Background

- Estuaries are dynamic ecosystems that provide valuable services to coastal communities.
- Freshwater inflow, largely derived from watershed runoff, determines estuarine ecological processes.
- Estuarine freshwater inflow is impacted by human land use along watersheds that feed estuaries, potentially creating conflicts of interests between upstream and downstream resources.
- Climate change will exacerbate challenges of balancing upstream demands for freshwater with downstream resources reliant on ecological stability.

Objectives

1. Summarize watershed modification and land use affecting major northern Gulf of Mexico estuaries to highlight upstream effects on coastal systems.
2. Develop a conceptual model to describe links between climatic factors, anthropogenic alterations, and estuarine processes.
3. Synthesize “lessons learned” from histories of major Gulf of Mexico estuaries to elucidate potential strategies to balance conflicts between upstream and downstream resources.

Land-use Impacts

- Ecotones
- Hypersalinity
- Hypoxia
- Erosion
- Freshwater Withdrawal
- Agriculture
- Canal/Leeve Construction
- Urbanization
- Hypersalinity
- Hyper-eutrophy
- Harmful Algal Blooms

Fig 1. Translation of impacts of anthropogenic alterations to watersheds (top tier) through changes in estuarine inflow (middle tier) on coastal systems (bottom tier). Images from https://ian.umces.edu/.

Fig 2. Land cover maps of key Gulf of Mexico estuaries. All six watersheds for estuaries are displayed with their major rivers (A). Land use along watershed are displayed for the Mississippi River Basin drainage into coastal Louisiana (B), Galveston Bay, TX (C), Mobile Bay, AL (D), Big Bend of Florida including Apalachicola-Chattahoochee-Flint (ACF) rivers basin and Suwannee River (E; left and right, respectively), and South Florida including discharge from Lake Okeechobee and Everglades drainages.

Table 1 Land cover area (hectares) of land use categories in major Gulf of Mexico watersheds (2019 the National Land Cover Database).

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Total Area</th>
<th>Open Water</th>
<th>Wetlands</th>
<th>Forest</th>
<th>Herbaceous</th>
<th>Barren Land</th>
<th>Agriculture</th>
<th>Developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippi River (B)</td>
<td>3,324,810</td>
<td>7,362,752</td>
<td>14,960,865</td>
<td>6,737,787</td>
<td>97,131,166</td>
<td>823,371</td>
<td>119,052,149</td>
<td>18,096,158</td>
</tr>
<tr>
<td>Galveston Bay (C)</td>
<td>6,497,230</td>
<td>431,514</td>
<td>581,791</td>
<td>1,156,480</td>
<td>1,291,952</td>
<td>17,817</td>
<td>1,755,097</td>
<td>1,262,576</td>
</tr>
<tr>
<td>Mobile Bay (D)</td>
<td>11,898,996</td>
<td>371,000</td>
<td>1,430,671</td>
<td>6,252,064</td>
<td>974,846</td>
<td>33,709</td>
<td>1,804,930</td>
<td>1,031,166</td>
</tr>
<tr>
<td>ACF Basin (E)</td>
<td>5,340,617</td>
<td>224,051</td>
<td>776,170</td>
<td>1,218,292</td>
<td>469,523</td>
<td>11,846</td>
<td>1,082,662</td>
<td>590,140</td>
</tr>
<tr>
<td>Suwannee River (E)</td>
<td>2,540,858</td>
<td>26,951</td>
<td>766,706</td>
<td>723,815</td>
<td>255,369</td>
<td>4,993</td>
<td>587,205</td>
<td>175,817</td>
</tr>
<tr>
<td>South Florida (F)</td>
<td>5,402,212</td>
<td>1,327,893</td>
<td>2,137,526</td>
<td>124,938</td>
<td>121,198</td>
<td>9,577</td>
<td>977,110</td>
<td>712,967</td>
</tr>
</tbody>
</table>

Fig 3. Conceptual schematic framework describing the pathways for how climate, land-use, and water management ultimately affect estuarine natural resources. Changes in freshwater quantity, quality, and timing drive physical environmental changes that alter estuary foundation species, production, and species composition, which can cause feedbacks on the environment. Pathways are considered in the context of concurrent climatic changes and restoration efforts.

Synthesis

- Land-use derived alteration of quantity, quality, and timing of freshwater inflow (Fig. 1) drives estuarine ecological changes (Fig. 3).
  - Changes in salinity regimes (e.g., withdrawal or diversion; Fig. 1) alter species distributions and subsequent interactions.
  - Declining water quality is often associated with urban and agricultural runoff (Fig. 1; e.g., Galveston Bay, Fig. 2C, Louisiana, Fig. 2B, Mobile Bay, Fig. 2D, and South Florida, Fig. 2F).
- Large-scale impacts are incurred when alterations affect foundation species (Fig. 3).
  - Eutrophication associated with marsh loss (e.g., Louisiana Fig. 2B).
  - Declines in water quality and habitat associated with nutrient loss (e.g., Galveston Bay, Fig. 2C, and Florida, Fig. 2E).
- Climate change impacts multiple levels (Fig. 3).
  - More variation in rainfall and more frequent extreme events (e.g., droughts/floods, Fig. 3).
  - Range expansions alter ecological organization and function (e.g., common snook in FL Big Bend, Fig. 2E, and mangroves across the Gulf).

Solution Development

- Integrative models are useful in understanding anthropogenic and climatic effects on watershed and estuarine processes.
  - Ecosystem modeling conducted by NAS initiatives for Louisiana (Fig. 2B) and Suwannee River, FL (Fig. 2E).
- Balance of upstream and downstream interests requires informed multiscale collaboration of managers and stakeholders.
  - e.g., SFERTF, HTF, and CWPPRA.

Acknowledgments

This project was conducted under the Coastal Resilience to Global Change working group at the Nature Coast Biological Station as a part of the Southeast Climate Adaptation Science Center.