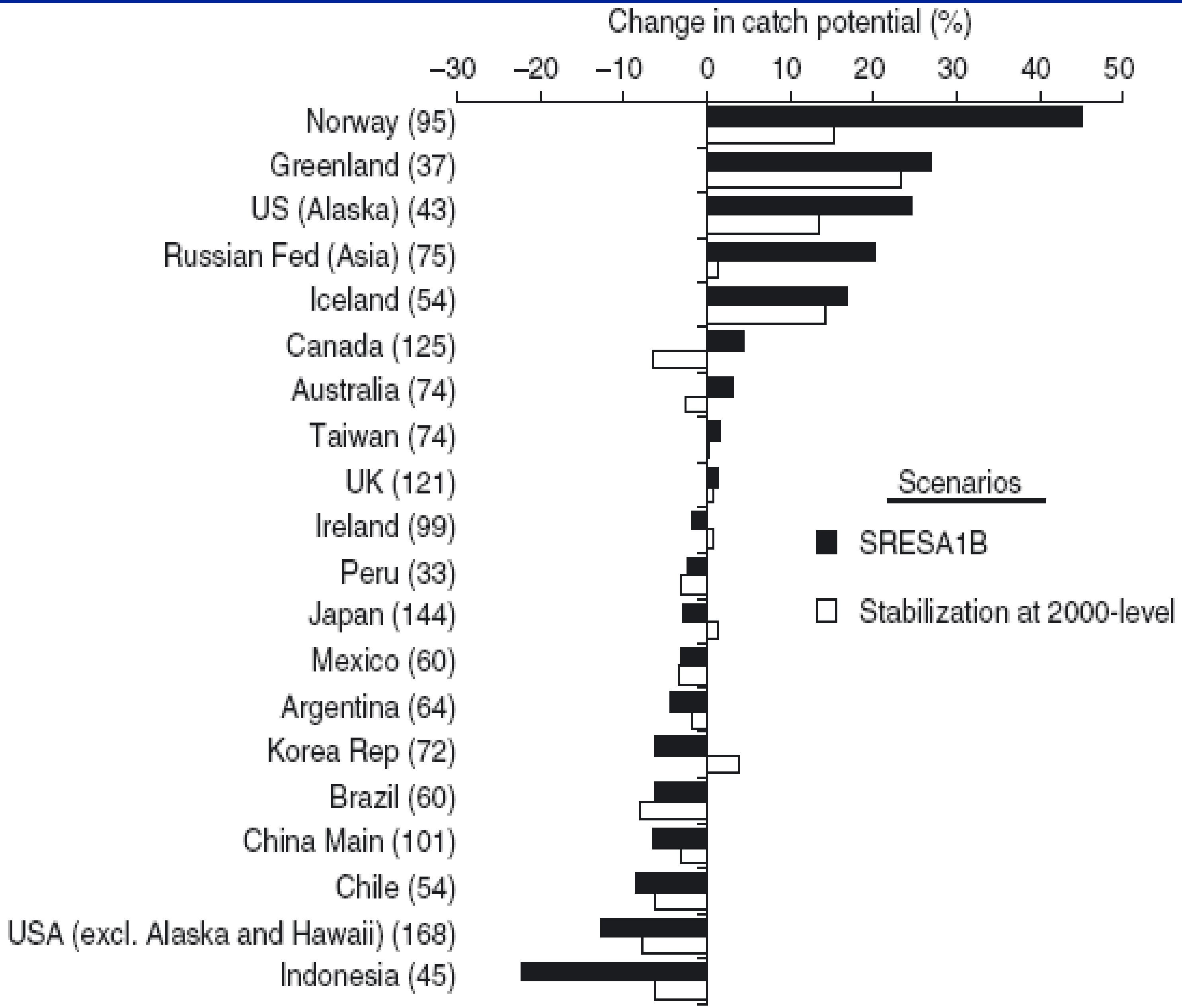
Estimated 2040 – 2060 primary production change (Pg-C deg^{-1} yr^{-1})



From Behrenfeld et al. 2007

- Six different coupled climate models
- Ocean biological responses to climate warming from industrial revolution to 2050
- Marginal sea-ice biome area decreases 42% (N) and 17% (S)
- Expansion of low production permanently stratified ocean by 4% (N) to 9.4% (S)
- Subpolar gyre biome expands 16% (N) and 7% (S)
- Stratification decreases nutrient supply and thus productivity in permanently stratified oceans
- Stratification, extended growing season, and sea ice retreat enhance production at high latitudes
- Significant shifts in community composition

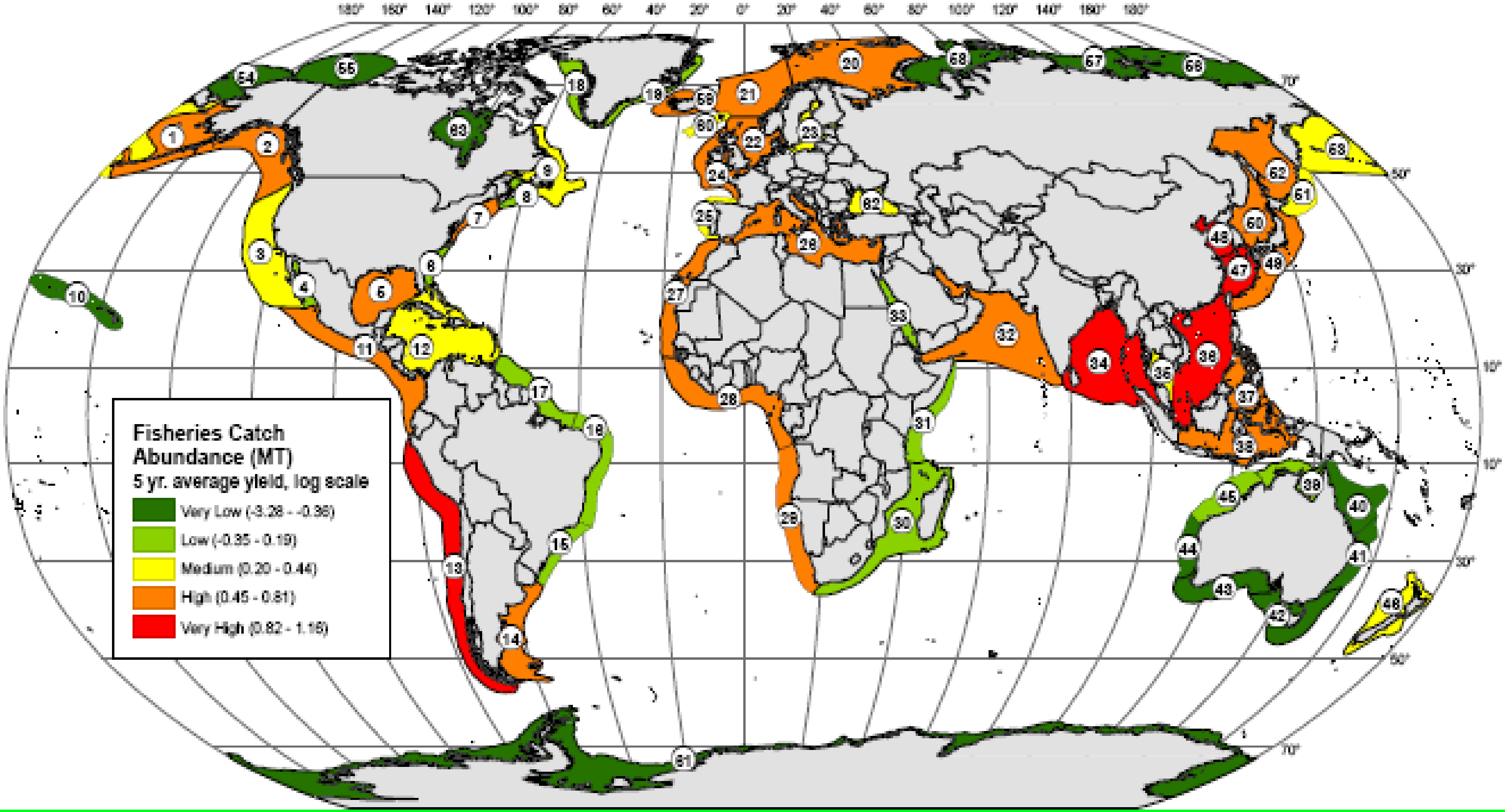
"Tidbits" from Behrenfeld, Sarmiento and others. 2004



Projected changes in 10-year averaged maximum catch potential from 2005 to 2055 by the 20 Exclusive Economic Zone regions with the highest catch in the 2000s. The numbers in parentheses represent the numbers of exploited species included in the analysis.

Cheung et al. Global Change Biology, 2009.

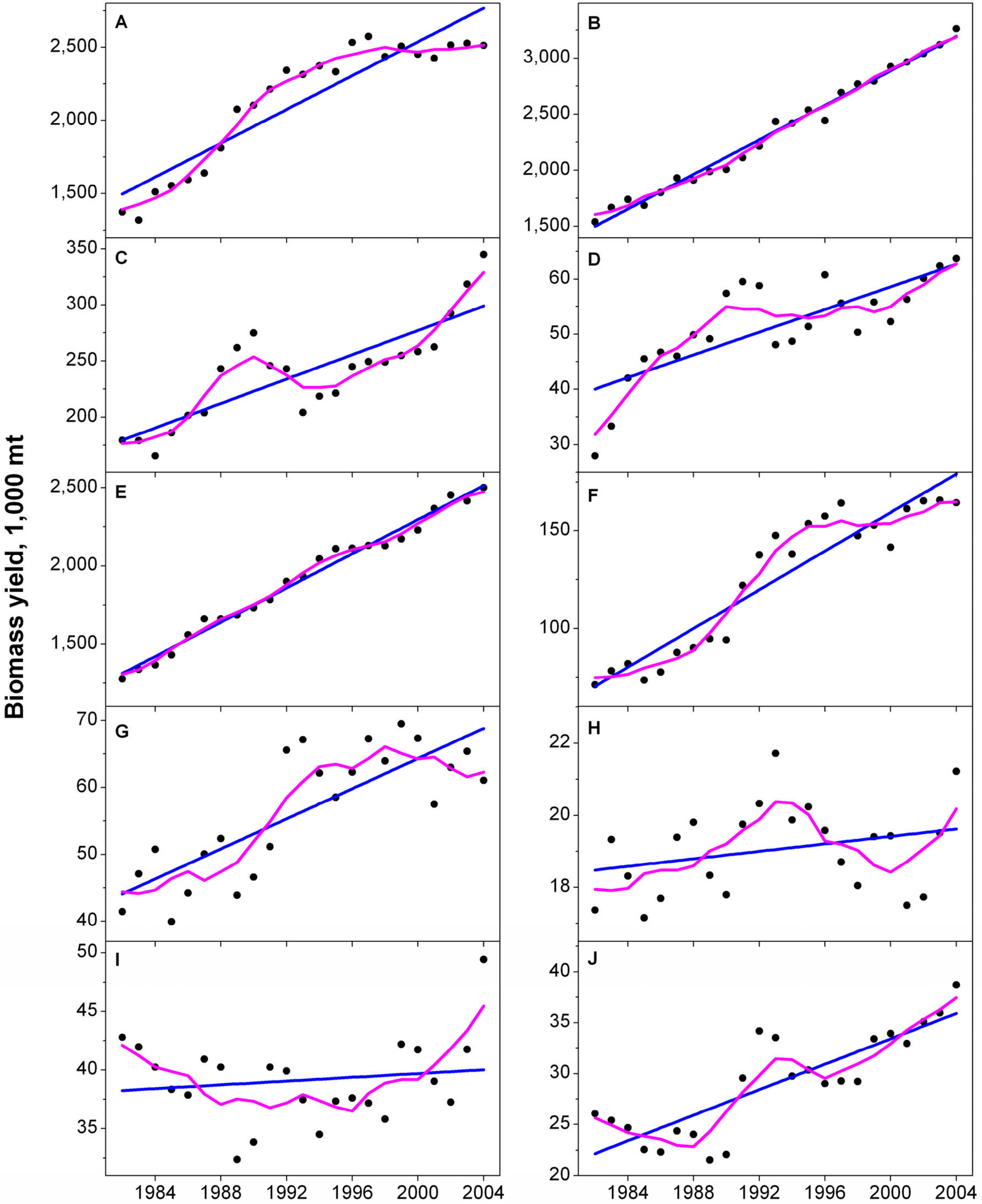
Fisheries Catch Abundance in Large Marine Ecosystems: 2000 - 2004

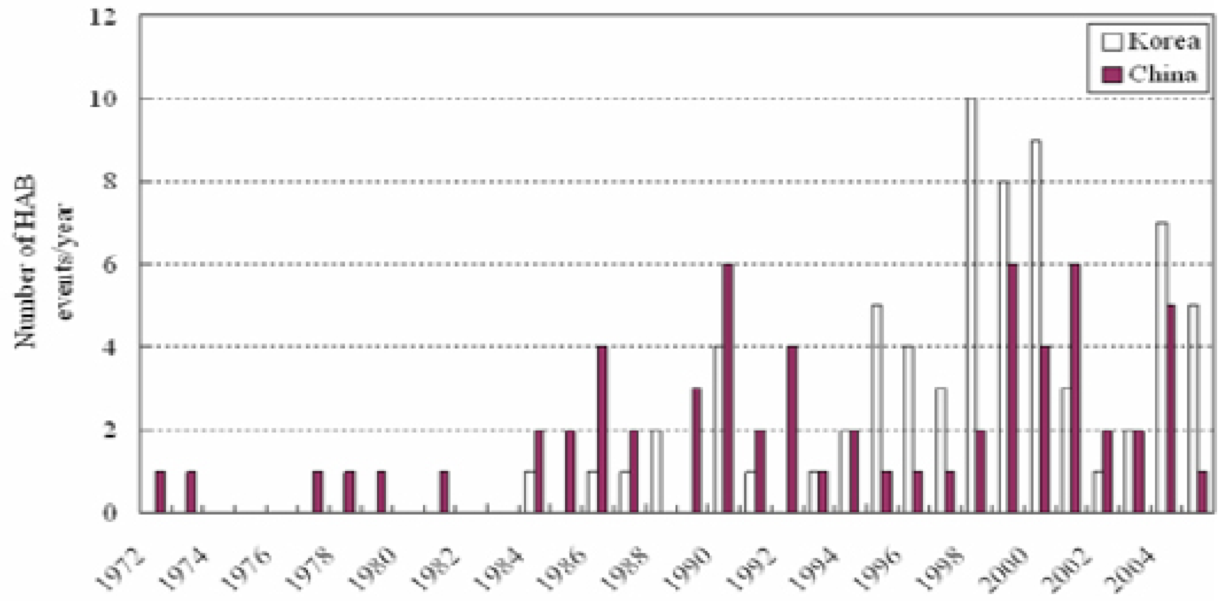


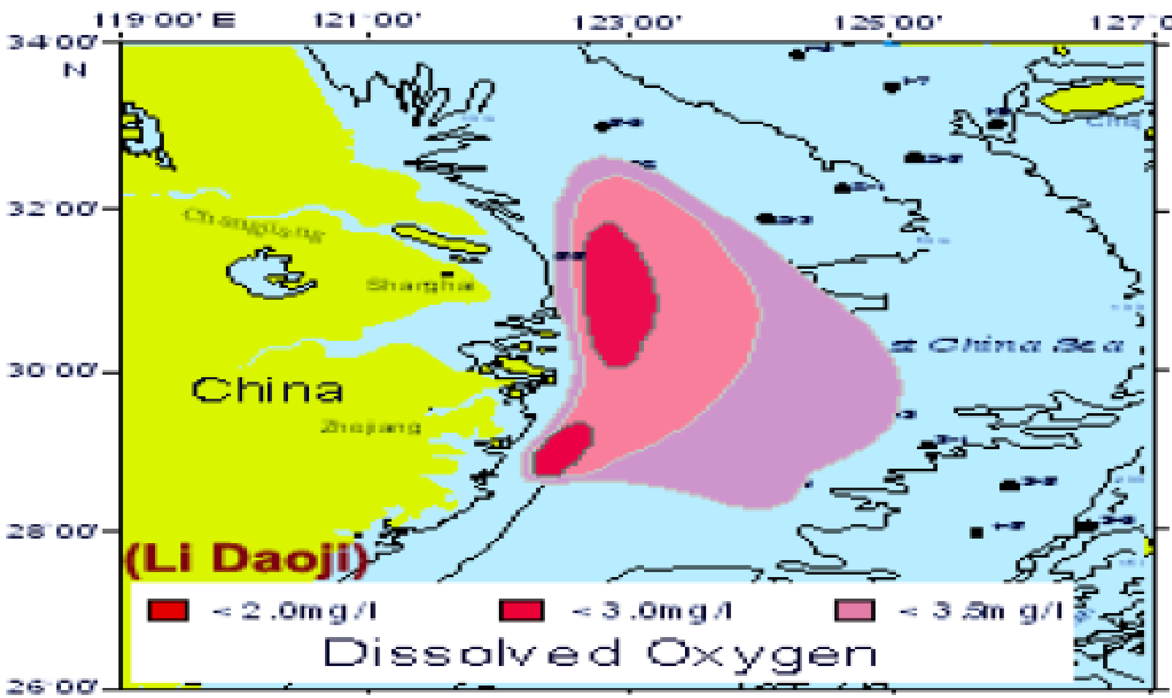
Courtesy of C. Damon, URI

CAP AND SUSTAIN

Comparative dynamics of fisheries biomass yield in the slow warming Indian Ocean and adjacent LMEs (see cluster C11 in Figure 6): Arabian Sea, LME 32 (A); Bay of Bengal, LME 34 (B); Agulhas Current, LME 30 (C); Somali Current, LME 31 (D); Indonesian Sea, LME 38 (E); North Australia, LME 39 (F); Northwest Australia, LME 45 (G); West-Central Australia, LME 44 (H); Southwest Australia, LME 43 (I); and, Southeast Australia, LME 42 (J). Linear regression is shown as blue trend line, adjacent averaging smoothing is shown as magenta trend line.







. Serious eutrophication, harmful algal blooms and dead zones in coastal areas.

Nutrient overenrichment and climate warming contribute to dead zone in the YSLME

Q. Tang, 2009, Figure 6

Yellow Sea Large Marine Ecosystem Management

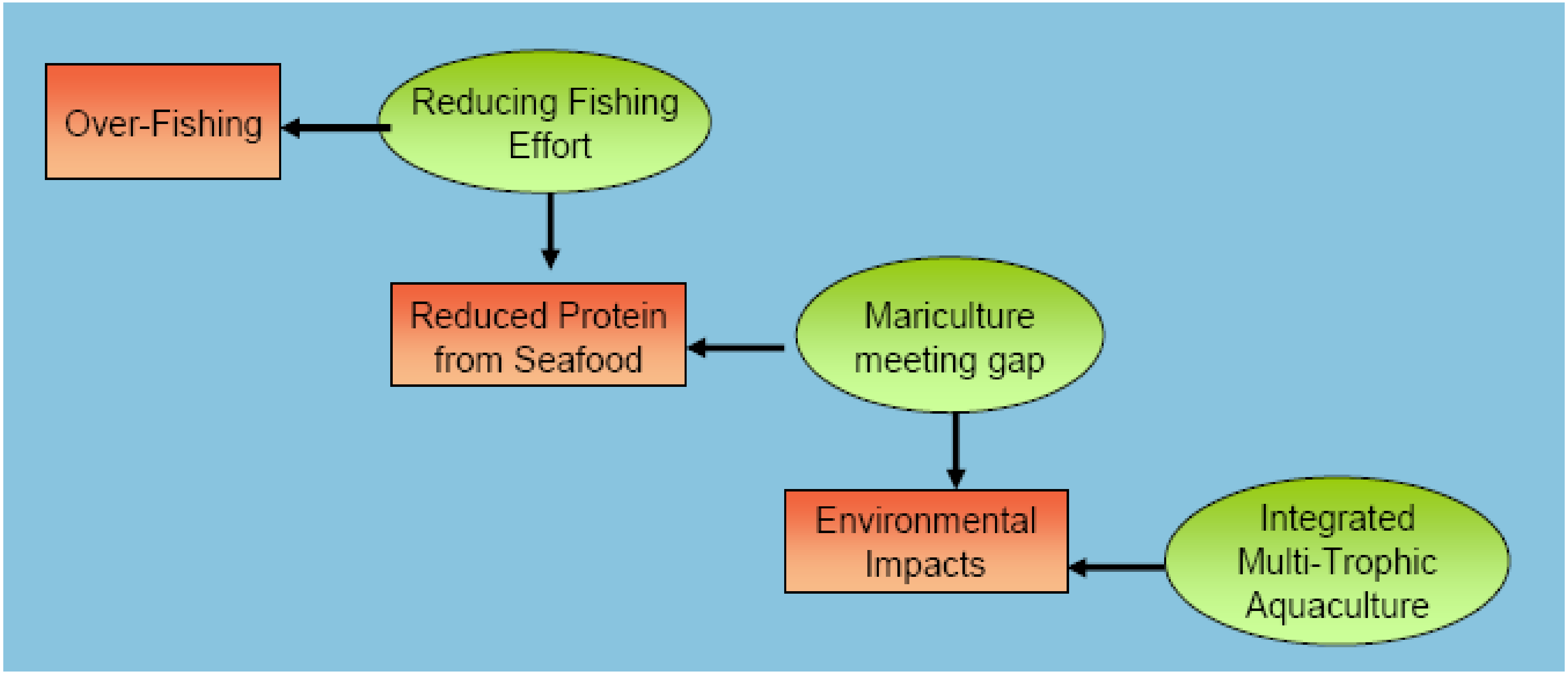


Figure 1. Logical considerations of management implementation

Walton and Jiang 2009, fig.1

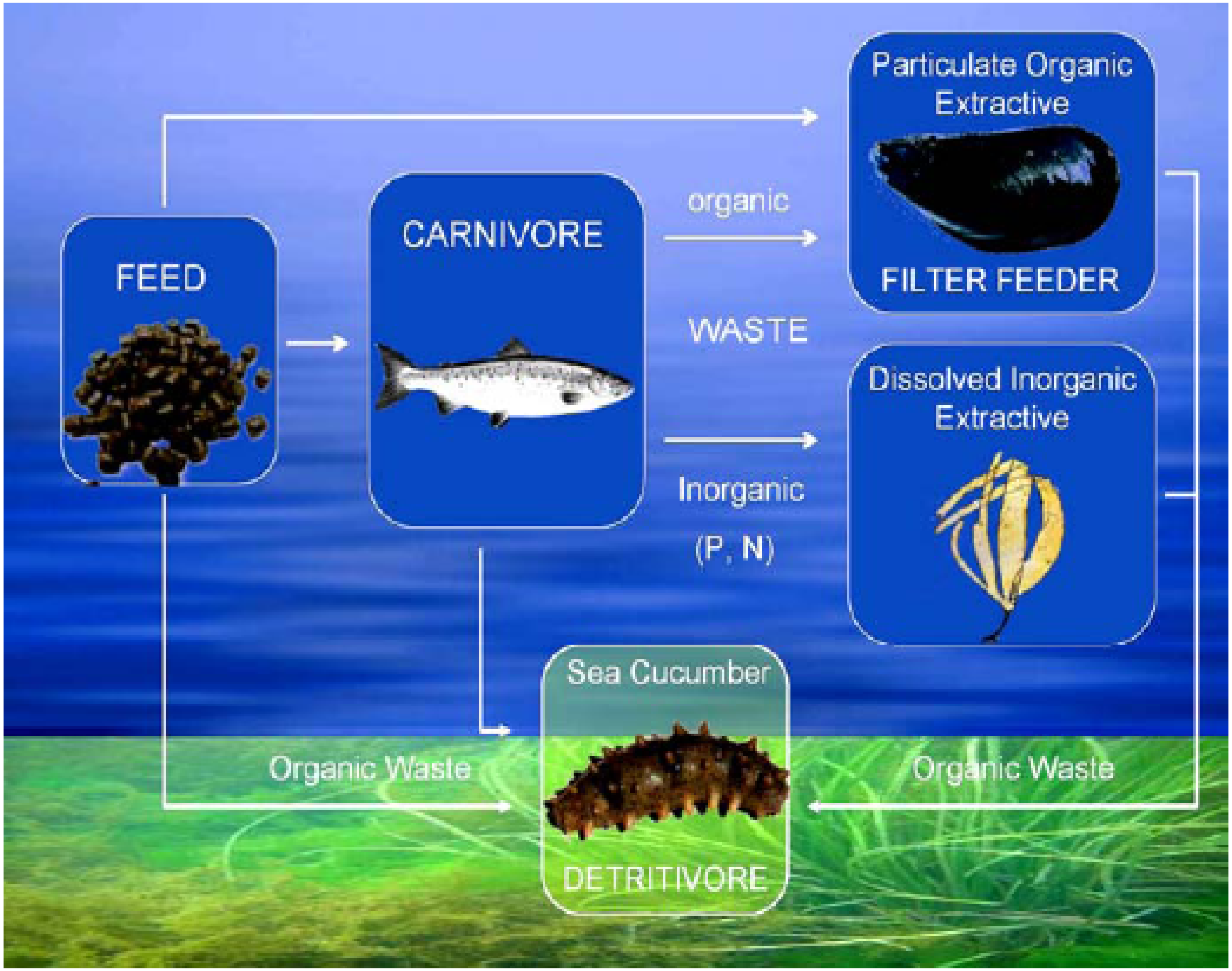


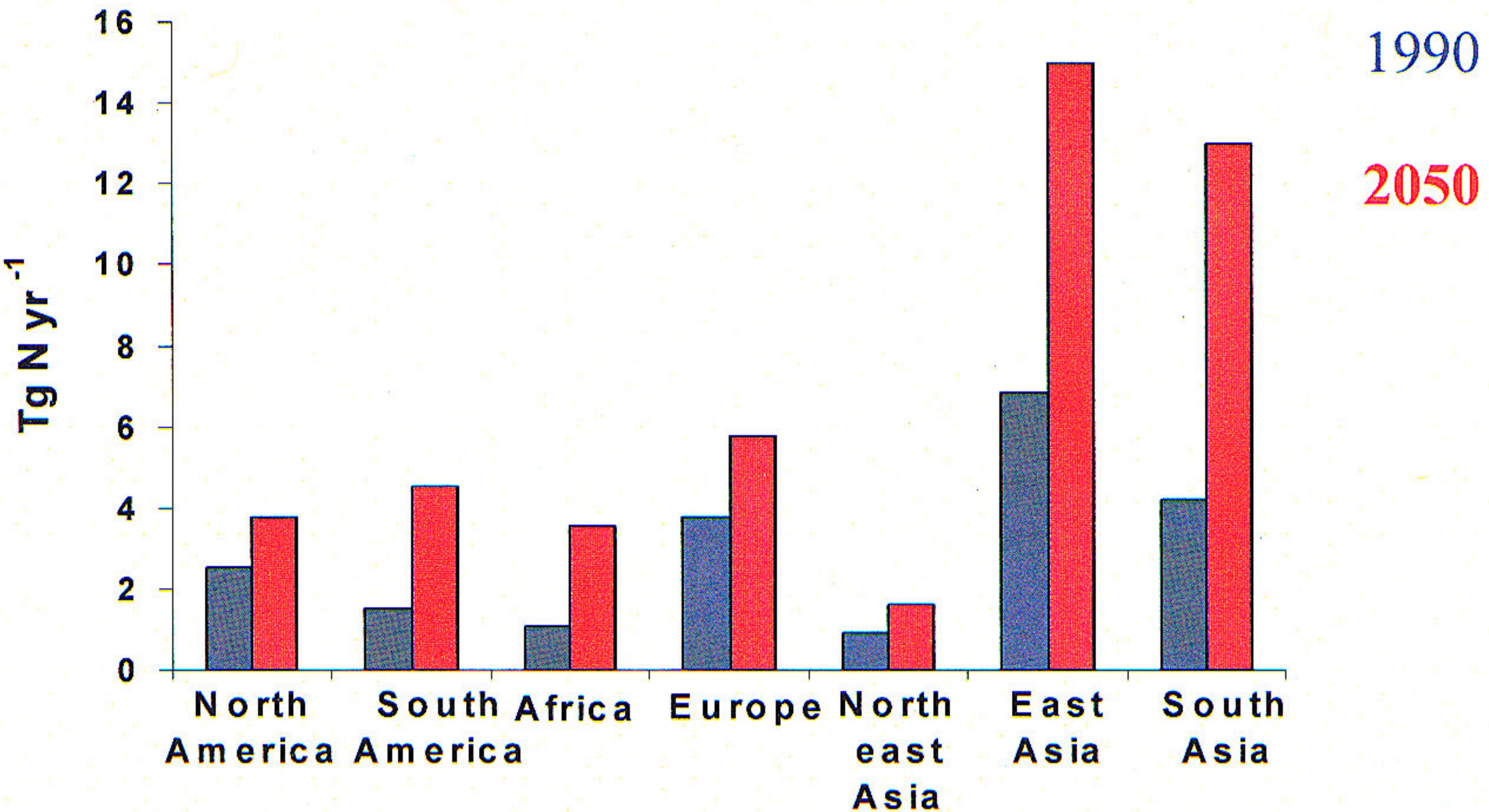
Figure 4. IMTA concept: The particulate waste in the water column is removed by filter feeding bivalves, while the portion that ends on the seafloor is utilised by sea cucumbers. The dissolved inorganic nutrients (N, P & CO_2) are absorbed by the seaweed that also produces oxygen, which in turn is used by the other cultured organisms. Modified from (Fang et al. 2009)

Walton and Jiang 2009, fig. 4

Photo: James Oliver/ IUCN

Figure 4. Nha Trang Bay, Vietnam – model Marine Protected Area

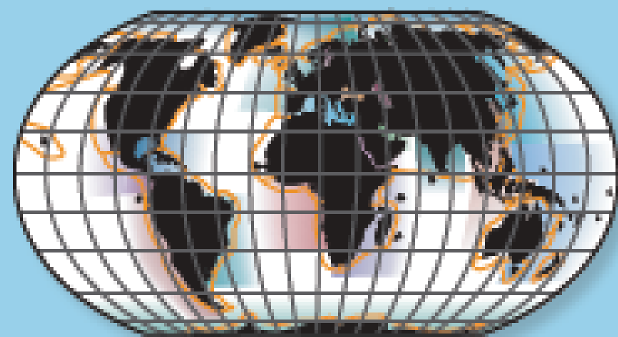
Oliver, Lundin and Laffoley 2009. fig.4



Predicted DIN export to coastal systems in 1990 and 2050 under a business-as-usual (BAU) scenario. Modified from Kroeze and Seitzinger (1998).

The UNEP Large Marine Ecosystem Report

A Perspective on Changing Conditions in LMEs of the World's Regional Seas



UNEP Regional Seas Report and Studies No. 182

UNEP

Regional Seas

GPA

2009 © International Union for Conservation of Nature and Natural Resources (IUCN)

CONCLUSIONS

- Socioeconomic benefits of $12.6 trillion annually in economic activity based on coastal ocean goods and services are at risk.
- The 5-module science-based metrics support an upward spiral toward ecosystem recovery activities by governments and developing nations
- Additional GEF financial support is required for governments to support 10,000 LME practitioners, to adapt to the effects of climate warming, reduce habitat loss, designate and manage marine protected areas, control nutrient overenrichment and recover depleted fisheries.