Environmental problem solving in coastal regions

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Outline

- **Land-sea interfaces** are regions of strong gradients and major human impacts

- We have entered the ‘**anthropocene’**

- Now is the time for a global scientific focus on **environmental problem solving**

- Case studies of coastal management demonstrate **solutions are possible**

- Key lessons and recommendations
Land-sea interfaces are regions of strong gradients and major human impacts.

**Coastal Zone**

**Coastal Zone Features**
- Coastal zone (+/- 200 m of sea level)
- ~20% of earth's surface
- >50% of human population (both growth and migration)
  - 70% of large cities (>1.6 million)
  - ~1 dam (>15 m) built per day over the last 100 y
- ~90% of global fisheries
  - Coastal fisheries feed ~1 billion people
- ~25% of global biological productivity
  - Mangrove forests, saltmarsh, seagrass meadows, kelp beds, coral reefs, microalgae

**Coastal Zone Processes**
- Strong gradients and variability
- Major sediment and nutrient sink
- Intense biogeochemical processing
- Intensified agriculture and animal production and associated nutrient runoff

[www.nioz.nl/loicz/](http://www.nioz.nl/loicz/)
Global issues: coastal regions impacted by population pressures

Few large river basins and many small river basins

Significantly impacted coastal regions
Polar issues: Climate change

Sensitive to climate change:
- Glacial, tundra and snow melting accelerated
- Oil development and toxicant deposition

Physical processes dominate:
- Fast ice scouring and sediment entrained in ice
- Biota: sea ice algae, under ice kelp, & walruses (arctic only)

Dynamic physical features:
- Gas ventilation & ice berg scouring
- Seasonal nutrient availability and limitation, low oxygen in winter

Seasonal productivity:
- Simple food webs;
- Deep water nutrient sources;
- Krill in antarctic
- Methane production;
- Bioaccumulation of toxics

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Temperate issues: Eutrophication

- Intensive land use - high yield
  - Nutrients from fossil fuel burning, intensified agriculture, manure/fertilizer runoff
  - Wetland draining & dams; toxicant production

- Historically degraded waterways
  - Nutrient enhanced runoff; high NO₃, P limitation in freshwater
  - Sediment deposition & nutrient flux

- Eutrophication with shifting sources
  - Harmful algal blooms; hypoxia/anoxia; seagrass loss
  - Variable limiting factors; expanding reforestation & aquaculture

- Productive coastal ecosystems
  - Phytoplankton; nutrient ratio sensitive, generally N limited, deposition leading to hypoxia
  - Salt marsh accretion; persistent upwelling

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Tropical issues: Coastal development

Catchment / Watershed
- Rapidly degrading ecosystems
  - Monsoonal rains; more dams
  - Deforestation, intensified fertilization, grazing, aquaculture, & burning

River / Estuary
- Impacted by coastal development
  - Pulsed sediment-laden runoff; deposition/scouring; resuspension & light limitation
  - Urban development & mangrove deforestation

Coastal
- Pulsed runoff
  - Mud deposition & resuspension
  - Harmful algal blooms; tropical seagrasses & macrograzers; benthic microalgae; fisheries declines

Reef
- Oligotrophic ecosystems
  - Mangroves, seagrasses and corals responsive to pulsed runoff
  - Low nutrient concentrations; co-limitation of nitrogen & phosphorus

Ocean
- Integration
  - Application
  - Network
We have entered the ‘anthropocene’—human impacts now dominate the globe.
Now is the time for a global scientific focus on environmental problem solving.

- Paradigm shifts occur when scientific discovery is effectively communicated to society.
- Societal needs provide impetus for discovery.
- The next paradigm shift needed is that we can solve ‘intractable’ environmental problems.
Focus on solving environmental problems when importance and uncertainty are high.
Studying environmental problems

- Scientific rigor
- Total commitment
- Understanding complexity
- Developing methodologies
- Yearning for truth
Solving environmental problems

• **Shared vision**
• **Organized participation**
• **Leadership**
• **Varied communication**
• **Effective actions**
In order to both study and solve problems, credibility, tenacity, creativity and virtue are needed.

“Wisdom is knowing what to do next; virtue is doing it.”

David S. Jordan
Observation Revolution

Data gathering capabilities dramatically increasing

In situ sensing

Remote sensing

Integration

Application

Network
Information Generation

Capacity for data analysis increasing

Quantitative models

Spatial analysis

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Knowledge Building

Synthesis and visualization techniques not utilized enough
Problem Solving

Need integrated and applied approach

Management

Informed decisions,
not knee jerk reactions

Monitoring

Feedback for management actions,
not well documented declines

Research

Research for problem solving,
not just curiosity driven research
Case studies of coastal management

**Chesapeake Bay**
- Vertical stratification
- Extended salinity gradient
- Residual nutrients

- Watershed Population: 15 million
- Watershed Area: 165,000 km²
- Bay Area: 13,000 km²

**Moreton Bay**
- Unstratified
- Narrow salinity gradient
- Nutrients in biota

- Watershed Population: 1.5 million
- Watershed Area: 21,220 km²
- Bay Area: 1,523 km²
Moreton Bay, East coast Australia
Problem: Fine grained sediments causing turbidity, killing seagrass

Fine grained sediments:
Enter the bay are deposited & resuspended, killing seagrass

Secchi depth (m)
Pink/red < 1 m

Sediment mud content (%)
Red > 90%

Suspended sediment concentration (mg/L)
Red > 100 mg/L

Seagrass area (green) and loss (red)

(Moreton Bay Study, 1999)
Research: Sediment comes from channel erosion in agricultural regions

Evidence for channel erosion

(Healthy Catchments – Healthy Waterways, in press)

70% of sediment in the Bay comes from 30% of catchment
Solution: Rehabilitate channels in eroding regions (fencing and replanting)
Problem: Sewage nutrients leading to algal blooms

= Sewage N
Research: Sewage plumes assessed & mapped

Sewage plume map (δ¹⁵ N)

(Moreton Bay Study, 1999)
Solution: Sewage treatment upgrades (biological nutrient removal)

Murrumba Downs Wastewater Treatment Plant - Total Nitrogen Discharge

Big steps towards a healthier Bay

The Brendale Wastewater Treatment Plant has undergone a $7 million upgrade. Pine Rivers Shire Council funded the upgrade with the help of a 40% grant from the...
Problem: Blooms of *Lyngbya majuscula* (cyanobacteria) causing human and ecosystem health problems.
Research findings: *Lyngbya* bloom initiation linked to forestry practices

Photosynthetic pigment concentration (mg/g)

- Seawater control
- Cleared pine forest
- Intact pine forest
- Canal development
- Mangrove
- Melaleuca
- Shirley Creek
- Sandstone Point
- Cofferock

Concentration mg/g

- Phycoerythrin
- Chlorophyll a

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Solution: Monitoring & revised forestry practices
Key Lessons

• **Tracers** useful in source identification

• **Environmental report cards** provide focus & feedback

• **Conceptual diagrams** useful in stakeholder dialogue

• **Communication** elicits effective actions

• **Cultural celebrations** build awareness & support
Chesapeake Bay, East coast USA

Extremely well studied
Intensively managed
Heightened awareness
Well funded
BUT
Continuing to degrade

37°N
Problem: Nutrient over-enrichment leading to more extensive hypoxia/anoxia

- Volume of Chesapeake Bay with dissolved oxygen deficiencies (< 2 mg/L)
- Walter Boynton data

Walter Boynton data
Research: Decomposing phytoplankton in bottom waters leads to oxygen depletion

Predicted vs Observed Hypoxic Volumes
Droughts and Floods
1950 - 2000

- Walter Boynton data
Solution: Nutrient reduction strategies for point and diffuse sources

- Walter Boynton data
Problem: Critical habitat loss (oyster reefs and seagrass beds)

Skipjacks

Oyster reefs

Seagrass - 1933

Oyster catch 1840–2000
Research findings: Filtration by oysters and seagrasses historically significant

- Shallow water volume filtration by oysters:
  - Pre-1870: 2.5 d
  - Current: 245 d  
  (Newell, 1988)

- Denitrification enhancement by oysters  
  (Newell et al., 2002)

- Seagrass sediment baffling:
  Historic seagrass captured 125% sediment load  
  (Kemp et al., 1988)
Solution: Oyster restocking and seagrass restoration programs

Caveats:
- Disease
- Hatchery limitations (2000 vs. 20 acres)
- Degraded habitat
- Location of food varies

Caveats:
- Water quality
- Propagule limitations
- Degraded habitat
Problem: Dams and riparian degradation leading to less coarse but more fine grained sediments

Conowingo Dam
Susquehanna River

Runoff
Upper Bay
Research findings: Extensive salt marsh and island loss with rising sea level.
Solution: Possible use of dredge spoil to augment marshes and islands

- Chesapeake salt marsh
- Poplar Island
- Sediment stabilization
Net Result: Chesapeake Bay ecosystem health not improving

Chesapeake Bay Foundation annual report card rankings

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### Intensive subwatershed restoration: Patuxent River

<table>
<thead>
<tr>
<th>Year</th>
<th>Forest</th>
<th>Residential</th>
<th>Urban</th>
<th>Agro</th>
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<tr>
<td>1850</td>
<td>14.3%</td>
<td>0.3%</td>
<td>0.0%</td>
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<tr>
<td>1953</td>
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<td>4.6%</td>
<td>1.2%</td>
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<tr>
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<td>15.5%</td>
<td>4.3%</td>
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**PATUXENT RIVER WATERSHED**

- **Clear Water**
- **Drainage**

**PATUXENT RIVER Fall Line Total Nitrogen Loading 1960-1999**

**PATUXENT RIVER Fall Line Total Phosphorus Loading 1960-1998**
Challenge: "It will cost too much"

Response: Investments in protection & restoration are cheapest now & can stimulate local economies.

Case Study: Mersey Basin Campaign

www.merseybasin.org.uk

25 yr. campaign

6 million people; world’s 1st industrial region

Negative value land turned into 5 star hotel

In 1985 3 raw sewage discharges; now swimmable water
**Challenge:** "There are too many different jurisdictions & stakeholders with divergent views"

**Response:** A participatory process can create a shared vision among a variety of stakeholders.

**Case Study: Mekong River Commission**

- **Large river system (8th in volume globally)**
- **Major fisheries**
- **High rice production**
- **17 million people; 70 ethnic minorities**

www.mrcmekong.org/
**Challenge:** "Population growth counteracts any progress made with management interventions"

**Response:** A proactive program that accounts for population growth and new development.

**Case Study: Healthy Waterways Campaign**

<table>
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<th>Urban Region</th>
<th>1995 Popn ('000s)</th>
<th>Ave Annual Growth 1990-95 (%)</th>
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<td>Vancouver, Canada</td>
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Recommendations

• Land-sea interfaces require intense management, research and monitoring efforts focused on *environmental problem solving*

• **Invest now**—resources (time & money) will be better spent on environmental protection and restoration sooner rather than later for both economic and ecological reasons

• Global case studies indicate that *creative solutions are possible* for Chesapeake Bay problems; focus is needed in terms of issues (nutrients) and geography (Patuxent River)

• There is a *global leadership opportunity* for environmental problem solving, the next major global scientific effort
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Adrian Jones
Tracey Saxby

www.nioz.nl/loicz

www.healthywaterways.org

http://ca.umces.edu