Freshwater Inflows Abstracts

BIOINDICATORS FOR FRESHWATER INFLOWS. IMPORTANCE OF NUTRIENTS FOR PHYTOPLANKTON.

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Increased population growth and industrialization has resulted in intense development of coastal areas worldwide. Resulting land-use changes have exacerbated runoff, municipal discharges, agriculture and contaminant loading to estuaries. With nutrient loading, changes in phytoplankton biomass, productivity and community structure have been observed as well as an increase and frequency of harmful algal blooms. Galveston Bay, Texas, provides a unique opportunity to study this phenomenon. The Trinity River supplies nitrogen (N) primarily as nitrate while the San Jacinto River supplies N primarily as ammonium in the upper Bay. In the lower Bay, there is an opening to the Gulf of Mexico and freshwater inflows are less influential. We hypothesize that the phytoplankton communities will respond differently to both the quantity and quality of the nutrient pulses across the Bay. Phytoplankton pigment and microscopic analyses (2008-2014) show an increase in biomass and productivity in the upper Bay compared to the lower Bay. Frequently the peaks in biomass were closely timed with those of freshwater inflows, although seasonal patterns were stronger and more important. Inversely in the lower Bay, biomass and productivity were not related to freshwater inflows or nutrients, but more frequently influenced by season. Across the Bay, we see a temporal shift from diatoms and dinoflagellates in the cooler months to cyanobacteria in the summer months. In years when there are prolonged periods of low flow, warm weather, we frequently see dinoflagellate blooms, some of which include harmful species (ex. *Karenia brevis, Dinophysis ovum*). In years when there are multiple freshets and warm weather earlier, diatom blooms occur in both the spring and early fall. We will apply the findings of this long term data set toward a better understanding of the phytoplankton community in relation to the dynamical forcing factors varying spatially and temporally within Galveston Bay.

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Poster presentation requested, oral presentation acceptable.

Topical area: Freshwater Inflow and Bay Circulation

INFLUENCE OF WATER QUALITY & FRESHWATER INFLOW ON TROPHIC ORGANIZATION IN TEXAS: HOW DOES GALVESTON BAY FIT IN?

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Within coastal bay systems, several mechanisms influence abiotic and biotic elements. The Texas coast is subject to varying climatic influences including hurricanes, drought, and extended periods of heavy rainfall. Alterations in levels of freshwater inflow into the estuarine ecosystem can have dramatic effects on water quality, primary production, and the abundance, distribution, and organization of various organisms. Data from this study was collected in conjunction with data compiled for the US Environmental Protection Agency's (US EPA) National Coastal Condition Assessment (NCCA) during the summer of 2015. These data were compared to historical records collected by probabilistic sampling programs conducted by the US EPA, US Geological Survey (USGS), the National Oceanographic and Atmospheric Administration (NOAA), and the Texas Commission on Environmental Quality (TCEQ). Data compiled include water temperature, salinity, turbidity, various nutrients, primary production, and catch per unit effort (CPUE) rates on various trophic groups of nekton collected with otter trawl. Supplemental water quality data was compiled from the TCEQ's Surface Water Quality Monitoring Information System (SWQMIS). Freshwater inflow estimates were derived from historical data collected by USGS monitoring stations on rivers directly adjacent to Texas' bays. Additionally, precipitation data collected by NOAA weather stations and buoys were compiled. Data gathered by the US EPA in their 2010 NCCA sampling were compared to values recorded during the 2015 NCCA to determine overall changes in variables used to assess water quality and trophic status of bays within the state. Data collected for Galveston Bay was compared to other bay systems within the state in order to elucidate differences in water quality and tropic organization. By understanding the influence of land-use changes and historical trends in water quality and freshwater inflow on nekton within Texas' bays, researchers can assist resource managers in the long-term conservation and management of the Galveston Bay ecosystem.

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Presentation Type: Poster

Requested Panel Session: Monitoring and Research

MODELING 63 YEARS OF SALINITY CONDITION IN GALVESTON BAY

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Texas is prone to multi-year droughts interrupted by watershed-drenching episodes of rainfall. Texas estuaries, lying at the receiving end of these catchments, are affected by subsequent highs and lows of surface inflows draining from inland watersheds which directly impact salinity condition, nutrient loading, and a variety of estuarine attributes. Historic records provide some measured insights into salinity condition and species responses at particular locations and times, but broader insights into whole-bay patterns of salinity over extended periods do not exist ... until now. That is, until we developed a 63-year simulation of salinity condition in Galveston Bay using the Texas Water Development Board's TxBLEND hydrodynamic and salinity transport model. For this, we compiled input for river hydrology, tidal elevation, precipitation, evaporation, and salinity boundary condition and developed model grids representative of changing bathymetric conditions over a 63-year period from 1950 - 2012. This exploratory effort resulted in a modeling tool for examining the impact of long-term patterns of freshwater inflow, as a result of drought and water-planning activities, on salinity condition in Galveston Bay. The simulation period allowed for examination of salinity patterns from Texas' historic drought of record in the 1950s to the recent, ongoing drought of today.

TxBLEND simulates salinity condition, water level, and circulation in estuaries and has been calibrated and validated for velocity, water level, and salinity over the period 1987 – 2005. However, historic salinity records were critical for evaluating model performance for 1950 – 1986 and 2006 – 2012. Fortunately, nearly 6,000 independent measurements of salinity, in addition to long-term monitoring records from 13 stations, were available for model validation. Model performance was evaluated by r^2, root mean square error, Nash-Sutcliffe efficiency criterion, and percent bias. Overall, TxBLEND captured well the long-term rise and fall of salinity in response to periods of drought and high inflows, but tended towards overprediction during the earlier period and in upper estuary locations. The model also failed to accurately capture short-term, high frequency variability in salinity. Intended to be a proof of concept, results from this multi-decadal simulation of salinity condition will be presented and discussed with respect to future applications which also must consider model performance and the need to improve model validation through further refinement of TxBLEND and acquisition of additional salinity data, particularly during the drought of the 1950's. The report (Guthrie *et al.* 2014) is available here:
www.twdb.texas.gov/surfacewater/bays/major_estuaries/trinity_san_jacinto/index.asp.

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Oral presentation

Suggested areas: Freshwater Inflow & Bay Circulation

PRO-ACTIVE APPROACHES TO SECURE FRESHWATER INFLOWS: INVESTIGATIONS OF SCOPE, SCALE, AND FEASIBILITY

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Projections of future water use in the river basins feeding Galveston Bay indicate the potential for amplification of the length and intensity of naturally-occurring drought conditions. However, there are pro-active means available that could ameliorate the severity of these conditions. Examples are voluntary wastewater dedications or market-driven transactions with willing participants to dedicate or re-manage existing water diversions to maintain or increase freshwater inflows to benefit the estuary.

We are evaluating ecosystem benefits that could be attained with example projects, including Trinity River acquisitions and the recent wastewater dedication by the City of Houston in the San Jacinto basin. The tools employed for effects assessment include salinity change modeling and habitat quality assessments for key bio-indicators. The results thus far have provided significant insights into data needs and spatial scale for evaluating such projects.

Ideally, evaluation techniques should be ‘scale-able’ to allow assessment of benefits of both large and small projects. Unfortunately, we find that data to support finer-scale assessment of ecosystem bio-indicators and the resolution of evaluation tools, such as salinity models, often fall short of what is needed to assess smaller-scale projects. This points to the need to invest in development of finer-scale models and more site-specific habitat characterizations to inform future management decisions.

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Type: Oral Presentation

Suggested Topical Area: Freshwater Inflow and Bay Circulation

BIOINDICATORS FOR FRESHWATER INFLOWS: DROUGHT EFFECTS ON PHYTOPLANKTON

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Galveston Bay, the seventh largest estuary in the United States, includes in its watershed the Houston and Dallas-Fort Worth metropolitan areas. Increase of freshwater use due to increase in occurrence and severity of droughts in the watershed is a concern for productivity in this economically important estuary. We report on the spatiotemporal variability of phytoplankton community resource limitation as a result of freshwater inflows. Six cross-system sites, representing the gradient of freshwater inflows into the Bay and Gulf, were sampled over 3 years (2010 to 2012) in March and July (high and low freshwater inflows, respectively), including a year of severe drought (2011). Bioassay treatments included eight nutrient-addition combinations, shaded, and grazers excluded. High Performance Liquid Chromatography (HPLC), coupled with ChemTax, was utilized to characterize the structure of phytoplankton communities via photopigment biomarkers. Dominant phytoplankton groups changed spatially and seasonally, but varied little between treatments. Diatoms, cyanobacteria, and chlorophytes were dominant in 2010 and 2011, but dinoflagellates were dominant in 2012, particularly in the spring. This was contrary to expectations of different dominant phytoplankton groups in 2011 compared to non-drought years. Limitation specific to each group differed spatially between seasons and across years, when limitation was present. During 2011 more groups exhibited nutrient limitation than in non-drought, with the exception of one river basin station. NO_3^- (N) and P were co-limiting across all stations during high flow, in addition to the combination of N, P, Si, and NH_4^+ (A). N and A were limiting across all stations during low flow, in addition to light in the mid-bay. Across stations, 2010 was not different from 2011; 2012 was different from 2010 and 2011. The drought year was different from the non-drought years, with the exception of one mid-bay station.

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Oral presentation desired, will accept poster presentation
Topic: Freshwater Inflow and Bay Circulation

EVALUATING FRESHWATER INFLOW, NUTRIENTS, AND SEDIMENT SUPPLY FROM THE TRINITY RIVER INTO GALVESTON BAY

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Research by the U.S. Geological Survey on the Trinity River, in conjunction with the Texas Water Development Board and the Galveston Bay Estuary Program, shows that discharge data from upstream gages, commonly used to estimate freshwater inflows into coastal ecosystems, may not represent actual discharge into Galveston Bay. This discharge attenuation appears to be a result of tidal influences near the coastal entrance and overland storage during storm events. Thus, enhancements to individual measurements and subsequent discharge computations for continuous monitoring in the lowest reach of the river are needed to ensure an adequate understanding of the mixing and physical exchange in the estuarine water. Additionally, the supply of nutrients and sediment entering Galveston Bay through the Trinity River is not well known, particularly during high flow periods, when substantial pulses from the rivers have a potential to affect bay productivity. Obtaining accurate freshwater inflow and nutrient/sediment input is fundamental to the assessment of the physical, chemical, and biological processes governing this aquatic system and imperative for regulating environmental flows for a sound ecological environment.

In tidally affected areas, index velocity methods are commonly applied to compute discharge by using acoustic Doppler meters. This method differs from the traditional stage-discharge method by separating velocity and area into two ratings, and it is also more appropriate when more than one specific discharge can be measured for a particular stage. USGS, in cooperation with Texas Water Development Board and the Galveston Bay Estuary Program, installed an acoustic Doppler meter in the Trinity River (Station Number: 08067252) and developed and index velocity rating to obtain a continuous record of discharge. This continuous record is used to estimate freshwater inflows into Galveston Bay and compare to discharge data from upstream stations commonly used for these estimates. In addition, water quality samples were collected to determine nutrient and sediment concentrations over a range of hydrologic conditions and evaluate Trinity River contributions to the Galveston Bay ecosystem. These improved methods for determining freshwater inflow contributions of discharge, sediment, and nutrients may be useful for inclusion in hydrodynamic and water quality models and may help fill a data gap of the volume of freshwater inflow entering Texas coastal ecosystems.

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Oral Presentation

BIOINDICATORS OF FRESHWATER INFLOWS: PHYTOPLANKTON DIVERSITY

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Galveston Bay, the largest watershed in Texas, is impacted by anthropogenic nutrient inputs from two growing major cities: Houston and Dallas-Fort Worth. Expansion of the Panama Canal in 2016 will lead to an increase in shipping into Galveston Bay, which in turn will lead to an increase in discharge of ballast water into the bay. These two inputs combined are likely to lead to an increase in invasive phytoplankton species and nutrient inputs and ultimately an increase in the frequency of algal blooms, some of which may be harmful. Because of this, it is important to understand the current phytoplankton diversity in order to know which harmful algal species are present, when they are abundant, and when they are most likely to produce blooms. Ultimately this information will provide early detection, avoid human illness from shellfish poisoning and possibly lead to regulation of nutrient inputs. Historically, diatoms have been found to be the most abundant phytoplankton in the winter and spring, when nutrient inputs into Galveston Bay are higher due to increased freshwater inflows. Small flagellates and cyanobacteria have been found to be the most abundant phytoplankton during times of warmer weather and low nutrient inputs due to low freshwater inflows into Galveston Bay. Daily samples are being taken from Galveston Bay near the entrance to the Gulf of Mexico. These samples will be examined with an Imaging FlowCytobot to document community composition shifts down to lowest practical identification level. Diversity will be assessed with traditional indices including the Shannon-Weiner and Simpson's diversity indices. Compared to previous studies, this approach will allow us to characterize much finer scale community composition changes concurrently with those in temperature and salinity. This information will also provide a library of phytoplankton types in Galveston Bay and, with concurrent water quality data, will be used to develop predictive tools or determine under which scenarios if any, harmful algal blooms are more likely to occur.

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Presentation Preference: Oral presentation preferred, will consider poster presentation if oral submittal not selected

Topic Area: Freshwater Inflow and Bay Circulation

BIOINDICATORS FOR FRESHWATER INFLOWS. IMPORTANCE OF PHYTOPLANKTON AS A METRIC FOR BAY HEALTH.

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Freshwater inflows play a key role in the biological complexity of estuarine ecosystems both temporally and spatially. Anthropogenic and natural stressors add to this variability and may negatively impact the biota. The population in Texas is expected to double by 2060 and with this growth comes a 27% increase in the demand on freshwater resources. To determine and then monitor the environmental quality within the Bay, a suite of freshwater bioindicators were selected. Included in a list with plants, clams, oysters (their disease and predators) as well as a variety of fish, are the phytoplankton. We have data for water quality and phytoplankton pigments from 2008 to 2013 for six fixed stations in Galveston Bay. A meta-analysis of this multi-year data set was used to examine significant relationships between biotic and abiotic factors. The multivariate statistic package PRIMER-e + and the PERMANOVA add on package were used to perform the analysis. Findings reveal that the following groups are the most important contributors to this Bay: cyanobacteria, diatoms, dinoflagellates, chlorophytes, and cryptophytes. In general, we found cyanobacteria were associated with higher salinities and warmer temperatures. This influenced the timing of blooms and the location. Diatoms by far appeared to be dominant across the entire bay and generally present at the highest concentrations during most times of the year. While dinoflagellates were present across the entire Bay, they were generally in lower concentrations than the diatoms but higher than the chlorophytes. Cryptophytes were associated with higher salinity waters and more prevalent after freshwater inflow events, but only if the freshets were significant in both magnitude and duration. The use of a variety of bioindicators of freshwater inflow is important for capturing the response to temporal and spatial changes in freshwater inflows over a variety of time scales. The findings from this study will be used to facilitate biological assessment of other Texas estuaries those further afield.

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Oral presentation requested, poster presentation acceptable.

Topical area: Freshwater Inflow and Bay Circulation

A Coastwide Perspective on Defining and Characterizing Drought Events in Texas Estuaries

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Texas estuaries are vulnerable to natural reductions in freshwater inflow now more than ever due to increasing demands for freshwater resources that have the potential to induce drought-like inflows at intervals more frequent than experienced by natural droughts. However, methods to identify drought effects in estuaries commonly are defined by conditions occurring within contributing watersheds as opposed to conditions occurring within the estuary itself. The focus of this study was to employ a method that allows conditions specific to an estuary (*i.e.,* surface inflow) to define a period of drought. Using a modified approach from Ward (2010), residual mass curves depicting cumulative inflow deficits were calculated for inflow records spanning up to 73 years to identify historical periods of drought in ten Texas estuaries. Droughts were defined as periods in which monthly inflow was below a specified drought criterion of 60 percent or less than long-term mean monthly inflow, for at least a minimum of one year. This presentation will describe drought characteristics and frequency among Texas estuaries as determined by the cumulative inflow departure method using drought metrics such as intensity, severity, and duration to compare drought events across estuaries and also will include an evaluation of corresponding salinity conditions.

Texas estuaries experienced between ten and 15 drought events over the 73 year period, and multi-year drought periods were common. In all ten estuaries, the cumulative inflow departure method identified either the drought of record (during the 1950's for most of Texas) or the recent, ongoing drought as one of the longest, most severe, or most intense. Surprisingly, upper coast estuaries that receive high annual inflow volumes recorded just as many drought events as the more arid lower-coast estuaries, although events on the upper coast tended to be of shorter duration. Upper-coast systems accumulated large deficits, upwards of 40 million acre-feet, during long drought events; whereas, the arid lower-coast estuaries accumulated less inflow deficit and also experienced less intense and less severe droughts. Increased salinity condition ranging from three to ten additional practical salinity units was observed during drought periods in all estuaries. This analysis demonstrated that drought is a frequent factor affecting estuarine health and productivity in Texas, but also that the cumulative inflow departure method identified periods in which estuaries experienced low inflow conditions that may not be captured by more typically reported terrestrial drought indices.

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Oral presentation

Suggested areas: Freshwater Inflow & Bay Circulation

WATER USE EFFICIENCY AND WATER CONSERVATION EDUCATION AS TOOLS TO MANAGE WATER RESOURCES IN THE GREATER HOUSTON-GALVESTON AREA

Emily Seldomridge, Galveston Bay Foundation, Webster, TX

Managing and protecting our water resources is one of the most critical issues facing Texas today. In particular, the population of Region H (the state water supply planning region of the Houston-Galveston area) is expected to roughly double between 2010 and 2060, which puts additional strain on currently limited water resources. About two-thirds of the total amount of water supply in Region H is surface water. The Initially Prepared 2016 Regional Water Plan projects Region H water shortages in the year 2020 to total 224,217 acre-feet per year, increasing to as much as 1,017,548 acre-feet per year in the year 2070. Improving water use efficiency allows communities to stretch existing water supplies and postpone or eliminate the need for expensive and environmentally damaging water supply projects, such as large reservoirs.

In Region H, one of the most cost effective measures to improve water use efficiency is to reduce discretionary water use (i.e., outdoor lawn and landscape irrigation). Current Region H outdoor water use accounts for one-third to nearly one-half of residential water use. Limiting outdoor irrigation to no more than twice per week may save as much as 38,000 acre-feet per year (based on current water use levels). By 2060 this equates to a savings of 62,348 acre-feet per year, which could potentially avoid $200 million in infrastructure costs. Houston's climate allows residents to use considerably less water on outdoor lawn and landscape irrigation, but Houstonians still use more water on a daily basis than the residents of drier regions such as Austin, El Paso and San Antonio. Therefore, water conservation education is fundamental to successful water use efficiency.

Through the Texas Living Waters Project, Galveston Bay Foundation in partnership with National Wildlife Federation and Sierra Club are working to advance water conservation education through a variety of tools including the Gulf Coast/Montgomery County Water Efficiency Network (a forum for water professionals to discuss successes and challenges to implementation of water conservation measures), an outdoor irrigation challenge to turn off automated controllers during winter months, a water conservation pledge to join the Galveston Bay Water Brigades, as well as public service announcements. Water use efficiency and water conservation education provide a significant opportunity to ensure water is available to meet all critical needs including water to support healthy rivers, bayous, and Galveston Bay.

While some water utilities have begun to realize the potential of water efficiency, the Houston-Galveston region has yet to take full advantage of the cheapest, most reliable, and most sustainable source of water – the one that's already on tap.

BIOINDICATORS FOR FRESHWATER INFLOWS: MICROBIAL TRAITS

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Heterotrophic microbial abundance and growth rates can be limited by inorganic nutrients in estuarine systems where allochthonous subsidies to autochthonous carbon spatiotemporally saturate heterotrophic carbon requirements. However, the eco-physiology of estuarine heterotrophic microbes in relation to nutrient availability in Galveston Bay remains poorly understood. A multivariate statistical analysis was conducted using the PRIMER/PERMANOVA packages and combined with a trait-based approach in order to target variability in the heterotrophic community associated with freshwater inflow events. Physiological groups were determined by differences in nucleic acid content using flow cytometry. Results indicate that there are significant temporal correlations between the relative abundances of heterotrophic physiological groups and a combination of temperature and dissolved inorganic nitrogen (DIN) availability. During warm temperatures (>28.1°C) and low DIN availability (<0.21 μmol L^{-1}) a unique heterotrophic physiological community structure was observed. Similarly, a significant shift was observed during a low salinity (<10.1) high DIN availability (>11.1 μmol L^{-1}) freshwater inflow event. Corresponding mesoscosm enrichment experiments validate episodic nitrogen limitation of heterotrophic groups. The timing of the different physiological groups response to nutrient enrichment supports the concept that lower nucleic acid fractions potentially have ‘streamlined’ genomes that garner a competitive advantage during nutrient limitation conditions while relatively higher nucleic acid fractions have more ecological plasticity and are more competitive during nutrient replete conditions. These findings suggest that nucleic acid content traits reflect ecological heterotrophic responses to environmental conditions, which could ultimately be utilized as bio-indicators of sustained freshwater inflow.

Bioindicators of Freshwater Inflows: Response to the TR/SJR BBEST recommendations

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Freshwater inflows play a key role in the biological complexity of estuarine ecosystems both temporally and spatially. Anthropogenic and natural stressors add to this variability and may negatively impact the biota. The population in Texas is expected to double by 2060 and with this growth comes a 27% increase in the demand on freshwater resources. With >11 million people currently residing within the Galveston Bay watershed pressure on freshwater resources will continue to increase. To determine and then monitor the environmental quality within the Bay, a suite of freshwater bioindicators were selected. The current bioindicators target both low salinity (*Rangia cuneata, Brevoortia patronus,* and *Ictalurus furcatus*) and high salinity conditions (*Lagodon rhomboides, Perkinus marinus* and *Stramonita haemastoma*). A meta-analysis of a 30 year data set pooled from various state agencies was used to examine significant relationships between biotic and abiotic factors using multivariate statistic package PRIMER-e + PERMANOVA add on package. Preliminary findings suggest that *Ictalurus furcatus, Perkinus marinus* and *Stramonita haemastoma* have a strong potential to be considered bioindicators of freshwater inflow and may be applicable to other bay systems. *R. cuneata*, *B. patronus* and *L. rhomboides* need further analysis before an evaluation can be finalized. Further efforts will be towards analyzing the variability in phytoplankton pigments in relation to environmental factors to determine their potential as bioindicators. The use of a variety of bioindicators of freshwater inflow is important for capturing the response to temporal and spatial changes in freshwater inflows over a variety of time scales. While phytoplankton would allow for early detection of disturbances, clams and fish provide an integrated view over a period of years. The findings from this study will be used to facilitate biological assessment of other Texas estuaries those further afield.

BIOINDICATORS OF FRESHWATER INFLOW: *RANGIA CUNEATA*

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Freshwater inflows are critical for success in both human and ecological spheres. Projections for growth in Texas predict increasing populations in coming decades which will increase demands on the state's available freshwater. To understand the relationship between environmental flow regimes and the ecosystems they support, environmental managers quantify the environment's demand by observing the responses of organisms within the ecosystem to changes in resource delivery. Organisms which are sensitive to such changes are known as bioindicators. In Texas, the brackish-water clam *Rangia cuneata* was selected as a potential bioindicator of the impacts of changes in freshwater inflow due to literature citing the organism's narrow range of salinity tolerance and limited mobility. For Galveston Bay, a vast historical record of both clam distribution and concurrent environmental parameters has been maintained by state agencies since 1983. A synthesis of this dataset was used to define trends in *R. cuneata* distribution and abundance and determine whether those metrics have historical relationships with environmental parameters. These data informed a present-day study of *in situ* populations of *R. cuneata* in Galveston Bay examining the relationship between clam health and environmental flows on a fine, qualitative scale. After three years of study from 2012 to 2014, a decrease in mean rangia meat indices and increases in mean shell lengths and areal density were observed. These findings support the hypothesis that rangia in Galveston Bay are aging faster than their rate of recruitment. Multivariate statistical analyses of clam health metrics and concurrent environmental parameters support a link between rangia health and variables influenced by freshwater inflow including salinity; however, the results were not robust enough to support the hypothesis that freshwater inflows are the primary driver of rangia health. This weakens the argument for its fitness as a bioindicator.