Balancing Freshwater Inflows in a Changing Environment

September 7, 2012 GBRA River Annex in Seguin, Texas
September 10, 2012 Bay Education Center in Rockport, Texas

Our Project...

Freshwater inflows: Determining flow regimes in the face of land use, climate change, and other unknowns

OBJECTIVE 1
Examine the effects of land use and climate change on freshwater inflows to the Guadalupe and Mission-Aransas.

OBJECTIVE 2
Improve inputs to the TxELEND salinity model of the Texas Water Development Board.

OBJECTIVE 3
Collaborate with intended users to identify and conduct a priority research project related to a focal species mentioned in the BBEST report.

OBJECTIVE 4
Develop shared systems learning among the local stakeholders and scientists for construction of a system dynamics model.
Focal species for determining freshwater inflow needs of the Mission-Aransas Estuary

Ed Buskey
Research Coordinator, Mission-Aransas NERR
Professor Department of Marine Science
The University of Texas at Austin

Senate Bill 3: Environmental Flow Recommendations

Directed the development of environmental flow recommendations to:

• **protect** a “sound ecological environment”
• **maintain** the productivity, extent, and persistence of key *aquatic habitats* in bays and estuaries
Focal Species

- Estuarine species sensitive to changes in salinity

- Changes in the abundance or distribution such species could indicate ecosystem change in response to altered freshwater inflow conditions
Focal Species

We chose studies for this project with consideration to:

- **Input from stakeholders and interested parties**

- **Study recommendations made in the BBASC Work Plan for Adaptive Management**

Stakeholder Survey Results

Mean Score

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marsh Plants</td>
<td>5.0</td>
</tr>
<tr>
<td>Rangia Clams</td>
<td>4.2</td>
</tr>
<tr>
<td>Oyster Reefs</td>
<td>4.0</td>
</tr>
<tr>
<td>White Shrimp</td>
<td>3.5</td>
</tr>
<tr>
<td>Blue Crab</td>
<td>3.0</td>
</tr>
<tr>
<td>Meroplankton</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Image of study participants and stakeholders.

Image of survey results bar chart.
Adaptive Management Plan

The BBASC Work Plan for Adaptive Management includes five focal species study recommendations:

1. Rangia clam investigations
2. Life cycle habitat and salinity studies for blue crab and white shrimp
3. Distribution and abundance of marsh vegetation in the Guadalupe estuary delta
4. Habitat suitability models for eastern oysters, blue crabs, and white shrimp
5. Role of Cedar Bayou in the exchange of water and meroplankton to the Guadalupe estuary
Adaptive Management Plan

The BBASC Work Plan for Adaptive Management includes five focal species study recommendations:

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<th>Study Recommendations</th>
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Blue crabs (*Callinectes sapidus*)

**Economic importance**
- 3.5 million lbs harvested in 2010  
- $3.1 million ex-vessel value

**Ecological importance**
- Preyed on by fish (e.g., red drum, croaker, cobia)
- Food source for endangered whooping cranes (60-98% of energy intake)
Selective tidal-stream transport

Phase 1
Position Maintenance
During the day and nocturnal ebb tides, megalopae maintain their position near the bottom.

Phase 2
Vertical Migration/Ascent
During nocturnal flood tides, megalopae ascend into the water column in response to rising salinity.

Phase 3
Hydrodynamic Transport
Megalopae swim in response to high turbulence to maintain their position in the water column and are transported up-estuary by strong flood-tide currents.

Phase 4
Settlement/Habitat Selection
Near the end of flood tide, megalopae are cues to settle by declining turbulence.

(Forward and Tankersley 2001)
Selective tidal-stream transport

Research Questions

Do the behavioral responses of crab megalopae to ambient changes in salinity differ between wet and drought years?
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Do the behavioral responses of crab megalopae to ambient changes in salinity differ between wet and drought years?

Laboratory experiments to examine the swimming behavior of crab megalopae under different salinity conditions

Could changes in megalopae behavior affect their transport into the estuary?
Research Questions

Do the behavioral responses of crab megalopae to ambient changes in salinity differ between wet and drought years?

- Laboratory experiments to examine the swimming behavior of crab megalopae under different salinity conditions

Could changes in megalopae behavior affect their transport into the estuary?

- Incorporate crab swimming behaviors under different salinity conditions into a larval transport model

Behavior Experiments

Do the behavioral responses of crab megalopae to ambient changes in salinity differ between wet and drought years?

- Use cameras to monitor megalopae swimming behavior under different salinity conditions

NORMAL

Add ocean salinity water

~30 ppt

~35 ppt

DROUGHT

Add hypersaline water

~35 ppt

~40 ppt
Transport Model

Could changes in megalopae behavior affect their transport into the estuary?

- Simulate circulation within study area
  - Use local wind and tide data
  - ADvanced CIRCulation model (ADCIRC)

Brown et al. 2000

Transport Model

Could changes in megalopae behavior affect their transport into the estuary?

- Simulate megalopae dispersal under different conditions
  - Examine relative influences of tides & winds
  - Test effects of different megalopae swimming behaviors by limiting times at which particles are free to move

Reyns et al. 2007
Transport Model

Could changes in megalopae behavior affect their transport into the estuary?

- Assess model results with field data
  - Current data from Seahorse tilt current meters
  - Megalopae abundance data from settlement collectors or traps

Any questions?
What is an estuary?

- An estuary is a partially enclosed water body where freshwater from rivers mix with saltwater from the sea.
- Tidally influenced: where water levels are affected by tides.
Why are estuaries important?

- **Environmental and Economic Benefits**
  - One of the most biologically productive habitats
  - Most fish and shellfish of commercial importance spend at least part of their lives in estuaries – “nurseries of the sea”
  - Filter, trap and transform many pollutants before they enter the sea (especially excess nutrients from agriculture and municipal waste)
  - Provide flood protection by absorbing excess flood waters and buffers against strong storms
  - Economic benefits from recreation, shipping, commercial fish catch

Why do estuaries need freshwater inflow?

- **Maintain zones of reduced salinity**
  - Some estuarine-dependent species require zones of reduced salinity
  - For other species reduced salinity reduces competition, predation and/or disease

- **Delivers essential nutrients to support plant growth at base of food web**

- **Delivers sediments to offset losses by erosion and coastal subsidence**
Meroplankton
Selective tidal-stream Transport

Ocean

Flood tide

Estuary

HIGH Salinity

LOW Salinity

Increasing Salinity
Selective tidal-stream Transport

- **Flood tide**: Increasing Salinity from Ocean to Estuary.
  - **High Salinity**: Moving towards the Estuary.
  - **Low Salinity**: Not moving as much.

- **Slack tide**: Decreasing Salinity from Estuary to Ocean.
  - **High Salinity**: Moving back to the Ocean.
  - **Low Salinity**: Moving towards the Ocean.

Selective tidal-stream Transport

Drought Conditions

Ocean

LOW Salinity

HIGH Salinity

Estuary

Ebb tide

Increasing Salinity

Ocean

LOW Salinity

HIGH Salinity

Estuary
Behavior Experiments

Do the behavioral responses of crab megalopae to ambient changes in salinity differ between wet and drought years?

- Use cameras to monitor megalopae swimming behavior under different salinity conditions

**NORMAL**
- Add *ocean salinity* water
  - ~30 ppt
  - ~35 ppt

**DROUGHT**
- Add *hypersaline* water
  - ~35 ppt
  - ~40 ppt

Add water from *ocean vs. estuary*
Focal Species
Developing a system-dynamics model

Balancing Freshwater Needs in a Changing Environment:
Building on May 30 Activities

September 7, 2012
Tarla Rai Peterson, PhD
Boone and Crockett Chair of Wildlife & Conservation Policy
Texas A&M University

Models lead to new perspectives

Emergence!

- perspective
- boundaries
- model
System-dynamics modeling tutorial

1. Tell a story of the system.
2. Identify components & actions
3. Translate into modeling language.
4. Retell the story with a model.
5. Try out the model and revise.

1. Tell the story of the estuary

What is the setting?
1. Tell the story of the estuary

Who are the characters?

What is the main action?

Photo Credit: Sally Morehead Palmer
2. Identify components & describe interactions

<table>
<thead>
<tr>
<th>Birds</th>
<th>Fishes</th>
<th>Plants</th>
<th>Humans</th>
<th>Invertebrates</th>
<th>Plankton</th>
<th>Water</th>
<th>Substrate / soil</th>
<th>Tides / Currents</th>
<th>Precipitation</th>
<th>Sunlight (Energy)</th>
<th>Wind</th>
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3. Translate into modeling language

The central components of the estuary are - - (STOCKS)

The actions that influence them are - - (FLOWS)

The issues that drive or inhibit those actions are - - (CONVERTERS)
4. Retell the story with a model

Use the components (stocks), actions (flows), and modifiers (converters) to draw a model map.

![Model Map Image]

4. Retell the story with a model

Use modeling software to formalize your model.

What data do we need?

How should the information fit together?

![Model Software Image]
Try out the model and revise

January 17
2012

Port Aransas
Freshwater Inflows:
Determining the Effects of Land Use & Climate Change

KIERSTEN MADDEN
Stewardship Coordinator
Mission-Aransas NERR

FUTURE FRESHWATER INFLOWS

Future Water Use
- Current land use
- Building/dwelling units
- Projected areas of future growth
- Population projections

Circulation Model
- Bay bathymetry
- Rainfall & evaporation
- Wind
- Freshwater from rivers
- Exchange with bays

Future Runoff
- Land use/land cover
- Elevation
- Soils
- Precipitation

Scenarios
- Land Use
- Climate Change
**FUTURE LAND USE**

**ARANSAS PASS, BAYSIDE, LAMAR, PORT ARANSAS, REFUGIO, ROCKPORT-FULTON (GROUP 1)**

- **High Density:** highly developed areas where people reside or work in high numbers; impervious surfaces = 80-100%
- **Medium Density:** areas with a mixture of constructed materials and vegetation; impervious surfaces = 50-79%
- **Low Density:** areas with a mixture of constructed materials and vegetation; impervious surfaces = 20-49%
- **Developed Open Space:** areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses; impervious surfaces = less than 20%

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**FUTURE LAND USE**

**ARANSAS PASS, BAYSIDE, LAMAR, PORT ARANSAS, REFUGIO, ROCKPORT-FULTON (GROUP 2)**

- **High Density:** highly developed areas where people reside or work in high numbers; impervious surfaces = 80-100%
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- **Low Density:** areas with a mixture of constructed materials and vegetation; impervious surfaces = 20-49%
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FUTURE LAND USE

AUSTWELL, BLOOMINGTON, PORT LAVACA, SEADRIFT, VICTORIA

High Density: highly developed areas where people reside or work in high numbers; impervious surfaces = 80-100%

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FUTURE LAND USE

KERRVILLE, NEW BRAUNFELS, SAN ANTONIO, SAN MARCOS, SEGUIN

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ICLUS INTEGRATED CLIMATE AND LAND USE SCENARIOS

LAND USE
- Commercial/Industrial
- Urban (<0.25 acres/unit)
- Suburban (0.25 – 2 acres/unit)
- Exurban (2 – 40 acres/unit)
- Rural (>40 acres/unit)

A2: Slower rate of economic growth. Restricted flow of people and ideas across regions. Fertility and average U.S. household size increase. Domestic migration is high, but net international migration is moderate.

This the highest ICLUS population project and for most areas in the U.S. represents a "worst case" pattern of development.

B1: Rapid social development in developing regions. Population rises rapidly until mid-century, then falls below replacement levels. Fertility and average U.S. household size decrease. Domestic migration is low, but net international migration is high.

This scenario consists of a low population projection and a slightly compact development pattern, which results in the least altered landscape for most areas of the U.S.
Create land use scenarios

Create indicators measuring impacts (economic, social, environmental)

Project impacts into the future

Experiment interactively and see changes

BUILD OUT

1. **Numeric Build-out**
   - Mathematical calculation based on area and density rules.
   - OUTPUT: Calculated Number
   - Area = 5 acres
   - Density = 1 DU/acre
   - Numeric DUs = 5

2. **Spatial Build-out**
   - Creates map layer with points or polygons representing buildings by possible locations.
   - OUTPUT: Points on map
   - Physical shape restricts development.
   - Spatial DUs = 4
WHAT’S NEXT?

Create land use scenarios

Create indicators measuring impacts (economic, social, environmental)

Experiment interactively and see changes

Project impacts into the future

QUESTIONS

Kiersten Madden
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Mission-Aransas NERR

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NERR

Current measurement

CURRENT METERS

INCLINOMETER
INCLINOMETER

Calibration curve example(s)

SIDE VIEW

TOP VIEW

Calibration curve example(s)
Seahorse current meters
Current meter painted w/ anti-fouling paint for longer-term deployment

Free-diving current meter retrieval

Current meter + its PVC stake

Seahorse tilt test deployment data

Mesquite Bay (2 wks, 1 reading/min)
Seahorse tilt test deployment data

**Ship Channel**  
(24 hrs, 1 reading/5 sec)

**Mesquite Bay**  
(2 wks, 1 reading/min)

**Surface**  
**Bottom**

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**Ship Channel**  
(24 hrs, 1 reading/5 sec)

**Mesquite Bay**  
(2 wks, 1 reading/min)
Deployment / Retrieval Methods
Timeline

Year 1
- Introduce project to intended users (i.e., workshops, interviews)
- Gather data for land use and climate scenario analysis
- Begin circulation study
- Identify focal species study with intended users
- Begin mediated modeling

Year 2
- Analyze land use and climate scenarios
- Continue circulation study
- Collect data for priority research project
- Update intended users through a series of workshops
- Expand mediated modeling effort

Year 3
- Summarize results of land use and climate change analysis
- Analyze and summarize circulation datasets
- Analyze and summarize results from priority research topic
- Discuss results with intended users
- Disseminate results to wider audience

Save the Date

January 17, 2013 is our next meeting
Location: University of Texas Marine Science Institute
Port Aransas, Texas

Questions?

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