Galveston Bay Status and Trends

Final Report

2017

Prepared for:

Texas Commission on Environmental Quality (TCEQ)
Galveston Bay Estuary Program (GBEP)
17041 El Camino Real. Ste. 210
Houston, Texas 77058

Project Coordinator
Lisa Marshall
Lisa.Marshall@tceq.texas.gov

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Prepared By:

Center for Texas Beaches and Shores (CTBS)
Texas A&M University, Galveston (TAMUG)
200 Seawolf Parkway
Galveston, Texas 77554

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EXECUTIVE SUMMARY

The Galveston Bay Status and Trends Project was originally developed to assist in achieving the goals of the Galveston Bay Comprehensive Conservation and Management Plan (CCMP). This report is the most recent analysis of parameters and trends across the entire Lower Galveston Bay Watershed for time periods from 1969-2016. Based on stakeholder involvement and expert opinion, a set of parameters were analyzed to assess the overall health of the watershed. These parameters fall into the following categories: nutrients, field measurements of water quality, coastal fisheries independent monitoring data, physical, microbiological health indicators, metals in sediment, aromatic organics in sediment, pesticides in sediment, reported toxic releases, colonial nesting waterbirds, reported oil spills, and land use/cover. Multiple variables within each category were statistically examined for trends in the Bay based on available data and sampling points. These data and their metadata are posted on the Status and Trends Atlas – an interactive web-based GIS system where users can visualize and analyze environmental trends for all variables selected in this project. The Status and Trends Atlas can be found at:

http://www.texascoastalatlas.com/AtlasViewers/StatusAndTrends/SnTatlas.html

Based on the graphical and statistical analyses, we find the following trends related to the environmental health of Galveston Bay:

- Assessed nutrient parameters are generally decreasing in Galveston Bay over time. The proportion of nutrient samples that exceeded the levels recommended by TCEQ also decreased from the 1970s to 2015.

- Trends for field water quality parameters are inconclusive. Dissolved oxygen shows some increasing trends depending on the season and subbay/watershed being analyzed. In contrast, the data show that specific conductance is decreasing across the watersheds within the Lower Galveston Bay Watershed.

- Physical variables are generally decreasing in intensity. In particular, the amount of total suspended solids is decreasing across Bay watersheds as is total organic carbon.

- Microbiological parameters are increasing overall. For example, Enterococci levels are increasing in both the subbays and watersheds. Chlorophyll-a shows increases from 2000 to the latest year sampled.

- The overall exceedance proportion of metals in surface waters is decreasing.

- Colonial nesting waterbird counts exhibited different trends depending on species. Black Skimmer, Black-crowned Night Heron, Great Blue Heron, and Roseate Spoonbill are all decreasing in abundance. The Brown Pelican is the one species that has exhibited an increasing trend in observed numbers.

- Trends in catch per unit effort (CPUE) observed by TPWD coastal fisheries independent monitoring program varied between reported species.

- For toxic releases, some chemicals, like ammonia, benzene, and chlorine, are decreasing, whereas nitric acid shows an increasing trend.
- Land-use change analysis indicates there are major increases in development and corresponding losses in wetlands and forests.

The Status and Trends project provides all stakeholders in the Lower Galveston Bay Watershed with an assessment of the overall health of the Bay over multiple decades where data are available. The findings of this report provide guidance to experts and decision makers on how future initiatives can further improve the health of this critical ecosystem.

ABBREVIATIONS

AT: Audubon Texas
BOD: Biochemical Oxygen Demand
C-CAP: Coastal Change Analysis Program
CPUE: Catch per Unit Effort
CRP: Clean River Program
CTBS: Center for Texas Beaches and Shores
DDT: Dichloro-diphenyl-trichloroethane
EPA: Environmental Protection Agency
GBEP: Galveston Bay Estuary Program
GLO: General Land Office
HARC: Houston Advanced Research Center
HUC: Hydrologic Unit Code
LOESS: Locally Weighted Scatterplot Smoother
LOQ: Limit of Quantitation
ML: Milliliter
MPN: Most Probable Number
NO^{3-}: Nitrate
NO^{2-}: Nitrite
NOAA: National Oceanic and Atmospheric Administration
NTU: Nephelometric Turbidity Units
PEL: Probable Effects Level
PPT: Parts Per Thousand
QAPP: Quality Assurance Project Plan
QA/QC: Quality Assurance/ Quality Control
SWQMIS: Surface Water Quality Monitoring Information System
TAMUG: Texas A&M University at Galveston
TCW: Texas Colonial Waterbird
TCEQ: Texas Commission on Environmental Quality
TNRIS: Texas Natural Resources Information System
TOC: Total Organic Carbon
TPWD: Texas Parks and Wildlife
TRI: Toxics Release Inventory
TSS: Total Suspended Solids
UG: Micrograms
USGS: United States Geological Survey
USFWS: United States Fish and Wildlife Service
YSI: Yellow Springs Instrument

INTRODUCTION

The Galveston Bay Estuary Program (GBEP), of the Texas Commission on Environmental Quality (TCEQ) developed and has been updating a Comprehensive Conservation and Management Plan (CCMP) since 1989 (Gonzalez & Lester, 2008). The CCMP for the Galveston Bay is called the Galveston Bay Plan and was originally published in 1994 (GBNEP, 1994). The Galveston Bay Plan was originally created to address three major problems: habitat degradation and its effect on fish and wildlife populations, competing human uses of the bay, and water and sediment quality problems. The Status and Trends project acquires and processes data that are vital to understanding the status of specific parameters and the trends that these parameters take as they change over time.

This report discusses the project funded by the Galveston Bay Estuary program to update and maintain the Status and Trends database for the Galveston Bay Estuary. Many databases (including water quality parameters, fisheries data, colonial nesting waterbirds, oil spills, and other environmental datasets) were cleaned, analyzed, and loaded onto an online geovisualization tool: the Texas Coastal Atlas. Datasets have different time spans, ranging from 1969 to 2016. In addition, there are variations in the number of samples taken for each parameter. Certain parameters are sampled regularly to determine a trend across the entire study area, while some are spatially limited or lack a sufficient number of data points. Overall, this project builds upon and continues the work done for the 2008 Status and Trends project. The current project also creates an online web mapping application that allows all stakeholders to access and utilize the data (see: http://www.texascoastalatlas.com/AtlasViewers/StatusAndTrends/SnTatlas.html).

PROJECT SIGNIFICANCE AND BACKGROUND

With guidance from the GBEP staff and the Monitoring and Research Committee, key data sources and datasets were identified as a priority for the region. The Status and Trends project incorporates these key datasets from federal and state agencies and evaluates the status and trend of each parameter. The final product, in addition to this final report, is the publication of the resulting data and metadata to an online web mapping application known as the Status and Trends Atlas (www.texascoastalatlas.com), which is part of the Texas Coastal Atlas project.

The goal of this project is to provide *"continued maintenance of the Galveston Bay Status and Trends database"* (TCEQ, 2014). As stated in the TCEQ Contract (no. 582-14-43083), this process involves "*collecting, storing, maintaining, and displaying data so the public can better visualize and understand the basic conditions along the Texas coast"* (TCEQ, 2014). This project builds upon and extends the previous Status and Trends project that was conducted by the Houston Advanced Research Center (HARC) (Gonzalez & Lester, 2008). Since 2000, the Status and Trends project database has been made available through an online clearinghouse. This project continues this tradition and adds interactive features available through the Atlas web mapping application. Users of the Status and Trends Atlas can select, query, chart, print, and view data temporally. The Atlas is connected to Google maps allowing users to observe and see trends from the regional level all the way down to a street view.

All aspects of this project were carried out in accordance with the GBEP Quality Assurance/Quality Control (QA/QC) procedures. Data quality in secondary data sources is always a challenge. Since this project involves no sampling or field data collection, all of the secondary data had to be assessed for data quality. The data included in the Status and Trends project originates from reliable sources with high quality data. Due to quality assurance issues, data from multiple sources were not combined or examined for the same parameters. This approach was taken because of differences in data collection methods between sources.

Quarterly reports were submitted to the GBEP project manager as well as yearly Quality Assurance audits. Coordination meetings were held to ensure that the project remained on schedule and that there is transparency in the data analysis and project implementation. In respect to the specific data analyses, data collection reports were submitted every year in addition to a database development report, database maintenance and delivery report, and query and analysis report. All of these reports adhere to the quality assurance procedures listed in the Quality Assurance Project Plan (QAPP), which is updated annually (TCEQ, 2014).

This project is particularly beneficial to scientists and experts because of the reproducibility of the data processing and analysis—as well as the graphical interpretation of the data. Metadata for all of the data is online through the Status and Trends Atlas. The metadata also includes the Python scripts that were used to process the data, making our result highly reproducible. The graphical analysis was conducted using Python and R scripts, which are available upon request. Overall the transparency, reproducibility, and well-documented metadata are considered highly valuable aspects of this project.

PROJECT WEBSITE

The Status and Trends project includes the online visual mapping application called the Status and Trends Atlas:

www.texascoastalatlas.com

The Texas Coastal Atlas (the collection of Atlases created and hosted by CTBS) is stored on a secure server through Rackspace (www.Rackspace.com). The server has a quad-core processor (2.6 ghz), and 256 GB of RAM. The Texas Coastal Atlas upgraded to this server in August 2016 in order to provide better backup and security protection. The data is stored on a SQL server using ArcServer software. In addition, ArcPortal 10.4 was used to help distribute the data for the Status and Trends project. ArcPortal allows for dataset sharing, querying, charting, and time-aware datasets. The Status and Trends project also leverages data from other CTBS research projects, including several socio-economic variables.

This online web mapping application allows users to query, analyze, compare, plot, and download data. The following paragraphs discuss these capabilities in further detail. The Status and Trends Atlas has many functions that allows stakeholders to utilize, interpret, and make maps based on its data. The following is a list of all of the different capabilities:

1. Layer List
2. Legend
3. Draw
4. Print
5. Google Street View
6. Swipe
7. Query
8. Measure
9. Chart
10. Time Slider
11. Help
12. Metadata
13. Download
14. Access Other Atlases

The *Swipe* tool allows the user to select two layers and then toggle between them to see how the landscape looks with each layer. This is beneficial when viewing a layer such as land cover. The land cover from 1996 could be one layer and 2010 the other. When the user swipes between 1996 and 2010, he or she can see the changes that occurred between these two time periods.

The *Query* tool allows the user to query based on time period, parameter type, or spatial location. The query is used to select out a subset of data. The selected data can then be viewed on the screen separately, as well as exported to a CSV or printed through the built-in print map function.

Chart is a very important tool that allows the user to take a specific query and examine the parameter over time. For instance, the user can select a specific type of nutrient, such as ammonia for a portion of the Galveston Bay. This selection can then be plotted to observe ammonia levels across a specific date range in that specific portion of the bay.

The *Time Slider* tool is very helpful, particularly for the Texas Parks and Wildlife (TPWD) interpolations that are available on the Atlas. The interpolations are made time aware so that a user can use the time slider tool to see how the interpolated parameters change across the Galveston Bay.

The *Help* icon is useful for novice users or users who want to use some of the other tools available through the Atlas. *Help* provides descriptions of the available tools, guides for how to best use them, and a series of video tutorials. This option assists users to quickly learn specific tools and complete analyses on the Atlas.

The *Metadata* tab is one of the most valuable aspects of the Status and Trends Atlas. This tab includes metadata for all of the parameters available on the Status and Trends Atlas. The metadata is very comprehensive and includes information from the primary data source and contact to the specific processes, and even the scripting files that were used to complete the cleaning and processing of the data.

The *Download* button makes all of the Status and Trends data available for the user to download and manipulate offline as desired.

GENERAL METHODOLOGY

The Status and Trends project incorporates data from multiple sources and includes a variety of parameters. The full set of parameters for the Status and Trends project is shown in Figure 1. This section discusses the general analysis methodology and describes the spatial extent of the Lower Galveston Bay Watershed. One of the advantages of the CTBS Status and Trends project is the documentation of methodology, data analysis, and metadata provided for each dataset and parameter.

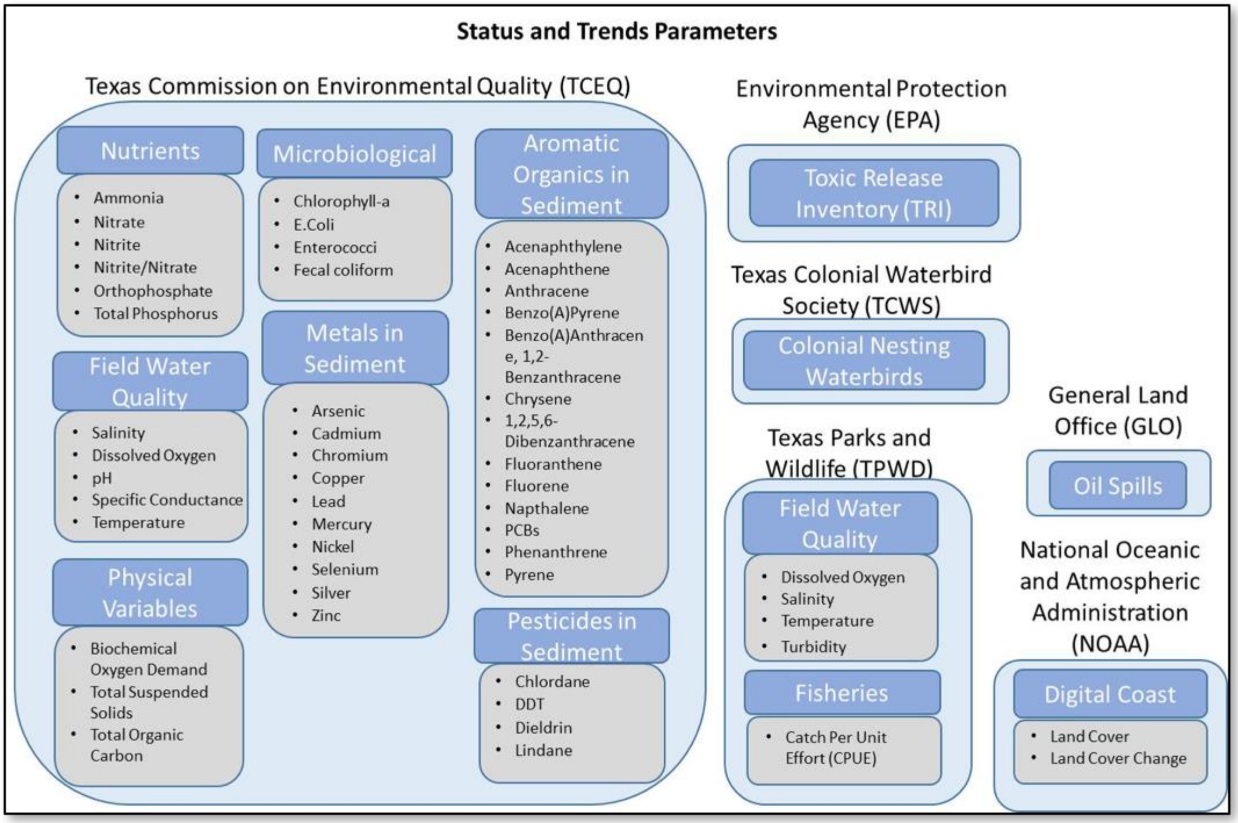


Figure 1: Parameters and data sources included in the 2017 Status and Trends project. These are the same parameters that are available on the Status and Trends Atlas. The data sources are located above each box, which lists specific parameters.

Spatial Extent

The spatial extent of this report is shown in Figure 2, which is known henceforth as the Lower Galveston Bay Watershed. For the Status and Trends project, all of the parameters are limited to samples collected in the Lower Galveston Bay Watershed. The Lower Galveston Bay Watershed has previously been used in reports for the Galveston Bay (Newell et al., 1994). The spatial extent of the data is made consistent across all parameters.

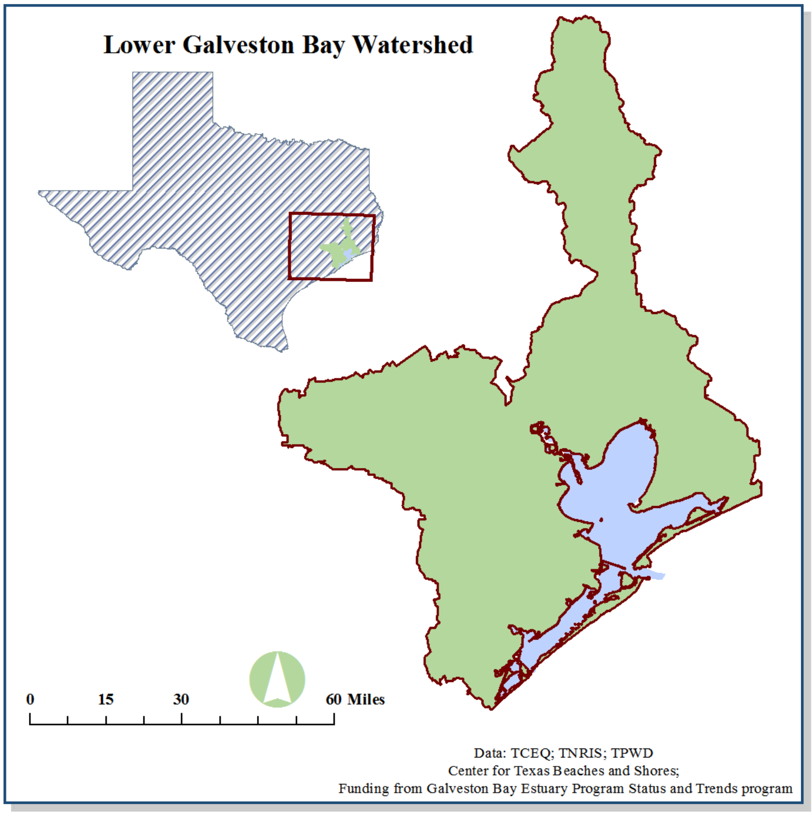


Figure 2: The spatial extent of the Lower Galveston Bay Watershed. The red box in the upper state of Texas map is the location of the Lower Galveston Bay Watershed and the green insert provides a larger image of the Watershed. Data for map from TCEQ, TNRIS, and TPWD.

The spatial extent of the Lower Galveston Bay Watershed is broken down into sub-regions for analysis, so a set of homogeneous samples could be isolated and analyzed (Figure 3). Out of all the sub-bays listed in Table 1, there were five that took priority for analysis in the Status and Trends report. These sub-bays are listed in Table 2. In addition to the sub-bays, the tributaries were also examined for environmental data trends. These tributaries are categorized by USGS watersheds and are listed in Table 2. It is important to include the tributaries because the indicators within the terrestrial environment are very vital. For analysis, the tributaries are divided into five watersheds that have boundaries from the United States Geological Survey (USGS) Hydrologic Unit Codes (HUCs). The five watersheds that are used in this report are included in Figure 4.

Table 1: List of subbays and other categories to define sampling points included in the 2017 Status and Trends database.

Subbays			**Other Categories**
1.Bastrop Bay	11.Dickinson Bay	21.Mud Lake	1.Tributaries
2.Black Duck Bay	12.Dollar Bay	22.Rollover Bay	2.Ocean
3.Boliver Roads	13.Drum Bay	23.San Jacinto Bay	3.Canal
4.Burnett Bay	14.East Bay	24.San Luis Pass	4.Reservoir
5.Carancahua Lake	15.Galveston Bay	25.Scott Bay	
6.Chocolate Bay	16.Green's Lake	26.Tabbs Bay	
7.Christmas Bay	17.Hall's Lake	27.Taylor Lake	
8.Clear Lake	18.Jones Bay	28.Trinity Bay	
9.Cox Lake	19.Lake Como	29.West Bay	
10.Crystal Bay	20.Moses Lake		

Table 2: Subbays and watersheds analyzed in the Status and Trends report.

Subbays	**Watersheds**
Christmas Bay	Buffalo San-Jacinto
Galveston Bay	East Galveston Bay
Trinity Bay	Lower Trinity
East Bay	North Galveston Bay
West Bay	West Galveston Bay

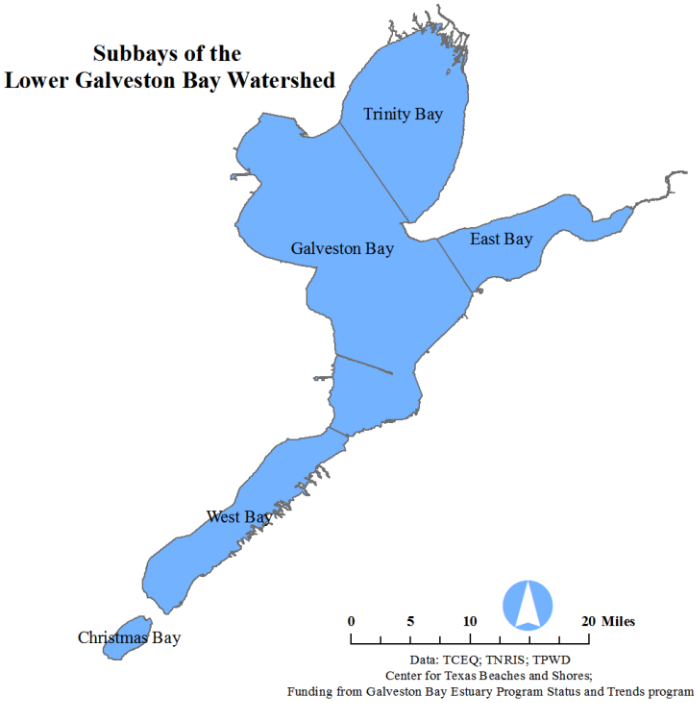


Figure 3: Select subbays of the Lower Galveston Bay Watershed used for analysis in the Status and Trends report. The subbays are defined by the Texas Parks and Wildlife Department.

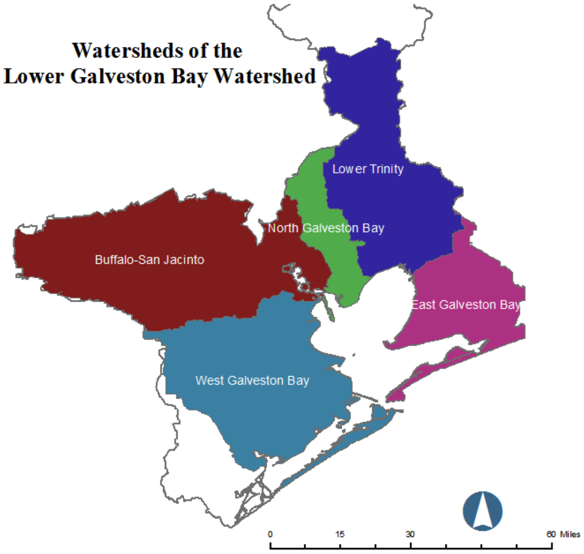
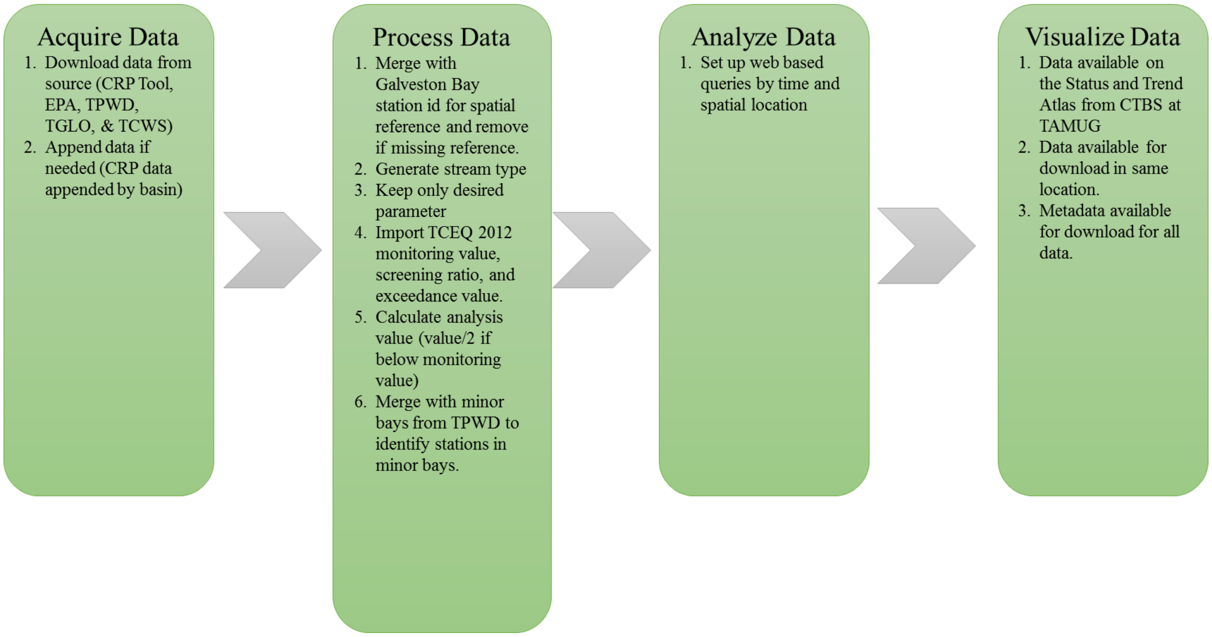


Figure 4: Watersheds that are used for analysis in the Status and Trends report. Each watershed is from the Hydrologic Unit Codes as defined by the United States Geological Survey.

Data Sources and Analysis

The following sections describe the methodology used to process each of the Status and Trends datasets. There are multiple data sources incorporated into the Status and Trends project. The ranges, parameter codes, and number of samples for each parameter or group are listed in Appendix C. The analytical approach for each dataset follows the same procedure: acquire data, process data, analyze data, and visualize data. Each of these categories has multiple steps that were completed to derive the final data product on the Status and Trends Atlas. This data process model is illustrated in Figure 5.



Acquire Data
1. Download data from source (CRP Tool, EPA, TPWD, TGLO, & TCWS)
2. Append data if needed (CRP data appended by basin)

Process Data
1. Merge with Galveston Bay station id for spatial reference and remove if missing reference.
2. Generate stream type
3. Keep only desired parameter
4. Import TCEQ 2012 monitoring value, screening ratio, and exceedance value.
5. Calculate analysis value (value/2 if below monitoring value)
6. Merge with minor bays from TPWD to identify stations in minor bays.

Analyze Data
1. Set up web based queries by time and spatial location

Visualize Data
1. Data available on the Status and Trend Atlas from CTBS at TAMUG
2. Data available for download in same location.
3. Metadata available for download for all data.

Figure 5: Data process to acquire, process, analyze, and visualize Status and Trends data.

Texas Commission on Environmental Quality (TCEQ)

The data obtained from TCEQ included the majority of the water quality indicators assessed in this project. These data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database and cover different categories, including: nutrients, field water quality, physical variables, aromatic organics in sediment, pesticides, microbiological, and metals in sediment. The SWQMIS database incorporates data from multiple submitting and collecting organizations (TCEQ, 2015). The submitting entity is responsible for submitting the data to the TCEQ and the collecting entity is the organization that collects the data in the field. Because there are many organizations that collect and provide data to the TCEQ, the set of parameters that is available through this database is very large. A full list of these parameters is listed in the Surface Water Quality Monitoring Data Management Reference Guide (TCEQ, 2015). The files are split into a sampling file and an events file. The sampling file contains only the data about the value sampled: station location (station ID), date and time characteristics, depth, and other fields. The events file includes the latitude and longitude of the station IDs so that the data can be spatially defined. When the data is submitted to the TCEQ SWQMIS database, it goes through a stringent quality assurance procedure before it is made publicly available (TCEQ, 2015). The data managers perform verification and validation checks. If corrections are needed, TCEQ staff contacts the appropriate entity to alter or validate the data (TCEQ, 2015).

When outliers are present in the data, they are dealt with in accordance to the SWQMIS Quality Assurance Procedure Plan (QAPP) (SWQMP, 2016). This excerpt from the QAPP (SWQM, 2016, pg. 80) describes this outlier analysis process:

> “Data validation level 2 compares the incoming data set with the data already existing in SWQMIS. Outliers are identified through checks against predefined ranges for each parameter. The SWQM project manager verifies each outlier or

> checks with the data submitter to resolve issues. The SWQM Program based the predefined ranges for outlier screening on the historical data record. The screening levels are also hierarchal, with screening values at the monitoring station, segment, basin, and statewide level. The outlier screening levels are based on the 1st and 99th percentile for each parameter. In order to avoid data bias, a minimum record count of 25 values is needed for the calculation. For example, if there are not at least 25 data points at the monitoring station level to set screening values, then the segment level is used. If there are not at least 25 records to set a screening level at the segment level, then the outlier check uses the basin level, etc. This allows for more water body specific screening levels and for monitoring stations with little data to use the less specific range until enough data has been collected to accurately set a more specific one. This method of outlier development is currently under review."

The data analyzed in this project is pulled from the Clean River Program (CRP). The CRP is accessiblethroughtheCRPdatatool: http://www80.tceq.texas.gov/SwqmisWeb/public/crpweb.faces. In order to access this data through the CRP website, the specific parameter or set of parameters is selected for each basin of interest. For the spatial extent of this project, there are seven basins that are fully or partially located within the Lower Galveston Bay Watershed (Table 4). While the entire SWQMIS database contains many monitoring codes, certain ones are omitted from the CRP database due to reduced reliability. The Status and Trends report pulls from the CRP database to ensure only the most reliable data are being used. The omitted monitoring types are listed in Table 3.

Table 3: Omitted monitoring types from SWQMIS CRP database.

Omitted Monitoring Types
biased event (BE)
biased flow (BF)
continuous data (CD)
continuous event (CE)
continuous flow (CF)
continuous quality assurance (CQ)
continuous season (CS)
continuous routine (CT)
DQO's not appropriate for 305(b) assessment (NA)
DQO's not appropriate for 305(b) 24 hour data (NI)
Non-point source sampling – samples that characterize non-point source loading (NP)
non-surface water sampling (NS)
real-time continuous monitoring (RS)
receiving water assessment (RW)
special event – sampling done at fish kills, spills, flood events (SE)
targeted monitoring (TM)
sampling collected under a TMDL QAPP, but not appropriate for 305(b) assessment (TN)
targeted monitoring special study – site specific monitoring to support permit actions (TS)
SWQM acquired nonpoint source sampling (XN)
equipment blank (EB)
field blank (FB)
field split (FS)
trip blank (TB)
quality assurance (QA)
data that is not from an accredited laboratory

Table 4: TCEQ Basin number and name.

Basin Number	Basin Name
7	Neches-Trinity Coastal Basin
8	Trinity River Basin
9	Trinity-San Jacinto Coastal Basin
10	San Jacinto River Basin
11	San Jacinto-Brazos Coastal Basin
24	Bays and Estuaries
25	Gulf of Mexico

The time period of each dataset varies, with ranges between 1969 and 2015. This variability is due to differences in sampling time, available funding, and where the data was updated for the previous Status and Trends project. When data were collected and analyzed in a lab, they were given a field that designates whether or not the sample value is above or below the Limit of

Quantitation/Reporting (LOQ). The LOQ is provided by the laboratory and is the lowest concentration at which the machinery can report a substance with a reasonable level of confidence. Each organization that submits data to the SWQMIS database has to have a QAPP in which the LOQ for each laboratory is defined. When a value is below the LOQ, the value is divided by two. This is a commonly-accepted method of analysis to calculate a value below the LOQ and was the same procedure that was used in the 2008 Status and Trends report (Gonzalez & Lester, 2008).

Exceedances

When applicable, exceedance levels are calculated for each parameter. These exceedance levels are based on the TCEQ screening levels obtained from the 2012 Guidance for Assessing and Reporting Surface Water Quality in Texas (TCEQ, 2012). This report is prepared in *"compliance with Sections 305(b) and 303(d) of the Federal Clean Water Act"* (TCEQ, 2012). In order to determine whether or not an observation has exceeded this screening level, a simple calculation of dividing the observation value by the TCEQ screening level was performed by TAMUG. If the value to screening ratio is above 1, then the observation is in exceedance and receives a score of one. In other cases, if the sample is less than the screening ratio, the sample is not in exceedance and receives a value of zero. Exceedance values are a binary variable and demonstrate whether each observation is above or below the screening levels for a particular ecosystem (e.g., salt water tributary, salt water subbay, or freshwater stream). Once the data has undergone a basic cleaning processes, the exceedance is calculated for each observation based on the screening level or probable effects level (PEL) (screening levels and PELs are listed in Appendix B).

Texas Parks and Wildlife Department

Texas Parks and Wildlife (TPWD) conducts routine sampling of hydrologic parameters and fisheries stocks within the Lower Galveston Bay Watershed. There are four different methods of collection that is included in their fisheries independent data monitoring program: gill net, trawl, bag seine, and oyster dredge. Each collection method is discussed in more depth in following sections. The hydrologic data includes four water quality parameters: dissolved oxygen (mg/l), salinity (PPT), temperature (degrees Celsius), and turbidity (NTUs: Nephelometric Turbidity Units). The fisheries data is utilized to calculate catch per unit effort (CPUE). The fisheries CPUE data were calculated by TAMUG for all species (full list of species included in Appendix D). A detailed description of TPWD collection methods for these data was obtained from *"Trends in relative abundance and size of selected finfishes and shellfishes along the Texas coast: November 1975- December 2003"* (Martinez-Andrade, Campbell, & Fuls, 2005) and the TPWD Resource Monitoring Operations Manual (Martinez-Andrade & Fisher, 2012).

Gill Nets

The gill net monitoring program was implemented in 1975 (Martinez-Andrade et al., 2005). According to Martinez-Andrade et al. (2005), the gill nets are used in the spring and fall to collect fish. Gill nets are primarily used to sample *"subadult and adult fish"* (Martinez-Andrade & Fisher, 2012). Hydrological data is collected during gill net sampling using a hydrologic sampling meter (YSI). According to the TPWD Resource Monitoring Operations Manual, 90 samples are collected by gill net for the Lower Galveston Bay Watershed in a calendar year

(Martinez-Andrade & Fisher, 2012, Table 2). The specifics of gill net collections are found in the TPWD Resource Monitoring Operations Manual (Martinez-Andrade & Fisher, 2012).

> *"Gill nets are set perpendicular to shore at or near sunset, with the smallest mesh nearest the shore and retrieved as soon as possible following sunrise the next day" (Martinez-Andrade & Fisher, 2012)*

The collected data include *"water depth and hydrological data at end of gill net farthest from shore following set and again the next morning before net retrieval begins. Sample should be collected from surface water 0-15.2 cm (0-6 in) and bottle labeled appropriately for transport to field station."* (Martinez-Andrade & Fisher, 2012).

Trawls

The trawl monitoring program was implemented in 1982 for the bays and in 1985 for the Gulf (Martinez-Andrade et al., 2005). According to Martinez-Andrade et al. (2005), trawls are used to sample monthly. All trawls in the bay are 10 minutes long and towed within the subbays (Martinez-Andrade et al., 2005). Trawls in the gulf are also 10 minutes long and *"trawls were towed linearly, parallel to the fathom curve; direction of tow (north or south) was randomly chosen for the initial tow and alternated on subsequent tows"* (Martinez-Andrade et al., 2005).

Trawls are primarily used to collect *"juvenile and subadult fish and invertebrates"* (Martinez-Andrade & Fisher, 2012). According to the Texas Parks and Wildlife Resource Monitoring Operations Manual (Martinez-Andrade & Fisher, 2012, Table 2), the Lower Galveston Bay Watershed has 240 samples collected by bay trawl and 192 collected by gulf trawl annually. There is extensive documentation on how both bay and gulf trawl sampling is conducted. Extensive documentation of collection methods can be found in the TPWD Resource Monitoring Operations Manual (Martinez-Andrade & Fisher, 2012).

> *"Coastal Fisheries trawls are 6.1 m (20 ft) wide otter trawls with 38 mm (1.5 in) stretched nylon multifilament mesh throughout. Trawl doors are 1.2 m (48 in) long and 0.5 m (20 in) wide, and constructed of 13 mm (0.5 in) plywood with angle iron framework and iron runners"* (Martinez-Andrade & Fisher, 2012).

Hydrological data is collected during trawls using a hydrologic sampling meter (YSI). This hydrological data is collected *"0.3 m (12 in) off bottom before trawling begins"* (Martinez-Andrade & Fisher, 2012).

Bag Seines

The bag seines monitoring program was implemented in 1977 (Martinez-Andrade et al., 2005). According to Martinez-Andrade et al. (2005), bag seines are used to sample monthly. This collection method is used to primarily collect *"fish and invertebrates"* (Martinez-Andrade & Fisher, 2012). According to the Texas Parks and Wildlife Resource Monitoring Operations Manual (Martinez-Andrade & Fisher, 2012, Table 2), Lower Galveston Bay Watershed has 240 samples collected by bag seine annually. Bag seines are *"pulled parallel to the shoreline for 15.2 m. The surface area sampled (nearest 0.01 ha) was estimated using distance pulled and length of extension of the bag seine"* (Martinez-Andrade et al., 2005).

Hydrological data is collected during gill net sampling using a hydrologic sampling meter (YSI). This hydrological data is collected *"approximately 3.1m (10 ft.) from shore. Sample should be collected from surface water (0-15 cm). To prevent catch bias, hydrological samples should be collected immediately adjacent to area intended for seining and away from prop wash."* (Martinez-Andrade & Fisher, 2012).

Oyster Dredge

The oyster dredge monitoring program was implemented in 1984 (Martinez-Andrade et al., 2005). According to Martinez-Andrade et al. (2005), oyster dredges are used to sample monthly. This collection method is conducted across oyster reefs and collects *"spat, juvenile and adult oysters"* (Martinez-Andrade & Fisher, 2012). According to the Texas Parks and Wildlife Resource Monitoring Operations Manual, the Lower Galveston Bay Watershed has 360 samples collected by oyster dredge annually (Martinez-Andrade & Fisher, 2012, Table 2). Oyster dredges are sampled in areas where there are defined reefs, and the dredges are *"pulled linearly for 30 seconds"* (Martinez-Andrade et al., 2005).

Hydrological data is collected during dredging using a hydrologic sampling meter (YSI) and is collected *"0.3 m off bottom"* (Martinez-Andrade & Fisher, 2012).

Catch per Unit Effort

Catch per unit effort (CPUE) is calculated by TAMUG. A flow chart depicting the CPUE calculation is shown below (Figure 6). TPWD collection methods determine how CPUE is calculated. If the collection method is using a bag seine, the total sample is divided by the number of attempts and multiplied by 0.03 resulting in catch per hectare. If the collection method is not bag seine, then the units of CPUE are catch per hour, meaning the total sample is divided by sample time (Figure 6):

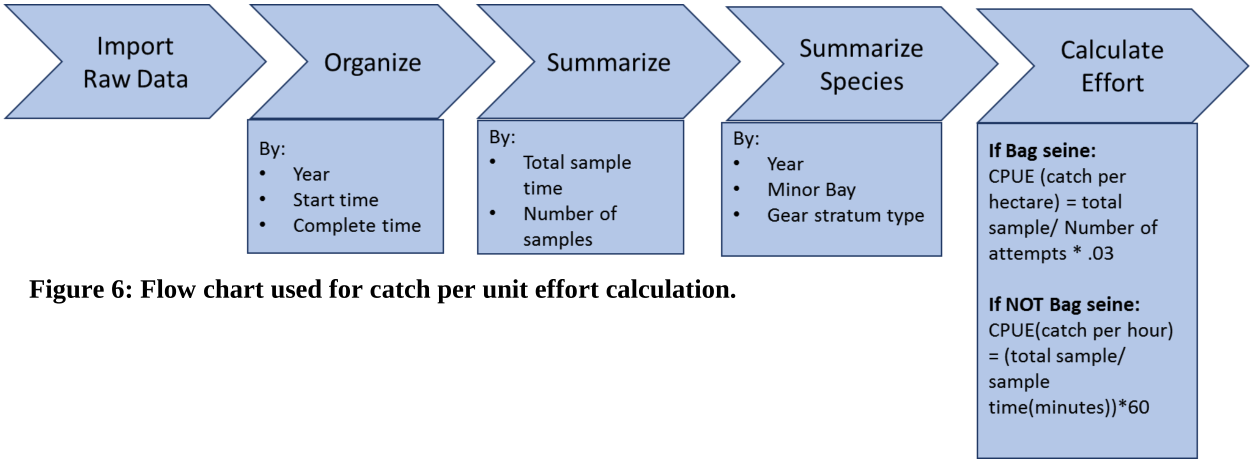


Figure 6: Flow chart used for catch per unit effort calculation.

Hydrological Data

Each of the four water quality parameters measured by TPWD were interpolated throughout the Lower Galveston Bay Watershed by season, year, and parameter. The depths for each of these parameters are included in the gear type collection methods sections. This analytical technique was done using a Python script that iterated through each parameter, generating an interpolation that utilized 100 points or greater and shows the trend of each parameter. A 100-point threshold was used to ensure a robust enough sample to have a reliable interpolation (Burrough and McDonnell, 1998). The interpolation used for these calculations is an inverse weighted distance and performed in ArcMap10.4. An example of the temperature interpolations in 2010 is shown in Figure 7. An interpolation is available on the CTBS Status and Trends Atlas for every parameter year and season (three-month grouping).

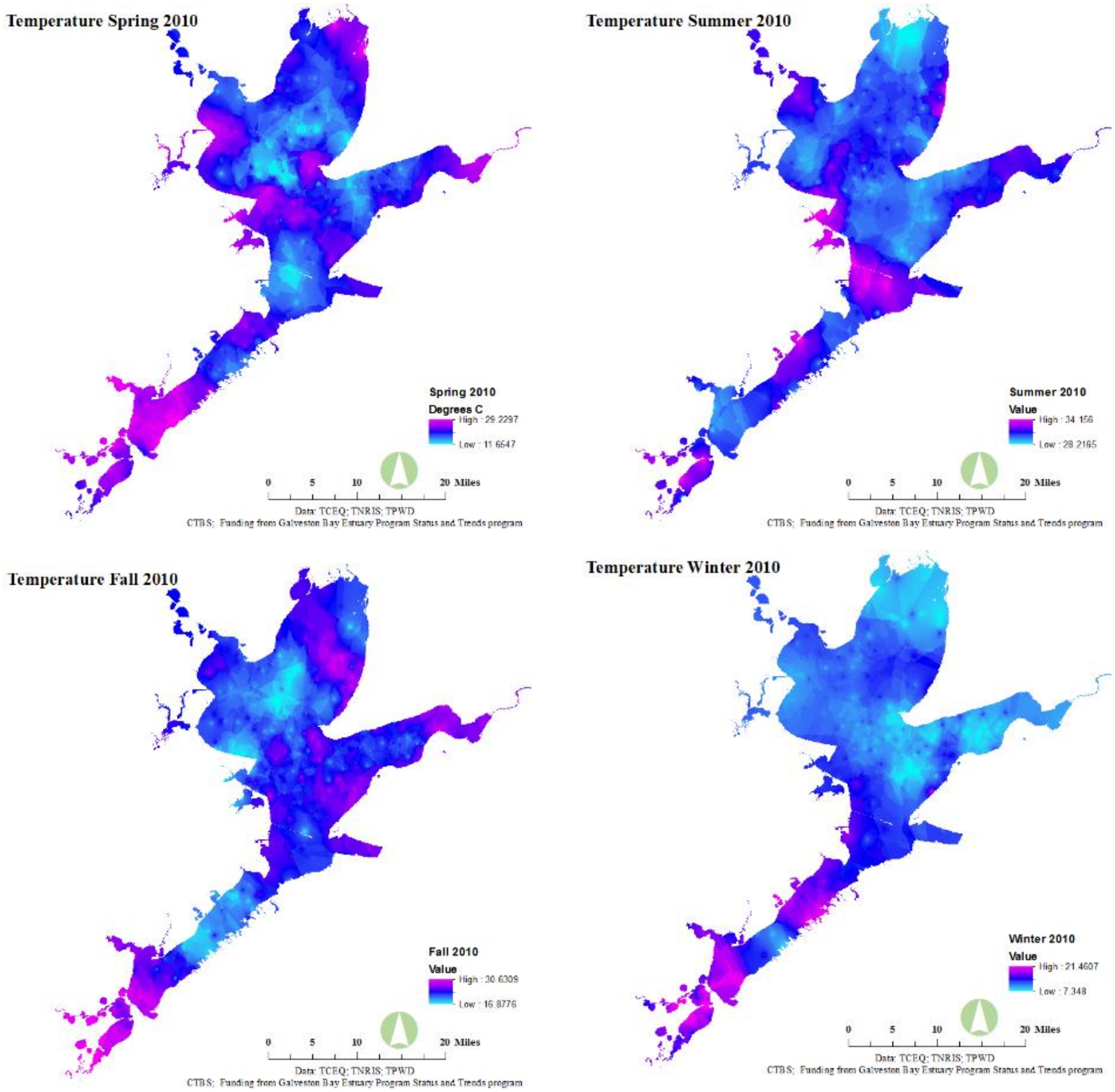


Figure 7: Temperature interpolations for four seasons in 2010 based on data from the Texas Parks and Wildlife Department. Each interpolation that is provided in the Status and Trends Atlas is based on an inverse weighted distance interpolation (IDW) calculated in ArcMap10.4. Each interpolated surface is based on at least 100 observation periods over the three-month season for each parameter.

General Land Office (GLO)

Oil spills data were obtained from the General Land Office (GLO) through communication with the open records specialist. The only manipulation that occurred with this data was to remove the non-spatial data components. The original dataset provided by GLO contained 323 observations, 18 of which had no spatial reference and therefore were dropped from the dataset. The attributes in this dataset are spill number (unique identifier of the spill number), spill source (where the spill originated from), description (description of the spill), date, region, county, water body spilled in, responsible party, amount in water (recorded in gallons), latitude, and longitude. The

Oil Spill Prevention and Response program at the GLO is responsible for the collection of these data. GLO adheres to the *Response and Incident Report Manual* to collect the data that are available for oil spills (TGLO, 2015).

Audubon Texas (AT)

The Audubon Texas (AT) chapter compiles Colonial Nesting Waterbirds data, which is collected by a volunteer network coordinated by the United State Fish and Wildlife Service (USFWS). This data includes many different waterbird species located within the Lower Galveston Bay Watershed ranging from 1973 to the present. At the time of the analysis, there were 6,898 total observations. These species are listed in Table 5.

Table 5: Colonial Nesting Waterbird species included in the Status and Trends database, 1973-Present.

Waterbird Species in Status and Trends Database
Anhinga
Black-crowned night-heron
Black skimmer
Brown pelican
Caspian tern
Cattle egret
Double-crested cormorant
Foster’s tern
Great blue heron
Great egret
Gull-billed tern
Laughing gull
Little blue heron
Least tern
Neotropic cormorant
Reddish egret
Roseate spoonbill
Royal tern
Sandwich tern
Snowy egret
Tricolored heron
White-faced ibis
White ibis
Yellow-crowned night-heron

Attributes within this dataset include colony code (a unique code for each colony), colony name (unique name of the colony), county, region (which region the observation is located in), latitude, longitude, year of siting, species name (name of specific bird species), units (whether or not the birds were recorded as a pair or single), and bird count (number of birds or pairs of birds observed).

Environmental Protection Agency (EPA)

The Toxics Release Inventory (TRI) data was obtained from the Environmental Protection Agency's (EPA) database in the Toxics Release Inventory Program (https://www.epa.gov/toxics-release-inventory-tri-program/tri-data-and-tools#tab-3). There were multiple fields included in the original dataset, and during the cleaning and processing conducted by TAMUG these fields were paired down to the following: year of release, TRI facility ID (facility identification number), FRS ID (identification number from EPA's Facility Registry System), facility name, street address, city, county, ST (State), ZIP (zip code), BIA (If the facility is on tribal land), Federal Facility (Whether or not facility is federal or not), Total Releases (total on and offsite releases), production waste (total amount of waste), and parent company (name of parent company). The temporal extent of the data is from 1987-2014.

National Oceanic and Atmospheric Administration (NOAA)

The National Oceanic and Atmospheric Administration (NOAA) oversees the Coastal Change Analysis Program (C-CAP), which hosts land cover data for the entire coast of the United States. This data is used to examine the land cover of the Lower Galveston Bay Watershed. The land cover data available for the region is available for years 1996, 2001, 2006, and 2010.

It should be noted that other important emissions, discharges, and environmental impacts are not included in the Status and Trends monitoring program. These include: chemical hazmat spills, air pollutants, stormwater overflows, permitted wastewater discharges, illegal dumping of municipal waste, red tide events, etc. As such, this report should only be considered a partial assessment of the health of the Bay. Any overall conclusions should be made with recognition that there are major data gaps in this report.

Quality Assurance

Each data source has a quality assurance level assigned to it based on the quality of the data that is received from the agency.

TCEQ: High

This data is attributed high quality because the primary data source has an EPA QAPP. The data processed for this report is secondary data and has well documented metadata.

TPWD: High

This data is attributed high quality because the primary data source has a QAPP. The data processed for this report is secondary data and has well documented metadata.

GLO: High

This data is attributed high quality because the primary data source has a Response and Incident Report Manual that outlines how oil spill data is to be collected. The data processed for this report is secondary data and has well documented metadata.

AT: High

This data is attributed high quality because the primary data source is TPWD (branch TCWS and managed by AT). The data processed for this report is secondary data and has well documented metadata.

EPA: High

Since this data is provided by a federal agency they are held to certain quality assurance standards, and therefore the data is listed as high quality. The data processed for this report is secondary data and has well documented metadata.

NOAA: High

These data are obtained through the federal government, and the data are required to be collected at a certain quality level. For this reason, the data processed for this report is secondary data and has high quality.

RESULTS, OBSERVATIONS, AND DISCUSSION

Nutrients

Total Phosphorus, Orthophosphate, Nitrate/Nitrite, Nitrate, Nitrite, & Ammonia

General Status of Nutrients

Overall, the status of the nutrients in the Lower Galveston Bay Watershed is characterized by decreasing levels of ammonia and total phosphorus from the 1970s to 2015. In addition, the exceedance proportions have also decreased, which indicates that there are proportionally fewer samples above the levels recommended by the TCEQ. However, isolating only the last fifteen years (2000-2015) shows that some parameters have increasing trends. These trends are discussed more in the following sections for the following nutrients: ammonia, total phosphorus, nitrate/nitrite, nitrate, nitrite, and orthophosphate. All data were accessed from the TCEQ SWQMIS CRP tool.

Detailed analysis of nutrients

Total Phosphorus

To better understand and visualize data trends, we use a commonly statistical procedure call LOESS Curve Fitting (local polynomial regression). This technique fits a smooth curve between two variables using nonparametric assumptions. This is a popular tool used in regression analysis that creates a smooth line through a timeplot or scatter plot to help vizualize relationship between variables and foresee trends. The approach is particularly useful where noisy data values, sparse data points, or weak interrelationships interfere with the ability to see a line of best fit.

Overall, the concentration of total phosphorus in the subbays and watersheds exhibits a downward trend over the entire time period measured (late 1960s through 2015). When only 2000-2015 is isolated for analysis, there is still a weak downward trend in the subbays. However, an increasing trend is observed in the Lower Galveston Bay watersheds. For this reason, both the entire time period for the subbays and watersheds are discussed in addition to the 2000-2015 time period.

Winter and spring have the strongest decreasing trends in phosphorous concentrations (Figure 8, Images C&D). The specific subbays showing these strong trends are Galveston Bay, Trinity Bay, and West Bay. It should be noted that in West Bay for winter and spring season, there are some large gaps in the data (Figure 8, Images E&F). In the winter trend line, there is a relatively sharp decrease until about 1990 and then a plateau of total phosphorus levels. This is why the LOESS regression (grey line and grey shaded confidence intervals) is present in Figure 8. In the faceted plot for the spring season, the data show that West Bay has a decreasing trend with an R^2 of 0.528. However, there is a lack of data in the first two decades of the graph, and the confidence interval of the LOESS regression is very large.

The exceedance graph for annual total phosphorus exceedance proportion in the subbays has a downwards trend with an R^2 of 0.561 (Figure 8, Image A). The LOESS regression line shows this more specifically; the downward trend starts around 1985, plateaus about ten years later, and is relatively flat thereafter. The yearly trend for total phosphorus in the five major subbays shows a decreasing trend with an R^2 of 0.389 (Figure 8, Image B).

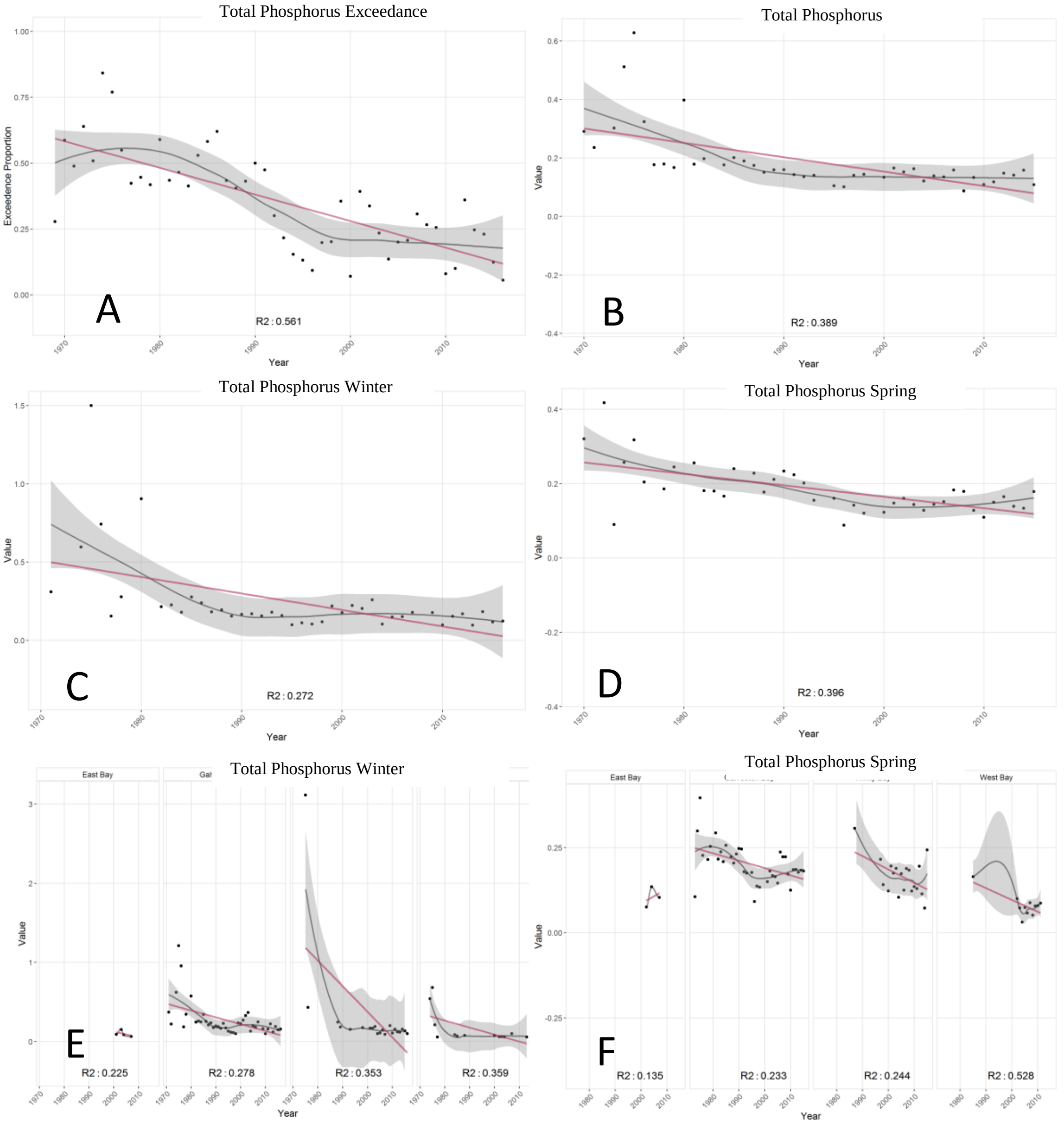


Figure 8: Total Phosphorus concentration values and exceedance proportion for the watersheds across seasons and subbays. Image A displays the exceedance proportion of total phosphorus. Image B graphs the annual average values of total phosphorus. Image C is the annual trend of total phosphorus. Image D displays the spring seasonal trend. Image E displays the annual winter values categorized by the subbays, and image F is the annual spring values categorized by the subbays. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology (Appendix A) section of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

The total phosphorus levels in the watersheds of the Lower Galveston Bay Watershed are decreasing in general. Throughout the entire study period, there are moderate downward trends for every season annually (Figure 9). Both the Buffalo-San Jacinto and North Galveston Bay watersheds seem to be driving this overall trend.

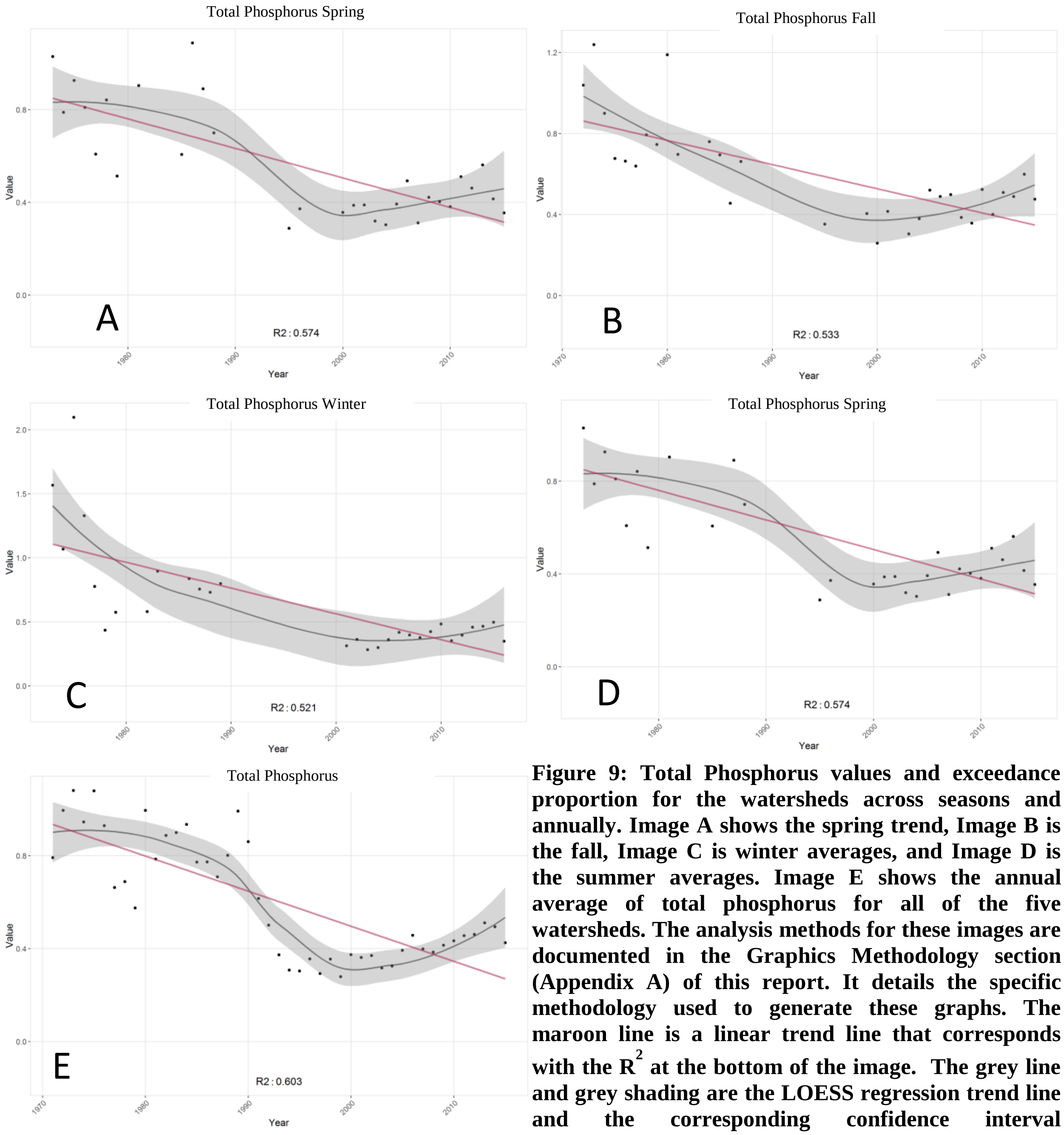


Figure 9: Total Phosphorus values and exceedance proportion for the watersheds across seasons and annually. Image A shows the spring trend, Image B is the fall, Image C is winter averages, and Image D is the summer averages. Image E shows the annual average of total phosphorus for all of the five watersheds. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

In all of the seasons, there is a noticeable data gap during the early 1990s. The LOESS regression in Figure 9 displays a dip until about 2000 and then an increase in total phosphorus values. When 2000-2015 time period is examined, all of the seasonal and annual averages are all positive. The annual trend shows a moderate decrease (R^2 is 0.699) and all of the seasons exhibit similar trends (summer R^2: 0.438, winter R^2:0.412, fall R^2:0.398, and spring R^2: 0.208). By watershed, for the 2000-2015-time period, North Galveston Bay has a couple seasons with moderately increasing trends (fall R^2: 0.322, summer R^2: 0.261). In the Lower Trinity Watershed, fall, winter, and spring all show decreasing trends (R^2: 0.288, R^2: 0.361, and R^2: 0.704 respectively).

Seasonally, on average the trend in fall, winter, and summer have decreasing trends as well as the annual average of total phosphorus in the five watersheds within the Status and Trends study area.

Orthophosphate (PO_4^{3-})

Orthophosphates have the chemical formula of PO_4^3 and can be introduced into water through multiple sources. Two of these sources are runoff and sewage treatment plants (Kinniburgh & Barnett, 2010). Runoff can lead to potential algal blooms, eutrophication, and resulting oxygen deficiencies (see the dissolved oxygen section for the effects of low oxygen levels) (NCSU, 2003).

The TCEQ data for orthophosphate is relatively limited and, as a result, there are not enough years and seasons sampled to show reliable trends in the subbays of the Lower Galveston Bay Watershed. The yearly average and exceedance proportion graphs for the subbays only have eight years of adequate sampling, and the seasonal averages have been sampled for four to six years. For this reason, there is no trend that can be determined in the orthophosphate levels of the subbays.

The number of orthophosphate samples in the watershed of the Lower Galveston Bay Watershed has more data points. The exceedances across the entire time period has decreased moderately (R^2: 0.372). In addition, the trend of the orthophosphate values from the early 1970s to present day have decreased annually across all watersheds (R^2: 0.618). However, there is minimal sampling up until 2000 (only four years with sufficient data). When examining the 2000-2015-time period by watersheds, there is no definitive trend.

Nitrogen

There are multiple forms of nitrogen that are analyzed and included in the Status and Trends report. Each type of nitrogen is slightly different and is useful to determine the water quality of the location where the sample was taken. In general, an excess of nitrogen can lead to eutrophication including hypoxia and low levels of dissolved oxygen (see the dissolved oxygen section for more details about the effects of hypoxia) (EPA, 2013).

> *“Sources of nitrogen include: wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges that contain corrosion inhibitors”* (EPA, 2013).

There are four different nitrogen parameters that are included in the Status and Trends project: ammonia, nitrate/nitrite, nitrate, and nitrite. All four of these types of nitrogen are inorganic. In surface water, nitrate is the primary form of inorganic nitrogen that is found. Ammonia is typically higher in areas that are near anthropogenic forces or sites that produce animal waste (Wall, 2013).

Nitrate/Nitrite

Frequently, nitrate and nitrite are measured together since nitrite is an intermediary product. When this is done, the levels of nitrite are normally lower than nitrate, but a combination of the two makes for an inclusive measurement (Wall, 2013). Nitrate/Nitrite overall does not have much of a trend in the five major subbays. The exceedance proportion has a very low R^2 of 0.012, indicating no substantial trend (Figure 10 Image A). However, in examining the LEOSS regression line we see there is an increase until 1990 and then a decrease and a plateau about ten years later. The average annual nitrate/nitrite for the major subbays is decreasing very slightly from the mid- 1970s to present day (R^2 of 0.0625) (Figure 10, Image B).

Seasonally, there are moderately increasing trends in spring (R^2: 0.225) and summer (R^2: 0.216) (Figure 10, Image C&D). The subbay with the most sampling is Galveston Bay, which has slight decreasing trends during spring and summer (Figure 10, Image E&F). In summary, we do not see a strong trend of nitrate/nitrite over time across the subbays. The watersheds do not have distinctive trends for nitrate/nitrite on average seasonally or annually. On a watershed, seasonal level, North Galveston Bay in winter and spring both have moderate, decreasing trends. The average seasonal trend for fall across all the watersheds is moderately increasing, and the trend for the spring is moderately decreasing. North Galveston Bay has a moderately decreasing trend in the winter and spring.

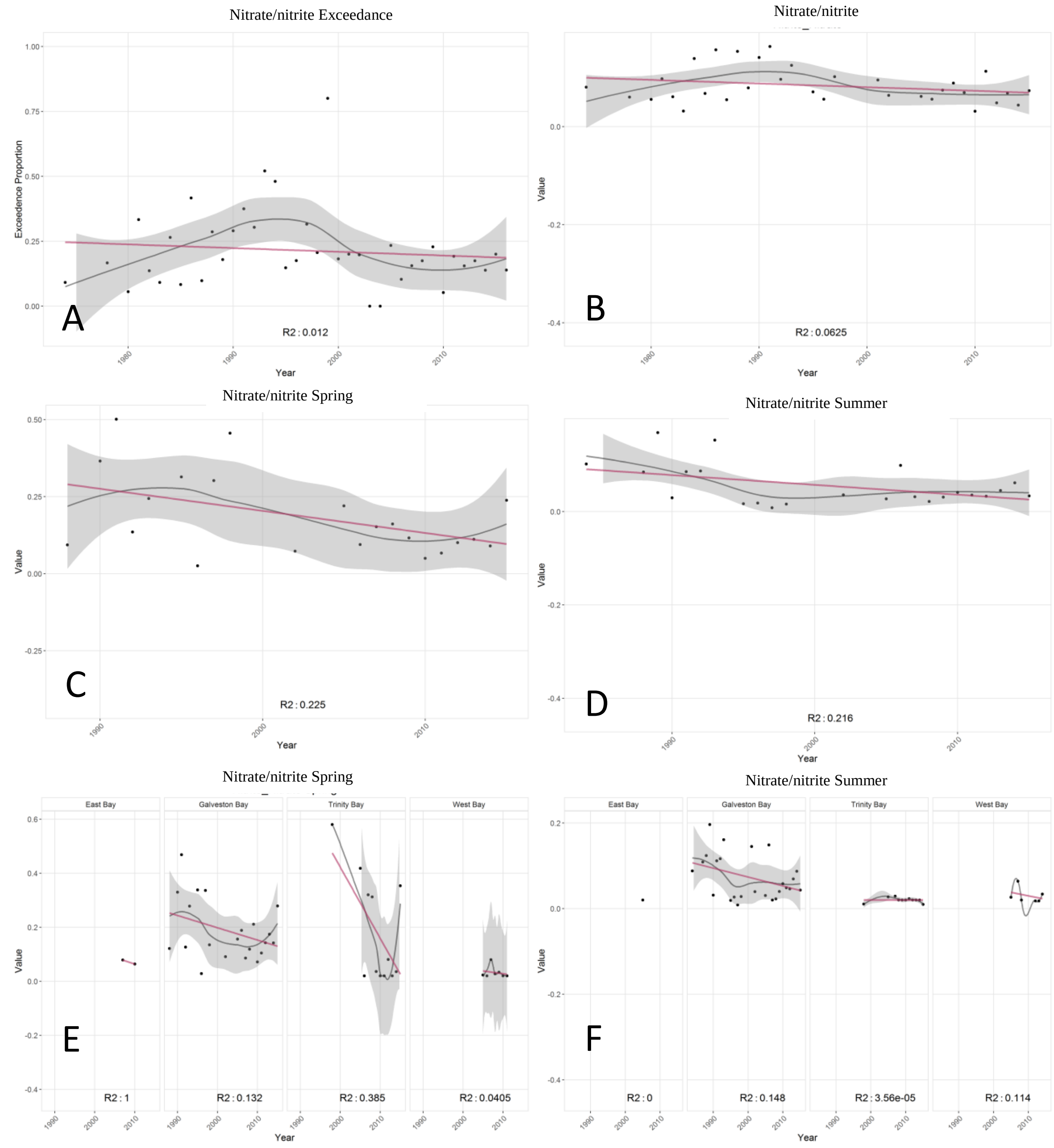


Figure 10: Nitrate/nitrite values and exceedance proportion in the subbays, seasonally, and annually in the Lower Galveston Bay Watershed. Image A shows the exceedance proportion of nitrate/nitrite. Image B is the annual averages and Image C shows the annual spring trend. Image D shows the annual summer trend, image E displays the annual spring values broken-down by the subbays, and image F is the annual summer values by the subbays. However, in some graphs all five bays are not displayed represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The marron line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading is the LOESS regression trend line and the corresponding confidence interval. The black dots are the actual values that are being plotted on the chart.

Nitrate (NO_3^-)

Nitrate (NO_3^-) is the form that many other nitrogen forms are converted into during the nitrogen cycle. Other forms of nitrogen found in fertilizers, soils, and waste are all transformed into nitrate (Wall, 2013). Excess levels of this nutrient can contribute to the development of hypoxia (low, < 2 mg/L, dissolved oxygen levels) or even anoxia (lack of oxygen). Nitrate can be added to the water through multiple sources, including sewage treatment plants and urban runoff.

Overall, nitrate has an increasing trend in both average annual values and annual exceedance proportion (Figure 11 images A&B). Out of the four seasons, the largest increase is seen during the summer (Figure 11 image C). The other seasons also have smaller increasing trends. Within the summer, the subbay with the strongest increasing trend is in Galveston Bay (Figure 11 image D). This subbay has relatively frequent sampling whereas none of the other subbays are sampled enough to be able to draw a reliable trend.

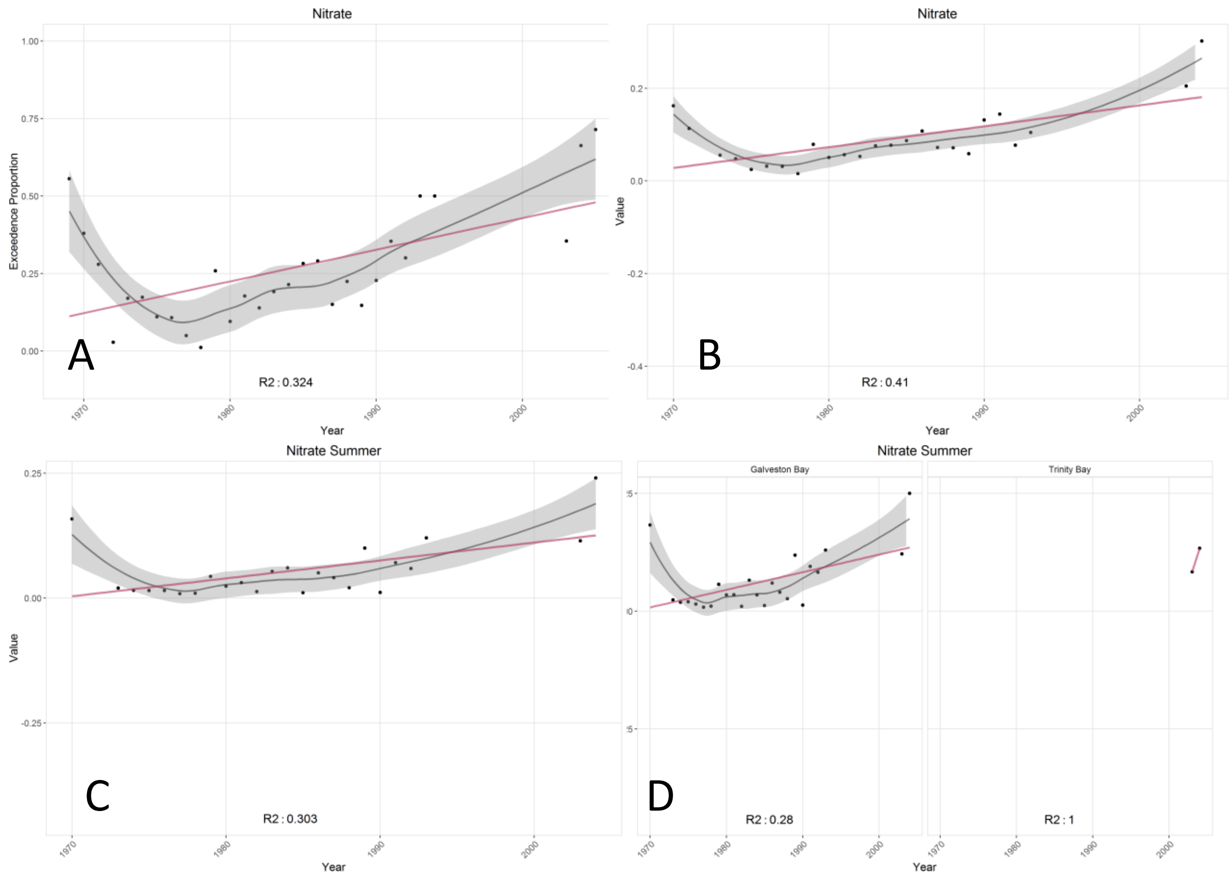


Figure 11. Nitrate values and exceedance proportion in the subbays of the Lower Galveston Bay Watershed. Image A shows the exceedance proportion and Image B, is the annual average for nitrate. Image C shows the annual summer nitrate trend, and image D displays the annual summer nitrate values by the subbays. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Nitrite (NO_2^-)

Levels of nitrite (NO_2^-) are typically low, and nitrite is often measured in conjunction with nitrate. The sources of nitrite are the same as nitrate, and the adverse health effects are similar (Wall, 2013).

> *Nitrite is "an intermediate product when ammonium is transformed into nitrate by microscopic organisms, and is therefore seldom elevated in waters for long periods of time"* (Wall, 2013).

Nitrite, like nitrate, has an overall increasing trend in the subbays of the Lower Galveston Bay Watersheds. The annual average is increasing steadily (R^2: 0.433) as is the exceedance proportion (R^2: 0.496) (Figure 12, Images A&B). There are not enough years sampled for any of the seasons to determine a trend (at most six years with reliable samples). In addition to the minimal sampling in the subbays, there were low sampling numbers in the watersheds, making it challenging to draw any reliable trends. The exceedance proportion shows a decreasing trend (R^2: 0.248) across the watersheds in the Lower Galveston Bay Watershed. There is a gap in data between the late 1990s and early 2000s, which is noted by the image in Figure 12 (Images C & D). In addition, the yearly trend for the watersheds has a moderately downward trend (R^2: 0.329). The data gap between the late 1990s and early 2000s still exists for this graphic (Figure 12, Image D).

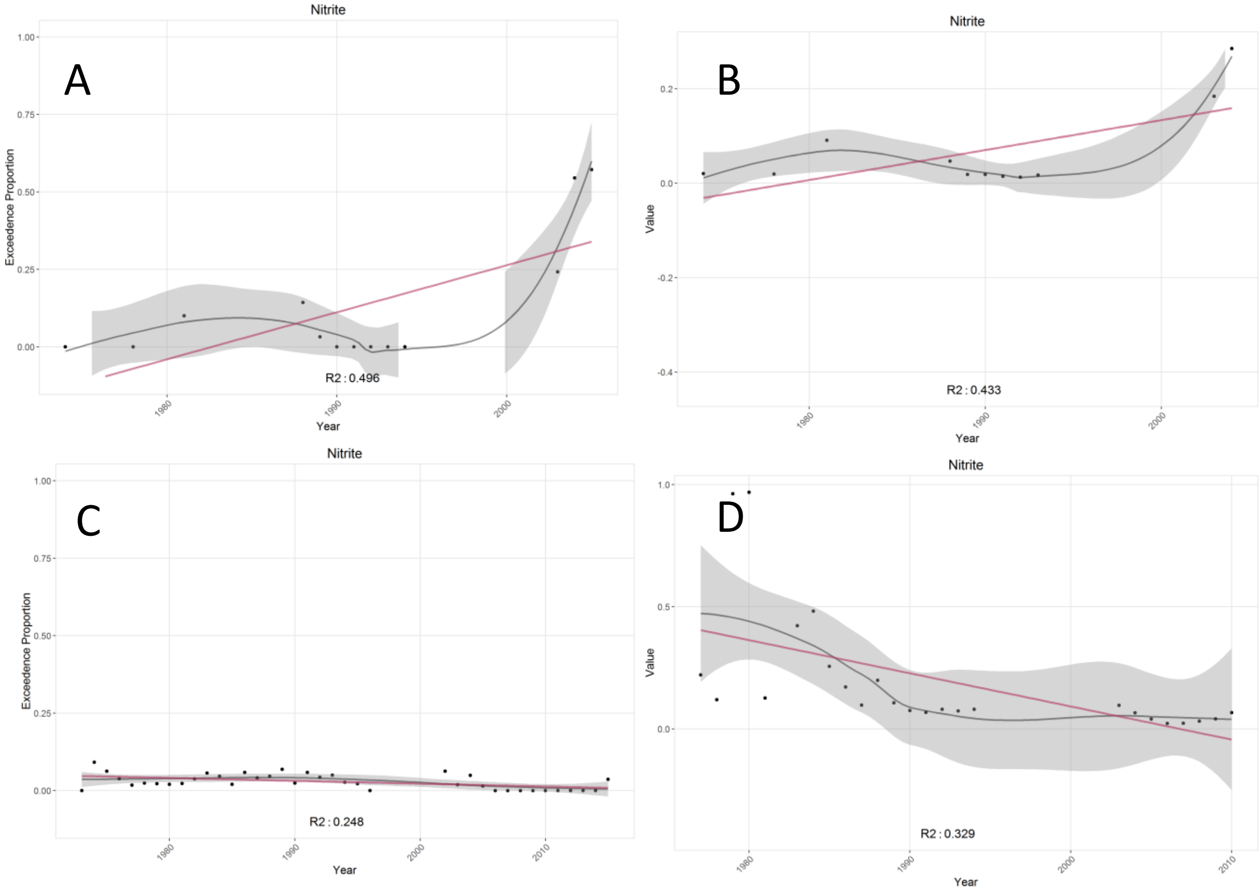


Figure 12: Nitrite values and exceedance proportion annually in the subbays and watersheds of the Lower Galveston Bay Watershed. Image A shows the exceedance proportion of the subbays, and Image B is the actual nitrite values averaged annually for nitrite in the subbays. Image C shows the exceedance proportion of nitrite for the watersheds, and Image D is the annual average trend for nitrite grouped by the five major bays. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of the report. It details the specific methodology that was used to obtain these trend analyses. The grey line and grey shading are the LOESS regression trend line and confidence interval respectively. The maroon line is a linear regression trend line and has an accompanying R2 at the bottom of both images.

Ammonia (NH^3 + NH^4)

Ammonia is a type of nitrogen that is harmful when introduced into the environment and has the chemical formula NH^3. NH^4 is officially known as ammonium and also included in this parameter. This parameter is referred to as ammonia in this report. Ammonia can enter a stream through runoff from precipitation, sewage treatment plant discharge, or interaction with the atmosphere (NCSU, 2003). The general annual trend of ammonia across the subbays is decreasing. Figure 13 (Image A) displays the decrease in exceedance proportion of ammonia samples (R^2: 0.425). Figure 13 (Image B) shows that there is also a decrease in the average annual ammonia values, although the trend is not quite as strong (R^2: 0.234).

Breaking down the time series by season, we see that the largest downward trend is observed in the winter season (Figure 13 image C). The ammonia winter season trend has an R^2 of 0.42, which shows a downward trend of ammonia levels throughout the time that is measured. The other seasons also have a downward trend but it is less extreme. In the winter season, when we examine each subbay separately, there are three subbays with larger decreasing trends: Galveston Bay (R^2: 0.305), Trinity Bay (R^2:0.71), and West Bay (R^2:0.418) (Figure 13 image D). Other subbays either have minimal trend or do not have a sufficient amount of sampling to be displayed.

Overall, the ammonia levels in the watersheds of the Lower Galveston Bay Watershed are decreasing. All of the seasonal averages, along with the annual average, show moderately decreasing trends (Figure 14). The LOESSS regression shows that with all of the seasonal and annual averages had a large decreasing trend to 1990 and then a plateau after that. For this reason, when the 2000-2015 time period is isolated the trends are not as strong.

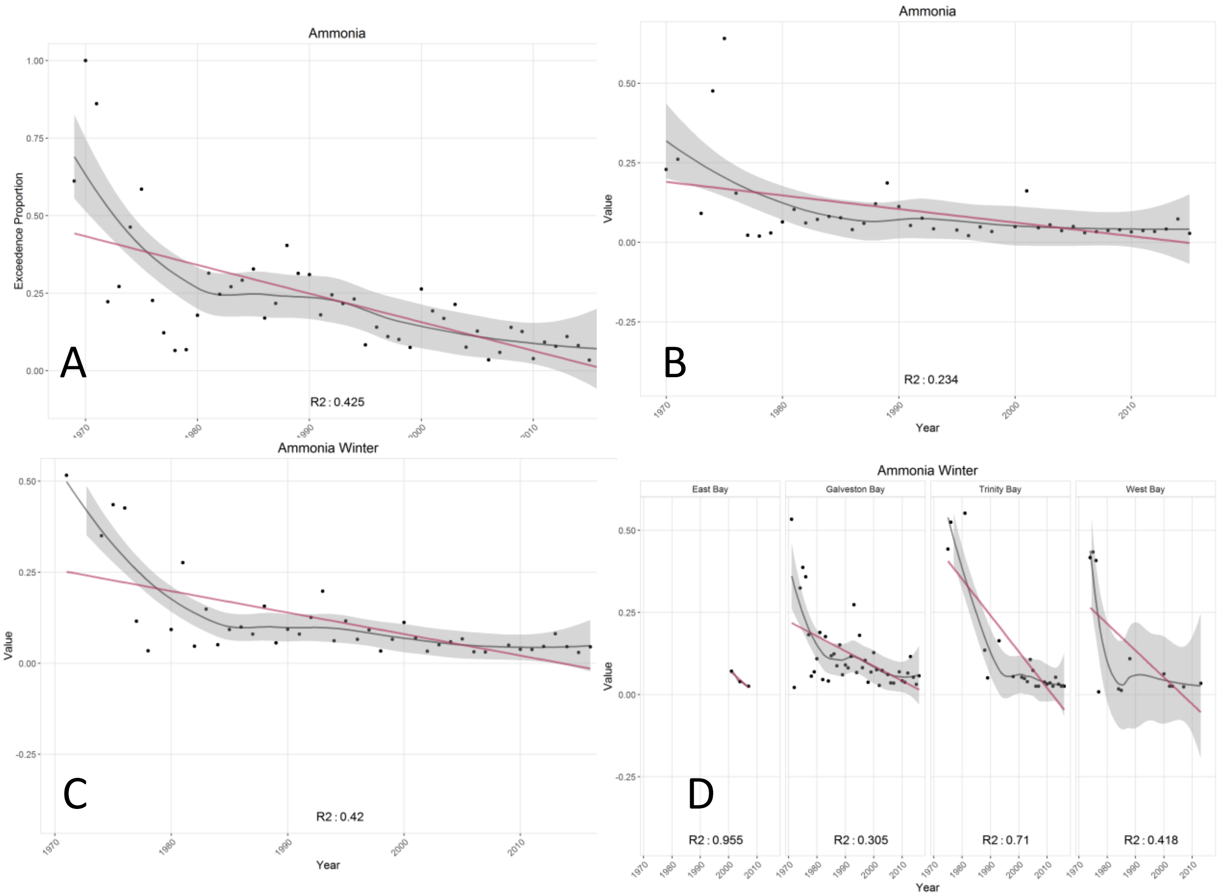
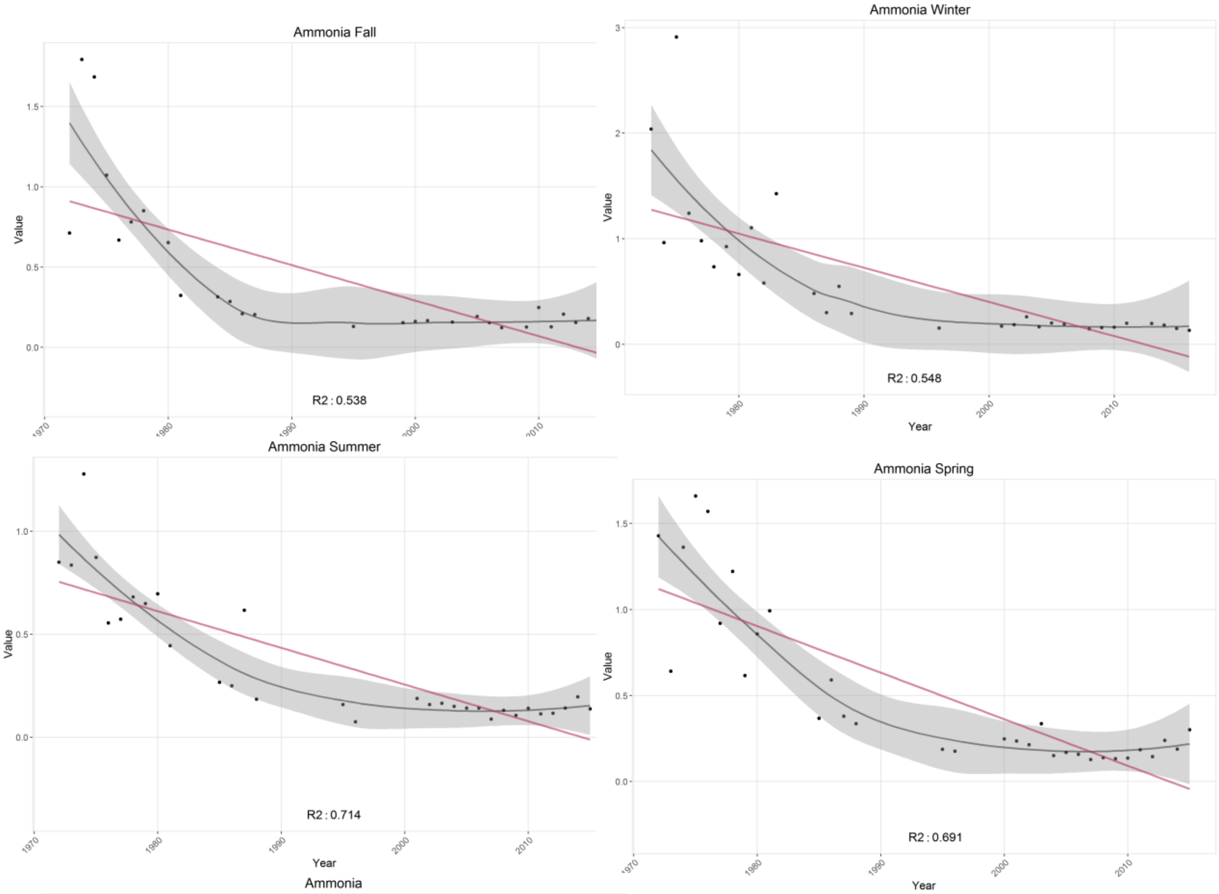


Figure 13: Ammonia values and proportion of exceedances in the subbays of the Lower Galveston Bay Watershed. Image A shows the exceedance proportion of ammonia, and Image B is the actual values averaged throughout time for ammonia. Image C shows the annual winter ammonia trend throughout time, and image D displays the annual winter ammonia values grouped by the five major bays. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.



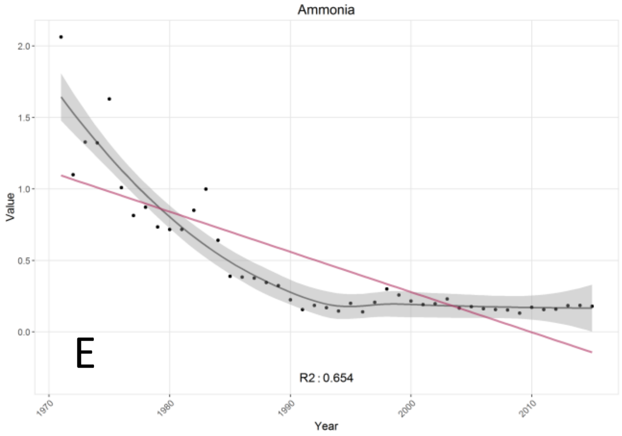


Figure 14: Ammonia annual and summer averages in the five watersheds of the Lower Galveston Bay Watershed. Image A shows fall seasonal average, Image B shows the winter seasonal average, and Images C and D show the summer and spring seasonal averages respectively. Image E is the yearly average for the five watersheds. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Field Water Quality

Salinity, pH, Dissolved Oxygen, Specific Conductance, Temperature

The field water quality indicators utilize data from both TCEQ and TPWD for the Status and Trends report. The TPWD data are only collected within the subbays, whereas the TCEQ data are collected in the subbays as well as the tributaries. The TPWD data are used for interpolations to estimate mesurements between observed field water quality samples. The TCEQ data are assessed in graphical form for both the subbays and watersheds.

One of the main assets of the TPWD data is the high number of samples in the subbays of the Galveston Bay, which allows for interpolations to be generated. Interpolations are generated by season and year for all of the field water quality parameters available through TPWD. Since one of the main benefits of this dataset is allowing Atlas users to visualize temporal changes across the Galveston Bay, there is no way to display this data in the report. Viewing these parameters can be very helpful in understanding the trends across space and through time. They are available on the Status and Trends Atlas (http://www.texascoastalatlas.com/AtlasViewers/StatusAndTrends/SnTatlas.html) where users can view, analyze, and download numerous environmental parameters for the Bay watershed.

General Status of Field Water Quality

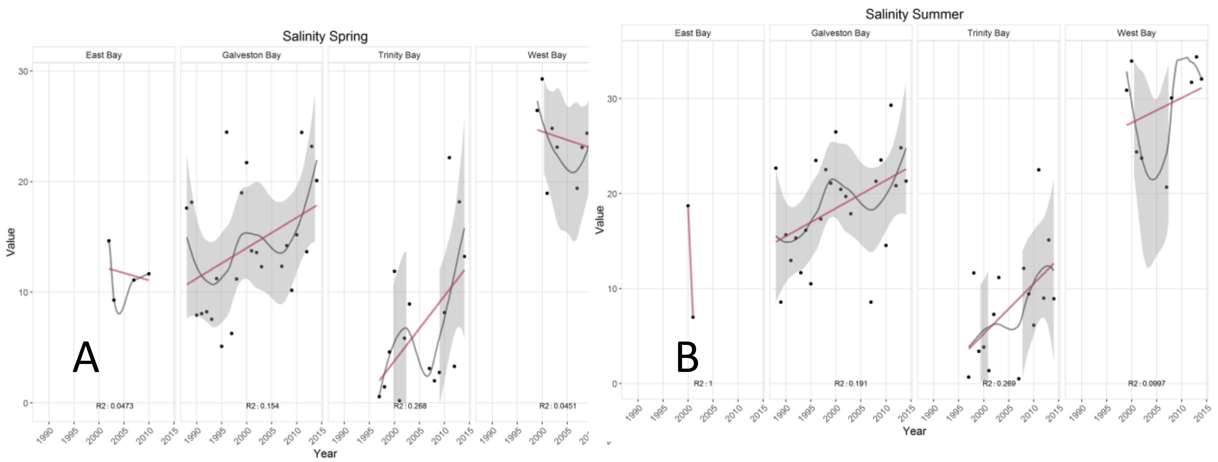
Salinity shows no distinctive trend throughout the study time period. PH increases in some of the watersheds, but demonstrates no substantial trend in the subbays. Dissolved oxygen shows mixed trends depending on watershed. Specific conductance is decreasing in some of the seasons and annually in the watersheds. The subbays for specific conductance are relatively inconclusive, and temperature has a few subbays that show decreasing trends.

Detailed Analysis of Field Water Quality

Salinity

According to the EPA, a simple definition of salinity is the measure of the “dissolved salt content of a body of water.” Different organisms need varying levels of salinity to survive and thrive. Some organisms have very specific, perhaps narrow, salinity requirements. For this reason, alterations in salinity can be stressful to some organisms and is important in structuring the overall composition of estuarine biological communities. In addition, salinity is used to classify waterbodies as an estuarine, palustrine, or mixed ecosystem (EPA, 2016).

In the subbays, there are no clearly observed trends in the seasonal or annual averages. The only subbays with distinguishable seasonal trends are spring and summer in Trinity Bay (R^2: 0.269 & 0.268 respectively). The only watershed with a moderate trend seasonally is North Galveston Bay in the summer (Figure 15, Image C).



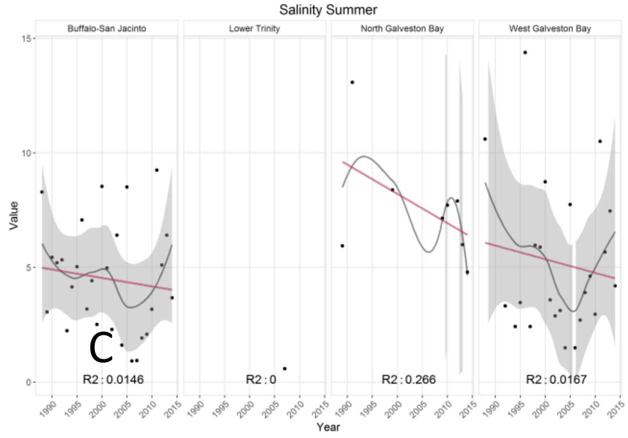


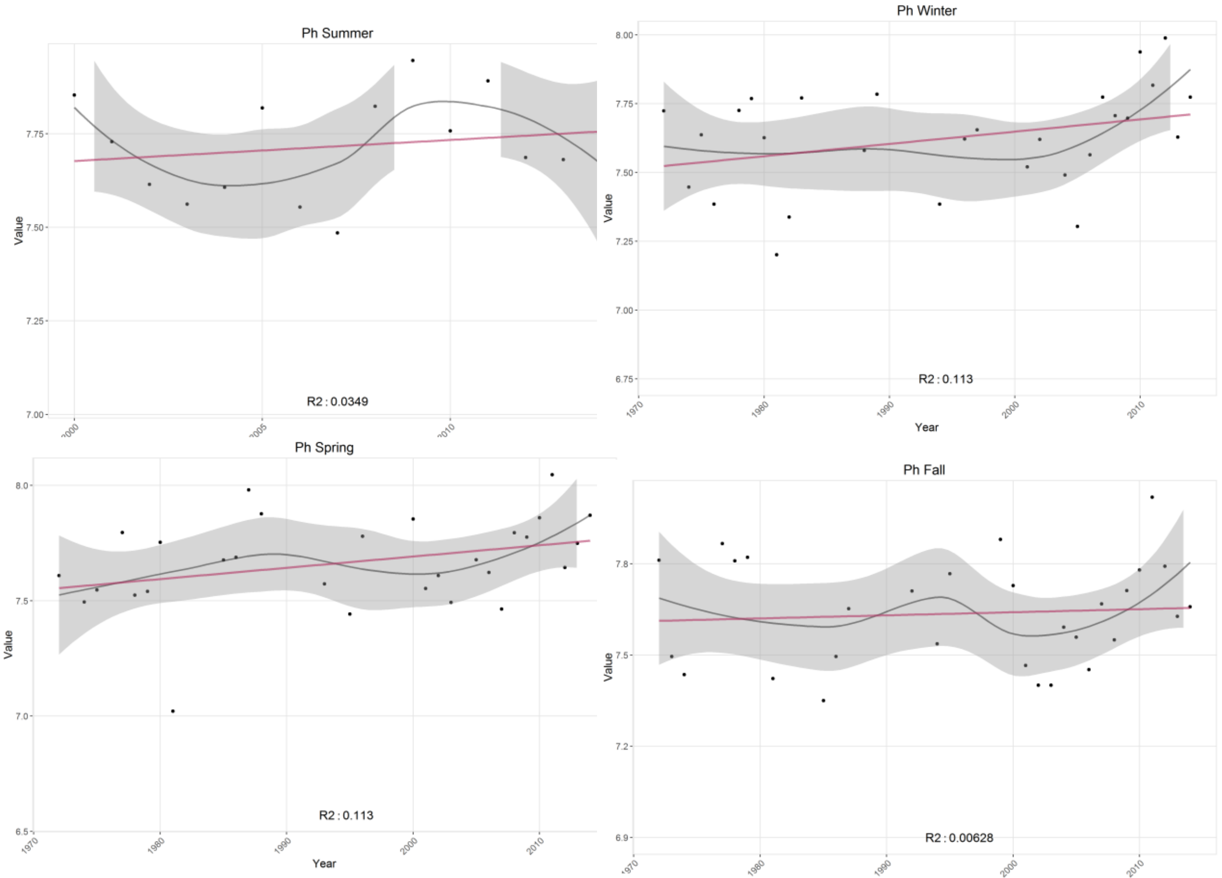
Figure 15: Salinity values for the five major subbays and watersheds of the Lower Galveston Bay Watershed. Image A shows the spring trend for the subbays. Image B displays the summer data for the subbays. Image C shows summer data for the major watersheds. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

pH

PH is an important indicator of the water quality of an ecosystem. The pH indicates the solubility of the water, which is how much material can be dissolved in the water (USGS, 2016). For parameters like metals, solubility determines how toxic the metals are to organisms. For drinking water, high pH can result in “bitter taste” and can be corrosive (USGS, 2016). Changes in pH are also an indication of pollution and can have adverse environmental effects (USGS, 2016).

All of the linear regression trends of pH over time (1990 – 2015) have low R^2s (for the yearly average and all four of the seasonal averages). However, the LOESS regression tells a different story (Figure 18). In all five of these graphs, there is a dip around the mid-1990s and then an increase until the most current year measured. For the annual as well as the four seasons, the R^2s are too low to determine a trend.

The seasonal and annual graphs of the watersheds do not have well-defined trends. For all four seasons, East Galveston Bay has moderately increasing trends (fall: R^2: 0.543, winter: R^2: 0.354, summer: R^2: 0.254, spring: R^2: 0.702). In addition, the Buffalo-San Jacinto watershed has increasing trends in winter (R^2: 0.318), summer (R^2: 0.344), and spring (R^2: 0.571). This result demonstrates that while all of the watersheds collectively do not have definitive trends across the seasons, certain watersheds have moderately increasing trends consistently across the seasons.



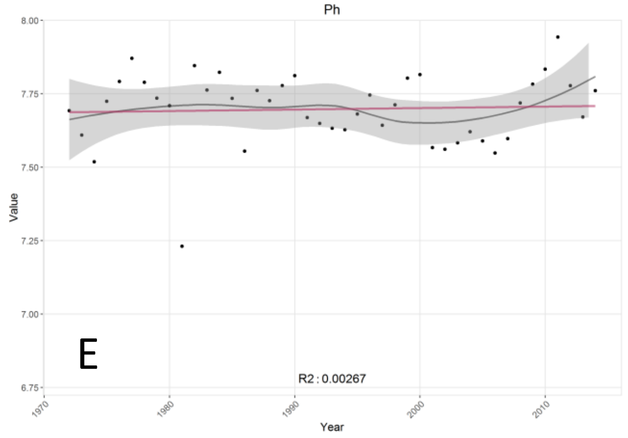


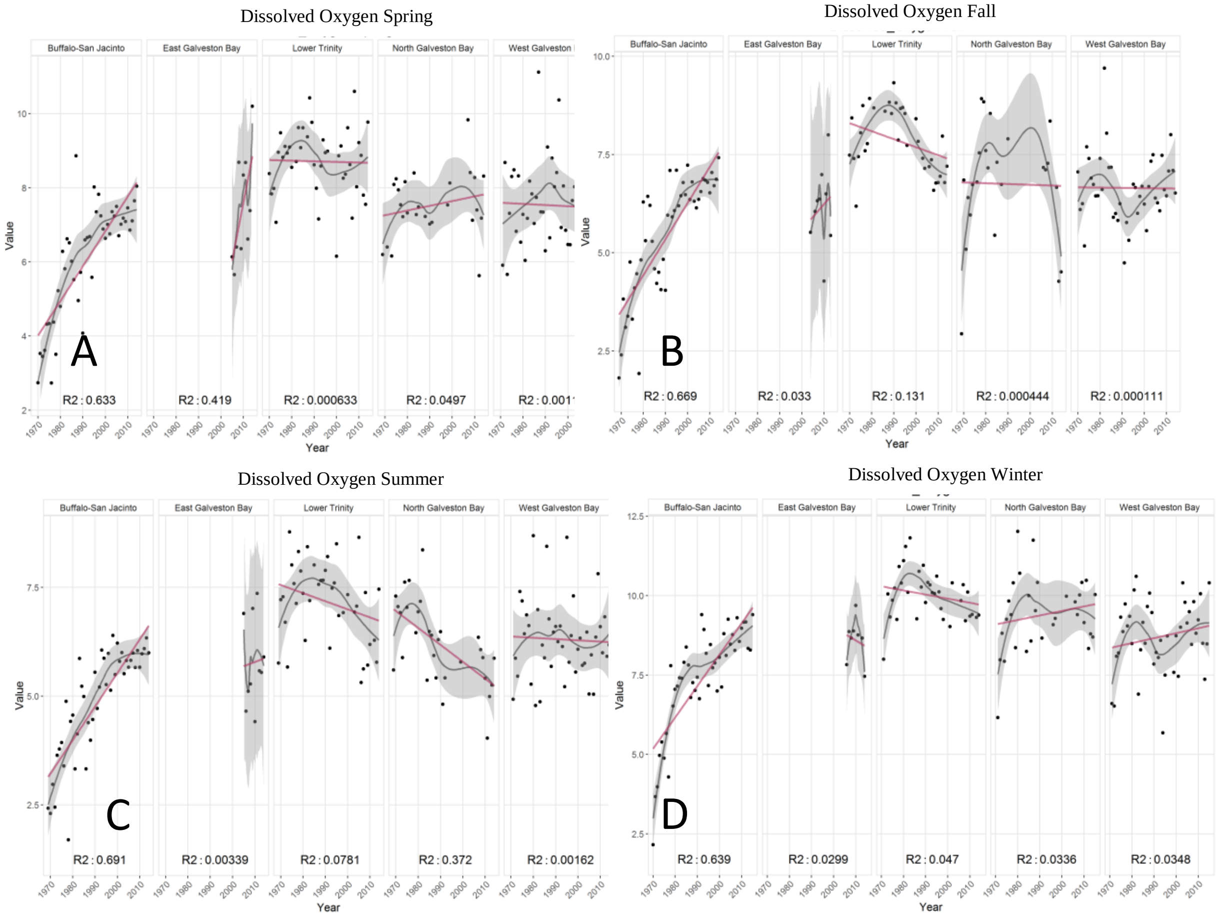
Figure 16: PH values in the five major watersheds of the Lower Galveston Bay Watershed. Image A shows fall seasonal average in the summer, Image B shows the winter seasonal average, and Images C and D show the spring and fall seasonal averages respectively. Image E is the yearly average for the five watersheds. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Dissolved Oxygen

Dissolved oxygen is an essential chemical for organisms in aquatic environments. When the dissolved oxygen in the water is low, it is known as hypoxia; water that is completely devoid of oxygen is known as anoxia. One of the contributors to low or non-existent dissolved oxygen levels in water is algal blooms (EPA, 2016). When these large algal blooms die off, sink to the bottom, and decompose dissolved oxygen is used in the process. When these low oxygen waters occur, organisms that require oxygen to survive have to move; those that cannot move will sometimes perish (EPA, 2016). As defined by the EPA for the National Aquatic Resource Surveys, when the dissolved oxygen levels in the water drop below 1.0 mg/l this is considered hypoxic and there is not many organisms that can survive in these conditions (EPA, 2016).

According to the Status and Trends project, dissolved oxygen does not display a strong trend for any of the seasonal or annual averages in the subbays or watersheds. There are a few watersheds that seasonally have well-defined trends. For the entire time period, the Buffalo-San Jacinto watershed has increasing trends of dissolved oxygen. Otherwise, there are minimal trends in this time period for dissolved oxygen (Figure 17).

Specific Conductance


Dissolved Oxygen Spring

Dissolved Oxygen Fall

Dissolved Oxygen Summer

Dissolved Oxygen Winter

Figure 17: Dissolved Oxygen for the five major watersheds of the Lower Galveston Bay Watershed. Image A shows the spring data for the watersheds, Image B displays the fall data, Image C shows the summer, and Image D the winter for the watersheds. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

The conductivity of the water is the “ability of the water to pass an electrical current” (EPA, 2016). Conductivity and salinity are positively correlated indicating an increase in salinity, which means an increase in conductivity. Salts are good conductors of electrical current; as the salt content increases so does the water conductivity (EPA, 2016). The best way to use conductivity as a water quality indicator is to compare the current conductivity to the baseline of established conductivity. Changes in conductivity could be a potential indicator of changes in water quality (EPA, 2016).

Specific conductance is a parameter that TCEQ has monitored for many years. For the subbays, there are no seasons with distinctive trends, nor does the annual average have a strong trend. The only subbay that seasonally has strong increasing trends is Trinity Bay in the spring and summer (R^2: 0.273 & 0.257 respectively) (Figure 18).

Specific conductance shows moderately decreasing trends in Buffalo-San Jacinto, East Galveston Bay, and North Galveston Bay watershed during the fall. The seasonal averages of winter and summer, in addition to the annual average, decrease throughout the entire study period. This result shows that during these months and on average annually, specific conductance is decreasing in the watersheds (Figure 19).

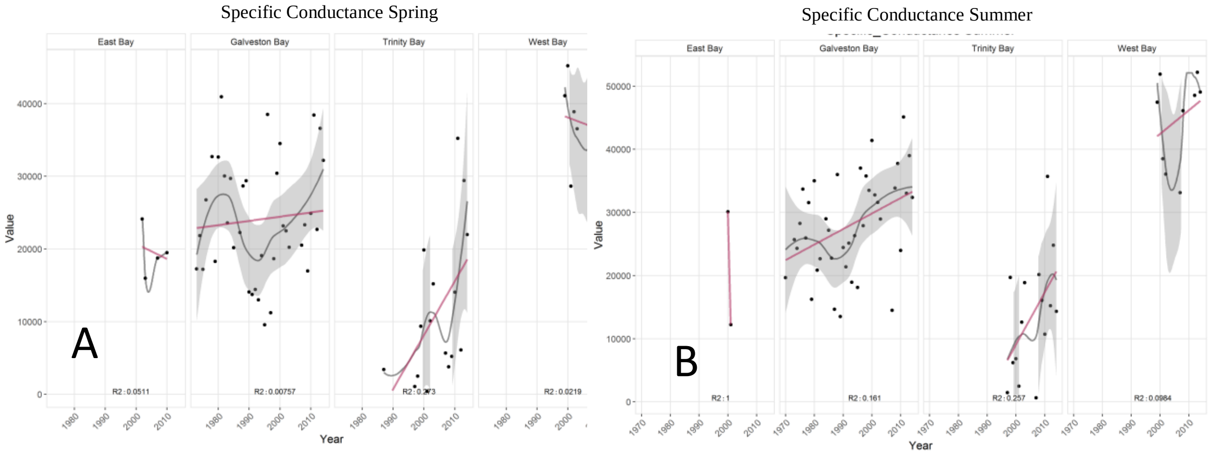


Figure 18: Specific conductance values for the spring and summer seasons by subbay in the Lower Galveston Bay Watershed. Image A is the spring season, and Image B is the summer season. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

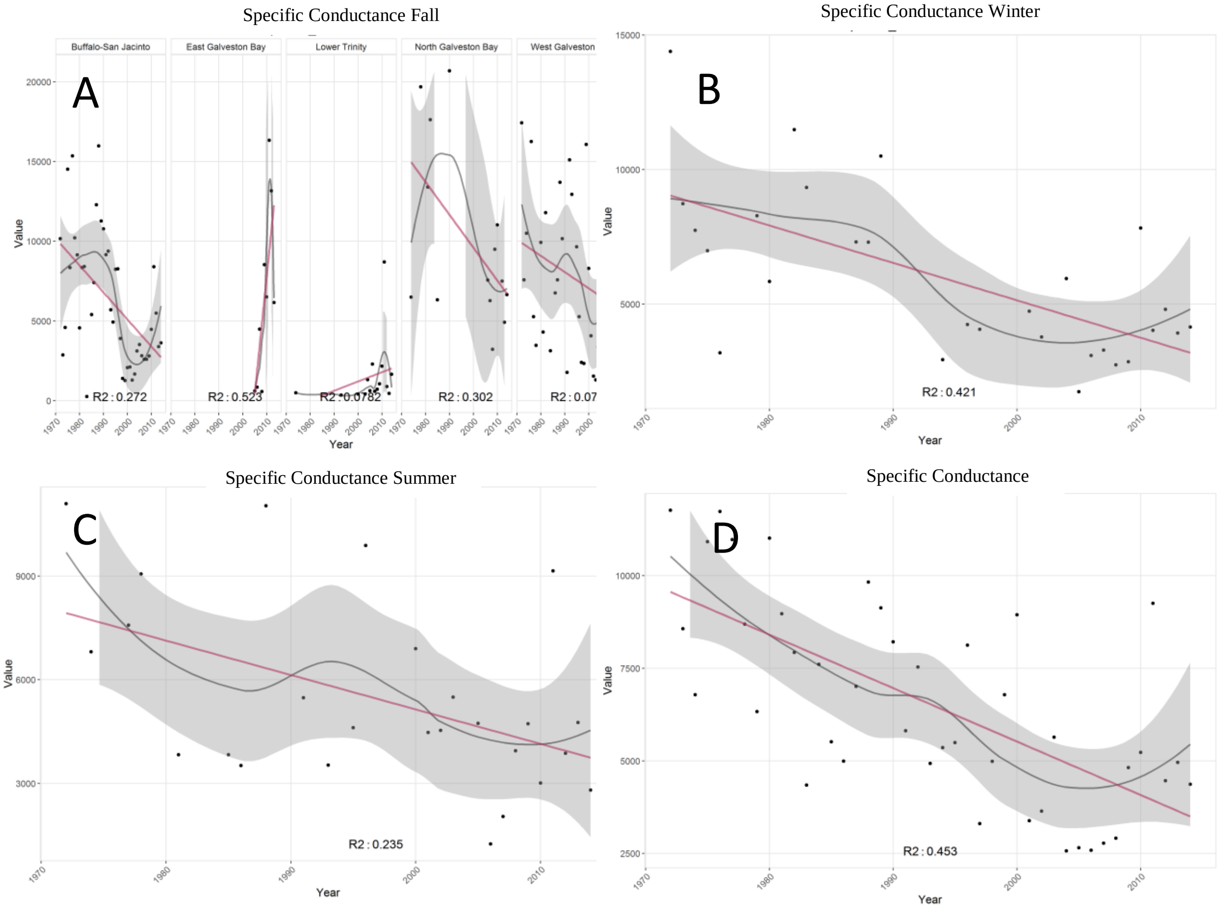


Figure 19: Specific conductance values in the five major watersheds of the Galveston Bay system. Image A shows the fall graph by watershed. Image B is the winter seasonal average for specific conductance across all of the five major watersheds. Image C is the summer seasonal average, and Image D is the yearly average. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Temperature

Changes in the water temperature can have adverse effects on the organisms that rely on specific temperatures to survive. Most organisms have a preferred range of habitat temperature for survival (USGS, 2016). Temperature also has an effect on some of the other parameters of water quality. Higher water temperatures mean higher conductivity (see conductivity section for more details about consequences of changes in conductivity), and warmer water contains less dissolved oxygen than colder water. In the fall season, both Galveston and West Bays show decreasing trends (R^2s: 0.236 & 0.482 respectively). The fall seasonal average trend is also decreasing.

Physical Variables

Biochemical Oxygen Demand, Total Suspended Solids, Total Organic Carbon

General status of physical variables

The three physical variables examined in the Status and Trends project are biochemical oxygen demand (BOD), total suspended solids (TSS), and total organic carbon (TOC). Based on the data available through the TCEQ SWQMIS CRP database, there are no discernable trends for BOD in either the subbays or watersheds. There is a decreasing trend for TSS in the watersheds, while there is no obvious trend in the subbays. TOC has strong decreasing trends in both the subbays and the watersheds.

Detailed analysis of physical variables

Biochemical Oxygen Demand (BOD)

When algae die in the water and sink, there are bacteria that break down the dead algae and consume oxygen in the process. BOD is the measure of how much oxygen is consumed in this process under aerobic conditions (Brown & Caldwell, 2001). In the data from TCEQ, BOD is not measured very frequently. In fact, the annual average graph for the subbays shows only 11 years, contributing to a very low R^2 (0.055) for the linear regression line, and large confidence intervals for the LOESS regression (Figure 20 Image A). In contrast, the yearly average for the watersheds has more samples then the subbays and shows a very slight decreasing trend (Figure 20 Image B).

Total Suspended Solids (TSS)

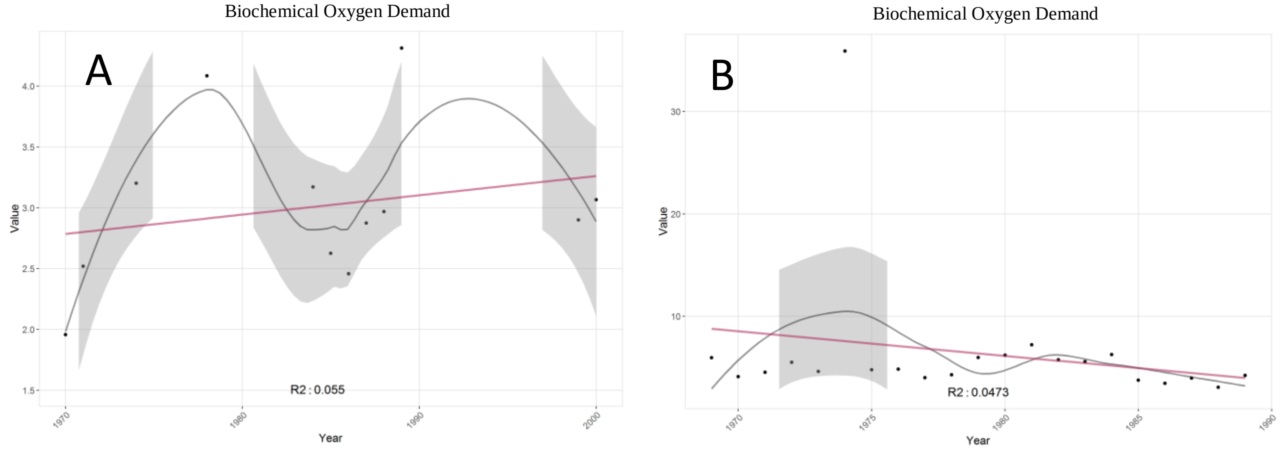


Figure 20: Biochemical Oxygen Demand in the bays and watersheds of the Galveston Bay system. Image A shows the average annual BOD values within the five major bays, and image B displays the average BOD values in the five watersheds. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

The amount of sediment in the water is measured through total suspended solids (TSS). TSS is the dry weight of the sediment in the water sample once the water has been removed (Brown & Caldwell, 2001). One of the effects of high TSS levels is the depth at which light can infiltrate the water (Brown & Caldwell, 2001). The higher the TSS, the murkier the water; therefore, the light cannot penetrate as far. As a result, there can be decreased algal growth and lowered productivity in photosynthetic organisms (such as phytoplankton) that rely on the sun for a source of energy (Brown & Caldwell, 2001).

The TSS trends for the Lower Galveston Bay Watershed are generally decreasing. The only season and subbay with a distinguishable trend is West Bay in the summer (R^2: 0.405). The annual trend for the subbays is slightly decreasing. The TSS in the watersheds has more seasons and subbays with stronger trends. In the fall, both Lower Trinity and West Galveston Bay show moderately decreasing trends (Figure 21, Image A). Decreasing trends are also observed in Lower Trinity during the winter and in the summer in West Galveston Bay (Figure 21, Image B&C). In the spring, both Buffalo-San Jacinto and West Galveston Bay watersheds have decreasing trends. For all of the four seasons and across the entire year there are strong decreasing trends (Figure 22, Image A-D).

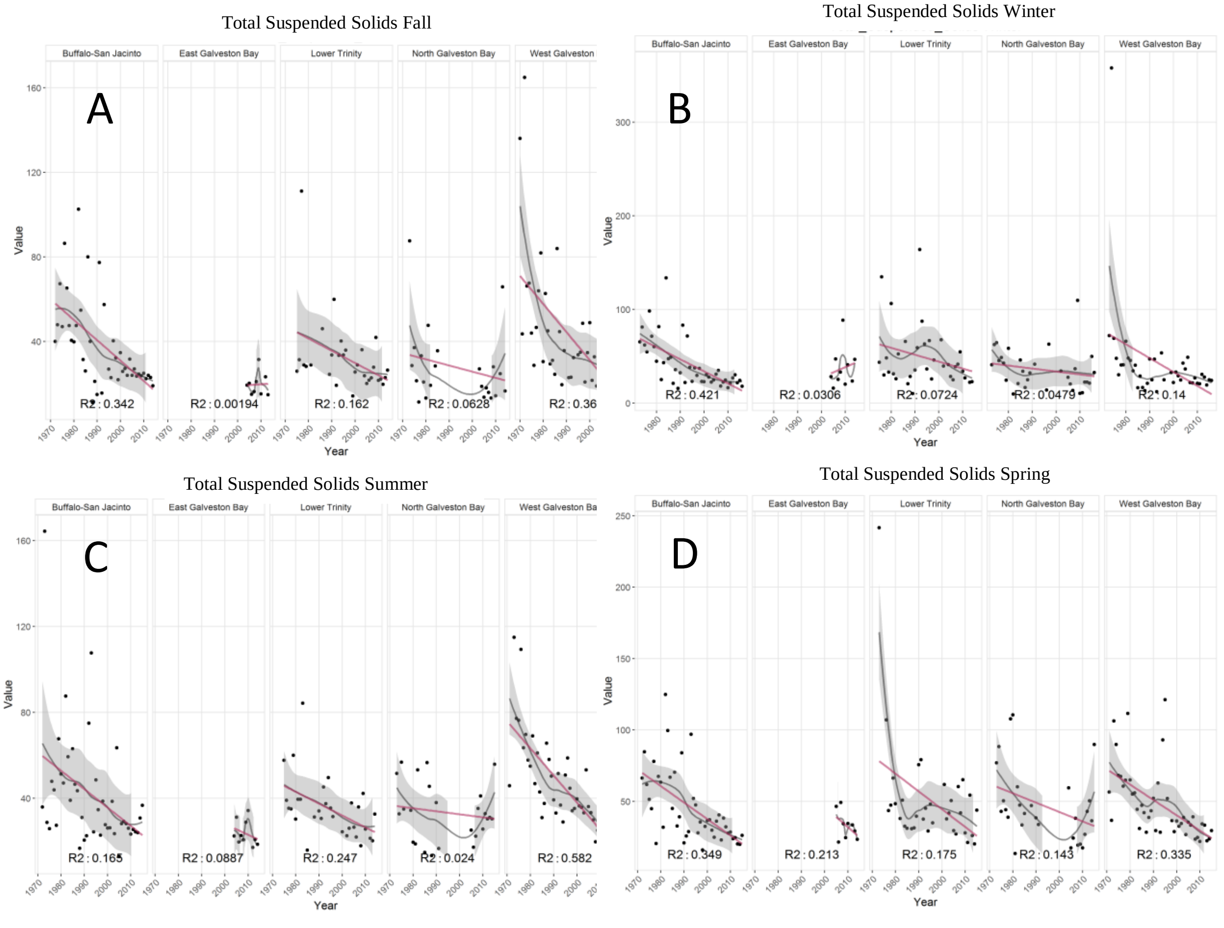
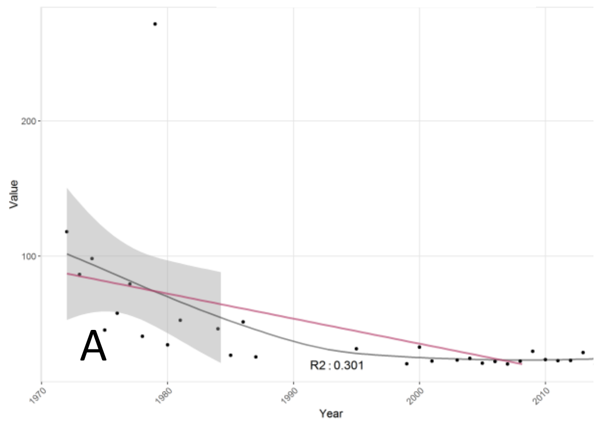
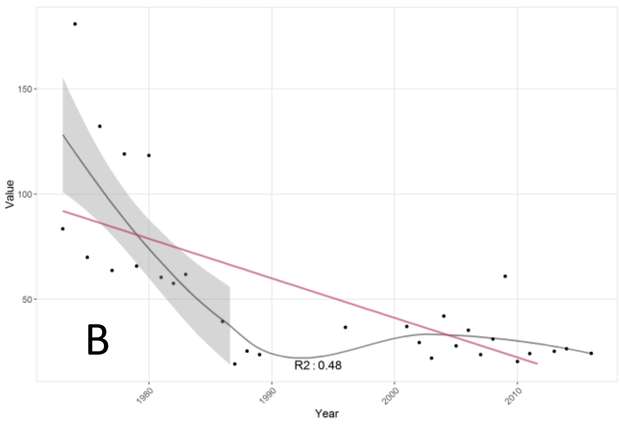


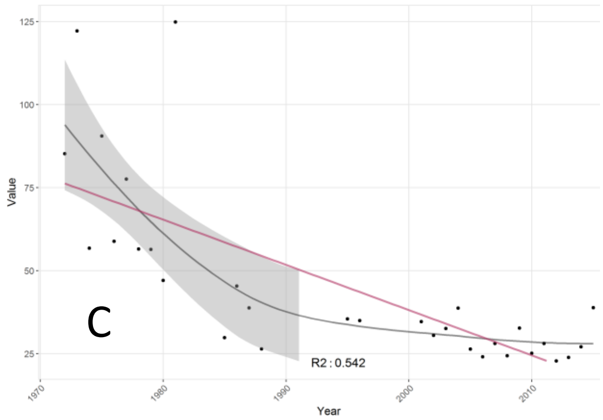
Figure 21: Total Suspended Solids for all of the watersheds by season. Image A shows the fall TSS levels by watershed. Image B is the winter TSS levels by each watershed. Image C shows the summer TSS levels by watershed, and Image D is the spring TSS levels. However, in some graphs all five bays are not displayed represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.



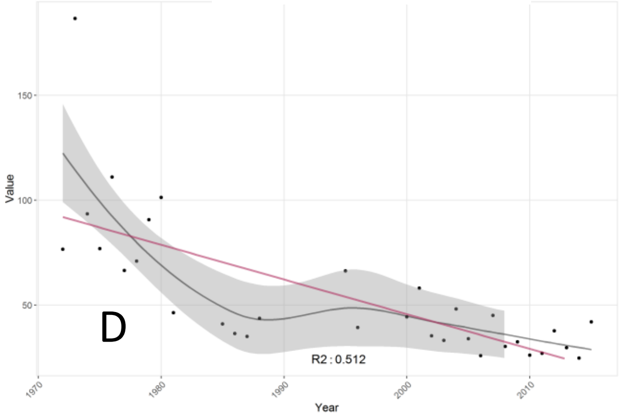
Total Suspended Solids Fall



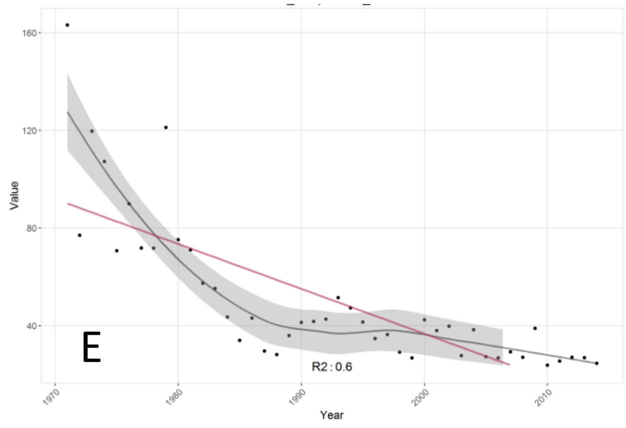
Total Suspended Solids Winter



Total Suspended Solids Summer



Total Suspended Solids Spring



Total Suspended Solids

Figure 22: Total Suspended Solids for the watersheds seasonal average and annual average. Image A shows the fall TSS seasonal average. Image B is the winter TSS seasonal average. Image C shows the summer TSS seasonal average, and Image D is the spring TSS seasonal average. Image E is the TSS annual average for the watersheds of the Lower Galveston Bay Watershed. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Total Organic Carbon (TOC)

Total organic carbon (TOC) is a combination of organic carbon and inorganic carbon (Schumacher, 2002). In instances where inorganic carbon is not present, the TOC is equal to the organic carbon (Schumacher, 2002). TOC is an important measurement because *"its presence or absence can markedly influence how chemicals will react in the soil or sediment"* (Schumacher, 2002).

There are a few seasons and subbays that have moderately decreasing total organic carbon values. Both Galveston Bay and Trinity Bay decrease in the fall and West Bay decreases in the winter. In the summer, Galveston Bay (R^2: 0.285) is also decreasing, and West Bay displays a similar trend in the spring (R^2: 0.781). See Figure 23, Images A-C.

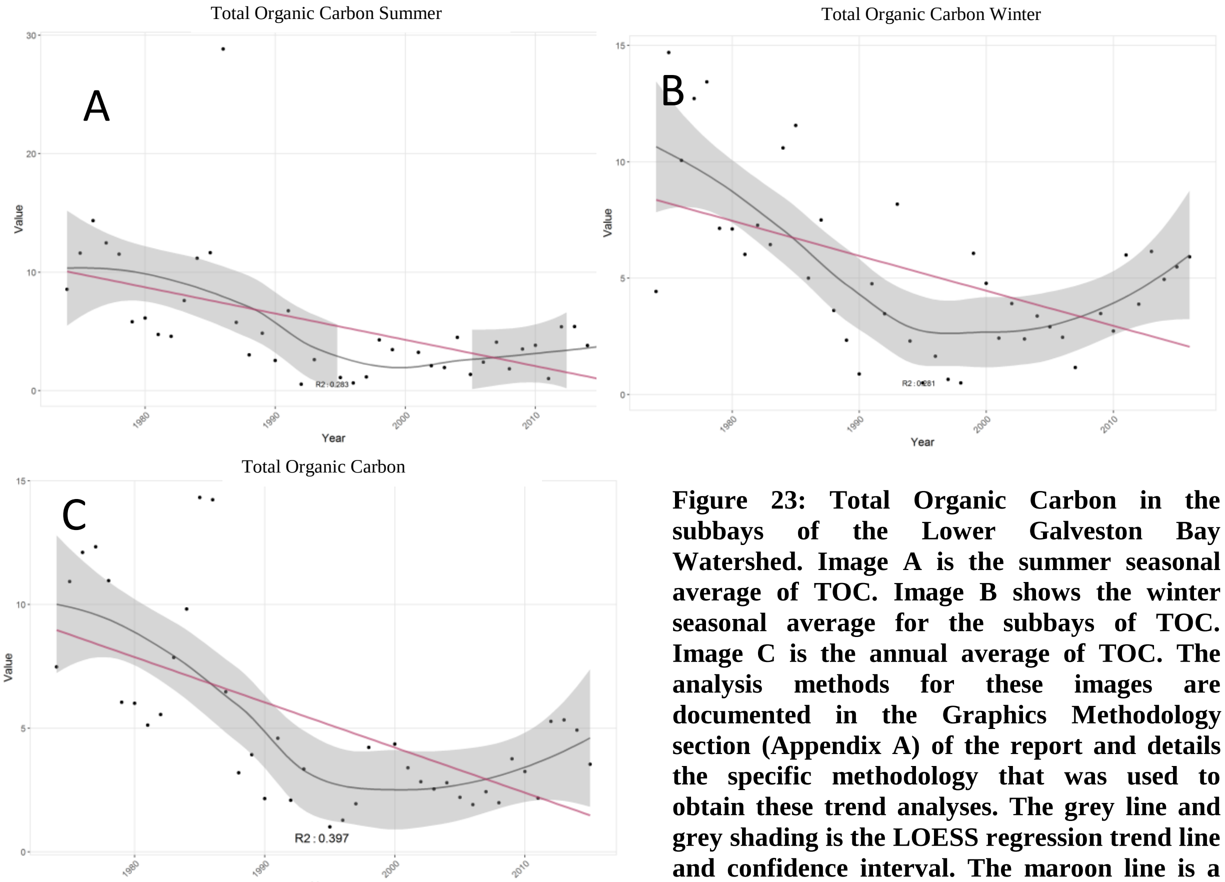


Figure 23: Total Organic Carbon in the subbays of the Lower Galveston Bay Watershed. Image A is the summer seasonal average of TOC. Image B shows the winter seasonal average for the subbays of TOC. Image C is the annual average of TOC. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of the report and details the specific methodology that was used to obtain these trend analyses. The grey line and grey shading is the LOESS regression trend line and confidence interval. The maroon line is a linear regression trend line and has an accompanying R2 at the bottom of both images.

In the five watersheds, there are multiple seasons that display decreasing trends (Figure 24 & 25). Buffalo-San Jacinto has decreasing trends in winter, summer, and spring (Figure 24, Images B-D). Lower Trinity has the same trends in summer and spring, while North Galveston Bay shows these trends in winter and spring (Figure 24, Images B-D). In North Galveston Bay, there is an increasing trend in the fall, but only five years of data are available. West Galveston Bay also has a decreasing trend in winter and summer (Figure 24, Images B&C). In addition, the seasonal trends across all of the five watersheds generally show that every season has a decreasing trend (Figure 25, Images A-D). The annual average is also decreasing (Figure 25, Image E).

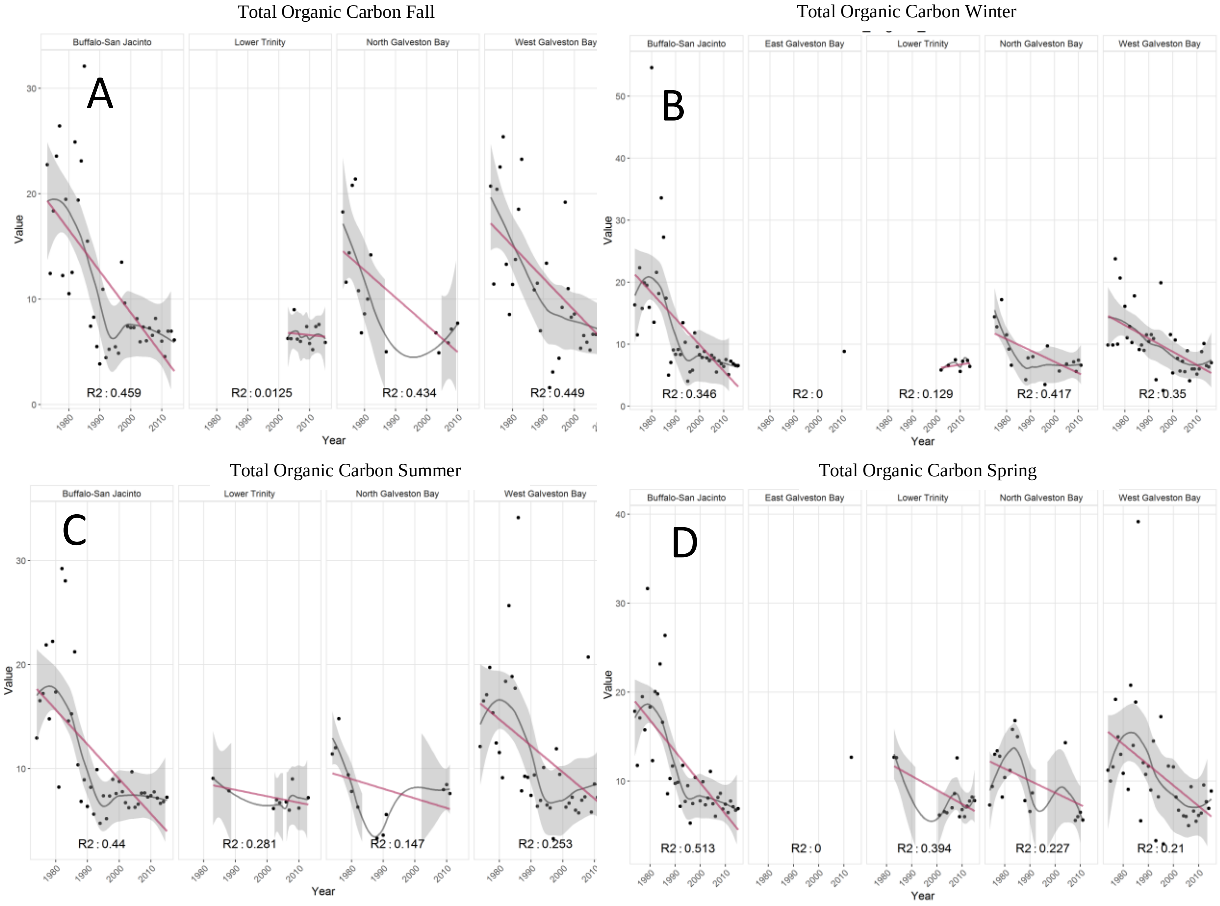
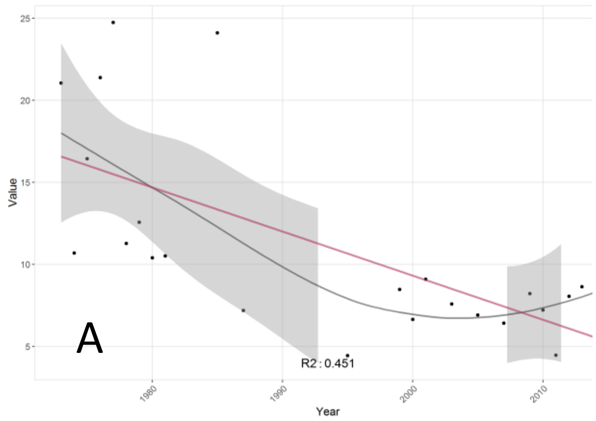


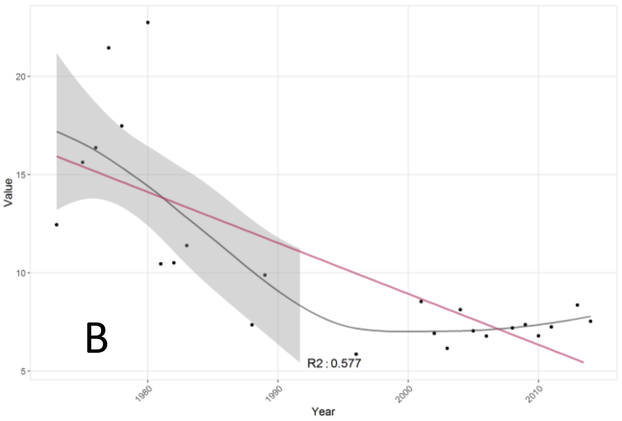
Figure 24: Total Organic Carbon for all of the watersheds by season. Image A shows the fall TOC levels by watershed. Image B is the winter TOC levels by each watershed. Image C shows the summer TOC levels by watershed and Image D is the spring TOC levels. However, in some graphs all five bays are not displayed represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The marron line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading is the LOESS regression trend line and the corresponding confidence interval. The black dots are the actual values that are being plotted on the chart.

If only the most recent time period (2000-2014) is selected, there are different trends seen in the watersheds. For the winter and spring averages the trend is increasing. The annual average shows an increase in the TOC levels in the watersheds. While there are overall decreasing trends when examining the entire study period, the more recent time period (2000-2014) shows increasing trends. This result demonstrates the dangers of examining just one linear regression line and assigning a trend value as it may not necessarily be representative of the actual performance of the parameter.

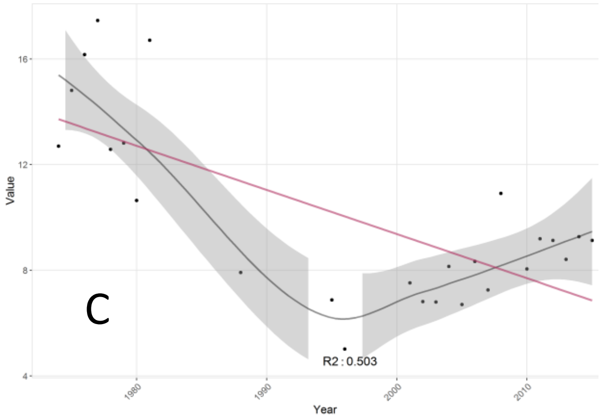
Total Organic Carbon Fall



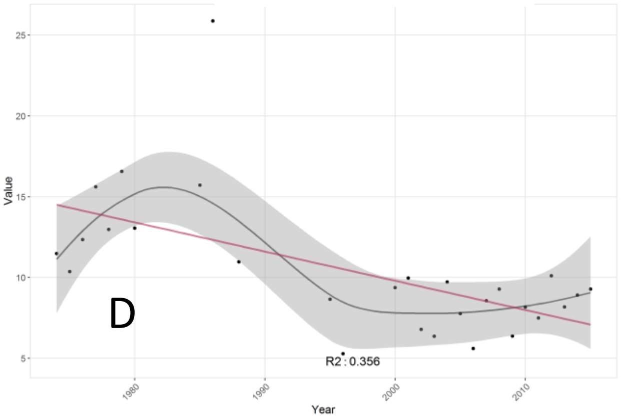
Total Organic Carbon Winter



Total Organic Carbon Summer



Total Organic Carbon Spring



Total Organic Carbon

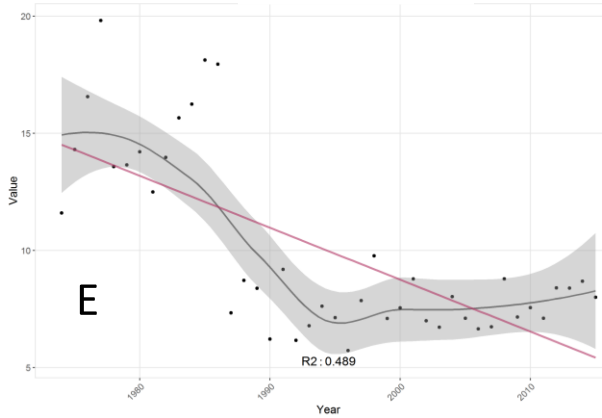


Figure 25: Total Organic Carbon for the watersheds seasonal average and annual average. Image A shows the fall TOC seasonal average. Image B is the winter TOC seasonal average. Image C shows the summer TOC seasonal average and Image D is the spring TOC seasonal average. Image E is the TOC annual average for the watersheds of the Lower Galveston Bay Watershed. However, in some graphs all five bays are not displayed represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The marron line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading is the LOESS regression trend line and the corresponding confidence interval. The black dots are the actual values that are being plotted on the chart.

Aromatic Organics and Pesticides in Sediment

A large amount of seafood is harvested from the Lower Galveston Bay Watershed, and it is important to monitor the aromatic organics in sediment and pesticide levels as it can potentially inform seafood advisories.

General Status of Aromatic Organics and Pesticides in Sediment

The limited sampling seen in the aromatic organics in sediments and pesticides makes it challenging to draw a conclusion on the general status of these parameters. Specifically, the aromatic organics in sediment consist of multiple parameters that are classified into two groups: semi-volatile compounds (12 polycyclic aromatic hydrocarbons: PAHs) and polychlorinated biphenyls (PCBs). The pesticides are included in a separate group and include: chlorine, DDT, dieldrin, and lindane. There are overall different trends in the exceedance proportion of parameters for different subbays and watersheds.

Detailed analysis of Aromatic Organics and Pesticides in Sediment

In accordance with the previous Status and Trends Report, the aromatic organics and pesticides in sediment are divided into three groups. There are relatively limited samples for some of the specific parameters, and grouping the organics and pesticides increases the sample size. This report contains the three groups, which are listed in Table 6.

Table 6: Groups of organics and pesticides and specific parameters included in each.

Semi-volatile compounds that consist of twelve polycyclic aromatic hydrocarbons (PAHs)	Pesticides	Polychlorinated biphenyls (PCBs)
1,2,5,6-Dibenzanthracene	Chlordane	
Acenaphthylene	DDT	
Acenaphthene	Dieldrin	
Anthracene	Lindane	
Benzo(A)Pyrene		
Benzo(A)Anthracene		
1, 2-Benzanthracene		
Chrysene		
Fluoranthene		
Fluorene		
Napthalene		
Phenanthrene		
Pyrene		

PAHs, PCBs, and pesticides are assessed by analyzing average percent of exceedance per decade. The exceedance per decade is calculated for each subbay and watershed. The following section breaks down the three different groups and discusses how the average exceedance over decades change within the subbays and watersheds throughout time. The 2010 decade does not contain the full 10 years because the data only extends through 2014.

Table 7: Exceedance percentage of pesticides, PCBS, and organics in the watersheds and subbays of the Lower Galveston Bay Watershed. Any decade and watershed or subbay listed as "-" means there is not viable sampling data to report as an exceedance proportion. The 2010 decade includes data from 2010-2014 because there were not other data available at the time. The decades and subbays/watersheds that have under ten samples were assessed.

Decade		1970	1980	1990	2000	2010
Pesticides						
Watersheds	Buffalo-San Jacinto	4%	3%	27%	31%	58%
	North Galveston Bay	-	0%	-	-	-
	West Galveston Bay	-	11%	-	-	-
Subbays	Galveston Bay	-	0%	14%	20%	-
	Trinity Bay	-	-	11%	17%	-
	West Bay	-	0%	-	-	-
PCBS						
Watersheds	Buffalo-San Jacinto	6%	12%	0%	27%	5%
	West Galveston Bay	-	6%	-	-	-
Subbays	Galveston Bay	-	0%	0%	7%	-
	Trinity Bay	-	0%	-	-	-
	West Bay	-	0%	-	-	-
Organics						
Watersheds	Buffalo-San Jacinto	-	-	43%	29%	3%
	West Galveston Bay	-	-	6%	-	-
Subbays	Galveston Bay	-	-	14%	3%	-
	Trinity Bay	-	-	18%	0%	-

Table 7 shows the exceedance proportion by watershed. As previously mentioned, some decades, parameters, and subbays/watersheds were sampled in a limited way. There are multiple decades and parameters that do not have sufficient sampling to report an exceedance proportion (Table 7). The Buffalo-San Jacinto watershed is the watershed most frequently sampled for pesticides, PCBs, and organics. From 1970 to 2010 the exceedance percentages of pesticides increase from 4% to 58%. PCBs in the same watershed have an exceedance percentage from 1970 to 2010 that decreases from 6% to 5%. Organics were first measured in this watershed starting in the 1990s, when the exceedance percentage was 43%; it decreased in the 2010 decade to 3%.

There are a couple subbays/watersheds that show changes throughout time (Figures 26 & 27). These figures represent watersheds that display large changes between the first measured decade and the final measured decade. The largest changes are represented in these maps. Pesticides in the Buffalo-San Jacinto watershed see the largest increase from 1970-2010 at 54.3%. The other two large increases are seen in Trinity Bay (6% from 1990 to 2000) and Galveston Bay (20% from 1980 to 2000). Organics have two subbays/watersheds with large decreases. Buffalo-San Jacinto decreased by 40% (1990 to 2010) and Galveston Bay decreased by 11.3% (1990-2000).

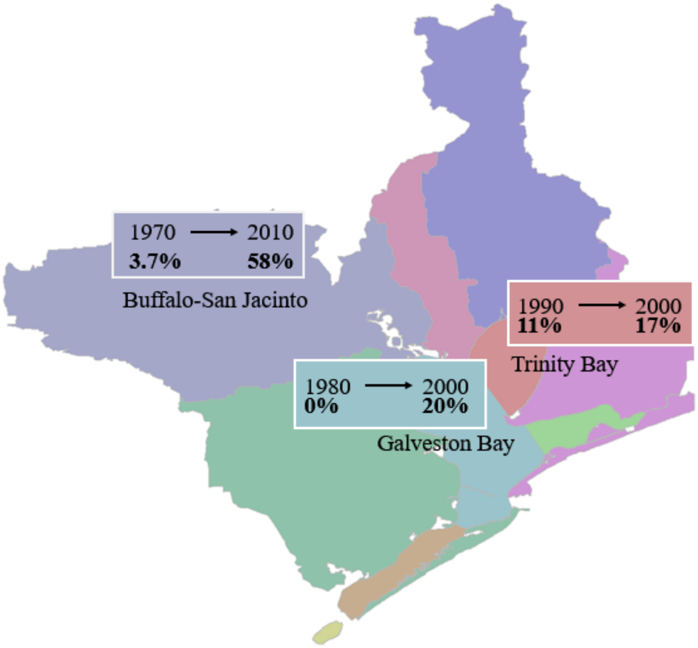


Figure 26: Pesticide changes in exceedance over decades in the watersheds. The 2010 decade includes data from 2010-2014 because there are not other data available at the time when the data was collected.

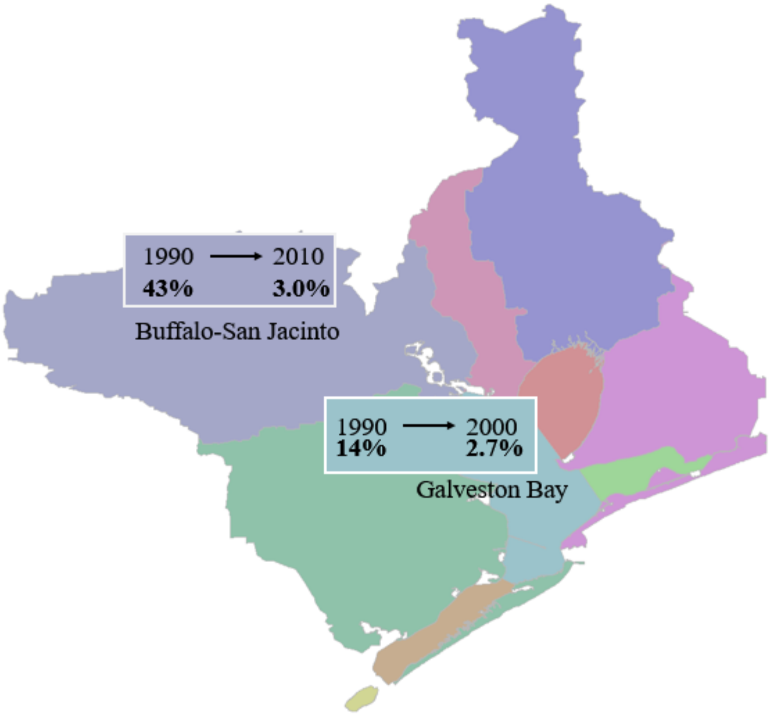


Figure 27: Organics changes in exceedance over decades in the watersheds. The 2010 decade includes data from 2010-2014 because there are not other data available at the time when the data was collected.

Microbiological

General Status of Microbiological Parameters

The general status of microbiological parameters differs for each parameter. Enterococci has increasing trends in some subbays or watersheds, but there are no annual or seasonal trends that have sufficient sampling. Fecal coliform has no trends for either the subbays or watersheds. *E. coli*, like fecal coliform, suffers from a lot of missing data and has no obvious trend for either the subbays or watersheds. Chlorophyll-a increases slightly in the subbays and more substantially in the watersheds of the Lower Galveston Bay Watershed.

Detailed analysis of microbiological parameters

The Galveston Bay Status and Trend project collects and analyzes data for four microbiological parameters (Table 8).

Each of the parameters has different sampling time frames and the habitats for the microbiological parameters are different. In general, enterococci and fecal coliform are found in salt water. However, the time frame for fecal coliform (data obtained from TCEQ) is 1973-2007 and enterococci is 2000-2014. *E. coli* is found in fresh water and was monitored through TCEQ from 2000-2014. Chlorophyll-a is found in both fresh and salt water.

Table 8: Microbiological parameters included in Status and Trends Report. (MPN: Most Probable Number)

Microbiological Parameters
Enterococci (MPN/100 ML) (salt water)
Fecal Coliform (#/100 ML) (salt water)
E. coli (MPN/100 ML) (fresh water)
Chlorophyll-A (Ug/L)

Enterococci

The bacteria enterococci is only found in salt water systems. Through TCEQ, this parameter began to be measured in the early 2000s. The subbay enterococci levels in both Trinity Bay and West Bay display moderate trends in the spring. In West Bay during the spring, there are only six recorded samples and one of them is much larger than the others (Figure 28, Image A). Spring in Trinity Bay has a larger number of samples, the first of which are high than the others in subsequent years. Overall, the spring average over the subbays is decreasing (R^2: 0.498) (Figure 28, Image B).

Both the yearly average for all of the seasons and subbays as well as the exceedance throughout the years show inconclusive trends. In addition, enterococci values that exceed 500 (MPN/100ml) (MPN stands for most probable number) have been removed from the analysis because they greatly skewed the trends.

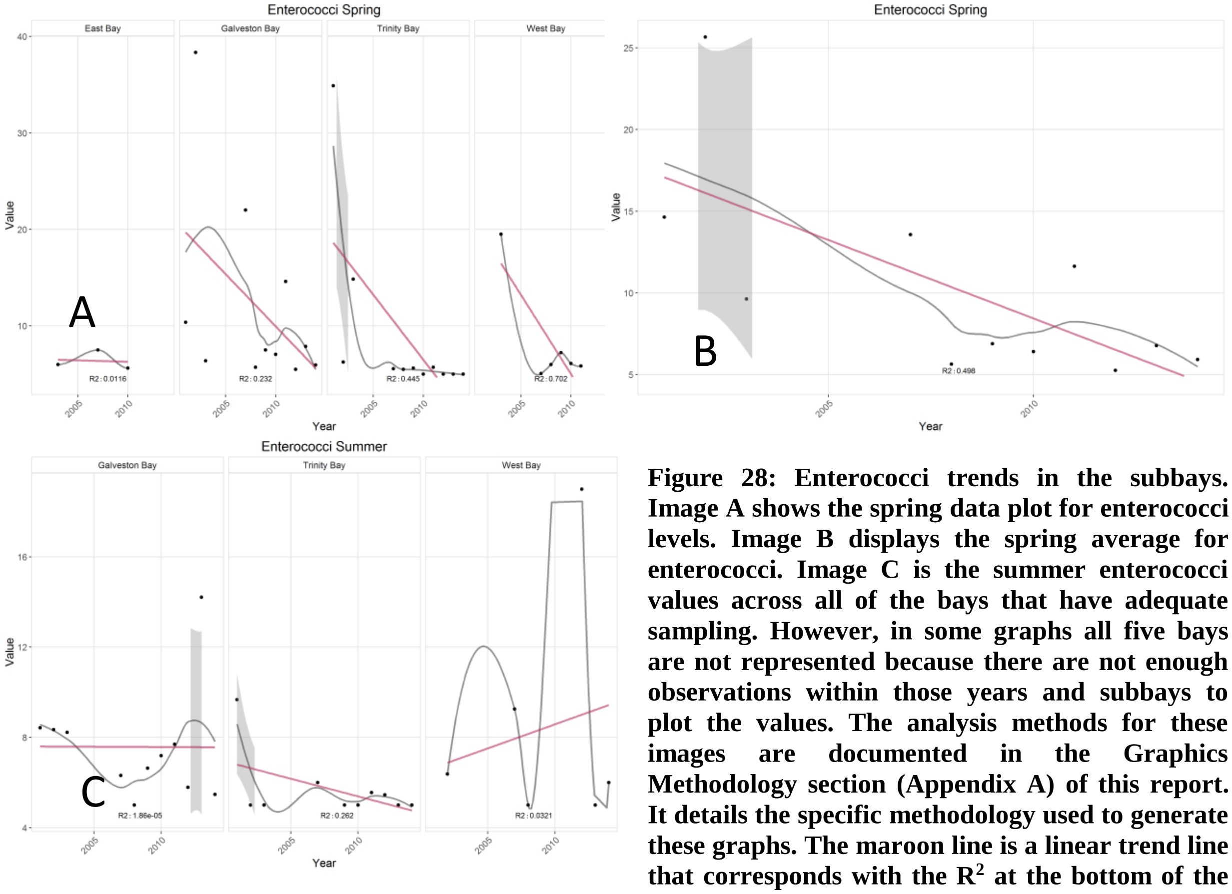
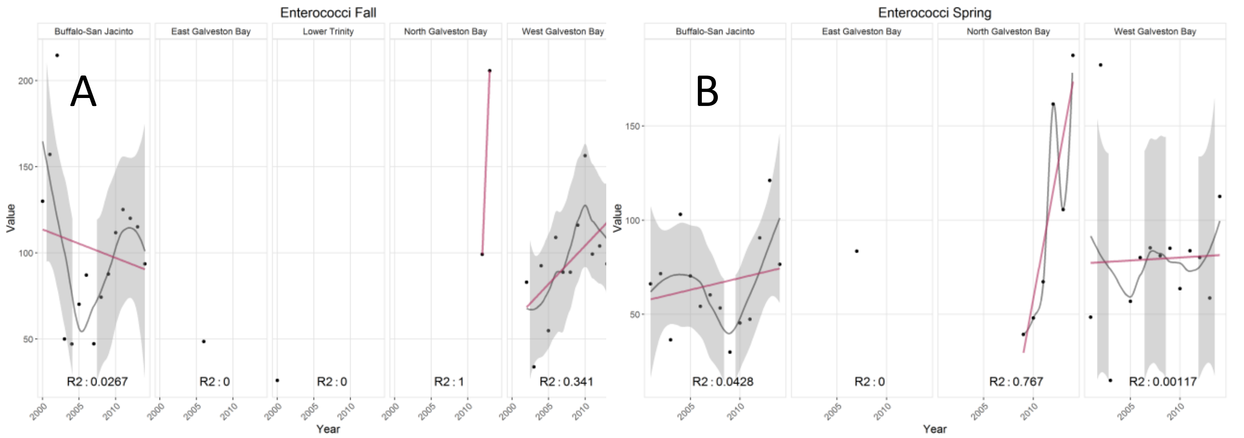
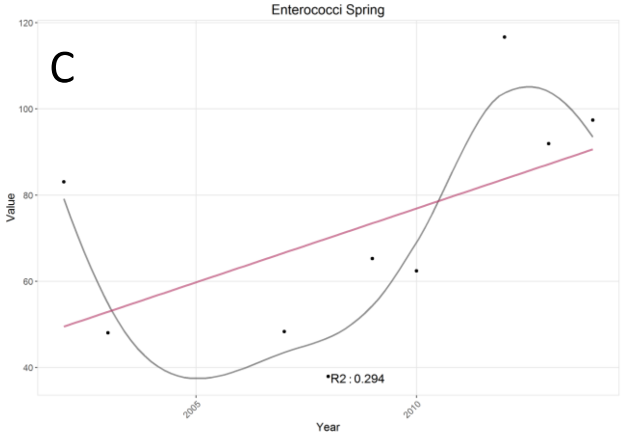
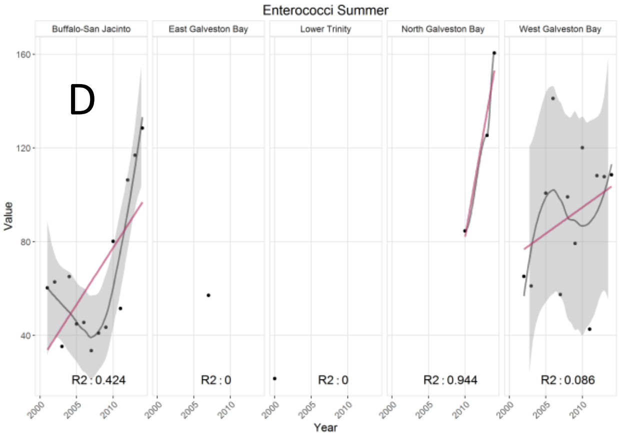


Figure 28: Enterococci trends in the subbays. Image A shows the spring data plot for enterococci levels. Image B displays the spring average for enterococci. Image C is the summer enterococci values across all of the bays that have adequate sampling. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart. It should be noted that any values above 500 were removed because they skewed the trends to a high level.

In the study watersheds, we observed some moderate trends for enterococci. In West Galveston Bay, for example, an increasing trend is seen during the fall (Figure 29, Image A). During the spring in North Galveston Bay there are large increases, although there are only six samples to analyze (Figure 29, Image B). The seasonal spring average also shows an increase. In the summer, the Buffalo-San Jacinto has a moderate increase from 2000 onward. The summer seasonal average is also increasing (Figure 29, Images D&E). There is no average annual trend in enterococci across the watersheds of the Lower Galveston Bay Watershed.







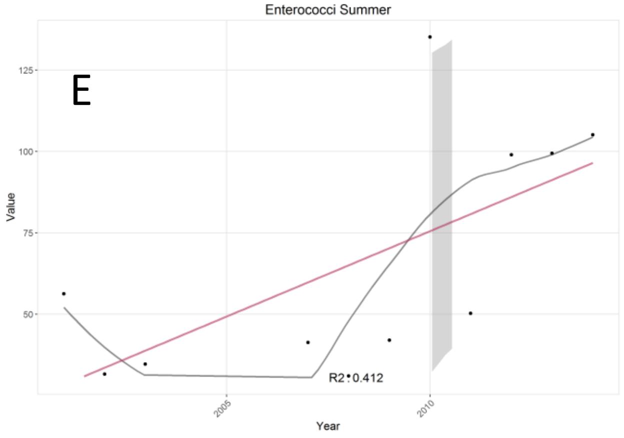


Figure 29: Enterococci trends in the watersheds. Image A is the enterococci levels in the watersheds during the fall. Image B displays the spring levels of enterococci in the watersheds. Image C shows the spring seasonal average, and Image D is the enterococci summer average by watershed. Image E shows the seasonal summer average. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart. It should be noted that any values above 500 were removed because they greatly skewed the trends.

Fecal Coliform

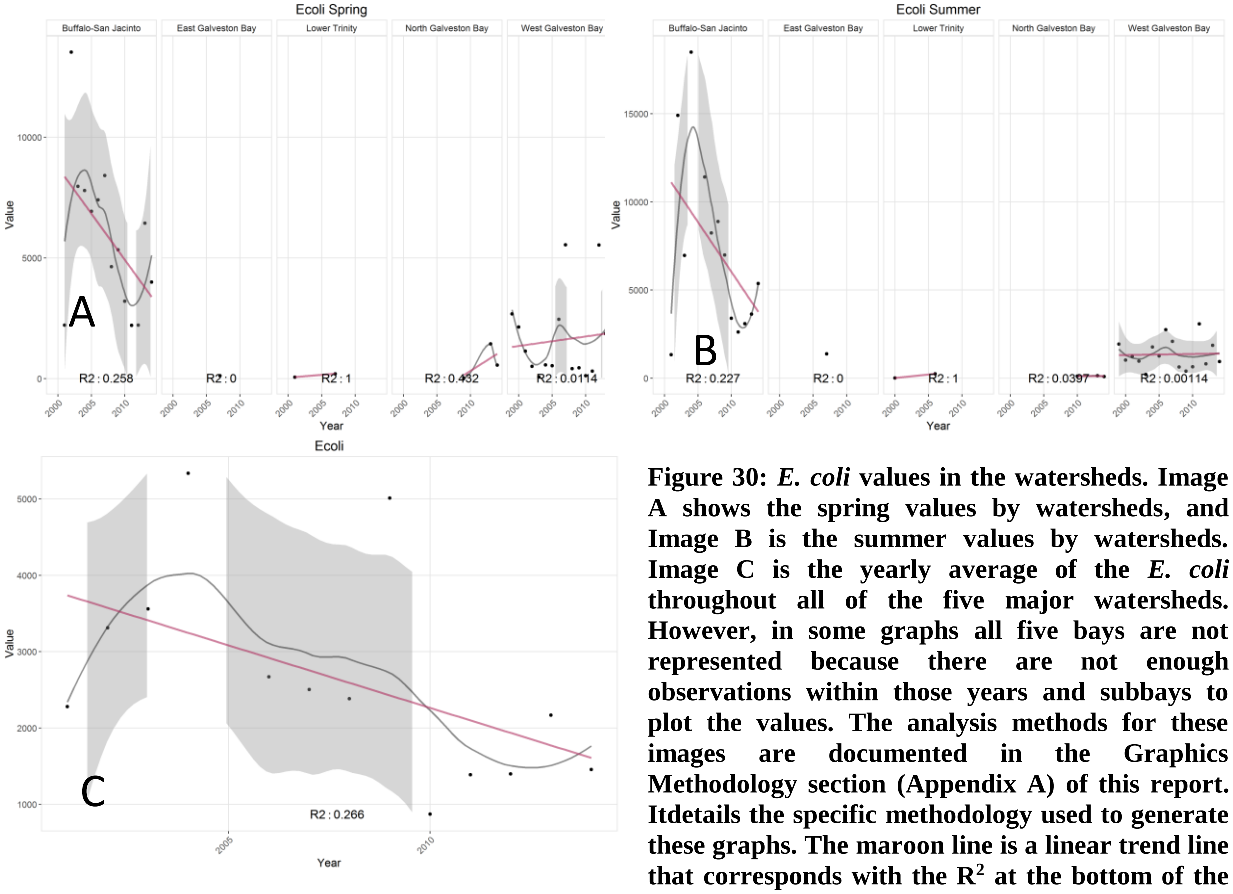


Figure 30: *E. coli* values in the watersheds. Image A shows the spring values by watersheds, and Image B is the summer values by watersheds. Image C is the yearly average of the *E. coli* throughout all of the five major watersheds. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. Itdetails the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Fecal coliform, like enterococci, is found only in salt water systems. In the subbays, there are no distinguishable trends by season. In addition, none of the seasonal averages, average exceedance, or annual averages have any obvious trends for the subbays. For this reason, no statistical conclusions can be drawn about the trends of fecal coliform over the study period from 200 to 2010. The conclusion holds true for study watersheds. It should be noted that observations measuring above 10,000 were removed from the analysis.

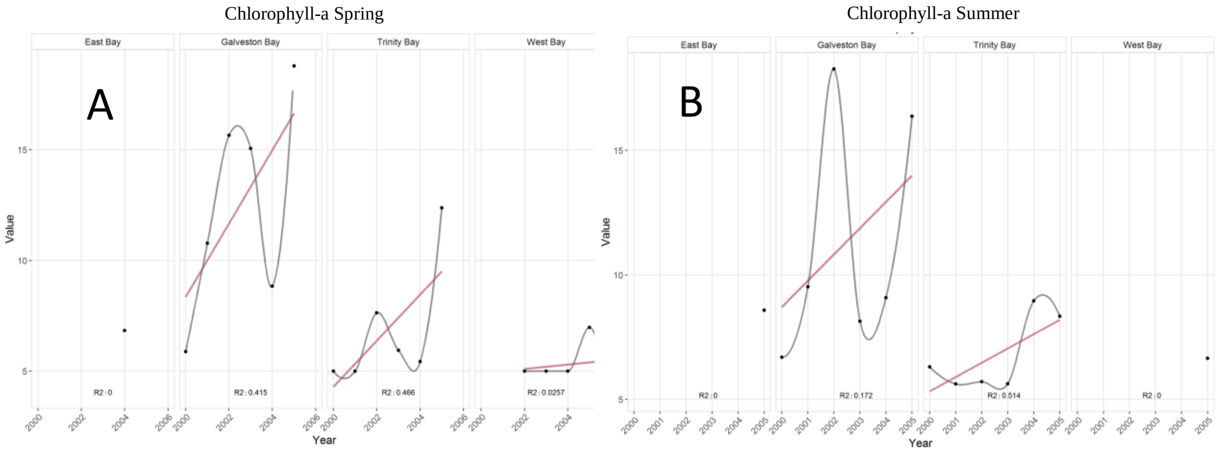
E. coli

E. coli is a bacterium found in fresh water. Minimal data is available for this parameter. In the subbays, not enough data is available to draw any trends. In the watersheds, the spring and summer in Buffalo-San Jacinto display decreasing trends. The yearly average of *E. coli* shows a decreasing trend. Like the subbays, watersheds are missing to many data points to see distinctive trends (Figure 30).

Chlorophyll-a

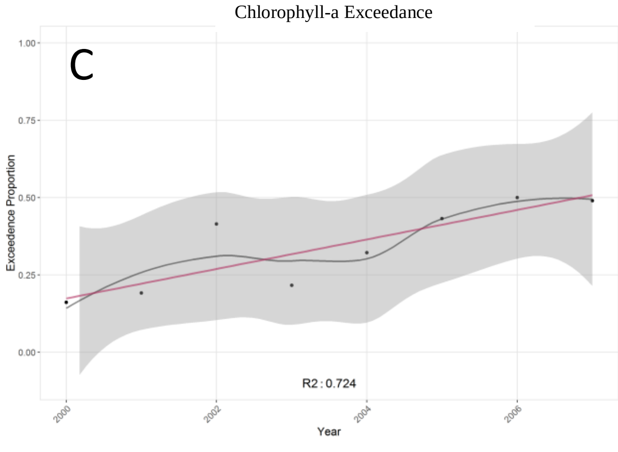
There is a long record of chlorophyll-a data available through TCEQ for the Lower Galveston Bay Watershed. However, local experts believe that the chlorophyll-a data collected before the 2000s is inaccurate. For this reason, chlorophyll-a is only assessed from 2000 to 2014.

Both Trinity Bay and Galveston Bay in the spring have increasing trends, but each subbay has only six samples. Trinity Bay also has an increasing trend in the summer. The exceedance for the seven years that are measured increases significantly based on the R-sqaured value (R^2: 0.724) (Figure 31), which means that the number of exceedances of chlorophyll-a in the subbays is increasing. Despite the increasing exceedance, there is no major annual average trend seen in the data.



Chlorophyll-a Spring

Chlorophyll-a Summer



Chlorophyll-a Exceedance

Figure 31: Image A shows the spring chlorophyll-a values by subbay, and Image B is the summer chlorophyll-a values by subbay. Image C shows the exceedance proportion of chlorophyll-a. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report and details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Table 9: R^2 values of the watersheds for spring and summer chlorophyll-a levels, 2000-2014.

Watersheds	**Spring (R^2)**	**Summer (R^2)**
Buffalo San-Jacinto	0.394 Inc.	0.297 Inc.
East Galveston Bay	0.867 Inc.	0.339 Dec.
Lower Trinity	0.481 Inc.	0.481 Inc.
North Galveston Bay	0.759 Dec.	0.339 Dec.
West Galveston Bay	0.266 Dec.	0.301 Dec.

There is also an increasing trend seen in the spring season (R^2:0.544). The winter has seen two watersheds with increasing trends: Buffalo-San Jacinto and East Galveston Bay in addition to an increasing trend in the winter for the seasonal average (Figure 32).

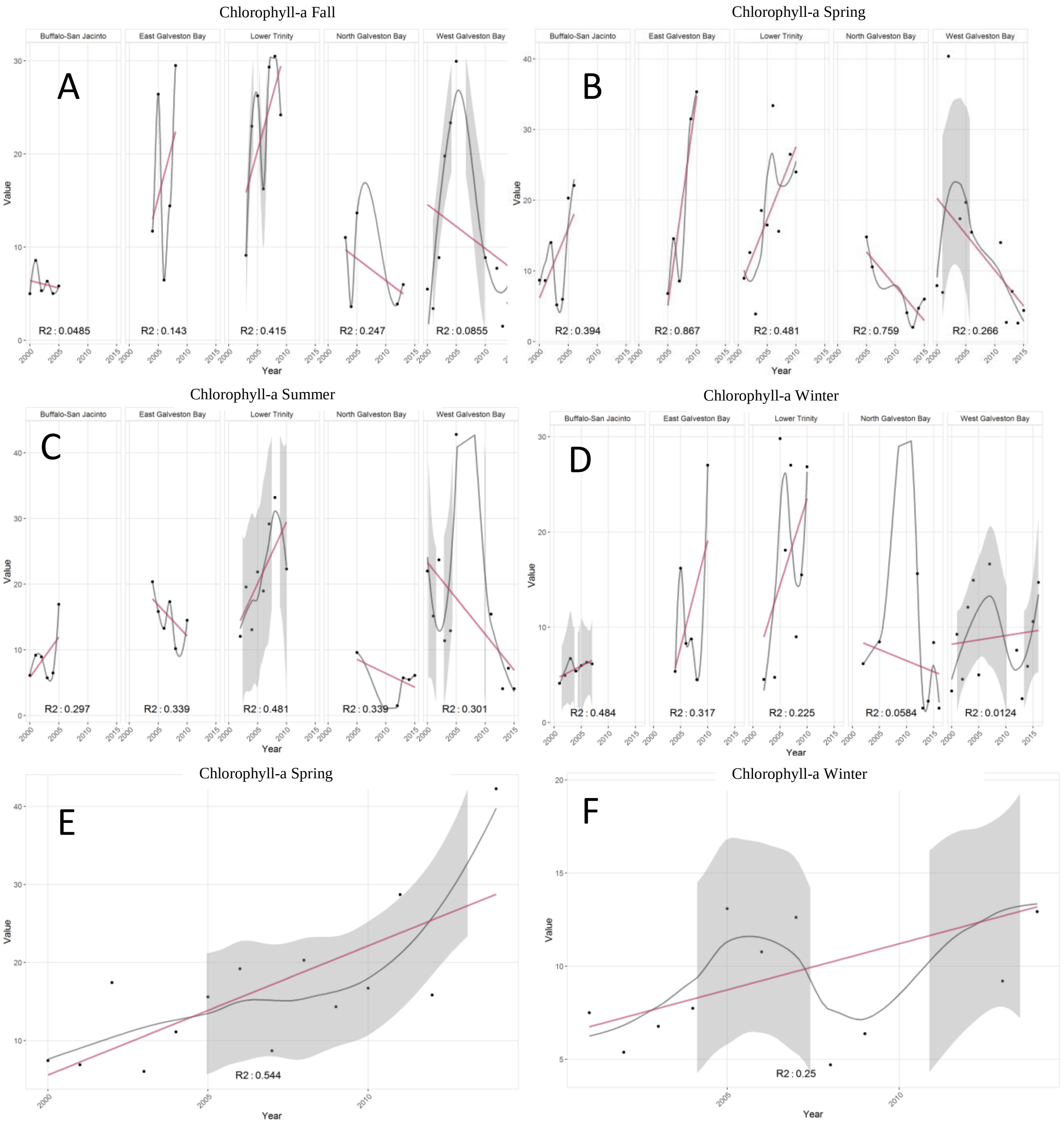


Figure 32: Chlorophyll-a trends in the watersheds. Image A shows the fall trends by watershed, Image B is the spring trends by watershed, Image C is the summer trends by watershed, and Image D is the winter trends by watershed. Image E is the seasonal average across all of the five major watersheds for spring, and Image F is the seasonal average for the winter. However, in some graphs all five bays are not represented because there are not enough observations within those years and subbays to plot the values. The analysis methods for these images are documented in the Graphics Methodology section (Appendix A) of this report. It details the specific methodology used to generate these graphs. The maroon line is a linear trend line that corresponds with the R^2 at the bottom of the image. The grey line and grey shading are the LOESS regression trend line and the corresponding confidence interval respectively. The black dots are the actual values that are being plotted on the chart.

Metals

General status of metals

The overall exceedance of metal parameters is decreasing in the Lower Galveston Bay Watershed. This trend includes all of the metals (except for selenium, which does not have a TCEQ screening level used to compute exceedance).

Detailed analysis of metals

There are 9 metals analyzed in the Status and Trends project. Due to limited sampling, all of the metals are grouped together for analysis. This way there are enough samples in total to assess the status and trends. The specific metals analyze in this study are included in Table 10.

Table 10: Metals included in the Status and Trends project.

Metals
Arsenic
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver

TCEQ measures PEL levels for metals, which defines the threshold for safe conditions. The PEL level for each metal is included in Appendix B. In order to first examine the exceedance of all metals across the subbays and watersheds, the exceedance proportion by decade for all of the metals combined by subbay and watershed were examined (Table 11). In the subbays, Galveston Bay has an exceedance percentage of 4%, whereas in the most recent decade (2010), this percentage has dropped to 1%. In the Buffalo-San Jacinto watershed there is a large decrease in the exceedance proportion across all decades. In 1970, this watershed shows a 19% exceedance in metals, whereas in 2010 there is just a 3% exceedance proportion (Table 11).

Table 11: Exceedance by decade of all metals within the Lower Galveston Bay Watershed subbays and watersheds. Selenium is omitted from the analysis because there is no TCEQ screening level that is provided for this metal. If there were under 10 samples for each parameter then the parameter and decade were not included in the analysis. The 2010 decade includes the years 2010-2014 due to data availability.

Metals		**1970**	**1980**	**1990**	**2000**	**2010**
Subbays	East Bay	-	-	-	0%	-
	Galveston Bay	4%	1%	0%	0%	1%
	Trinity Bay	0	2%	1%	0%	0%
	West Bay	-	2%	0%	0%	-
Watersheds	Buffalo-San Jacinto	19%	9%	3%	8%	3%
	West Galveston Bay	2%	2%	1%	0%	-

When examining specific metals, there are a couple of metals that exhibit trends and have adequate samplings in the subbays. For arsenic, only Christmas Bay has an instance where there is an exceedance. This only occurs once and there are no other instances across all of the subbays (Figure 33). Cadmium has no exceedances in the subbays. Chromium, like arsenic, has one exceedance, which occurs in Trinity Bay. Neither copper nor lead have any exceedances in the subbays. Mercury shows one exceedance in Galveston Bay, as does nickel, although its one occurrence takes place in Trinity Bay. Silver is in exceedance more frequently, as shown by Figure 34. Even though there are some exceedance occurrences for silver in the major subbays, the trend for all of the subbays is decreasing (Figure 34).

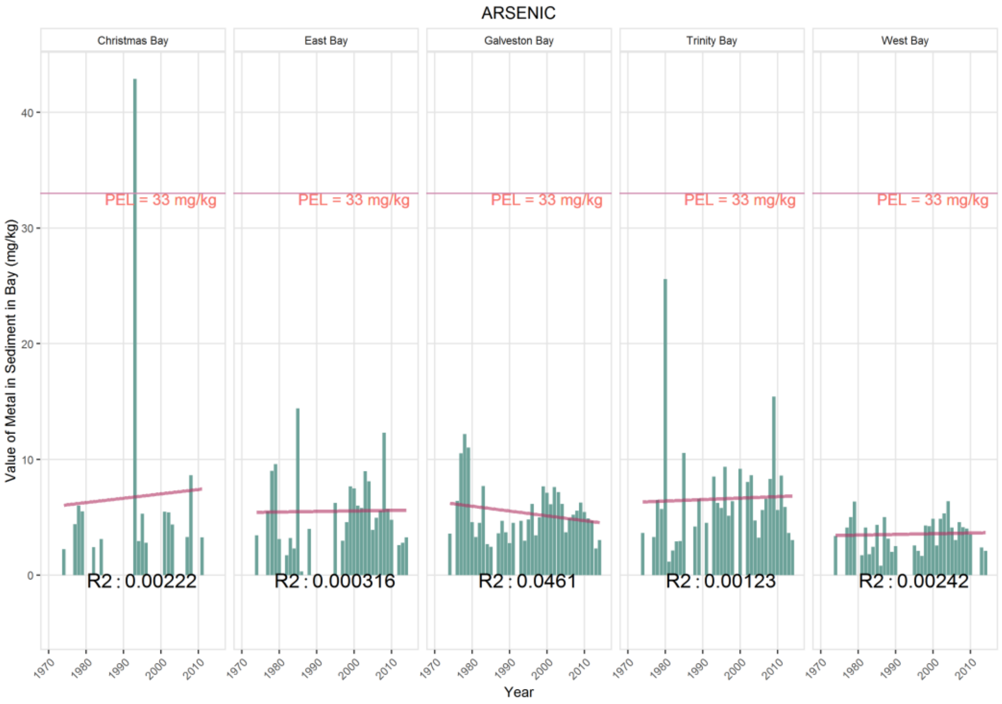


Figure 33: Arsenic levels and corresponding PEL values in the subbays of the Lower Galveston Bay Watershed. Data obtained from TCEQ.

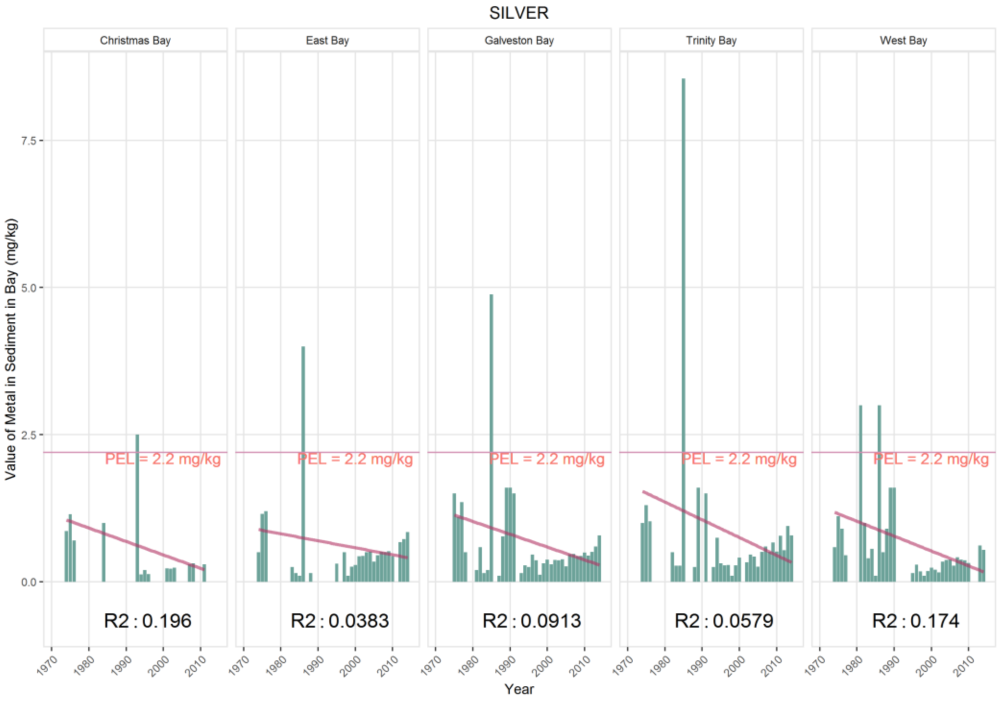


Figure 34: Silver levels and corresponding PEL values in the subbays of the Lower Galveston Bay Watershed. Any values above 400 mg/kg were removed due to the extraneous nature of these values. Data obtained from TCEQ.

Oil Spills

General status of oil spills

The general status of the oil spills in the Lower Galveston Bay Watershed is inconclusive because the trends are not strong enough to indicate an increase or decrease in volume or frequency of spills. A detailed analysis shows that there are variations within the time periods of data collected for the study area. There is also large variability between the years for volume and frequency of oil spilled.

Detailed analysis of oil spills

The frequency and amount of oil spilled in the Galveston Bay is collected by the Texas General Land Office (GLO). The details for the analysis of the GLO data are included in the General Methodology section of the report. Only spills for the Galveston Bay are included in this analysis. Figure 35 shows the amount of oil spilled (in gallons) by year over the Galveston Bay. The time period for the GLO oil spills data is 1998 through the first part of 2016.

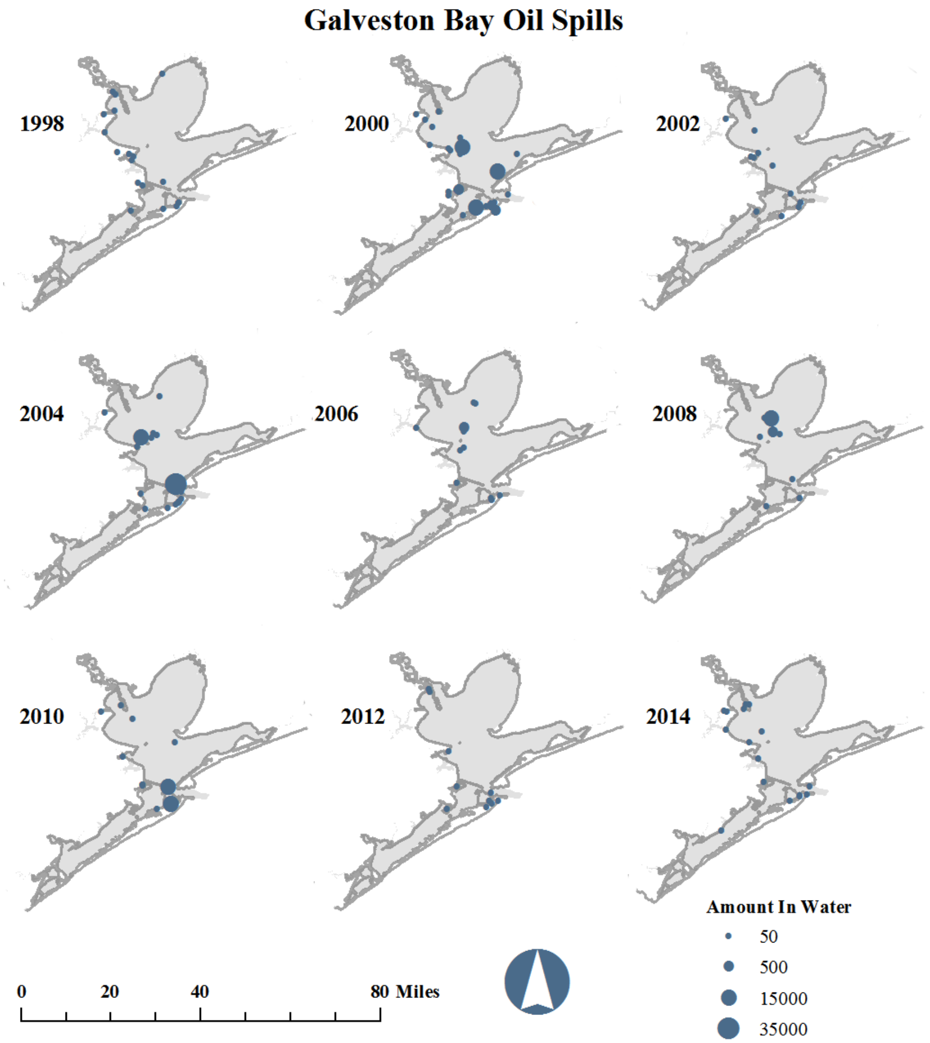


Figure 35: Galveston Bay oil spills: 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014. The size of the dot represents the amount of oil spilled during the reported spill. Data obtained from the General Land Office.

In addition to showing the frequency, location, and amount of oil spills (Figure 35), the source of each of the spills is also recorded. Figure 36 contains three images- the top left is the amount of oil spilled by three spill sources: facility, other, and unknown. The top right image is the amount of oil spilled by vessels. These graphs are split because some high-volume spills from vessels prevent all three sources from being put on the same scale. Lastly, the bottom image illustrates the number of oil spills that have occurred by year for each spill source. The number of events recorded and amount of oil spilled every year for each spill source are shown in Table 12. Overall, the spills from vessels had the largest volume of oil spilled throughout the time period. Figure 36 shows that 2004 had a big spike for facility and vessel oil spill amounts, and 2001 had a large spill volume for vessels. A relatively even split is shown between the facility, unknown, and vessel spill sources.

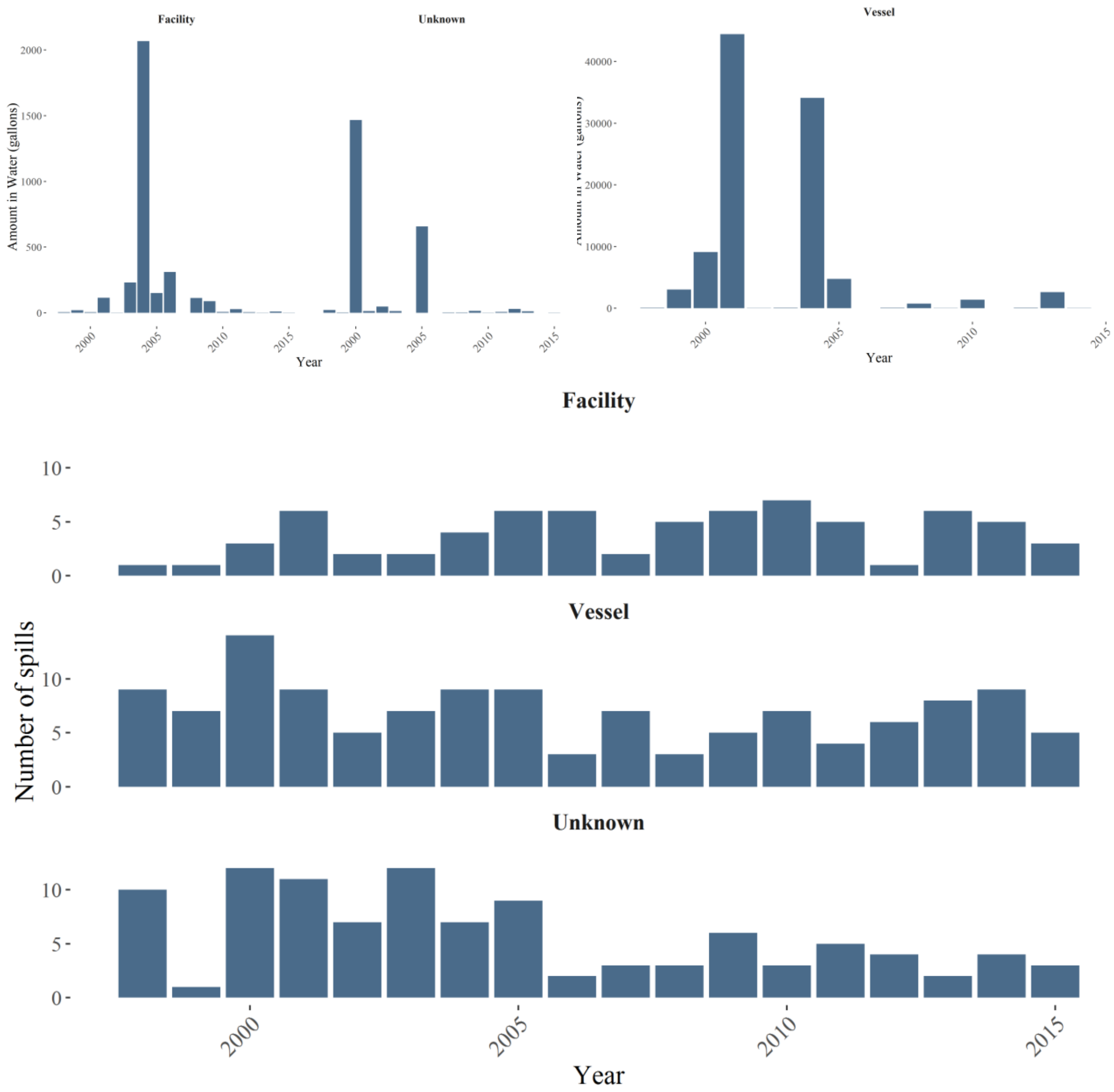


Figure 36: Amount and number of oil spills by source. Top image shows the number of gallons spilled by each type of spill source (facility, other, and unknown). The image on the right top shows the number of gallons spilled by vessels. The bottom image shows the number of spills that have occurred by each spill source.

Table 12: Oil spills in the Galveston Bay. Data recorded by Texas General Land Office, 1998-2015.

	Gallons Spilled				**Number of Spills**			
Year	Facility	Unknown	Vessel	**Total Volume of Spills**	Facility	Unknown	Vessel	**Total Number of Spills**
1998	5	20	82	**106**	1	9	9	**19**
1999	20	3	3,036	**3,059**	1	1	7	**9**
2000	5	117	9,103	**9,224**	3	10	14	**27**
2001	115	11	44,423	**44,549**	6	10	9	**25**
2002	2	48	36	**86**	2	7	5	**14**
2003	231	13	86	**330**	2	11	7	**20**
2004	2,067	0	34,096	**36,163**	4	7	9	**20**
2005	151	28	4,751	**4,930**	6	8	9	**23**
2006	310	0	10	**320**	6	2	3	**11**
2007	0	0	61	**61**	2	1	7	**10**
2008	113	4	750	**867**	5	3	3	**11**
2009	89	15	28	**132**	6	6	5	**17**
2010	7	0	1,374	**1,380**	7	2	7	**16**
2011	27	0	11	**38**	5	2	4	**11**
2012	5	0	61	**66**	1	2	6	**9**
2013	1	1	2,586	**2,588**	6	1	5	**12**
2014	11	1	48	**59**	5	4	9	**18**
2015	1	2	12	**14**	3	3	5	**11**
Total	3,160	261	100,552	**103,973**	71	89	123	**283**

Colonial Nesting Waterbirds

General status of waterbirds

There are many waterbirds that are assessed in the Status and Trends report. Certain species, such as the Brown Pelican show a distinctive increasing trend. Other species such as Black Skimmer, Black-crowned Night Heron, Great Blue Heron, and Roseate Spoonbill have distinctive decreasing trends. There are also many other species that have variations in trends.

The time period for the colonial nesting waterbirds data is 1973-2015. Figure 37 shows the locations of all the places where these waterbirds were recorded throughout this time range. This figure illustrates the spatial spread across the Lower Galveston Bay Watershed.

Detailed analysis of waterbirds

There are multiple colonial nesting waterbirds species that are examined for this report. Specifically, there are 24 bird species catalogued from 1973 – 2015 (Table 13). The data for the colonial nesting waterbirds comes from Audubon Texas, which hosts data collected by the United States Fish and Wildlife Service (see the General Methodology section for more detail about data collection).

Species with the strongest trends (as identified as $R^2 \geq 0.5$ for bird species) are Black Skimmer, Black-crowned Night Heron, Brown Pelican, Great Blue Heron, and Roseate Spoonbill. These, along with a few other species, are discussed in more detail below.

Black Skimmer

Black Skimmers are found along the whole Gulf coast and tend to live on the beaches. The trend of the Black Skimmer is shown in Figure 38 (Image A). The Black Skimmer has a decreasing trend throughout the time period; the included LOESS regression displays a downward trend that has plateaued since the mid-1990s.

Table 13: Trend of bird species within Lower Galveston Bay Watershed. Bird samples are all located within one mile of the Galveston spatial extent boundary. All of the samples within the minor bays are also included. High increase is defined as above $R^2 > 0.5$, moderate increase is $R^2 > 0.25$ and $R^2 < 0.5$. High decrease is $R^2 > 0.5$, and moderate decrease is $R^2 > 0.25$ and $R^2 < 0.5$

Species	R2	Trend
Anhinga	0.02	No Trend
Black Skimmer	0.31	↓
Black-crowned Night Heron	0.44	↓
Brown Pelican	0.62	↑
Caspain Tern	0.04	No Trend
Cattle Egret	0.07	No Trend
Double-crested Cormorant	0.24	No Trend
Forster's Tern	0.04	No Trend
Great Blue Heron	0.38	↓
Great Egret	<0.001	No Trend
Gull-billed Tern	0.10	No Trend
Laughing Gull	0.08	No Trend
Least Tern	0.06	No Trend
Little Blue Heron	0.01	No Trend
Neotropic Cormorant	0.05	No Trend
Reddish Egret	0.01	No Trend
Roseate Spoonbill	0.41	↓
Royal Tern	0.05	No Trend
Sandwich Tern	0.04	No Trend
Snowy Egret	0.01	No Trend
Tricolored Heron	0.20	No Trend
White Ibis	0.01	No Trend
White-faced Ibis	0.21	No Trend
Yellow-crowned Night Heron	0.02	No Trend

↑	High Increase
↑	Moderate Increase
No Trend	
↓	Moderate Decrease
↓	High Decrease

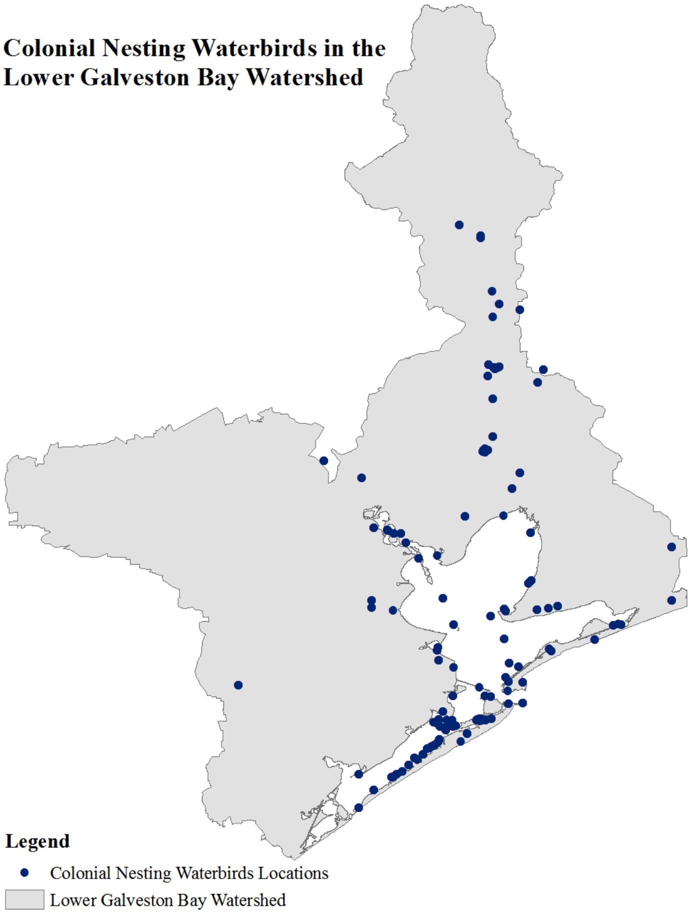


Figure 37: Colonial nesting waterbird locations in the Lower Galveston Bay Watershed. The colonial nesting waterbird locations include a range of 1973-2015.

Black-crowned Night Heron

The Black-crowned Night Heron is found in both fresh and salt water habitats, and tends to form nests in tree groves and in marsh vegetation (Audubon, 2016). According to Audubon, the area of study commonly has Black-crowned Night-Herons year-round. These birds typically eat fish and other aquatic organisms. Figure 38 (Image B) indicates there has been a slight decrease in the number of pairs. This decrease could be attributed to the loss of habitat or water pollution.

Brown Pelican

Brown Pelicans reside in salt water environments and are common in the Gulf of Mexico. In the 1970s, Brown Pelicans were at high risk because DDT affected their eggs; once DDT was banned the Brown Pelican population seemed to rebound (Audubon, 2016). Brown Pelicans have a diet of fish and feed by dropping from the air into the water to catch their prey. In the Lower Galveston Bay Watershed, there was an increase in the number of Brown Pelicans from 1995 onwards (Figure 38, Image C).

Great Blue Heron

The Great Blue Heron is commonly found across the majority of the United States. This bird is highly adaptable and can be found in many habitats and can be disturbed by human encroachment on their habitats (Audubon, 2016). In the Lower Galveston Bay Watershed, these birds have experienced a decrease throughout the time period (R^2: 0.375). The LOESS regression shows that the decrease was larger in the 1980s and then plateaued in the following years (Figure 38, Image D).

Roseate Spoonbill

Roseate Spoonbills are common in the Gulf of Mexico, according to Audubon (2016). These are birds that feed by wading in the shallows and typically consume fish and other small aquatic organisms. Roseate Spoonbills are known to breed in Texas and prefer mangroves and shrubby habitat for nesting (Audubon, 2016). Roseate Spoonbills began to rebound in Texas at the beginning of the 20th century. Their numbers are being negatively influenced by habitat degradation (Audubon, 2016). There is a slight decrease in the number of these brightly colored birds according to the data from the Status and Trends database (Figure 38, Image E).

Royal Tern

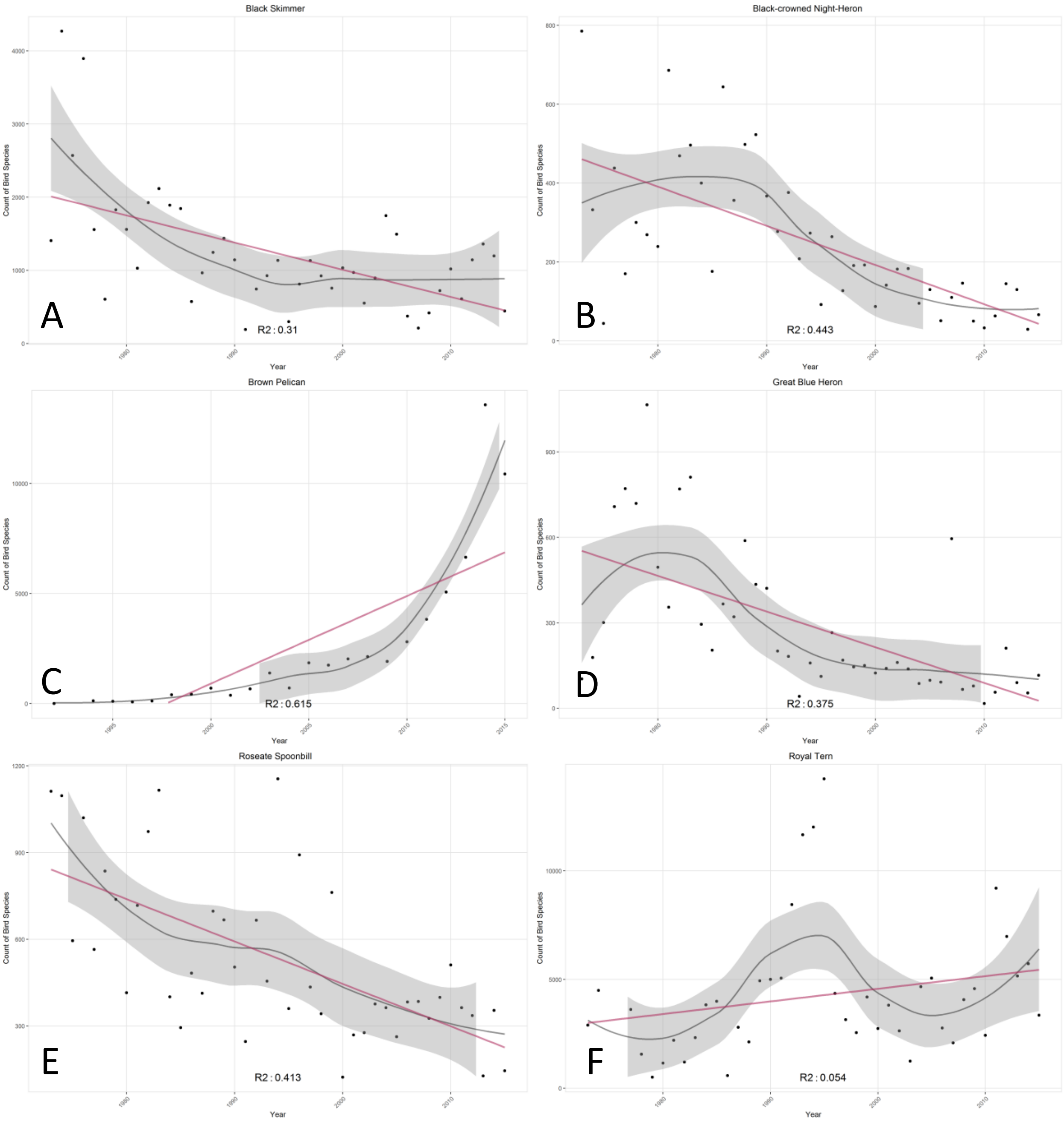
The Royal Tern is seen in many coastal areas, including the Gulf of Mexico. This species was in decline in the 19th century when their eggs were harvested for food. In the 20th century, the Royal Tern has increased in numbers (Audubon, 2016). These birds nest on the ground, typically in a sandy environment such as a beach, and rely on fish for food. The trend throughout the study area shows an increase until around 1990 and then a decrease and subsequent plateau in the number of bird pairs to until the present (Figure 38, Image F).

Sandwich Tern

The Sandwich Tern, like many other bird species, is susceptible to habitat degradation and prefers to live in coastal waters and on beaches (Audubon, 2016). In the late 19th century, the Sandwich Tern suffered a decline in population when their eggs were harvested for food (Audubon, 2016). This species of bird is common in all seasons along the Gulf Coast and in the study area. Like the Royal Tern, the Sandwich Tern nests in open and often sandy areas, which makes their nesting habitats more subject destruction from beachfront development. The data for the Lower Galveston Bay Watershed displays a spike in the number of pairs of Sandwich Terns in 1990 and then a decrease and plateau in the more recent years (Figure 38, Image G). This trend is very similar to the one seen by the Royal Tern.

White-faced Ibis

The White-faced Ibis lives in marshes and feeds in shallow waters. This bird is commonly found in all seasons in the Lower Galveston Bay Watershed and in the Gulf of Mexico (Audubon, 2016). The White-faced Ibis prefers marshy areas to nest and tends to reside in fresh water environments, but can tolerate salt water as well. In the Lower Galveston Bay Watershed, there was a decrease in the number of birds observed from 1985 to 2000. Then, the number of birds held steady from 2000 until present (Figure 38, Image H).


Black Skimmer
Count of Bird Species
0
1000
2000
3000
4000
1980
1990
2000
2010
Year
R2 : 0.31
A
Black-crowned Night-Heron
Count of Bird Species
0
200
400
600
800
1980
1990
2000
2010
Year
R2 : 0.443
B
Brown Pelican
Count of Bird Species
0
5000
10000
1995
2000
2005
2010
2015
Year
R2 : 0.615
C
Great Blue Heron
Count of Bird Species
0
300
600
900
1980
1990
2000
2010
Year
R2 : 0.375
D
Roseate Spoonbill
Count of Bird Species
300
600
900
1200
1980
1990
2000
2010
Year
R2 : 0.413
E
Royal Tern
Count of Bird Species
0
5000
10000
1980
1990
2000
2010
Year
R2 : 0.054
F

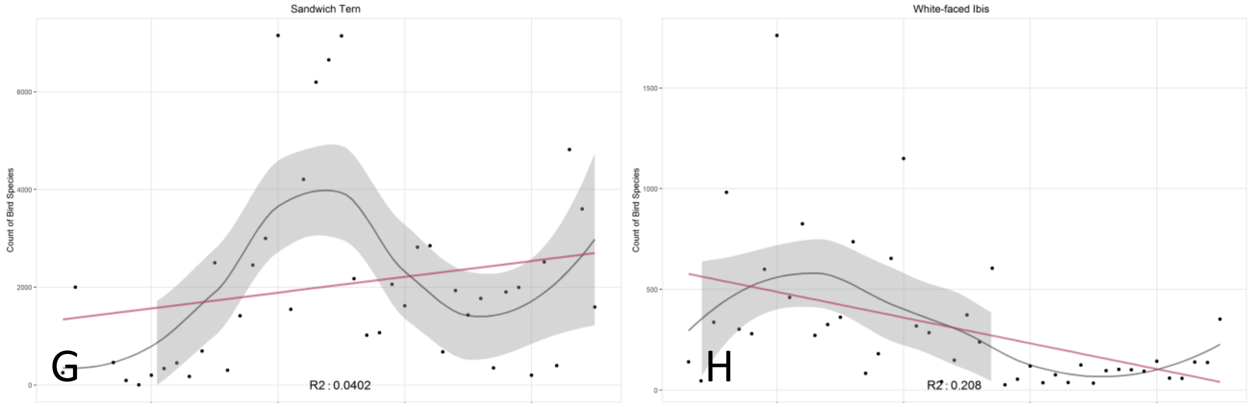


Figure 38: Bird species trends. Image A is the Black Skimmer; Image B is the Black-crowned Night Heron; Image C is the Brown Pelican; Image D is Great Blue Heron; Image E is the Roseate Spoonbill; Image F is the Royal Tern; Image G is the Sandwich Tern; and Image H is the White-faced Ibis.

Coastal Fisheries

In examining the trends of these predatory species, we gain an understanding of Bay-wide health at the top level of the food chain. As mentioned in the General Methodology section, there are four different methods of collection by TPWD that are analyzed in this report: gill net, trawls, bag seines, and oyster dredge.

General status of coastal fisheries

There are many fisheries species that are available for analysis through the Status and Trends Atlas. For the purposes of this report, a representative five predatory species are examined. The spotted seatrout shows an overall increase in the number of species observed from the mid-1980s to the most recent year recorded. This increase is seen in multiple subbays and across multiple collection methods. Overall, sand seatrouts have decreasing trends in the subbays of the Lower Galveston Bay Watershed. While the largest decreasing trend is seen in Christmas Bay, there is a lot of variability in the data. Only the bag seine collection method has a distinguishable trend for sand seatrout. Red drum shows some increasing trends in the subbays, whereas black drum does not have a definitive trend. The southern flounder, collected by gill net, shows a decreasing trend. Overall, within these five species, there is a lot of variability within the trends. For this reason, more analysis is needed on fisheries species to determine which species are the best indicators for a definitive status of the fisheries within the Galveston Bay.

Detailed analysis of fisheries

There are numerous fisheries species that are included in the TPWD coastal fisheries data. A list of these species is available in Appendix D. This report follows the format of the 2008 Status and Trends Report (Gonzalez & Lester, 2008), assessing the same five fish indicator species listed in Table 14.

Table 14: Predatory fish species included in the analysis of the Status and Trends Report.

Fisheries species
Spotted seatrout (*Cynoscion nebulosus*)
Sand seatrout (*Cynoscion arenarius*)
Red drum (*Sciaenops ocellatus*)
Black drum (*Pogonias cromis*)
Southern flounder (*Paralichthys lethostigma*)

Spotted Seatrout

Increasing trends of spotted seatrout are seen in East Bay, Galveston Bay, and Trinity Bay when collected by gillnet (Figure 39 Image E). For the trawl collection method, West Bay shows an increasing trend (R^2: 0.803). For this species and collection method, this subbay has the smallest number of samples (Figure 39 Image F). The other subbays also show increasing trends, although they are not very strong.

Sand Seatrout

The sand seatrout collected with the bag seine method has a decreasing trend in Christmas Bay. All of the other subbays for this collection method and species also have decreasing trends, but they are not as strong as the one seen in Christmas Bay (Figure 39 Image C). The LOESS regression for this graph show a lot of variation in the subbays. In particular, East Bay, Galveston Bay, and Trinity Bay all show a peak in the mid-1990s and then a decrease until the mid-2000s—with a slight increase after that. This result could be an indication of fluctuation in the sand seatrout stock (Figure 39, Image C). No other collection methods and subbays have distinguishable trends for this species.

Red Drum

Red drum has moderately increasing trends in gill net collection for both Trinity Bay and West Bay (Figure 39, Image B). All of these subbays have relatively similar trends, although the LEOSS regression shows some variation in the specific patterns of each subbay for red drum collected by gill net (Figure 39, Image B). None of the other collection methods have enough sampling data to produce observed statistical trends.

Black Drum

There are no black drum subbays that have moderately increasing or decreasing trends for either the bag seine or gill net collection method. The only subbay that shows a moderate trend is Christmas Bay— with the trawl collection method. Christmas Bay shows an increasing trend for black drum (Figure 39, Image A). All of the other subbays for this collection method also show increasing trends, although more moderate than Christmas Bay. It should be noted that the trend in Christmas Bay is based on relatively few samples, and the collection period begins in the late 1990s (Figure 39, Image A).

Southern Flounder

The southern flounder, collected by gill net, has a relatively strong decreasing trend in Christmas Bay (Figure 39, Image D). All of the other subbays for southern flounder that are collected by gill net also show decreasing trends. No other collection methods and subbays have strong data trends for the southern flounder.

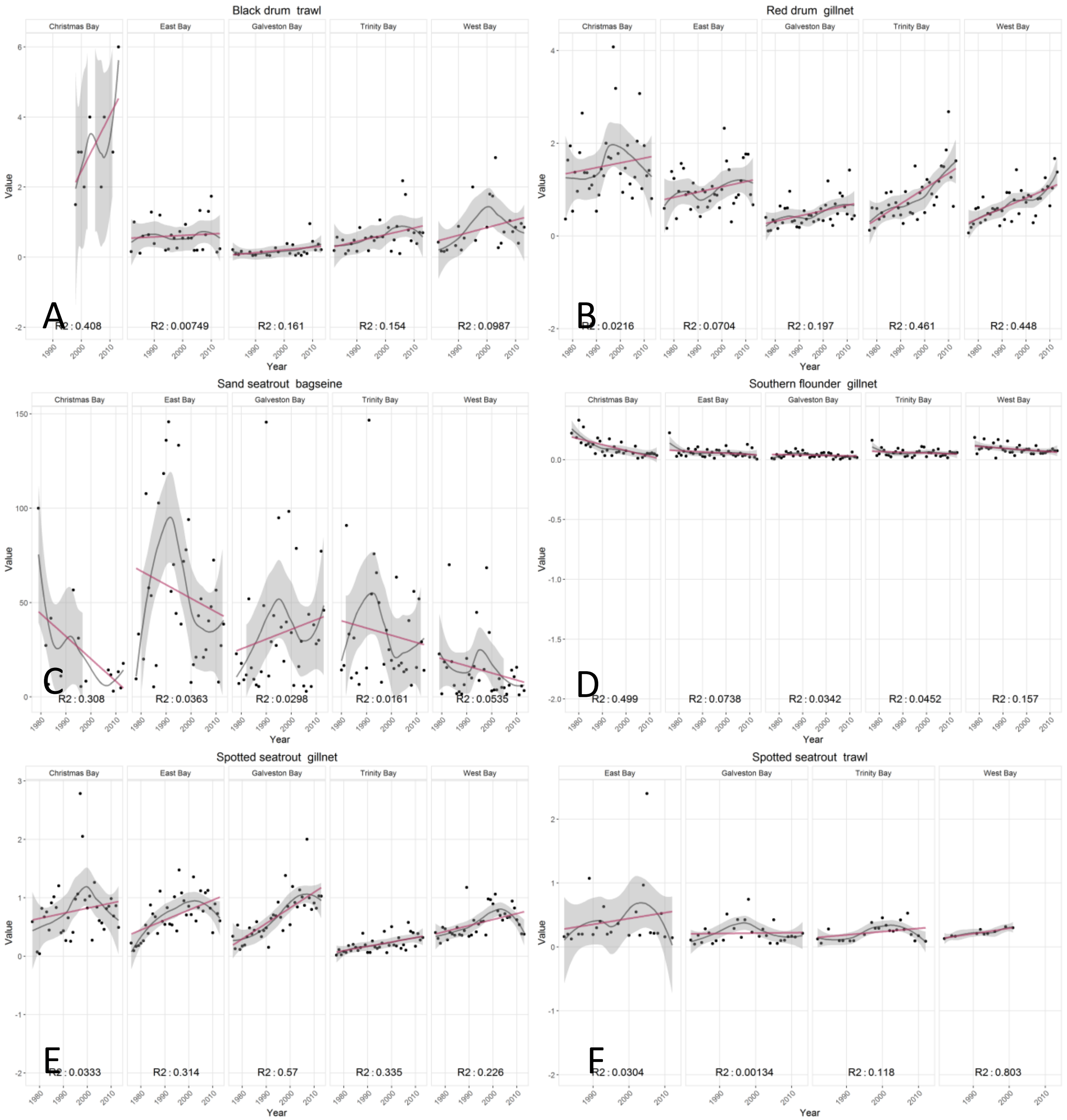


Figure 39: Catch per unit effort (CPUE) of specific predatory fisheries species. Image A shows the CPUE of black drum with the trawl collection method. Image B is the red drum with the gill net collection method. Image C is the sand sea trout collected by bag seine. Image D shows the CPUE of the southern flounder collected by gill net. Image E shows the spotted seatrout collected by gill net, and Image F is the spotted sea trout collected by trawl.

Land Use Change

General status of land use change

In general, there was a lot of land use alteration in the Lower Galveston Bay Watershed between 1996 and 2010 (the time period with available land use data for the area). There are trends that are observed relatively consistently across the region's land use types. Wetlands are consistently being depleted. Large decreases are seen across the entire Lower Galveston Bay Watershed in addition to some of the surrounding counties. The specific type of wetland that is decreasing depends on location; some types of wetlands are increasing. In the Lower Galveston Bay Watershed, all types of development have shown a very large increase between 1996 and 2010. Large decreases are also observed in multiple types of forest in the Lower Galveston Bay Watershed.

In order to understand more specifically where the changes of land use type have occurred, this study separately examines the five major counties surrounding the majority of the Lower Galveston Bay Watershed. Harris County and Liberty County are the two counties with the largest changes in wetlands between 1996 and 2010. In addition to a loss of wetlands, there are also large losses of forest within the counties. There is increased development within the region. Development is expanding away from the city of Houston, and the land use in areas of rapid development is being altered. The following section discusses the different types of land change in more detail.

Detailed analysis of land use change

Land use change in the Lower Galveston Bay Watershed

Wetland alteration has occurred throughout the Lower Galveston Bay Watershed. Land cover data from the National Oceanic and Atmospheric Administration (NOAA) were used to determine the extent and amount of wetlands altered from 1996 to 2010. NOAA has an initiative called the Coastal Change Analysis Program (C-CAP), which provides land cover data at intervals from 1996 to 2010. This dataset has 22 different land cover classifications based on Landsat Thematic Mapper satellite imagery (NOAA, 2003). The C-CAP classification system is based on different previous classification systems, including Anderson (1976), Cowardin, Carter Golet, & LaRoes (1979), and Dobson (1993). The 22 different types of land cover that are included in the NOAA C-CAP data are listed in Table 15.

Table 15: NOAA C-CAP land cover classifications based on Landsat Thematic Mapper satellite imagery. For more information on these classifications visit: https://coast.noaa.gov/data/digitalcoast/pdf/ccap-class-scheme-regional.pdf.

NOAA C-CAP Land Cover Classification
Background
Developed, High Intensity
Developed, Medium Intensity
Developed, Low Intensity
Developed, Open Space
Cultivated Crops
Pasture/Hay
Grassland/Herbaceous
Deciduous Forest
Evergreen Forest
Mixed Forest
Scrub/Shrub
Palustrine Forested Wetland
Palustrine Scrub/Shrub Wetland
Palustrine Emergent Wetland
Estuarine Forested Wetland
Estuarine Scrub/Shrub Wetland
Estuarine Emergent Wetland
Unconsolidated Shore
Bare Land
Open Water
Palustrine Aquatic Bed
Estuarine Aquatic Bed

Wetlands are defined primarily based on the classification by Cowardin (1979), and the classifications used are partially derived from Cowardin (1979). For instance, an emergent wetland consists of mostly herbaceous vegetation, whereas scrub/shrub wetland refers to the secondary growth type of wetlands (Jacob & Lopez, 2005). Forested wetlands are wooded (Jacob & Lopez, 2005). In an effort to understand the most recent wetlands alteration data, this study uses the most current NOAA C-CAP classifictions and analyzes the trend of wetland alteration over several time periods starting in 1996. The data are at a 30-meter resolution and can be downloaded from the NOAA C-CAP online mapping portal as raster files. These land use data are available every five years, and, in this region, the years that are available are 1996, 2001, 2006, and 2010. The wetland types included are: palustrine forested wetland, palustrine scrub/shrub wetland, palustrine emergent wetland, estuarine forested wetland, estuarine scrub/shrub wetland, and estuarine emergent wetland.

Initially, this study looked at the changes in major land cover types within the entire Lower Galveston Bay Watershed (Table 16). There has been a decrease of about 25,668 acres of wetlands between 1996 and 2010. The largest decrease by acreage is 25,857 acres in palustrine forested wetland (6%). Palustrine scrub/shrub wetlands have a very slight decrease (53 acres), as do estuarine scrub/shrub wetlands (22 acres). Estuarine emergent wetlands have a 22-acre decrease, which represents 7% of the whole because there were very few acres of these types of wetlands initially. Palustrine emergent wetlands and estuarine forested wetlands actually show a very slight increase in the acreage of wetlands from 1996 to 2010 (Table 16).

Table 16: Lower Galveston Bay Watershed. The 22 land cover classes in 1996, 2001, 2006, and 2010—and changes between 1996 and 2010.

Land Cover Class	**Total acres 1996**	**Total Acres 2001**	**Total Acres 2006**	**Total Acres 2010**	**Change in Acres (1996-2010)**	**% Change in Acres (1996-2010)**	**Category Change 1996-2010**
Developed, High Intensity	129,040	136,677	154,666	161,474	32,434	25%	159,402
Developed, Medium Intensity	288,487	305,882	330,011	344,756	56,269	20%	
Developed, Low Intensity	239,196	255,197	266,962	281,893	42,697	18%	
Developed, Open Space	188,884	202,163	204,998	216,886	28,002	15%	
Cultivated Crops	259,874	258,859	256,443	252,021	-7,853	-3%	
Pasture/Hay	723,895	694,492	673,040	656,224	-67,671	-9%	
Grassland/Herbaceous	157,307	181,586	180,290	166,112	8,805	6%	
Deciduous Forest	125,443	122,030	111,787	104,595	-20,848	-17%	-102,067
Evergreen Forest	263,947	224,173	207,572	198,893	-65,054	-25%	
Mixed Forest	139,259	137,135	130,131	123,094	-16,165	-12%	
Scrub/Shrub	137,012	138,333	148,661	161,905	24,893	18%	
Palustrine Forested Wetland	453,570	448,197	438,087	427,713	-25,857	-6%	-25,668
Palustrine Scrub/Shrub Wetland	74,258	72,975	70,456	74,205	-53	0%	
Palustrine Emergent Wetland	179,032	179,176	176,092	179,305	273	0%	
Estuarine Forested Wetland	0	0	62	52	52	N/A	
Estuarine Scrub/Shrub Wetland	314	314	298	292	-22	-7%	
Estuarine Emergent Wetland	162,415	162,392	162,899	162,354	-61	0%	
Unconsolidated Shore	22,690	22,849	24,479	24,171	1,480	7%	
Bare Land	8,303	9,788	15,585	13,867	5,564	67%	
Open Water	98,436	98,938	99,297	102,188	3,752	4%	
Palustrine Aquatic Bed	5,541	5,715	5,382	5,205	-336	-6%	
Estuarine Aquatic Bed	1,201	1,231	905	898	-303	-25%	

Across the entire Lower Galveston Bay Watershed, there is a large increase in development (Table 16). The largest percentage increase is in high intensity development (80-100% impervious surface), which saw an increase of 25% (32,434 acres) between 1996 and 2010. The second highest percentage change and largest increase in acres is in medium intensity development (50-79% developed) of 20% (56,269 acres) (Table 16). Low intensity development increased 18% (42,697 acres), and developed open space 15% (28,002). Medium and low intensity development have larger changes in the number of acres because there was more medium and low intensity development in the Lower Galveston Bay Watershed before 1996. Altogether, between 1996 and 2010, there was a 159,402-acre increase in development within the study area.

Forest lands also underwent a noticeable change in the Lower Galveston Bay Watershed between 1996 and 2010. There are three types of forest present: evergreen, deciduous, and mixed. All three of these forest types have decreased between 1996 and 2010, with the largest percentage and acreage in evergreen forests (25%; 65,054 acres) (Table 16).

Land use change in the counties of the Lower Galveston Bay Watershed

In an effort to examine the differences in land use across the counties of the Lower Galveston Bay Watershed (and specifically how different land uses have changed over the past 15 years) (1996 to 2010), we examined the counties of the Galveston Bay Estuary: Brazoria, Galveston, Chambers, Harris, and Liberty. Each county has the majority of its area (if not all of it) within the bounds of the Lower Galveston Bay Watershed.

Table 17 details the amount of wetland and development land cover (by county) for each of the four years of data available. There is a decrease of about 28,797 acres of wetland from 1996 to 2010. The majority of the wetland loss comes from Harris County, and the second largest wetland loss comes from Liberty County. In addition to wetland loss, we calculated high levels of forest loss in both of these counties (Table 17). Harris County has the largest increase in development, followed by Brazoria County. For this reason, we examine Harris, Liberty, and Brazoria Counties separately for changes in specific land covers.

Table 17: Wetland and development land uses in the 5-county region. Data from NOAA C-CAP, 1996-2010.

County	Land Cover Class	Change in Acres (1996-2010)	Total
Brazoria	Development (High, Medium, Low, Open Space)	14,507	150,694
Galveston		11,820	
Chambers		4,197	
Harris		116,861	
Liberty		3,309	
Brazoria	Wetlands (Palustrine Forested, Scrub/Shrub and Emergent; Estuarine Forested, Scrub/Shrub and Emergent)	-3,184	-28,869
Galveston		-3,606	
Chambers		-3,058	
Harris		-12,778	
Liberty		-6,243	
Brazoria	Forest (Deciduous, Evergreen, Mixed)	-3,592	-94,038
Galveston		-2,356	
Chambers		-1,604	
Harris		-59,690	
Liberty		-26,796	

Harris County

In Harris County, the variation in type of wetland loss follows the trend seen in the entire Lower Galveston Bay Watershed. This means that the majority of the wetland loss is palustrine forest wetland. Harris County lost 10,912 acres of this wetland type from 1996-2010 (16%). The other major type of wetland that was lost during this time period was palustrine scrub/shrub wetland at 1,989 acres (12%). Other types of wetlands had minimal losses in Harris County between 1996 and 2010. There are also large losses in forest land during this time period. Evergreen forests see a decrease of 35,336 acres (38%), followed by deciduous forests with 13,855 acres (26%), and mixed forests with a 10,498 acre (25%) loss. In total, there have been 59,690 acres of forest land lost over this time period within Harris County (Table 18).

Table 18: Harris County land cover class changes between 1996 and 2010, in addition to percentage changes in the same time period.

	Harris County Land Cover Class	Change in Acres (1996-2010)		Percent Change 1996-2010
Development	Developed, High Intensity	21,787	116,861	24%
	Developed, Medium Intensity	40,675		20%
	Developed, Low Intensity	32,106		24%
	Developed, Open Space	22,293		23%
Wetlands	Palustrine Forested Wetland	-10,912	-12,778	-16%
	Palustrine Scrub/Shrub Wetland	-1,989		-12%
	Palustrine Emergent Wetland	113		1%
	Estuarine Forested Wetland	0		0%
	Estuarine Scrub/Shrub Wetland	-11		-8%
	Estuarine Emergent Wetland	21		1%
Forest	Deciduous Forest	-13,855	-59,690	-26%
	Evergreen Forest	-35,336		-38%
	Mixed Forest	-10,498		-25%
Agriculture	Cultivated Crops	-2,504	-47,784	-7%
	Pasture/Hay	-40,412		-24%
	Grassland/Herbaceous	-4,868		-11%

Harris County has experienced a large change in development in addition to the loss of wetlands. High intensity development had the largest percentage increase between 1996 and 2010 at 24% (21,787 acres). Both medium and low intensity development also had high percentage increases: 24% and 20% respectively. Similarly, developed open space increased by 23% (22,293 acres). All of these development types show a very large increase over the 15-year period, indicating that wetland loss is the result of increasing development.

In Harris County, there is also a large change in agricultural land. There is a substantial decrease in pasture/hay land in this county (40,412 acres: -24% between 1996 and 2010). This large decrease is followed by a decrease in grassland/herbaceous land of 4,868 acres (11%) and cultivated crops of 2,504 acres (7%).

Liberty County

Liberty County in 1996 experienced the lowest amount of development compared to any of the other five counties (the development total in Liberty County was 22,739 acres). In addition, Liberty County had the second highest decrease in total wetland acreage between 1996 and 2010 (6,243 acres) (Table 17).

Table 19: Liberty County land cover class changes between 1996 and 2010, in addition to percentages changes in the same time period.

	Liberty County Land Cover Class	**Change in Acres (1996-2010)**		**Percent Change 1996-2010**
Development	Developed, High Intensity	545	3,309	59%
	Developed, Medium Intensity	149		7%
	Developed, Low Intensity	1,545		11%
	Developed, Open Space	1,070		20%
Wetlands	Palustrine Forested Wetland	-15,025	-6,243	-6%
	Palustrine Scrub/Shrub Wetland	6,232		46%
	Palustrine Emergent Wetland	2,544		17%
	Estuarine Forested Wetland	0		0%
	Estuarine Scrub/Shrub Wetland	0		0%
	Estuarine Emergent Wetland	6		967%
Forest	Deciduous Forest	-1,233	-26,796	-6%
	Evergreen Forest	-16,801		-21%
	Mixed Forest	-8,762		-13%
Agriculture	Cultivated Crops	473	12,838	1%
	Pasture/Hay	13,805		59%
	Grassland/Herbaceous	-1,440		-1%

Unlike in Harris County, where there was a large decrease in agricultural land, Liberty County had an increase in agricultural land use during the 1996-2010 time period. In total, 12,838 acres of crops, pasture, and grassland/herbaceous were added to the county during this time period. However, this total number is slightly misleading because while cultivated crops and pasture/hay increased, grassland/herbaceous decreased. The largest amount of increase in this agriculture category is the pasture/hay land cover, which had a 59% increase from 1996-2010 (Table 19).

Another land cover type that saw big changes in Liberty County is development. There has been a 59% increase in high intensity development (80-100% impervious surface) over the 15-year period. While 59% seems like a large increase, the total acreage increase is much lower than in Harris County (545 acres). Low intensity development in Liberty County shows the largest acreage increase of the development types with 1,545 acres (11% increase). In total, there has been an increase of 3,309 acres of development in Liberty County between 1996 and 2010.

Wetlands in Liberty County have the second largest decrease out of the five counties. The only wetland type that is decreasing in this county is palustrine forested wetlands (15,025-acre decrease: 6%). The county's other wetland types showed an increase, with palustrine scrub/shrub wetlands adding 6,232 acres and palustrine emergent wetlands adding 2,544 acres between 1996-2010. There are very minimal estuarine wetlands of any sort in this county due to its location; the only estuarine wetland change is an increase of 6 acres.

Forest land in this county has seen a decrease from 1996-2010. In total, there were 26,796 acres of forests lost, with the majority of these forests being evergreen forests (16,801 acres; 21%). Mixed forests followed at 8,762 acres (13%) and then deciduous forests with a 1,233-acre decrease (6%).

Brazoria County

Brazoria County has the second highest change in development between 1996 and 2010 (following Harris County). Brazoria County had a total increase in development of 14,507 acres. The largest acreage increase is medium intensity development (4,478 acres; 33%), followed by low intensity development with 4,403 acres (18%). Developed open space has also increased a relatively large amount (13%), representing 3,500 additional acres. The smallest acreage of increased development is high intensity development with 2,125 acres, but the percentage of increase is relatively large at 40% (Table 20).

Table 20: Brazoria County land cover class changes between 1996 and 2010, in addition to percentage changes in the same time period.

	Brazoria County Land Cover Class	Change in Acres (1996-2010)		Percent Change 1996-2010
Development	Developed, High Intensity	2,125	14,507	40%
	Developed, Medium Intensity	4,478		33%
	Developed, Low Intensity	4,403		18%
	Developed, Open Space	3,500		13%
Wetlands	Palustrine Forested Wetland	-2,492	-3,184	-2%
	Palustrine Scrub/Shrub Wetland	-1,444		-4%
	Palustrine Emergent Wetland	652		1%
	Estuarine Forested Wetland	0		0%
	Estuarine Scrub/Shrub Wetland	0		0%
	Estuarine Emergent Wetland	101		0%
Forest	Deciduous Forest	-2,318	-3,592	-5%
	Evergreen Forest	-581		-3%
	Mixed Forest	-693		-4%
Agriculture	Cultivated Crops	-1,629	-7,642	-2%
	Pasture/Hay	-6,370		-3%
	Grassland/Herbaceous	357		1%

There are minimal changes in the amount of wetland loss with the county (a total of 3,184-acre decrease across all four wetland types). There are also relatively small changes in forests (a total of 3,592 acres decrease in forest land cover, with no more than 5% per forest type). Agriculture land also experienced minimal changes in this county.

Toxic Release Inventory (TRI)

General status of Toxic Release Inventory

The large number chemicals included in the Toxic Release Inventory (TRI) makes it infeasible to conclude an all-inclusive trend. For this reason, this study analyzes only a few of the chemicals that have ample sampling and direct application to human health. Overall, out of the four chemicals that were chosen for analysis (ammonia, benzene, chlorine, and nitric acid), ammonia, benzene, and chloride all show strong decreasing trends. Nitric acid has been increasing from the mid-1980s to the most recent year sampled.

Detailed analysis of Toxic Release Inventory

The Toxic Telease Inventory is a vast database collected by the EPA. There are many toxins that are recorded in this database (all of these chemicals are included in Appendix E). A few specific chemicals from toxic release sites were evaluated during the time period within the entire Galveston Bay area. The methodology for the graphing of the toxic release chemicals is included in the Graphing Methodology section of this report (Appendix A).

Ammonia is one toxic chemical consistently released from indistrial sites. Ammonia levels across the whole Lower Galveston Bay Watershed shows a moderate decrease in the average levels from 1984 to 2014 (R^2: 0.615) (Figure 40). Ammonia can increase the nutrients levels in streams and rivers and can aid in decreasing dissolved oxygen levels.

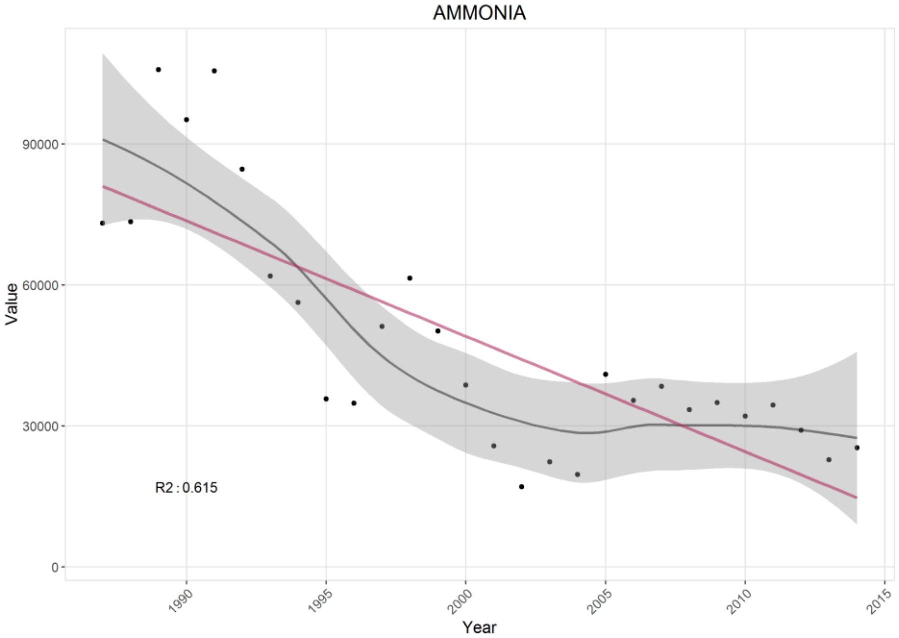


Figure 40: Average ammonia amount from Toxic Release Inventory across the entire Lower Galveston Bay Watershed.

Another notable chemical is benzene. Based on the findings of the American cancer society, benzene is a substance that is known to cause cancer, particularly leukemia (AMC, 2016). An understanding of the trends for this chemical is important to the public. According to the Toxic Release Inventory, we see that the average amount of benzene throughout the years is decreasing from 1984 to 2014 (R^2: 0.645) (Figure 41). However, the LEOSS regression displayed in Figure 41, shows that there is a sharp decrease until about 2000, followed by more of a plateau. In addition, the sampling before 2000 was more limited.

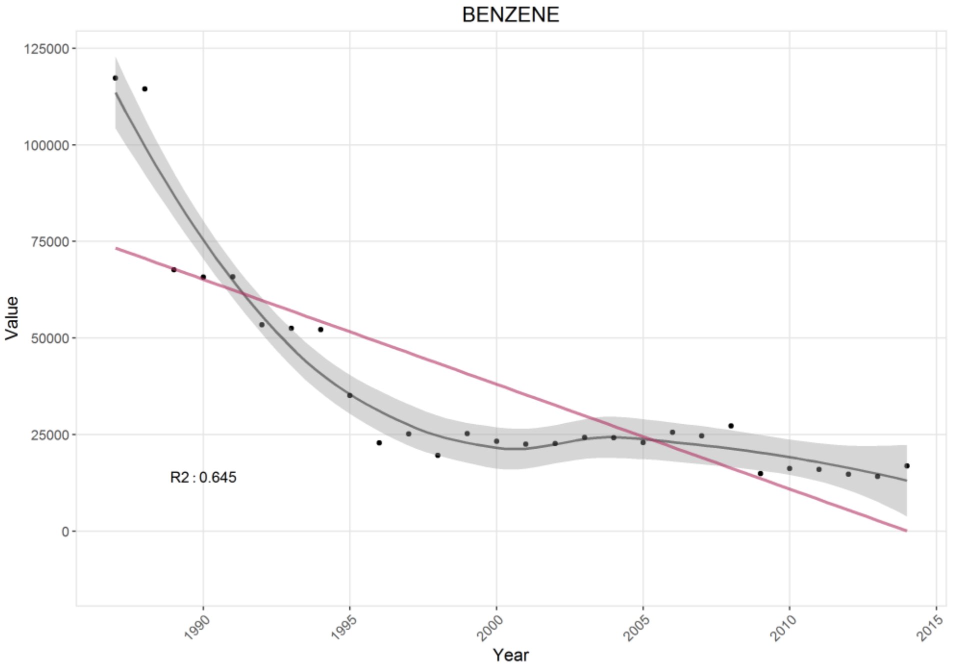


Figure 41: Average benzene amount from the Toxic Release Inventory across the entire Lower Galveston Bay Watershed.

Chlorine is another chemical that is frequently released from TRI facilities. The average chlorine levels across time show a relatively strong decrease (R^2: 0.724) (Figure 42). Chlorine is frequently used to bleach clothing or paper and in cleaning products. In addition, chlorine can be used as a sanitation chemical to clean "sewage and industrial waste" (NYSDOH, 2011).

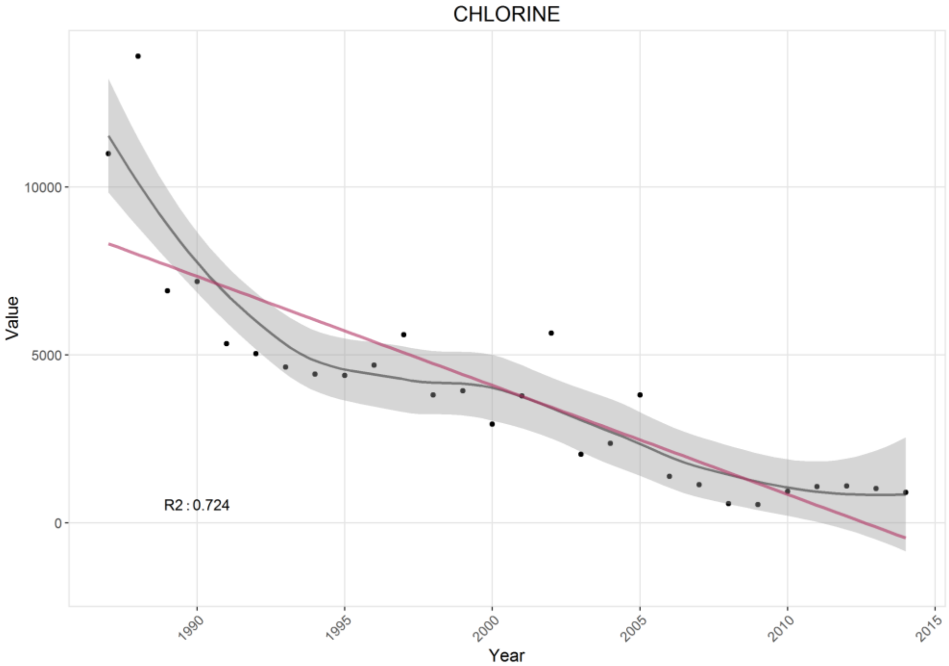


Figure 42: Average chlorine amount from Toxic Release Inventory across the entire Lower Galveston Bay Watershed.

Nitric acid is a chemical that is created from ammonia (EssentialChemistry, 2013). According to The University of New York, the majority of the chemicals produced from nitric acid are used to create fertilizers (EssentialChemistry, 2013). Nitric acid from the TRI facilities shows a moderate increase from the late 1980s (R^2: 0.56) (Figure 43).

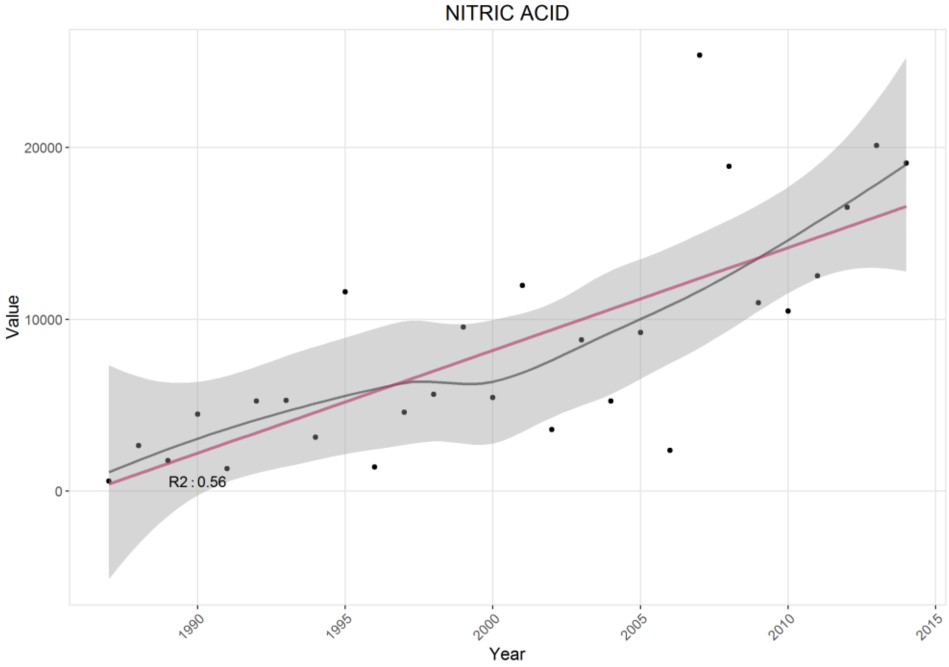


Figure 43: Average nitric acide amount from Toxic Release Inventory across the entire Lower Galveston Bay Watershed.

SUMMARY

This report has assessed many parameters from various sources across long periods of time. While there there is much variation in the parameters, there are some overall general trends that can be observed. These general trends lend some insight into the overall health of various parts of the Lower Galveston Bay Watershed ecosystem.

- Nutrients are generally decreasing in the water across the assessed parameters. The proportion of nutrient samples that exceeded the levels recommended by TCEQ also decreased from the 1970s to 2015. When only the 2000-2015 time period (where most of the observation are made) is isolated, however, there are some parameters that are increasing.

- The field water quality parameters have a more inconclusive trend. Salinity and temperature show no particular trend across the study time period, whereas pH is increasing in some watersheds. Dissolved oxygen shows some increasing trends depending on the season and subbay/watershed being analyzed. In contrast, the data show that specific conductance is decreasing across the watersheds within the Lower Galveston Bay Watershed.

- The physical variables analyzed are generally decreasing in intensity. In particular, the amount of total suspended solids is decreasing across Bay watersheds and total organic carbon is decreasing in both watersheds and subbays.

- Aromatic organics in sediment and pesticides have inconclusive trends across the study time period, partially due to the lack of sampling points for these parameters.

- Microbiological parameters are increasing overall. For example, Enterococci levels are increasing in both the subbays and watersheds. Fecal coliform and *E. coli* were missing from the samples rendering trend analysis infeasible. Chlorophyll-a shows increases from 2000 to the latest year sampled.

- The overall exceedance proportion of metals is decreasing. There is a lot of variability in the measurements and certain metals are sampled more than others. However, in general, there is a decreasing trend in the amount of samples that exceed the recommended TCEQ screening levels.

- No trend is determined in the oil spills across Galveston Bay. This is partially because the frequency and volume of oil that is spilled is totally dependent upon the year and the different events that have occurred during the year.

- The colonial nesting waterbirds have a wide range of trends. Out of the species that show trends, four species (Black Skimmer, Black-crowned Night Heron, Great Blue Heron, and Roseate Spoonbill) are decreasing in abundance. The Brown Pelican is the one species that has an increasing trend.

- The coastal fisheries are also species dependent, and certain species have increasing trends while others show decreases.

- This report also discusses mutliple chemicals that are released from toxic release sites. Some chemicals, like ammonia, benzene, and chlorine, are decreasing, whereas nitric acid shows an increasing trend.

- Land-use/cover change analysis indicates there are major increases in development as well as losses in wetlands and forests. This trend is constant across the Lower Galveston Bay Watershed and in some of the counties that make up the Lower Galveston Bay Watershed.

The Status and Trends project provides all stakeholders in the Lower Galveston Bay Watershed with valuable data, analysis, and interpretation of the data trends. This report builds on the Status and Trends project that has been frequently executed over the years. This report is an essential part of understanding and protecting the health of the Lower Galveston Bay Watershed.

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APPENDIX A: GRAPHICS METHODOLOGY

The graphics displayed in this report are numerous and vary in the way they are created for each parameter. Each graphic is analyzed in a fashion that best represents the parameter of interest and the trend of this parameter.

In many of the graphs, a locally weighted scatterplot smoother (LOESS) regression in combination with a simple linear regression is fit to the data. A LOESS regression is included because it is a smoothing equation that smooths y given x (Cleveland, Cleveland, McRae, & Terpenning, 1990). A smoothing regression allows the viewer to observe changes over time that are not necessarily linear and understand where the dips and peaks of the trends are. One of the drawbacks with LOESS regression is that a value for model fit (such as an R^2 in linear regression) is not easily attainable. For this reason, a linear regression trend line is also included in the graphs in order to numerically define the strength of the trend.

Year Definition

Another aspect of these graphics is how the years are calculated for the data collected from TCEQ. Each season has three months and are divided as follows:

- Spring: March, April, May
- Summer: June, July, August
- Fall: September, October, November
- Winter: December, January February

Due to the winter season encompassing two calendar years, a seasonal year classification is used for analysis. The year definition in this report, when noted, is January and February of the previous year and March-December of the listed year (Figure 1). For example, the year 2002 would have the months of March-December in the calendar year of 2002 and January and February of calendar year 2003 (Figure 1).

Below is a description of each of the graph types utilized in this Status and Trends Report.

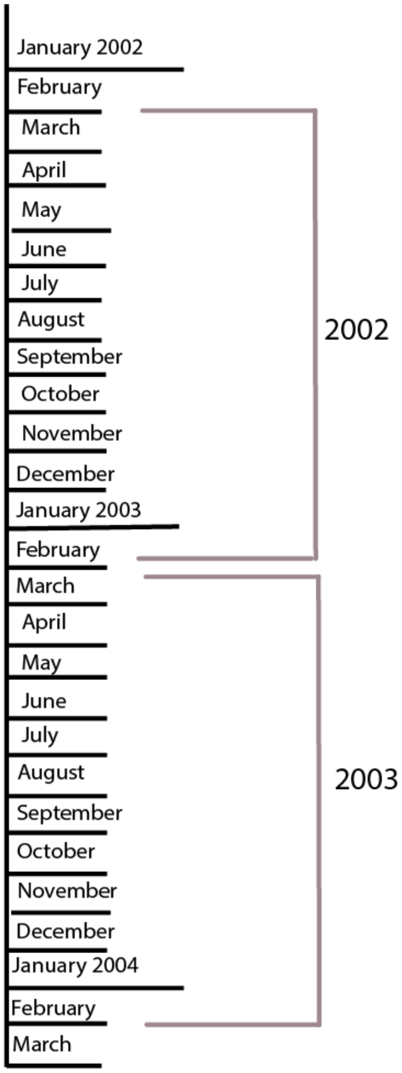

Figure 1: Definition of years for the analysis of TCEQ data.

TCEQ Graph Types

The TCEQ graphics are all generated in the scripting language Python, incorporating the statistical program R. Utilizing both of these programs makes the graphs completely automated, well documented, and reproducible. When alterations are needed for a specific graph, these changes can be made and the whole collection of graphs can be re-generated.

Graph 1: Seasonal Graphics by Subbay or Watershed

These graphs show the seasonal averages for each parameter broken-down by the subbays or watersheds that are of interest in the Lower Galveston Bay Watershed. All years, seasons, and subbays/watersheds are included in this graph except for combinations that have under five samples. In addition, these graphics also select samples that are only less than or equal to 0.3001 meters in depth for select variables (ammonia, chlorophyll-a, dissolved oxygen, *E. coli*, enterococci, fecal coliform, nitrate, nitrite, nitrite/nitrate, orthophosphate, pH, salinity, specific conductance, temperature, total suspended solids, total phosphorus, biochemical oxygen demand and total organic carbon), so that only the surface samples are being selected for analysis. There are a few extraneous values that are omitted in the analysis. When an observation is removed it is recorded in the results and analysis discussion of the parameter. The seasonal year description above is used in these graphics.

Graph 2: Seasonal Graphics Yearly

These graphs show the seasonal averages for each parameter on a yearly scale across the five major subbays or watersheds of interest in the Lower Galveston Bay Watershed. All years and seasons are included in this graph except for combinations that are under five samples. In addition, these graphics also select samples that are only less than or equal to 0.3001 m in depth (see above list for specific parameters), meaning that only surface samples are being selected for analysis. There are a few extraneous values that are omitted from the analysis, and when an observation is removed it is recorded in the results and analysis discussion of the parameter. The seasonal year description above is used in these graphics.

Graph 3: Annual Graphics

These graphs show the annual averages for each parameter across the five major subbays or watersheds of interest in the Lower Galveston Bay Watershed. There are multiple manipulations performed on the data for these graphs, which are listed below:

1. Values that are measured at depths below 0.3001 meters (see above list for specific parameters) are removed from the analysis so that only the surface values are being assessed.
2. Years lacking measurement in all four seasons are removed. With many variables, there is seasonal variability and any year where all seasons are not measured could skew the annual values.
3. Years with less than ten samples per year are removed from the analysis.
4. Generate an average of the parameter of interest across each year, season, and subbay or watershed.
5. Generate an average of the parameter of interest across each year and season.
6. Generate an average of the parameter of interest across each year.

There are a few extraneous values that are omitted in the analysis, and when an observation is removed it is recorded in the results and analysis discussion of the parameter. The seasonal year description above is used in these graphics.

Graph 4: Exceedance by Year

The exceedance by year graphs show the proportion of exceedances per year for each parameter for both subbays and watersheds. Exceedance is only calculated for certain parameters and, therefore, if the parameter is a metal, organic, or pesticide, it is not considered for graphical analysis. In addition, if there are under ten samples per year, this year is removed from the analysis. The year definition that was discussed previously is the same year definition that is used in these graphs.

Table 1: Exceedance by decade
Exceedance by decade. The exceedance by decade analysis is used for the aromatic organics in sediment, pesticides, and metals in sediment analysis. In order to understand the exceedance levels through decades, the data is processed to provide these values. For the aromatic organics in sediment and pesticide calculations, any decades, subbays/watersheds, and parameters (these are defined as the groups of parameters: PAHs, pesticides, and PCBS) that have under ten samples are removed from the calculations. For the metals, any decades, subbays/watersheds, and parameters (as defined by each of the metals) that have under ten samples are removed from the calculations. This means there are at least ten samples per parameter and decade within each of the subbays/watersheds, which provides a much more robust exceedance number.

EPA Graph Types

The Toxic Release Inventory (TRI) from the EPA has all of the locations and amounts of chemicals released from these locations over time, beginning in the late 1980s. The data available through the Status and Trends project is for all of the stations within the Lower Galveston Bay Estuary. The data used for graphing is grouped by chemical and year. Only the years and chemicals with ten samples or more are included.

TPWD Graph Types

The fisheries data from TPWD is used to calculate CPUE (as described in the General Methodology section). The graphics that are included in the report go through a simple process. Each species is grouped by species type and gear type, and then graphs are generated for each of these groups.

AT Graph Types

The colonial nesting waterbirds data obtained from Audubon Texas are grouped by the specific species type. For these species groups the sum of the number of bird pairs that are observed is calculated by year. Thus, for every year the total number of bird pairs is the value used in the graphics.

APPENDIX B: SCREENING LEVELS FOR TCEQ PARAMETERS

Parameter Group	Parameter	Screening Level (mg/l)		
		Tributary (saltwater)	Subbay (saltwater)	Stream (freshwater)
Nutrients (mg/l)	Ammonia	0.46	0.1	0.33
	Nitrate	1.1	0.17	1.95
	Nitrite	1.1	0.17	1.95
	Nitrite/Nitrate	1.1	0.17	1.95
	Orthophosphate	0.46	0.19	0.37
	Total Phosphorus	0.66	0.21	0.69
Aromatic Organics in Sediment (ug/kg)	Acenaphthylene	500		89
	Acenaphthene	640		130
	Anthracene	1100		845
	Benzo(A)Pyrene	1600		1050
	Benzo(A)Anthracene, 1,2-Benzanthracene	1600		1450
	Chrysene	2800		1290
	1,2,5,6-Dibenzanthracene	260		140
	Fluoranthene	5100		2230
	Fluorene	540		536
	Napthalene	2100		561
	PCBs	676		180
	Phenanthrene	1500		1170
	Pyrene	2600		1500
Metals in Sediment (mg/kg)	Arsenic	33		70
	Cadmium	4.98		9.6
	Chromium	111		370
	Copper	149		270

	Lead	128		218
	Mercury	1.06		0.71
	Nickel	48.6		51.6
	Selenium	N/A		N/A
	Silver	2.2		3.7
	Zinc	459		410
Microbiological	Chlorophyll-a (mg/l)	21	11.6	14.1
	E.Coli (MPN/100ml)	N/A		394
	Enterococci (MPN/100ml)	89	70	N/A
	Fecal coliform (#/100 ml)	400		
Field Water Quality	Salinity (PPT)	N/A		
	Dissolved Oxygen (mg/l)	N/A		
	pH (standard)	N/A		
	Specific Conductance (us/cm @ 25 deg)	N/A		
	Temperature (Celsius)	N/A		
Physical Variables (mg/l)	Biochemical Oxygen Demand	N/A		
	Total Suspended Solids	N/A		
	Total Organic Carbon	N/A		
Pesticides (ug/kg)	Chlordane	4.79		17.6
	DDT	62.9		4.77
	Dieldrin	61.8		4.3
	Lindane	4.99		0.99

APPENDIX C: PARAMETER GROUPS, NAMES AND CODES, NUMBER OF OBSERVATIONS, AND DATE RANGES FOR TCEQ PARAMETERS

Parameter Group	Parameter	Parameter Code	Number of Observations	Date Range
Nutrients	Ammonia	610	32,647	1969-2014
	Nitrate	620	15,919	1969-2014
	Nitrite	615	5,031	1969-2014
	Nitrite/Nitrate	630	12,492	1969-2014
	Orthophosphate	671	11,782	1974-2014
	Total Phosphorus	665	25,993	1969-2014
Aromatic Organics in Sediment	Acenaphthylene	34203	4276	1973-2014
	Acenaphthene	34208		
	Anthracene	34223		
	Benzo(A)Pyrene	34250		
	Benzo(A)Anthracene, 1,2-Benzanthracene	34529		
	Chrysene	34323		
	1,2,5,6-Dibenzanthracene	34559		
	Fluoranthene	34379		
	Fluorene	34384		
	Napthalene	34445		
	PCBs	39519		
	Phenanthrene	34464		
	Pyrene	34472		
Metals in Sediment	Arsenic	1003	11854	1973-2014
	Cadmium	1028		
	Chromium	1029		
	Copper	1043		

	Lead	1052		
	Mercury	71921		
	Nickel	1068		
	Selenium	1148		
	Silver	1078		
Microbiological	Chlorophyll-a	32211	1,260	2000-2014
	E.Coli	31699	9,037	2000-2014
	Enterococci	31701	6,976	2000-2014
	Fecal coliform	31616	11,042	1973-2007
Field Water Quality	Salinity	480	36,709	1973-2014
	Dissolved Oxygen	300	42,423	1968-2014
	pH	400	36,593	1969-2014
	Specific Conductance	94	38,938	1969-2014
	Temperature	10	46,557	1968-2014
Physical Variables	Biochemical Oxygen Demand	310	15236	1968-2008
	Total Suspended Solids	530	56,981	1969-2015
	Total Organic Carbon	680	21864	1973-2015
Pesticides	Chlordane	39351	418	1976-2014
	DDT	39373	430	1973-2013
	Dieldrin	39383	459	1973-2014
	Lindane	39783	438	1973-2014

APPENDIX D: LIST OF TPWD SPECIES CODES

Species_code	Common_name	Scientific_name
1	Oilfish	Ruvettus pretiosus
2	Largescale fat snook	Centropomus mexicanus
3	Lesser amberjack	Seriola fasciata
4	Fringed filefish	Monacanthus ciliatus
5	Red porgy	Pagrus pagrus
6	Neotropic cormorant	Phalacrocorax brasilianus
7	Bobcat	Lynx rufus
8	Longnose batfish	Ogcocephalus corniger
9	Opossum pipefish	Microphis brachyurus
10	Blackbar drum	Pareques iwamotoi
11	Greater siren	Siren lacertina
12	Fringed pipefish	Anarchopterus criniger
13	Spotted sunfish	Lepomis punctatus
14	Bantam sunfish	Lepomis symmetricus
15	Glasseye snapper	Priacanthus cruentatus
16	Common raccoon	Procyon lotor
17	Mink	Mustela vison
18	Ruddy duck	Oxyura jamaicensis
19	Common muskrat	Ondatra zibethicus
20	Balao	Hemiramphus balao
21	Smooth trunkfish	Lactophrys triqueter
22	Wrasse bass	Liopropoma eukrines
23	Blue tilapia	Oreochromis aureus
24	Amazon molly	Poecilia formosa
26	White grunt	Haemulon plumierii

28	Escolar	Lepidocybium flavobrunneum
31	Spinycheek scorpionfish	Neomerinthe hemingwayi
33	Eastern river cooter	Pseudemys concinna concinna
36	Flagfin mojarra	Eucinostomus melanopterus
38	Nilgai	Boselaphus tragocamelus
41	Sea bream	Archosargus rhomboidalis
46	Golden shiner	Notemigonus crysoleucas
48	Mexican tetra	Astyanax mexicanus
53	American coot	Fulica americana
59	Alligator snapping turtle	Macrochelys temminckii
60	Greater white-fronted go	Anser albifrons
61	Smallscale lizardfish	Saurida caribbaea
62	Hybrid bass (striped x w)	Morone x (M. saxatilus x M. c
63	Southern leopard frog	Rana sphenocephala
64	Texas silverside	Menidia clarkhubbsi
65	Smallmouth bass	Micropterus dolomieu
66	American black duck	Anas rubripes
68	Feral hog	Sus scrofa
73	Western diamond-backed rattlesnake	Crotalus atrox
74	Bowfin	Amia calva
75	Spotfin hogfish	Bodianus pulchellus
90	White-winged dove	Zenaida asiatica
95	Family trouts	Family Salmonidae
100	Goldfish	Carassius auratus
101	Southern sailfin catfish	Pterygoplichthys anisitsi
102	Irish pompano	Diapterus auratus
103	Atlantic anchoveta	Cetengraulis edentulus
104	Keeltail needlefish	Platybelone argalus

105	Family frogs	Family Ranidae
106	Pig frog	Rana grylio
107	American bullfrog	Rana catesbeiana
108	Black snapper	Apsilus dentatus
109	Whitefin sharksucker	Echeneis neucratoides
110	Unicorn filefish	Aluterus monoceros
111	Snake mackerel	Gempylus serpens
112	Puddingwife	Halichoeres radiatus
113	Marbled grouper	Dermatolepis inermis
114	Longfin mako	Isurus paucus
115	Cubera snapper	Lutjanus cyanopterus
116	Cottonwick	Haemulon melanurum
117	Coney	Cephalopholis fulva
118	Bonefish	Albula vulpes
119	Black jack	Caranx lugubris
121	Eastern cottontail	Sylvilagus floridanus
125	Dwarf herring	Jenkinsia lamprotaenia
126	Longear sunfish	Lepomis megalotis
127	Ribbon Shiner	Lythrurus fumeus
131	Smooth softshell (turtle)	Apalone mutica
132	Common loon	Gavia immer
137	Spottail tonguefish	Symphurus urospilus
141	Smallscale fat snook	Centropomus parallelus
143	Whitespotted soapfish	Rypticus maculatus
152	Red-eared slider	Trachemys scripta elegans
156	(Mackerel – unidentified)	Genus Scomberomorus
157	(Flounder – unidentified)	Genus Paralichthys
161	(Menhaden - - unidentified)	Genus Brevoortia

163	(Killifish – unidentified)	Genus Fundulus
164	(Seatrout – unidentified)	Genus Cynoscion
165	Gold brotula	Gunterichthys longipenis
179	Grass carp	Ctenopharyngodon idella
184	Rock bass	Ambloplites rupestris
197	Spotted batfish	Ogcocephalus pantostictus
198	(Batfish - unidentified)	Genus Ogcocephalus
199	Family rails, gallinules	Family Rallidae
200	Greater scaup	Aythya marila
204	Mourning dove	Zenaida macroura
205	Freckled cardinalfish	Phaeoptyx conklini
212	Tidewater silverside	Menidia peninsulae
220	Canada goose	Branta canadensis
221	Sandhill crane	Grus canadensis
224	White-tailed deer	Odocoileus virginianus
225	Snow goose	Chen caerulescens
226	Horned grebe	Podiceps auritus
232	Unclassified food	Commercial landings only
233	Unclassified scrap	Commercial landings only
234	Kingfish (whiting)	Commercial landings only
235	Unclassified tuna	Commercial landings only
236	(Shark - unidentified)	Order Lamniformes/Squaliforme
237	Yellowfin grouper	Mycteroperca venenosa
239	Ocellated frogfish	Antennarius ocellatus
240	Yellowfin tuna	Thunnus albacares
242	Common goldeneye	Bucephala clangula
247	Bottlenose dolphin	Tursiops truncatus
250	Northern bobwhite quail	Colinus virginianus

252	(Family emydid turtles)	Family Emydidae
253	Nutria	Myocastor coypus
254	Family loons	Family Gaviidae
255	Family ducks, geese, and swans	Family Anatidae
256	Snowy grouper	Hyporthodus niveatus
257	Red hind	Epinephelus guttatus
258	Dotterel filefish	Aluterus heudelotii
261	Black bellied whistling	Dendrocygna autumnalis
262	Fulvous whistling duck	Dendrocygna bicolor
263	Wood duck	Aix sponsa
264	American widgeon	Anas americana
265	Green-winged teal	Anas crecca
266	Northern pintail	Anas acuta
267	Blue-winged teal	Anas discors
268	Northern shoveler	Anas clypeata
269	Cinnamon teal	Anas cyanoptera
270	Mottled duck	Anas fulvigula
271	Mallard	Anas platyrhynchos
272	Gadwall	Anas strepera
273	Lesser scaup	Aythya affinis
274	Redhead	Aythya americana
275	Ring-necked duck	Aythya collaris
276	Canvasback	Aythya valisineria
277	Bufflehead	Bucephala albeola
278	Hooded merganser	Lophodytes cucullatus
279	Common merganser	Mergus merganser
280	Red-breasted merganser	Mergus serrator
281	American alligator	Alligator mississippiensis

288	Eared grebe	Podiceps nigricollis
289	Diamond-backed terrapin	Malaclemys terrapin
291	Short bigeye	Pristigenys alta
292	Longnose anchovy	Anchoa nasuta
306	Blotched cusk-eel	Ophidion grayi
311	Cubbyu	Pareques umbrosus
324	Cottonmouth jack	Uraspis secunda
326	Pygmy filefish	Stephanolepis setifer
333	(Silverside – unidentified)	Genus Menidia
336	White crappie	Pomoxis annularis
350	Leopard toadfish	Opsanus pardus
351	Twospot flounder	Bothus robinsi
357	Polka-dot batfish	Ogcocephalus cubifrons
359	Family Medusafishes	Family Centrolophidae
360	(Shiner - unidentified)	Genus Notropis
361	(Tilapia - unidentified)	Genus Tilapia
362	Silk snapper	Lutjanus vivanus
363	King snake eel	Ophichthus rex
364	Yellowedge grouper	Hyporthodus flavolimbatus
365	Family molas	Family Molidae
366	Family porcupinefishes	Family Diodontidae
367	Family puffers	Family Tetraodontidae
368	Family boxfishes	Family Ostraciidae
369	Family spikefishes	Family Triacanthodidae
370	Family filefishes	Family Monacanthidae
371	Family triggerfishes	Family Balistidae
372	Family tonguefishes	Family Cynoglossidae
373	Family American soles	Family Achiridae

374	Family righteye flounder	Family Pleuronectidae
375	Family lefteye flounders	Family Paralichthyidae
376	Family flying gurnards	Family Dactylopteridae
377	Family searobins	Family Triglidae
379	Family scorpionfishes	Family Scorpaenidae
380	Family butterfishes	Family Stromateidae
381	Family billfishes	Family Istiophoridae
382	Family swordfishes	Family Xiphiidae
383	Family mackerels	Family Scombridae
384	Family cutlassfishes	Family Trichiuridae
385	Family surgeonfishes	Family Acanthuridae
386	Family wormfishes	Family Microdesmidae
387	Family gobies	Family Gobiidae
388	Family sleepers	Family Eleotridae
389	Family dragonets	Family Callionymidae
390	Family combtooth blennie	Family Blenniidae
391	Family clinids	Family Clinidae
392	Family threadfins	Family Polynemidae
393	Family stargazers	Family Uranoscopidae
394	Family flatheads	Family Percophidae
395	Family jawfishes	Family Opistognathidae
396	Family barracudas	Family Sphyraenidae
397	Family mullets	Family Mugilidae
398	Family parrotfishes	Family Scaridae
399	Family wrasses	Family Labridae
400	Family damselfishes	Family Pomacentridae
401	Family butterflyfishes	Family Chaetodontidae
402	Family spadefishes	Family Ephippidae

403	Family sea chubs	Family Kyphosidae
404	Family goatfishes	Family Mullidae
405	Family drums	Family Sciaenidae
406	Family porgies	Family Sparidae
407	Family grunts	Family Haemulidae
408	Family mojarras	Family Gerreidae
409	Family tripletails	Family Lobotidae
410	Family snappers	Family Lutjanidae
411	Family dolphinfishes	Family Coryphaenidae
412	Family jacks	Family Carangidae
413	Family remoras	Family Echeneidae
414	Family cobias	Family Rachycentridae
415	Family bluefishes	Family Pomatomidae
416	Family tilefishes	Family Malacanthidae
417	Family cardinalfishes	Family Apogonidae
418	Family bigeyes	Family Priacanthidae
419	Family sunfishes	Family Centrarchidae
421	Family sea basses	Family Serranidae
422	Family temperate basses	Family Moronidae
423	Family snooks	Family Centropomidae
424	Family pipefishes	Family Syngnathidae
425	Family snipefishes	Family Macroramphosidae
426	Family cornetfishes	Family Fistulariidae
427	Family boarfishes	Family Caproidae
428	Family dories	Family Zeidae
429	Family squirrelfishes	Family Holocentridae
430	Family armorheads	Family Pentacerotidae
431	Family beardfishes	Family Polymixiidae
432	Family New World	Family Atherinopsidae

	silvers	
433	Family livebearers	Family Poeciliidae
434	Family pupfishes	Family Cyprinodontidae
435	Family needlefishes	Family Belonidae
436	Family flyingfishes	Family Exocoetidae
438	Family grenadiers	Family Macrouridae
439	Family pearlfishes	Family Carapidae
440	Family cusk-eels	Family Ophidiidae
441	Family cods	Family Gadidae
442	Family codlets	Family Bregmacerotidae
443	Family batfishes	Family Ogcocephalidae
444	Family frogfishes	Family Antennariidae
445	Family goosefishes	Family Lophiidae
446	Family clingfishes	Family Gobiesocidae
447	Family toadfishes	Family Batrachoididae
448	Family sea catfishes	Family Ariidae
449	Family North American catfish	Family Ictaluridae
450	Family suckers	Family Catostomidae
451	Family carps and minnows	Family Cyprinidae
452	Family lanternfishes	Family Myctophidae
453	Family lancetfishes	Family Alepisauridae
454	Family greeneyes	Family Chlorophthalmidae
455	Family lizardfishes	Family Synodontidae
456	Family mooneyes	Family Hiodontidae
457	Family anchovies	Family Engraulidae
458	Family herrings	Family Clupeidae
459	Family snake eels	Family Ophichthidae
460	Family conger eels	Family Congridae

461	Family duckbill eels	Family Nettastomatidae
462	Family morays	Family Muraenidae
463	Family freshwater eels	Family Anguillidae
464	Family tenpounders	Family Elopidae
465	Family gars	Family Lepisosteidae
466	Family mantas	Family Mobulidae
468	Family eagle rays	Family Myliobatidae
469	Family round stingrays	Family Urolophidae
471	Family stingrays	Family Dasyatidae
472	Family skates	Family Rajidae
473	Family electric rays	Family Torpedinidae
474	Family guitarfishes	Family Rhinobatidae
475	Family sawfishes	Family Pristidae
476	Family angel sharks	Family Squatinidae
477	Family dogfish sharks	Family Squalidae
478	Family hammerhead sharks	Family Sphyrnidae
480	Family requiem sharks	Family Carcharhinidae
481	Family cat sharks	Family Scyliorhinidae
482	Family mackerel sharks	Family Lamnidae
483	Family thresher sharks	Family Alopiidae
484	Family sand tigers	Family Odontaspididae
485	Family carpet sharks	Family Rhincodontidae
487	Family cow sharks	Family Hexanchidae
488	Green sunfish	Lepomis cyanellus
489	Family topminnows	Family Fundulidae
490	Family snake mackerels	Family Gempylidae
491	Family tarpons	Family Megalopidae
492	Ocean sunfish	Mola mola

493	Porcupinefish	Diodon hystrix
494	Checkered puffer	Sphoeroides testudineus
495	Bandtail puffer	Sphoeroides spengleri
496	Marbled puffer	Sphoeroides dorsalis
497	Scrawled cowfish	Acanthostracion quadricornis
498	Jambeau	Parahollardia lineata
499	Orangespotted filefish	Cantherhines pullus
500	Scrawled filefish	Aluterus scriptus
501	Orange filefish	Aluterus schoepfii
502	Sargassum triggerfish	Xanthichthys ringens
503	Black durgon	Melichthys niger
504	Ocean triggerfish	Canthidermis sufflamen
505	Rough triggerfish	Canthidermis maculata
506	Queen triggerfish	Balistes vetula
507	Gray triggerfish	Balistes capriscus
508	Longtail tonguefish	Symphurus pelicanus
509	Pygmy tonguefish	Symphurus parvus
510	Spottedfin tonguefish	Symphurus diomedeanus
511	Deepwater dab	Poecilopsetta beanii
512	Sash flounder	Trichopsetta ventralis
513	Dusky flounder	Syacium papillosum
514	Windowpane	Scophthalmus aquosus
515	Family cichlids	Family Cichlidae
518	Spotfin flounder	Cyclopsetta fimbriata
519	Spotted whiff	Citharichthys macrops
520	Horned whiff	Citharichthys cornutus
521	Flying gurnard	Dactylopterus volitans
522	Bluespotted searobin	Prionotus roseus
523	Barred searobin	Prionotus martis

524	Horned searobin	Bellator militaris
525	Armored searobin	Peristedion miniatum
528	Slender searobin	Peristedion gracile
530	Hunchback scorpionfish	Scorpaena dispar
531	Bluefin driftfish	Psenes pellucidus
532	Man-of-war fish	Nomeus gronovii
533	Silver-rag	Ariomma bondi
534	Longbill spearfish	Tetrapturus pfluegeri
535	White marlin	Tetrapturus albidus
536	Blue marlin	Makaira nigricans
537	Sailfish	Istiophorus platypterus
538	Swordfish	Xiphias gladius
539	Bluefin tuna	Thunnus thynnus
540	Blackfin tuna	Thunnus atlanticus
541	Cero	Scomberomorus regalis
542	Atlantic bonito	Sarda sarda
543	Skipjack tuna	Katsuwonus pelamis
544	Little tunny	Euthynnus alletteratus
545	Rio Grande cichlid	Cichlasoma cyanoguttatum
546	Frigate mackerel	Auxis thazard
547	Wahoo	Acanthocybium solandri
548	Doctorfish	Acanthurus chirurgus
549	Pink wormfish	Microdesmus longipinnis
550	Freshwater goby	Ctenogobius shufeldti
551	Spotfin dragonet	Foetorepus agassizi
552	Seaweed blenny	Parablennius marmoreus
553	Molly miller	Scartella cristata
554	Hairy blenny	Labrisomus nuchipinnis
555	Knobbed porgy	Calamus nodosus

556	Freckled stargazer	Gnathagnus egregius
557	Goby flathead	Bembrops gobioides
558	Swordtail jawfish	Lonchopisthus micrognathus
559	Mountain mullet	Agonostomus monticola
560	Bucktooth parrotfish	Sparisoma radians
561	Hogfish	Lachnolaimus maximus
562	Pearly razorfish	Xyrichtys novacula
563	Painted wrasse	Halichoeres caudalis
564	Slippery dick	Halichoeres bivittatus
565	Red hogfish	Decodon puellaris
566	Cocoa damselfish	Stegastes variabilis
567	Beaugregory	Stegastes leucostictus
568	Dusky damselfish	Stegastes adustus
569	Brown chromis	Chromis multilineata
570	Sunshinefish	Chromis insolata
571	Night sergeant	Abudefduf taurus
572	Sergeant major	Abudefduf saxatilis
573	French angelfish	Pomacanthus paru
574	Gray angelfish	Pomacanthus arcuatus
575	Blue angelfish	Holacanthus bermudensis
576	Reef butterflyfish	Chaetodon sedentarius
577	Spotfin butterflyfish	Chaetodon ocellatus
578	Bermuda chub	Kyphosus sectatrix
579	Sand drum	Umbrina coroides
580	High-hat	Pareques acuminatus
581	Spottail pinfish	Diplodus holbrookii
582	Sheepshead porgy	Calamus penna
583	Whitebone porgy	Calamus leucosteus
584	Saucereye porgy	Calamus calamus

585	Jolthead porgy	Calamus bajonado
586	Burro grunt	Pomadasys crocro
587	Striped grunt	Haemulon striatum
588	Sailors choice	Haemulon parra
589	Spanish grunt	Haemulon macrostomum
590	Tomtate	Haemulon aurolineatum
591	Porkfish	Anisotremus virginicus
592	Black margate	Anisotremus surinamensis
593	Yellowfin mojarra	Gerres cinereus
594	Vermilion snapper	Rhomboplites aurorubens
595	Yellowtail snapper	Ocyurus chrysurus
596	Mutton snapper	Lutjanus analis
597	Dolphinfish	Coryphaena hippurus
598	Pompano dolphinfish	Coryphaena equiselis
599	Palometa	Trachinotus goodei
601	Bay anchovy	Anchoa mitchilli
602	Atlantic croaker	Micropogonias undulatus
604	Gulf menhaden	Brevoortia patronus
606	Gizzard shad	Dorosoma cepedianum
608	Spot	Leiostomus xanthurus
610	Hardhead catfish	Ariopsis felis
611	Gafftopsail catfish	Bagre marinus
612	Striped mullet	Mugil cephalus
613	Sand seatrout	Cynoscion arenarius
614	Spotted seatrout	Cynoscion nebulosus
615	Inland silverside	Menidia beryllina
616	Southern flounder	Paralichthys lethostigma
617	Blue catfish	Ictalurus furcatus
619	Hogchoker	Trinectes maculatus

620	Star drum	Stellifer lanceolatus
621	Sheepshead	Archosargus probatocephalus
622	Channel catfish	Ictalurus punctatus
623	Bigmouth buffalo	Ictiobus cyprinellus
624	White perch	Morone americana
625	Black drum	Pogonias cromis
626	Naked goby	Gobiosoma bosc
627	Silver perch	Bairdiella chrysoura
628	Crevalle jack	Caranx hippos
629	Red drum	Sciaenops ocellatus
630	Silver jenny	Eucinostomus gula
631	Smallmouth buffalo	Ictiobus bubalus
632	Spotted bass	Micropterus punctulatus
633	Pinfish	Lagodon rhomboides
634	Atlantic spadefish	Chaetodipterus faber
635	Southern stingray	Dasyatis americana
637	Redear sunfish	Lepomis microlophus
641	Atlantic threadfin	Polydactylus octonemus
642	Pigfish	Orthopristis chrysoptera
644	Bighead searobin	Prionotus tribulus
645	Inshore lizardfish	Synodus foetens
646	Blackcheek tonguefish	Symphurus plagiusa
647	Bay whiff	Citharichthys spilopterus
648	Horse-eye jack	Caranx latus
649	Ocellated flounder	Ancylopsetta ommata
650	Least puffer	Sphoeroides parvus
651	Striped blenny	Chasmodes longimaxilla
652	Common carp	Cyprinus carpio
654	Chain pipefish	Syngnathus louisianae

655	Lookdown	Selene vomer
656	Cobia	Rachycentron canadum
657	Silver seatrout	Cynoscion nothus
658	Finescale menhaden	Brevoortia gunteri
659	Ladyfish	Elops saurus
660	Cownose ray	Rhinoptera bonasus
661	Margintail conger	Paraconger caudilimbatus
662	Lined seahorse	Hippocampus erectus
663	Spotted moray	Gymnothorax moringa
664	Speckled worm eel	Myrophis punctatus
665	Atlantic needlefish	Strongylura marina
666	Timucu	Strongylura timucu
667	Rough silverside	Membras martinica
668	Leatherjacket	Oligoplites saurus
669	Atlantic bumper	Chloroscombrus chrysurus
670	Schoolmaster	Lutjanus apodus
671	Lane snapper	Lutjanus synagris
672	Atlantic tripletail	Lobotes surinamensis
673	Banded drum	Larimus fasciatus
674	Golden topminnow	Fundulus chrysotus
675	Alligator gar	Atractosteus spatula
676	Gulf kingfish	Menticirrhus littoralis
677	Longspine porgy	Stenotomus caprinus
678	Crested blenny	Hypleurochilus geminatus
679	Crested cusk-eel	Ophidion josephi
680	Atlantic cutlassfish	Trichiurus lepturus
681	Spanish mackerel	Scomberomorus maculatus
682	Harvestfish	Peprilus paru
683	Gulf butterfish	Peprilus burti

684	Highfin goby	Gobionellus oceanicus
685	Sharksucker	Echeneis naucrates
686	Sheepshead minnow	Cyprinodon variegatus
687	Striped burrfish	Chilomycterus schoepfii
688	Skilletfish	Gobiesox strumosus
689	Gulf toadfish	Opsanus beta
690	Atlantic midshipman	Porichthys plectrodon
691	Longnose killifish	Fundulus similis
692	Bayou killifish	Fundulus pulvereus
693	Rainwater killifish	Lucania parva
694	Barbfish	Scorpaena brasiliensis
696	Southern stargazer	Astroscopus y-graecum
697	Longnose gar	Lepisosteus osseus
699	Planehead filefish	Stephanolepis hispidus
701	American eel	Anguilla rostrata
702	Gulf killifish	Fundulus grandis
703	Blackedge cusk-eel	Lepophidium brevibarbe
704	Palespotted eel	Ophichthus puncticeps
705	American plaice	Hippoglossoides platessoides
706	Spottail goby	Ctenogobius stigmaturus
707	(Lionfish – unidentified)	Genus Pterois
710	Green goby	Microgobius thalassinus
711	Threadfin shad	Dorosoma petenense
712	Atlantic thread herring	Opisthonema oglinum
713	Gulf pipefish	Syngnathus scovelli
714	Lined sole	Achirus lineatus
715	Common snook	Centropomus undecimalis
716	Spotted snake eel	Ophichthus ophis
717	Skipjack herring	Alosa chrysochloris

718	Bluegill	Lepomis macrochirus
719	Black crappie	Pomoxis nigromaculatus
720	Warmouth	Lepomis gulosus
721	Goldeye	Hiodon alosoides
722	Gray snapper	Lutjanus griseus
723	Fat sleeper	Dormitator maculatus
724	Atlantic stingray	Dasyatis sabina
725	Bonnethead	Sphyrna tiburo
726	Dog snapper	Lutjanus jocu
727	Spotted eagle ray	Aetobatus narinari
728	Spotted gar	Lepisosteus oculatus
729	Shortnose gar	Lepisosteus platostomus
730	Tarpon	Megalops atlanticus
731	Shrimp eel	Ophichthus gomesi
732	Scaled sardine	Harengula jaguana
733	Striped anchovy	Anchoa hepsetus
734	Dusky anchovy	Anchoa lyolepis
735	Largescale lizardfish	Saurida brasiliensis
736	Black bullhead	Ameiurus melas
737	Yellow bullhead	Ameiurus natalis
738	Brown bullhead	Ameiurus nebulosus
739	Flathead catfish	Pylodictis olivaris
740	Stippled clingfish	Gobiesox punctulatus
741	False silverstripe halfbeak	Hyporhamphus meeki
742	Diamond killifish	Adinia xenica
743	Saltmarsh topminnow	Fundulus jenkinsi
744	Western mosquitofish	Gambusia affinis
745	Sailfin molly	Poecilia latipinna

746	Dwarf seahorse	Hippocampus zosterae
747	Dusky pipefish	Syngnathus floridae
748	Northern pipefish	Syngnathus fuscus
749	White bass	Morone chrysops
750	Yellow bass	Morone mississippiensis
751	Striped bass	Morone saxatilis
752	Bluefish	Pomatomus saltatrix
753	Florida pompano	Trachinotus carolinus
754	Atlantic moonfish	Selene setapinnis
755	Bull shark	Carcharhinus leucas
756	Mottled mojarra	Eucinostomus lefroyi
757	Freshwater drum	Aplodinotus grunniens
758	Southern kingfish	Menticirrhus americanus
759	Northern kingfish	Menticirrhus saxatilis
760	White mullet	Mugil curema
761	Feather blenny	Hypsoblennius hentz
762	Freckled blenny	Hypsoblennius ionthas
763	Atlantic sharpnose shark	Rhizoprionodon terraenovae
764	Largescaled spinycheeks	Eleotris amblyopsis
765	Emerald sleeper	Erotelis smaragdus
766	Bigmouth sleeper	Gobiomorus dormitor
767	Frillfin goby	Bathygobius soporator
768	Lyre goby	Evorthodus lyricus
769	Violet goby	Gobioides broussonetii
770	Darter goby	Ctenogobius boleosoma
771	Clown goby	Microgobius gulosus
772	King mackerel	Scomberomorus cavalla
773	Bandtail searobin	Prionotus ophryas
774	Mexican searobin	Prionotus paralatus

775	Bigeye searobin	Prionotus longispinosus
776	Leopard searobin	Prionotus scitulus
777	Shortwing searobin	Prionotus stearnsi
778	Three-eye flounder	Ancylopsetta dilecta
779	Fringed flounder	Etropus crossotus
780	Gulf flounder	Paralichthys albigutta
781	Fringed sole	Gymnachirus texae
782	Smooth puffer	Lagocephalus laevigatus
783	Blackedge moray	Gymnothorax nigromarginatus
784	Finetooth shark	Carcharhinus isodon
785	Yellow jack	Caranx bartholomaei
786	Sandbar shark	Carcharhinus plumbeus
787	Blacktip shark	Carcharhinus limbatus
788	Smalltail shark	Carcharhinus porosus
789	Yellow chub	Kyphosus incisor
790	Lemon shark	Negaprion brevirostris
791	Largemouth bass	Micropterus salmoides
792	Code goby	Gobiosoma robustum
793	Spinner shark	Carcharhinus brevipinna
794	Scalloped hammerhead	Sphyrna lewini
795	Great hammerhead	Sphyrna mokarran
796	Lesser electric ray	Narcine bancroftii
797	Clearnose skate	Raja eglanteria
798	Freckled pikeconger	Hoplunnis macrura
799	Spotted pikeconger	Hoplunnis tenuis
802	Spanish sardine	Sardinella aurita
803	Offshore lizardfish	Synodus poeyi
804	Pancake batfish	Halieutichthys aculeatus
805	Shortnose batfish	Ogcocephalus nasutus

806	Roughback batfish	Ogcocephalus parvus
807	Atlantic bearded brotula	Brotula barbata
808	Gulf hake	Urophycis cirrata
809	Southern hake	Urophycis floridana
810	Spotted hake	Urophycis regia
811	Rock sea bass	Centropristis philadelphica
812	Dwarf sand perch	Diplectrum bivittatum
813	Blackear bass	Serranus atrobranchus
814	Bar jack	Caranx ruber
815	Bluntnose jack	Hemicaranx amblyrhynchus
816	Bigeye scad	Selar crumenophthalmus
817	Rough scad	Trachurus lathami
818	Red snapper	Lutjanus campechanus
819	Wenchman	Pristipomoides aquilonaris
820	Barred grunt	Conodon nobilis
821	Red goatfish	Mullus auratus
822	Dwarf goatfish	Upeneus parvus
823	Great barracuda	Sphyraena barracuda
824	Guaguanche	Sphyraena guachancho
825	Ragged goby	Bollmannia communis
826	Atlantic chub mackerel	Scomber colias
827	Blackwing searobin	Prionotus rubio
828	Mexican flounder	Cyclopsetta chittendeni
829	Shoal flounder	Syacium gunteri
830	Bigeye tuna	Thunnus obesus
837	Blackfin snapper	Lutjanus buccanella
838	Offshore tonguefish	Symphurus civitatium
839	Gulf Smoothhound	Mustelus sinusmexicanus
841	Bigeye	Priacanthus arenatus

842	Whalesucker	Remora australis
843	Remora	Remora remora
844	Whip eel	Bascanichthys scuticaris
846	Round herring	Etrumeus teres
847	Black driftfish	Hyperoglyphe bythites
848	Blueline tilefish	Caulolatilus microps
849	Class Bony fishes	Class Osteichthyes
851	Queen snapper	Etelis oculatus
852	Spotted scorpionfish	Scorpaena plumieri
853	Longspine scorpionfish	Pontinus longispinis
854	Smoothhead scorpionfish	Scorpaena calcarata
855	Florida smoothhound	Mustelus norrisi
856	Broad flounder	Paralichthys squamilentus
857	Atlantic angel shark	Squatina dumeril
858	Night shark	Carcharhinus signatus
859	Blackline tilefish	Caulolatilus cyanops
860	Duckbill flathead	Bembrops anatirostris
861	Spreadfin skate	Dipturus olseni
862	Lancer stargazer	Kathetostoma albigutta
863	Conger eel	Conger oceanicus
864	Spiny flounder	Engyophrys senta
865	Leatherback seaturtle	Dermochelys coriacea
866	Loggerhead seaturtle	Caretta caretta
867	Kemp's ridley seaturtle	Lepidochelys kempii
868	Hawksbill seaturtle	Eretmochelys imbricata
869	Green seaturtle	Chelonia mydas
871	Blue runner	Caranx crysos
872	Sooty eel	Bascanichthys bascanium
873	Bluntnose stingray	Dasyatis say

874	Spotfin mojarra	Eucinostomus argenteus
875	Round scad	Decapterus punctatus
876	Family seaturtles (scute)	Family Chelonidae
877	Bluntnose sixgill shark	Hexanchus griseus
878	Nurse shark	Ginglymostoma cirratum
879	Whale shark	Rhincodon typus
880	Sand tiger	Carcharias taurus
881	Thresher shark	Alopias vulpinus
882	White shark	Carcharodon carcharias
883	Shortfin mako	Isurus oxyrinchus
885	Marbled cat shark	Galeus arae
886	Chain dogfish	Scyliorhinus retifer
887	Blacknose shark	Carcharhinus acronotus
888	Silky shark	Carcharhinus falciformis
889	Oceanic whitetip shark	Carcharhinus longimanus
890	Dusky shark	Carcharhinus obscurus
891	Tiger shark	Galeocerdo cuvier
892	Smooth dogfish	Mustelus canis
893	Smalleye hammerhead	Sphyrna tudes
894	Cuban dogfish	Squalus cubensis
895	Smalltooth sawfish	Pristis pectinata
896	Largetooth sawfish	Pristis pristis
897	Atlantic guitarfish	Rhinobatos lentiginosus
898	Rosette skate	Leucoraja garmani
899	Roundel skate	Raja texana
900	Roughtail stingray	Dasyatis centroura
901	Smooth butterfly ray	Gymnura micrura
902	Yellow stingray	Urobatis jamaicensis
903	Manta	Manta birostris

904	Honeycomb moray	Gymnothorax saxicola
905	Yellow conger	Rhynchoconger flavus
906	Whiptail conger	Rhynchoconger gracilior
907	Ridged eel	Neoconger mucronatus
908	Threadtail conger	Uroconger syringinus
909	Sailfin eel	Letharchus velifer
910	Spotted spoon-nose eel	Echiophis intertinctus
912	Snapper eel	Echiophis punctifer
913	Mooneye	Hiodon tergisus
914	Sand diver	Synodus intermedius
915	Snakefish	Trachinocephalus myops
916	Shortnose greeneye	Chlorophthalmus agassizi
918	Longnose greeneye	Parasudis truculenta
919	Longnose lancetfish	Alepisaurus ferox
922	Goosefish	Lophius americanus
924	Singlespot frogfish	Antennarius radiosus
925	Striated frogfish	Antennarius striatus
926	Sargassumfish	Histrio histrio
927	Atlantic batfish	Dibranchus atlanticus
928	Tricorn batfish	Zalieutes mcgintyi
929	Antenna codlet	Bregmaceros atlanticus
932	Metallic codling	Physiculus fulvus
934	Stripefin brotula	Neobythites marginatus
935	Bank cusk-eel	Ophidion holbrooki
936	Striped cusk-eel	Ophidion marginatum
937	Pearlfish	Carapus bermudensis
938	Marlin-spike	Nezumia bairdi
939	Flying halfbeak	Euleptorhamphus velox
940	Ballyhoo	Hemiramphus brasiliensis

941	Margined flyingfish	Cheilopogon cyanopterus
942	Spotfin flyingfish	Cheilopogon furcatus
943	Atlantic flyingfish	Cheilopogon melanurus
944	Oceanic two-wing flyingfish	Exocoetus obtusirostris
945	Blackwing flyingfish	Hirundichthys rondeletii
946	Smallwing flyingfish	Oxyporhamphus micropterus
947	Sailfin flyingfish	Parexocoetus brachypterus
948	Bluntnose flyingfish	Prognichthys occidentalis
949	Flat needlefish	Ablennes hians
950	Redfin needlefish	Strongylura notata
951	Houndfish	Tylosurus crocodilus
952	Beardfish	Polymixia lowei
954	Squirrelfish	Holocentrus adscensionis
955	Longspine squirrelfish	Holocentrus rufus
956	Buckler dory	Zenopsis conchifera
957	Deepbody boarfish	Antigonia capros
958	Bluespotted cornetfish	Fistularia tabacaria
959	Longspine snipefish	Macroramphosus scolopax
960	Sargassum pipefish	Syngnathus pelagicus
961	Bank sea bass	Centropristis ocyurus
962	Sand perch	Diplectrum formosum
963	Rock hind	Epinephelus adscensionis
964	Speckled hind	Epinephelus drummondhayi
965	Goliath grouper	Epinephelus itajara
966	Red grouper	Epinephelus morio
967	Warsaw grouper	Hyporthodus nigritus
968	Nassau grouper	Epinephelus striatus
969	Spanish flag	Gonioplectrus hispanus

970	Longtail bass	Hemanthias leptus
971	Red barbier	Hemanthias vivanus
972	Butter hamlet	Hypoplectrus unicolor
974	Black grouper	Mycteroperca bonaci
975	Yellowmouth grouper	Mycteroperca interstitialis
976	Gag	Mycteroperca microlepis
977	Scamp	Mycteroperca phenax
978	Western comb grouper	Mycteroperca acutirostris
979	Atlantic creolefish	Paranthias furcifer
980	Graysby	Cephalopholis cruentata
981	Pygmy sea bass	Serraniculus pumilio
982	Tattler	Serranus phoebe
983	Belted sandfish	Serranus subligarius
984	Greater soapfish	Rypticus saponaceus
985	Bridle cardinalfish	Apogon aurolineatus
986	Flamefish	Apogon maculatus
988	Blackmouth bass	Synagrops bellus
989	Keelcheek bass	Synagrops spinosus
990	Anchor tilefish	Caulolatilus intermedius
991	Tilefish	Lopholatilus chamaeleonticeps
992	Sand tilefish	Malacanthus plumieri
993	Marlinsucker	Remora osteochir
994	African pompano	Alectis ciliaris
995	Rainbow runner	Elagatis bipinnulata
996	Greater amberjack	Seriola dumerili
997	Almaco jack	Seriola rivoliana
998	Banded rudderfish	Seriola zonata
999	Permit	Trachinotus falcatus
1800	No species caught	None

3000	Tar ball	Tar ball
4070	(Tri-lobe segmented algae)	Halimeda incrassata
9000	(Side-gilled sea slug)	Pleurobranchaea inconspicua
9001	(Vitrinella)	Solariorbis blakei
9002	Short macoma	Macoma brevifrons
9003	Mexilhao mussel	Perna perna
9004	(Dovesnail – unidentified)	Genus Costoanachis
9005	Pointed venus	Anomalocardia auberiana
9006	Family porcelain crabs	Family Porcellanidae
9007	(Family cerith snails)	Family Cerithiidae
9008	(Sea slug)	Polycera hummi
9009	Amber glassy-bubble	Haminoea succinea
9010	Striped snapping shrimp	Alpheus formosus
9011	Tinted cantharus	Pollia tincta
9012	Striped false limpet	Siphonaria pectinata
9013	Delicate ark	Barbatia tenera
9014	(Banded brittle star)	Hemipholis elongata
9015	(Brittle star)	Microphiopholis atra
9016	Spined fiddler	Uca spinicarpa
9017	Yellow cone	Conus stimpsoni
9018	Radial-ridged corbula	Corbula swiftiana
9019	Olive nerite	Neritina usnea
9020	Eastern auger	Terebra dislocata
9022	Matagorda macoma	Macoma mitchelli
9023	Smooth duckclam	Anatina anatina
9024	(River shrimp – unidentied)	Genus Macrobrachium
9025	(Beach flea)	Orchestia grillus

9026	(Class malacostracan crustaceans	Class Malacostraca
9027	(Family mysid shrimps)	Family Mysidae
9028	Bristled river shrimp	Macrobrachium olfersii
9029	(Rock-boring urchin)	Echinometra lucunter
9030	Variable cerith	Cerithium lutosum
9031	Banded snapping shrimp	Alpheus armillatus
9032	Delicate swimming crab	Portunus anceps
9033	Family longeye shrimps	Family Ogyrididae
9034	Plicate hornsnail	Cerithidea pliculosa
9035	Family freshwater clams	Family Unionidae
9036	Flamingo tongue	Cyphoma gibbosum
9037	Eastern melampus	Melampus bidentatus
9038	Family bristle worms	Family Amphinomidae
9039	Longfinger neck crab	Podochela riisei
9040	Diffuse ivory bush coral	Oculina diffusa
9041	(Mayfly nymphs)	Genus Isonychia
9042	(Family nerite snails)	Family Neritidae
9043	Miniature moonsnail	Tectonatica pusilla
9044	Eastern white slippersnail	Crepidula plana
9045	Family tritons	Family Ranellidae
9046	Bareye hermit	Dardanus fucosus
9047	Squatter pea crab	Tumidotheres maculatus
9048	(Stonefly nymphs)	Genus Claassenia
9049	(Ghost shrimp)	Glypturus acanthochirus
9050	(Damselfly nymphs)	Suborder Zygoptera
9051	Phylum moss animals	Phylum Bryozoa
9052	Ocellate box crab	Calappa ocellata
9053	Order isopods	Order Isopoda

9054	Calico clam	Macrocallista maculata
9055	(Sea squirt)	Molgula manhattensis
9056	(Family tellins and macoma)	Family Tellinidae
9057	Purple marsh crab	Sesarma reticulatum
9058	Striped porcelain crab	Porcellana sigsbeiana
9059	Bigclaw snapping shrimp	Alpheus heterochaelis
9060	Class squids and octopus	Class Cephalopoda
9061	Awl miniature cerith	Cerithiopsis emersonii
9062	Granulose purse crab	Acanthilia intermedia
9063	(Mud-burrowing heart urchin)	Moira atropos
9064	Atlantic thorny oyster	Spondylus americanus
9065	Zostera shrimp	Hippolyte zostericola
9066	Carolina marshclam	Polymesoda caroliniana
9067	Pacific white shrimp	Litopenaeus vannamei
9068	(Sauerkraut bryozoan)	Zoobotryon verticillatum
9069	(Family majid crabs)	Family Majidae
9070	Phylum segmented worms	Phylum Annelida
9071	Slender sargassum shrimp	Latreutes fucorum
9072	Slender inshore squid	Loligo pleii
9073	Gulf dovesnail	Costoanachis semiplicata
9074	(Spiny-back scud)	Gammarus mucronatus
9075	Order amphipods	Order Amphipoda
9076	Horse conch	Pleuroploca qigantea
9077	Sea-whip simnia	Simnialena marferula
9078	Cut-ribbed ark	Anadara floridana
9079	Order sea pens	Order Pennatulacea

9080	Southern marshclam	Polymesoda maritima
9081	White-beard ark	Barbatia candida
9082	Dimpled hermit	Pagurus impressus
9083	(Mitchell's wentletrap)	Amaea mitchelli
9084	Mossy ark	Arca imbricata
9085	Blackpoint sculling crab	Cronius ruber
9086	Greedy dovesnail	Costoanachis avara
9087	(Sea cucumber)	Allothyone mexicana
9088	(Mole crab)	Lepidopa benedicti
9089	(Seahare - unidentified)	Genus Aplysia
9090	Class acorn worms	Class Enteropneusta
9091	Smooth elbow crab	Heterocrypta granulata
9092	Atlantic distorsio	Distorsio clathrata
9093	(Rosette-scaled brittle)	Ophiolepis elegans
9094	Atlantic calico scallop	Argopecten gibbus
9095	Class hydrozoans	Class Hydrozoa
9096	Family snapping shrimps	Family Alpheidae
9097	(Sargassum crab)	Callinectes marginatus
9098	(Onion anemone)	Paranthus rapiformis
9099	Redleg humpback shrimp	Exhippolysmata oplophoroide
9100	Broadback mud crab	Eurytium limosum
9101	Marsh grass shrimp	Palaemonetes vulgaris
9102	(Colonial hydroid – unidentified)	Genus Bougainvillia
9103	Family pea crabs	Family Pinnotheridae
9104	(Night shrimp)	Processa hemphilli
9105	(Spiny snail fur)	Podocoryne carnea
9106	Southern clamworm	Nereis succinea
9107	Elongate macoma	Macoma tenta

9108	Sea scallop	Placopecten magellanicus
9109	Brown grass shrimp	Leander tenuicornis
9110	(Class snails)	Class Gastropoda
9111	(Order veneroid bivalves)	Order Veneroida
9112	Atlantic papermussel	Amygdalum papyrium
9113	(Many-ribbed jellyfish)	Rhacostoma atlanticum
9115	Dark falsemussel	Mytilopsis leucophaeata
9116	(Spiral bryozoan)	Amathia alternata
9117	(Tricolor anemone)	Calliactis tricolor
9118	Australian spotted jellyfish	Phyllorhiza punctata
9119	(Order nudibranchs)	Order Nudibranchia
9120	Common jingle	Anomia simplex
9121	Order bugs	Order Hemiptera
9122	Cinnamon river shrimp	Macrobrachium acanthurus
9123	Common Atlantic slippers	Crepidula fornicata
9124	Portuguese man o' war	Physalia physalis
9125	(Dragonfly nymphs)	Suborder Anisoptera
9126	Lady-in-waiting venus	Puberella intapurpurea
9127	Sargassum shrimp	Latreutes parvulus
9128	Intermediate cyphoma	Pseudocyphoma intermedium
9129	Thick lucine	Lucina pectinata
9130	Family slipper lobsters	Family Scyllaridae
9131	(Giant waterbug – unidentified)	Genus Belostoma
9132	(Water scorpion – unidentified)	Genus Ranatra
9133	Lobate mud crab	Eurypanopeus abbreviatus
9134	Fine-ribbed auger	Terebra protexta

9135	Variable coquina	Donax variabilis
9136	(Giant mantis shrimp)	Lysiosquilla scabricauda
9137	Cayenne keyhole limpet	Diodora cayenensis
9138	Surf hermit	Isocheles wurdemanni
9139	Atlantic ghost crab	Ocypode quadrata
9140	Puerto Rican sand crab	Emerita portoricensis
9141	Eastern tube crab	Polyonyx gibbesi
9142	Gulf sand fiddler	Uca panacea
9143	Silky tegula	Tegula fasciata
9144	Thin cyclinella	Cyclinella tenuis
9145	Incongruous ark	Anadara brasiliana
9146	Rough shellback crab	Hypoconcha parasitica
9147	Virgin nerite	Neritina virginea
9148	Hairy sponge crab	Cryptodromiopsis antillensi
9149	Texas quahog	Mercenaria campechiensis te
9150	Texas venus	Agriopoma texasianum
9151	Florida spiny jewelbox	Arcinella cornuta
9152	(Dark-banded mantis shrimp)	Bigelowina biminiensis
9153	Ragged seahare	Bursatella leachii pleii
9154	Caribbean spiny lobster	Panulirus argus
9155	Marsh periwinkle	Littoraria irrorata
9156	Mudflat fiddler	Uca rapax
9157	Furrowed frog crab	Raninoides loevis
9158	(Striped sea slug)	Armina wattla
9159	Angelwing	Cyrtopleura costata
9160	Red swamp crawfish	Procambarus clarkii
9161	Transverse ark	Anadara transversa
9162	Kinglet rock shrimp	Sicyonia typica

9163	Royal sea star	Astropecten articulatus
9164	Broadspine ghost shrimp	Dawsonius latispina
9165	(Purple jellyfish)	Pelagia noctiluca
9166	Shortfinger neck crab	Podochela sidneyi
9167	Beach ghost shrimp	Callichirus islagrande
9168	(Fiddler crab – unidentied)	Genus Uca
9169	Parchment tube worm	Chaetopterus variopedatus
9170	Thick-ringed venus	Lirophora clenchi
9171	Ponderous ark	Noetia ponderosa
9172	Yellow eggcockle	Laevicardium mortoni
9173	Florida fighting conch	Strombus alatus
9174	Estuarine ghost shrimp	Lepidophthalmus louisianensis
9175	Roughwrist soft crab	Chasmocarcinus mississippie
9176	Disk dosinia	Dosinia discus
9177	Knobbed mud crab	Hexapanopeus paulensis
9178	Coastal mud shrimp	Upogebia affinis
9179	Atlantic wing-oyster	Pteria colymbus
9180	Olivepit porcelain crab	Euceramus praelongus
9181	Giant tun	Tonna galea
9182	Sargassum nudibranch	Scyllaea pelagica
9183	Alternate tellin	Tellina alternata
9184	Concentric nutclam	Nuculana concentrica
9185	Phylum nemertean worms	Phylum Nemertinea
9186	Stout tagelus	Tagelus plebeius
9187	Class polychaete worms	Class Polychaeta
9188	Minor jacknife	Ensis minor
9190	Tampa tellin	Tellina tampaensis
9191	Scorched mussel	Brachidontes exustus

9192	Crested oyster	Ostrea equestris
9193	Daggerblade grass shrimp	Palaemonetes pugio
9194	Granulate shellback crab	Hypoconcha arcuata
9195	(Short-fingered hermit)	Pagurus brevidactylus
9196	Class jellyfish	Class Scyphozoa
9197	(Sea cucumber – unidentied)	Genus Leptosynapta
9198	Florida grass shrimp	Palaemon floridanus
9199	Red-joint fiddler	Uca minax
9200	(Common bugula)	Bugula neritina
9201	Convex slippersnail	Crepidula convexa
9202	Cancellate cantharus	Solenosteira cancellaria
9203	Brown rangia	Rangia flexuosa
9204	Arctic hiatella	Hiatella arctica
9206	Phylum Sponges	Phylum Porifera
9207	Sawtooth elbow crab	Platylambrus serratus
9208	Order hydroids	Order Hydroidea
9209	Gulf squareback crab	Speocarcinus lobatus
9210	Dwarf surf clam	Mulinia lateralis
9211	(Brown-banded hermit)	Pagurus annulipes
9212	Sharp nassa	Nassarius acutus
9213	Family crayfishes	Family Astacidae
9214	Flatback mud crab	Eurypanopeus depressus
9215	(Sea wasp)	Chiropsalmus quadrumanus
9216	Class brittle stars	Class Ophiuroidea
9217	Antilles glassy-bubble	Haminoea antillarum
9218	Striate bubble	Bulla striata
9219	(Short-spined sea urchin)	Lytechinus variegatus
9220	Hays rock shell	Stramonita haemastoma

		canalic
9221	Atlantic surfclam	Spisula solidissima
9222	Smooth mud crab	Hexapanopeus angustifrons
9223	Roughneck shrimp	Rimapenaeus constrictus
9224	Sand snapping shrimp	Alpheus floridanus
9225	Blue land crab	Cardisoma guanhumi
9226	Four-tentacle box jelly	Tamoya haplonema
9227	Sargassum swimming crab	Portunus sayi
9230	(Family elongate squids)	Family Loliginidae
9231	Royal red shrimp	Pleoticus robustus
9232	Banded porcelain crab	Petrolisthes galathinus
9233	Pipe cleaner sea pen	Virgularia presbytes
9234	(Sea squirt)	Ciona intestinalis
9235	Mushroom jellyfish	Rhopilema verrilli
9236	Lion's mane jellyfish	Cyanea capillata
9237	(Sea star-unidentified)	Genus Echinaster
9238	Giant eastern murex	Hexaplex fulvescens
9239	Furcated spider crab	Stenocionops furcatus
9240	Skeleton shrimp	Family Caprellidae
9241	Cross-barred venus	Chione cancellata
9242	Many-ribbed jellyfish	Aequorea forskalea
9243	Mottled seahare	Aplysia brasiliana
9244	(Sergestid shrimp)	Acetes americanus
9245	Southern ribbed-mussel	Geukensia granosissima
9246	Shouldered pearwhelk	Busycotypus plagosus
9247	False shark eye	Neverita delessertiana
9248	Peppermint shrimp	Lysmata wurdemanni
9249	(Hydromedusa)	Nemopsis bachei

9250	Shark eye	Neverita duplicata
9251	Surf mole crab	Albunea gibbesii
9252	Hooked mussel	Ischadium recurvum
9253	Pearwhelk	Busycotypus spiratus
9254	Fragile surfclam	Mactrotoma fragilis
9255	(Hermit crab – unidentified)	Superfamily Paguroidea
9257	(Dorid nudibranch)	Montereina branneri
9258	(Hyperiid amphipod)	Family Hyperiidae
9259	Class sea cucumbers	Class Holothuroidea
9260	Rose shrimp	Parapenaeus politus
9261	Banded tulip	Fasciolaria lilium lilium
9262	Giant hermit	Petrochirus diogenes
9263	False angelwing	Petricolaria pholadiformis
9264	Well-ribbed dovesnail	Costoanachis translirata
9265	(Aeolidiid nudibranch)	Berghia verrucicornis
9266	Pleated sea squirt	Styela plicata
9267	Eelgrass isopod	Erichsonella attenuata
9268	Redhair swimming crab	Portunus ordwayi
9269	Serrate arrow shrimp	Tozeuma serratum
9270	White Atlantic semele	Semele proficua
9271	Western Dondice	Dondice occidentalis
9272	Order Coleoptera	Order Coleoptera
9272	Order beetles	Order Coleoptera
9282	False arrow crab	Metoporhaphis calcarata
9283	(Blue-spot hermit)	Paguristes hummi
9284	(Offshore mantis shrimp)	Squilla chydaea
9285	Order soft corals	Order Alcyonacea
9286	Yellow pricklycockle	Trachycardium muricatum

9287	Phylum comb jellies or s	Phylum Ctenophora
9288	(Aeolidiid nudibranch)	Cerberilla tanna
9289	Purplish semele	Semele purpurascens
9290	Bruised nassa	Nassarius vibex
9293	Southern quahog	Mercenaria campechiensis
9294	Lettered olive	Oliva sayana
9295	Common sundial	Architectonica nobilis
9296	Blood ark	Anadara ovalis
9297	Flecked box crab	Hepatus pudibundus
9298	Beach mole crab	Albunea paretii
9299	Atlantic rangia	Rangia cuneata
9300	Eastern oyster	Crassostrea virginica
9301	Family right-handed herm	Family Paguridae
9302	Family rubble and pebble	Family Panopeidae
9303	Pearwhelk--Unidentified	Genus Busycotypus
9304	Family swimming crabs	Family Portunidae
9305	Spotted porcelain crab	Porcellana sayana
9307	(Striped sea star)	Luidia clathrata
9308	Atlantic giant cockle	Dinocardium robustum
9309	Scotch bonnet	Phalium granulatum
9310	Green porcelain crab	Petrolisthes armatus
9312	Sea nettle	Chrysaora quinquecirrha
9313	Longnose spider crab	Libinia dubia
9314	Class sessile tunicates	Class Ascidiacea
9315	Common nutmeg	Cancellaria reticulata
9316	White baby ear	Sinum perspectivum
9317	(Moonsnail — unidentified)	Genus Neverita

9318	Moon jelly	Aurelia aurita
9319	(Phosphorus jelly)	Mnemiopsis mccradyi
9320	Sawtooth penshell	Atrina serrata
9321	(Purple-spined sea urchin)	Arbacia punctulata
9322	Yellowline arrow crab	Stenorhynchus seticornis
9323	Common octopus	Octopus vulgaris
9325	Cryptic teardrop crab	Pelia mutica
9327	Lightning whelk	Busycon sinistrum
9328	Florida rocksnail	Stramonita haemastoma flori
9329	Flatclaw hermit	Pagurus pollicaris
9330	Thinstripe hermit	Clibanarius vittatus
9331	Pink purse crab	Persephona crinita
9332	(Swimming crab)	Portunus ventralis
9334	Estuarine mud crab	Rhithropanopeus harrisii
9335	Oystershell mud crab	Panopeus simpsoni
9337	(Luciferid shrimp)	Lucifer faxoni
9338	Arrow shrimp	Tozeuma carolinense
9339	Order anemones	Order Actiniaria
9340	White elbow crab	Leiolambrus nitidus
9341	(Banded sea star)	Luidia alternata
9342	By-the-wind sailor	Velella velella
9343	(Sea walnut)	Beroe ovata
9344	Stilt spider crab	Anasimus latus
9345	Eyespot rock shrimp	Sicyonia stimpsoni
9346	Paper scallop	Amusium papyraceum
9348	Gulf frog crab	Raninoides louisianensis
9349	Speckled snapping shrimp	Synalpheus fritzmuelleri
9350	Asian tiger prawn	Penaeus monodon

9352	(Heart urchin)	Brissopsis alta
9353	Cannonball jelly	Stomolophus meleagris
9354	(Five-holed sand dollar)	Mellita quinquiesperforata
9355	(Two-spined starfish)	Astropecten duplicatus
9356	(Sea pansy)	Renilla muelleri
9358	Longspine swimming crab	Portunus spinicarpus
9359	Blotched swimming crab	Portunus spinimanus
9360	Humpback shrimp	Solenocera vioscai
9489	Yellow box crab	Calappa sulcata
9490	Flame box crab	Calappa flammea
9491	Calico box crab	Hepatus epheliticus
9600	White shrimp	Litopenaeus setiferus
9603	(Common mantis shrimp)	Squilla empusa
9605	Blue crab	Callinectes sapidus
9607	Ohio shrimp	Macrobrachium ohione
9609	(Grass shrimp)	Genus Palaemonetes
9618	Brown shrimp	Farfantepenaeus aztecus
9636	Gulf stone crab	Menippe adina
9638	Estuarine snapping shrimp	Alpheus estuariensis
9640	Pink shrimp	Farfantepenaeus duorarum
9643	Longwrist hermit	Pagurus longicarpus
9653	Bay scallop	Argopecten irradians
9698	Portly spider crab	Libinia emarginata
9700	Class starfishes	Class Asteroidea
9707	Roughback shrimp	Rimapenaeus similis
9708	Family penaeid shrimps	Family Penaeidae
9709	Seabob	Xiphopenaeus kroyeri

9830	Iridescent swimming crab	Portunus gibbesii
9831	Brown rock shrimp	Sicyonia brevirostris
9832	Lesser rock shrimp	Sicyonia dorsalis
9833	Longfin inshore squid	Loligo pealeii
9834	(Rimapenaeid shrimp – unidentified)	Genus Rimapenaeus
9835	Atlantic brief squid	Lolliguncula brevis
9836	Lesser blue crab	Callinectes similis
9837	Mottled purse crab	Persephona mediterranea
9839	Florida lady crab	Ovalipes floridanus
9840	Speckled swimming crab	Arenaeus cribrarius
9847	Phylum mollusks	Phylum Mollusca
9848	Suborder crabs and lobst	Suborder Reptantia
9851	(Lesser mantis shrimp)	Gibbesia neglecta
9876	Gulf grassflat crab	Dyspanopeus texanus

APPENDIX E: TOXIC RELEASE CHEMICALS

1,1,1,2-TETRACHLOROETHANE

1,1,1-TRICHLOROETHANE

1,1,2,2-TETRACHLOROETHANE

1,1,2-TRICHLOROETHANE

1,1-DICHLORO-1-FLUOROETHANE

1,2,3-TRICHLOROPROPANE

1,2,4-TRICHLOROBENZENE

1,2,4-TRIMETHYLBENZENE

1,2-BUTYLENE OXIDE

1,2-DIBROMOETHANE

1,2-DICHLOROBENZENE

1,2-DICHLOROETHANE

1,2-DICHLOROETHYLENE

1,2-DICHLOROPROPANE

1,2-PHENYLENEDIAMINE

1,3-BUTADIENE

1,3-DICHLOROBENZENE

1,3-DICHLOROPROPYLENE

1,3-PHENYLENEDIAMINE

1,4-DICHLORO-2-BUTENE

1,4-DICHLOROBENZENE

1,4-DIOXANE

1-CHLORO-1,1-DIFLUOROETHANE

ETHYLENEIMINE

ETHYLIDENE DICHLORIDE

FAMPHUR

FENOXYCARB

FENVALERATE

FLUOMETURON

FLUORINE

FLUOROURACIL

FOLPET

FOMESAFEN

FORMALDEHYDE

FORMIC ACID

FREON 113

GLYCIDOL

HEPTACHLOR

HEXACHLORO-1,3-BUTADIENE

HEXACHLOROBENZENE

HEXACHLOROCYCLOPENTADIENE

HEXACHLOROETHANE

HEXACHLOROPHENE

HEXAZINONE

HYDRAMETHYLNON

HYDRAZINE

2,2-DICHLORO-1,1,1-TRIFLUOROETHANE

2,3-DICHLOROPROPENE

2,4,5-TRICHLOROPHENOL

2,4-D

2,4-D 2-ETHYL-4-METHYLPENTYL ESTER

2,4-DIAMINOANISOLE

2,4-DIAMINOTOLUENE

2,4-DICHLOROPHENOL

2,4-DIMETHYLPHENOL

2,4-DINITROPHENOL

2,4-DINITROTOLUENE

2,4-DP

2,6-DIMETHYLPHENOL

2,6-DINITROTOLUENE

2-ACETYLAMINOFLUORENE

2-ETHOXYETHANOL

2-MERCAPTOBENZOTHIAZOLE

2-METHOXYETHANOL

2-METHYLLACTONITRILE

2-METHYLPYRIDINE

2-NITROPHENOL

2-NITROPROPANE

2-PHENYLPHENOL

3,3-DICHLORO-1,1,1,2,2-

HYDRAZINE SULFATE

HYDROCHLORIC ACID (1995 AND AFTER ACID AEROSOLS"""" ONLY)""""""

HYDROGEN CYANIDE

HYDROGEN FLUORIDE

HYDROGEN SULFIDE

HYDROQUINONE

IMAZALIL

IRON PENTACARBONYL

ISOBUTYRALDEHYDE

ISODRIN

ISOPRENE

ISOPROPYL ALCOHOL (MANUFACTURING,STRONG-ACID PROCESS ONLY,NO SUPPLIER)

ISOSAFROLE

LEAD

LEAD COMPOUNDS

LINDANE

LINURON

LITHIUM CARBONATE

MALATHION

MALEIC ANHYDRIDE

MALONONITRILE

MANEB

MANGANESE

MANGANESE COMPOUNDS

PENTAFLUOROPROPANE

3,3'-DICHLOROBENZIDINE

3,3'-DIMETHOXYBENZIDINE

3-CHLOROPROPIONITRILE

3-IODO-2-PROPYNYL BUTYLCARBAMATE

4,4'-DIAMINODIPHENYL ETHER

4,4'-ISOPROPYLIDENEDIPHENOL

4,4'-METHYLENEBIS(2-CHLOROANILINE)

4,4'-METHYLENEDIANILINE

4,6-DINITRO-O-CRESOL

4-DIMETHYLAMINOAZOBENZENE

4-NITROPHENOL

ACEPHATE

ACETALDEHYDE

ACETAMIDE

ACETONE

ACETONITRILE

ACETOPHENONE

ACIFLUORFEN, SODIUM SALT

ACROLEIN

ACRYLAMIDE

ACRYLIC ACID

ACRYLONITRILE

ALACHLOR

ALDICARB

ALDRIN

M-CRESOL

M-DINITROBENZENE

MECOPROP

MERCURY

MERCURY COMPOUNDS

METHACRYLONITRILE

METHAM SODIUM

METHANOL

METHIOCARB

METHOXONE

METHOXONE SODIUM SALT

METHOXYCHLOR

METHYL ACRYLATE

METHYL CHLOROCARBONATE

METHYL ETHYL KETONE

METHYL HYDRAZINE

METHYL IODIDE

METHYL ISOBUTYL KETONE

METHYL ISOCYANATE

METHYL METHACRYLATE

METHYL PARATHION

METHYL TERT-BUTYL ETHER

METHYLENE BROMIDE

METHYLENEBIS(PHENYLISOCYANATE)

METRIBUZIN

ALLYL ALCOHOL

ALLYL CHLORIDE

ALPHA-NAPHTHYLAMINE

ALUMINUM (FUME OR DUST)

ALUMINUM OXIDE (FIBROUS FORMS)

AMETRYN

AMITROLE

AMMONIA

AMMONIUM NITRATE (SOLUTION)

AMMONIUM SULFATE (SOLUTION)

ANILAZINE

ANILINE

ANTHRACENE

ANTIMONY

ANTIMONY COMPOUNDS

ARSENIC

ARSENIC COMPOUNDS

ASBESTOS (FRIABLE)

ATRAZINE

BARIUM

BARIUM COMPOUNDS

BENDIOCARB

BENOMYL

BENZAL CHLORIDE

BENZENE

BENZIDINE

MIXTURE

MOLINATE

MOLYBDENUM TRIOXIDE

MONOCHLOROPENTAFLUOROETHANE

M-XYLENE

MYCLOBUTANIL

N,N-DIMETHYLANILINE

N,N-DIMETHYLFORMAMIDE

NALED

NAPHTHALENE

N-BUTYL ALCOHOL

N-DIOCTYL PHTHALATE

N-HEXANE

NICKEL

NICKEL COMPOUNDS

NICOTINE AND SALTS

NITRAPYRIN

NITRATE COMPOUNDS

NITRIC ACID

NITRILOTRIACETIC ACID

NITROBENZENE

NITROGLYCERIN

N-METHYL-2-PYRROLIDONE

N-METHYLOLACRYLAMIDE

N-NITROSODIETHYLAMINE

N-NITROSODIPHENYLAMINE

BENZO(G,H,I)PERYLENE

BENZOIC TRICHLORIDE

BENZOYL CHLORIDE

BENZOYL PEROXIDE

BENZYL CHLORIDE

BERYLLIUM

BERYLLIUM COMPOUNDS

BIFENTHRIN

BIPHENYL

BIS(2-CHLORO-1-METHYLETHYL) ETHER

BIS(2-CHLOROETHYL) ETHER

BIS(CHLOROMETHYL) ETHER

BIS(TRIBUTYLTIN) OXIDE

BORON TRIFLUORIDE

BROMACIL

BROMINE

BROMOCHLORODIFLUOROMETHANE

BROMOFORM

BROMOMETHANE

BROMOTRIFLUOROMETHANE

BRUCINE

BUTYL ACRYLATE

BUTYL BENZYL PHTHALATE

BUTYRALDEHYDE

C.I. BASIC GREEN 4

N-NITROSO-N-ETHYLUREA

N-NITROSO-N-METHYLUREA

N-NITROSOPIPERIDINE

O-ANISIDINE

O-CRESOL

OCTACHLOROSTYRENE

O-DINITROBENZENE

ORYZALIN

O-TOLUIDINE

O-TOLUIDINE HYDROCHLORIDE

OXYFLUORFEN

O-XYLENE

OZONE

PARALDEHYDE

PARAQUAT DICHLORIDE

PARATHION

P-CHLOROANILINE

P-CRESOL

PENDIMETHALIN

PENTACHLOROBENZENE

PENTACHLOROETHANE

PENTACHLOROPHENOL

PERACETIC ACID

PERMETHRIN

PHENANTHRENE

C.I. FOOD RED 15

C.I. SOLVENT YELLOW 14

C.I. SOLVENT YELLOW 34

CADMIUM

CADMIUM COMPOUNDS

CAPTAN

CARBARYL

CARBOFURAN

CARBON DISULFIDE

CARBON TETRACHLORIDE

CARBONYL SULFIDE

CARBOXIN

CATECHOL

CERTAIN GLYCOL ETHERS

CHLORDANE

CHLORENDIC ACID

CHLORIMURON ETHYL

CHLORINE

CHLORINE DIOXIDE

CHLOROACETIC ACID

CHLOROBENZENE

CHLOROBENZILATE

CHLORODIFLUOROMETHANE

CHLOROETHANE

CHLOROFORM

CHLOROMETHANE

PHENOL

PHENOTHRIN

PHENYTOIN

PHOSGENE

PHOSPHINE

PHOSPHORIC ACID

PHOSPHORUS (YELLOW OR WHITE)

PHTHALIC ANHYDRIDE

PICRIC ACID

PIPERONYL BUTOXIDE

PIRIMIPHOS METHYL

P-NITROANILINE

POLYCHLORINATED ALKANES

POLYCHLORINATED BIPHENYLS

POLYCYCLIC AROMATIC COMPOUNDS

POTASSIUM DIMETHYLDITHIOCARBAMATE

POTASSIUM N-METHYLDITHIOCARBAMATE

P-PHENYLENEDIAMINE

PRONAMIDE

PROPACHLOR

PROPANIL

PROPARGITE

PROPARGYL ALCOHOL

PROPICONAZOLE

PROPIONALDEHYDE

PROPOXUR

CHLOROMETHYL METHYL ETHER
CHLOROPHENOLS
CHLOROPICRIN
CHLOROPRENE
CHLOROTETRAFLUOROETHANE
CHLOROTHALONIL
CHLOROTRIFLUOROMETHANE
CHROMIUM
CHROMIUM COMPOUNDS(EXCEPT CHROMITE ORE MINED IN THE TRANSVAAL REGION)
COBALT
COBALT COMPOUNDS
COPPER
COPPER COMPOUNDS
CREOSOTE
CRESOL (MIXED ISOMERS)
CROTONALDEHYDE
CUMENE
CUMENE HYDROPEROXIDE
CUPFERRON
CYANIDE COMPOUNDS
CYCLOATE
CYCLOHEXANE
CYCLOHEXANOL
CYFLUTHRIN
CYHALOTHRIN
PROPYLENE
PROPYLENE OXIDE
PROPYLENEIMINE
P-XYLENE
PYRIDINE
QUINOLINE
QUINONE
QUINTOZENE
RESMETHRIN
SACCHARIN (MANUFACTURING, NO SUPPLIER NOTIFICATION)
SAFROLE
SEC-BUTYL ALCOHOL
SELENIUM
SELENIUM COMPOUNDS
SETHOXYDIM
SILVER
SILVER COMPOUNDS
SIMAZINE
SODIUM AZIDE
SODIUM DIMETHYLDITHIOCARBAMATE
SODIUM HYDROXIDE (SOLUTION)
SODIUM NITRITE
SODIUM O-PHENYLPHENOXIDE
SODIUM SULFATE (SOLUTION)
STRYCHNINE AND SALTS

DAZOMET

DECABROMODIPHENYL OXIDE

DI(2-ETHYLHEXYL) PHTHALATE

DIALLATE

DIAMINOTOLUENE (MIXED ISOMERS)

DIAZINON

DIBENZOFURAN

DIBUTYL PHTHALATE

DICAMBA

DICHLOROBENZENE (MIXED ISOMERS)

DICHLORODIFLUOROMETHANE

DICHLOROFLUOROMETHANE

DICHLOROMETHANE

DICHLOROPENTAFLUOROPROPANE

DICHLOROTETRAFLUOROETHANE (CFC-114)

DICHLORVOS

DICOFOL

DICYCLOPENTADIENE

DIEPOXYBUTANE

DIETHANOLAMINE

DIETHYL PHTHALATE

DIETHYL SULFATE

DIFLUBENZURON

STYRENE

STYRENE OXIDE

SULFURIC ACID (1994 AND AFTER ACID AEROSOLS""" ONLY)""""

TEBUTHIURON

TEMEPHOS

TERBACIL

TEREPHTHALIC ACID

TERT-BUTYL ALCOHOL

TETRABROMOBISPHENOL A

TETRACHLOROETHYLENE

TETRAMETHRIN

THALLIUM

THALLIUM COMPOUNDS

THIABENDAZOLE

THIOACETAMIDE

THIODICARB

THIOPHANATE ETHYL

THIOPHANATE-METHYL

THIOUREA

THIRAM

TITANIUM TETRACHLORIDE

TOLUENE

TOLUENE DIISOCYANATE (MIXED ISOMERS)

DIGLYCIDYL RESORCINOL ETHER

DIHYDROSAFROLE

DIISOCYANATES

DIMETHOATE

DIMETHYL CHLOROTHIOPHOSPHATE

DIMETHYL PHTHALATE

DIMETHYL SULFATE

DIMETHYLAMINE

DIMETHYLAMINE DICAMBA

DIMETHYLCARBAMYL CHLORIDE

DINITROBUTYL PHENOL

DINITROTOLUENE (MIXED ISOMERS)

DINOCAP

DIOXIN AND DIOXIN-LIKE COMPOUNDS

DIPHENYLAMINE

DISODIUM CYANODITHIOIMIDOCARBONATE

DIURON

D-TRANS-ALLETHRIN

EPICHLOROHYDRIN

ETHOPROP

ETHYL ACRYLATE

ETHYL CHLOROFORMATE

ETHYLBENZENE

ETHYLENE

TOLUENE-2,4-DIISOCYANATE

TOLUENE-2,6-DIISOCYANATE

TOXAPHENE

TRADE SECRET CHEMICAL

TRANS-1,3-DICHLOROPROPENE

TRANS-1,4-DICHLORO-2-BUTENE

TRIADIMEFON

TRIALLATE

TRIBENURON METHYL

TRIBUTYLTIN METHACRYLATE

TRICHLORFON

TRICHLOROETHYLENE

TRICHLOROFLUOROMETHANE

TRIETHYLAMINE

TRIFLURALIN

TRIPHENYLTIN HYDROXIDE

TRIS(2,3-DIBROMOPROPYL) PHOSPHATE

TRYPAN BLUE

URETHANE

VANADIUM (EXCEPT WHEN CONTAINED IN AN ALLOY)

VANADIUM COMPOUNDS

VINYL ACETATE

VINYL CHLORIDE

VINYLIDENE CHLORIDE

ETHYLENE GLYCOL

ETHYLENE OXIDE

ETHYLENE THIOUREA

ETHYLENEBISDITHIOCARBAMIC ACID, SALTS AND ESTERS

WARFARIN AND SALTS

XYLENE (MIXED ISOMERS)

ZINC (FUME OR DUST)

ZINC COMPOUNDS

ZINEB