SLR-Driven Changes in Mouth Closure and Stratification in Intermittently Open Estuaries

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Outline

What is an Intermittently Open Estuary?

The continuum of estuary types in southern CA
• Hydrology
• Geological setting
• Management
• Stratification

Dominant Processes in IOE’s

Potential influences of SLR
What is an Intermittently Open Estuary?

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[Diagram showing tides and waves with labels: Ocean Tide, Lagoon Tide, Waves (NDBC 46218), Hs (m), Tp (sec)]

created by ESA with funding from UCSB
Continuum of Estuaries in Southern CA

- Each wetland archetype is influenced by an estuary mouth
- Each estuary mouth lies on a continuum from \textit{permanently closed} to \textit{permanently open}

Major differences in estuarine wetland conditions resulting from differences in:
- Hydrology
- Geological setting
- Management
- Stratification
**Estuary Continuum in Southern CA:** Role of Hydrology

**Wet Season:** High flows scour open the mouth. Lagoon hydrology influenced by ocean tides.

**Dry Season:** Low flows unable to prevent waves from depositing sediment. If basin is large, tidal flows alone may keep the mouth open.
**Estuary Continuum in Southern CA: Role of Hydrology**

**Wet Season:** High flows scour open the mouth. Lagoon hydrology influenced by ocean tides.

**Dry Season:** Low flows unable to prevent waves from depositing sediment. Mouth Closes. WL rises.

**Dry Season:** Inflows become weaker than losses to evaporation, seepage.

**Wet Season:** First major rainfall event fills lagoon, opens mouth.

![Graph showing changes in water levels over time](image)
Estuary Continuum in Southern CA: Role of Geology

- Influences basin size and tidal prism
- Influences availability of sediment for building the beach
- California influenced by strong uplift and regional variations in geology (Jacobs, Stein, Longcore 2010)
• Structures, dredging maintain open-mouth conditions in some systems
• Infrastructure limits potential for upland transgression
• Management of mouth closures (breaching) affect seasonal hydrology cycle
• Beach conditions influenced by nourishment activities
Estuary Continuum in Southern CA: Stratification

**Open–mouth conditions**
- Strong tidal mixing
- Gradient from salty at mouth to fresher upstream

**Closed–mouth conditions**
- No tidal mixing
- Salty layer sinks to the bottom
- Vertical mixing possible in shallow estuaries
- Long residence time of saltwater in deeper pockets, or deep estuaries
What Processes Contribute to Estuary Mouth Closure?

- Larger Basin, Higher Streamflow
- More Wave Exposure

Usually closed or perched
Intermittently closed
Always Open
What Processes Contribute to Mouth Opening (‘Breaching’)?

- Beach seepage
- Freshwater runoff
- Evapotranspiration

- For weak inflows or large basins, it may take months or years to reach breach height
- As beach rises with SLR, time to breach will increase

Courtesy of Kenneth and Gabrielle Adelman
What Do We Expect to Change with SLR?

- More Wave Exposure
- Larger Basin, Higher Streamflow
- How Long It Takes to Breach
- Beach Height
- Beach Height Increases

Basin size increases IF SLR outpaces accretion

Increase in depth of estuary AND depth of trapped saltwater

Hydrologic, geologic, mgmt context matters
Potential Response to SLR: Small/constrained lagoons

- Upward and landward movement of the beach
- Limited upland transition space
- If SLR outpaces accretion in lagoon:
  - Slight increase in estuary volume
  - In wave-exposed regions, mouth will still close due to wave action
  - Longer closed-mouth conditions, since greater volume to fill
  - Greater depth and volume of trapped saltwater, less likely for vertical mixing
Potential Response to SLR: Large/Unconstrained Estuaries

- Upward and landward movement of the beach
- Greater upland transition space
- If SLR outpaces accretion in lagoon:
  - Progressive increase in estuary volume and depth
  - Longer periods of open-mouth conditions (greater tidal prism)
  - Longer closed-mouth conditions (larger volume to fill to beach level)
  - Greater depth and volume of trapped saltwater, less likely for vertical mixing
- Net change in seasonal conditions depends on water balance
Potential Response to SLR: Estuaries with urban infrastructure

- Upward and landward movement of the beach
- Limited upland transition space
- If SLR outpaces accretion in lagoon:
  - Progressive increase in estuary volume and depth
  - Seasonal hydrology constrained by mouth management
  - Increase in closure/breach events constrain the hydrology
  - Greater depth and volume of trapped saltwater, but increased need for breaching → salinity influenced by number of breach events
Potential Response to SLR: Conclusions

• SLR will result in upward shift of estuary WLs, but the amount depends on morphology feedback, which is shaped by regional contexts (Doughty et al. 2018)

• Expected feedback with accretion rates (Thorne 2016, 2018)

• High level of uncertainty at this time due to multiple feedbacks

• Need for continued and focused monitoring in near future
Thank you!