

Managing for Resilience in Coastal and Ocean Ecosystems

Jane Lubchenco
Oregon State University
17 April 2008



PISCO
Partnership for Interdisciplinary Studies of Coastal Oceans

Oregon State UNIVERSITY OSU

Today's Voyage

1. Science and Society
2. Climate Changes and Oceans
3. Other Global Changes
4. What's at Risk?
5. Response Options:Adaptation & Resilience

5.2 Adaptation and mitigation of impacts on the marine environment and ecosystems

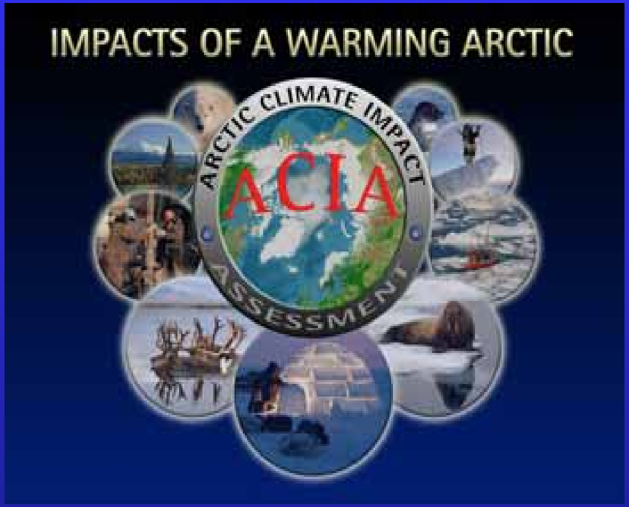
Mitigation and Adaptation are decisions to be made by society,

but they should be INFORMED by science

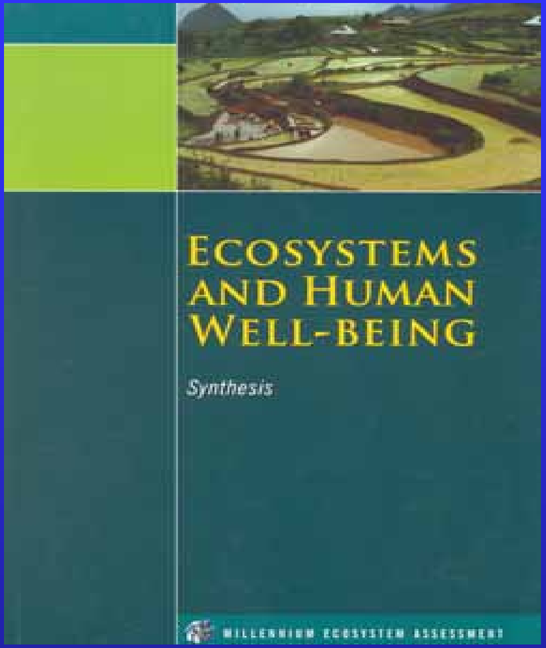
Role of science: To inform

1. Discover how systems work (natural, social and coupled social-natural systems)
2. Document changes
3. Understand consequences of changes
4. Develop and evaluate options for alternate pathways

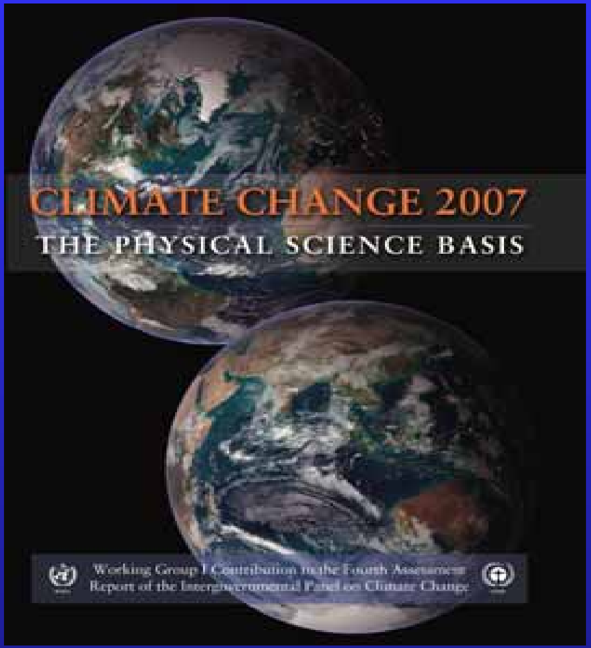
International Scientific Assessments



Arctic Climate Impact Assessment, 2005



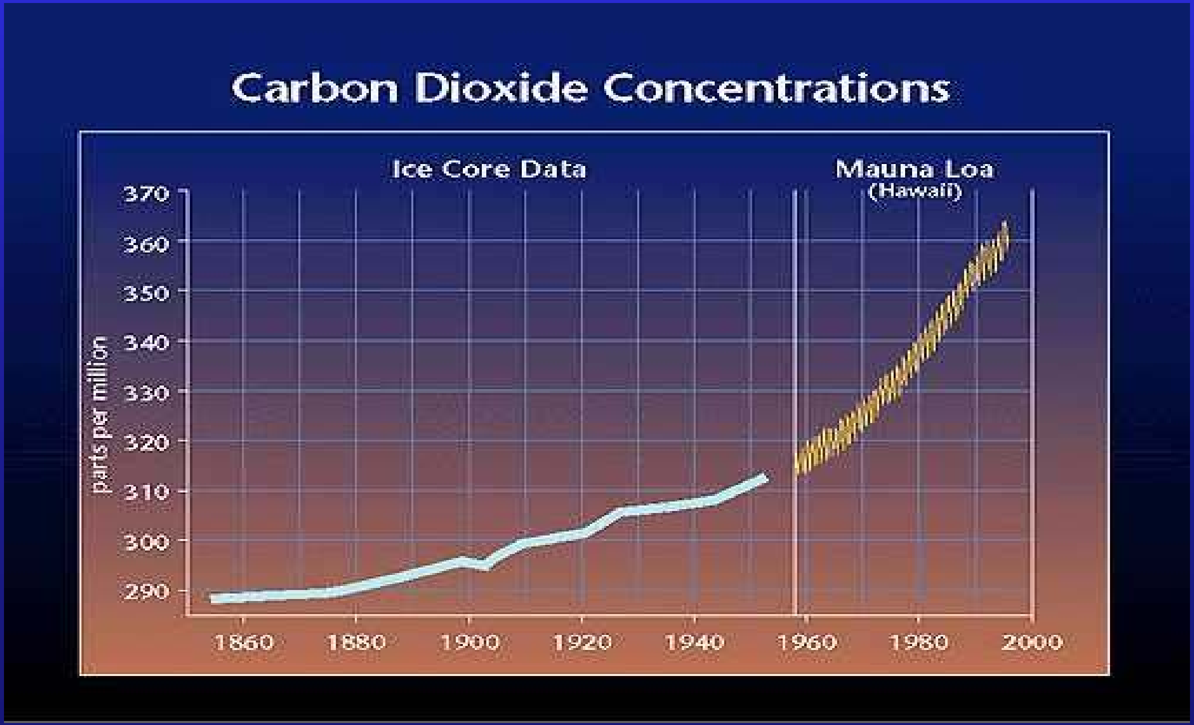
Millennium Ecosystem Assessment, 2006



Intergovernmental Panel on Climate Change, AR4, 2007

Climate Change and Oceans

1. Expected (predicted) changes
2. Surprises



Predicted physical changes

1. Oceans temperatures will increase
2. Hydrological cycle will be enhanced
3. Ice caps and sea ice will melt
4. Sea level will rise
5. Storminess will increase
6. Storm tracks will shift
7. Patterns of salinity will change
8. Ocean circulation may change.

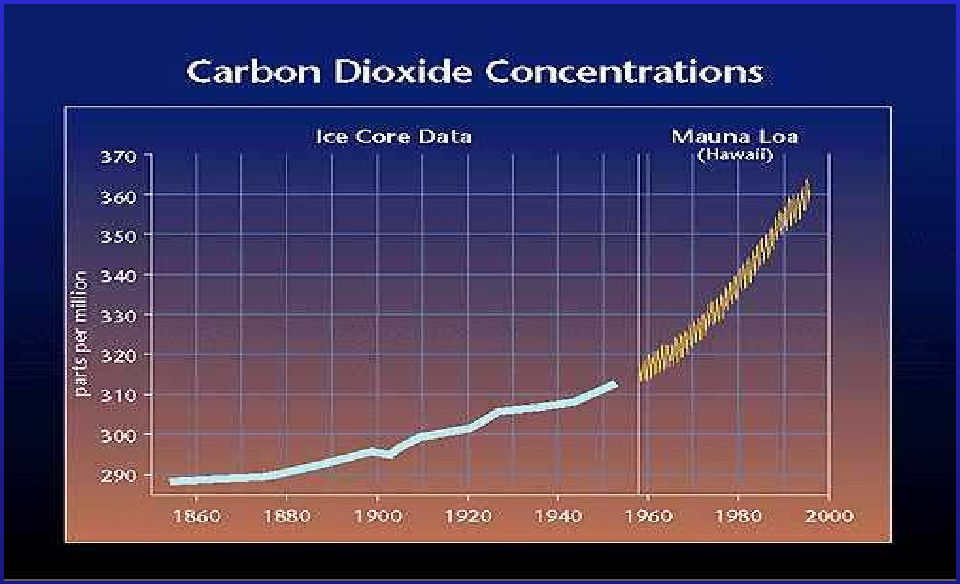
Predicted physical changes

1. Oceans temperatures will increase
2. Hydrological cycle will be enhanced
3. Ice caps and sea ice will melt
4. Sea level will rise
5. Storminess will increase
6. Storm tracks will shift
7. Patterns of salinity will change
8. Ocean circulation may change.

1-7 are all happening, in most cases faster than predicted

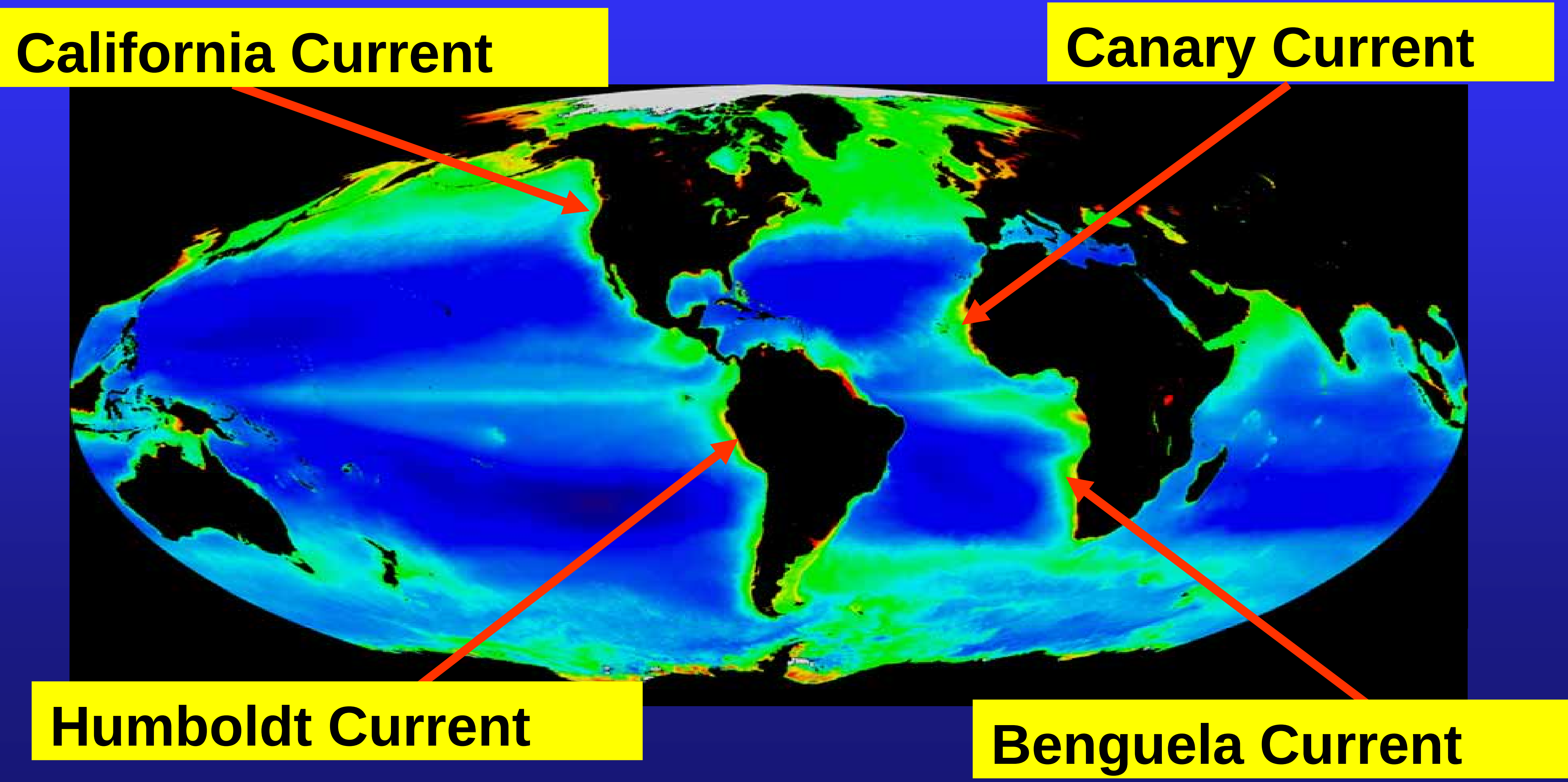
Climate Changes and Ocean Ecosystems

1. Expected (predicted) changes
2. **Surprises?**
    1. **Acidification**
    2. **Expansion of oligotrophic gyres ?**
    3. **Changes in Coastal upwelling dynamics ?**



Eastern Boundary Coastal Upwelling Ecosystems

1% surface area; 20% of fisheries



Northern portion of California Current Large Marine Ecosystem

1. Normal dynamics
2. Recent anomalies
3. Are changes really new?
4. Possible causes

‘Normal’ Upwelling off Oregon & Washington

- **Seasonal upwelling**: from Spring Transition to Fall Transition (April-Oct)
- **Intermittent**
- Fuels **highly productive and diverse ecosystem**: phytoplankton, zooplankton, small fishes, larger fishes, birds, mammals, people

Hypoxia/Anoxia in Oregon and Washington

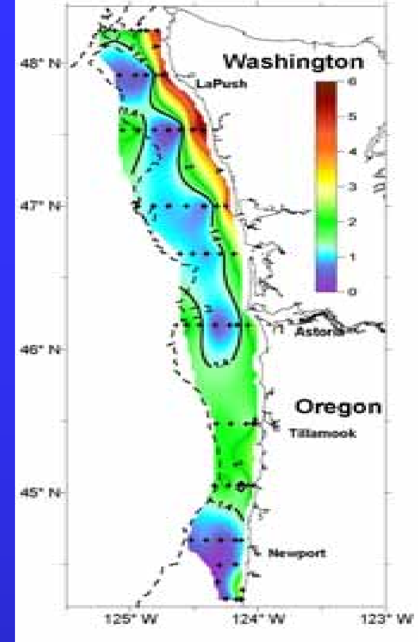
- First seen in 2002
- 6 events in 6 years (2002-2007)
- 2006:
  - Longest lasting – 4 months
  - Largest off Oregon and Washington
  - Thickest ~2/3 of water column
  - Most severe – anoxic = no oxygen

Jack Barth & Kipp Shearman

COAS
College of Oceanic and Atmospheric Sciences
Oregon State University

OrCOOS
Oregon Coastal Ocean Observing System

Jack Barth &
Murray Levine



Bill Peterson et al.

NOAA

Francis Chan
Jack Barth
Jane Lubchenco

Waldo Wakefield

Aimee Keller

NOAA

Groundfish Survey

Microbiology
Oregon State OSU

Steve Giovannoni et al.

Mike Donellan, Bill Miller

State of OREGON
Fish & Wildlife

Hypoxia can occupy up to 80% of the shelf water column

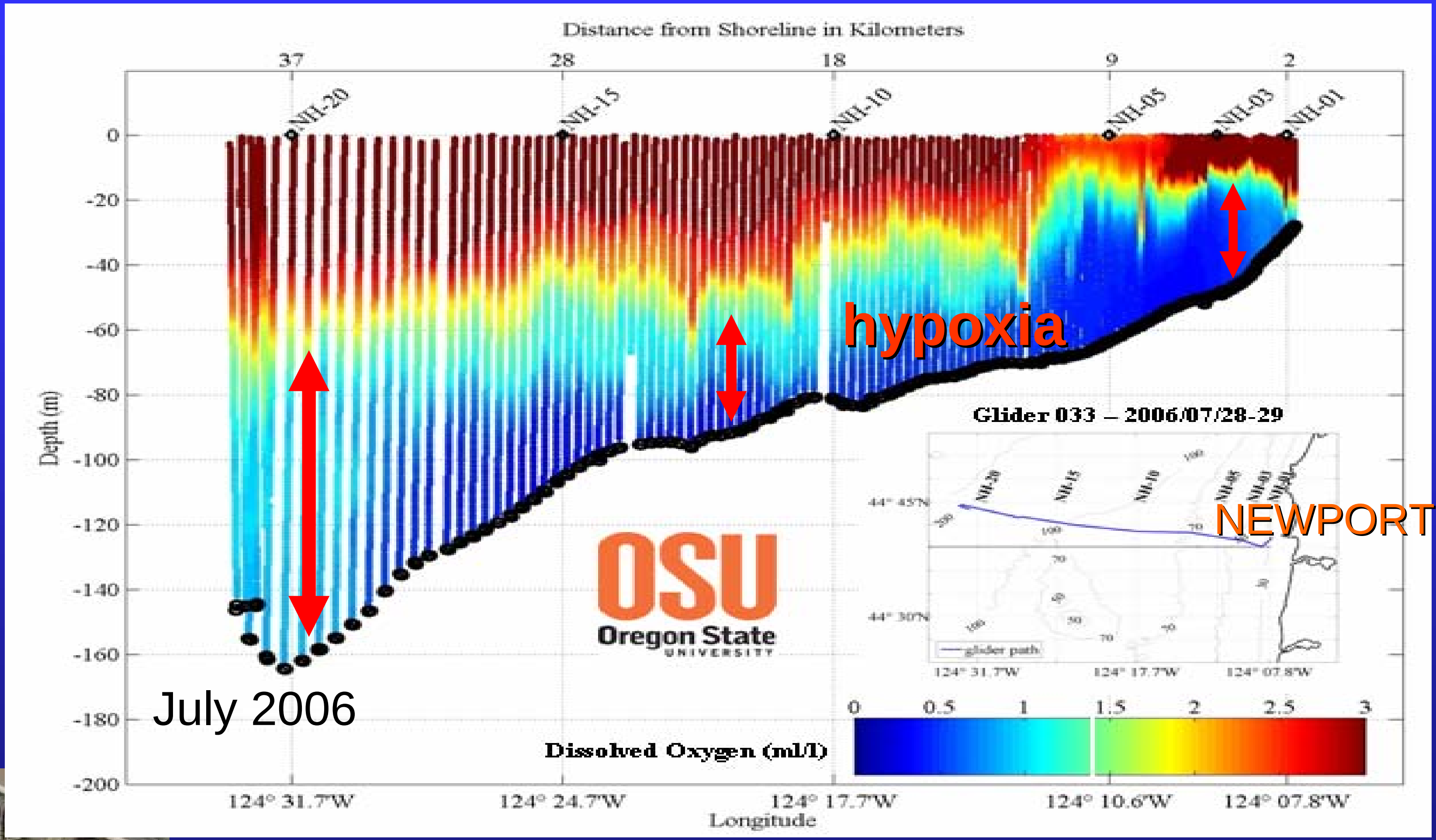


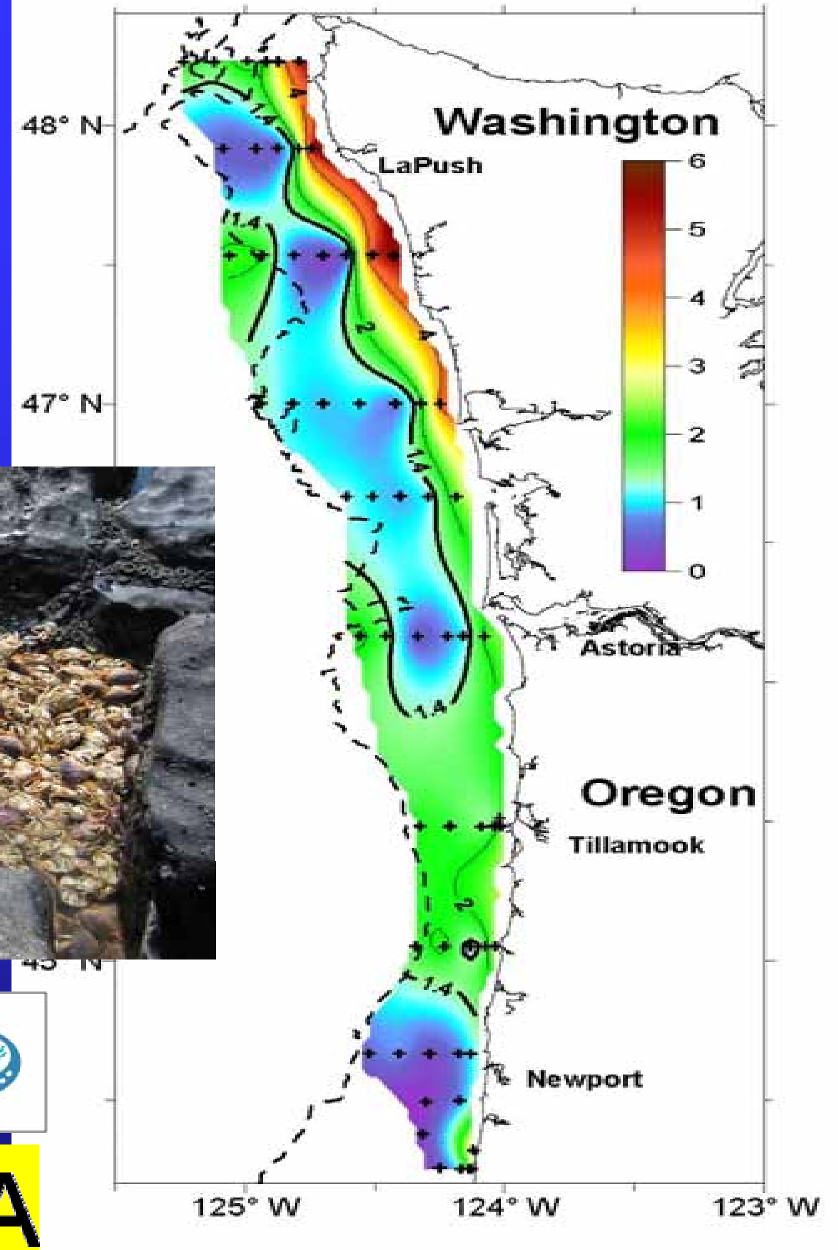
Figure: Jack Barth/ Kipp Shearman

OSU glider

…and extend to within 1km of the surf-zone, encompassing important shallow ecological and fishery habitats

PISCO

Severe hypoxia can be a regional-scale phenomenon



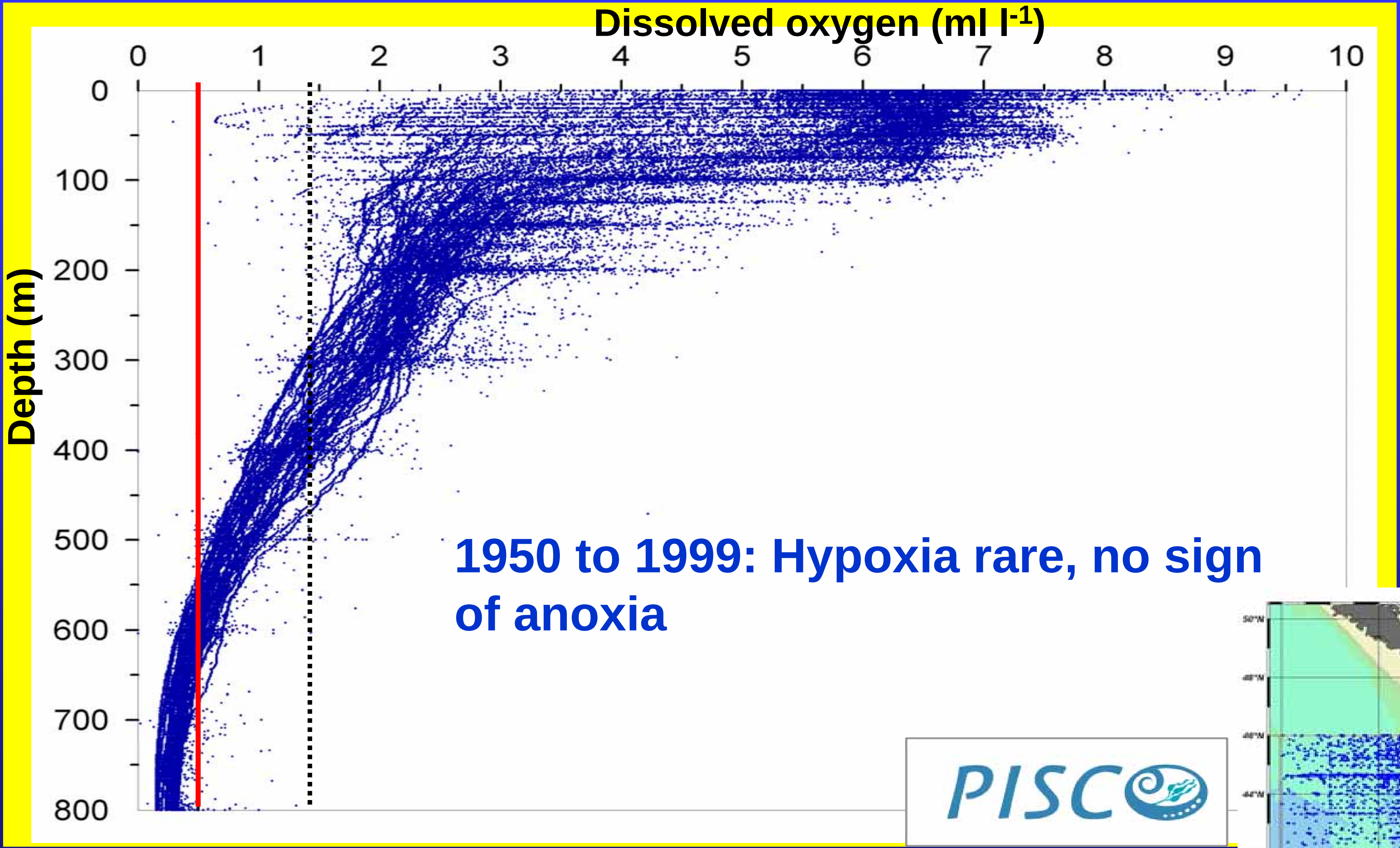
PISCO

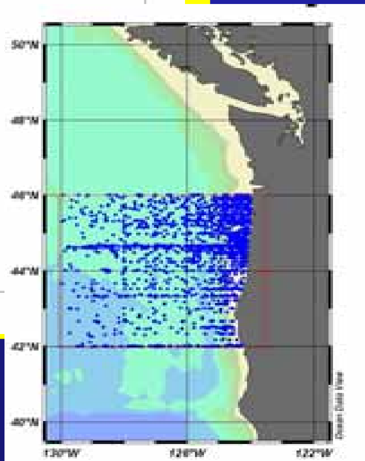
NOAA

September 20-28, 2006 BPA and PISCO cruises (Figure Courtesy Bill Peterson, Cheryl Morgan NOAA)

Is severe hypoxia really new in this system?

Hypoxia is not a normal feature of the Oregon Coast

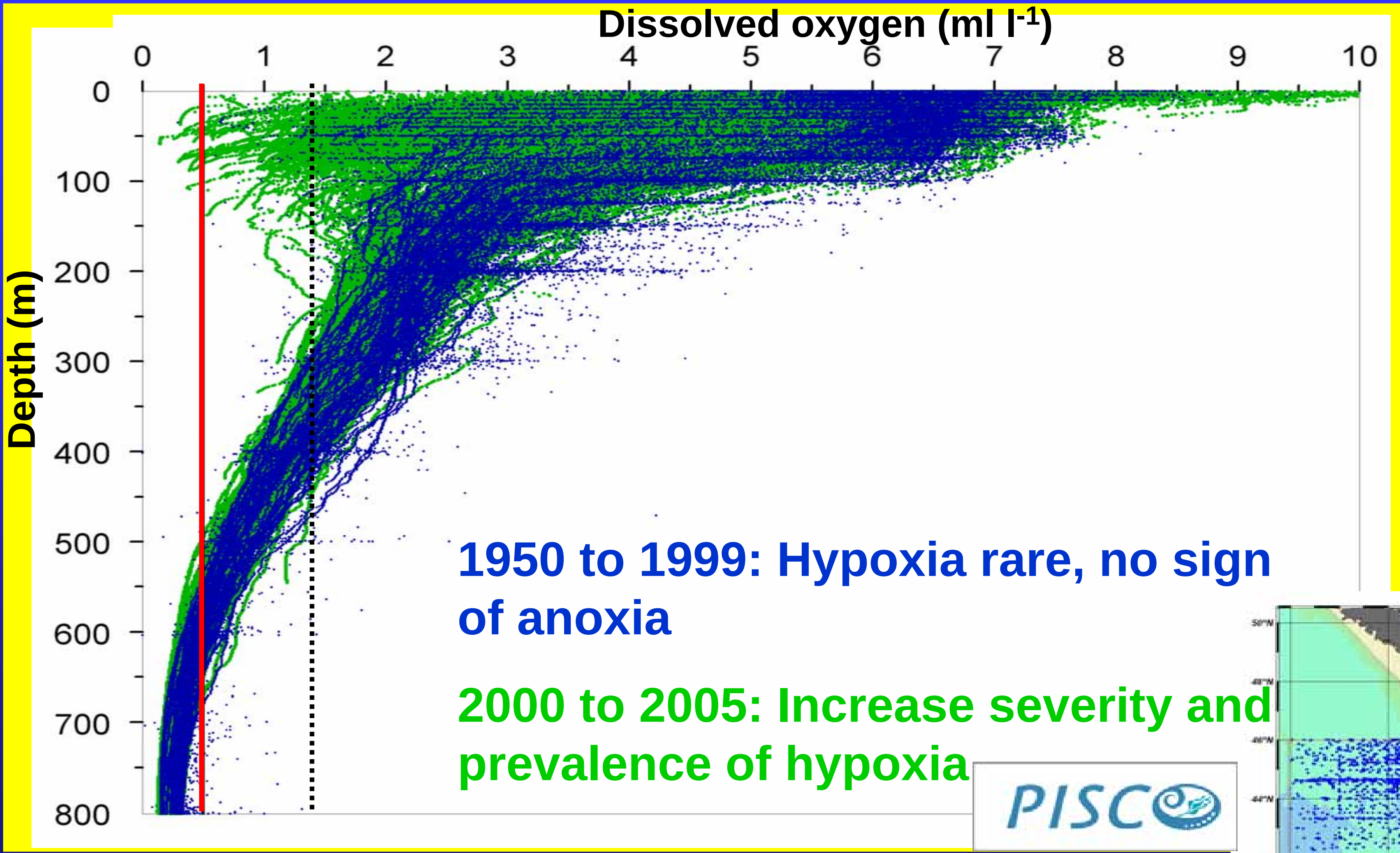




National Oceanographic Data Center, NOAA, OSU Archives, GLOBEC LTOP

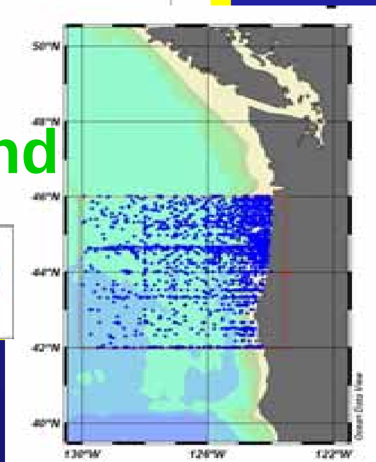
Chan et al. *Science* 2008

A changing picture



1950 to 1999: Hypoxia rare, no sign of anoxia

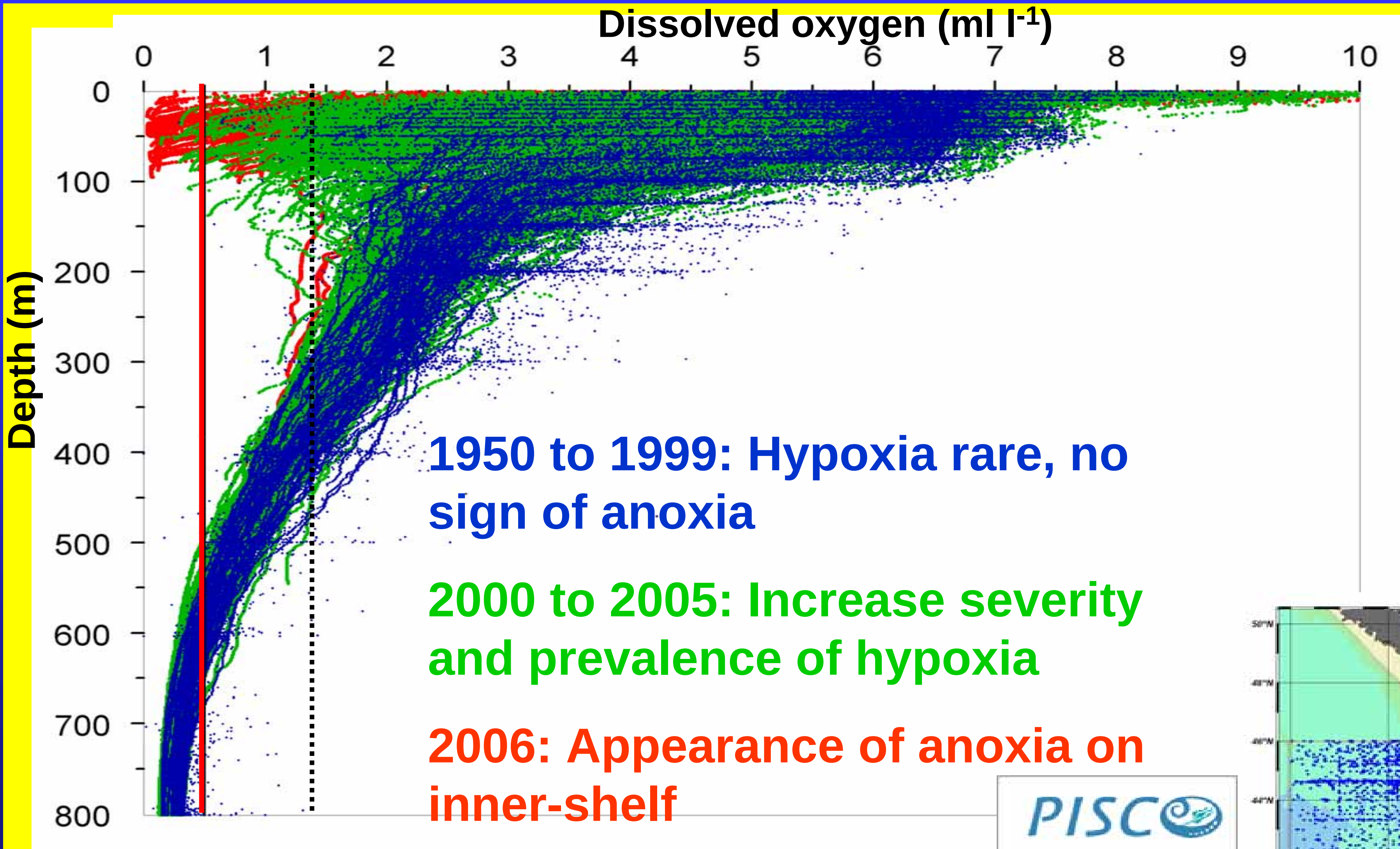
2000 to 2005: Increase severity and prevalence of hypoxia

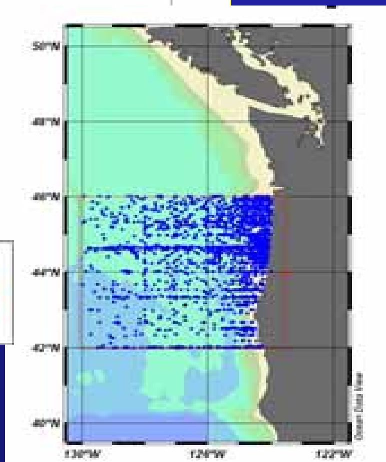


National Oceanographic Data Center, NOAA, OSU Archives, GLOBEC LTOP, NOAA, PISCO

Chan et al. *Science* 2008

2006 was highly anomalous





National Oceanographic Data Center, NOAA, OSU Archives, GLOBEC LTOP, NOAA, PISCO

Chan et al. *Science* 2008

What has changed?

1) Land conditions? no

2) Ocean conditions? yes 2002*, 2007

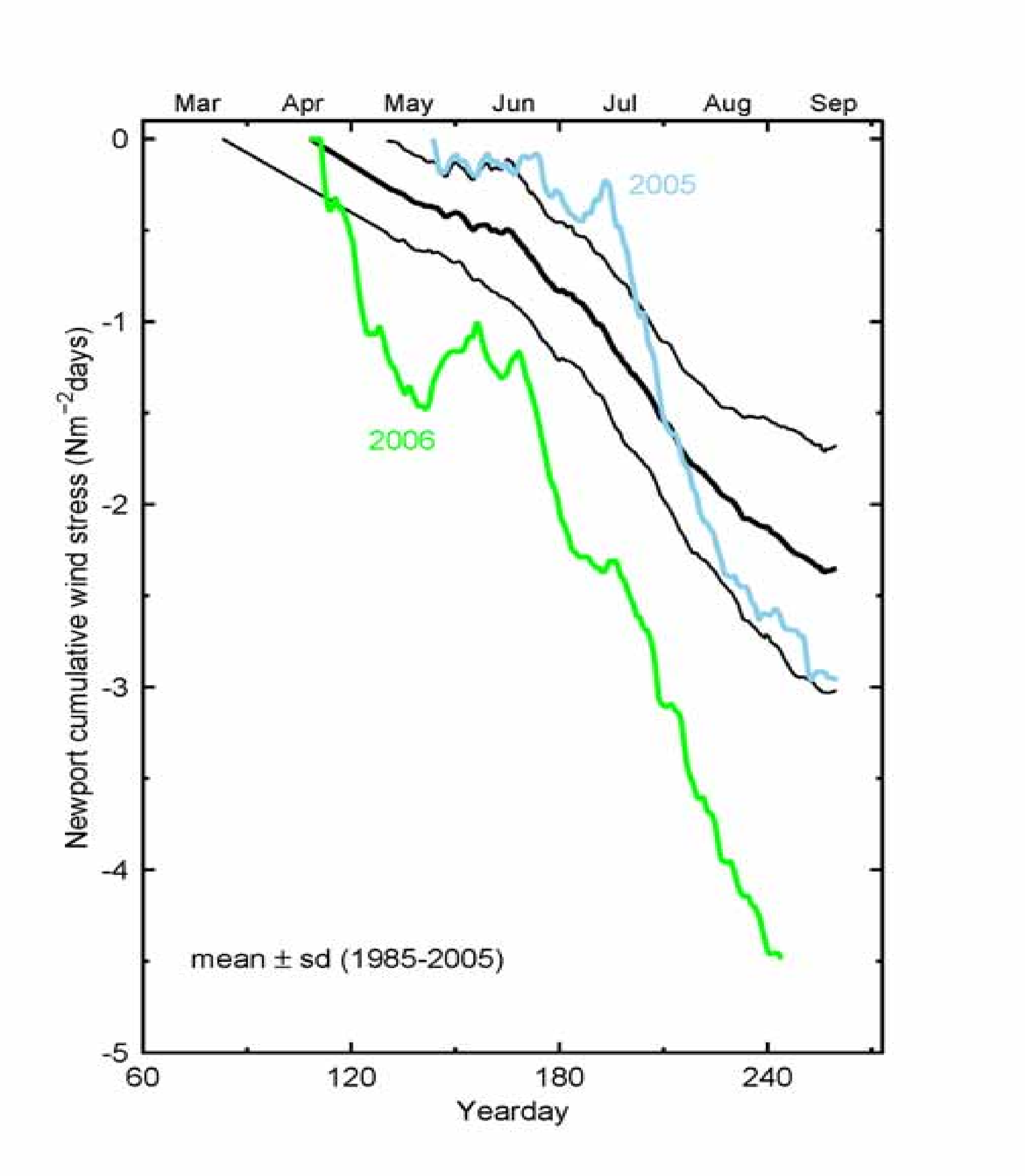
3) Wind conditions? yes '05-'07**

* Grantham et al. *Nature* 2004

** Barth et al. *PNAS* 2007; Bane et al. *PNAS* 2007; in prep

“supercharged” upwelling in 2006

Cumulative wind stress since Spring Transition

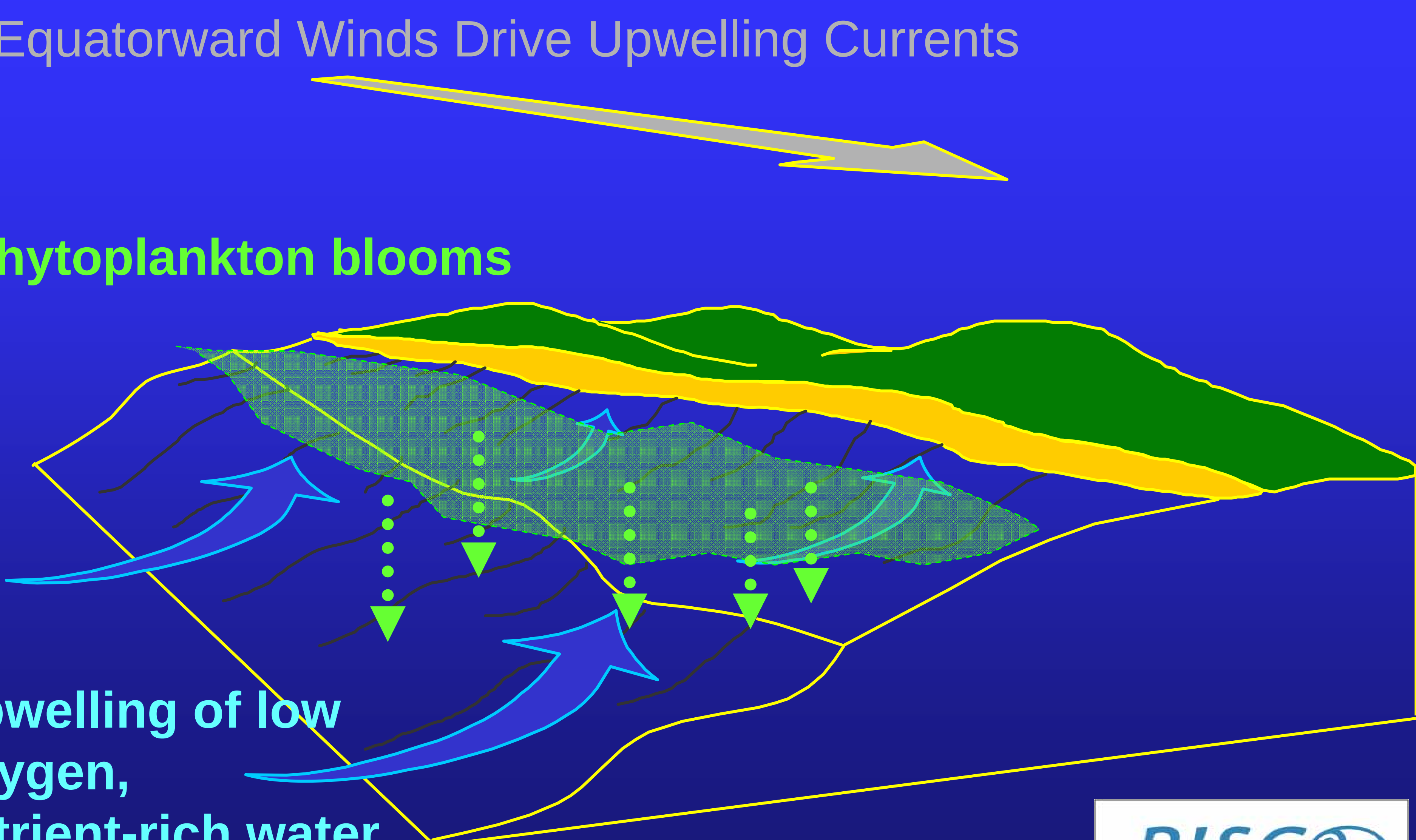


Equatorward, Upwelling favorable

Barth/Pierce (OSU)

2006 Supercharged upwelling: Massive phytoplankton blooms

What causes hypoxic zones to form along our coast?



Biological, ecological, social and economic consequences?

Perpetua Reef
ODFW + PISCO ROV surveys

2000 = normal

2002 = first hypoxia

2006 = severe hypoxia/anoxia

50m deep, 1 km off shore

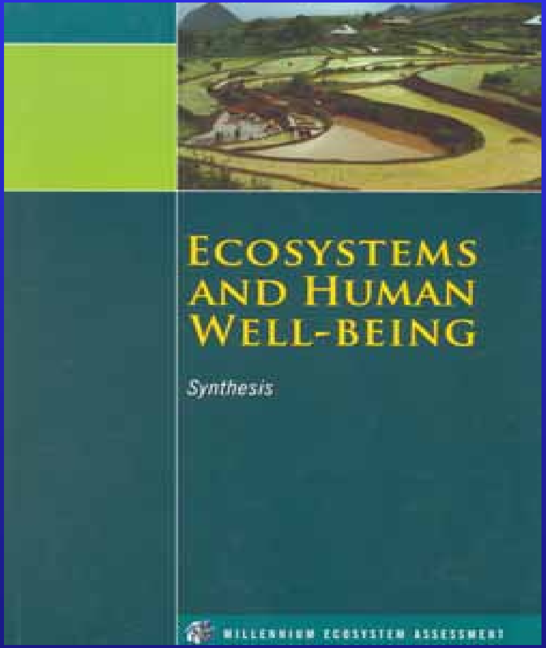
Working Hypotheses

- Fundamental changes in ocean and atmospheric conditions in the northern California Current Ecosystem have changed
- In ‘05, ‘06 and ’07, changes in the timing and intensity of coastal winds seems to be driving most of the observed anomalies
- Changes in ocean and atmospheric circulation are consistent with our understanding of climate change

Today's Voyage

1. Science and Society
2. Climate Changes and Oceans
3. Other Global Changes
4. What's at Risk?
5. Response Options:Adaptation & Resilience

Millennium Ecosystem Assessment: Global ocean trends



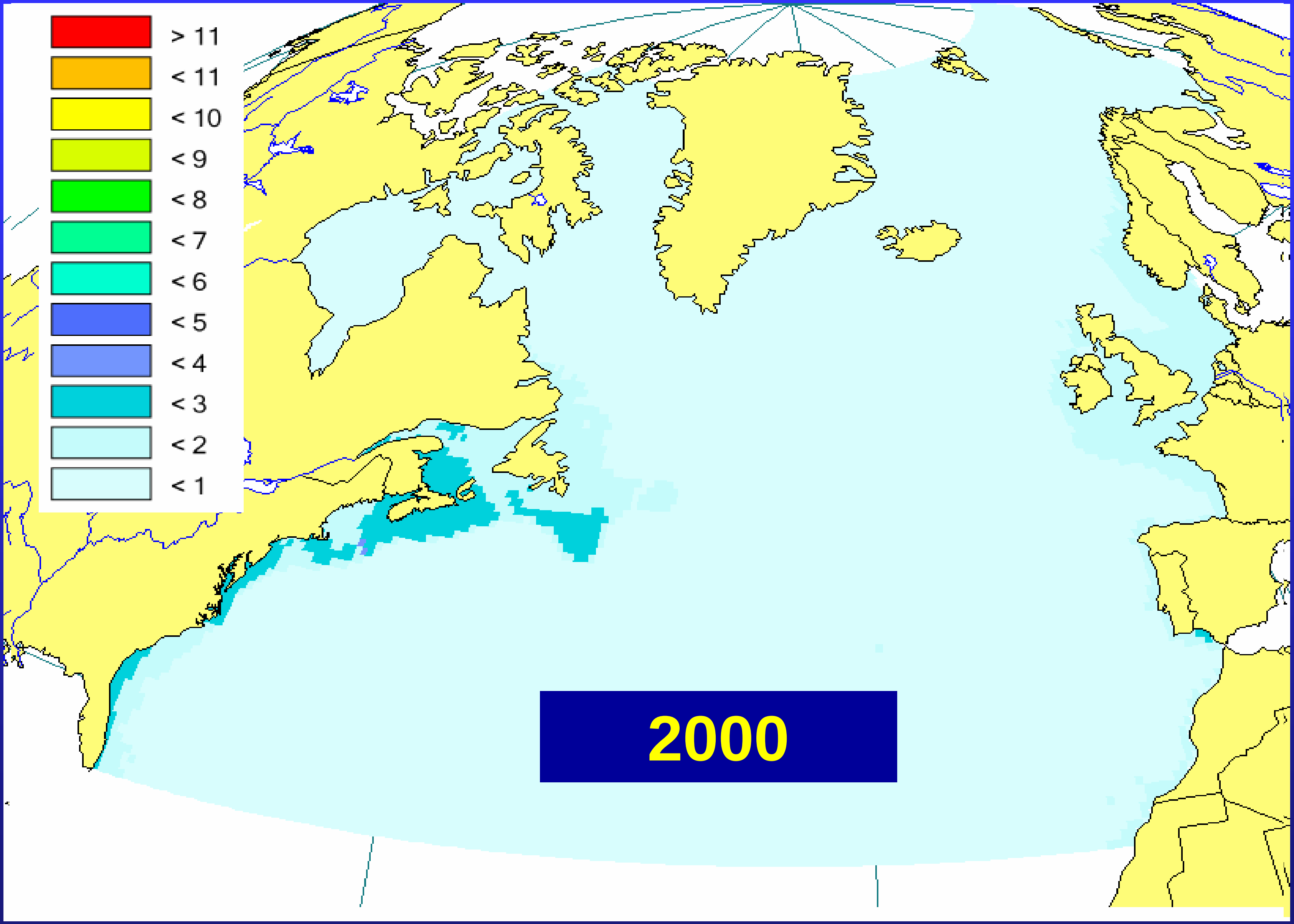
1. Depletion and disruption of ocean ecosystems
2. Loss of resilience (increased likelihood of abrupt changes)

www.MAweb.org 2006

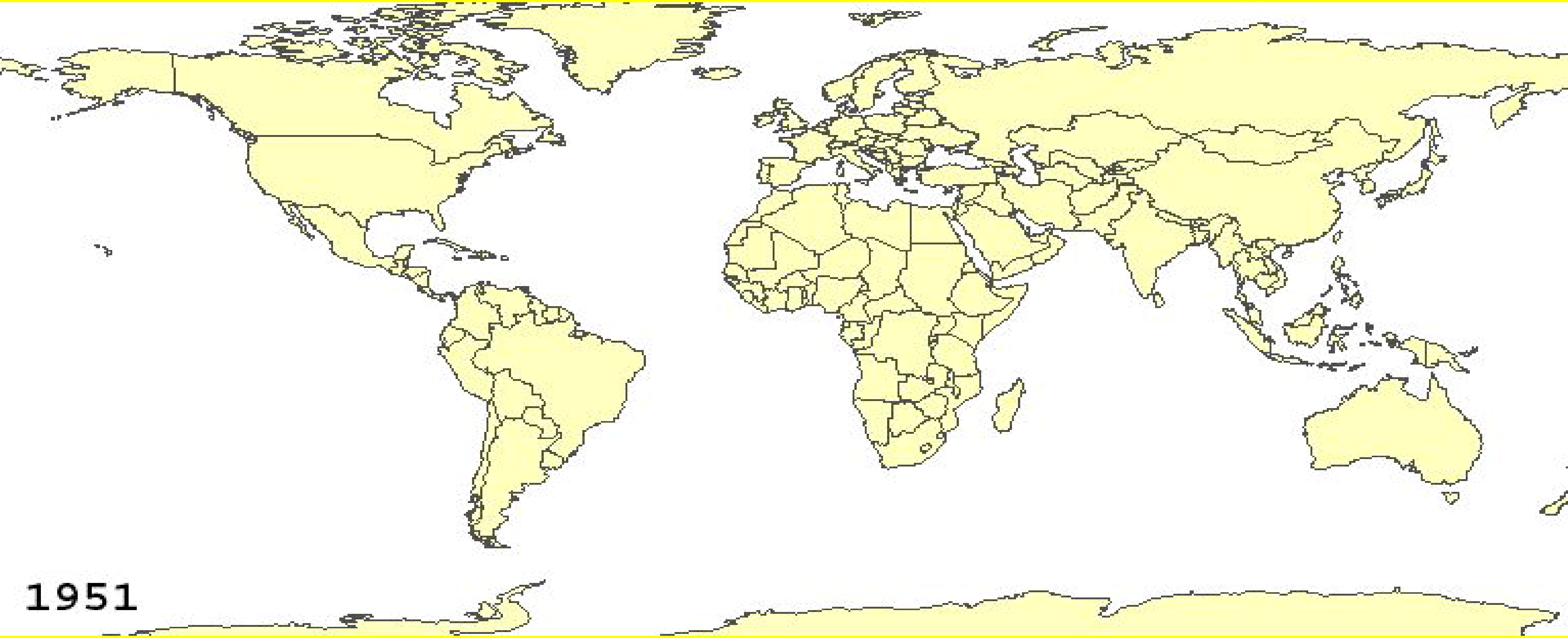
Causes

- Overfishing, destructive fishing
- Pollution, especially nutrient pollution
- Coastal development: loss of critical coastal habitats
- Climate change and ocean acidification

Biomass of Table Fish (tons per km²)



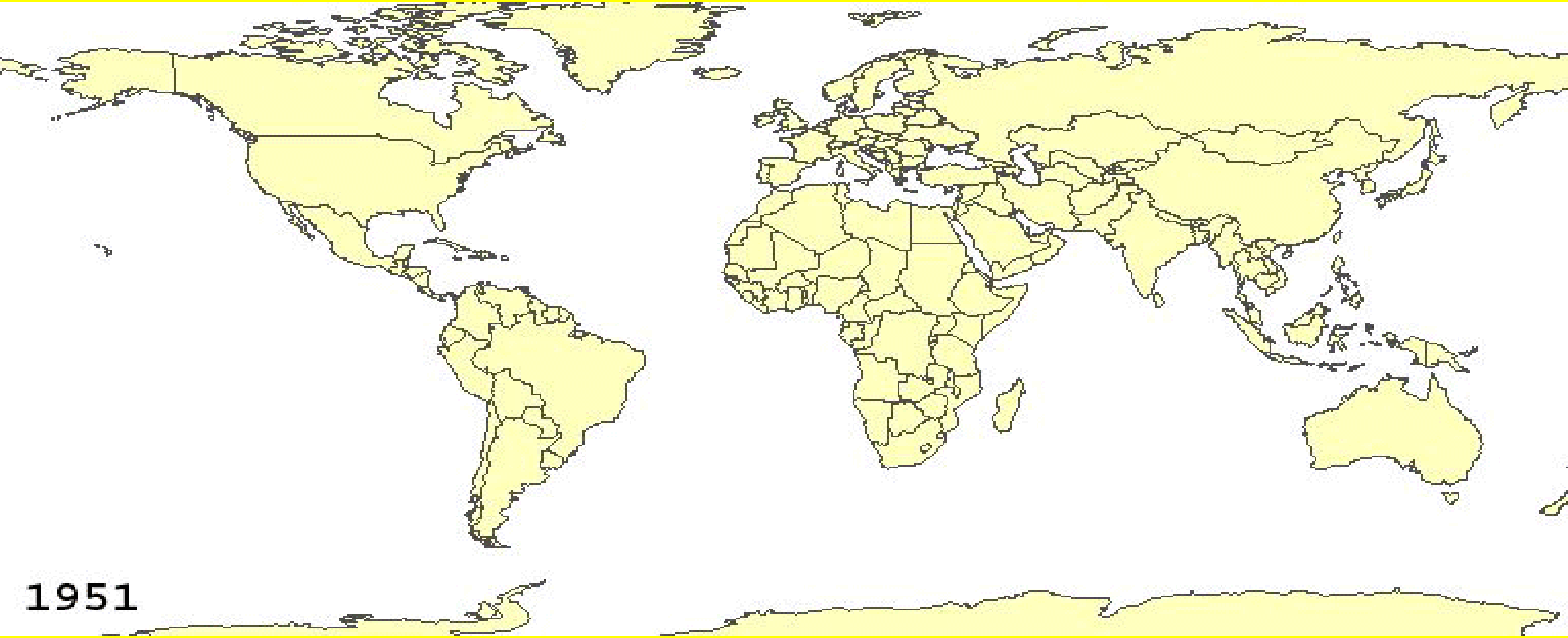
Source: Christensen et al. 2003, Fish & Fisheries



Year of Peak Fish Harvest

- Pre-peak
- Harvest peak
- Post-peak

Source: Millennium Ecosystem Assessment and Sea Around Us project



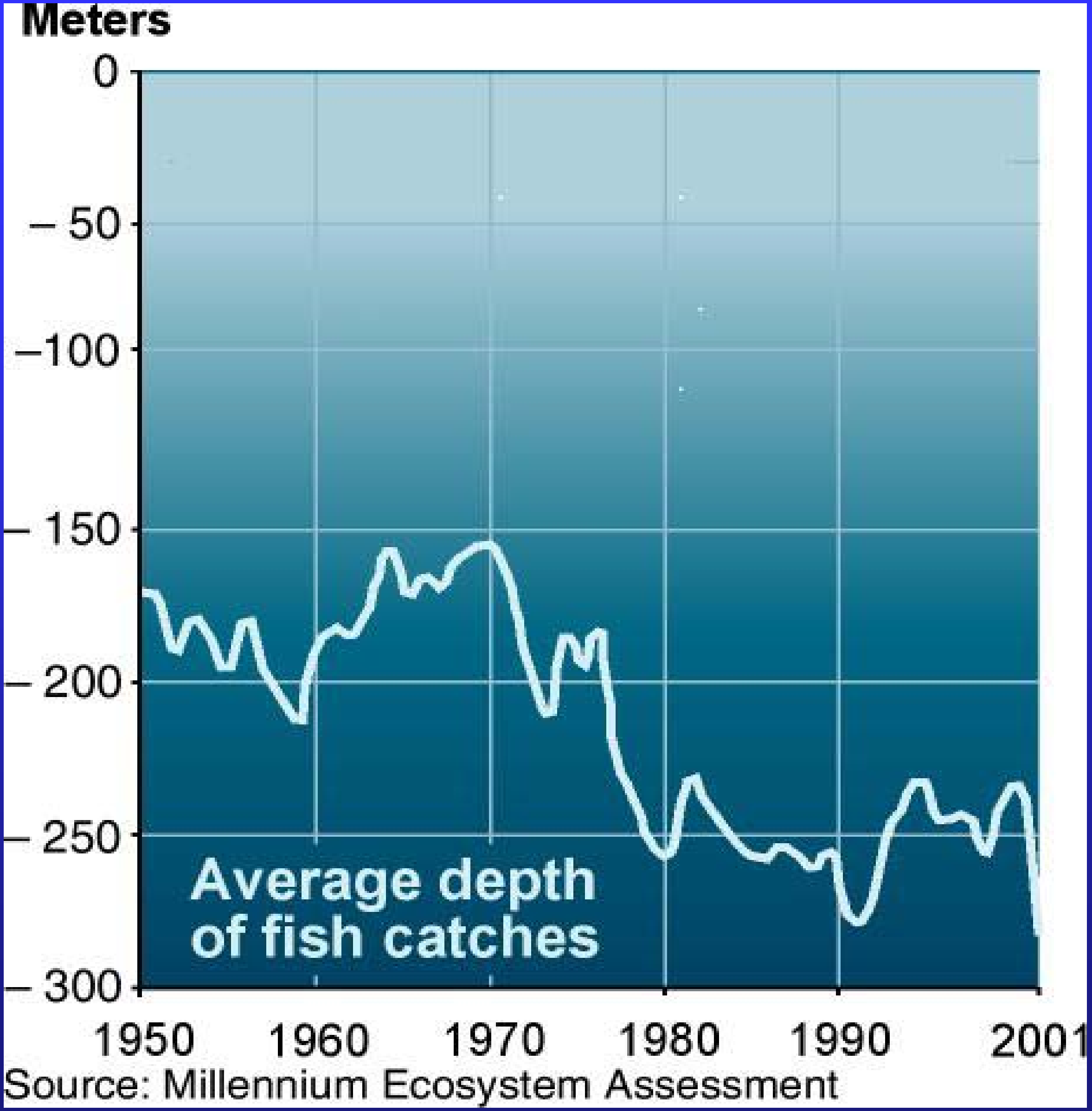
Year of Peak Fish Harvest

- Pre-peak
- Harvest peak
- Post-peak

Source: Millennium Ecosystem Assessment and Sea Around Us project

Fishing Deeper and Deeper:

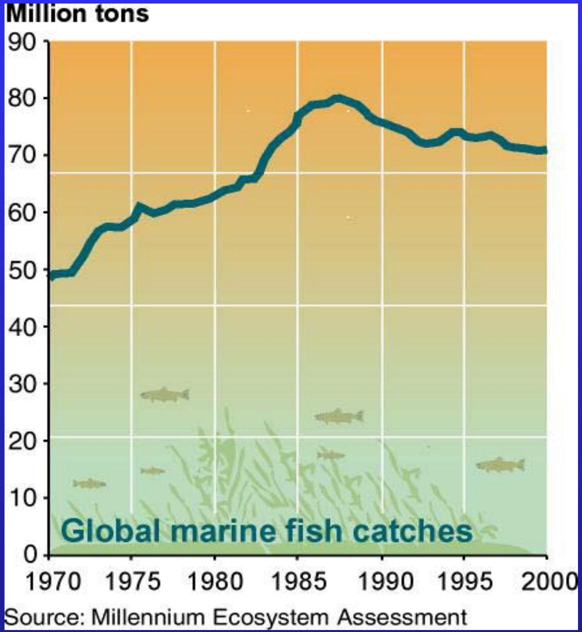
Global Average Depth of Fish Catches

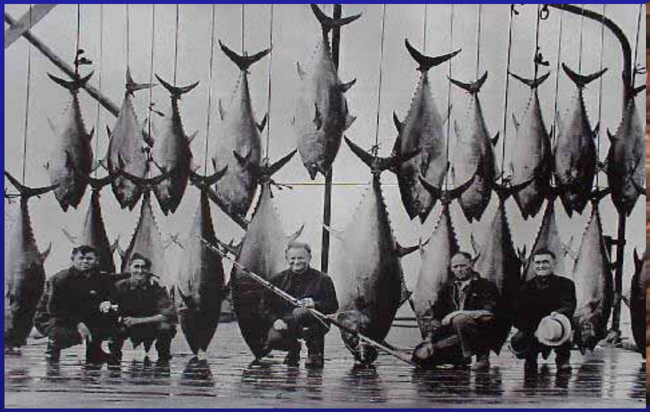


www.MAweb.org

The Oceans are Being Depleted

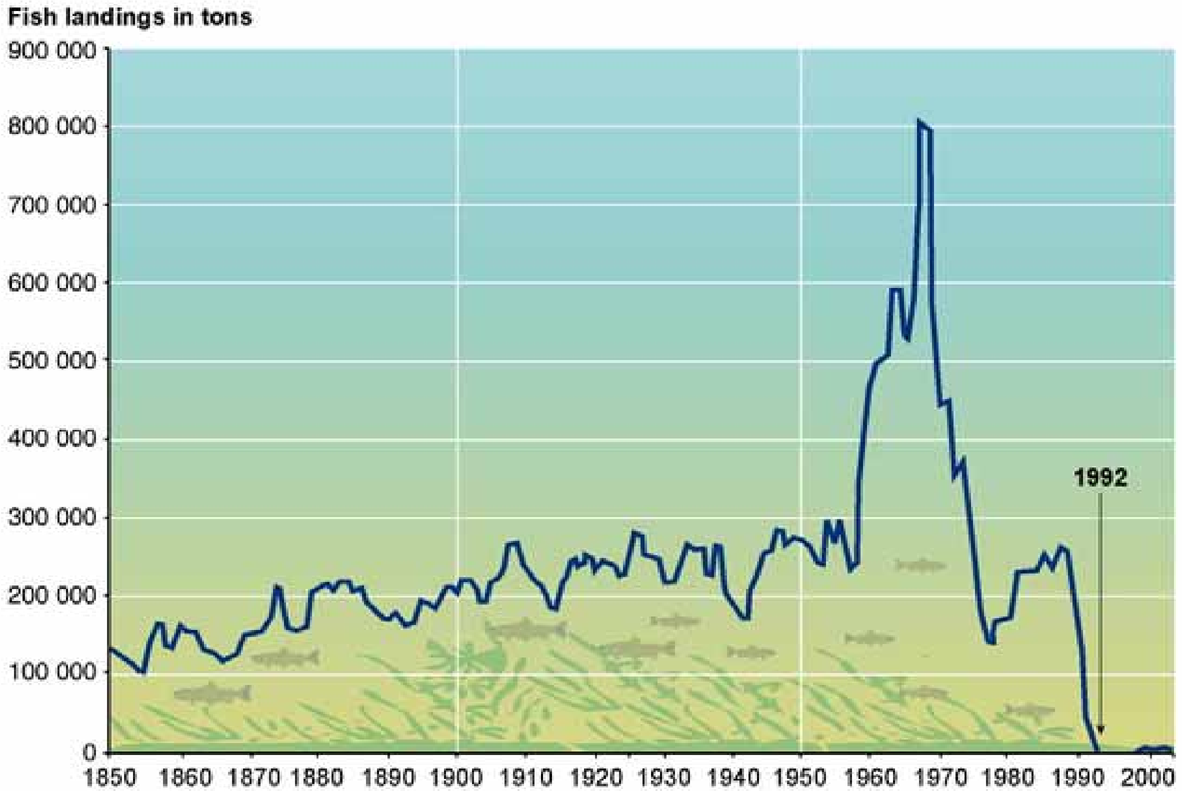
- Global fisheries peaked in 1980s and are now declining*
- 25% of global fisheries are significantly depleted*
- 90% of all big fish are gone**





*** UN FAO 2005**
**** Myers and Worm 2003 *Nature***
-www. MAweb.org

There is an increased likelihood of abrupt changes

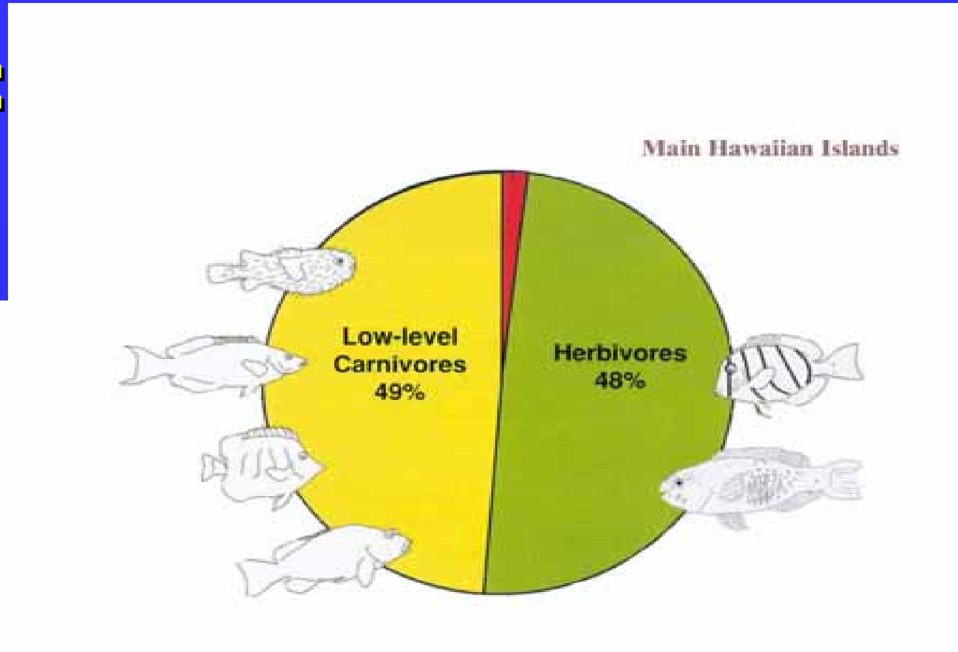


Newfoundland Cod landings

www.MAweb.org

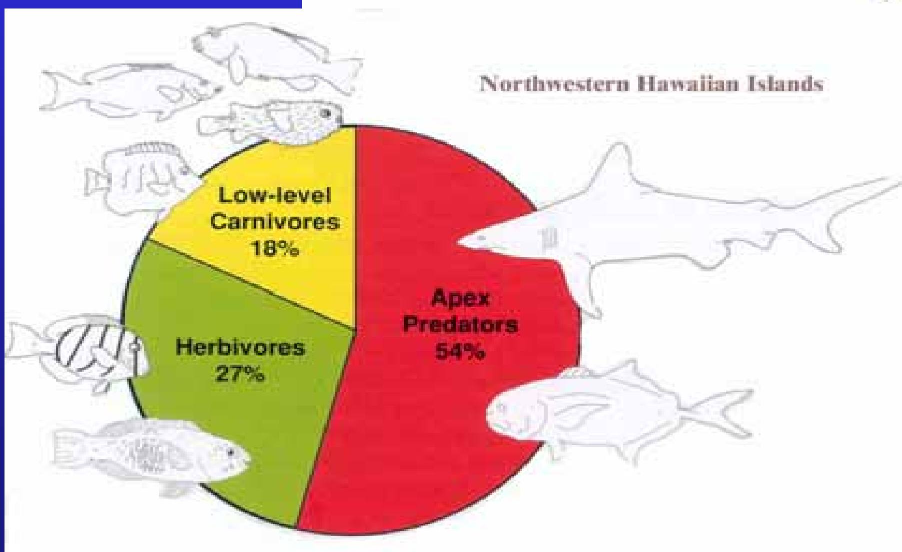
The Result:
Empty Oceans
Empty Nets

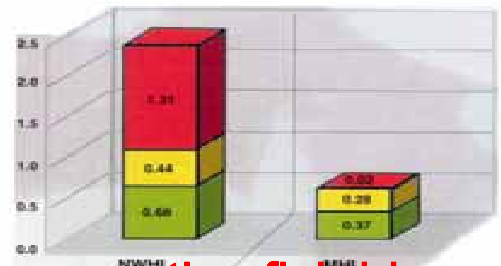
Fishing & trophic structure: insight from Hawaii



NW Hawaiian Islands = Little fishing

Main Hawaiian Islands = heavily fished



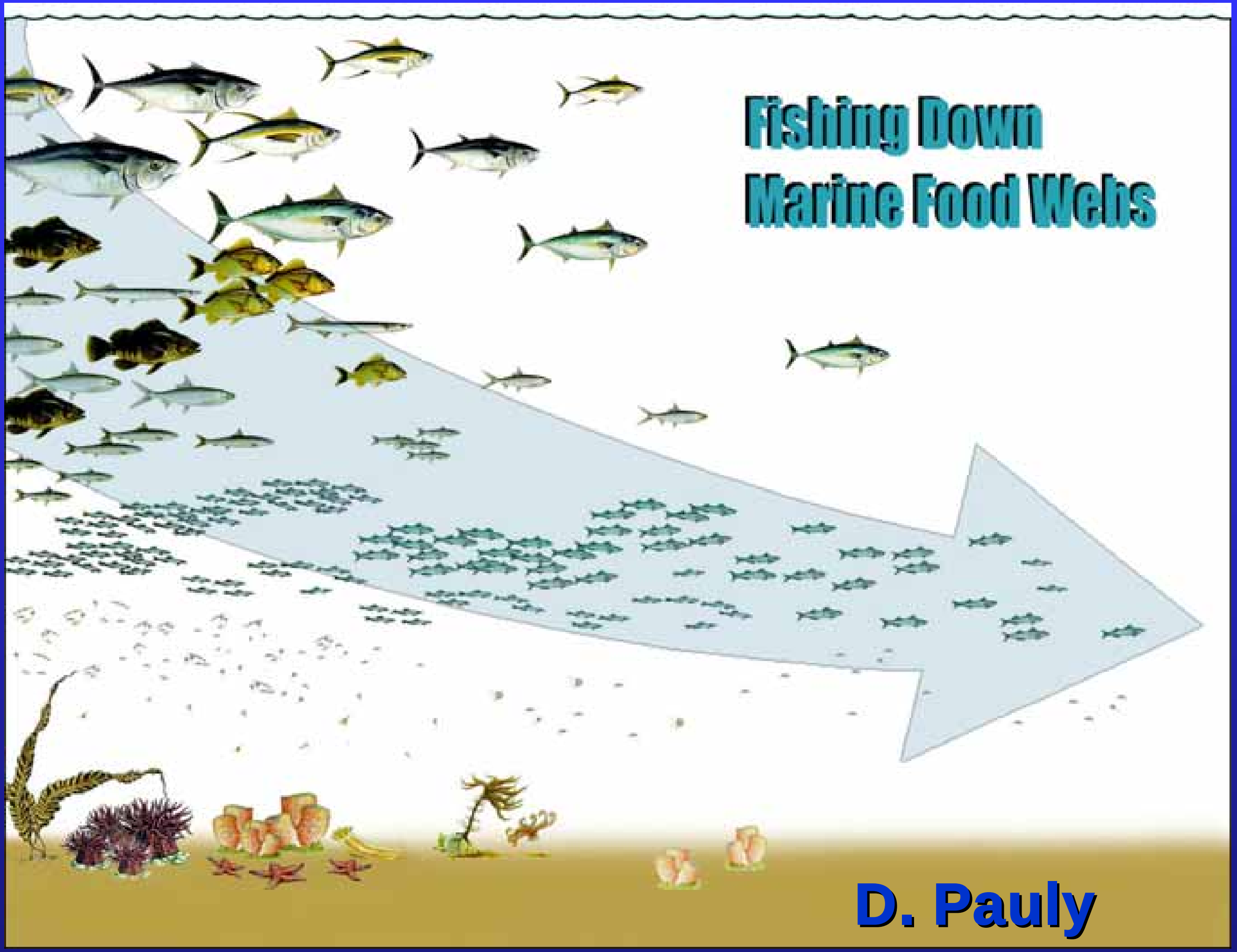


Comparative fish biomass (mT/ha)

(Friedlander and DeMartini 2002)

Ocean Ecosystems are being disrupted

by removal of apex predators, other key species, biomass, habitat destruction, invasive species, and pollution



1 consequence: outbreaks of pests & pathogens

a) Increasing outbreaks of jellyfish and epidemics of bacterial and other coral reef diseases around the world

Bacterial
Disease killing
coral

Jelly
outbreaks

b) Transformation of lush, diverse coral reefs into slimy, weedy algal- and bacterial-dominated places

Biological Causes of Declines & Disruption

1. Rate of Fishing > rate of replenishment
2. Cumulative and interactive effects of fishing, pollution, coastal development, upstream activities, climate change
3. Ecosystem impacts of fishing: habitat destruction, by-catch, species interactions
4. Selective catch of big old fat female fish (BOFFF) undermines replenishment
5. Evolutionary changes in life history characteristics.

Ocean Ecosystem Services at Risk

Provisioning
- seafood
- habitat
- fuel wood
- genetic resources

Regulating
- climate regulation
- disease & pest regulation
- coastal protection
- detoxification
- sediment trapping

Cultural
- spiritual
- recreational
- aesthetic
- educational

Supporting
- Nutrient cycling
- Primary production

Converting an ecosystem means losing some services and gaining others – e.g., A mangrove ecosystem:

Provides nursery and adult habitat ,
Seafood, fuel wood, & timber;
traps sediment; detoxifies pollutants;
protects coastline from erosion & disaster

Converting a mangrove means losing some services and gaining others

Gain: housing,

Shrimp,

Or crops

Loose: nursery and adult habitat ,
Seafood, fuelwood, & timber;
traps sediment; detoxifies pollutants;
protects coastline from erosion & disaster

MA: 60 % of Global Ecosystem Services are at Risk

Today’s Voyage

1. Science and Society
2. Climate Changes and Oceans
3. Other Global Changes
4. What’s at Risk?
5. **Response Options: Adaptation & Resilience**

Response Options for Society

1. Mitigation*
    1. Reduce GHG emissions
    2. Enhance sinks to reduce extent of impacts
2. Adaptation
3. Suffer the consequences

* "Many impacts can be avoided, reduced or delayed by mitigation" - IPCC AR4 WG2

Adaptation

'Adaptive capacity' = the ability of a system to

- adjust to climate change
- moderate potential damages
- take advantage of opportunities
- cope with consequences

- IPCC AR4 WG2

IPCC: Types of Adaptation

1. **Technological**

   Coastal dykes; bridges; port fortification

2. **Behavioral**

   Fish in different places, for different species

3. **Management & Policy**

   Fishery management policies: NPFMC's trawl closure areas in newly ice-free waters in Alaska

‘Adaptation’ is usually construed to mean adaptation by humans;

adaptation by other species is rarely considered, despite the fact that it is the interactions of species in an ecosystem that provide critical ecosystem services = the life support systems for Earth

Adaptation by other species:

1. Migrate
2. Acclimate
3. Adapt genetically = evolve

Additional Response Option:

Create the conditions for other species to adapt

Maximize likelihood that other species can adapt by

1. Reduce stresses over which we have control
    1. Reduce flow of nutrients to coasts
    2. Manage fisheries conservatively
    3. Adopt ecosystem-based management
    4. Reduce introduction of invasive species

Maximize likelihood that other species can adapt by

1. Reduce stresses over which we have control
2. Protect as much habitat and biodiversity as possible
    1. Create networks of no-take Marine Reserves
    2. Protect critical coastal habitat

Maximize likelihood that other species can adapt by

1. Reduce stresses over which we have control
2. Protect as much habitat and biodiversity as possible
3. Explore interventions to enhance adaptation (with extreme caution)

Today's Voyage

1. Science and Society
2. Climate Changes and Oceans
3. Other Global Changes
4. What's at Risk?
5. Response Options: Adaptation & Resilience

Conclusions

1. Climate change is altering ocean ecosystems in profound ways
2. Climate-driven changes interact with many other global changes
3. Consequence: the vast majority of marine ecosystem services are likely declining and at increasing risk
4. This has huge consequences for human well-being

Conclusions, part 2

5. Aggressive mitigation and adaptation strategies will likely be required to avoid the most serious impacts
6. To be effective, adaptation strategies will need to target ability of humans and other species to adapt

Conclusions, part 3

7. Significantly greater attention should be given to creating conditions for species to adapt: reducing stresses over which we have control and protecting as much biodiversity and habitat as possible.

www.MAweb.org
www.PISCOweb.org
www.COMPASSOnline.org
www.JointOceansCommission.org

PISCO