Watershed Modification Effects on Coastal Ecosystems: a Synthesis from Key Gulf of Mexico Estuaries

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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 conflict 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

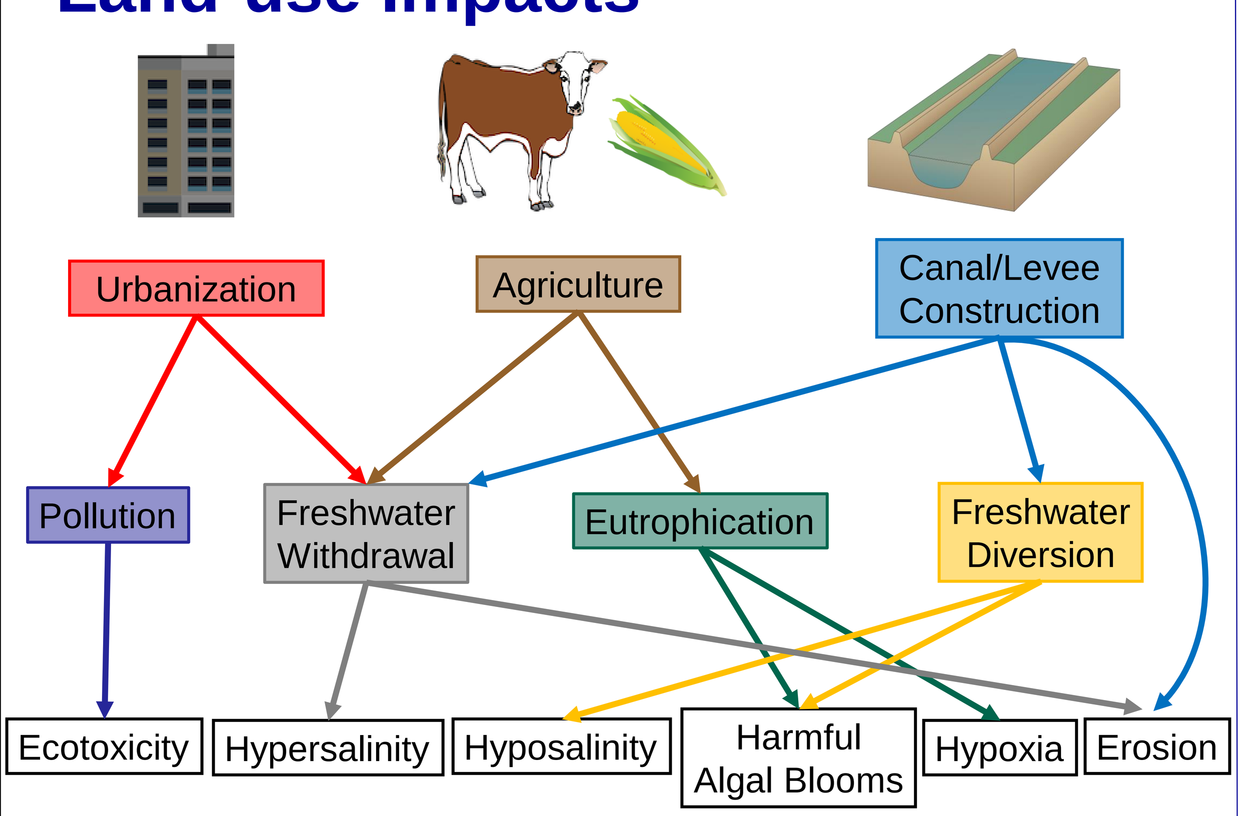


Fig 1. Translation of impacts of anthropogenic alterations to watersheds (top tier) through changes in estuarine inflow (middle tier) on coastal systems (bottom tier). Images from https://ian.umces.edu/.

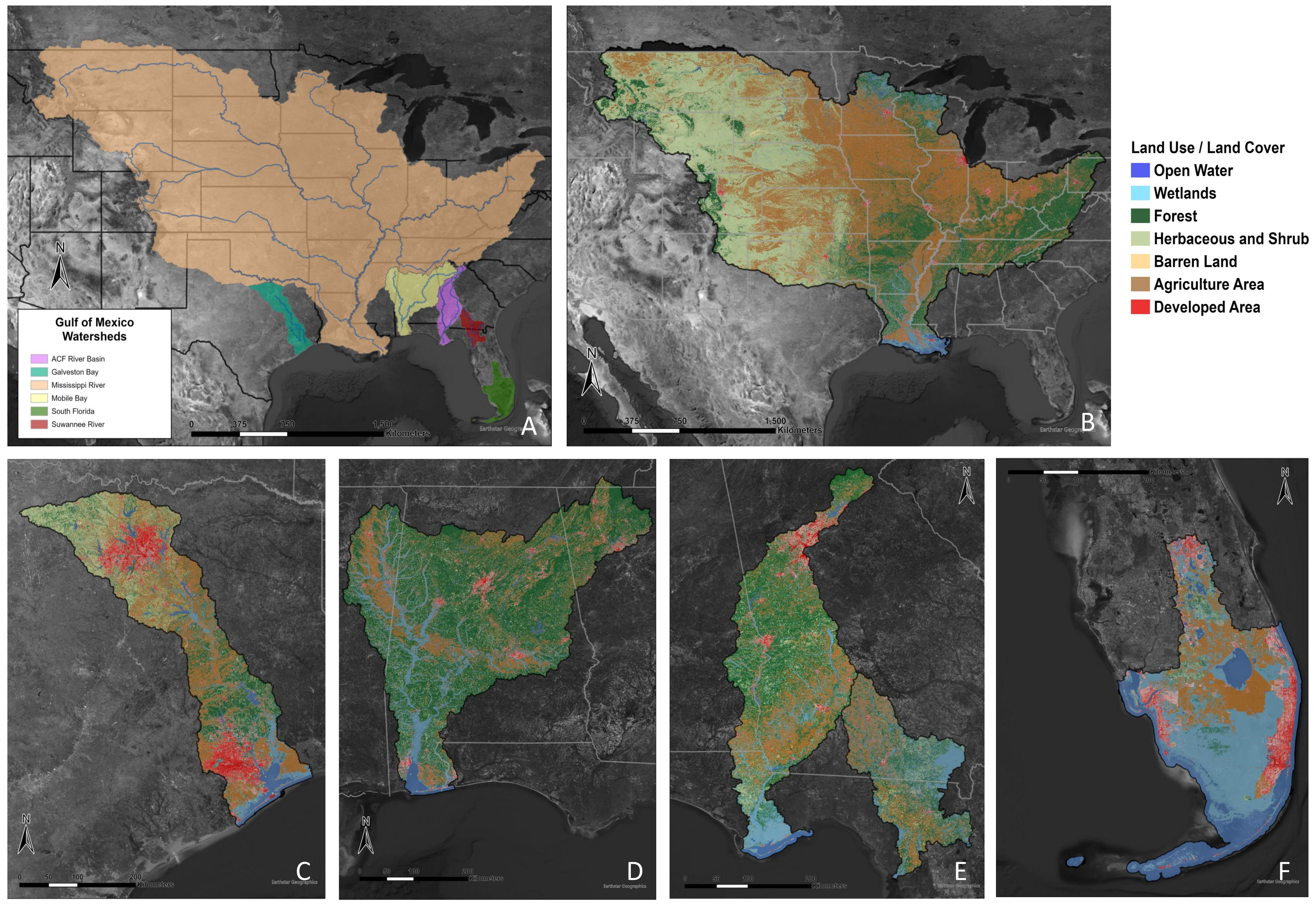
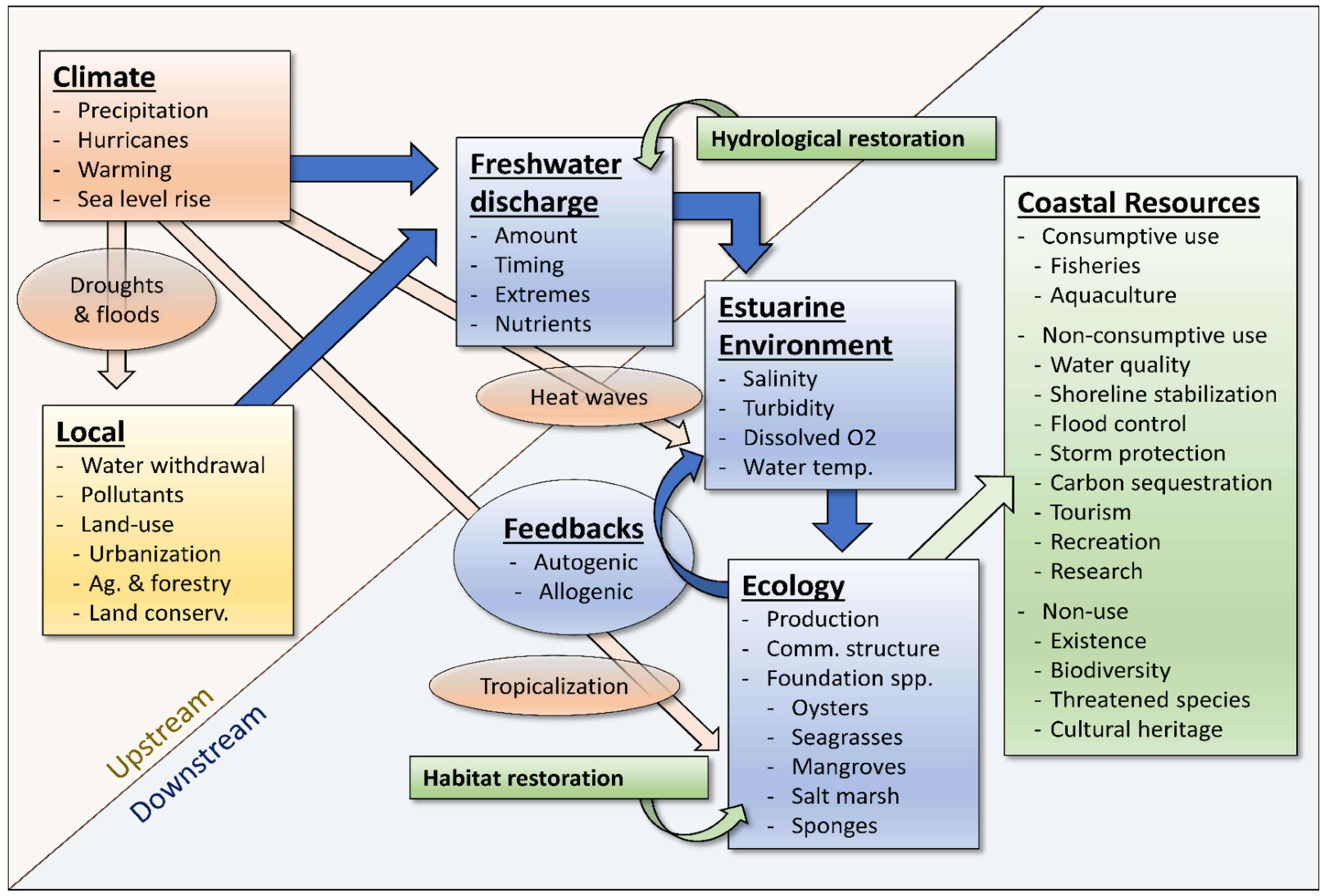


Fig 2. Land cover maps of key Gulf of Mexico estuaries. All six watersheds for estuaries are displayed with their major rivers (A). Land use along watersheds are displayed for the Mississippi River Basin drainage into coastal Louisiana (B), Galveston Bay, TX (C), Mobile Bay, AL (D), Big Bend of Florida 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).

Watershed	Total Area	Open Water	Wetlands	Forest	Herbaceous	Barren Land	Agriculture	Developed
Mississippi River (B)	324,810,201	7,362,752	14,960,865	67,377,787	97,137,116	823,371	119,052,149	18,096,158
Galveston Bay (C)	6,497,230	431,514	581,791	1,156,480	1,291,952	17,817	1,755,097	1,262,576
Mobile Bay (D)	11,898,986	371,000	1,430,671	6,252,664	974,846	33,709	1,804,930	1,031,166
ACF Basin (E)	5,340,617	224,051	796,101	2,196,292	469,523	11,846	1,062,662	580,140
Suwannee River (E)	2,540,858	26,951	766,706	723,815	255,369	4,993	587,205	175,817
South Florida (F)	5,402,212	1,327,893	2,137,526	124,938	112,198	9,577	977,110	712,967

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**).
  - Extensive erosion associated with marsh loss (e.g., Louisiana **Fig. 2B**).
  - Declines in water quality and habitat associated with oyster loss (e.g., Galveston Bay, **Fig. 2C**, and FL Big Bend, **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

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