Examining Human Impacts on Global Biogeochemical Cycling via the Coastal Zone & Ocean Margins

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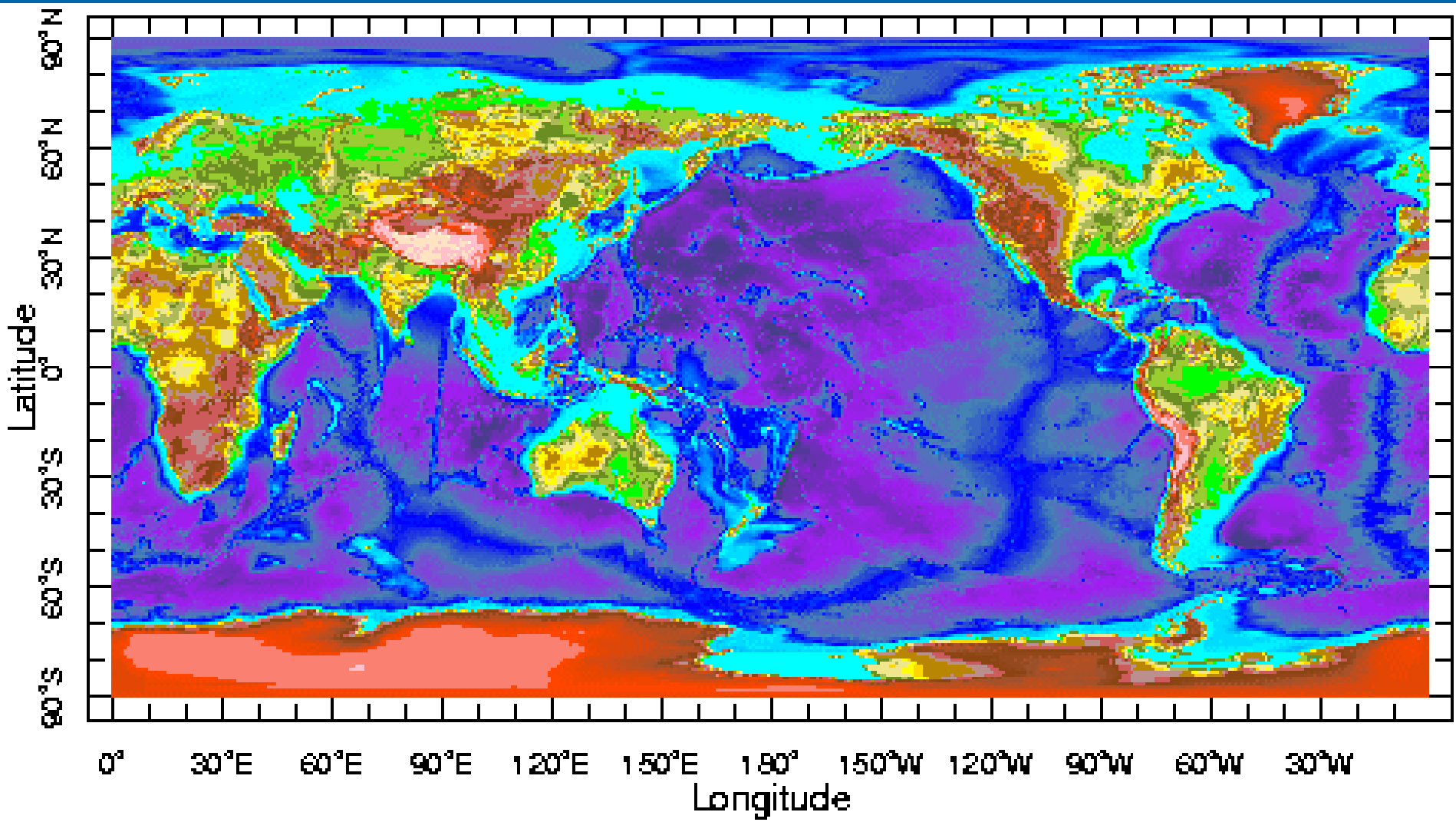
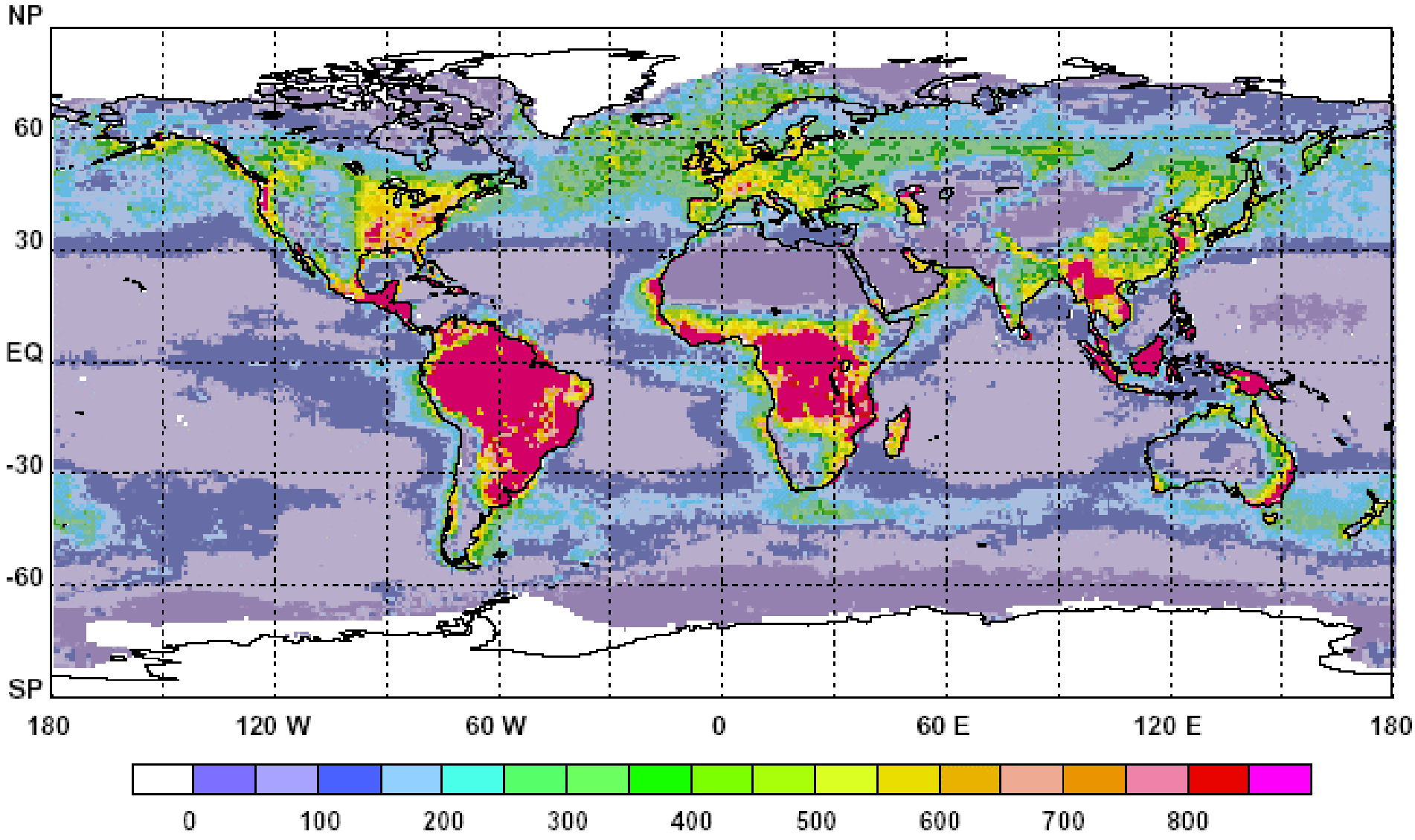
Shelf area = 7 % of ocean surface



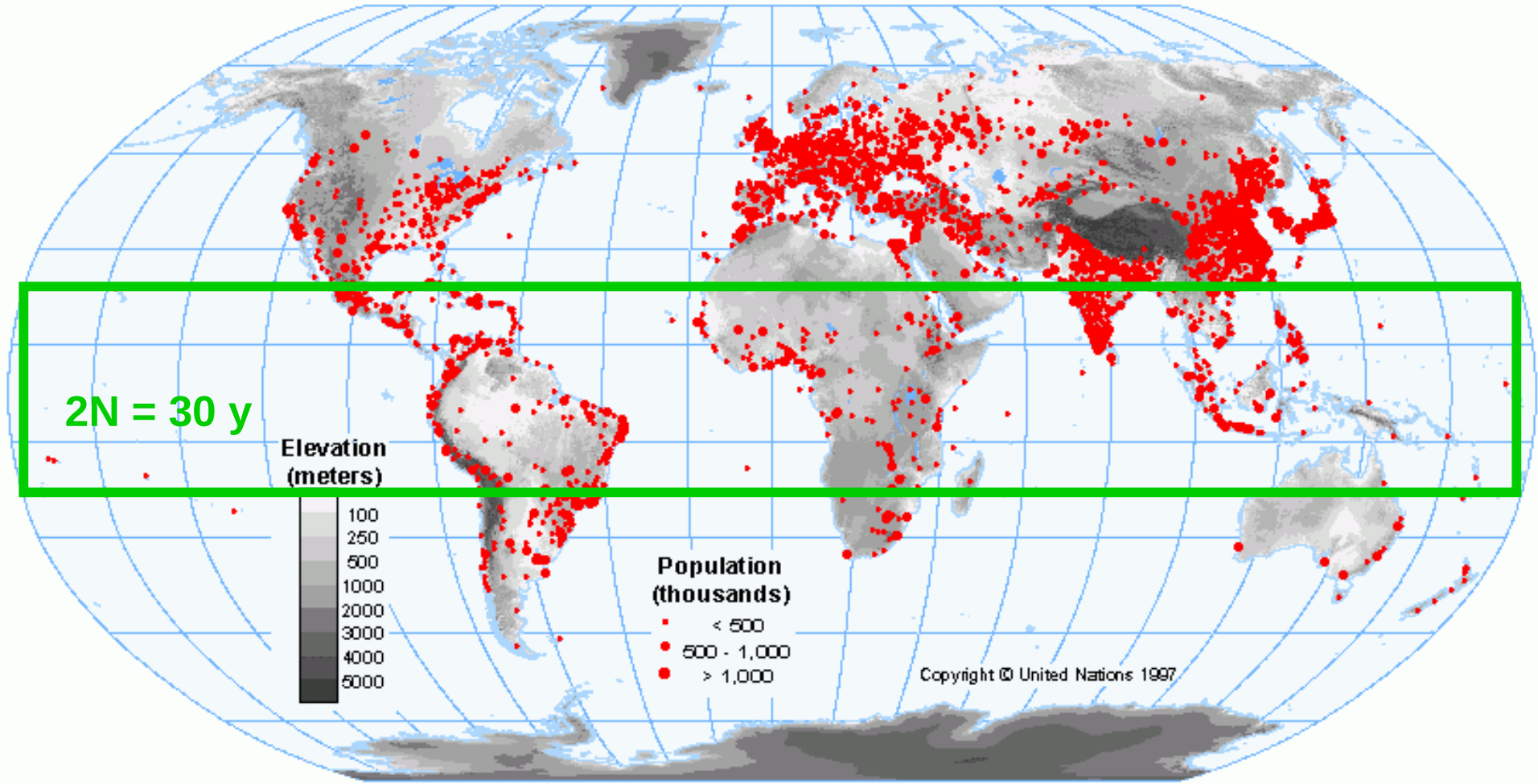
WORLDBATH topography (IRB Climate Data library)

Shelf = 20% of Ocean NPP; supports 90% of Marine Fisheries Production



g C m^2 yr^{-1} (Field et al. 1998)

Coastal population = 2.2 billion (40% of total) *(Burke et al., 2001)*



Anthropogenic drivers

- 90% of global population in tropical developing world by 2050 (UN 2002)
- Growth points: coastal and urban centers; 2N in 30 years
- Consumption = F (Population, Affluence, Technology) (Ehrlich & Johnson 1971)
- Waste generation:

  Agricultural waste, Domestic & Industrial

Man & Continental Margin Biogeochemistry

- Nutrient loading
- Ecosystem response : Eutrophication cascade
  - Eutrophication historically & currently compounded by overfishing
  - Hypoxic zones, denitrification & competing microbial pathways, and greenhouse gases
  - Additional jeopardy from aquaculture & damming

Eutrophication: Early Records

Region	Onset	Global Population[6]
Old World ➢Oslofjord[1] ➢North Sea[2]	Mid 1800s	1 b (1804)
New World ➢New Bedford Estuary[3] ➢Chesapeake Bay[4]		2 b (1927)
➢Gulf of Mexico[5]	Mid 1900s	3 b (1960)

[1]Dale et al. 1999; [2]Billen et al. 1999; [3]Pospelova et al 2002; [4]Zimmerman & Canuel 2000; [5]Rabalais et al. 2002; [6]UN 1998

Inorganic Nutrient Loading

Period	DIP, 10^9 mols yr^{-1}			DIN, 10^9 mols yr^{-1}		
	Natural	Anthro	Total	Natural	Anthro	Total
1890s (Galloway & Cowling 2002)						360
1970s (Meybeck 1982)	13	13	26	320	160	480
1990s (Smith et al. 2003)	21	53	74	400	950	1350
Upwelling (Chen et al., in press)			500			10000

Inorganic loading & fertilizer use

(Tilman et al 2001)

Year	Population (billion)	Irrigated land (10^6 ha)	P 10^6 MT	N 10^6 MT
2000	6.1	280	34.3	87.0
2020	7.5	367	47.6	135.0
2050	8.6	529	83.7	236.0

Organic nutrient loading

Period	10^9 Moles = Gmoles			
	DOP	TDP	DON	TDN
1970s (Meybeck 1982)	39	65	1060	1540

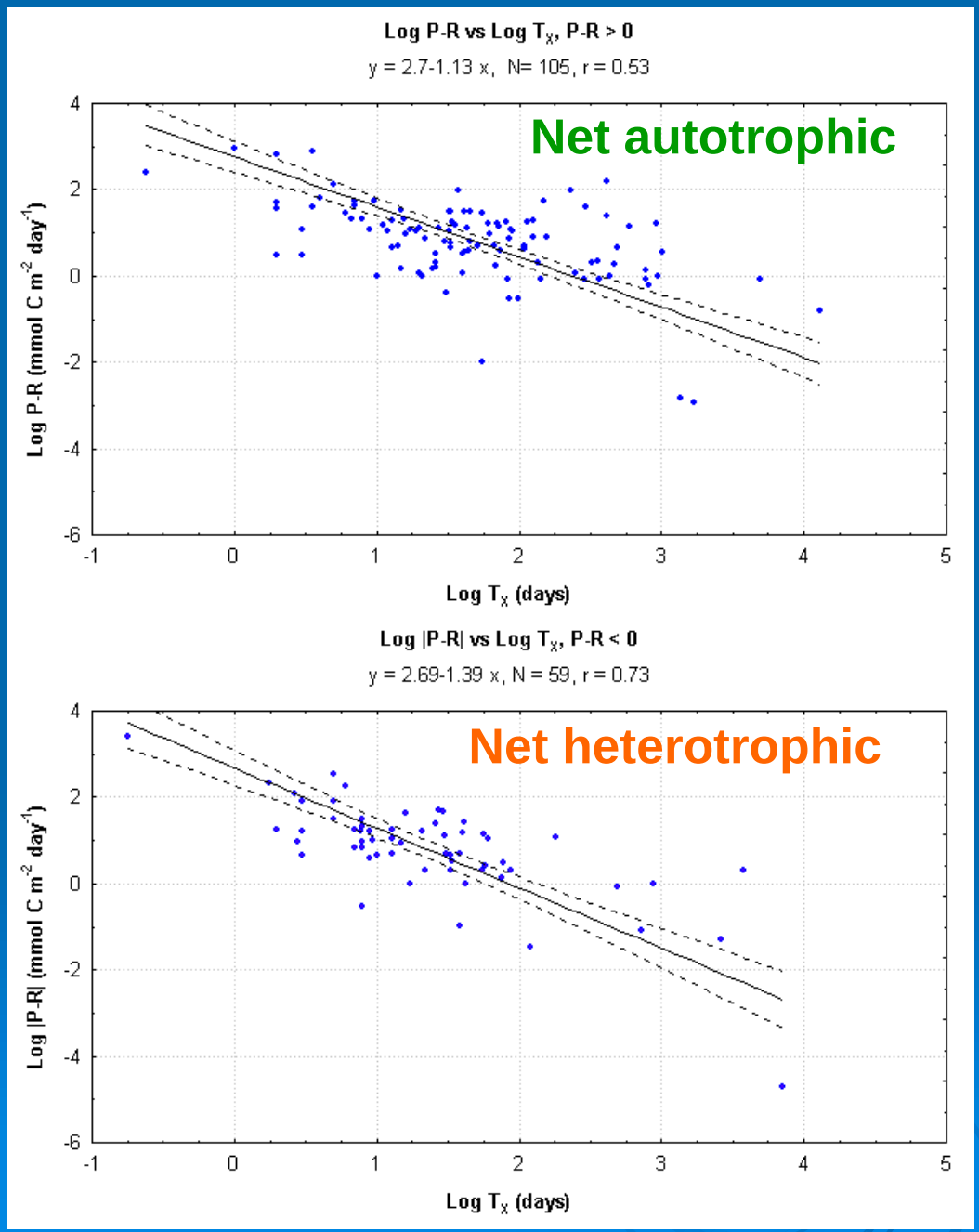
Seitzinger & Sanders 1997:

40-75% of DON (2 weeks) → Microbial growth + remineralization

Organic loading & Organic waste production

Matter	O_2	C	N	P
Phytoplankton				
➢Redfield et al. '63	-138	106	16	1
➢Takahashi et al. '85	-175	122	16	1
Organic waste (San Diego-McGlone et al. 2000)	- 62	40	12	1

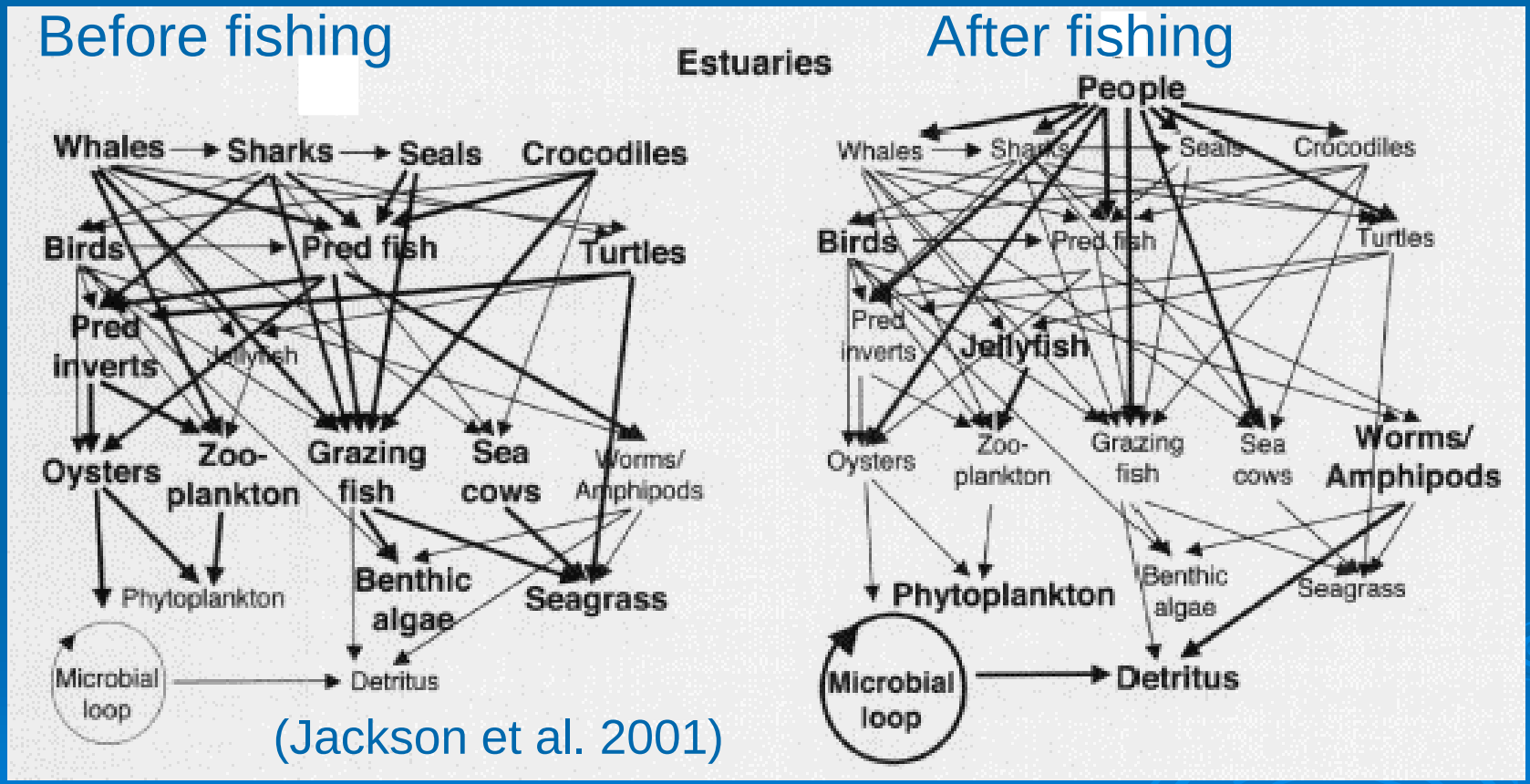
- Enriched in nutrients relative to C; enriched in N relative to Redfield ratio
- $C:O_2$ for waste = 1.55;
- $C:O_2$ for phytoplankton = 1.30-1.43



Area-specific rates (NEP) & net of (N fixation-denitrification highest in systems with exchange times <100 d and areas < 1000 km^2

(Smith et al. submitted paper for CMTT synthesis book)

Ecosystem response to historical overfishing + heavy nutrient load



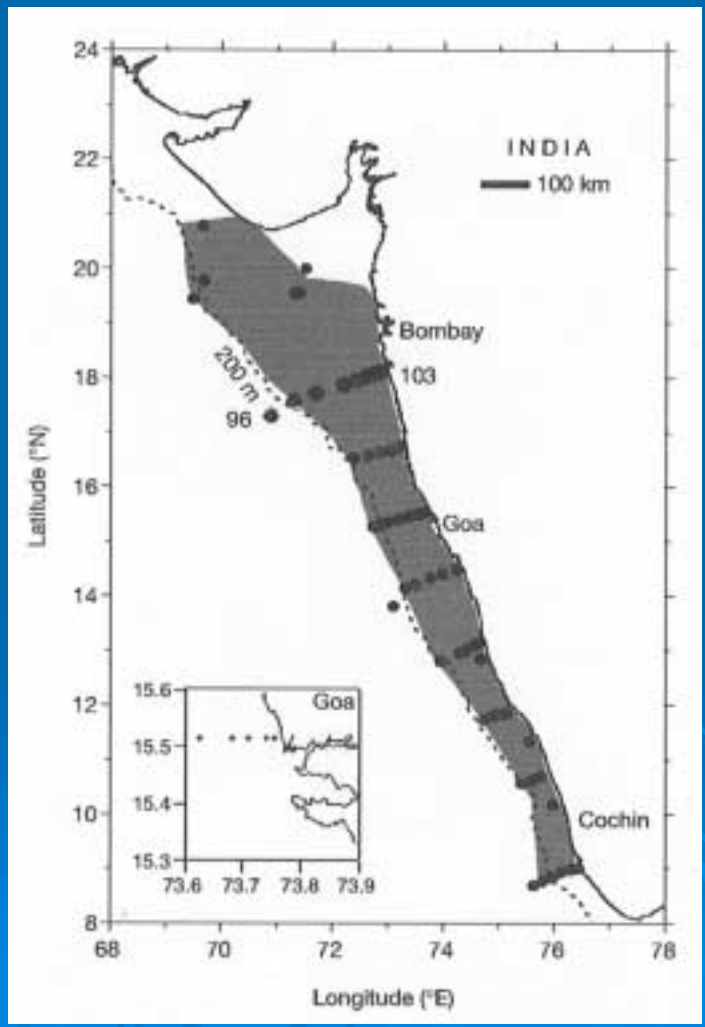
- Loss of suspension feeders & seagrasses
- Add nutrients → Microbialization of the coastal ocean

Eutrophication + Upwelling => Anoxia => N_2O efflux (Naqvi et al. 2000)

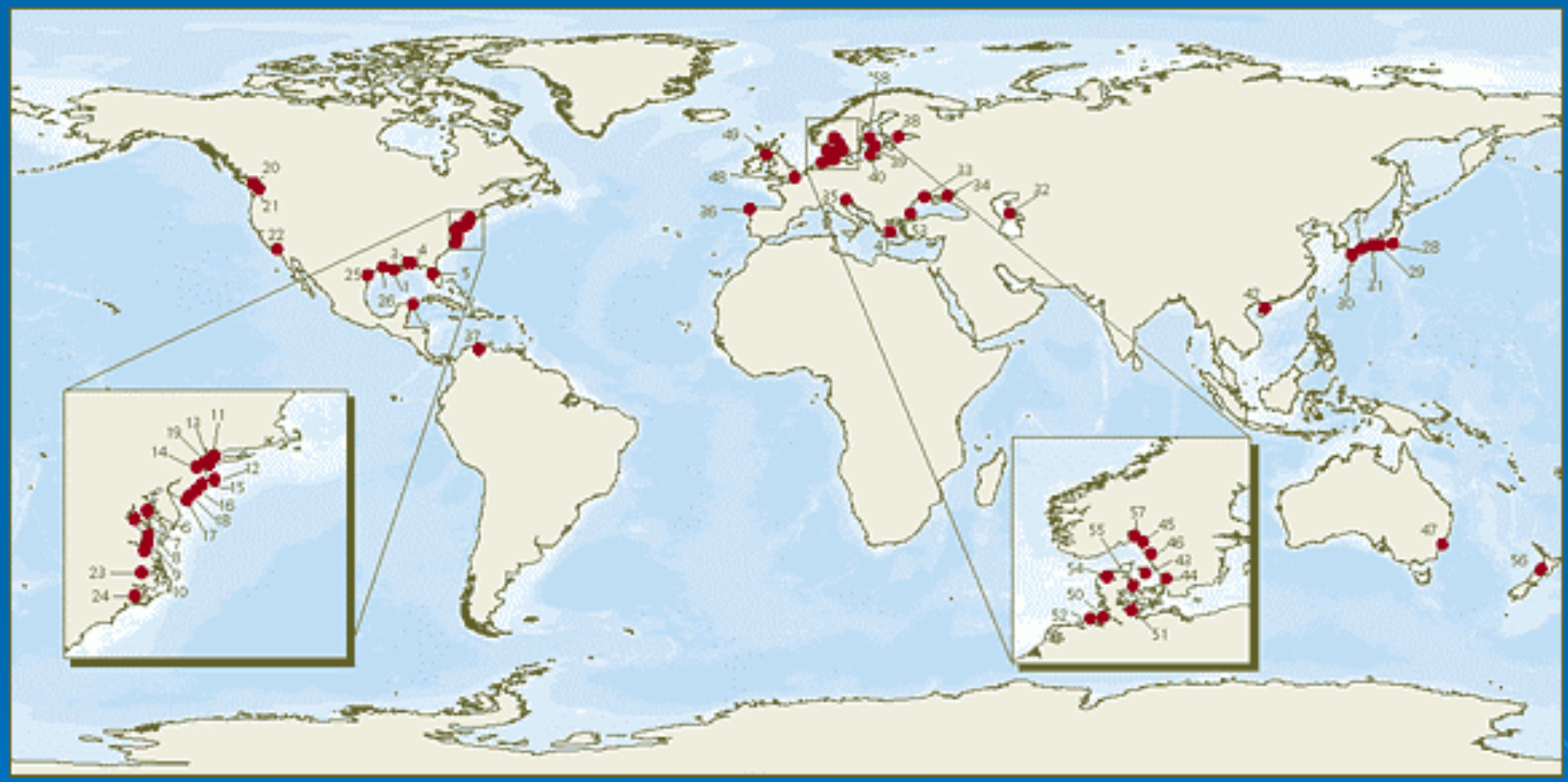
Western Indian Shelf:

- Intensified O_2 depletion because of eutrophication
- N2O efflux =

  0.06-0.39 Tg, (6 mos for 180,000 km^2) = annual efflux from all of Arabian Sea

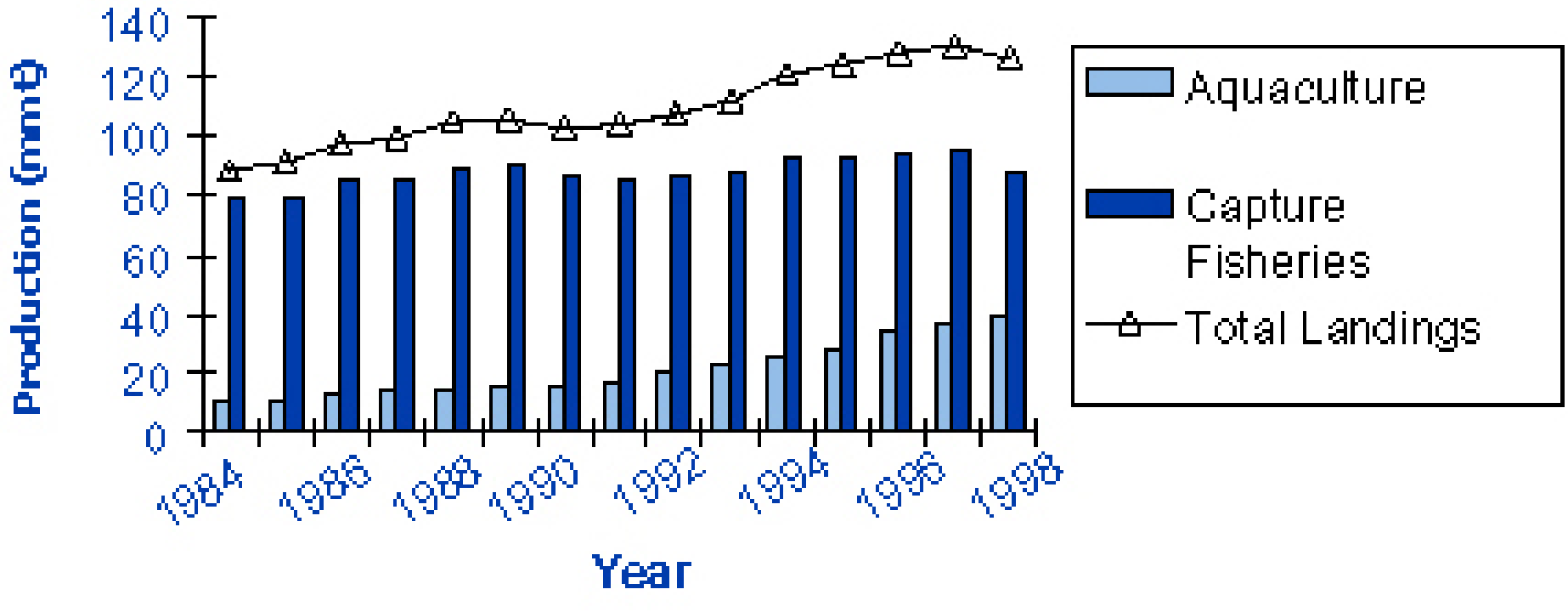


Gulf of Mexico: Hypoxia and suppressed benthic denitrification (Childs et al. 2002)



- No N_2O release perhaps because of nitrate limitation or competition from organisms capable of DNRA
- Increase in residence time of reactive nitrogen → hypoxia maintained

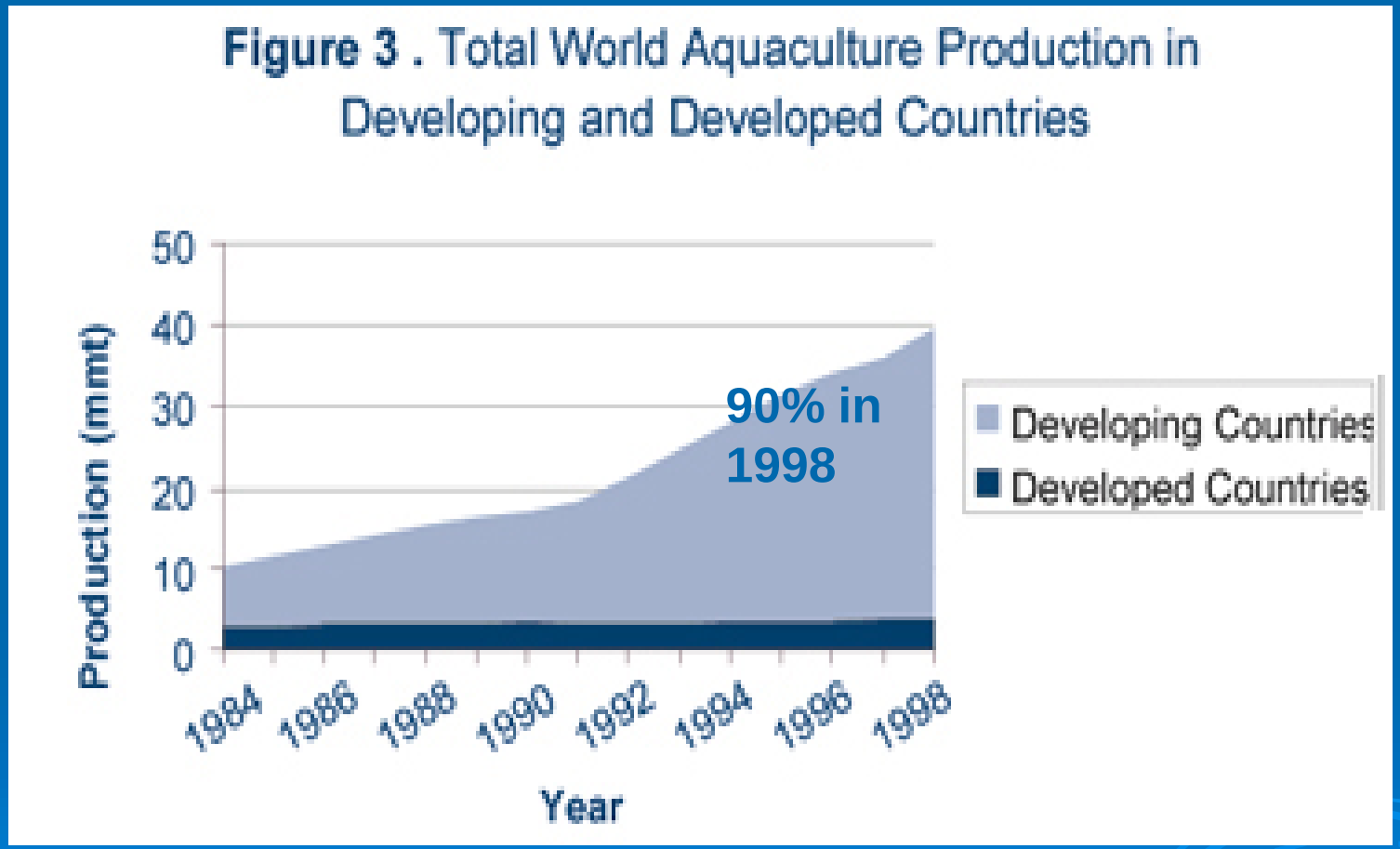
Aquaculture & Fisheries



1) 7.4 M tons (1980) to 42 M tons (1999) (USD 5.3 B)
2) Growth rate: 10% pa (terrestrial is 3%; capture fish is 0.8%)
3) 30% of per capita food fish supply in 1997 from culture
4) Global projection: 47 M tons in 2010

(SOFA 2002)

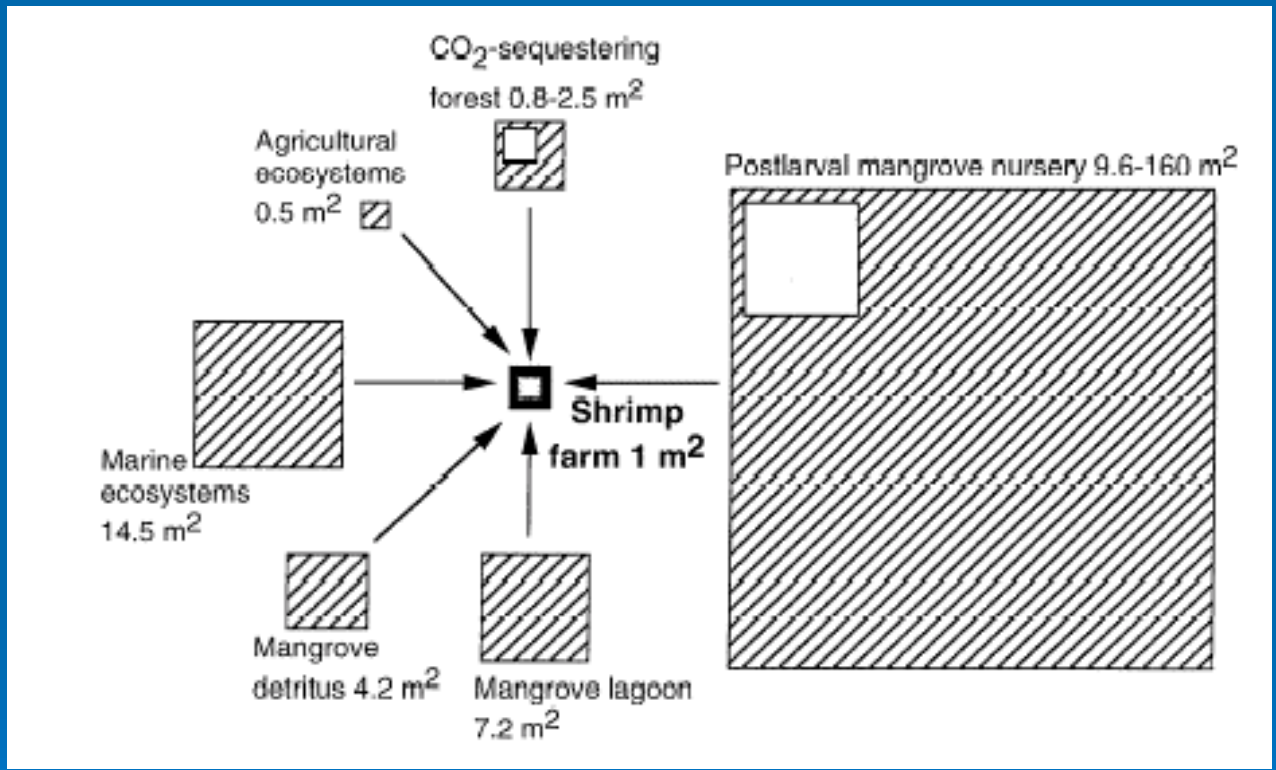
Collapsing fisheries & Aquaculture



Developing countries >> Developed nations

(SOFA 2002)

Ecological footprint of a semi-intensive shrimp farm



- Filter nutrient load: 22 ha for every ha Intensive farm; 3 ha for a ha semi-intensive farm
- Provide postlarvae: 160 X farm area

(Folke et al. 1998)

Supporting shrimp farms

Mangrove Area	
1920	500,000 ha
1988	272,000 ha
1990	132,500 ha
1994	120,500 ha
1977	106,133 ha

Fishponds	
1952	88,681 ha
1988	224,000 ha

To support farms in 1952, Philippines needed at least 16 M ha.

If mangroves were just for shrimp ponds, cover in 1920 could support at most 2800 ha

Dams

- Three Gorges Dam (proposed): Reduced freshwater outflow by 10% would reduce upwelling rate by 10%, thus reducing fisheries production in East China Sea. Damming has greater effects on deltaic processes than on fisheries production which is mostly subsidized by upwelling (Chen, 2000)
- Aswan Dam (1965): Nile river inputs replaced by anthropogenic nutrients from fertilizer and sewage. Fish and prawn landings have increased beginning early 1982 (Nixon 2003).

Some comments

- Human imprint significant on continental margins, specially big on small nearshore systems.
- Potential for this to expand cross-shelf with aeolian deposition of anthropogenic iron on continental shelf and with N_2O emitting hypoxic zones
- Dire need to understand microbial processes that drive impacted systems
- Mitigation will need controls for all waste sources as well as constraints on overfishing