Conceptual Model of Effects of Reduced Freshwater Inflow in the Anahuac National Wildlife Refuge

By

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The Texas Environmental Flows Initiative (TEFI) Working Group is a consortium of organizations (including Ducks Unlimited, Harte Research Institute, Meadows Center for Water and the Environment, National Fish and Wildlife Foundation, National Wildlife Federation, Western Water Project and The Nature Conservancy) working together to develop market-based projects to deliver freshwater to bays and estuaries of the Texas Gulf coast. The goal of TEFI is to establish water transactions as a viable tool for coastal protection and restoration in Texas by creating successful precedents that provide both on-the-ground ecological benefits and a demonstration of the feasibility of such transactions. One project under consideration is the Anahuac Environmental Flows Wetland Restoration project.

The Anahuac National Wildlife Refuge (ANWR), is located in the Gulf-Chenier Plan adjacent to the Galveston Bay estuary system, and is experiencing major marsh degradation. This project would achieve long-term restoration of habitat, countering the marsh degradation through the delivery of up to 10,000 acre-feet per year of water for an initial period of ten years, with an option for a long-term lease extension of up to 40 additional years. The project focuses on restoring natural hydrology on two Refuge tracts totaling 6,540 acres. The tracts have been affected by watershed-scale impairment of sheet-flow coupled with channelization of downstream and adjacent bayous that, collectively, has increased salinity levels. Historical subsidence effects also may be a contributing factor.

The increased freshwater flow to the tracts will benefit near-shore aquatic species by helping to maintain healthy marsh habitat used by those species, particularly in early life stages, and to reduce the highly elevated salinity levels that occur during drought conditions within the tracts

and in waterways adjacent to the tracts. These tracts are located near the rookery and wetlands at High Island, and provide key habitat for an extensive list of wading birds and waterfowl species adversely affected by the Deepwater Horizon oil spill. This project targets a key component of an inter-connected system of important habitats within the Chenier Plain, and will build on previously made oil-spill funding investments to help advance large-scale, long-term restoration.

The objective of the current report is to identify potential ecological benefits of a restoration project in ANWR. This includes identifying near shore aquatic species with which the ANWR staff has specific management objectives, and how introduction of freshwater might benefit marsh habitats.

Maintaining the integrity of the marsh itself is a high priority of ANWR staff because they have seen marsh collapse over recent decades that they believe to be related to increases in salinity (Figure 1). Marsh peat collapse is a common problem world-wide. However, when salinity intrusion occurs, the marsh plants growth is stunted and the can either die or simply not grow because of the salinity stress and intolerance to the high-saline conditions. When this happens, the root structure is lost, which destabilizes the organic-rich sediments of the marsh. Plants die, decomposition leads to highly reducing conditions where sulfides, produced by sulfate-reducing bacteria, is toxic to the live plants, which exacerbates the death of more plants, further destabilizing the marsh plant sediments. The increasing salinity thus provides two mechanisms for marsh collapse: 1) high salinity that stresses the plants, and 2) delivery of sulfate, which is a metabolic source for sulfate-reducing bacteria. Eventually the loss of plants leads to increases in erosion, total collapse of vegetated marsh, and conversion of the marsh habitat to an open-water habitat.

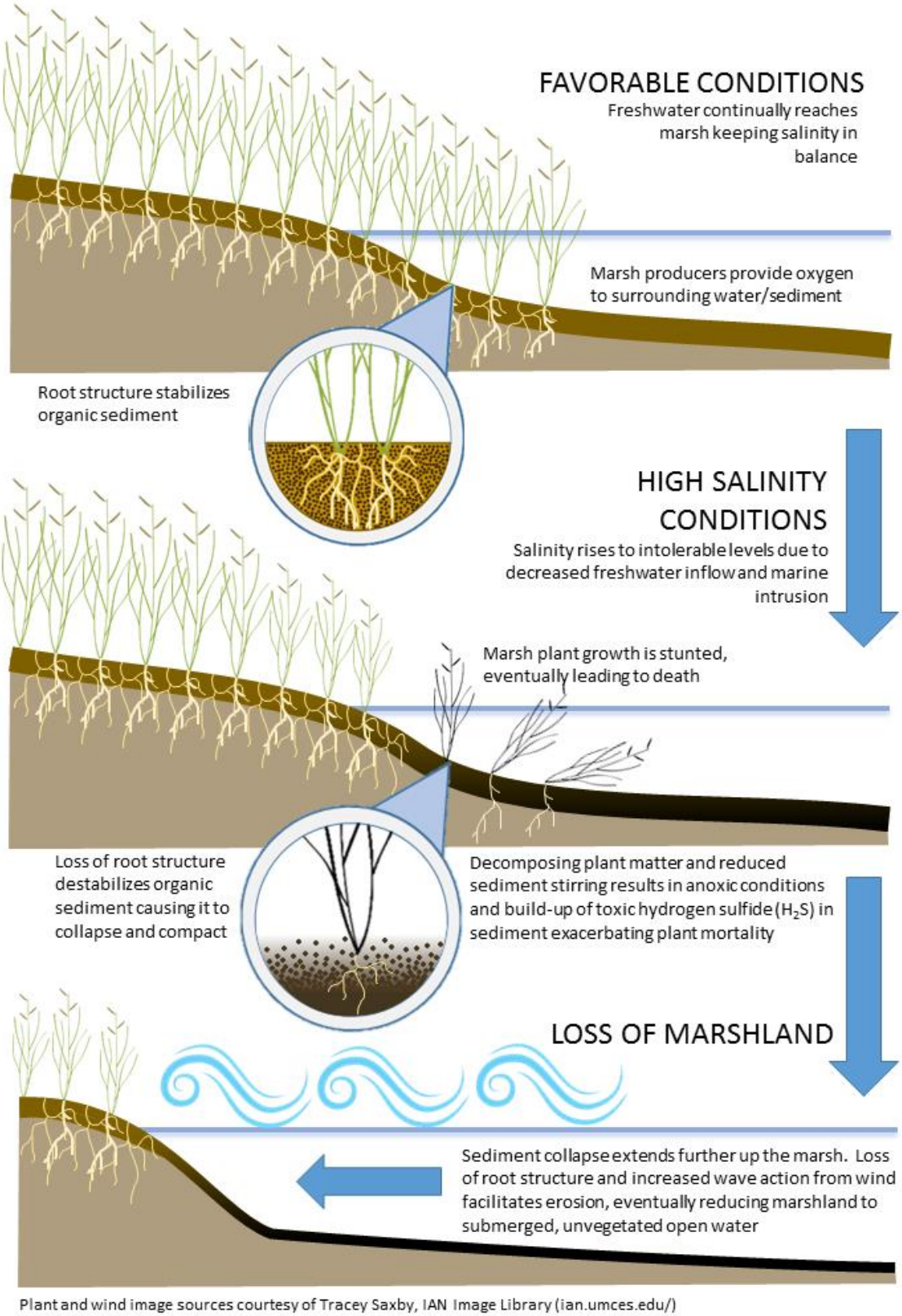
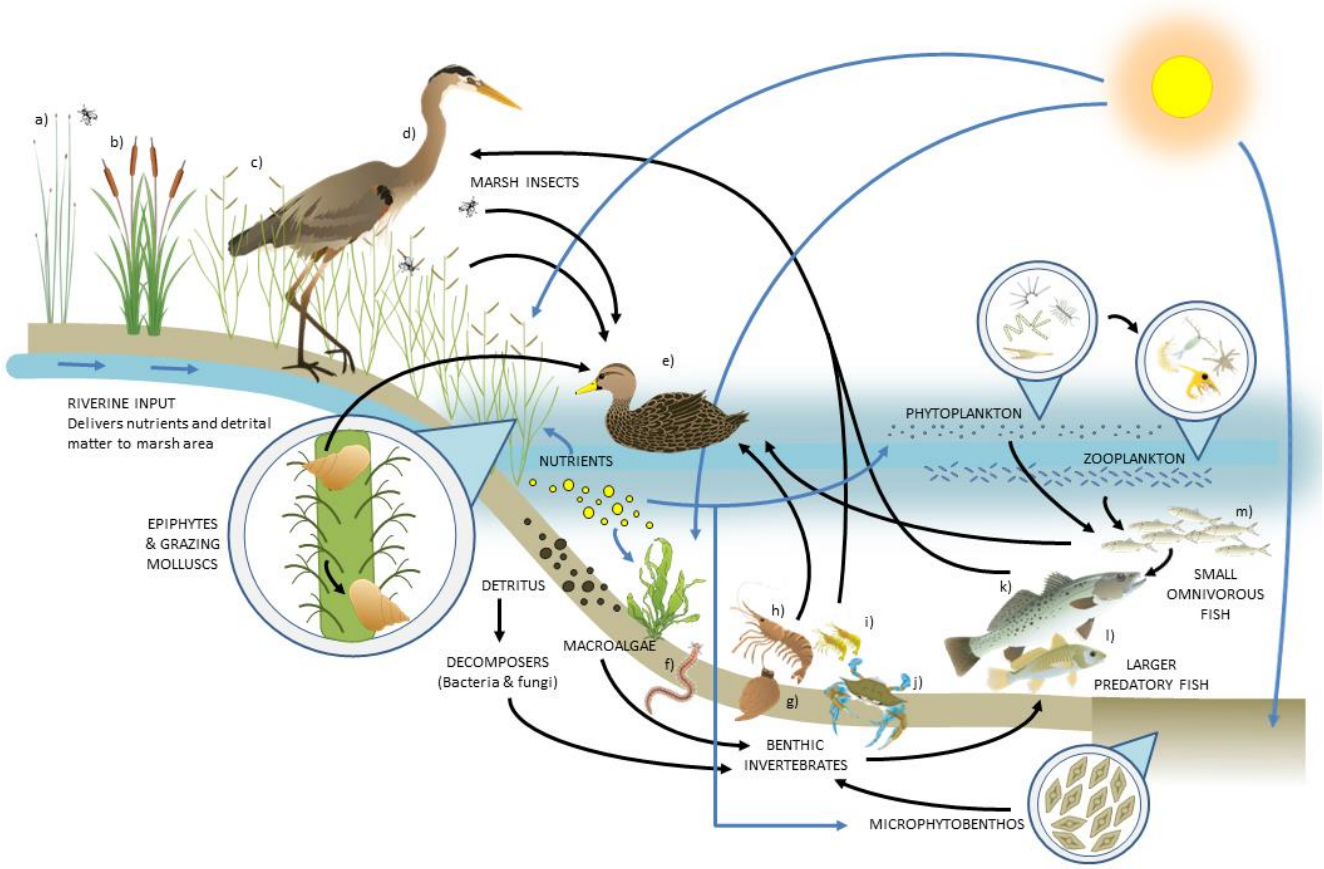


Figure 1. Conceptual model on how higher salinities lead to marsh collapse.

A healthy marsh is critical for the near-shore aquatic species that utilize the marsh as both nursery and adult habitats. More particularly, one of the focal species at the ANWR tracts is the mottled duck, a species of concern along the upper Texas coast. Discussions with ANWR staff and Ducks Unlimited have indicated that a freshwater delivery pattern beneficial to waterfowl, especially mottled duck, would also produce significant benefits for a broad suite of species, including near-shore aquatic species.

By maintaining the health and productivity of the marsh habitat on the tracts, all species using that habitat will benefit because the marsh habitat supports an enormously complex food web (Figure 2). There are essentially two food chains in a marsh: 1) The grazing food chain, which begins with the sun driving primary production by phytoplankton, which are fed upon by zooplankton and ultimately higher trophic levels such as fish. 2) The detrital chain, which starts with decaying macrophytes (such as marsh grass, seagrass, or macroalgae) that creates detritus, which is consumed by benthic invertebrates, which are then consumed by fish and higher trophic levels. Decomposition of macrophytes also liberates and recycles nutrients back to the water column, which can then in turn fuel phytoplankton and the grazing food chain. Thus, a key species, such as the mottled duck, depends on both food-chains in a very complex marsh food web. The structural redundancy of a marsh food web that is indicated by the many, complex, interconnections, is responsible for the high productivity and ecosystem services that a marsh provides.



a) sedge grass (*Eleocharis sp.*), b) cattails (*Typha latifolia*), c) cordgrass (*Spartina sp.*), d) great blue heron (*Ardea herodias*), e) mottled duck (*Anas fulvigula*), f) polychaete worms, g) molluscs, h) brown shrimp (*Farfantepenaeus aztecus*), i) dagger blade grass shrimp (*Palaemonetes pugio*), j) blue crab (*Callinectes sapidus*), k) spotted seatrout (*Cynoscion nebulosus*), l) Atlantic croaker (*Micropogonias undulatus*), m) Gulf menhaden (*Brevoortia patronus*)

Biota image sources: Tracey Saxby, Jane Thomas, Chip Chenery, and Dieter Tracey; IAN Image Library (ian.umces.edu/imagelibrary/)

Figure 2. Conceptual diagram of the Anahuac marsh food web.

Healthy coastal marshes provide many ecosystem services, which are benefits to mankind, as well as providing key habitat for living aquatic resources. The primary ecosystem services (i.e., benefits to man) of marshes are: the vast food web that is supported that eventually leads to harvestable living marine resources, recreational opportunities as a result of these key species, sediment stabilization that leads to erosion control thus marshes act as a buffer during storm events. As demonstrated in Figure 2, the marshes support large and complex food webs, which could not exist without the complexity of the marsh itself. In fact, the largest threat to marshes protected from development is changes in hydrology that can alter freshwater, nutrient and sediment supply, which is vital to maintaining marsh health. When marshes are stressed by altered hydrology, marsh collapse can occur (Figure 1), and when mashes are converted to open water, then all of the species that utilize the marsh are threatened.

REFERENCES USED TO CREATE CONCEPTUAL MODEL DIAGRAMS

PEAT COLLAPSE DIAGRAM

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Image Sources

Tracey Saxby, IAN Image Library (ian.umces.edu/imagelibrary/): *Spartina patens* (Saltmeadow Cordgrass)

ANWR FOOD WEB DIAGRAM

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https://www.sms.si.edu/irlspec/Palaemonetes_pugio.htm (accessed 15 June 2017)
https://en.wikipedia.org/wiki/Gulf_menhaden (accessed 14 June 2017)
http://www.fishbase.org/summary/1589 (accessed 14 June 2017)

Image Sources

Note: Image names are listed here as they occur in the IAN image library, and do not reflect their labeling in the produced diagram.

Tracey Saxby, IAN Image Library (ian.umces.edu/imagelibrary/): *Eleocharis spp.* (Spike Bush), *Typha orientalis* (Bulrush), *Spartina patens* (Saltmeadow Cordgrass), *Ardea herodias* (Great Blue Heron), fly, snail, *Enteromorpha intestinalis* (Gutweed), *Cynoscion nebulosus* (Spotted Seatrout), *Brevoortia tyrannus* (Atlantic menhaden), *Ceratium furca* (Dinoflagellate), *Chaetoceros affinis* (Diatom), *Thalassiothrix nitzschioides* (diatom), *Asterionellopsis glacialis* (Diatom), crustacean nauplius, *Acartia spp.* (Copepod), *Gammarus spp.* (Amphipod)

Jane Thomas, IAN Image Library (ian.umces.edu/imagelibrary/): Duck, *Rangia cuneata* (Atlantic Rangia), *Micropogonias undulatus* (Atlantic croaker), crab zoea

Dieter Tracey, IAN Image Library (ian.umces.edu/imagelibrary/): Polychaete with white bristles, Prawn shrimp

Jane Hawkey, IAN Image Library (ian.umces.edu/imagelibrary/): *Penaeus monodon* (Tiger Prawn): adult

Chip Chenery, IAN Image Library (ian.umces.edu/imagelibrary/): *Callinectes sapidus* (Blue Crab): juvenile