# Managing biodiversity in capture fisheries

Presentation to FAO Expert Consultation :

**CLIMATE CHANGE AND BIODIVERSITY FOR FOOD AND AGRICULTURE**

# Apologia & Acknowledgement

- NOT a science expert in:
  - MARINE CLIMATE CHANGE
  - FISH POPULATION GENETICS
  - FISHERY DEPENDENCE IN COMMUNITIES

- Acknowledgement
  - Alex Rogers, Institute of Zoology, London for most of the pictures

# General structure

1. What climate change means for ocean, coastal, and **freshwater** ecosystems

2. What fishing has done and may do to genetic diversity of fish populations

3. Social and economic importance of fisheries

4. What putting 1,2 and 3 together may mean

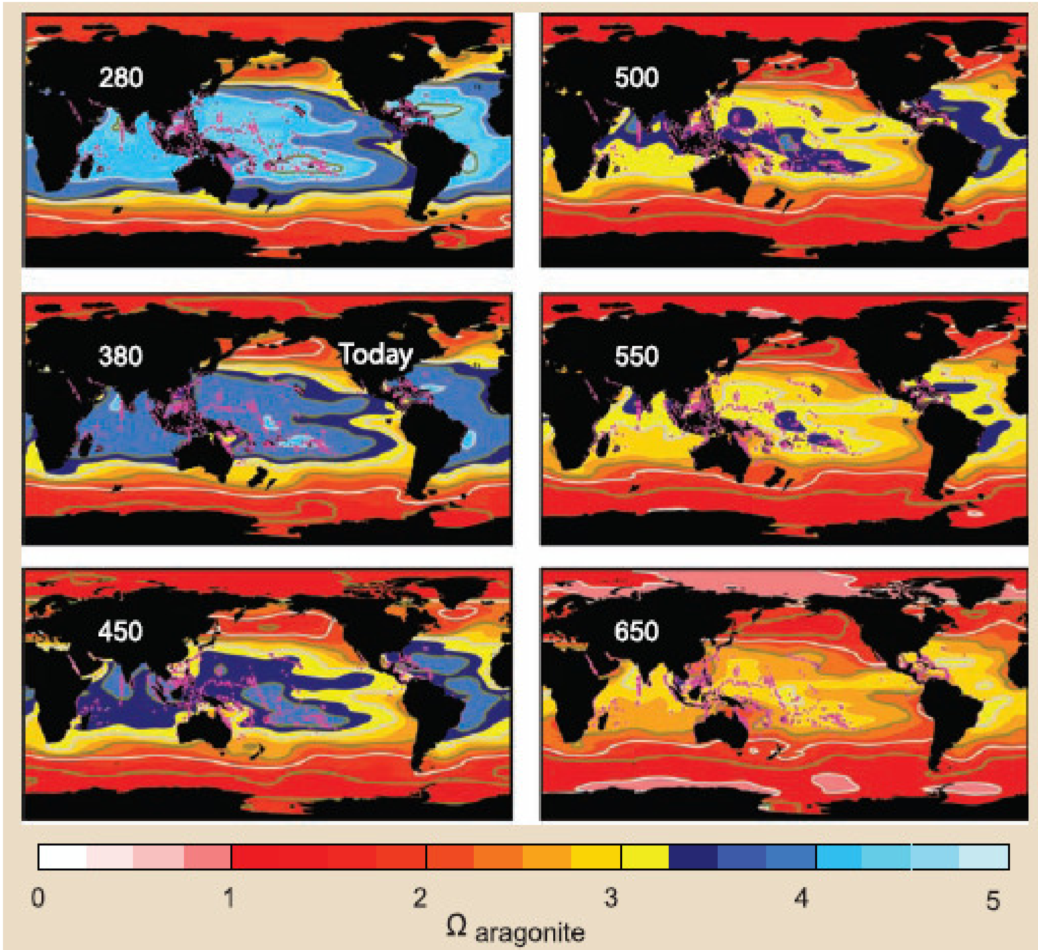
# Point to remember

- Unlike agriculture, livestock husbandry, aquaculture, and plantation forestry, capture fisheries are not just supposed to COEXIST with biodiversity of natural, functioning ecosystems, they are USING those natural ecosystems and have to conserve the same biodiversity that they are exploiting

# Climate change and ocean physics and chemistry

- Increase in temperature
  - ABSOLUTE change must be viewed in context of low background variation )
- Salinity
  - Decrease esp in mid and high latitudes – increased rainfall and ice melt
  - Increase in low latitudes – decreased rainfall, increased evaporation
- Acidification –
  - small absolute butg biggest change in $3x10^8$ yr

# Ocean acidification

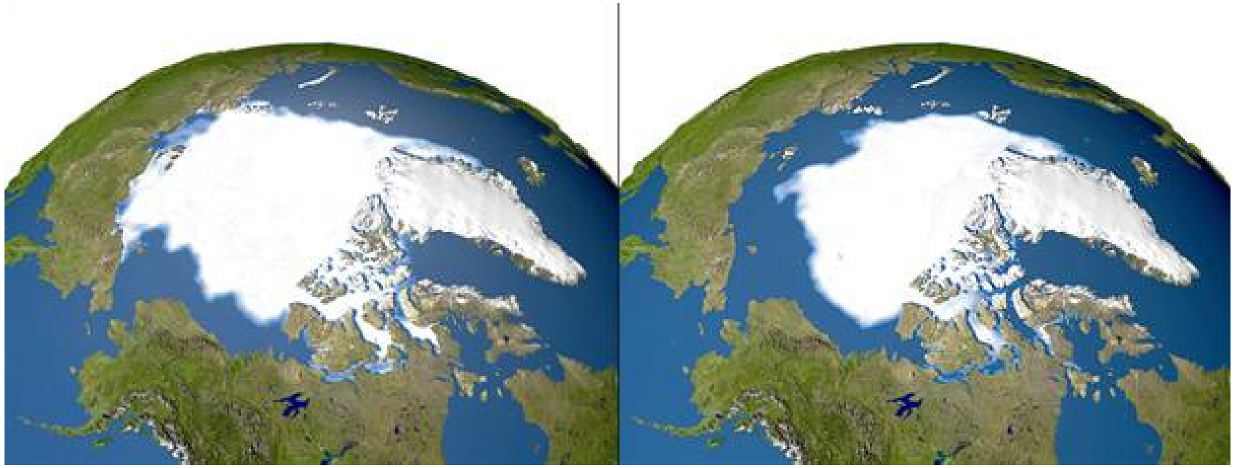


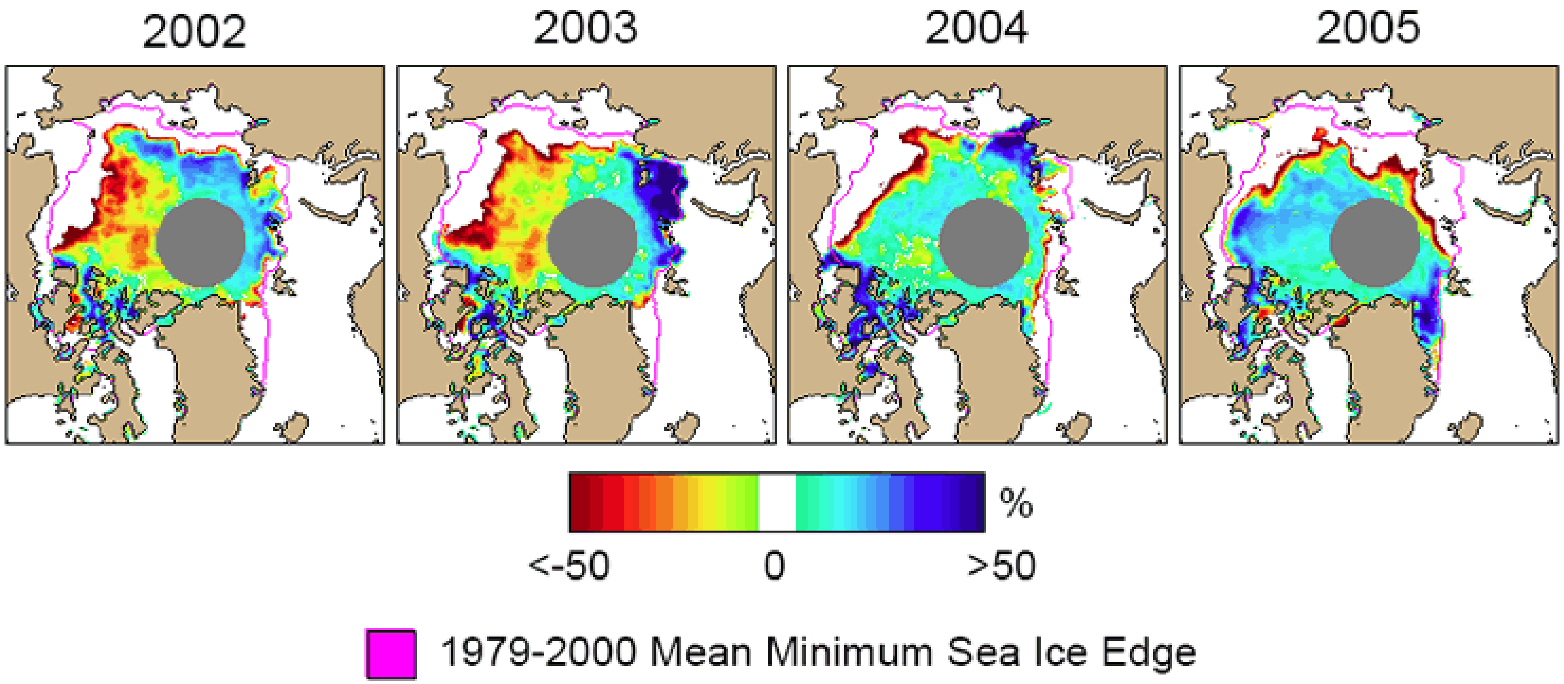

**Model of aragonite saturation at ocean surface vs ppm $CO_2$ in atmosphere (Hoegh-Guldberg et al. 2007 Science)**

# Climate change and ocean physics and chemistry - 2

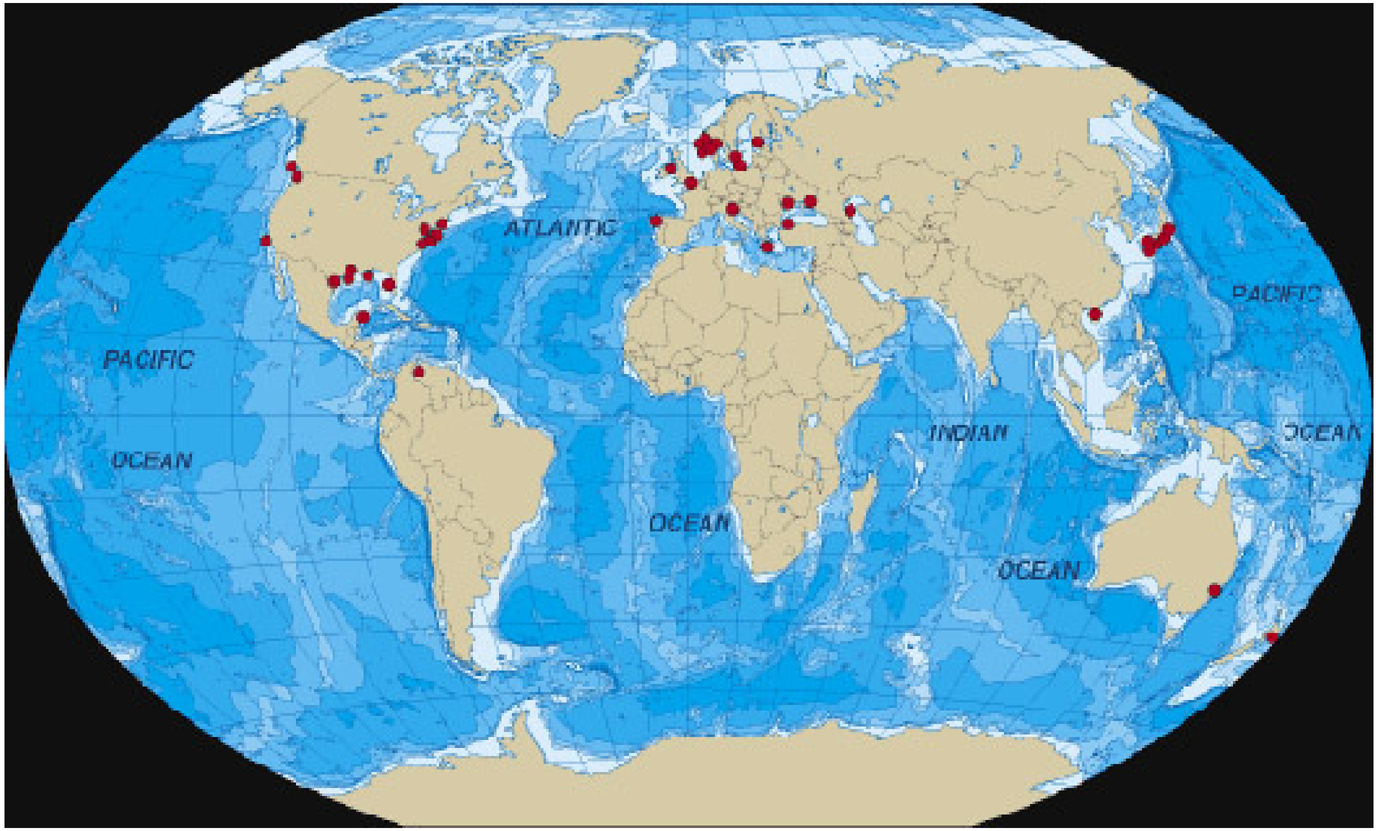
- Currents
  - Wind driven surface & coastal; models vary, some weaken, some strengthen
  - Thermo-haline: weaken (longer term and potentially much more serious – the global heat “conveyer belt”)
- Stratification (light fresh above deep saline)
  - Increase esp. at mid & high latitudes (possibly big)
  - More frequent and stronger El Nino–like events
- Hypoxia
  - Increase esp. at low and mid latitudes

# Shrinking ice pack





# Ocean dead zones are spreading




**R. Diaz**

# Climate change and estuarine / freshwater ecosystems

- (less thorough investigation)
- Direct transfer of increases or decreases in rainfall to flow rates and lake levels
- Increase in storminess
  - More flooding, more seasonal lake shrinking
  - More estuarine scouring
- Sea level rise
  - Estuaries change, coastal flooding & change

# What do the physical changes mean for fisheries resources?

# Increase in Temperature

- Energetics and $O_2$ requirement - both f (temperature)
  - Fish in warmer water need more food & $O_2$ but warmer water has less dissolved oxygen
- "Optimal Environmental window" has steep shoulders –
  - NON-LINEAR responses to temperature changes
- Changes in distribution to seek traditional niche, not adaptation to new conditions)
- Increase in "Invasive species"
- Big potential impact on artisianal fisheries species composition and sharing arrangements for commercial harvests

# Changes in Currents

- Migration routes can change
  - Different species or timing of availability
- Changes in transport of eggs/larvae (Mid-High)
  - Spawning grounds positioned so buoyant eggs/larvae carried to nursery grounds
  - Temp sensitive development rate is supposed to have eggs in right place and condition
- Fronts and bioregional zones will change position affecting the PELAGIC TRIAD (low-mid)
  - Enrichment, Concentration, Retention

# Increases in Stratification

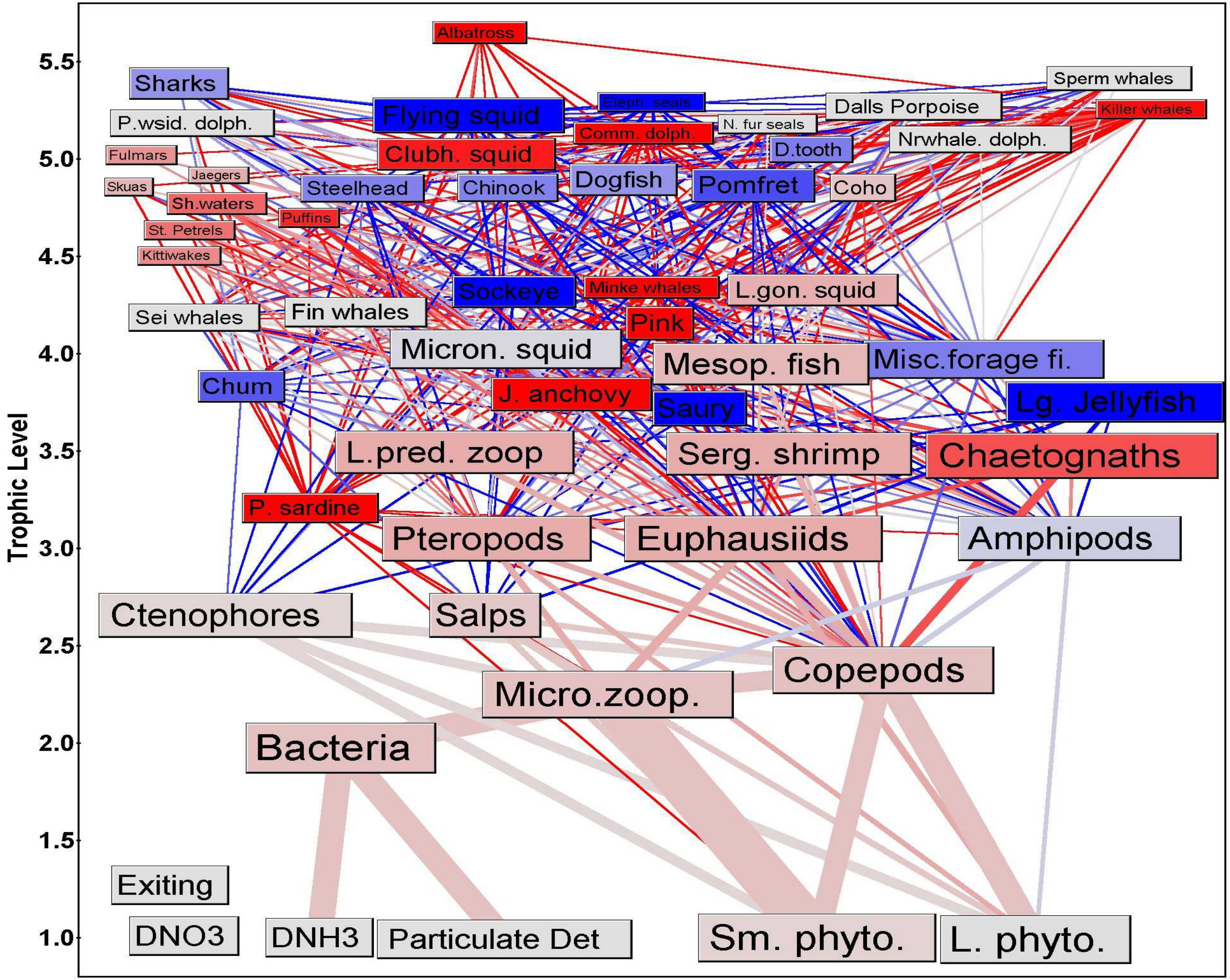
- WATER COLUMN MIXING in mid/high lat.
  - Spring bloom depletes nutrients
  - Summer warming is restricted to surface layer
  - Fall mixing renews nutrients, moves heat
- Stronger stratification
  - reduces productivity in both pathways,
  - positive feedback on temp & salinity differences increases stratification more
- Stronger stratification keeps bottom waters cold
  - Increased likelihood of catastrophic die-offs, esp young ages and benthos (food & shelter)

# Increased Ocean Acidification

- Increase dissolved inorganic carbon (DIC), shift the equilibrium to a lower pH and lower carbonate concentration ($CO_3^{2-}$).
  - $CO_3^{2-}$ concentrations already decreased by ~30μmol kg-1 and pH by 0.1 unit.
- Affects negatively
  - Harvested species crustaceans, molluscs etc
  - Habitat forming species – corals, sponges etc
  - Lower trophic levels – diatoms, zooplankton etc

# Aggregate effects

- Changes in TIMING of oceanographic events
  - Earlier spring blooms
  - Longer "growing season" (but less mixing)
  - "Match-Mismatch" processes have more mis-matches – more failures, fewer successes
- Changes in fish communities
  - Different locations of tolerances / niches
  - Different mixes of species productivities
  - Leads to different predator-prey linkages (Prediction of pathways a farce)
  - Different yields & bycatches to same fisheries


Trophic Level
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Albatross
Sharks
Sperm whales
Eleph. seals
Dalls Porpoise
Flying squid
Killer whales
P.wsid. dolph.
N. fur seals
Comm. dolph.
D.tooth
Nrwhale. dolph.
Fulmars
Clubh. squid
Jaegers
Skuas
Dogfish
Steelhead
Chinook
Pomfret
Coho
Sh.waters
Puffins
St. Petrels
Kittiwakes
Sockeye
Minke whales
L.gon. squid
Fin whales
Sei whales
Pink
Micron. squid
Mesop. fish
Misc.forage fi.
Chum
J. anchovy
Lg. Jellyfish
Saury
L.pred. zoop
Serg. shrimp
Chaetognaths
P. sardine
Pteropods
Euphausiids
Amphipods
Ctenophores
Salps
Copepods
Micro.zoop.
Bacteria
Exiting
DNO3
DNH3
Particulate Det
Sm. phyto.
L. phyto.

# Special Coastal Challenges

- Estuaries under particular threat from
  - Less run-off but more floods; hypoxia
  - Sea level rise and more big tropical storms
  - Fish production tied to vegetation that cannot adapt to size/rate of change and catastrophes
- Coral reefs under particular threat from bleaching (temp, sun) plus acidification
  - Loss of plankton production & fish cover,
  - Strong relationship of fish diversity and productivity to structural diversity

# 1998 mass coral bleaching event – associated with El Niño and high SST

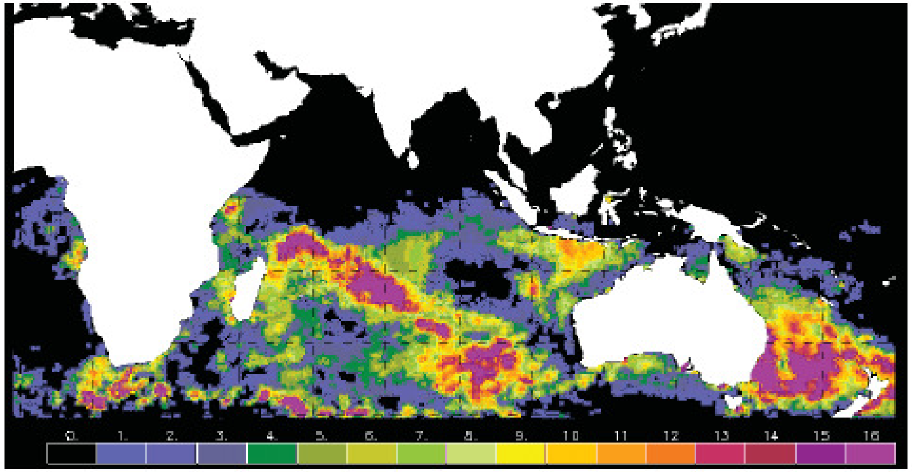
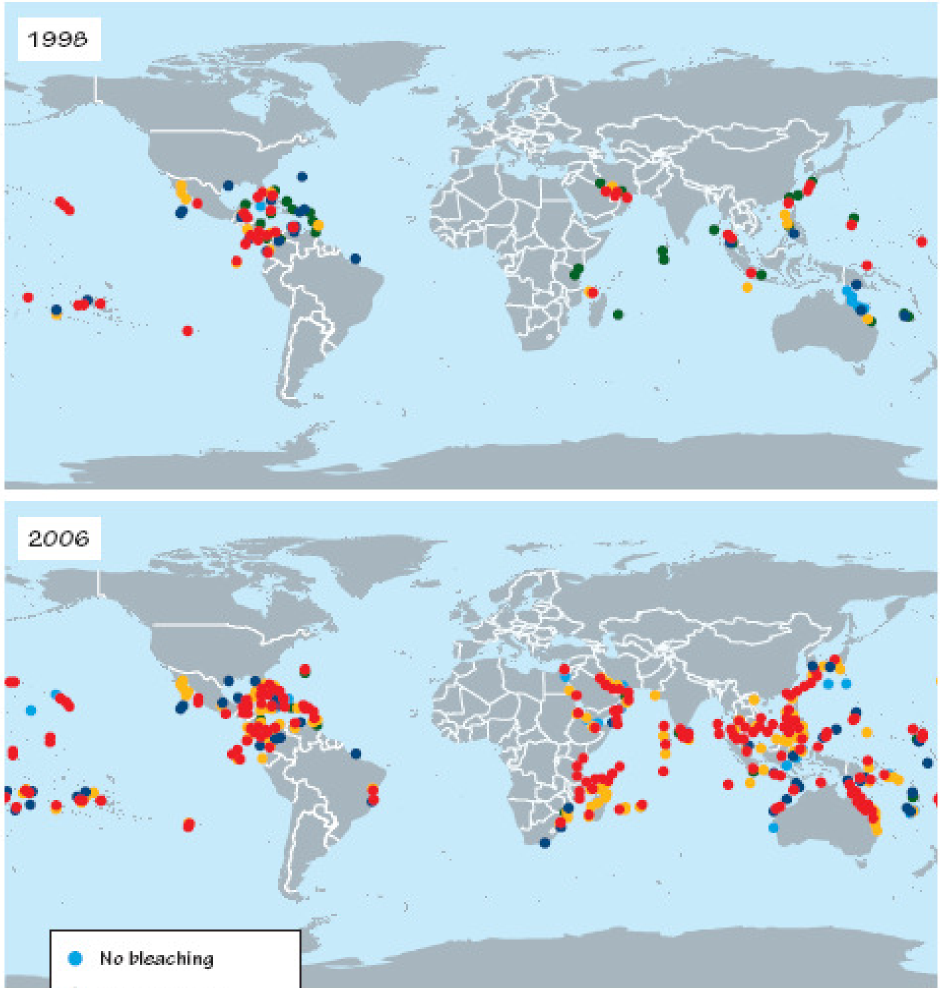
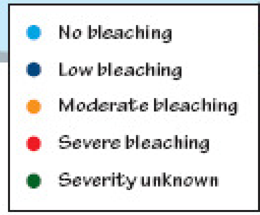



**Figure 2.3 NOAA Degree heating weeks (DHW) map for the eastern hemisphere for 31 March 1998**




Coral bleaching events 1998 and subsequently.

- DHW = Degree Heating Weeks. Combine intensity of temperature anomaly with duration over previous 12 weeks.
- 1 DHW = 1°C above expected summer maximum for 1 week.
- 4 DHW conditions become stressful and bleaching likely.
- 8 DHW Severe stress and mortality.

# Fisheries effects on Genetics

Note: Even a SUSTAINABLE fishery is likely to harvest ¼ to 1/3 of mature individuals annually!

# New field of study (1993+)

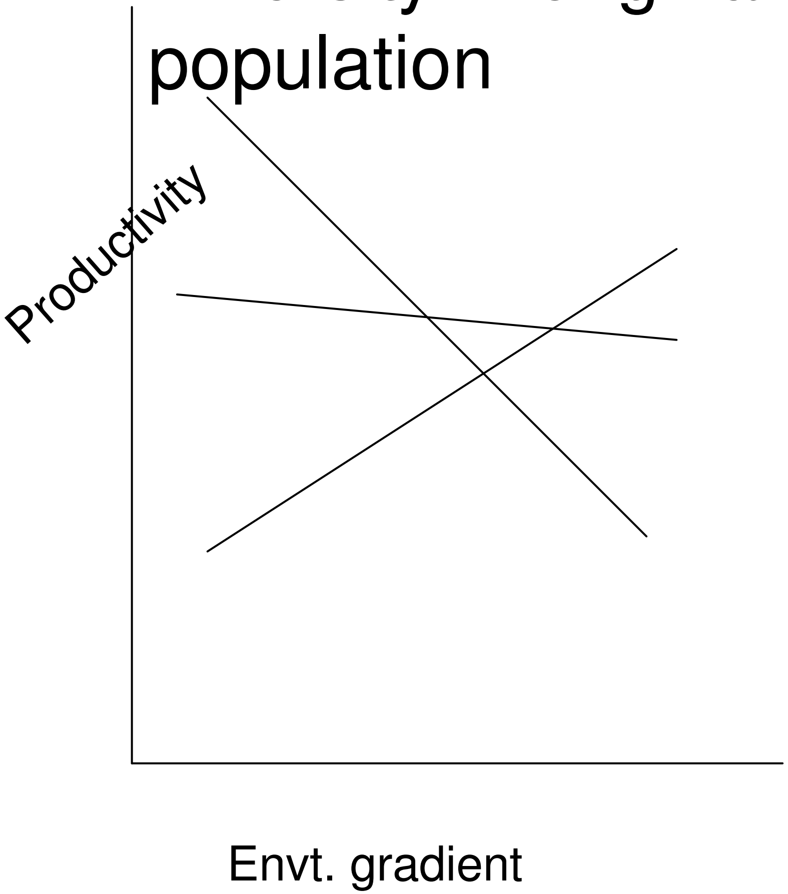
- CONCEPTS long established in fisheries
  - Avoid local depletion
  - Avoid recruitment overfishing
  - Density dependence as core of fishing down $B_0$ to remove N from K
    - Increased growth and reproduction
    - Increase yield overall (R per S and S per R both considered in management strategies)

# HARD to disentangle genetic consequences of fishing

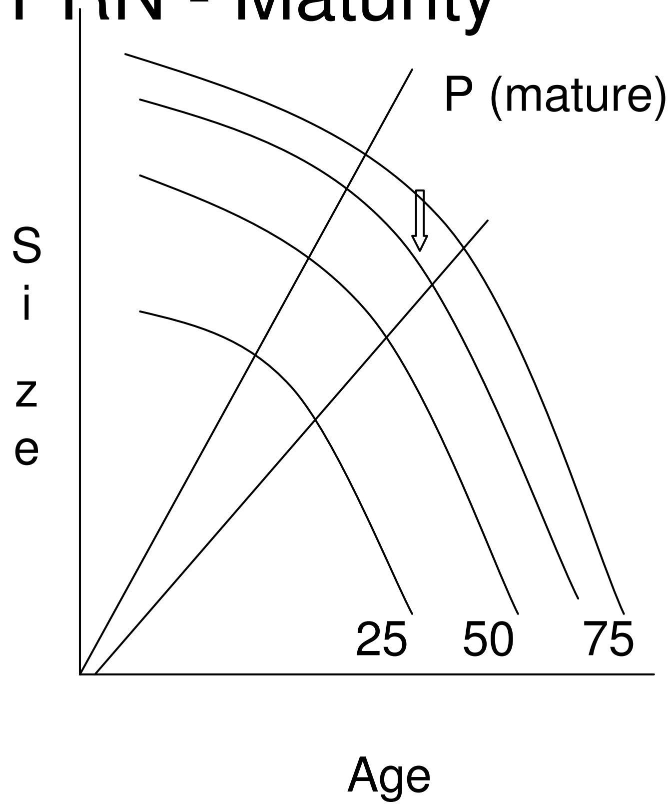
- Phenotypic responses easily quantified, but must partition out:
  - Effects of decreasing density
  - Responses to environmental variation
- Probabilistic reaction norms:
  - Within a population is there sufficient diversity to allow productivity to be maintained over range of environmental conditions?
  - How does P (maturity) vary with age and size?

# Genetic Cartoons

- Diversity in original population




- PRN - Maturity



# What does fishing do to exploited populations?

- Generally size selective so favours:
  - Fast maturation (younger)
  - Maturation at smaller size
  - Higher proportion of energy into reproductive effort rather than growth
- This changes life history of species to more “r” adapted and less “K” adapted
  - Yield in more numerous, smaller packages with greater handling time - less Y per R
  - Fecundity is highly non-linear with size – less R per S

# What does fishing do to exploited populations?

- Reduces abundance
  - Effective population size smaller with higher risk of inbreeding and less genetic diversity
  - Risks of bottlenecks higher
- May fragment widespread populations
- May fish out adapted metapopulations
  - "Weak stock management" in salmon – fisheries are on mixed stocks, with exploitation matched to larger, more productive ones. Small stocks adapted to less productive rivers are systematically over-fished

# How big are these effects – Life history effects

- Most work on salmon, cod, plaice, herring
- About 20-30% of growth rate, age of maturation, etc is heritable
- Reduction in cod age of maturation from 8-11 to 4-7 (Northeast Arctic and Nfld cod)
- Genetic effects of overfishing on size/age of maturation
  - detectable in four generations;
  - reversible in 80-140 generations.

# Strength and scale of evidence

| TYPE OF CHANGE | # species | # studies | % change |
|---|---|---|---|
| Mature younger | 6 | 10 | 23-25 |
| Mature smaller | 7 | 13 | 20-33 |
| Lower PMRN midpoint | 5 | 10 | 3-49 |
| Reduced annual growth | 6 | 6 | 15-33 |
| Increased fecundity | 3 | 4 | 5-100 |
| Loss of genetic diversity | 3 | 3 | 21-25 |

# How Big - Population size effects and genetic diversity

- Bottlenecks
  - Overfished populations often reduced > 80%
  - Recovery not evenly apportioned among remaining stock components
- Effective population size commonly >$10^5$ LESS than census size
  - North Sea plaice;
    - $N_{census}$ = **$10^9$ mature individuals**
    - Annual harvest = **$8x10^7$ kg** (wt per harvest < 1kg)
    - **$N_{effective}$ = 20,000 individuals**

# Other genetic issues

- Fragmentation needs more study, much work on stream and lake species
  - Herring – BC: at least 35% of spawning metapopulations lost in 40 years
- Salmon meta-populations – at least 40% of NA West Coast stocks extirpated or at risk
- Evidence of inbreeding (homozygosity of local population units) –NE Arctic cod
  - Absent in 1930s,
  - Present in 1950s
  - Strong in 1980s

# What does this mean for food security?

# Role of Fisheries

- Capture fisheries peaked a decade ago
  - 80-100 mmt is upper limit of marine capture fisheries
  - > 25% of stocks over-exploited
- Crucial for Sub-Sahara Africa and S/E Asia
  - 40% of protein in diet + 2.5 Billion in trade (Africa)
  - 400 MILLION people dependent for food
  - 150 million dependent for work in fisheries
  - Fisheries ports are commerce centres
  - Central pillar of sustainable livelihoods
- Developed world – 300 million Euro in Europe

# Generalisations from 1,2,3 - Genetics

- Fisheries have reduced genetic diversity within and among populations of a species (less capacity to adapt)
- Directional selection pressure due to fisheries much stronger than natural selection to reverse effects after over-fishing is reduced.
- Fisheries have altered suite of genetic strategies in fish communities (lower life history diversity)
- Changing climate requires greater diversity for local adaptation to change
- RATE of change due to climate faster than time of adaptations to past changes
- Greater fragmentation accentuates negative effect

# Generalisations from 1,2,3 - Fisheries

- Capture fishery yields lower (less yield per recruit due to life history changes)
- More of yield from small pelagic-like stocks (less stable yields)
- Traditional fisheries will exploit different communities – likely less efficient.
- Coastal fisheries particularly hard-hit and least mobile
- Capture fisheries that can chase traditional stocks will challenge management structures

Thank you – and sorry the news wasn't better.