Sandy beach ecosystems and climate variability
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• World’s coastlines total almost $10^6$ km

• Sandy beaches dominate open coastlines

• Accreting beaches are the exception (<10%)

• > 80 % are experiencing some erosion
Sandy beaches: main physical factors

- Tides
- Waves
- Sand
Sandy beaches provide irreplaceable ecosystem services to society.

Environment and biota are being threatened by several drivers acting at multiple temporal and spatial scales.

Severely under-represented in climate change ecology.

Do sandy beaches respond to climate change in ways that are consistent with expectations of hypotheses from general climate-change ecology?

The physical environment: coastal squeeze

- Beaches are caught between rising sea and expanding human activity
- Retreat is not possible in most cases because of urban development
- Beach and dunes reduced/lost
Coastal squeeze + erosion: negative socio-economic effects
Coastal squeeze: negative socio-economic effects
Increase in temperature, onshore winds and extreme events

Uruguayan coast:

Increase in temperature, and in the frequency, intensity and speed of onshore winds

Long-term increase in wave height, swash width, and decrease in beach slope ➔ EROSION

Ortega et al. 2013, Defeo et al. 2013
Climate fluctuations affect the social-ecological system

**Habitat**
- Fishery habitat
  - Nursery areas
  - Adult areas
  - Water circulation patterns
  - Productivity of lower trophic levels
- Climate
  - Temperature increase
  - Sea level rise
  - Rainfall/drought
  - Storms
  - Winds
  - Acidification

**Fauna**
- Adult production and distribution
  - Growth and natural mortality
  - Distribution shifts due to changes in habitat suitability
- Recruitment
  - Spawning stock biomass of adult stock
  - Retention/dispersal of eggs and larvae by currents
  - Growth and mortality of early life history stages

**Society**
- Revenue
  - Catch per unit effort
  - Size of fish caught
  - Species of fish caught
- Costs
  - Cost of vessel insurance and replacement
  - Cost of gear replacement
  - Cost of repairs, relocation and facilities
  - Lost fishing days
    - Increased investment costs
    - Increased operating costs
- Fishing communities
  - Increased fishing pressure from new entrants displaced from elsewhere
  - Disrupted multi-occupational lifestyles in rural areas
  - Safety of fishers
  - Disruption and relocation of landing sites
  - Shifts from small- to medium-scale fishing
- Economics of other sectors
  - Increased freshwater demands due to drought
  - Increased energy demands and flood protection (dam building)
  - Labour migration due to economic disruption

Hall 2011, Defeo & Castilla 2012, Defeo et al. 2013
Loss of intertidal habitat, catchability, fishing days and $$$

Perception of fishers: fishing days

- Much less: 8
- Less: 12
- Normal: 6
- More: 2
- Much more: 0
95% of species, abundance and biomass made up by three taxa:

- Crustaceans (isopods, amphipods, hippids, mysids, decapods)
- Molluscs (bivalves and gastropods)
- Polychaete worms

How do they respond to the beach environment and climate variability?
Almost collapsed fishery stocks, despite management strategies (area-based + co-management) that succeeded in other benthic fisheries (Chile, Uruguay)
Mass mortalities of this cold-water clams during the last 2 decades decimated populations throughout entire distribution ranges in the Atlantic and Pacific:

1. Important SOCIAL-ECOLOGICAL SYSTEMS: fisheries and human livelihoods affected
2. Community structures and ecosystems drastically changed
3. Possible causes: fishing PLUS temperature increase, algal blooms, diseases

Atlantic yellow clam: mass mortalities and increasing temperature

Atlantic Multidecadal Oscillation

Monthly values for the AMO index, 1856-2009

Increase in temperature

Mass mortalities that began in late 1993

Closed fishery until 2008, without showing evidence of stock recovery, particularly in the adult (harvestable) stock

ENSO affected landings in Peru and Northern Chile: closed season in Peru since 1999...

Unit price: another significant predictor of long-term trends

\[
\text{Price} = 232(\text{year}) - 456759 \\
R^2 = 0.93^* 
\]
Ecological effects of climate variability: tropicalization

**Changes being assessed:**

1. Increasing SST
2. Phytoplankton biomass, composition and intensity of blooms
3. Benthic community structure
4. Population abundance
5. Persistence of invasive species
6. Range shifts

**Massive mortalities of yellow clam**

**Experimental management**

**Adult abundance (%)**

**Donax hanleyanus**

**Emerita brasiliensis**

**Mesodesma mactroides**

**Donax peruvianus**

**Emerita analoga**

**Others**
Climate change and transitional waters

Changes in:

- Temperature
- Precipitations
- Sea level
- Water runoff

Hypotheses to be tested:

- Spp composition shifts
- Expansion of exotic species (*Corbicula*)?
- Increase in mortality of marine species

Basset et al. 2013, Schoeman et al. 2014
Sandy beaches as social-ecological systems

Environment

Long term management policies

Ecosystem
Processes, functions
Biodiversity
Abundance/structure

Services
Fisheries
Tourism
Protection to extreme events

Management tools
Time
Space
Species
Sizes
Effort

Governance modes and institutional structures
Government-based
Co-management
Decentralized

UNCERTAINTY
Ecological, Statistical, Socio-economic, Governance

Sandy beach management requires the integration of ecology with socio-economic and institutional factors
Conclusions: sandy beaches & climate variability

1. Different lines of evidence support a climate change interpretation as a primary causal agent in sandy beaches

2. Effects on the environment:
   a. Coastal squeeze (sea level rise and urbanization)
   b. Changes in beach morphodynamics: erosion
   c. Increase in swash width

3. Effects on macrofauna:
   a. Biodiversity loss: a major driver of ecosystem change (regime shifts)
   b. Across taxa: similar effects in parallel communities (Atlantic and Pacific)
Conclusions: sandy beaches & climate variability

1. Biophysical changes affected socio-economic issues: *sandy beaches as social-ecological systems*

2. Effects of climate variability swamped management measures

3. Long-term policies, early warning systems (e.g. red tides) and co-governance of SES are needed

4. Institutional adaptive capacity to cope with climatic and human drivers of change

Gutierrez et al. 2011 - Nature