EVALUATING THE EFFECTS OF BIVALVE SHELLFISH AQUACULTURE AND ITS ECOLOGICAL ROLE IN THE ESTUARINE ENVIRONMENT IN THE UNITED STATES

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Bivalve Shellfish Aquaculture in the U.S.

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- U.S. represents less than 1% of world production is a net importer of bivalve shellfish
- Often difficult to distinguish wild harvest from "farmed" aquaculture
- U.S. West Coast = significant portion of "hatchery" raised shellfish production

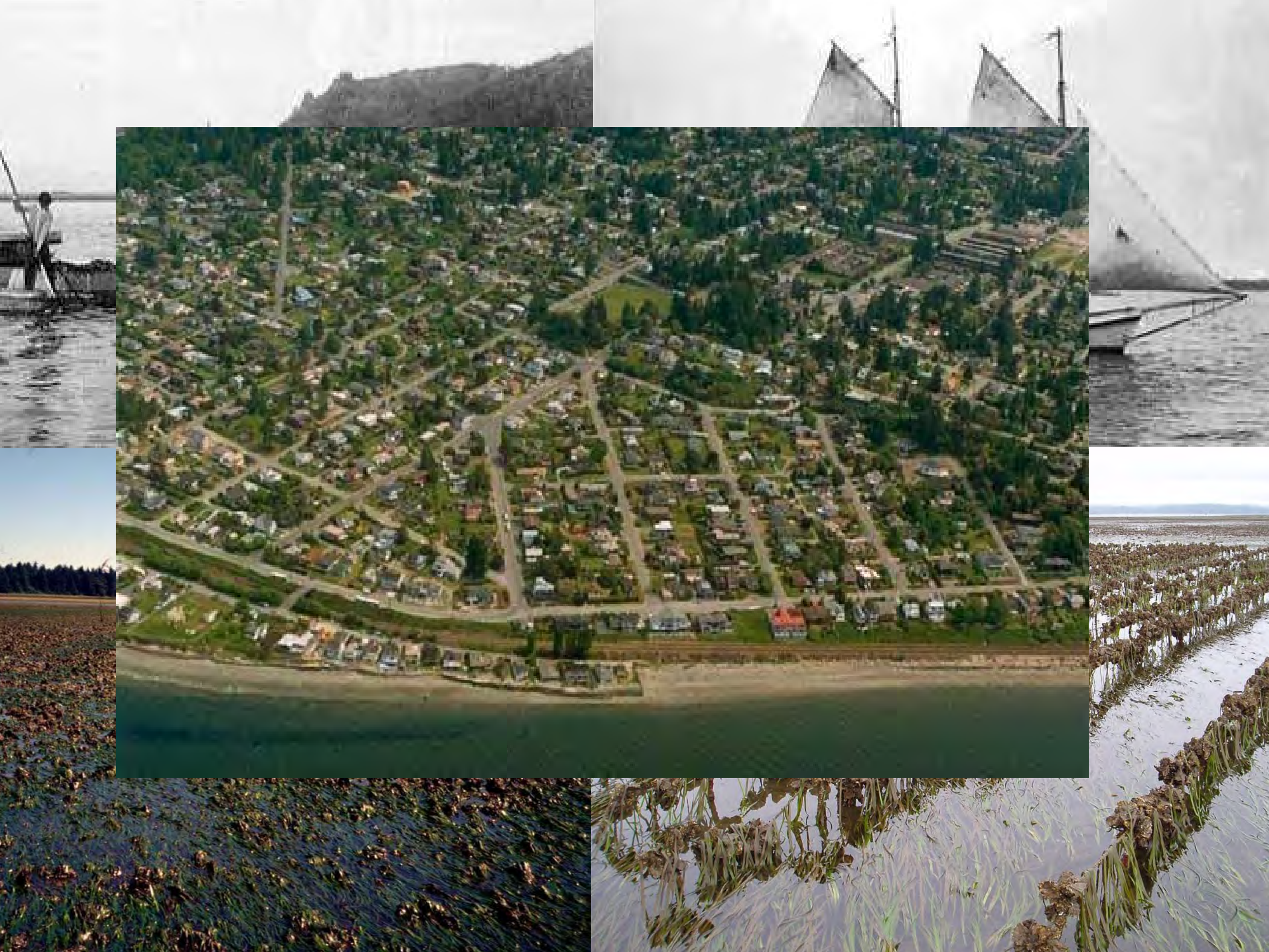
Location	Oysters	Clams	Mussels
World	4.9 million mt	4.1 million mt	1.9 million mt
U.S.	16,000 mt	50,000 mt	2,000 mt
Farmed	60%	10%	15%

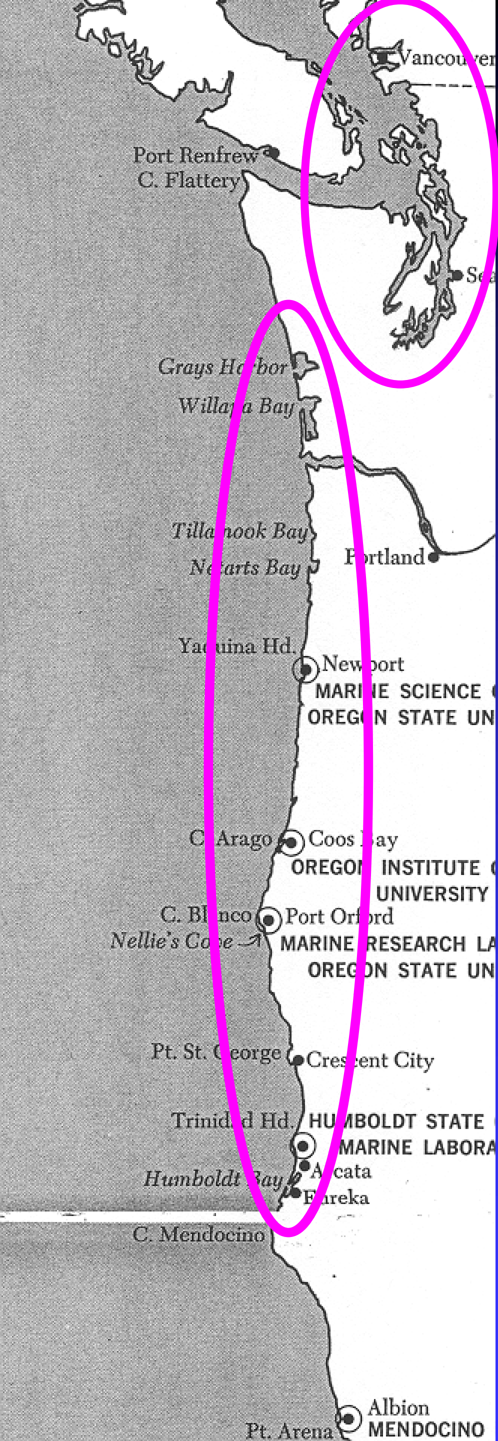
NOAA Statistics 2005

Ecologists view aquaculture as a “disturbance”

A disturbance is a relatively discrete event in time that disrupts an ecosystem, community or population structure and changes resources substrate availability or the physical environment

- Disturbances are normal events and can be “natural” or anthropogenic
- Context is very important





Physical and Biological Context Also Important

Most US West <u>Open</u> Coast estuaries have:

- Broad intertidal flats
  - Willapa Bay 63% = 63.7 km^2
  - Yaquina Bay 35% = 6 km^2
  - Coos Bay = 48% = 18 km^2
  - Humboldt Bay 45% = 28 km^2
- Small area relative to the coastline, small riverine influx, large tidal influence, strong winds can influence a shallow and therefore well mixed water column and also the substrate
  - Biology particularly 1º production but also use by 2º consumers is greatly influenced by nearshore coastal ocean and strong winds over shallow tidal flats

Physical "disturbances" causing change are a regular feature of these systems

Disturbances in PNW Estuaries

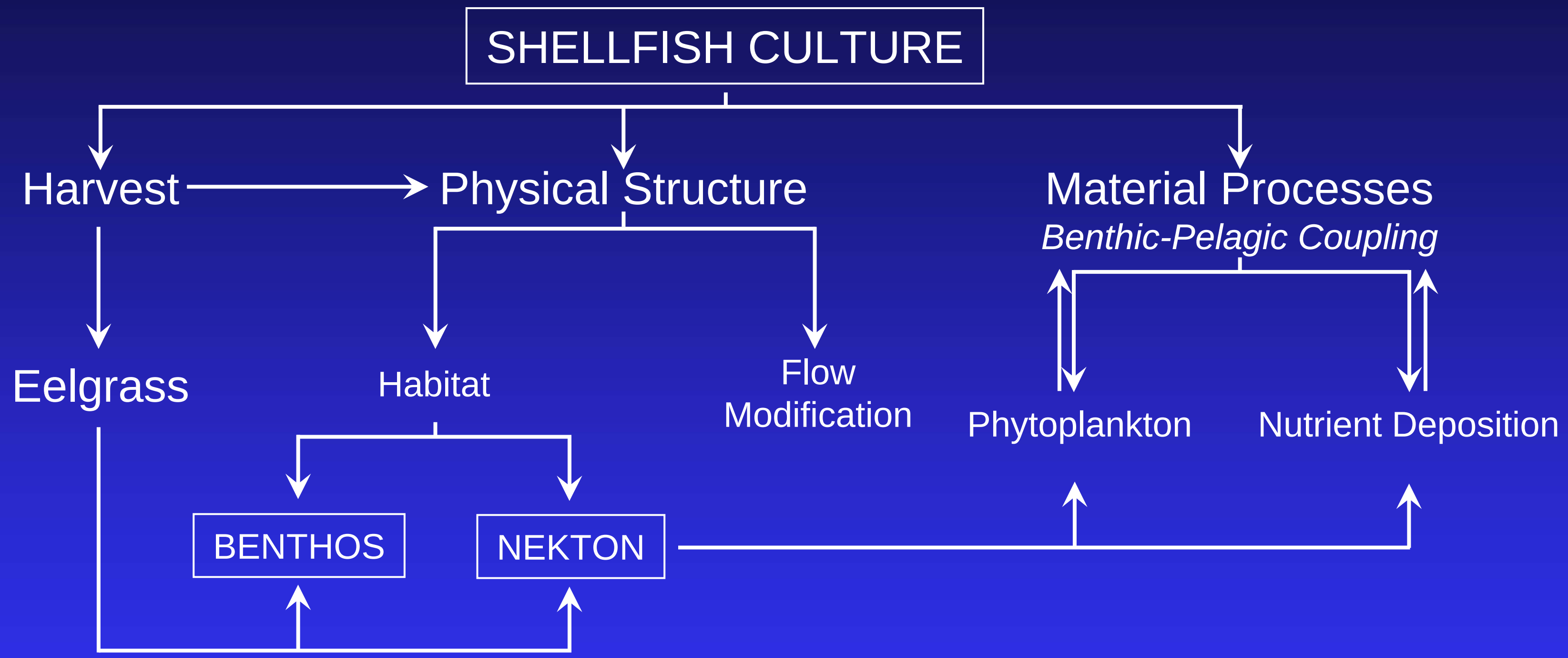
Natural

- Storms
  - Wind
  - Watershed (sediments and fresh water Columbia influences estuaries to the north)
- Earthquakes
  - Tsunamis
- Ocean and Atmosphere
  - Tides
  - El Nino, Decadal Oscillations
- Biological
  - Nutrients and phytoplankton production
  - Recruitment events
  - Engineering – bioturbation, feeding

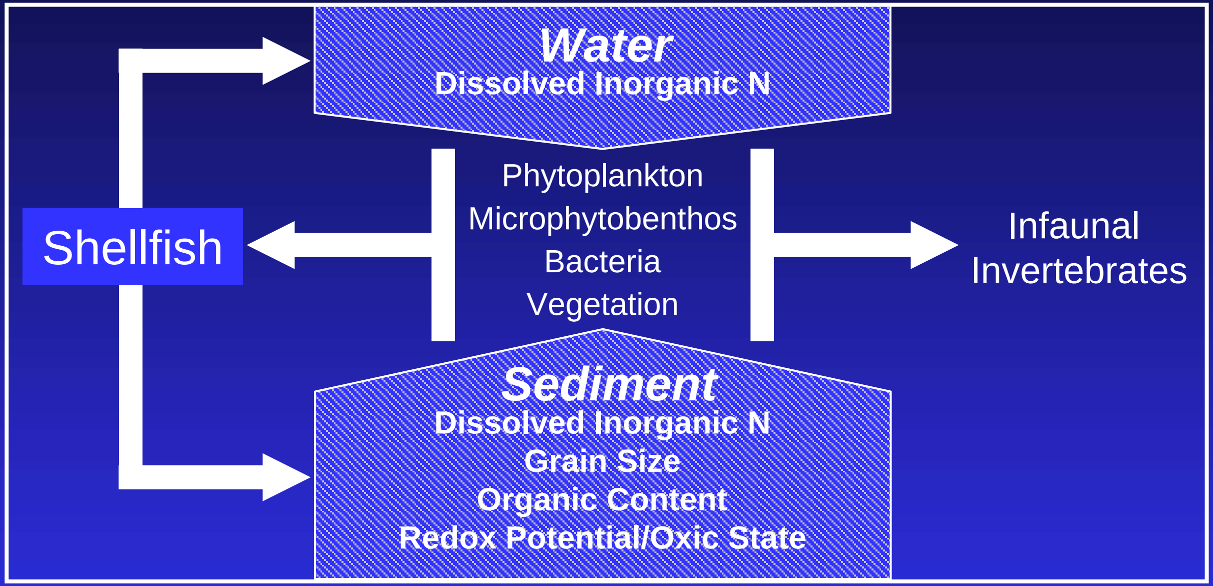
Human

- Watershed or Upland Development
  - Nutrients and other chemical pollutants
  - Increased hard surfaces
  - Forest clearing, agricultural development
  - Diking, Fill and Wetland loss
  - Dredging
  - Dams
- Fishing
- Introduced Species
  - *Spartina, drills, tunicates, green crabs*
- Aquaculture
- Climate Change

Effects of Bivalve Shellfish Aquaculture on the Estuarine Environment



Material Processes



- Alteration of Water Quality – Depends on filtration capacity of bivalves relative to estuarine residence time - complicated by hydrography and phytoplankton growth
- Alteration of Sediment Properties – Also depend on bivalve density relative to water flow
- Feedbacks

Physical Structure

- Depends on existing structure, but shellfish generally add hard structure (except infaunal bivalves (clams), but these too are very often protected with netting or even tubes)
- Usually compared with other forms of structure namely submerged aquatic vegetation (eelgrass).
  - Can have both direct (press disturbance = replacement) and indirect effects (shading or water clarity and nutrients)
- Hard substrate can add the ability to attract other non-indigenous species

Estuarine Habitats

Effects on Benthos and Larger Fish and Invertebrates

- Both oysters and eelgrass provide structure and habitat and generally more diversity than that found in open unstructured habitat, particularly for small benthic invertebrates
- Habitat use by large mobile invertebrates and fish depends on species and life history stage.
- Regional differences are likely. Estuarine fish diversity: West coast << East and Gulf coasts at least in open coast estuaries, perhaps not fjords

Press and Pulse Disturbances

- Frequency and intensity of disturbance important as well as location and substrate
  - Eelgrass disappearing many places, but grows fast in WB
  - Type of harvest and implement important particularly for effect on eelgrass - Longlines=Handpicking> Dredging, but biomass and production lower in all aquaculture types than in nearby eelgrass beds
  - Soft substrate = more impact and slower recovery. Seedlings survive better, grow faster, and are more plentiful in dredged areas after disturbance than in longlines or eelgrass meadows in WB

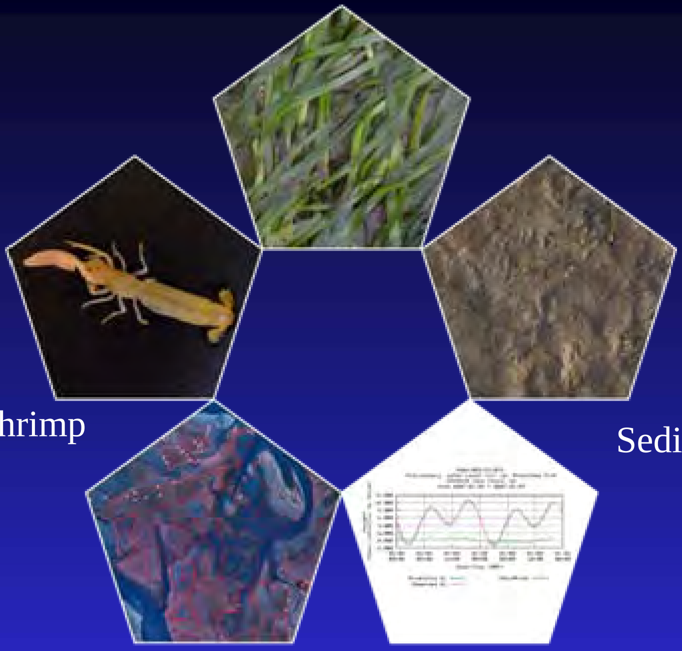
Need to examine effects on larger spatial and temporal scales

- Carrying Capacity Models
  - Box models
  - Coupled Biological- Physical Models
- Spatial Planning
- EBM
  - Social- Ecological- Physical System
  - Adaptive Management for Resilience

Willapa Bay

- Aerial infrared photos in 2005
- Ground truthing and mapping in 2006 (4,238 stations)
- Photo rectification and GIS layer creation

Vegetation



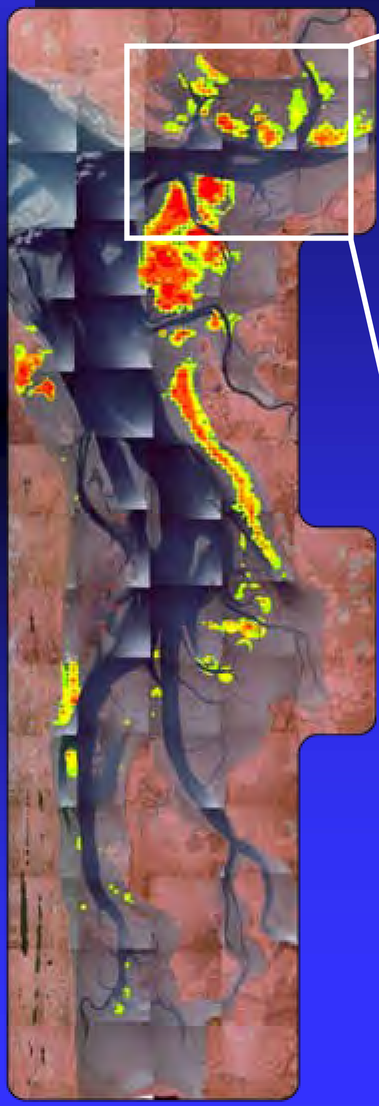
Shrimp

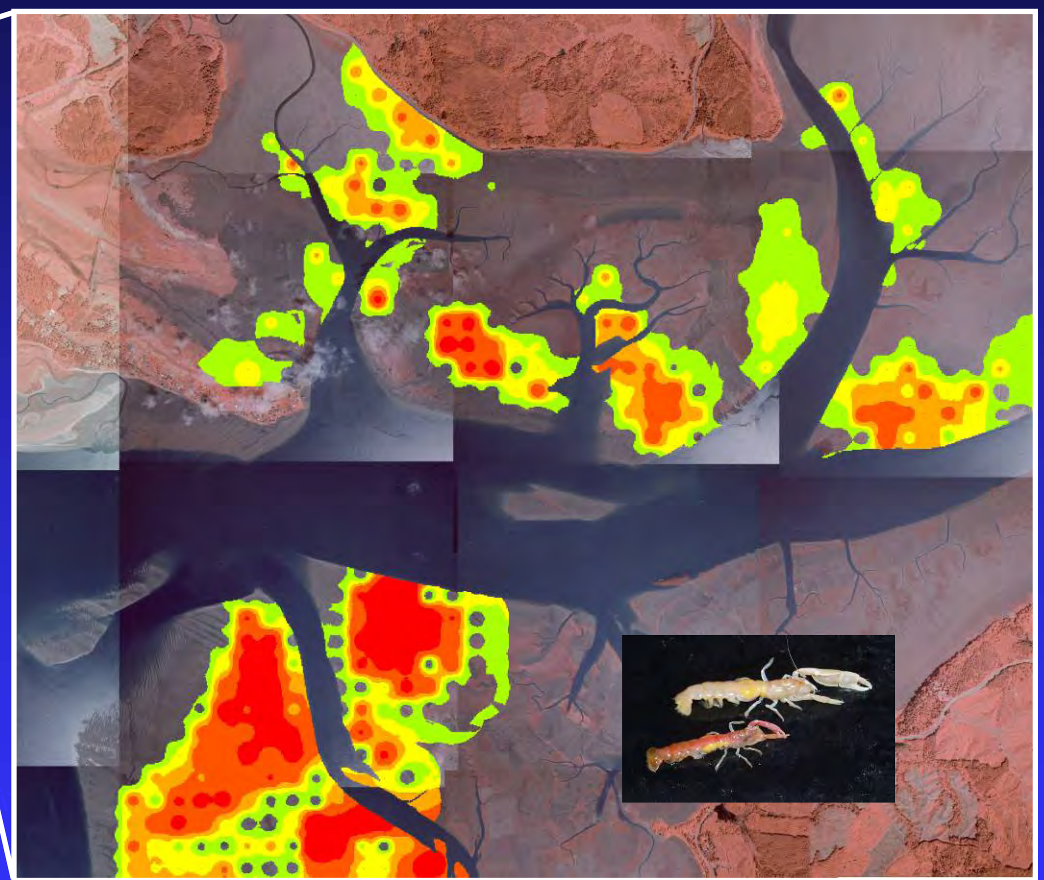
Sediment

Aquaculture

Elevation

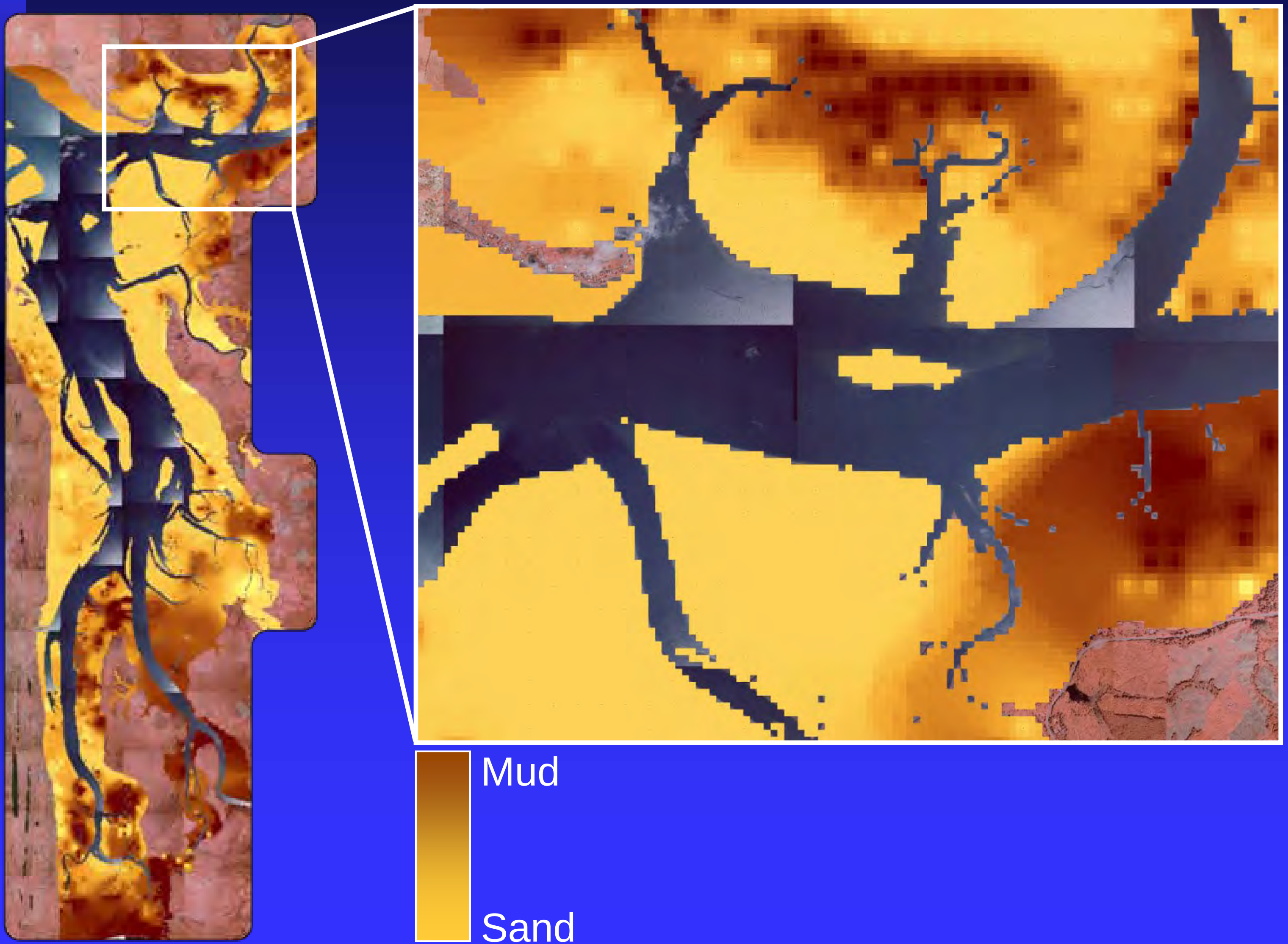
Burrowing Shrimp



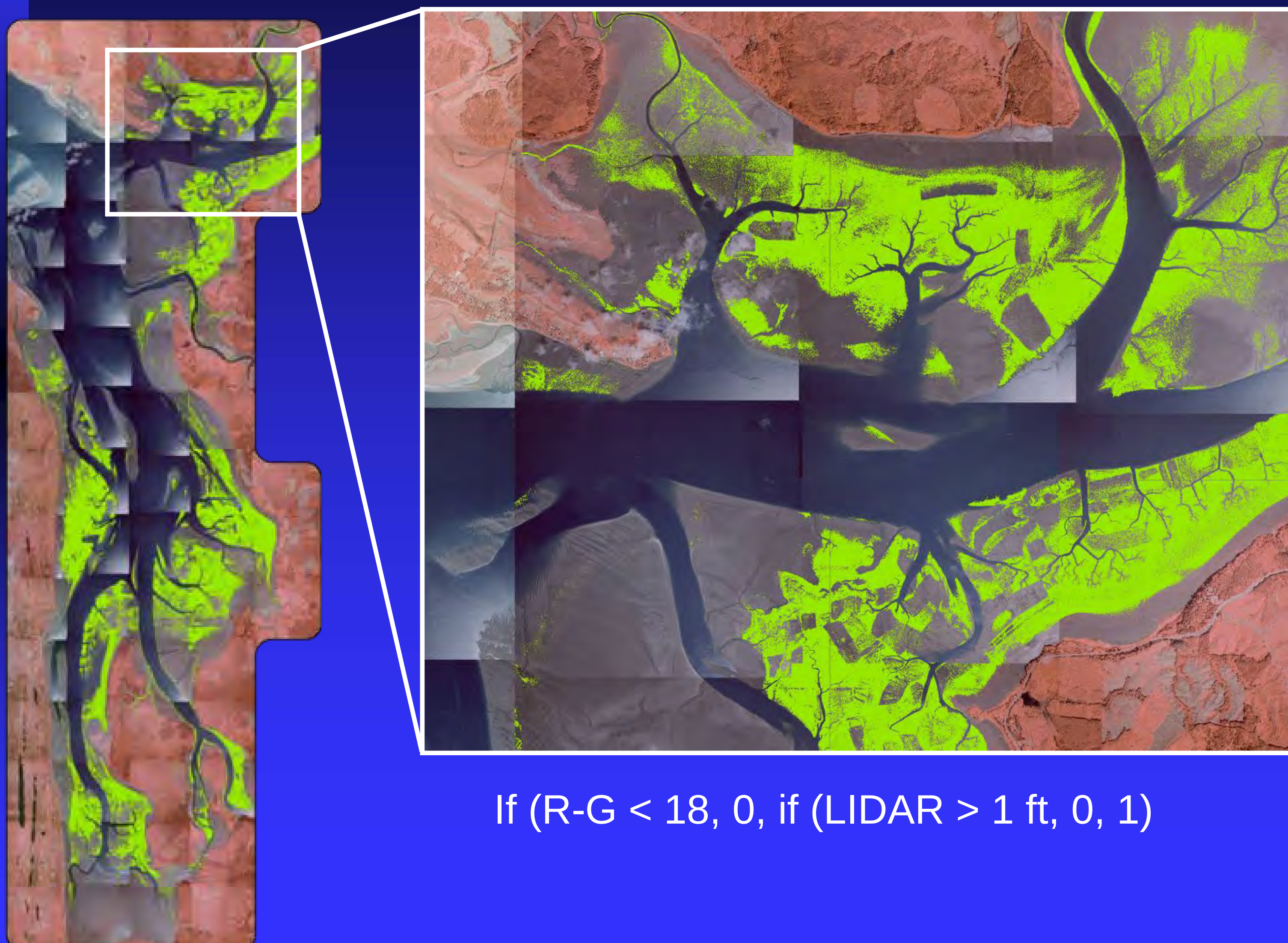


- 20 – 40 burrows/m^2
- 40 – 60 burrows/m^2
- 60 – 80 burrows/m^2
- 80 – 120 burrows/m^2
- 120 – 260 burrows/m^2

Sediment



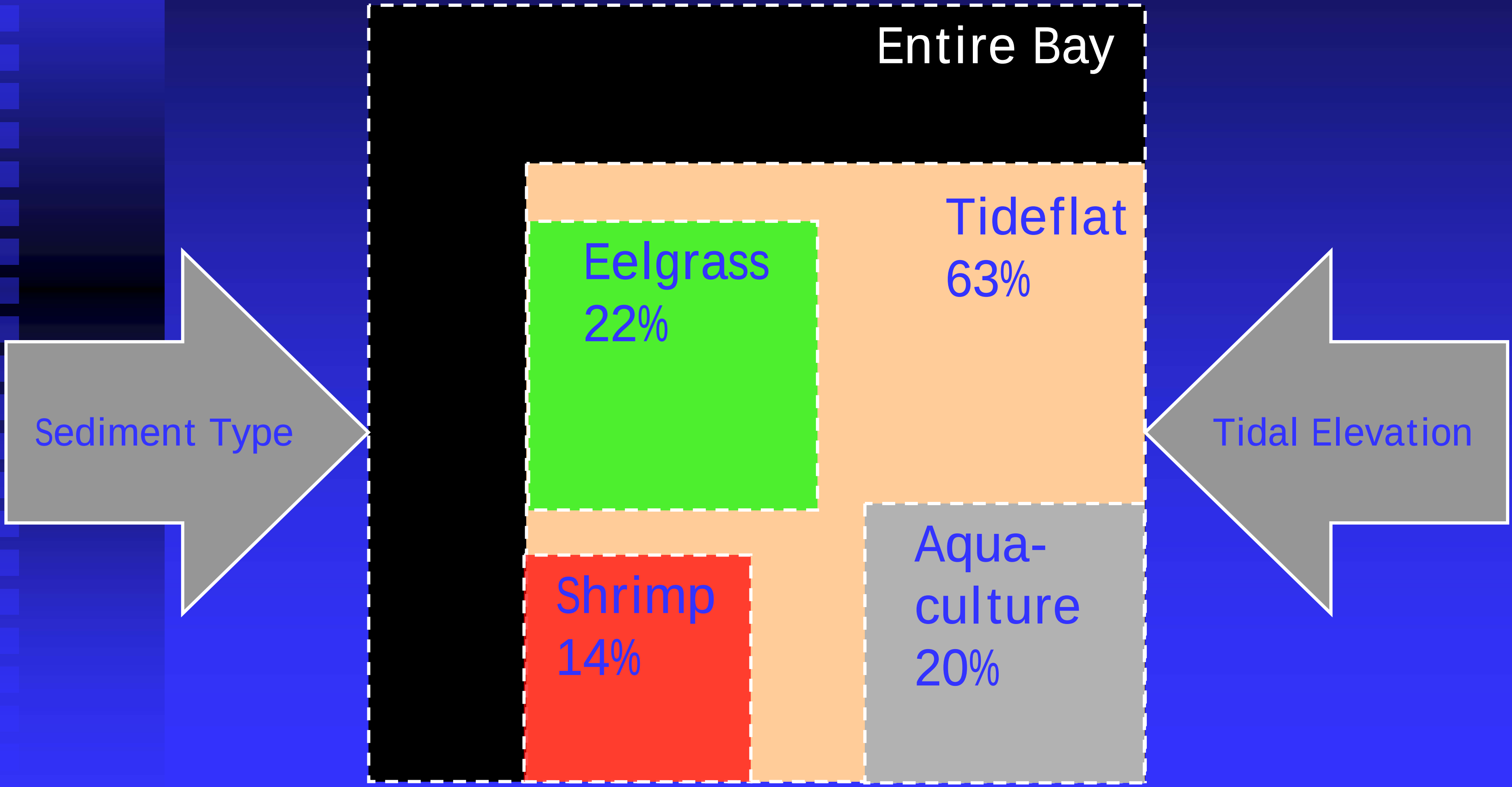
Vegetation



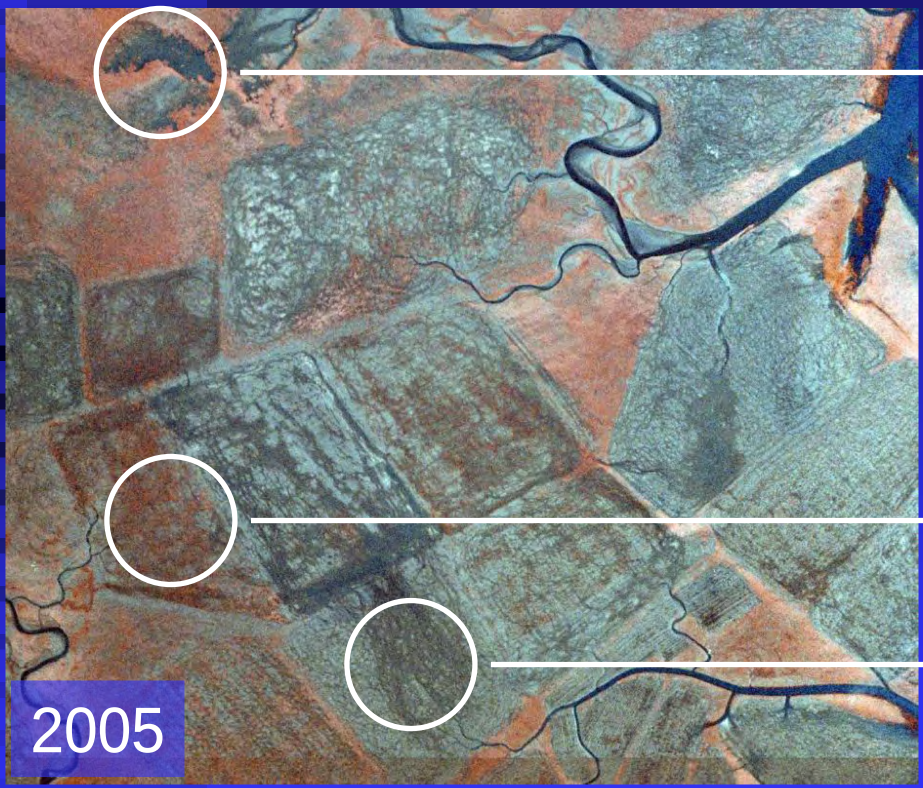
If (R-G < 18, 0, if (LIDAR > 1 ft, 0, 1)

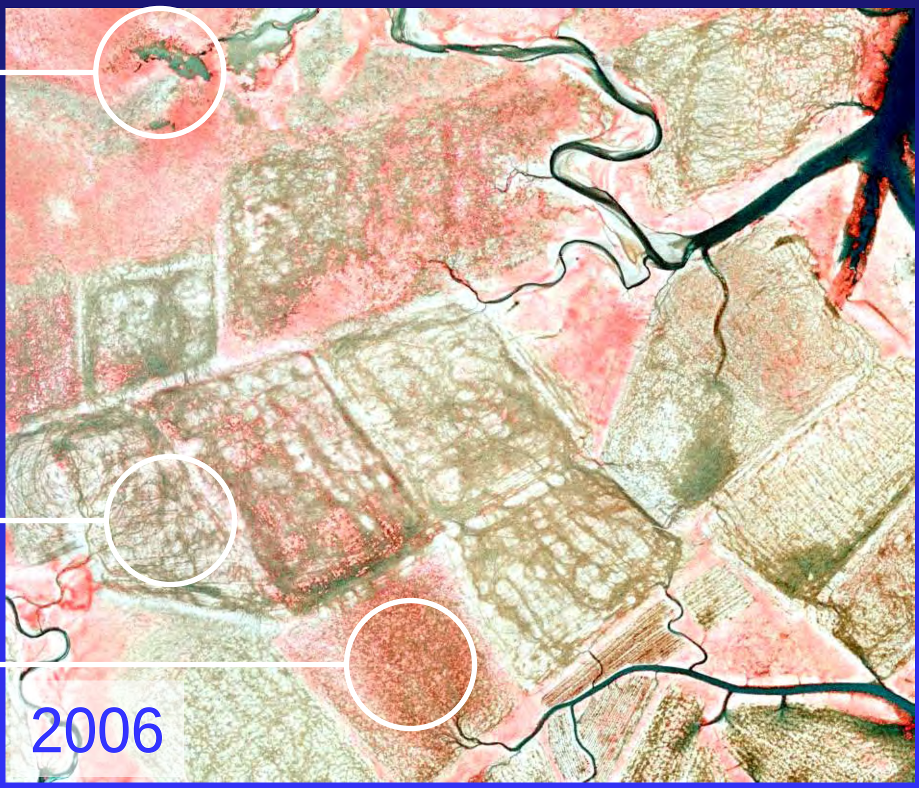
Aquaculture

Interaction



These are just snapshots.
What happens over time?





- Recovery from disturbance
- Natural edge change
- Patch size & dynamics

Do these changes matter on even longer temporal scales ?

Evaluate these with monitoring and educated re-constructions

Evaluation

- 1. Quantify effects experimentally.
- 2. Determine whether effects scale up spatially and temporally using GIS and carrying capacity models.
- 3. Include social considerations and use ecosystem models to evaluate effects on "resilience" of entire system.
- 4. Place aquaculture "disturbance" in context, conduct risk assessments.

Resilience and Stability

- West coast estuarine ecosystems are resilient to many disturbances because they regularly experience them. At present scale, even in places like Willapa Bay where 20% of the intertidal area is devoted to oyster aquaculture, this disturbance appears to have short term “temporary” effects, but does not seem likely to cause regime shifts.
- Forces more likely to do so - at least in West coast USA coastal estuaries are:
  - Large scale more permanent habitat changes like estuarine fill and diking (or removal)
  - Forestry practices and surface hardening in the watershed (with attendant changes like large sediment and nutrient additions to the estuary)
  - Species that have either been removed from the system (large predators?) or introduced to the system (some historically with aquaculture) and have cascading effects eg. *Spartina*
  - “Natural” disturbances that reset the clock at similar scales (e.g. tsunamis).
  - Climate shifts, hypoxic events, climate change?

“A resilient world would embrace ecological variability and change”

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