Impacts of land use and climate change on coastal foodwebs and fisheries

Impactos del uso de la tierra y el cambio climático en las redes alimentarias y pesquerías costeras

Impacts de l'utilisation des terres et du changement climatique sur les réseaux trophiques côtiers et la pêche

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EXTENDED ABSTRACT

The sustainability of coupled human-natural aquatic systems will be shaped by how landscape-level human-induced stressors (e.g., watershed, land, and water use) interact with new temperatures, precipitation, and ecological regimes resulting from a changing climate. At GCFI, I presented ongoing work led by researchers at the University of Florida Institute of Food and Agriculture Sciences to model the impacts of land use and climate change on coastal food webs, fisheries, and natural resources. Two distinct approaches were described: 1) a conceptual model for how watershed modifications impact Gulf of Mexico (GoM) ecosystems, and 2) an end-to-end computational hydrologic and ecological modeling approach to quantitatively forecast these impacts.

To develop the conceptual model, we conducted literature reviews and case studies for five major GoM watershed-estuary systems: Galveston Bay, TX; Mississippi-Atchafalaya River Basin, LA; the Big Bend of Florida; and South Florida. The social and ecological systems underpinning each of these GoM watershed-estuary case studies are unique. Their histories exemplify complex contemporary challenges for managing alterations in how estuaries are connected to upstream aquatic systems (via water) and concurrently affected by global changes. The case studies showed a management desire to protect ecosystem services by restoring freshwater quantity and quality delivery to estuaries. For example, the Mississippi River and South Florida case studies showed a need for substantial hydrological modifications of the system to reset the flow dynamics to mimic pre-manipulation conditions. These necessitate large-scale multi-state and multi-agency cooperation.

The conceptual model demonstrated how environmental drivers operate individually and concurrently (**Fig. 1**). In particular, climatic drivers often exacerbate anthropogenic effects by (1) changing the quantity, quality, timing, and extremes of freshwater inputs into estuaries, and (2) altering estuarine landscapes and ecological processes. Freshwater availability along watersheds and subsequently inflow into estuaries is heavily linked to rainfall patterns. Indeed, GoM estuaries have undergone decreases in overall freshwater inflow (Marshall et al. 2021), and climate forecasts predict that there will further decrease in future rainfall, with decreases in seasonal inflows offsetting potential increases due to increased frequency and severity of tropical storms (Neupane et al. 2021). The conceptual model showed how decreases in rainfall could interact with increased human water use via urbanization, changes in agricultural crops and practices, and water conservation strategies and implementation.

The second part of the GCFI presentation described efforts to better understand these mechanistic processes with computational ecosystem models. Simulations provide useful tools to establish management goals and examine possible effects of large-scale environmental alterations, such as climate change, land-use changes, and environmental restoration (e.g., de Mutsert et al. 2012). Examining a watershed-to-estuary continuum crosses scientific disciplines. This "end-to-end" modeling approach for the Suwannee River Ecosystem Model (SREM) linked climatic, ecological, and socio-economic drivers. Such computational modeling was made possible by leveraging an array of partnerships that have made available their data collected in long-term sampling programs. Much of our work has thus involved data curation and synthesis, and to date, we have compiled over 1.1 million measurements relevant to the Suwanee River estuary system.

I focused the talk on the ecological SREM that was developed using Ecopath with Ecosim and Ecospace. The Ecopath modeling approach represents the most widely-used software application in marine systems ecology (Colléter et al. 2015). Our final SREM Ecopath model has 66 functional groups, including six multi-stanza groups for snook, red drum, spotted seatrout, mullet, oysters, and clams. Diet compositions of fishes were derived from data collected from Florida Fish and Wildlife fisheries independent monitoring programs as well as other regional models (Sinnickson et al., 2021). The eight fishing fleets in the model included private recreational, charter, red drum, spotted seatrout, snook, commercial stone crab, commercial oyster, and clam aquaculture. The dynamic Ecosim model was fit with 64 timeseries synthesized from long-

term monitoring efforts in the region. Spatially-explicit biological and ecosystem processes were modeled with the Ecospace SREM (29.40°–29.05°N, 83.30°–82.95°W). Ecospace incorporates the food web developed in Ecopath and the time-dynamic elements of Ecosim (e.g., vulnerabilities, multi-stanza aging, fishery dynamics) by allocating biomasses, fleets, and foraging arenas across a gridded map (Walters et al. 1999). It models how individuals move to find and follow prey sources, avoid predators, and seek/avoid habitats or environmental conditions. For our objectives, this allowed the Ecospace SREM to explore, describe, and forecast the economic and ecological impacts from the region's changing hydrology.

Preliminary model results showed general declines in some ecologically important and recreationally-harvested species in the system, including spotted seatrout, red drum, sand seatrout, and several forage fishes (**Fig. 2**). Meanwhile, populations of snook, a poleward expanding neotropical "non-native" species, expanded exponentially. Future scenario modeling with the Ecospace SREM will examine the impacts of altered drought/flood frequency and severity in conjunction with forecasted land-use scenarios, e.g., agricultural and urban development in the basin. Collectively, this end-to-end modeling framework can help to mechanistically understand and forecast how altered hydrology due to landscape and climate changes will affect salinity, temperature, and nutrients regimes in the estuary, that, in turn, drive the system's foundation species (e.g., seagrasses and oysters), biological production, and foodweb processes; These, in turn, will determine the quality, stability, and value of the region's coastal fisheries, aquaculture, and natural resources.

KEYWORDS: Climate change, foodwebs, fisheries

LITERATURE CITED

Colléter, M., Valls, A., Guitton, J., Gascuel, D., Pauly, D., & Christensen, V. (2015). Global overview of the applications of the Ecopath with Ecosim modeling approach using the EcoBase models repository. *Ecological Modelling*, 302, 42-53.

de Mutsert, K., Cowan Jr, J.H. and Walters, C.J., (2012). Using Ecopath with Ecosim to explore nekton community response to freshwater diversion into a Louisiana estuary. Marine and Coastal Fisheries, 4(1): 104-116.

Marshall, D.A., La Peyre, M.K., Palmer, T.A., Guillou, G., Sterba-Boatwright, B.D., Beseres Pollack, J. and Lebreton, B. (2021). Freshwater inflow and responses from estuaries across a climatic gradient: An assess-

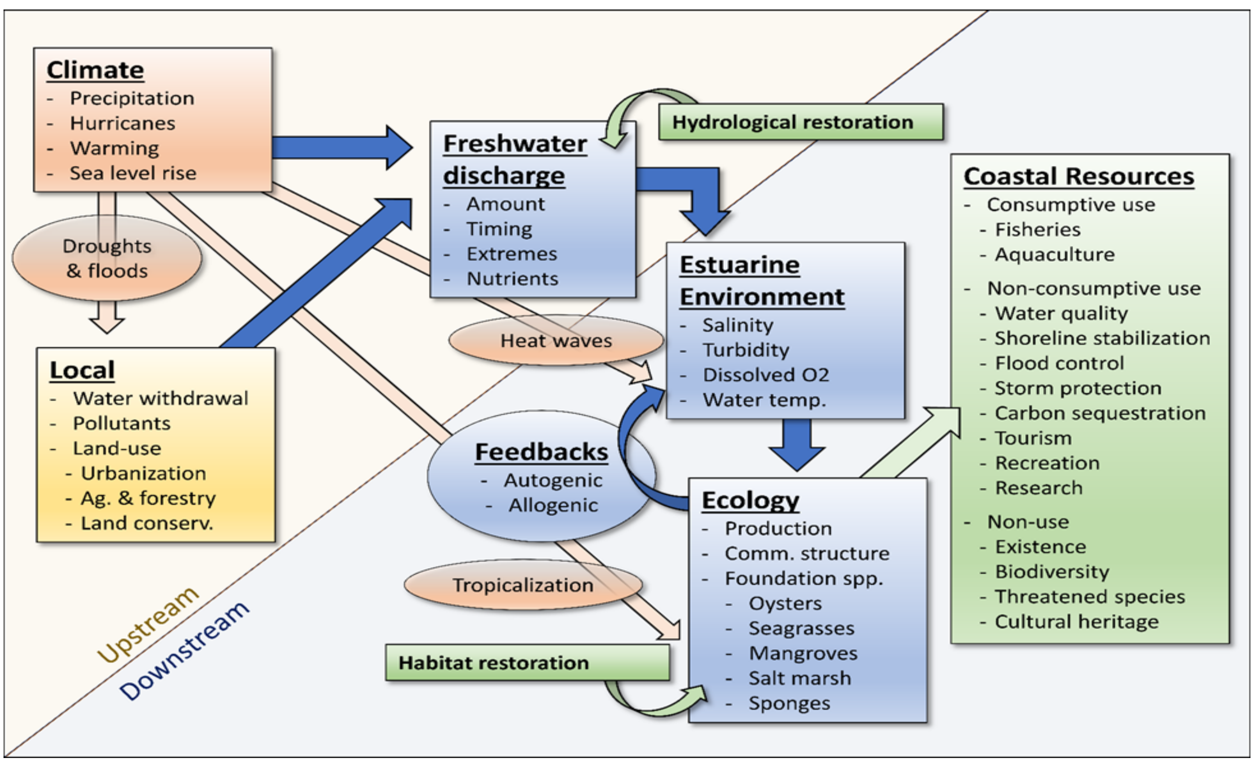

Figure 1. Conceptual schematic framework describe the pathways for how climate, land-use, water management ultimately affects estuarine living marine resources. Changes in freshwater quantity, quality, and timing drive physical environmental changes that alter estuary foundations, production, species composition, which in can cause feedbacks on the environment, considered in the context of concurrent climatic changes and restoration efforts.

ment of northwestern Gulf of Mexico estuaries based on stable isotopes. *Limnology and Oceanography*, 66 (9), pp.3568-3581.

Neupane, R. P., Ficklin, D. L., Knouft, J. H., Ehsani, N., and Cibin, R. (2019). Hydrologic responses to projected climate change in ecologically diverse watersheds of the Gulf Coast, United States. *International Journal of Climatology* 39, 2227–2243. doi:10.1002/joc.5947.

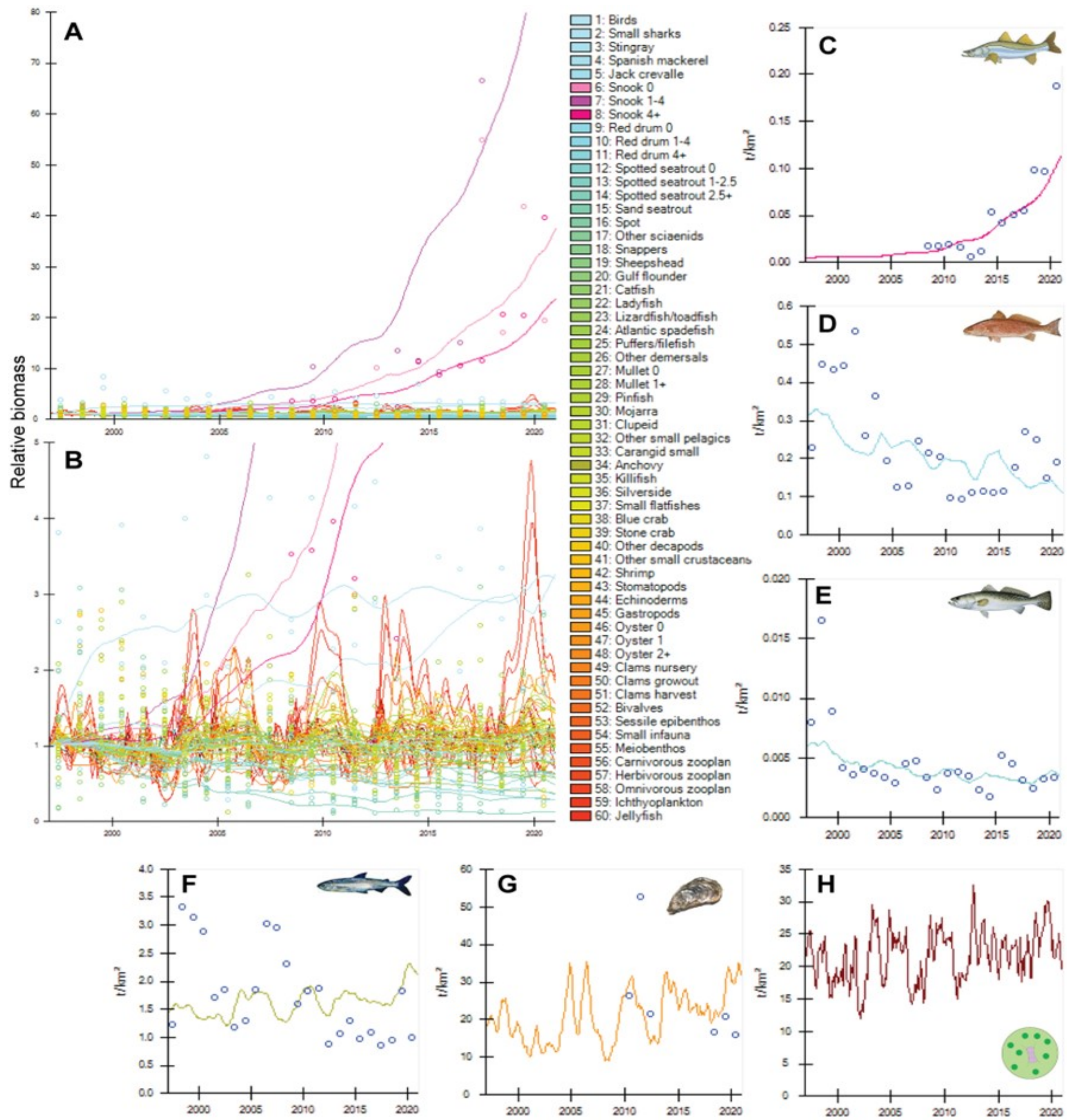

Figure 2. Ecosim Suwannee River Estuary model outputs. **A**, **B**) Sixty consumers, four primary producers, and two detrital functional groups were simulated and fit to reference timeseries data from 1997–2020. Relative biomass simulation predictions and their reference observations are shown for **C**) Snook age 4+, **D**) Red drum age 1–4, **E**) Spotted seatrout age 0, **F**) Anchovy, **G)**, Oyster age 1, and **H**) Phytoplankton.