Nutrient Sources, Fate, Transport, and Effects Study of Galveston Bay, Texas

Rachel Windham,
Department of Marine Biology
Texas A&M University at Galveston
Acknowledgements:

Dr. Antonietta Quigg
Members of the Phytoplankton Dynamics Laboratory
Galveston Bay

- Galveston Bay is an estuary located on the Texas coast (northwest Gulf of Mexico)
- 600 square miles (1,500 square kilometers) of open water
- Largest estuary in Texas and 7th largest in the nation
- Freshwater sources: Trinity River and San Jacinto River
- Supports multi-billion dollar fisheries industry (crab, shrimp, oyster)
- Highly productive; source of 1/3 of the state’s commercial fisheries revenue
Watershed spans area of 24,000 square miles (62,000 square kilometers)

- Trinity River and San Jacinto River have origins in highly-urbanized Dallas-Fort Worth metroplex and Houston area respectively

- Freshwater inflows (FWI) maintain salinity gradients, nutrient loads, and sediment inputs contributing to the health of Galveston Bay

- Nutrient loading can positively impact the ecosystem in appropriate quantities; however, in excessive amounts, nutrients can contribute to harmful algal blooms which further impact the system by contributing to hypoxia and fish kills
Urbanization

- Houston and Dallas populations expected to double by 2050
- Recent changes in land use and development could affect nutrient influx via freshwater inflows into Galveston Bay especially considering increased flow from Houston (wastewater)
- Important to monitor current nutrient loads and assess impacts on the ecosystem
Objectives

• Support continued research to understand nutrient fluxes in Galveston Bay

• Determine nutrient budget for ecosystem

• Examine the effect of nutrient loading associated with freshwater inflows on the phytoplankton community

• Particular focus on freshwater inflows from the Trinity River and to a lesser degree, those associated with the San Jacinto River

• Perform intensive resource limitation assays (RLAs) across six locations in the Trinity-San Jacinto Estuary during March and July (representative of “high-flow” and “low-flow” periods)

• Use the resulting data and conclusions to develop the next generation of predictive models relating freshwater inflows to bay health
Nutrient and sediment loading

• Assessment of **phytoplankton response to nutrient loading** through resource limitation assays in concert with assessment of water quality

• Treat seawater with **nutrient additions** and incubate for one week in ambient conditions

• Analyze phytoplankton **community health** by observing parameters such as chlorophyll-\(a\) concentration, pigment composition and fluorescence response
Project Evolution


- Included nutrient addition treatments of nitrogen, phosphorous, and a combination of nitrogen and phosphorous

- Yielded three notable insights:
  - Phytoplankton response to nutrient additions higher in periods of low-flow
  - Different responses in scale and species composition of phytoplankton communities at different stations
  - Phytoplankton frequently co-limited by nutrients, typically nitrogen and phosphorous

Introduction  Methods  Results & Analysis  Other Projects  Future Efforts
More Intensive Study

- 2010-2012: Examined phytoplankton community response to nutrient additions on a finer spatial scale
- Investigated response to different nitrogen sources (nitrate vs. ammonium)
  - Nitrate, ammonium, phosphate, nitrate & phosphate, nitrate & ammonium, silicate, “all”
- Note that 2011 was among the warmest and driest years on record for Texas since the record’s origin in 1871 (one of the top five driest years on record for the watershed)
- Extreme conditions in 2011 presented opportunity to observe seasonal responses with freshwater inflow influence “turned off”
- Comparing 2011 data to higher flow years (2010 and 2012) could inform system function in “normal,” “drought,” and “recovery” stages
FWI During Study Period

Discharge (cfs)*

USGS 08066500 Trinity Rv at Romayar, TX

- Discharge
- Period of approved data

Gage Height (ft)

USGS 08066500 Trinity Rv at Romayar, TX

- Gage height
- Period of approved data
Nutrient Limitation

Dissolved inorganic nitrogen (DIN): phosphorus (P) ratios calculated from 2010 to 2012. The secondary y-axis is the average monthly Trinity River discharge (cfs) data collected from the USGS.

- With a few exceptions, DIN:P ratios were always < 1 at Stations 1, 3 and 5 suggesting phytoplankton were N limited at these locations for most of the study period (especially during 2011) switching to P limited in the winter.
By contrast, at the San Jacinto River influenced station, we found DIN:P ratios were frequently in the range of 7:1 to 12:1 (neither N or P limited), especially from April-May to December. In the winter time, from January to March, DIN:P ratios were greater than 14 indicative of P limitation at this station.
Chlorophyll-a Concentrations of RLA Treatments

Example:

[Bar chart showing Chlorophyll-a concentration for different stations in March 2010]
Chlorophyll-a Concentrations of RLA Treatments

Introduction                          Methods                          Results & Analysis
Results & Analysis                          Other Projects                          Future Efforts

March 2010

March 2011

March 2012*

August 2010

July 2011

July 2012
Bioassay in 2012

- March (blue) – high flow
- July (green) – low flow

- N-nitrate, A-ammonium, NA, NP, All treatments responded significantly more than the control consistent with previous findings of N limitation and/or NP co-limitation

- “Sediment” treatments revealed alleviation of light-limitation in March (higher chlorophyll) but not in July
(A) Clusters A & B dominated by samples from Feb-May & Oct-Nov = periods of higher flows, more nutrients and sediments
Cluster C dominated by samples from June-Sep = periods of lower flows and warmer temperatures and more chlorophyll
Clusters A & B had the highest fucoxanthin, alloxanthin and peridinin concentrations. Cluster C had the highest chlorophyll b and zeaxanthin.
Progress Summary

- **Completed Bioassays through 2013**

- Ammonium elicited similar response to the addition of nitrate in terms of chlorophyll-$a$ biomass, but a different part of the phytoplankton community responded (will follow up).

- Preliminary evaluations reveal that phytoplankton biomass is either nitrogen or nitrogen and phosphorus co-limited in the bay; as most GOM estuaries are N limited with recent studies pointing to N-P co-limitation, important to investigate link to freshwater inflows.

- With more droughts and population increases predicted to occur, the necessity of freshwater inflow studies is great.
Other Projects

- Findings are being used to develop intense process-based understanding of the linkages between the magnitude of freshwater inflows and nutrient loading on primary productivity for the Galveston Bay ecosystem.

- Particularly important given water rights issues which are currently being debated in Texas (Senate Bill 3).
Phytoplankton

- Monthly surveys completed to mid 2013
- Multi-year data reveals patterns of when specific genera are observed
Taxonomic Distinctness of Phytoplankton 2005-06 and 2008-12
- Station 1 has greatest diversity while Stations 2 & 6 have less
- Drop is observed at all stations in 2010 & 2011
- May be associated with development and presence of a drought
Monthly 2-day sampling trips conducted using a Dataflow to measure surface water quality.

Concurrently measures temperature, pH, dissolved oxygen (DO), salinity, water clarity (beam transmittance), chlorophyll \(a\) (in situ fluorescence), and dissolved organic matter (DOM; in situ fluorescence).

GPS on board allows for geo-referencing for all measurements for each variable.

Can map water quality over temporal and spatial scales.
Example from 2009

- Salinity in August (low flow) and November (high flow; after freshet)

Following slide:
quarterly salinity interpolations for the years 2010, 2011, and 2012
2010
Jan  | Mar  | Jun  | Oct

2011
Jan  | Mar  | Jun  | Oct

2012
Jan  | Mar  | Jun  | Oct
Vallisneria americana (Wild Celery)

- Commonly studied as a **bioindicator** in other bays
- Continuing surveys this spring
- In terms of a bioindicator for Galveston Bay, perhaps best only to show impact of extremely low flows and provide caution
**Ruppia maritima**
(widgeongrass, ditch-grass or tassel pondweed)

- Seagrass tolerant of lower salinities
- Utilized by birds and aquatic animals
- Potential as a bioindicator???
Rangia cuneata (Atlantic Rangia)

- Pattern of decline in populations since 1980’s observed in Galveston Bay, Sabine Lake and San Antonio Bay
- Bioindicator suitability for Galveston Bay still to be determined – adults tolerant of higher salinities, but larvae hard to identify
- Additional data will be collected across 2014 – TPWD/SWG funding
Rangia Distribution in Galveston Bay

1980s

1990s

2000s

2010-Present
Updated TxBLEND Model

- TxBLEND is a two-dimensional, depth-averaged hydrodynamic and salinity transport model used to simulate salinity conditions in bays (TWDB)

- The model allows \textit{a comparison between observed and simulated data}

- We* updated the TxBLEND model outputs for 1983-2012

* (with Mr. Joe Trungale; Trungale Engineering and Science)
Time series of salinity measured with the dataflow at station 21 (red) compared to modeled salinity at the nearest TxBLEND Node (1833; blue) - June 2008 to December 2012.
The objectives of future efforts:

• Examine and analyze the phytoplankton and water quality samples collected up to the present day,

• Continue the high spatial and temporal resolution mapping of Galveston Bay water quality parameters,

• Investigate the paired distribution of *Vallisneria* and *Ruppia* plants as well as that of *Rangia* clams in relation to salinity gradients in Galveston Bay, and

• Using the data collected, develop a better understanding of the use of phytoplankton, flora and fauna as biological indicators of the effects of freshwater inflows in Galveston Bay.

• Define influence of nutrient and sediment load on the phytoplankton, flora and fauna in Galveston Bay,
Applications

• These data will be critical to the understanding of estuarine dynamics at various levels of stress.

• Understanding nutrient impacts and their relationships with freshwater inflows will help to prepare for additional stressors such as expanding population and increased drought.

• Ultimately, knowledge gained from these studies will help to inform management plans for the watershed.
Thanks for the continued support!