


SAN ANTONIO BAY

Status and Trends Reports

REPORT 1: Water Quality, Benthic Macrofauna, and Epibenthic Fauna
REPORT 2: Marine Resources
REPORT 3: Colonial Nesting Waterbirds
REPORT 4: Whooping Crane
REPORT 5: Upland Birds
REPORT 6: Attwater's Prairie Chicken
REPORT 7: Aplomado Falcon

March 2014




SAN ANTONIO BAY:
STATUS AND TRENDS REPORTS

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Executive Summary

The San Antonio Bay System is located between Matagorda and Aransas bays along the Texas coast and at the terminus of the San Antonio River and the Guadalupe River watersheds, approximately 10,000 mi^2 (GSMA BBEST, 2011). The average depth within the bay is approximately 4 feet and the maximum natural depth is 7 feet; exceptions include Espiritu Santo Bay with a maximum depth of approximately 8 feet and Steamboat Pass with depths down to about 31 feet. The San Antonio Bay System exchanges water with Matagorda Bay, located to the northeast, and with Aransas-Copano Bay, located to the southwest. Marine water is exchanged between the Gulf of Mexico and the estuarine system through the Pass Cavallo tidal inlet, the Matagorda ship channel, and through Cedar Bayou, when open. The San Antonio Bay System project area is composed of Espiritu Santo Bay, Hynes Bay, Guadalupe Bay, Mesquite Bay, Carlos Bay, Ayres Bay, Mission Lake, and Pringle Lake. Communities located within the San Antonio Bay System project area include the communities of Port O'Connor, Seadrift, Austwell, and Tivoli. The larger City of Victoria is located just outside the project boundary. Counties within the project area include: Aransas, Calhoun, Refugio, and Victoria.

Map showing the San Antonio Bay System project area using Google Earth Pro software.

This large (531 km^2) estuarine complex is one of the seven major estuaries along the Texas coast and is extremely unique in that wetlands associated with large portions of the surrounding shoreline provides critical wintering habitat for the last wild flock of the endangered Whooping Crane (*Grus americana*). This iconic species is part of the higher biodiversity that is also dependent on a healthy, functioning ecosystem. Focal guilds representative of the San Antonio Bay system include nesting colonial waterbirds and migratory/wintering waterfowl and shorebirds. Additionally, the San Antonio Bay also supports important commercial (oysters and shrimp) and recreational fisheries, which depend on surrounding wetlands for maintaining water quality and providing nursery grounds for fish and shellfish.

The San Antonio Bay Partnership (SABP) received funding to develop the *Habitat Conservation and Coastal Public Access Plan for the San Antonio Bay System* from the Texas General Land Office, Coastal Management Program, Cycle 16 funding. The SABP is a regional, non-profit, stakeholder-driven planning and management program for the SABS. The purpose of the Partnership is to create and sustain a working partnership of committed stakeholders in order to *protect, restore, and enhance* the natural resources of the SABS for the benefit of the ecosystem and its human uses. SABP stakeholders include businesses, conservation organizations, local governments, and resource agencies. The planning process was able to build upon the previous partnerships and collaborations that have been formed since the creation of the SABP, which resulted in strong stakeholder input throughout the development of the plan, ensuring a higher-likelihood of its implementation following completion.

As part of the plan development process, scientific data for the San Antonio Bay System was reviewed by knowledgeable stakeholders and used to produce “status and trends reports” for the following topics: (1) water quality, benthic macrofauna, and epibenthic fauna; (2) finfish and shellfish; (3) colonial nesting waterbirds; (4) Whooping Crane; (5) upland birds; (6) Attwater’s Prairie Chicken; and (7) Aplomado Falcon. The results of these status and trends reports are presented in this document. In addition to providing valuable information about the current status of the natural resources of the SABS, these reports also highlight potential natural resource issues, identify additional research and monitoring needs, and recommend potential conservation and management actions for the planning area.

The SABP would like to thank the authors that contributed their time and efforts to creating these reports. Without their contributions, this important aspect of the planning process would not have taken place. SABP would also like to thank the Texas General Land Office, Coastal Management Program for providing the funding to complete this planning effort, including the creation of these reports.

REPORT 1: Water Quality, Benthic Macrofauna, and Epibenthic Fauna

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DATA	HRI Stations: • Water Quality: salinity, temperature, dissolved oxygen, pH, chlorophyll, nutrients • Biological: benthic macrofauna TPWD Fisheries Independent Monitoring Program: • Water Quality: salinity, temperature, dissolved oxygen, turbidity • Biological: epibenthic fauna
TIMEFRAME	HRI Stations: 1987 – 2012 (except 2001-2003) TPWD: 1986-2012

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INTRODUCTION

The San Antonio Bay Partnership is in the process of identifying the status and trends of estuarine conditions of San Antonio Bay. Relevant to this effort is the Harte Research Institute (HRI) long-term study of the ecosystem dynamics of the San Antonio Bay as it relates to freshwater inflow from the Guadalupe River. This study is being performed by the Ecosystem Studies group, which moved to HRI from the University of Texas Marine Science Institute in September 2006. The group began freshwater inflow studies in San Antonio Bay in January 1987 and continues sampling today (as this is written in May 2012). The original goal of the study was to use benthic indicators to determine freshwater inflow needs of the estuary (Montagna and Kalke, 1992, 1995; Montagna and Yoon, 1991; Montagna et al., 2011b; Russell and Montagna, 2007). Much of the data collected during the initial study was used in a major report often referred to as the State Methodology (Longley, 1995). More recently, a second goal has been added to the San Antonio Bay study, and that is to determine the effects of land-use/land-cover change (Arismendez et al., 2009) and climate change in Texas estuaries (Montagna et al., 2007; 2011b) with a focus on San Antonio Bay.

One of the most important findings of the long-term studies is that estuarine dynamics along the Texas coast is driven by year-to-year variability in freshwater inflow, and this variability is apparently driven by long-term, and global-scale climatic events, e.g., El Niño, which affects rates of freshwater inflow (Tolan, 2007; Montagna et al., 2011b; Pollack et al., 2011). Therefore, this report documents long-term changes in populations and communities that are influenced by freshwater inflow. The best indicator of productivity is the change in biomass of the community over time.

Analysis of benthic (i.e., bottom dwelling) invertebrate communities have been widely used as bioindicators in assessment and monitoring studies worldwide. We expect indicator organisms to do for us today what canaries did for miners in the 18th and 19th century. Indicator organisms should have (at least) five characteristics that make them useful to detect change (Soule, 1988): (1) they should direct our attention to qualities of the environment; (2) they should give us a sign that some characteristic is present; (3) they should express a generalization about the environment; (4) they should suggest a cause, outcome or remedy, and (5) finally, they should show a need for action.

Benthic organisms have been especially useful in environmental research. There are several reasons why these organisms are good indicators of environmental stress. Benthos are usually the first organisms affected by water quality changes or pollution. Because of gravity, everything ends up in bottom sediments. Materials from watersheds and freshwater will be transported downstream to the coastal sea bottoms. Everything dies and ends up in the detrital food chain, which is utilized by the benthos. Pollutants are usually tightly coupled to organic matrices, therefore benthos have great exposure through their niche (food) and habitat (living spaces) to pollutants. Benthos are relatively long-lived and sessile, so they integrate pollutants effects of over long temporal and spatial scales. Benthic invertebrates are sensitive to change in environmental conditions and pollutants in particular, thus biodiversity loss is an excellent indicator of environmental stress. Bioturbation and irrigation of sediments by benthos effect the mobilization and burial of xenobiotic materials. Benthic biomass is an excellent indicator of system productivity (Kim and Montagna, 2012).

This report was created to answer several questions: What is the current status of water quality in San Antonio Bay? What is the status of benthic indicators? What are the trends in in water quality and benthic indicators over time? The approach is to perform a simple analysis of the existing HRI water quality and benthic data bases. The Texas Parks and Wildlife hydrography data base is added to increase our ability to distinguish spatial and temporal trends in water quality, and the TPWD trawl database is added to provide information at higher trophic levels. These data sets are described in Kim and Montagna (2012) and benthic methods are described in Montagna and Kalke (1992).

METHODS

Estuarine Data Acquisition

Four stations have been sampled quarterly for macrofauna and water quality by the authors since January 1987 (except from 2001 to 2003, Figure 1.1). These stations are hereinafter termed 'HRI stations'. Water quality measurements including salinity, temperature, dissolved oxygen and pH were taken simultaneously with macrofauna samples using YSI and Hydrolab datasondes. Samples were also taken on many of these dates to be analyzed for chlorophyll, ammonium, nitrate plus nitrite, phosphate, and silicate.

Benthic macrofauna were sampled using a 6.7-cm diameter core tube (35.4 cm^2 area) to a depth of 10 cm. Three replicate cores were collected from each station on each sampling date and were preserved with 5 % buffered formalin. In the laboratory, organisms were extracted on a 0.5 mm sieve, sorted using a stereo microscope, identified to the lowest practical identifiable level (usually species), and enumerated. Biomass was determined after combining individual macrofauna into higher taxa levels (Crustacea, Mollusca, Polychaeta, and others) and drying at 50 °C for 24 h. Mollusc shells were removed with 1 N HCl prior to drying and weighing.

Texas Parks and Wildlife Department (TPWD) have used a standardized fishery-independent monitoring program (A.K.A. Coastal Fisheries Monitoring Program, CFMP) to determine the relative abundance and size of fish and invertebrates in Texas coastal waters since the late 1970's (Martinez-Adrade et al., 2005). Trawl sampling of epifauna in each Texas estuary has been included in the sampling program since 1982, although trawl sampling was carried out in Texas estuaries as early as 1975. Trawls are 6.1 m wide at the mouth, with doors 1.2 m long by 0.5 m tall. Nets have a mesh of 3.8 cm. Epifauna was sampled bi-monthly using beam trawls in ten locations within each estuary using a stratified-random sampling design. Tows were taken in a circular pattern for 10 minutes.

Bi-monthly water quality data for each estuary were obtained from the TPWD to determine hydrological characteristics for drought and non-drought periods. TPWD have collected salinity, temperature, dissolved oxygen and turbidity data throughout each estuary simultaneously with the sampling of fish and invertebrates in the coastal fisheries monitoring program (Martinez-Andrade, 2005).

Changes in Estuarine Water Quality

San Antonio Bay was divided into two regions by the Gulf Intracoastal Water Way (GIWW) into upper and lower San Antonio Bay (Figure 1.1). The four HRI stations were evenly distributed, with stations A and B being located in the upper bay and stations C and D being located in the lower bay. Mean quarterly values of each water quality variable for each region were correlated with time to identify any long term trends. In addition, recent trends were determined by only using the time period from January 2004 to

January 2012 in correlations. Both Pearson and Spearman's rank correlations were used to determine trends. Pearson correlations determine the presence or absence of regular linear relationships, whereas Spearman's rank correlations determine the presence or absence of monotonic relationships (that are not necessarily linear).

Water quality data from TPWD sampling stations was also used to provide a finer temporal scale and greater spatial coverage (Figure 1.1). The drawback to this data is that the sampling strategy is not fixed (strategy is stratified random) and the same sampling stations are not consistently used. Both Pearson and Spearman rank correlations were also used to determine trends. Although all data is plotted, only data since January 1986 is used in correlations. The reasons for choosing these dates are because sampling was inconsistent before 1982 and there are potential errors in the database before 1986.

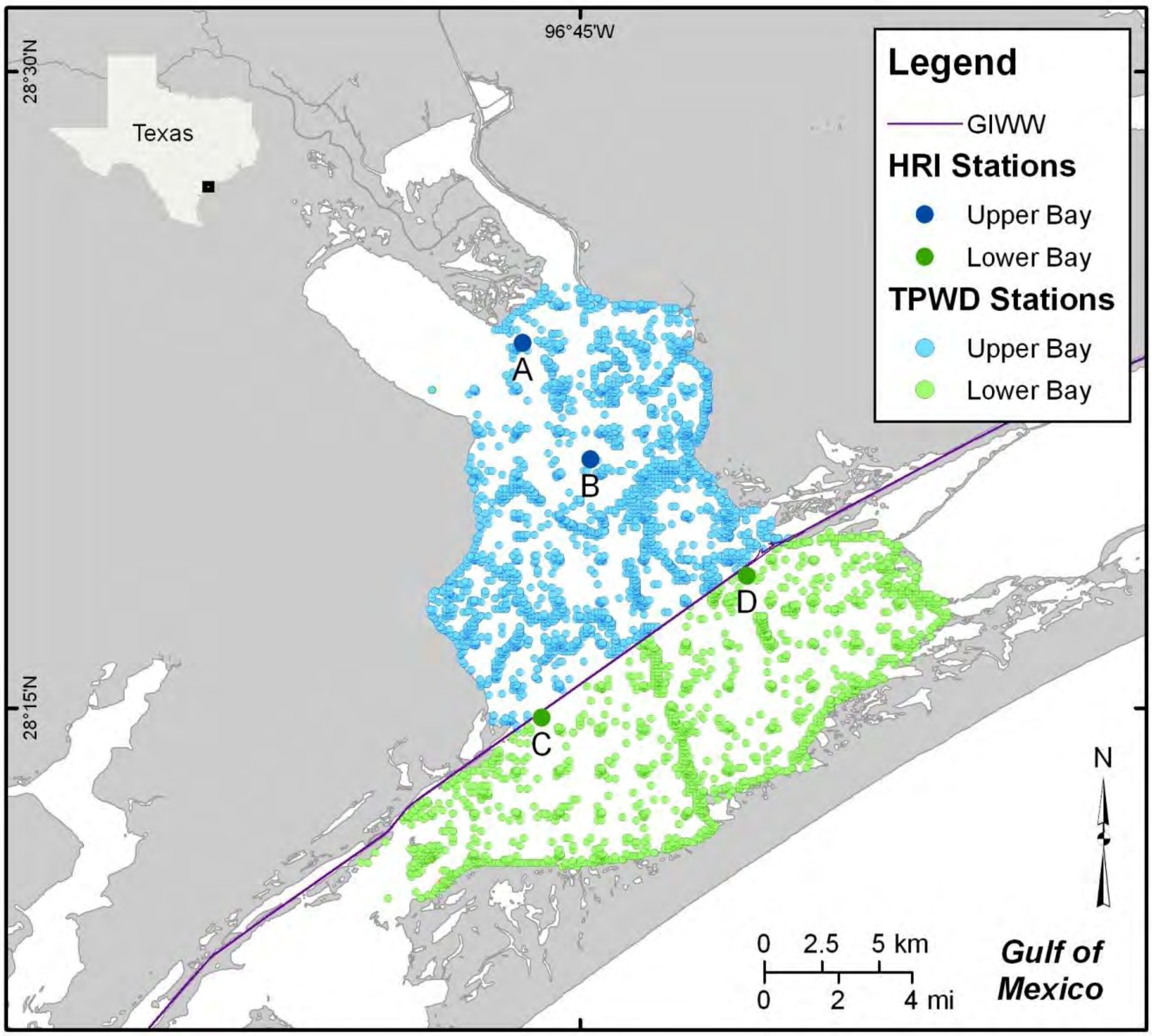

Figure 1.1 Map of sampling stations within San Antonio Bay.

Changes in Macrofauna and Epifauna Communities

Mean macrobenthic abundance, biomass and diversity were calculated for each quarterly sampling event for the two regions within the estuary. Mean epifaunal abundance, species richness (number of species) and diversity were determined for the whole bay. San Antonio Bay was not split up into two regions for epifaunal analyses because epifauna are mobile.

Macrofaunal diversity was calculated using Hill's N1 diversity index (Hill, 1973). Hill's N1 was used because it has units of number of dominant species, and is more interpretable than most other diversity indices (Ludwig and Reynolds, 1988). As with the water quality variables, the biotic variables were correlated with time using Pearson and Spearman's rank correlations to determine long-term trends.

RESULTS

Water Quality

Upper and Lower San Antonio Bay had mean salinities of 11-13 and 18-19 respectively over the past 25 years (Table 1.1 and Table 1.3, Figure 1.2 and Figure 1.7) although in the past eight years there has been a period of significantly increasing salinity (Table 1.2) as much of Texas has been in a large drought over the last year. A significant increase in salinity was detected when using the HRI- data for analysis but not when using the TPWD data. Salinity is often used as a proxy for freshwater inflow so there is little surprise that it is correlated with some nutrient concentrations in San Antonio Bay. Increased salinity, which equates to decreased flow, is negatively correlated with nitrate plus nitrite (NN) and silicate concentrations in the upper bay and pH, chlorophyll, NN, phosphate, and silicate concentrations in the lower bay (Table 1.1).

There have been significant decreases in ammonium, NN, and phosphate in both regions of the bay since 1987 but no significant changes in temperature, dissolved oxygen (DO) concentrations (DO), pH, or chlorophyll concentrations (Figure 1.3 through Figure 1.6). NN is the only nutrient to have a significant change over the recent eight-year period; however this significant decrease only occurred in the upper bay. Using monthly TPWD data, significant declines in dissolved oxygen concentrations and turbidity levels were detected in both the upper and lower regions of the bay while there was no significant change in salinity or temperature (Figure 1.7 and Figure 1.8).

As expected, temperature has a highly seasonal cycle. This seasonal cycle is also obvious with dissolved oxygen concentrations.

Macrofauna and Epifauna Communities

Benthic macrofauna abundance and N1 diversity has significantly decreased in both regions of the bay (Table 1.4 and Figure 1.9). Biomass has significantly decreased but only in the lower bay. N1 diversity is a measure of dominant species, therefore a decrease in N1 diversity over time is indicative of a decreasing number of dominant species throughout the estuary.

Contrary to the trend in benthic macrofauna over time, there has been a significant increase in epifaunal abundance and species richness over time (Table 1.5 and Figure 1.10). This increase in epifaunal abundance could in part be the cause of the decrease in macrobenthic abundance, because the macrobenthos make up the diet of many epifaunal species. There has been no significant change in the N1 diversity of epifauna in San Antonio Bay.

Table 1.1 Simple statistics of quarterly HRI-collected water quality and correlations with time and salinity in upper and lower San Antonio Bay over all years (Jan 1987 to Jan 2012).

Variable	N	Mean	Std Dev	Median	Min	Max	Correlation with Time				Correlation with Salinity			
							Pearson		Spearman		Pearson		Spearman	
							r	p	r	p	r	p	r	p
Upper Bay														
Salinity	88	10.8	8.2	11.3	0.0	33.0	**0.25**	**0.0214**	**0.24**	**0.0255**	1.00	-	1.00	-
Temperature(°C)	88	22.5	6.4	24.2	9.5	31.6	0.10	0.3749	0.08	0.4509	-0.12	0.2568	-0.16	0.1447
DO(mg l^{-1})	80	8.5	1.9	8.0	5.3	14.0	-0.14	0.2306	-0.16	0.1528	0.11	0.3224	0.09	0.453
pH	72	8.3	0.4	8.3	7.1	10.3	-0.07	0.5865	-0.05	0.6704	-0.17	0.1522	-0.13	0.2871
Chlorophyll (µg l^{-1})	44	12.3	10.1	9.6	1.3	59.4	0.17	0.2783	0.29	0.0564	0.08	0.6119	0.09	0.5506
Ammonium (µmol l^{-1})	77	3.2	4.1	2.1	0.0	27.3	-0.08	0.5113	**-0.32**	**0.0052**	0.10	0.3931	-0.02	0.8459
Nitrate+Nitrite (µmol l^{-1})	76	24.3	26.3	19.5	0.1	166.7	**-0.34**	**0.003**	**-0.33**	**0.0041**	**-0.44**	**<.0001**	**-0.46**	**<.0001**
Phosphate (µmol l^{-1})	76	3.3	2.6	2.8	0.1	15.5	**-0.52**	**<.0001**	**-0.48**	**<.0001**	-0.16	0.1544	-0.17	0.151
Silicate (µmol l^{-1})	76	146.7	127.8	124.0	12.2	1093.0	-0.14	0.2211	-0.09	0.4652	**-0.33**	**0.004**	**-0.48**	**<.0001**
Lower Bay														
Salinity	87	18.2	9.5	20.6	0.2	36.9	0.18	0.102	0.17	0.1215	1.00	-	1.00	-
Temperature(°C)	87	22.3	6.5	24.0	8.9	31.4	0.07	0.524	0.06	0.6043	-0.12	0.2723	-0.10	0.3609
DO(mg l^{-1})	79	8.1	1.7	7.7	4.3	14.6	-0.21	0.067	-0.21	0.0677	-0.05	0.6469	-0.13	0.2553
pH	72	8.2	0.3	8.2	6.9	9.6	-0.05	0.6615	-0.02	0.8482	**-0.33**	**0.0053**	**-0.32**	**0.0055**
Chlorophyll (µg l^{-1})	44	9.9	8.0	8.4	0.8	39.2	-0.06	0.6872	0.05	0.7319	**-0.39**	**0.0086**	-0.30	0.0504
Ammonium (µmol^{-1})	76	1.8	2.2	1.3	0.0	11.4	**-0.33**	**0.0034**	**-0.39**	**0.0005**	-0.10	0.4016	-0.11	0.3654
Nitrate+Nitrite (µmol l^{-1})	75	5.3	9.9	1.2	0.0	57.3	**-0.30**	**0.0092**	**-0.29**	**0.012**	**-0.48**	**<.0001**	**-0.41**	**0.0003**
Phosphate (µmol l^{-1})	75	1.9	1.7	1.4	0.0	6.7	**-0.58**	**<.0001**	**-0.46**	**<.0001**	**-0.38**	**0.0007**	**-0.26**	**0.0257**
Silicate (µmol l^{-1})	74	105.8	66.3	89.0	8.4	334.3	-0.05	0.6719	-0.06	0.6383	**-0.57**	**<.0001**	**-0.54**	**<.0001**

Table 1.2 Simple statistics of quarterly HRI-collected water quality and correlations with time in upper and lower San Antonio Bay over recent years (Jan 2004 to Jan 2012).

Variable	N	Mean	Std Dev	Median	Min	Max	Pearson		Spearman's Rank	
							r	p	R	p
Upper Bay										
Salinity	33	12.5	8.9	11.4	0.2	33.0	**0.55**	**0.001**	**0.53**	**0.0014**
Temperature(°C)	33	23.1	6.3	24.6	9.5	31.6	-0.02	0.9108	0.03	0.8724
DO(mg l^{-1})	33	8.1	1.7	7.7	5.3	12.1	0.06	0.7298	-0.02	0.9074
pH	33	8.3	0.2	8.2	7.7	8.8	0.21	0.2419	0.22	0.2217
Chlorophyll (µg l^{-1})	32	13.6	10.8	9.7	1.3	59.4	-0.01	0.9581	0.08	0.6507
Ammonium (µmol l^{-1})	32	3.1	5.5	1.2	0.0	27.3	-0.14	0.4495	-0.05	0.8064
Nitrate+Nitrite (µmol^{-1})	32	20.1	18.1	17.7	0.1	58.9	**-0.42**	**0.0155**	**-0.41**	**0.0182**
Phosphate (µmol l^{-1})	32	2.0	1.2	1.8	0.1	5.2	0.05	0.7888	0.07	0.7123
Silicate (µmol l^{-1})	32	150.2	73.1	128.8	41.3	286.4	-0.28	0.117	-0.21	0.258
Lower Bay										
Salinity	33	19.3	9.6	20.6	0.9	36.9	**0.44**	**0.0105**	**0.43**	**0.0123**
Temperature(°C)	33	22.9	6.3	24.3	9.7	31.3	-0.05	0.7684	-0.01	0.9455
DO(mg l^{-1})	33	7.7	1.1	7.4	6.0	10.0	0.01	0.9401	0.02	0.9147
pH	33	8.2	0.2	8.2	7.9	8.6	-0.20	0.2763	-0.16	0.3625
Chlorophyll (µg l^{-1})	32	10.7	8.5	8.8	0.8	39.2	-0.16	0.3845	-0.18	0.3354
Ammonium (µmol^{-1})	32	1.0	1.5	0.5	0.0	7.1	0.28	0.1249	0.08	0.6605
Nitrate+Nitrite (µmol l^{-1})	32	3.2	5.8	1.1	0.0	26.3	-0.13	0.4924	-0.09	0.6221
Phosphate (µmol l^{-1})	32	1.1	0.7	1.0	0.0	2.7	0.16	0.3823	0.24	0.1908
Silicate (µmol l^{-1})	32	115.4	66.0	94.0	35.7	257.8	-0.25	0.1662	-0.16	0.3867

Table 1.3 Simple statistics of TPWD-collected monthly water quality, and correlations with time in upper and lower San Antonio Bay (Jan 1986 to Dec 2009).

Variable	N	Mean	Std Dev	Median	Min	Max	Pearson		Spearman's Rank	
							r	p	R	p
Upper Bay										
Salinity	288	12.6	8.6	12.0	0.0	34.7	0.01	0.8998	-0.01	0.9189
Temperature(°C)	288	22.6	6.1	23.6	8.2	31.5	0.06	0.3174	0.06	0.2753
DO(mg l^{-1})	288	8.3	1.6	7.9	5.5	13.8	**-0.19**	**0.0012**	**-0.19**	**0.0016**
Turbidity(NTU)	288	28.4	21.4	22.0	1.4	132.5	**-0.29**	**<.0001**	**-0.34**	**<.0001**
Lower Bay										
Salinity	288	19.5	9.3	21.0	0.0	38.4	0.00	0.9585	0.01	0.9252
Temperature(°C)	288	23.0	6.2	24.3	9.7	32.0	0.08	0.1777	0.09	0.1409
DO(mg l^{-1})	288	8.0	1.4	7.9	4.9	13.4	**-0.23**	**0.0001**	**-0.21**	**0.0004**
Turbidity(NTU)	288	22.9	20.7	16.5	0.8	142.5	**-0.32**	**<.0001**	**-0.45**	**<.0001**

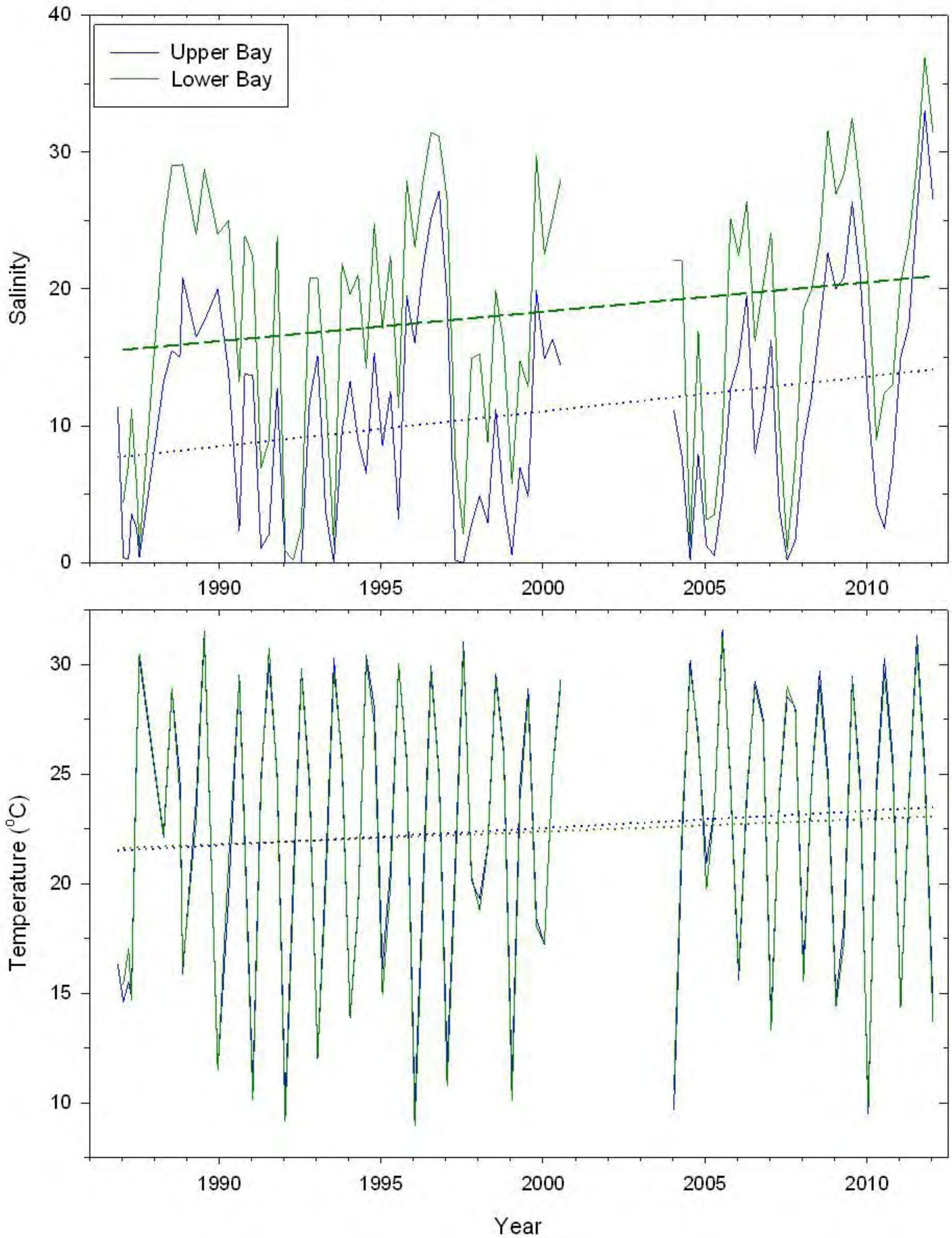

Figure 1.2 Quarterly salinity and temperature - HRI data. Dashed line represents significant linear relationship. Dotted line represents non-significant linear relationship.

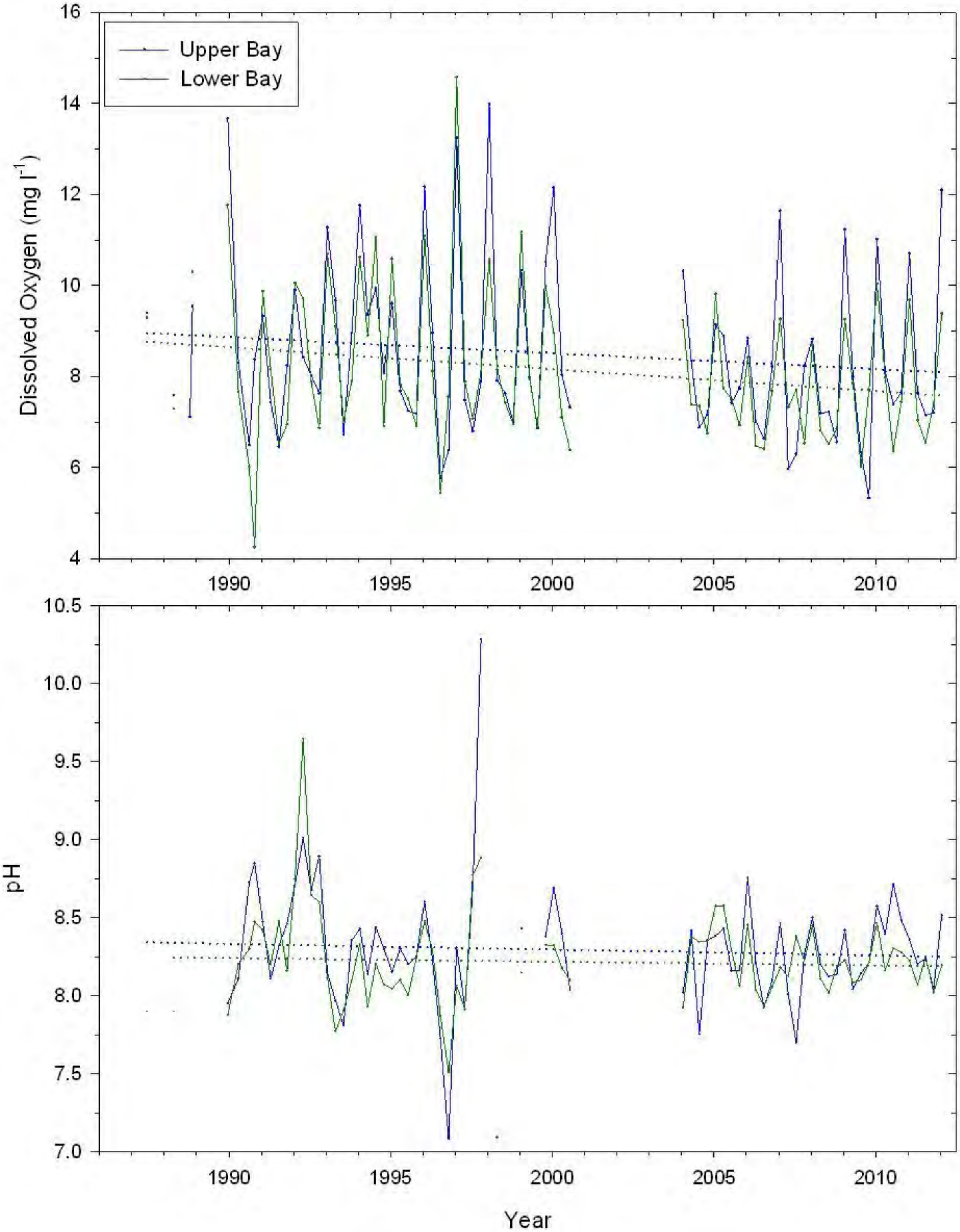

Figure 1.3 Quarterly dissolved oxygen concentrations and pH - HRI data.
Dotted line represents non-significant linear relationship.

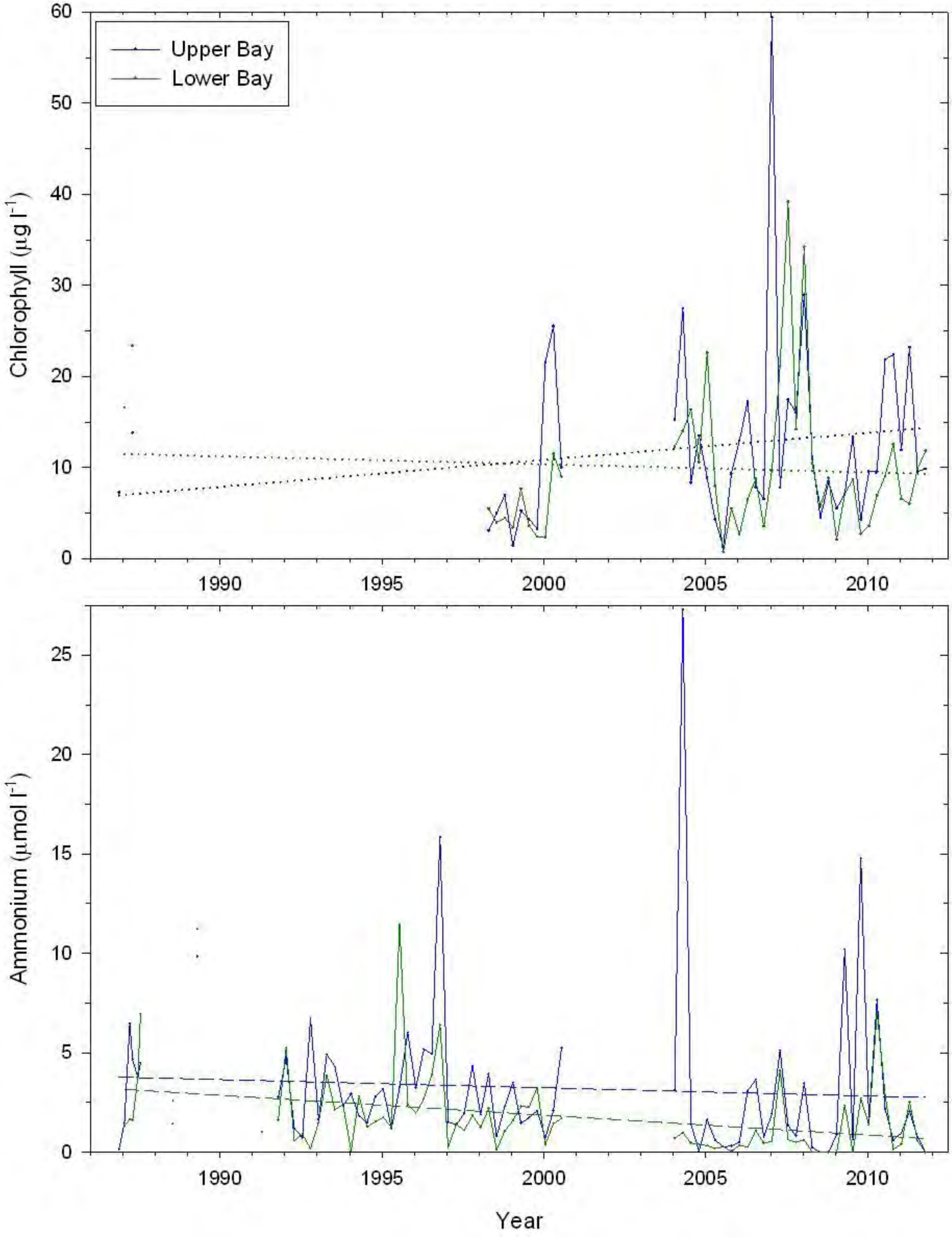

Figure 1.4 Chlorophyll and ammonium concentrations - HRI data. Dashed line represents significant linear relationship. Dotted line represents non-significant linear relationship.

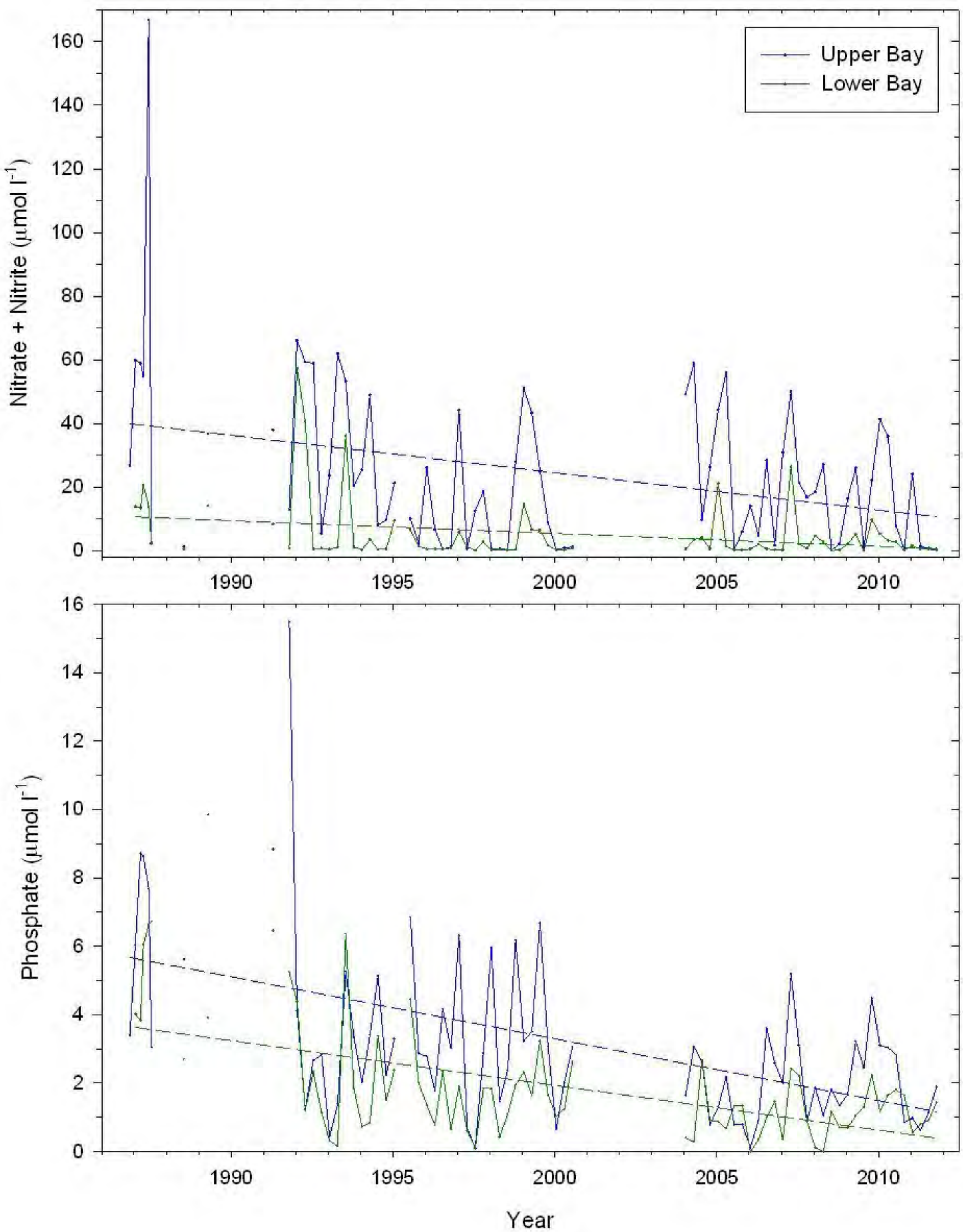

Figure 1.5 Quarterly nitrate plus nitrite, and phosphate concentrations - HRI data. Dashed line represents significant linear relationship. Dotted line represents non-significant linear relationship.

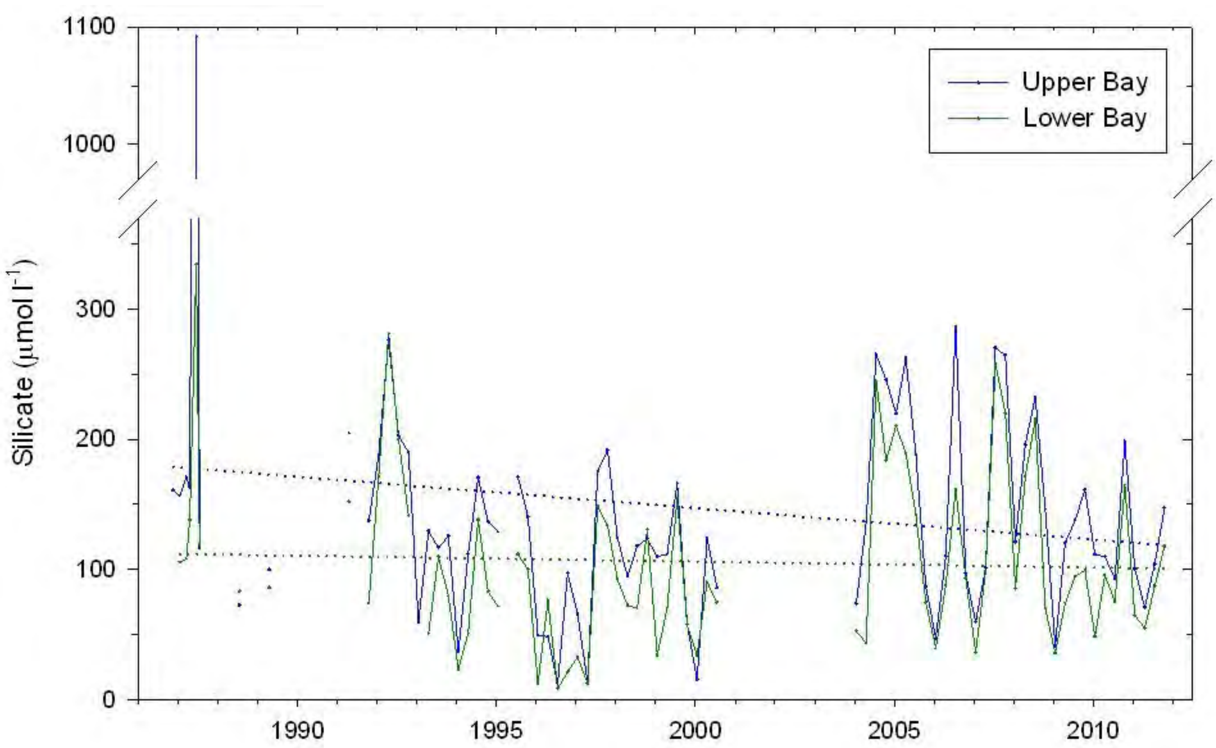

Figure 1.6 Quarterly silicate concentrations - HRI data. Dotted line represents non-significant linear relationship.

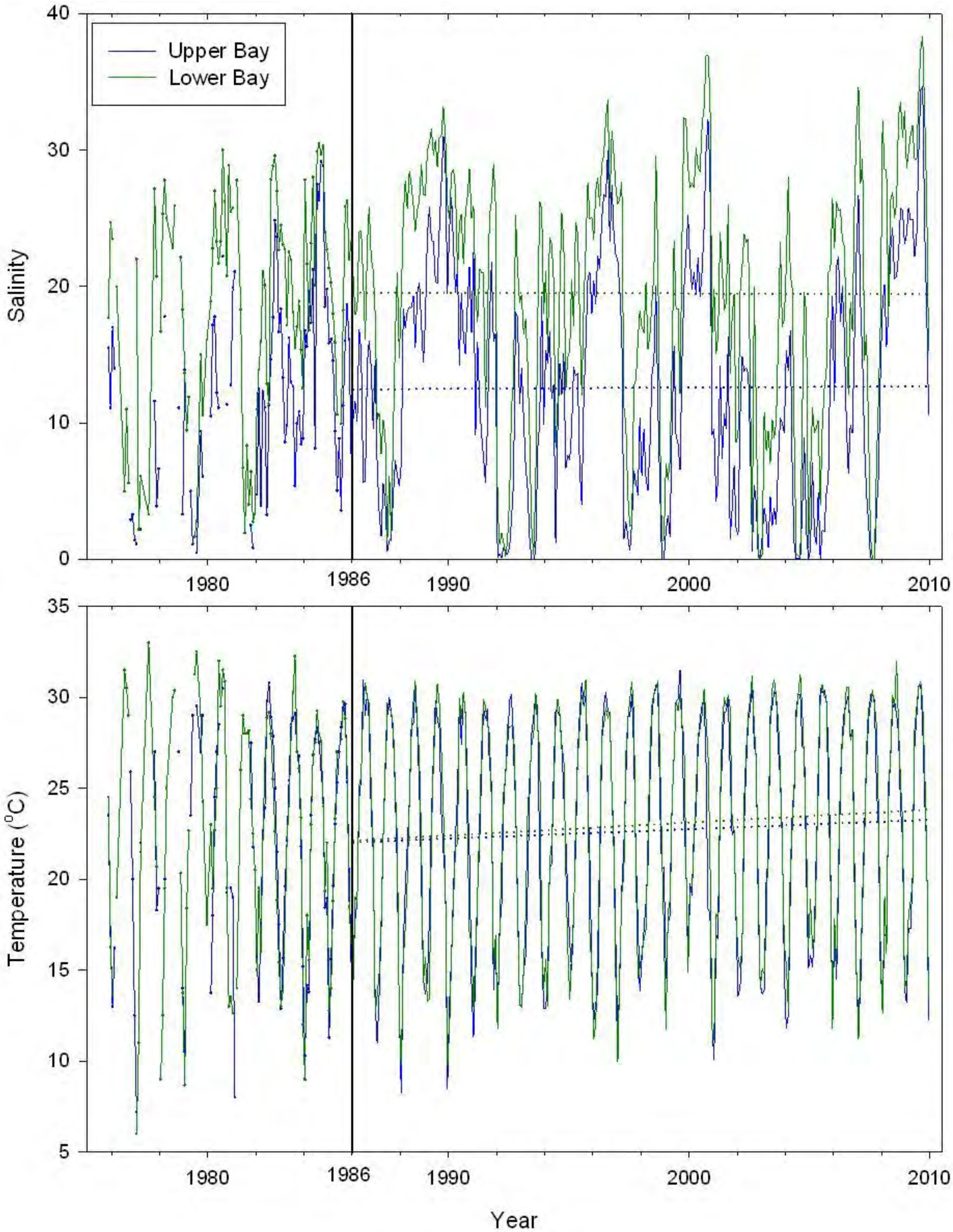

Figure 1.7 Monthly salinity and temperature - TPWD data. Dotted line represents non-significant linear relationship.

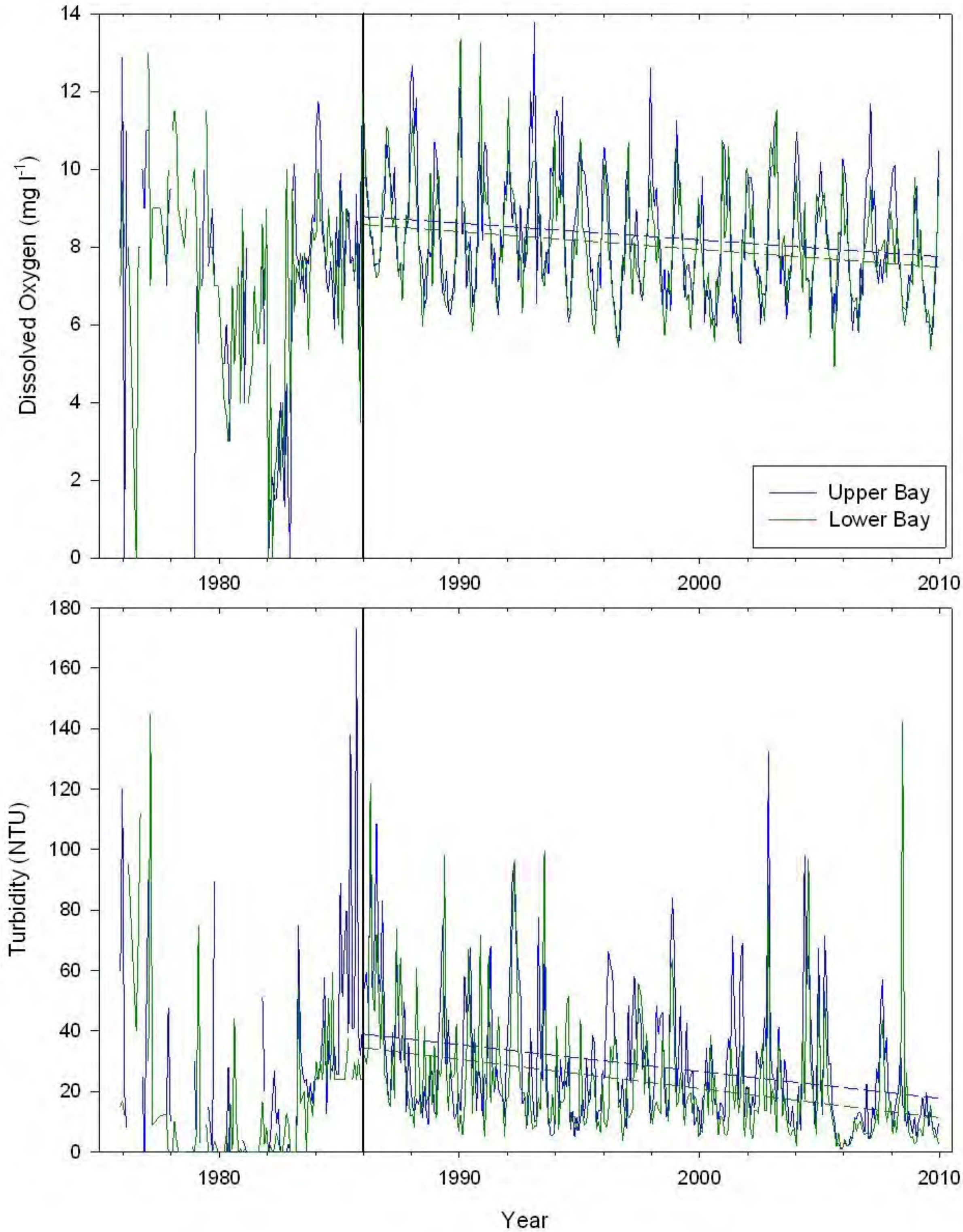

Figure 1.8 Monthly dissolved oxygen and turbidity - TPWD data. Dashed line represents significant linear relationship.

Table 1.4 Summary statistics and correlations of univariate benthic macrofauna variables with time. Pearson and Spearman Rank correlations were conducted on $\log_e$ transformed data.

Variable	N	Mean	Std Dev	Median	Min	Max	Pearson		Spearman's Rank	
							r	p	R	p
Upper Bay										
Abundance (n m^{-2})	85	20242	19008	15411	2080	126693	**-0.57**	**<.0001**	**-0.60**	**<.0001**
Biomass (g m^{-2})	85	13.52	15.39	7.56	0.47	70.42	-0.11	0.3326	-0.18	0.107
N1 Diversity (35-cm^{-2})	85	2.99	0.72	2.92	1.41	4.82	**-0.32**	**0.0031**	**-0.28**	**0.0092**
Lower Bay										
Abundance (n m^{-2})	85	9659	8428	7564	1702	56207	**-0.46**	**<.0001**	**-0.48**	**<.0001**
Biomass (g m^{-2})	85	4.00	12.43	2.06	0.09	114.48	**-0.35**	**0.001**	**-0.33**	**0.0022**
N1 Diversity (35-cm^{-2})	85	3.45	1.48	2.96	1.20	8.29	**-0.31**	**0.0043**	**-0.29**	**0.0066**

Table 1.5 Summary statistics and correlations of univariate epibenthic fauna variables with time. Pearson and Spearman rank correlations were calculated using $\log_e$-transformed data.

Variable	N	Mean	Std Dev	Median	Min	Max	Pearson		Spearman's Rank	
							r	p	R	p
Abundance (tow^{-1})	336	200	192	134	4	1014	**0.53**	**<.0001**	**0.53**	**<.0001**
Biomass (g m^{-2})	336	8.09	2.57	8.07	2.07	14.25	**0.50**	**<.0001**	**0.49**	**<.0001**
N1 Diversity (35-cm^{-2})	336	3.66	1.04	3.52	1.50	7.14	-0.03	0.5381	-0.03	0.5556

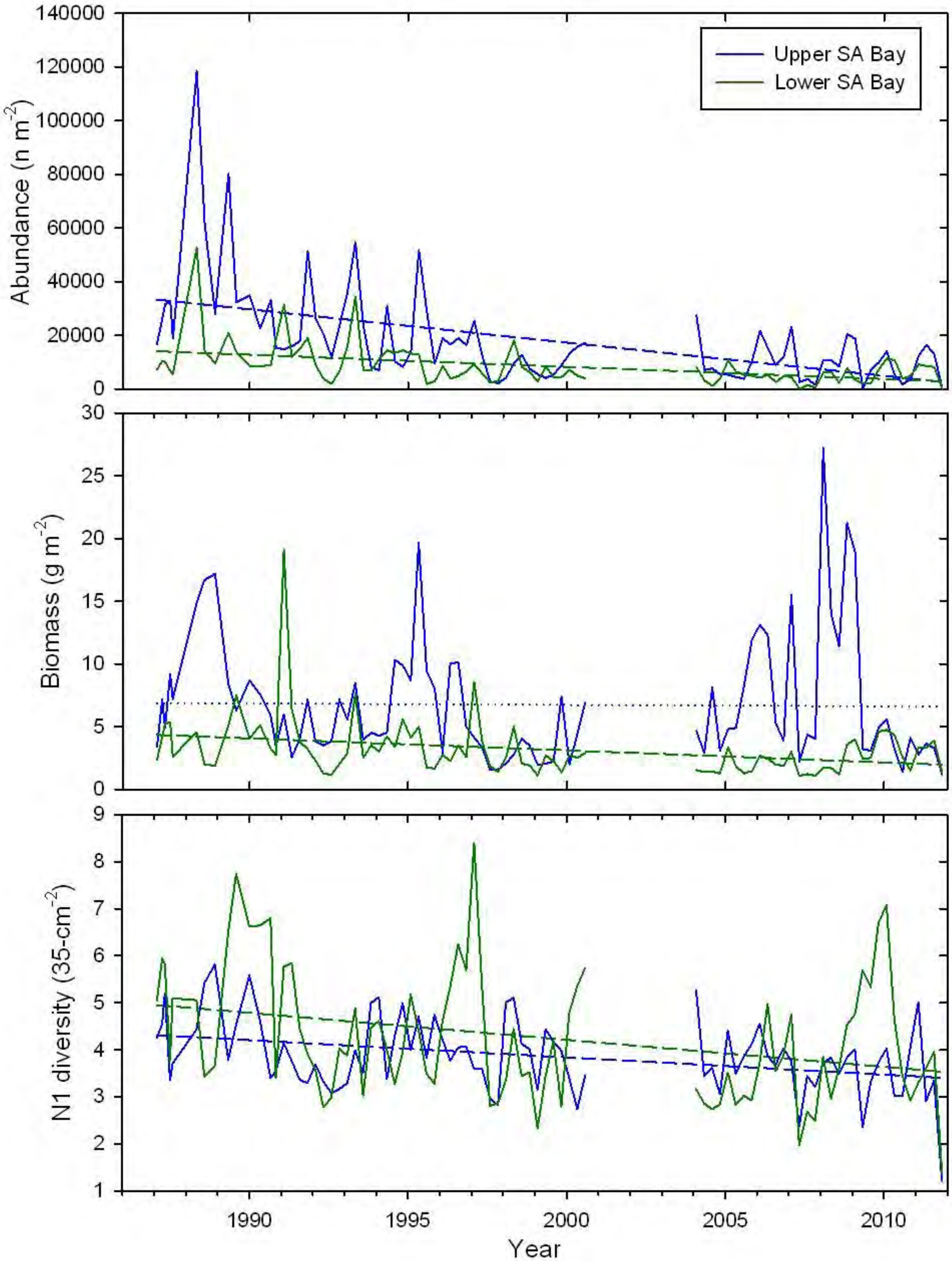

Figure 1.9 Benthic macrofauna abundance, biomass and N1 diversity over time. Dashed line represents significant linear relationship. Data shown is detransformed from the $\log_e$ transformation that was used in statistical analyses.

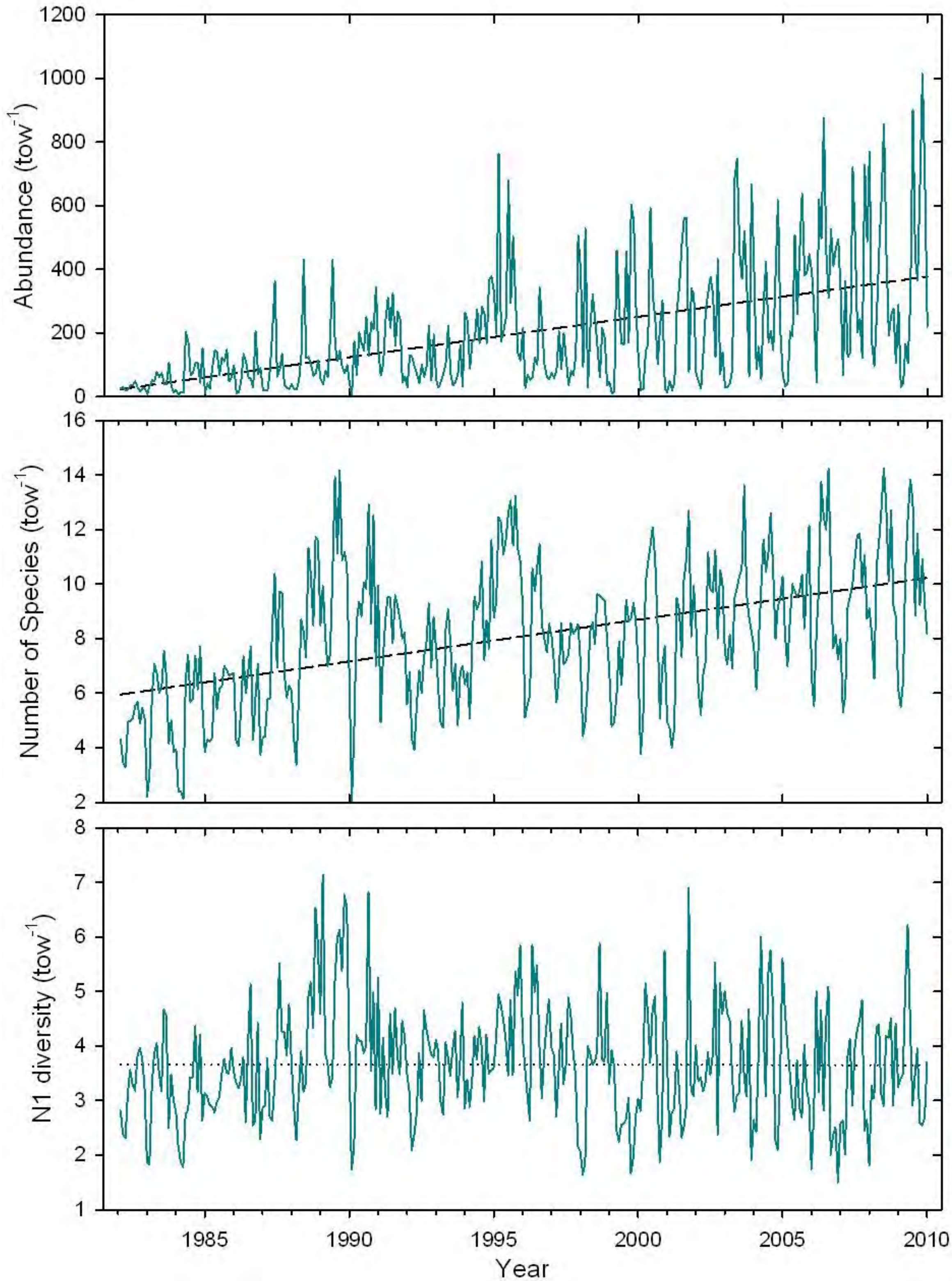

Figure 1.10 Epibenthic fauna abundance, number of species and N1 diversity over time. Dashed line represents significant linear relationship.

DISCUSSION

San Antonio Bay is a dynamic estuary, and like others in Texas, its ecosystem is defined by the freshwater that it receives. Recent drought has caused increases in salinity to occur although no significant increase has occurred in the lower bay and analysis of two different datasets disagree on whether there has been a significant increase in salinity over time in the upper bay. Increases in salinity in San Antonio Bay are associated with decreases in nitrate plus nitrite, silicate, phosphate, chlorophyll and pH.

While the abundance and diversity of the macrobenthos has been decreasing over time in San Antonio Bay, the abundance and number of epifaunal species per trawl has been increasing. From this limited analysis, it is uncertain whether there is a link between the epifauna and the macrobenthos, but it is probable. It is also uncertain what the relationship between these organismal groups and the changes in water quality are, but it is probable that the organisms have both been affected by changes in water quality over time.

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REPORT 2: Marine Resources

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DATA	TPWD Fishery Independent Data • CPUE for bag seine, trawl, and gill net • Salinity TPWD Fishery Dependent Data • Recreational and commercial landings
TIMEFRAME	TPWD Fishery Independent Data: 1982-2011 TPWD Fishery Dependent Data • Recreational Harvest Data: 1982-2011 • Commercial Harvest Data: 1981-2010

INTRODUCTION

In her 2004 testimony to the United States House of Representatives, Fisheries Conservation, Wildlife and Oceans Subcommittee, Resources Committee, Dr. Cynthia Jones (Member, Committee on Improving the Collection and Use of Fisheries Data, Ocean Studies Board, National Research Council, The National Academies) stated:

> *"Marine fish are important as a source of food, item of commerce, focus of recreational opportunity, and element of cultural tradition in the United States and worldwide. Data from marine fisheries contribute to our understanding of the marine environment and how humans use living marine resources. A comprehensive understanding of the challenges currently facing marine fisheries science and management requires consideration of both the biological and human dimensions."*

For these reasons, the Coastal Fisheries Division of the Texas Parks & Wildlife Department (TPWD) established monitoring programs for Texas marine resources over 30 years ago. The TPWD marine monitoring database contains fishery dependent and independent, commercial and recreational, and biotic and abiotic data. In this chapter, we will use this data to evaluate the status and trends of selected marine resources of the San Antonio Bay system (SAB) (Figure 2.1).

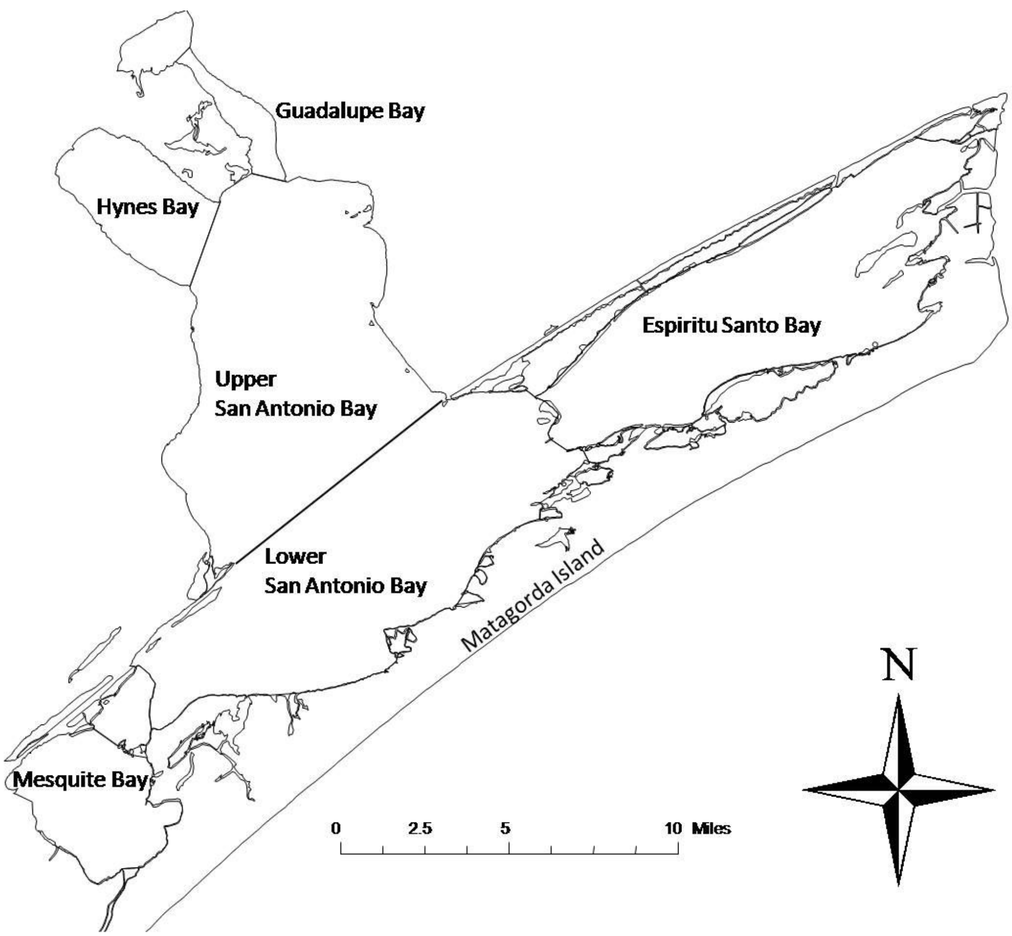


Figure 2.1 Guadalupe Estuary

The fundamental elements of this database are the different species using the estuary. The abundance patterns of each species serve as indicators of the prevailing environmental and ecological conditions. Additionally, an examination of all the species collectively can reveal how the complete biotic assemblage has changed over time and how it compares with other estuaries. Together these analyses will allow for a better understanding of the causes of faunal changes within the estuary, how this biota reacts to environmental extremes, and what makes each estuary unique.

Fishery Independent Data

Fishery independent data is typically collected by researchers without the involvement of any recreational or commercial fishing activity and is used to complement fishery dependent data. Often this type data is collected within some type of random site-selection program and thus eliminates many of the biases inherent in fishery dependent data such as variable skill in finding the target species and avoiding geographic areas thought not to harbor the target species. This type of data is sometimes collected over the geographic range of the target species or over a specified area such as an estuary. Information available from fishery independent data typically includes species composition, average size, relative abundance, sex ratio, population age structure, and associated environmental parameters. Various fishing gears can be used to collect this data including fish traps, gill nets, trawls, electro fishing, dredges, seines, and acoustic or video methods. For this report, fishery independent data collected by the TPWD is presented.

Fishery Dependent Data

The Food and Agriculture Organization defines a fishery as an activity leading to harvesting of fish. Fishery dependent data is collected from the fishery itself, using both commercial and recreational sources. Anglers are met at the dock and interviewed for trip information; commercial fishers are either met at the dock and interviewed, accompanied onboard by observers, or their landings information is provided later via a systematic commercial data reporting process. Mail-in surveys are also sometimes used to gather fishery dependent information. These data are typically used to estimate fishing mortality, assess fishing effort, and determine species size and composition. When combined with fishery independent data, a resource manager has estimates of current population trends and mortality associated with fishing activity, allowing a more complete picture of a species status than can be obtained by using either data source alone.

Recreational Harvest Data

Recreational harvest from the SAB is important both biologically, as a source of fish mortality, and economically, as the source of revenue for a strong local fishing industry infrastructure. Recreational fishery dependent data can include species composition, fishing effort, angler origin, area fished, methods or fishing gear used, species targeted, landings (numbers, weight, or volume harvested), and sizes (lengths and/or weights). Combined with commercial harvest data, this data allows the fishery manager to estimate total fishing mortality and fishing effort. Collectively, these data allow fishery managers to implement harvest restrictions based on the anticipated impact to anglers and fish populations. For this report, TPWD fishery dependent data is presented.

Commercial Harvest Data

To assess the commercial fishing mortality component of fishery dependent mortality, managers collect commercial harvest data. These data were collected through mandatory self-reporting by dealers and on-site visits to dealers. Self-reported harvest information was reported to the TPWD and the National Marine Fisheries Service (NMFS). Beginning April 1, 1985, the two agencies instituted a formal cooperative agreement to collect and exchange commercial fisheries statistics.

Commercial harvest data typically included landings, species composition, sizes, fishing time (effort), area fished, and value of the catch. This section summarizes SAB landings and ex-vessel value of selected seafood and bait species purchased from commercial fishermen by seafood and bait dealers and reported to TPWD and/or the NMFS. Because commercial fishing effort, and thus landings, can be affected by economics as well as population trends, the landings trends can be difficult to interpret.

A more thorough description of data collection methodology and historical procedural changes is presented by Choucair et al. (2006).

Assemblage Data

Due to the complex nature of estuarine environments, only part of the story can be explained by analyzing individual species. Individuals within a species and different species interact with each other, in ways such as predator-prey, competition for resources, and competition for habitat, to form a fluid system. By looking at the system as a whole and analyzing all of the data together, including environmental variables, the investigator is able to account for the mechanisms that explain the health and stability of the system (Greenstreet and Hall, 1996), and to provide a more accurate tool for making future predictions.

Spatial Distribution of Species

Spatial distribution of organisms within an estuarine environment can also provide useful information in terms of health and changes in the environment and is sometimes the only perceivable response to stimuli. Species distribution could indicate changing factors, from physical habitat to hydrological variables. Because habitat can provide a variety of resources to aquatic organisms, such as protection from predators, a food source (be it vegetation or prey using the habitat themselves), or even a location for reproduction (Brown-Peterson *et al*., 1988), higher species abundance would be expected in the preferred areas. By examining the spatial abundance of species catch within the SAB, a better understanding of the ecosystem is gained while also highlighting areas that play an important role in the health of the ecosystem.

Species Diversity

Describing the ecology of an area can be very difficult due to its complex nature and many interactions. A measurement of species richness (number of species) or abundance (number of individual animals) alone does not adequately describe its nature. By using a diversity index, which combines species richness with relative abundance and evenness of the distribution, larger amounts of information about the ecosystem itself are provided than with the individual measurements (Begon *et. al,* 1996).

METHODS

Fishery Independent Data

The TPWD Coastal Fisheries Division Database, 1982-2011, was used to present trends in fishery independent data. Those data are the result of a program that is based on a random sampling methodology. Three fishing gears were used throughout the estuary: trawls, seines, and gill nets. There were 6,721 seine samples, 7,801 trawl samples, and 2,942 gill net samples in the 1982-2011 database used for this report. Trawls were used in areas where the water depths were deep enough to accommodate the gear, and seines and gill nets were used only on shorelines.

Each gear targets specific habitats and sizes of organisms. Seines target smaller organisms that inhabit shallow shoreline areas. Trawls target small and medium size organisms that inhabit deeper open water habitats. Gill nets target medium size to large organisms that live up to 600 feet from the shoreline. Each gear has an associated unit of effort, and the catch rate is expressed as *number of organisms caught per unit of effort*, or CPUE. For seines, the unit of effort is the *area* swept by the seine and is expressed in hectares (ha). For trawls and gill nets, the unit of effort is *how long* the gear is deployed and is expressed in hours. CPUE trends, or catch trends, are a measure of relative abundance and are used as a proxy for population trends. The assumption is that catches go up when the population goes up, and vice versa. Collectively, these three gears can be used to census populations of animals over a large size range and over several habitat types.

The geographic area for this report is the marine area covered by the San Antonio Bay System: Espiritu Santo Bay, San Antonio Bay, Mesquite Bay, Sundown Bay, and the minor bays adjacent to these bays (Figure 2.1). For this study, only estuarine data were used, no Gulf data were included.

The actual sites for sample collection were randomly selected throughout the estuary from all appropriates sites for each gear. With the exception of gill nets, there are currently 20 samples collected with each gear each month within each of the TPWD-designated major bay systems; although in the early years of the sampling program, seines were used less frequently. For this study, all data from San Antonio Bay and a portion of the data from the Mission-Aransas Estuary (Mesquite and Sundown Bays) were used. Gill nets were used during a 10-week period in the spring-summer and a 10-week period in the summer-fall. During each 10-week period, 45 gill net samples were collected by deploying the nets one hour prior to sunset and retrieving them as soon after sunrise as possible the next day, typically before noon. For all three gears, annual mean un-weighted catch rates (No/hr or No/ha) are presented. The criteria employed to select the species presented were: (1) commonly occurring species: occurring in at least 10% of the samples for a gear, or (2) being numerous (i.e., having made up at least 5% of the total numbers for a gear). For this analysis, some organism groups were excluded including jelly fish, ctenophores, colonial organisms, and organisms which were not identified to species.

A *sample* consisted of deployment and retrieval of the gear in a standardized manner, identification of each species, enumeration of the number of individuals of each species, measurement of up to 19 individuals (35 with blue crab and 50 with commercial shrimp in trawl samples), and collection of environmental data. The environmental data consisted of turbidity, salinity, temperature, and oxygen. Water depth, latitude, longitude, and time of sample are also recorded for each sample. A more thorough description of the fishery dependent data collection methodology is presented by Choucair et al. (2006).

Fishery Dependent Data

Recreational Harvest Data

The TPWD Coastal Fisheries Division conducted daytime recreational angler surveys, including private and party boats, around the SAB throughout the year from 1982-2011. In this data set, private boats are recreational anglers and party boats are guided fishing trips. The harvest program's primary objective was to develop estimates of daytime annual fishing pressure, landings, catch rates, species compositions, and size compositions for recreational trips lasting 12 hours or less in Texas marine waters. Secondary objectives included summarization of the angler residential origin and species sought.

For this study, only bay and pass fishing trips were used; no Gulf trips or landings were included. These surveys were conducted at angler access points such as boat ramps and wet slips. For harvest surveys, angler access sites were selected using a random weighted process where each site was weighted according to historical angler use. This procedure resulted in access sites with more fishing activity being surveyed more often than lower-activity sites. Some surveys were conducted at free public sites while many were at private sites where anglers pay to use the facilities. Additional observations (roving counts) of activity at these same access sites was used to allow extrapolation of survey data to those sites for days when surveys were not actually conducted. The combination of survey and roving count data allows fishery managers to develop estimates of total annual landings over the entire estuary for each harvested species.

The survey schedule consists of two "seasons," a high-use season, May 15–November 20, and a low-use season, November 21–May 14. "Annual" data is presented for each May 15–May 14 period (e.g., May15, 2009 to May 14, 2010) with most of the fishing activity occurring in the former year. For the SAB, there were 112 survey days conducted during a May 15–May14 "year."

The data collected during boat interviews upon completion of the trips included trip length (effort), number of anglers per boat, permanent residence county of each angler, activity (recreational fishing, party boat, tournament fishing, pleasure riding, etc.) area fished, gear type used, species targeted, species landed, and numbers and sizes of species landed. The species selected for presentation were the seven most landed from the SABS. A more thorough treatment of the TPWD Coastal Fisheries Division recreational fishery harvest program methodology is presented by Choucair et al. (2006).

Commercial Harvest Data

Selected species were chosen to present a summary of the SAB commercial harvest. Commercial landings were submitted monthly by licensed seafood dealers. Eastern oyster (*Crassostrea virginica*) landings were converted to meat weight, and bait shrimp landings are reported as live (heads-on) weight. All non-bait shrimp landings were reported as tails (heads-off) weight. All other seafood products are reported in live weight (round weight) or converted to such. Annual landings and ex-vessel value are presented for selected marine fauna harvested from the SAB from 1981-2010. For commercial landings, Mesquite and Sundown bays were not included.

Assemblage Data

All assemblage data from Texas bays were analyzed using Primer v. 6.0 (Clarke and Gorley, 2006) unless otherwise noted. This program was developed to analyze similarity (how alike species' composition, proportion, and abundance are between sites/times) and dissimilarity (how different species' composition, proportion, and abundance are between sites/times) between samples. The catch data were taken from the fishery independent sampling of the TPWD from 1982–2011. The SAB assemblage data were analyzed both temporally, to show variation over the previous 30 years, and spatially, to show the species assemblage of San Antonio Bay in relation to the other seven major bays along the Texas coast (Sabine Lake; Galveston Bay; Matagorda Bay; Aransas/Copano Bay, Corpus Christi Bay; Upper Laguna Madre; Lower Laguna Madre). For temporal analysis within San Antonio Bay, annual collections were averaged prior to any further analysis. For spatial analysis along the Texas coast, collections were averaged by bay over all years prior to any further analysis.

Bag seine, bay trawl, and gillnet collection data were used for analysis because the gears target different habitat, size ranges, and behavior of organisms, thus giving a representative picture of the species assemblage. Because certain species dominated the catches in terms of number of individuals, transformation of the raw data was required so that the analysis was not driven by a handful of species. All data were transformed using a square root transformation to partially, but not completely down weight the effect of the most prevalent species as recommended by the software producers (Clarke and Warwick 2001). A similarity index was then calculated using the Bray-Curtis method to show the extent to which groups (either temporally within San Antonio Bay or spatially between San Antonio Bay and the other Texas coastal bays) shared particular species and abundances. This similarity index was the basis for subsequent analyses, contrary to similarity.

Once the similarity indices were calculated, hierarchical clustering techniques were used to group those years/bays which were most similar to produce a dendrogram. Concurrent with the cluster analysis, a similarity profile (SIMPROF) routine was run to determine which of these cluster groups had differences that were statistically significant from each other. Following the clustering and SIMPROF test, it was necessary to determine which species were causing the differences between the significantly different cluster groups, either spatially or temporally. To do this, a similarity percentage (SIMPER) analysis was run on the transformed data. The cluster groups were compared between each other and the percentage that each species contributed to the overall difference was returned. Coastwide, the cluster group containing San Antonio Bay was compared to every other group which was significantly different. Cluster groups containing annual samples were compared between each other as well.

Spatial Distribution of Species

Spatial distribution maps of catch data for bag seine, bay trawl, and gillnet catch data was produced using the bubble plot feature on JMP 9.0. Location and abundance of species catch were displayed and information regarding salinity was also visualized to account for a well-known variable which can affect distribution (Blaber, 1997). A map was superimposed on the data using the map function on the bubble plot feature utilizing the NASA server data. San Antonio Bay was divided into smaller minor bays which differed substantially in either location or environmental variables as a means of more easily describing locations within the bay system as a whole (Figure 2.1). Mean salinities were calculated based on any catch that contained the species. While salinity may be an important component in spatial distribution of a species, it is not the lone determining factor and so caution must be taken when interpreting figures presented here in terms of salinity.

Species Diversity

Species and diversity indices were produced by year and coastwide using Primer 6.0. The Shannon-Weiner diversity index was calculated as well as the species richness by year in SAB from 1982 – 2011. During this same time period, the average diversity index and species richness was calculated over all other major bays along the Texas coast.

RESULTS

Fishery Independent Data

Population trends were developed for the most numerous or common faunal species in the San Antonio Bay System. There was a mixture of increasing and decreasing trends as well as some which appear to have not changed over time. As is common with field data, there was much year-to-year variation in the catch data for most species due to environmental perturbations, harvest activity, and undetermined causes. Suspected causes of trends include environmental episodes, commercial harvest interactions, and harvest restrictions. These suspected causes are discussed for each species as appropriate.

All regulated species protected by size or bag limits were evaluated. However, several of the species discussed below are not regulated or harvested in significant numbers, and several of the species are usually associated with primarily freshwater habitats. As such, their presence in the estuary and the resulting data may not be characteristic of the entire population. Omission from this discussion does not imply that a species is not ecologically important.

Grass shrimp, *Palaemonetes spp*, were the largest component of seine catches and were the third most numerous species in all gears combined. They constituted 18% of the total seine catch and occurred in almost 45% of all seine samples. Only brown shrimp, *Farfantepenaeus aztecus*, and pinfish, *Lagodon rhomboides*, were caught in more seine samples. Their entire life cycle is played out within the estuary. Because there are multiple grass shrimp species in the estuary and their field identification is problematic, they are grouped and simply called 'grass shrimp' in aggregate. Grass shrimp are not large animals (seldom reaching 2") and are not used as bait or food. However, owing to their abundance, small size, and location within habitat used by many juvenile predators, they can be a very important link in the food web for many fish. There is no harvest pressure on this group and their population is not in distress (Figure 2.2).

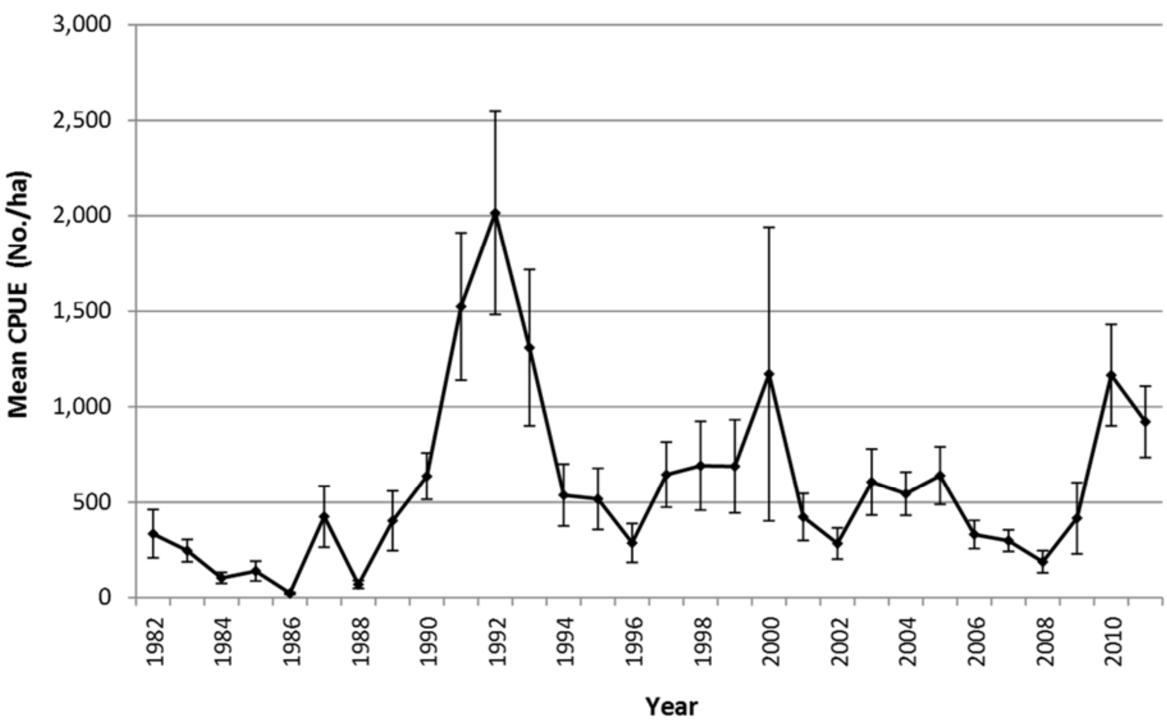


Figure 2.2 Grass shrimp annual mean seine catch rate ± standard error.

Sheepshead minnows, *Cyprinodon variegatus*, comprised 7.7% of the seine catch and occurred in over 30% of the samples. This small fish species is typically less than 2” in length and, like grass shrimp, is not used as bait or food in any substantial numbers. Found in the estuary during all seasons and for all its life cycle, sheepshead minnows can thrive in a wide variety of environmental conditions including salinities from fresh water to sea water and even hypersaline environments (Patillo 1997). Therefore, it was unexpected that its CPUE trend would seem to indicate a population in decline (Figure 2.3). Patillo (1997) reported that this species has been shown to be a component of the diet of lady fish, *Elops saurus,* whose population has increased coincidently with the decline of the sheepshead minnow. Sheepshead minnows are also prey for several species of fish and birds.

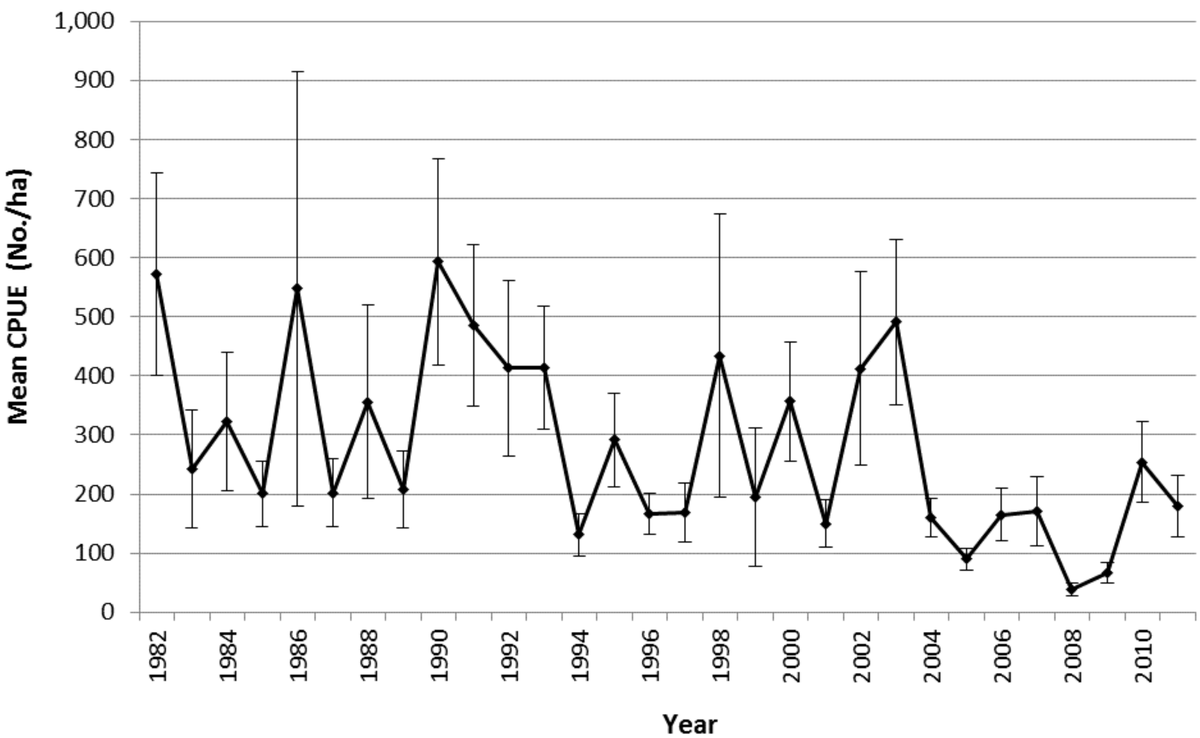


Figure 2.3 Sheepshead minnow annual mean seine catch rate ± standard error.

White mullet, *Mugil curema*, accounted for over 3% of the seine catch and occurred in over 19% of the samples. This species spawns outside the estuary and is found in the bays primarily during May–September. In SAB, this species is typically encountered at 1-10” in length. White mullet are harvested for bait by individuals but not generally sold in large numbers at bait stands in this area. Their population, represented by these part-time residents, is not in distress (Figure 2.4).

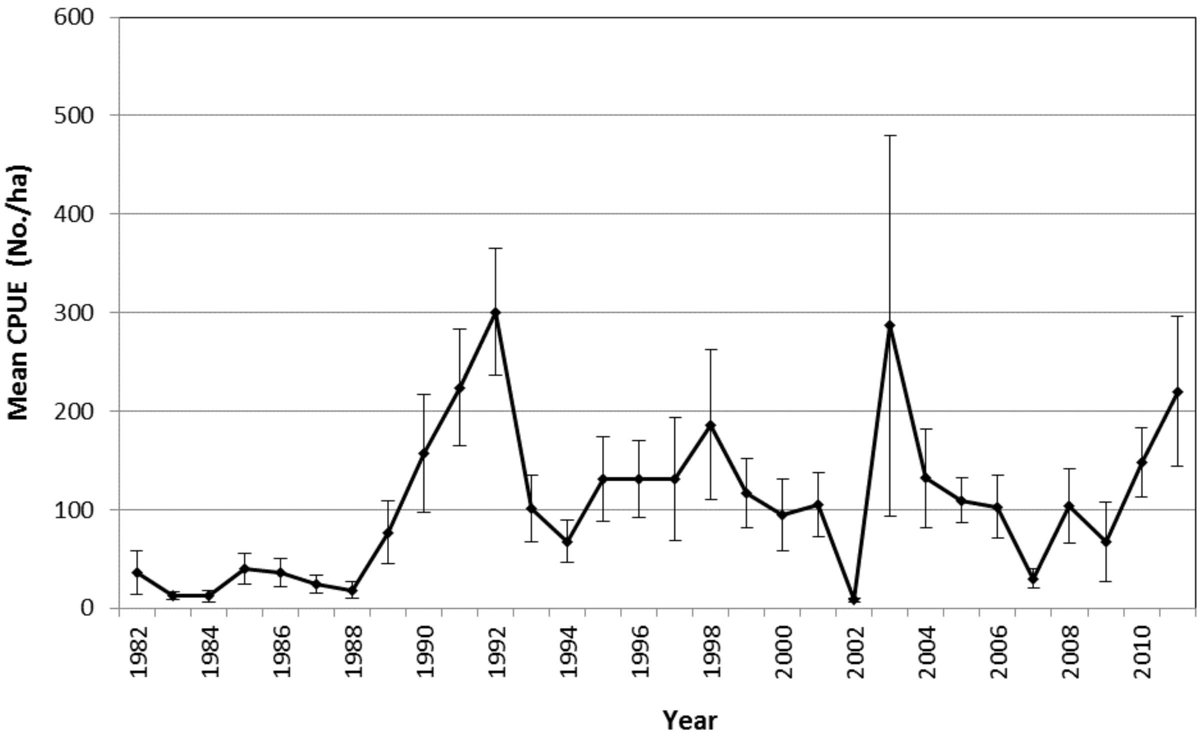


Figure 2.4 White mullet annual mean seine catch rate ± standard error.

Longnose killifish, *Fundulus similis*, a small fish species, inhabit shallow shoreline habitats, consequently making up less than 2% of the seine while being fairly common, occurring in almost 24% of the samples. Similar to the sheepshead minnow, their population appears to be declining with fewer high abundance years in the last decade (Figure 2.5). Longnose killifish are prey for several species of fish and birds.

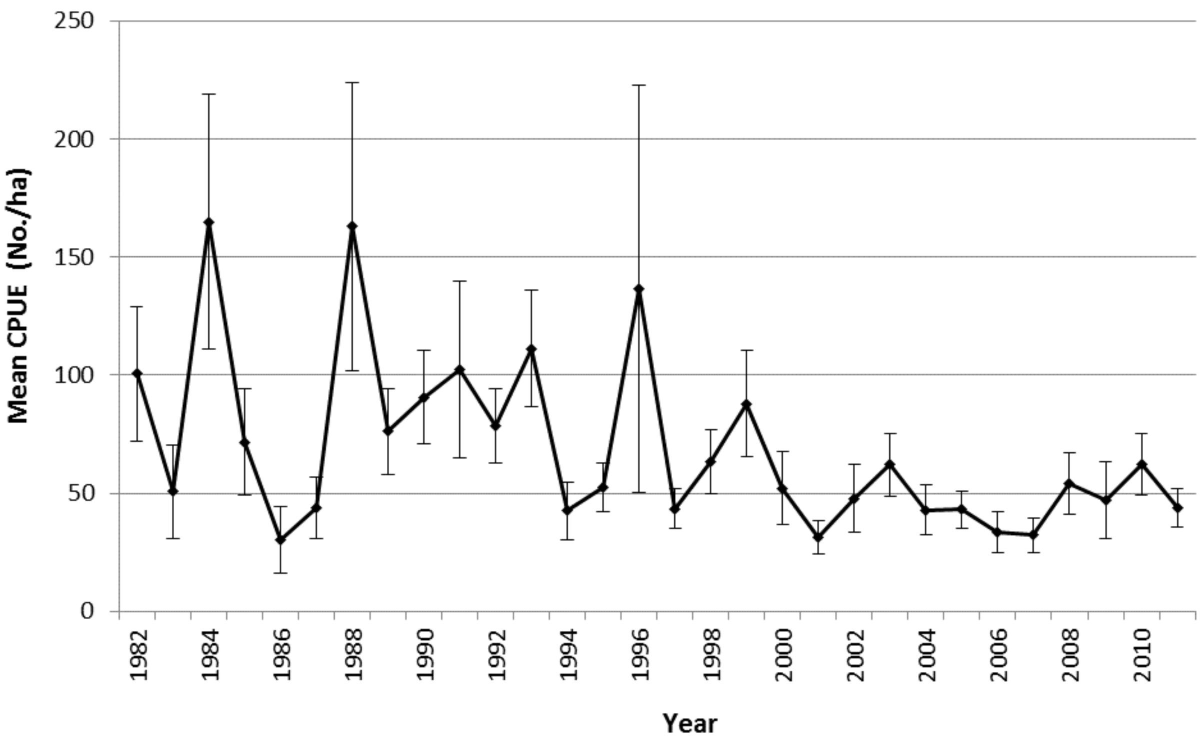


Figure 2.5 Longnose killifish annual mean seine catch rate ± standard error.

Gulf killifish, *Fundulus grandis*, are another small fish species that inhabit shallow shoreline areas. As such, they were caught primarily in seine samples where they made up just slightly over 1% of total numbers yet occurred in over 20% of the samples. As with sheepshead minnow and longnose killifish, this species uses the estuary for its entire life cycle. Gulf killifish are used as flounder bait but not often harvested commercially. Similar to longnose killifish, their population appears to be decreasing with fewer high abundance years in the last decade (Figure 2.6).

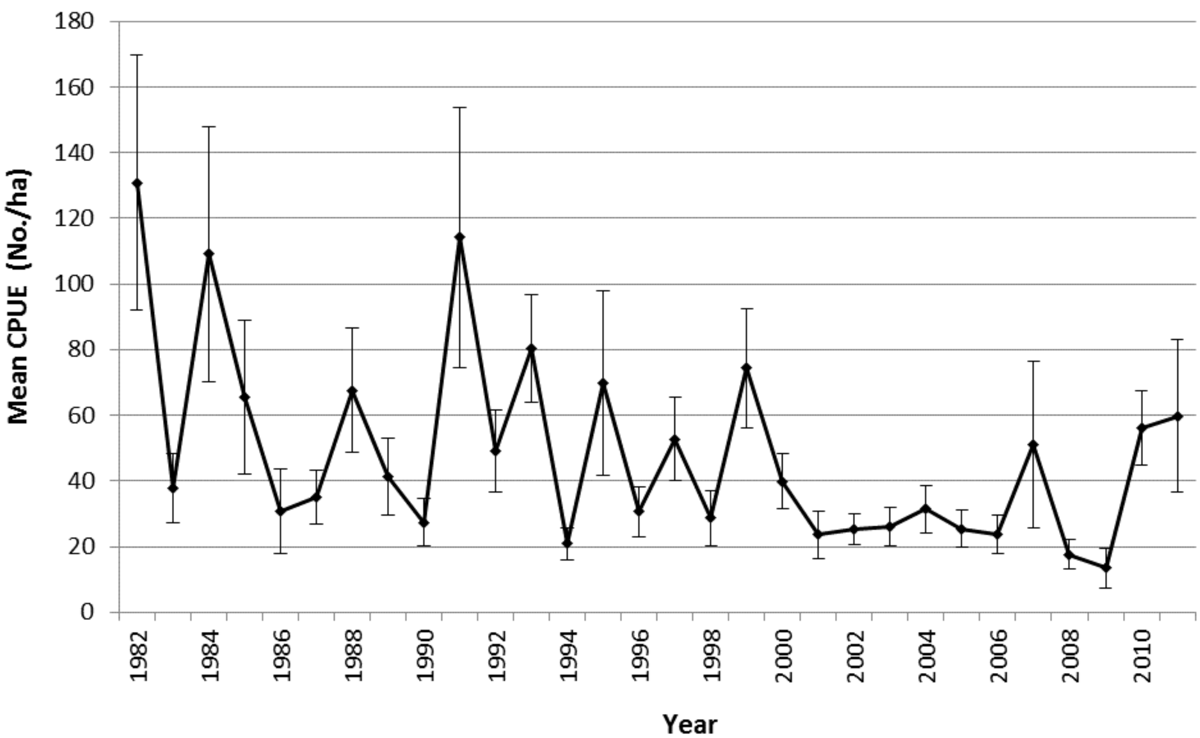


Figure 2.6 Gulf killifish annual mean seine catch rate ± standard error.

Spotfin mojarra, *Eucinostomus argenteus*, another small fish, uses both estuarine and marine habitats. They appeared primarily in seine samples, accounting for less than 1% of the total numbers, and occurred in over 12% of the samples. The estuarine population for this species has been low but relatively stable for the past 30 years (Figure 2.7).

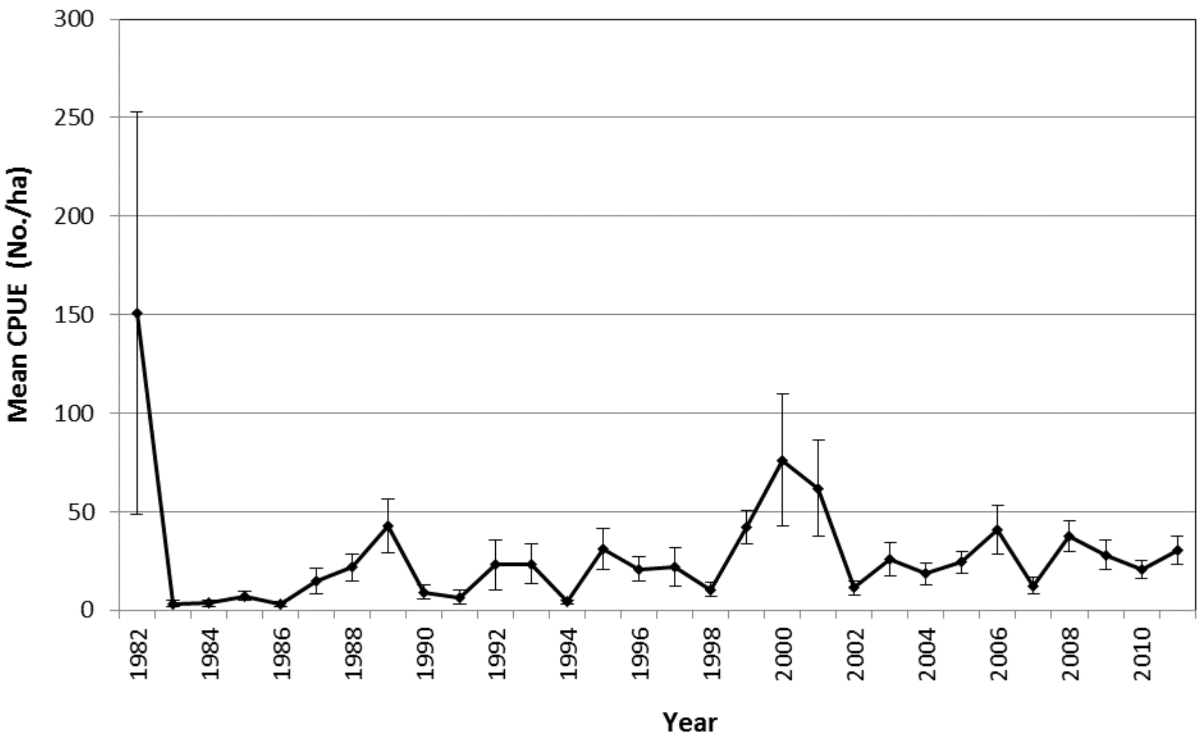


Figure 2.7 Spotfin mojarra annual mean seine catch rate ± standard error.

Pinfish, *Lagodon rhomboides*, are a small fish species and one of only 5 species to meet the selection criteria for all 3 gears, but were most numerous in seines and trawl samples comprising over 13% and 7% of the catch, respectively. Not only were they numerous in these 2 gears, they also occurred in over 40% of the samples indicating a common and wide-spread species occurring in large numbers. Because of their small size, they made up less than 1% of the gill net catch, a gear that targets larger fish, and yet still occurred in over 10% of the samples.

This species spawns in the Gulf during the winter and is found in the estuary primarily during March–October. However, during its tenure in the bay, it is one of the most numerous small fish species. As such, it is an important food source for larger predator fish such as spotted seatrout. Though their population appears to be increasing slightly there is substantial year-to-year variability (Figures 2.8, 2.9, and 2.10). Catch variability notwithstanding, this species has experienced record seine and gill net catches in the last decade while trawl catches were also increasing. There is a limited "perch trap" bait fishery for pinfish; however, with the large numbers of pinfish in the bay this harvest is not likely to be a threat to their population.

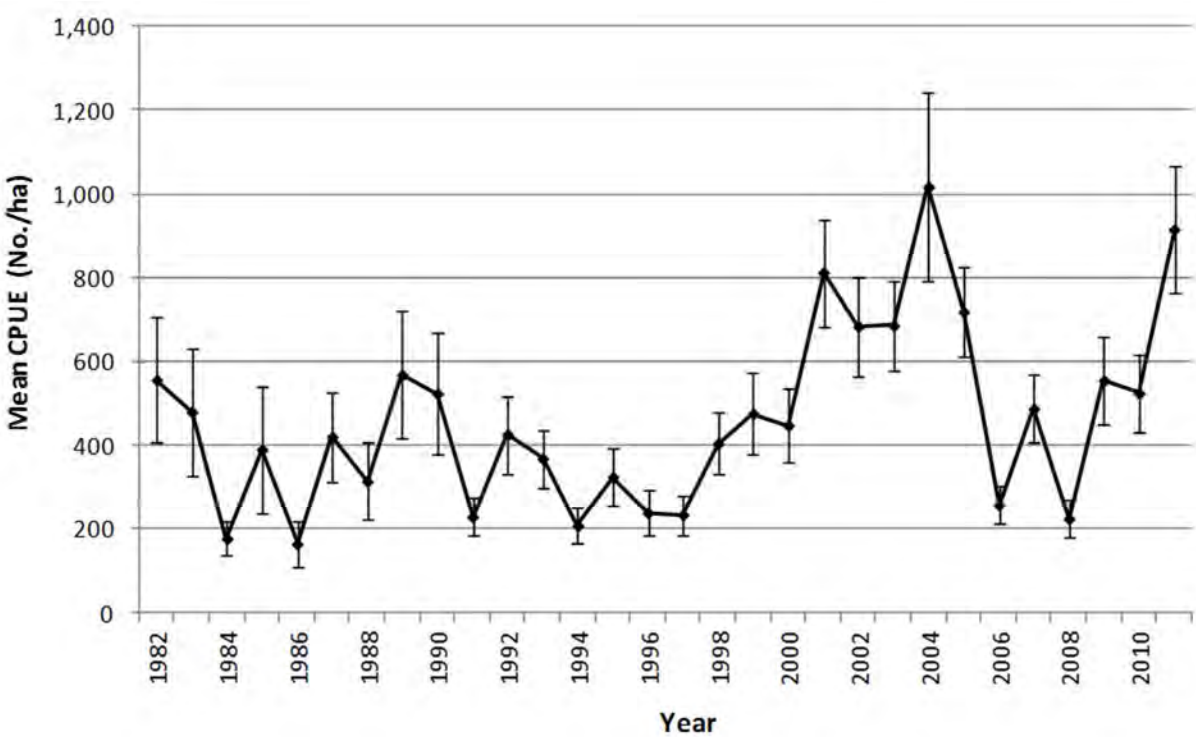


Figure 2.8 Pinfish annual mean seine catch rate ± standard error.

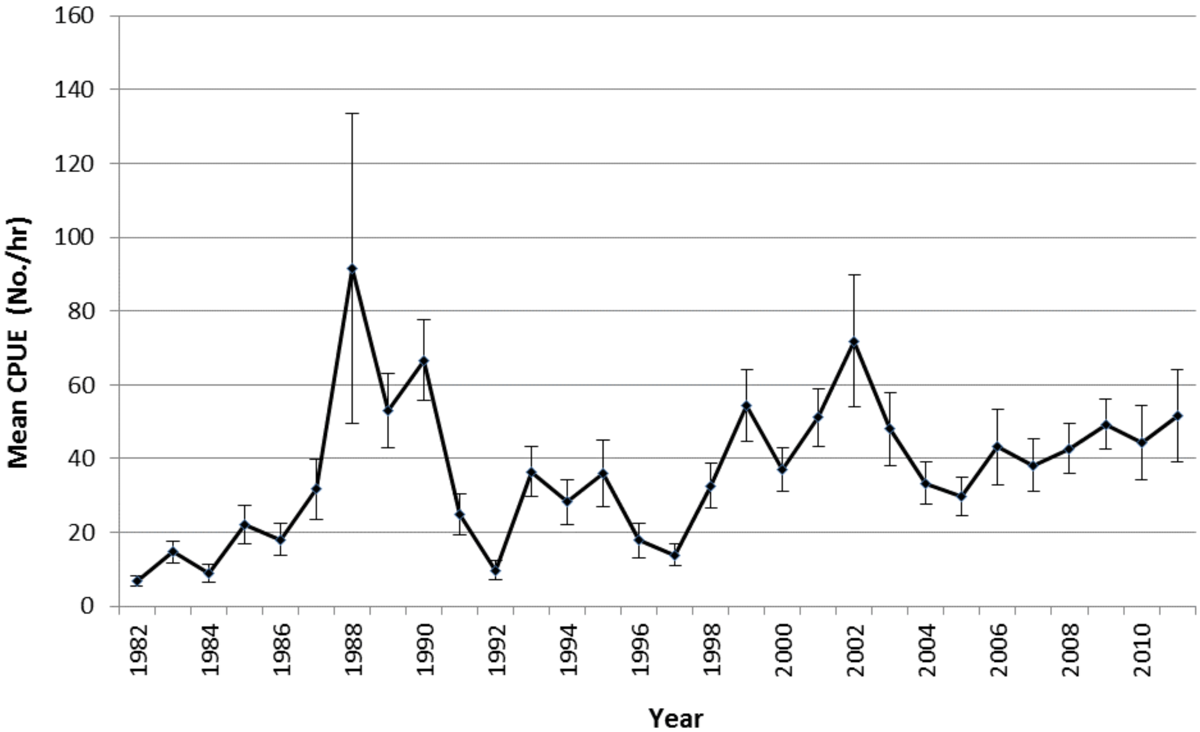


Figure 2.9 Pinfish annual mean trawl catch rate ± standard error.

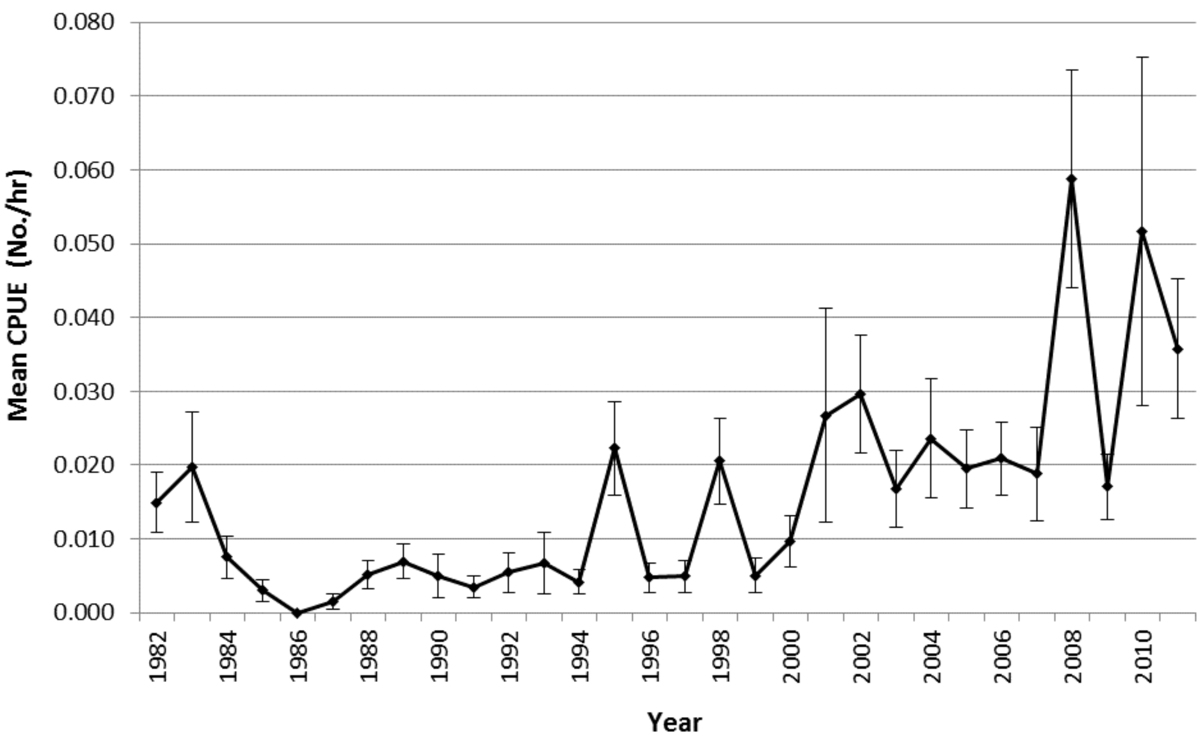


Figure 2.10 Pinfish annual mean gill net catch rate ± standard error.

Brown shrimp, *Farfantepenaeus aztecus*, occurred only in seine and trawl samples where they were the most numerous animals in both fishing gears at 11% and 20% of the catch, respectively. The seine catches were highly variable sometimes producing very low and very high catch rates in successive years (Figure 2.11). Although this species is seen in low numbers in trawl samples during September through February, when it attains a size large enough to be susceptible to the gear during spring and summer, it is caught in large numbers. Trawl catches were also variable with the lowest and highest annual CPUEs occurring within 7 years of each other and 3 of the highest 4 occurring in the last decade (Figure 2.12). With a recent trend of higher trawl catches, and a record catch in 2007, the last decade has seen the brown shrimp catch rates increase substantially allowing for a larger contribution to the gulf spawning stock. Because this species is an annual crop, reproducing outside the estuary, the SAB population of maturing juveniles is not necessarily representative of the Gulf-wide population.

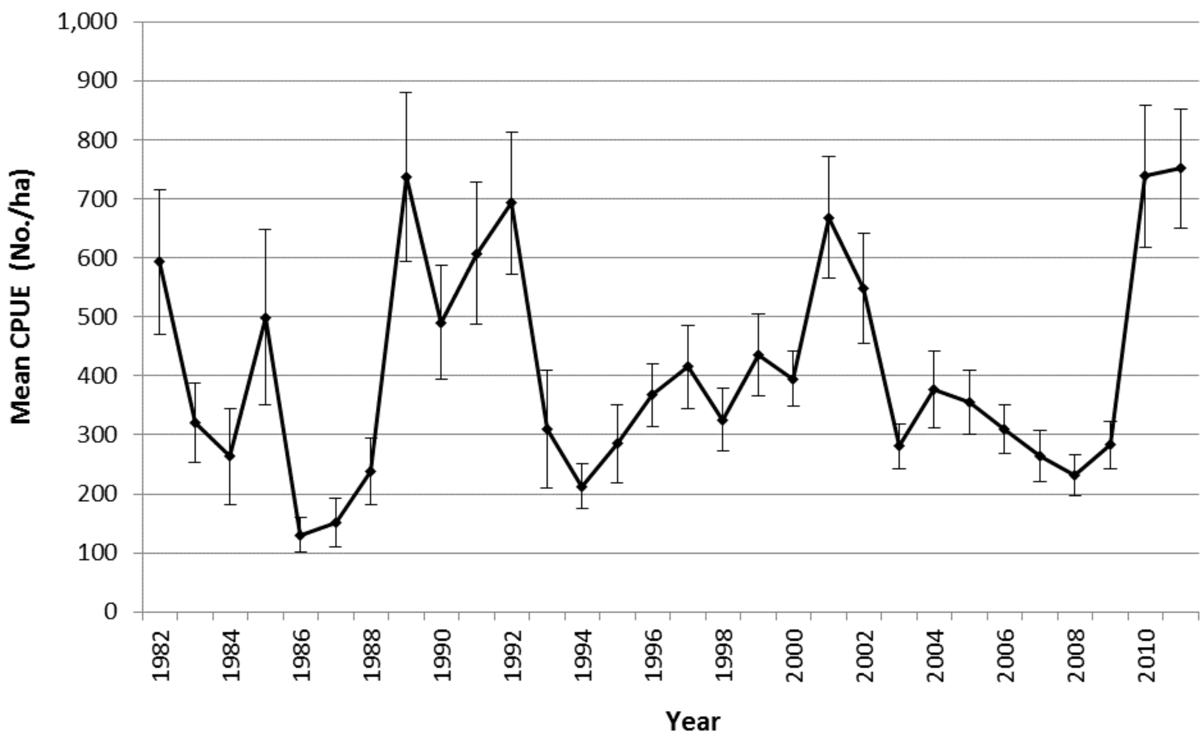


Figure 2.11 Brown Shrimp annual mean seine catch rate ± standard error.

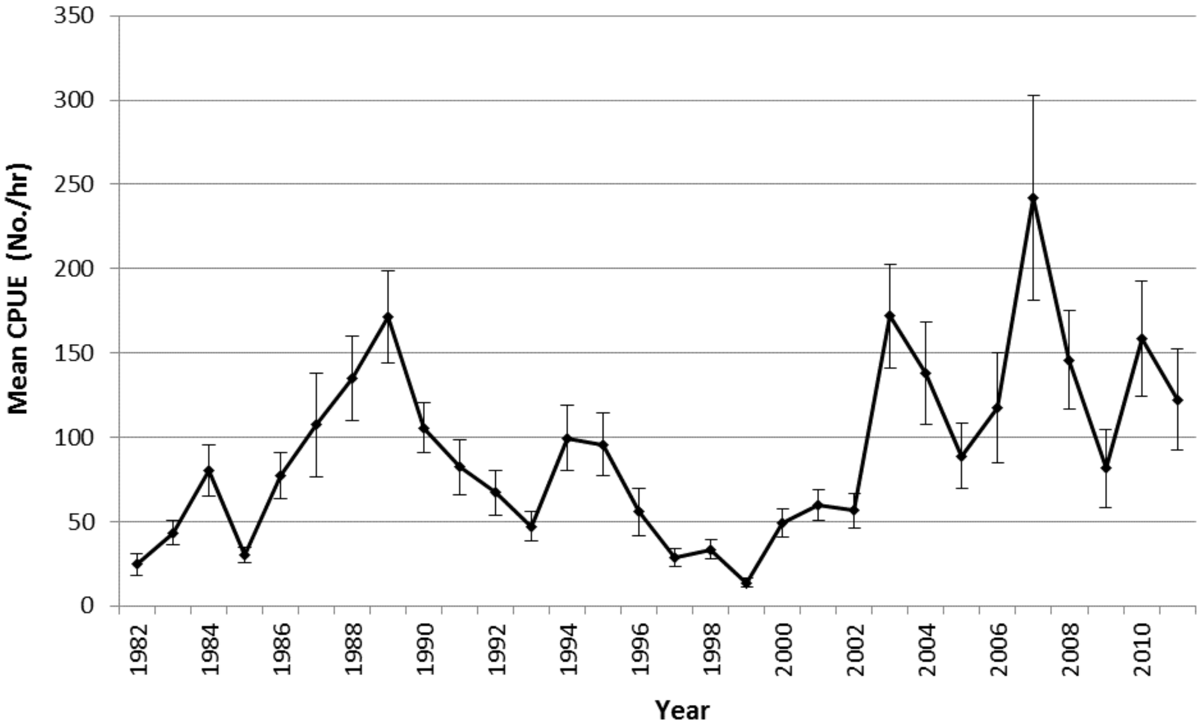


Figure 2.12 Brown shrimp annual mean trawl catch rate ± standard error.

Over the years, there have been several harvest regulation changes designed to promote conservation of shrimp populations. Of these changes, the license management program potentially has the most impact on the fishery via reduction in the fishing effort. With the enactment of this program by the Texas Legislature in 1995, the TPWD ceased selling shrimping licenses. In addition, the agency began buying back and retiring licenses from willing sellers (Figure 2.13). Through 2012, 65% of the bay and bait shrimping licenses have been retired, totaling 2,110 licenses.

Shrimp imports were another of the variables indirectly affecting shrimp abundance in the estuary. Imports have increased creating substantial price competition with locally caught shrimp (Figure 2.14). At the same time, the cost of fuel diesel increased dramatically during the last decade. With the cost of operating boats going up and the product worth less at the dock, the economic feasibility of participating in the shrimp fishery was reduced. Combined with the license buyback program, these phenomena have resulted in a reduction in the number of participants in the fishery. This was revealed each year since 1994 in the May 15th opening day boat counts for the Spring Open Season (brown shrimp season) (Figure 2.15). The boats counted were seen shrimping on the opening day via aerial flights. As a result of this decreased effort and subsequent decreased landings, there were potentially more shrimp available to the fishery independent trawl sampling. This potential increased availability was realized with higher trawl catches during the last decade (Figure 2.12) which are indicative of an increased estuarine population.

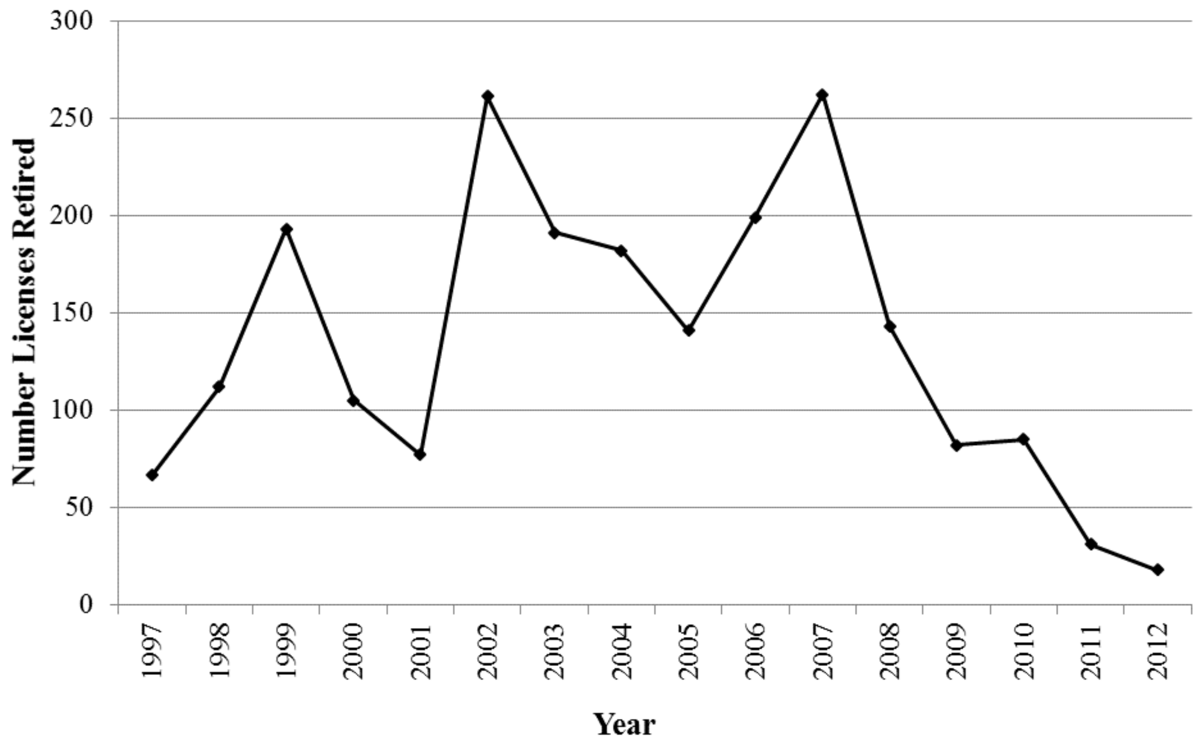


Figure 2.13 Number of bay and bait shrimping licenses bought back and retired, by year.

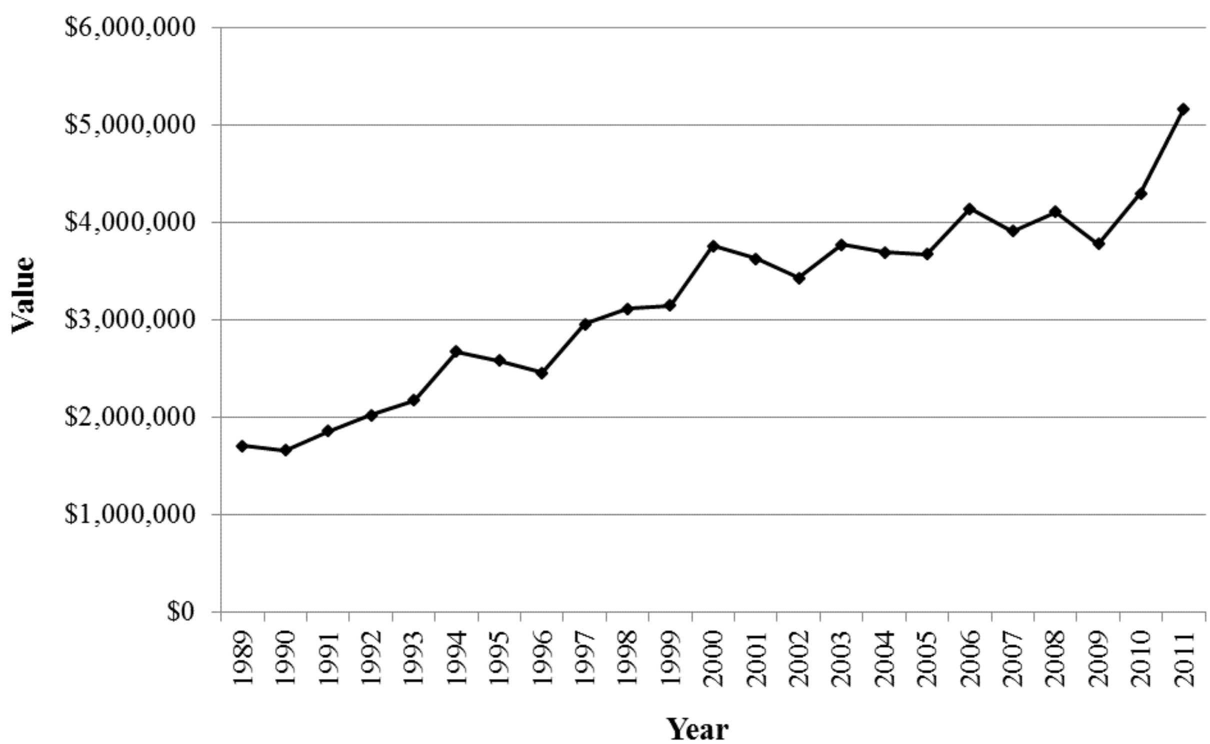


Figure 2.14 Value of shrimp imported to the United States (USDA 2012).

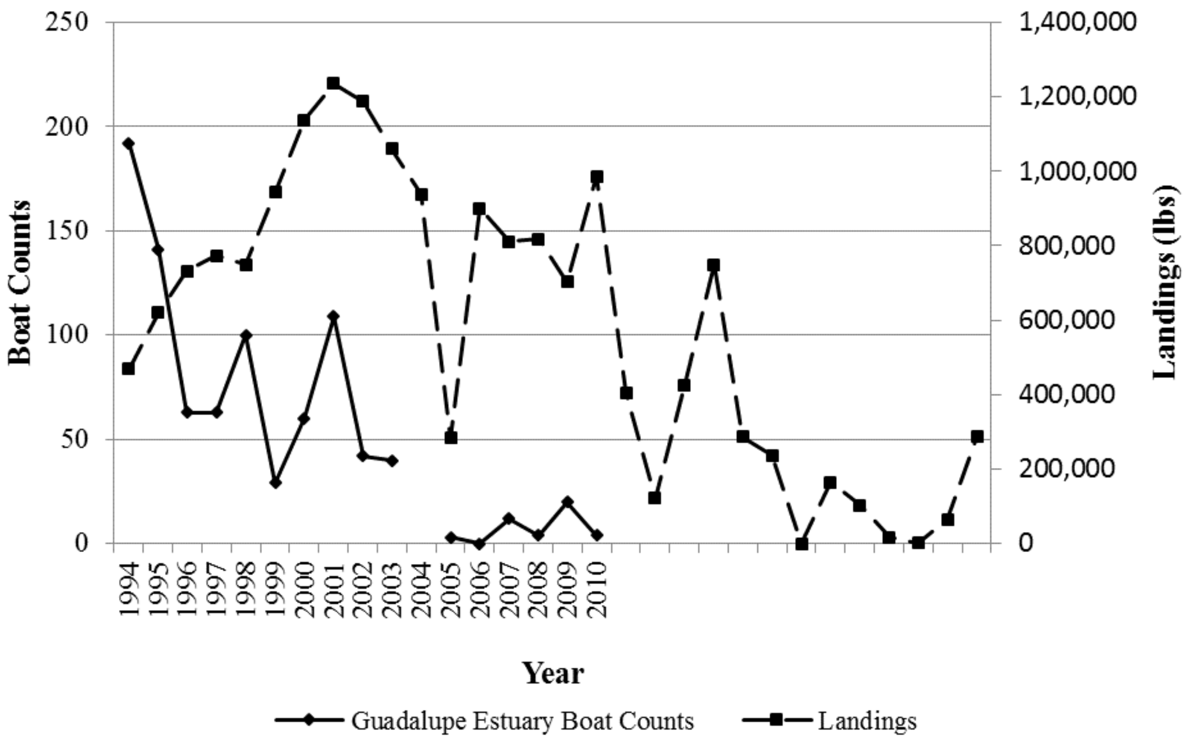


Figure 2.15 Guadalupe Estuary May 15 boat counts and annual grooved shrimp landings.

White shrimp, *Litopenaeus setiferus*, like brown shrimp, were caught only in seines and trawls. In seines, they accounted for over 6% of the total catch while they occurred in over 25% of the samples. In trawls, they accounted for over 7% of the total catch and occurred in over 42% of all samples. Seine catches were highly variable with alternating troughs and peaks (Figure 2.16) while trawl catches were very different, being relatively stable until increasing during the last decade (Figure 2.17). Because this species is an annual crop reproducing outside the estuary, the SAB population of maturing juveniles is not necessarily representative of the Gulf-wide population.

As with brown shrimp, white shrimp seine catches show little effect from commercial shrimping activity within the estuary, while trawl catches exhibit some relationship with that fishery. As commercial economic viability and license buy backs began to reduce the number of fishery participants early last decade, trawl catches began to increase with the 3 highest CPUEs on record occurring during that time period (Figure 2.16). Because the commercial fishery and the TPWD trawl program use similar gears and fish similar areas, with fewer commercial boats working there were more shrimp available to the fishery independent trawl sampling. This was evident in the increased CPUEs which are indicative of an increased estuarine population.

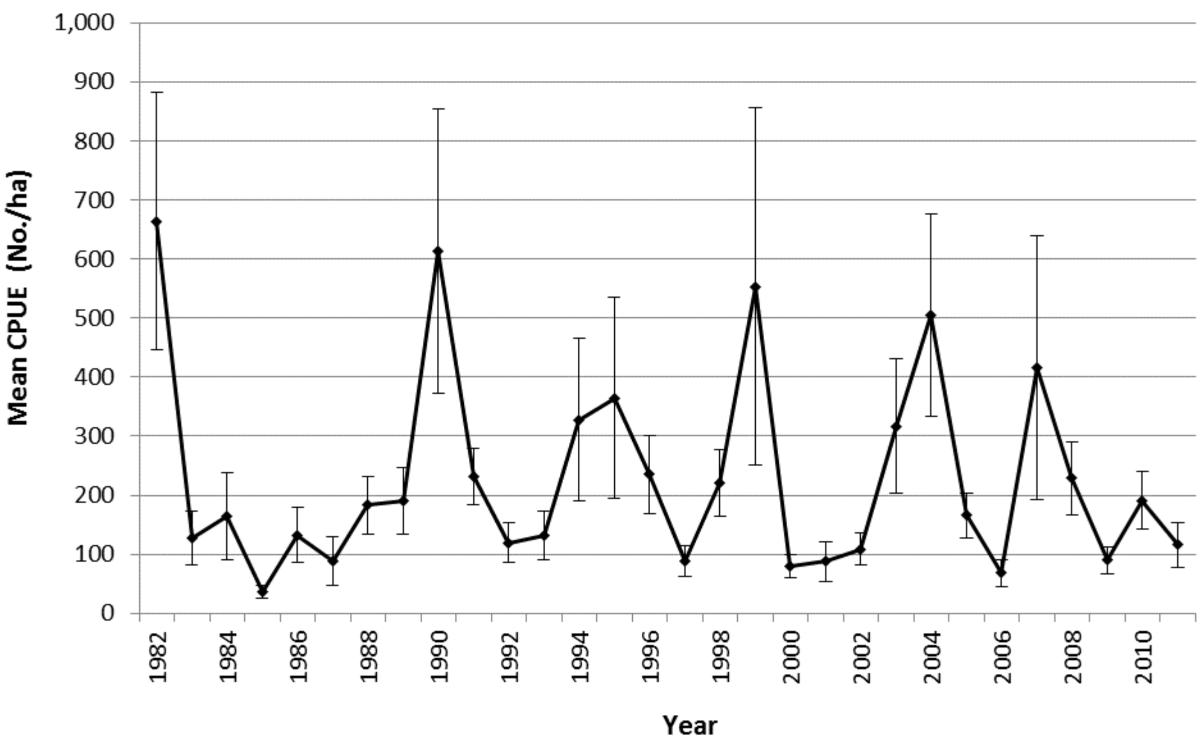


Figure 2.16 White shrimp annual mean seine catch rate ± standard error.

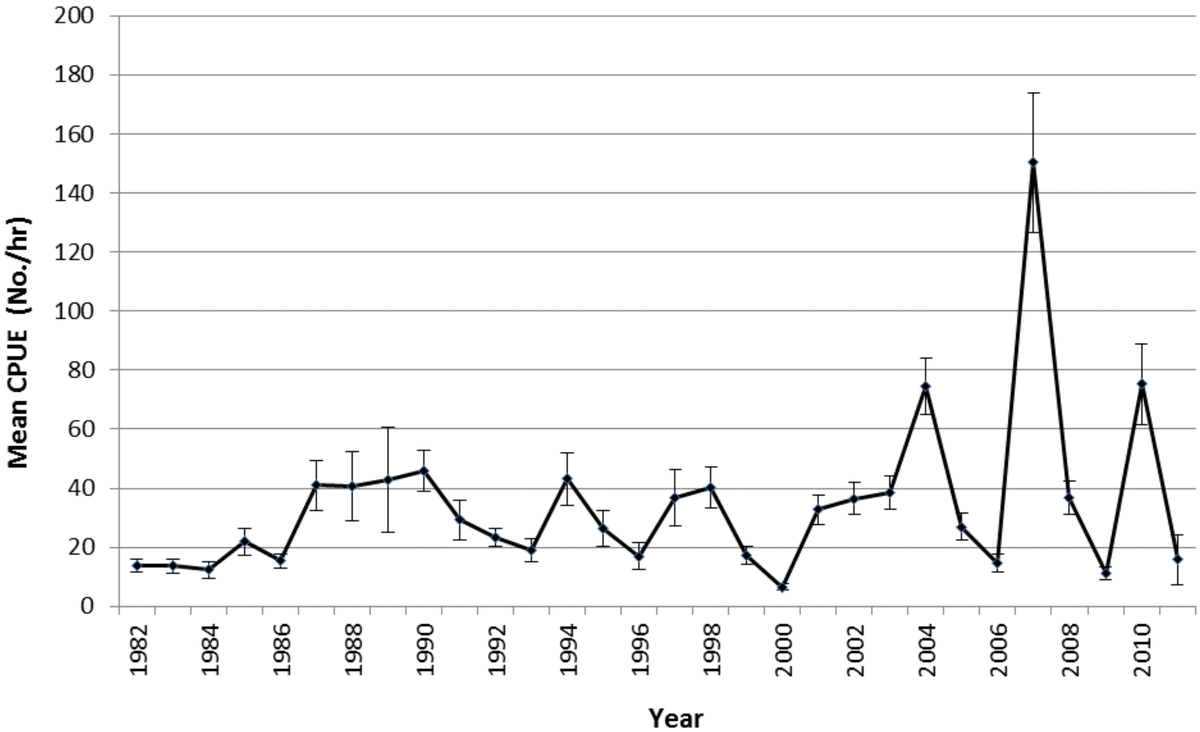


Figure 2.17 White shrimp annual mean trawl catch rate ± standard error.

Spot, *Leiostomus xanthurus*, were a very numerous and common species in SAB. They were common in all three gears and numerous in seines and trawls comprising 6% and 12% of the catch, respectively, and were the third most numerous species in trawl catches. Catches also indicate that spot were one of the most common species in the estuary occurring in 42%, 51%, and 30% of the samples in seines, trawls, and gill nets, respectively (Figures 2.18, 2.19, and 2.20).

The population trend appears to be increasing, but catches were highly variable with the 2 highest trawl CPUEs of the last thirty years occurring during the last decade (Figure2.19). This trend would seem to indicate that spot were substantially impacted by the shrimp fishery and responded positively to the reduced fishing effort in the last decade (Figure 2.15). This was confirmed by Fuls et al (2002) in a study of commercial shrimp fishery bycatch in San Antonio Bay System where spot were in the top four bycatch species caught. While trawl data indicates a recovering population, it remains to be seen if the population will continue to rebound from shrimp fishery impacts.

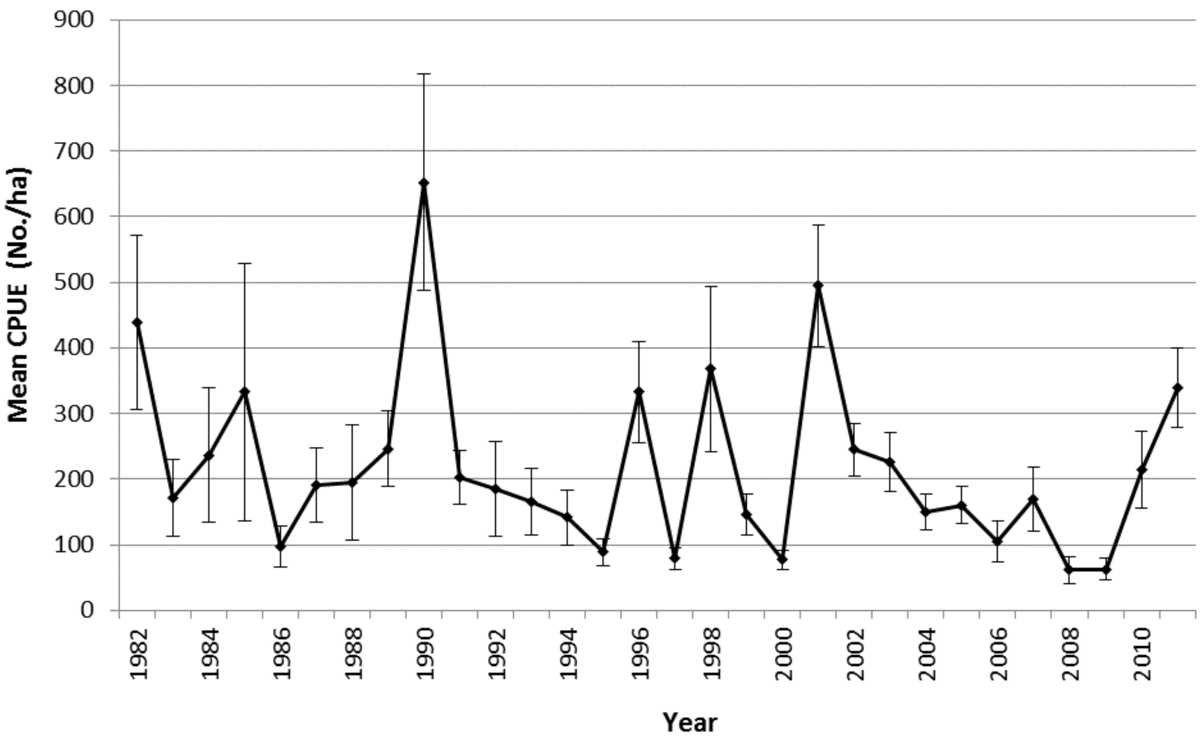


Figure 2.18 Spot annual mean seine catch rate ± standard error.

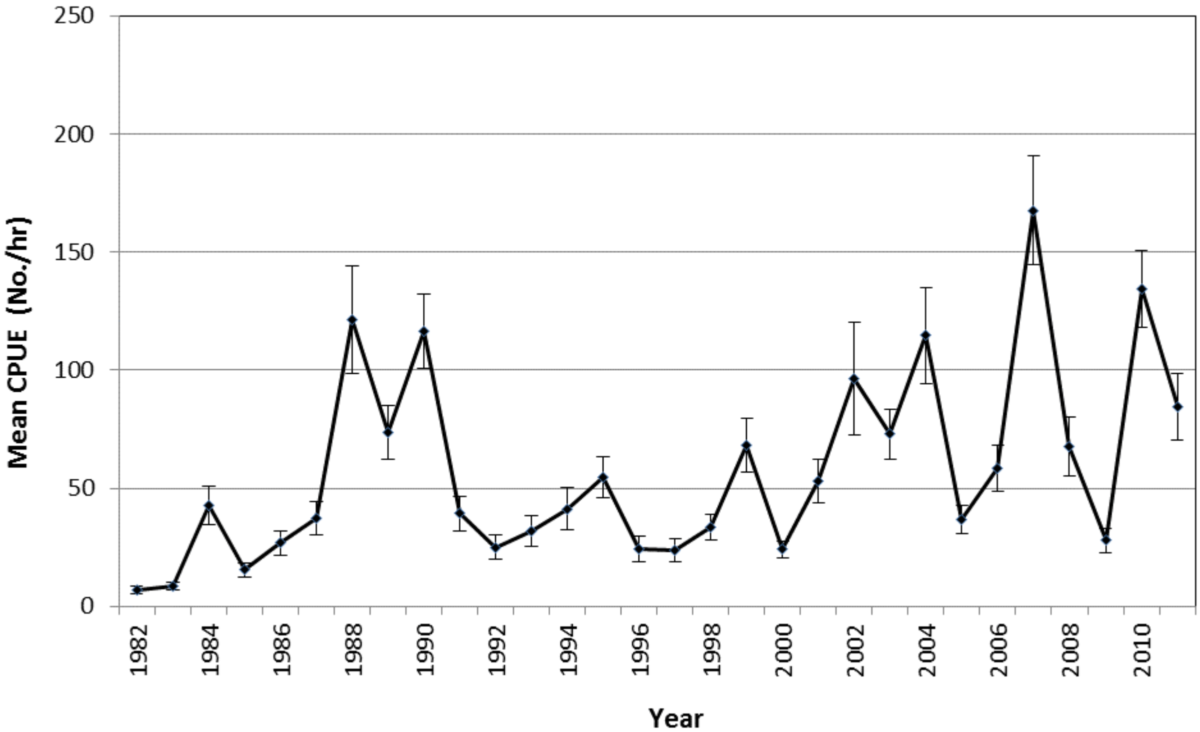


Figure 2.19 Spot annual mean trawl catch rate ± standard error.

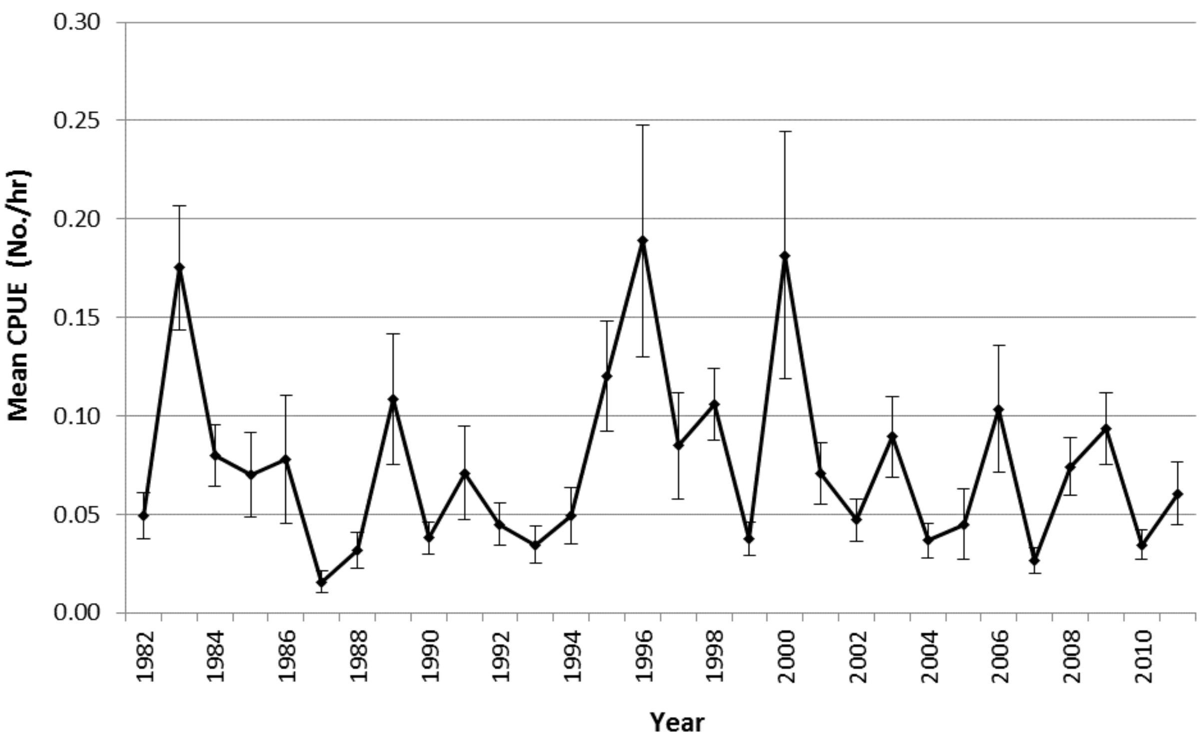


Figure 2.20 Spot annual mean gill net catch rate ± standard error.

Bay anchovy, *Anchoa mitchilli*, is another small fish which generally inhabit open waters of the estuary. This behavior makes them more available to trawls than the other gears. In seines, they comprised less than 3% of the catch and was caught in over 17% of seine samples, so were not very numerous but were fairly common (Figure 2.21). However, in trawl samples they made up almost 4% of the total catch and were captured in over 44% of all samples; only three species were caught more often in trawls. The trend appears to higher trawl CPUEs with six of the highest seven CPUEs occurring during the last decade (Figure 2.22). Along with spot, bay anchovy were a numerous species in the 1994-95 bycatch study (Fuls et al, 2002) and appears to be benefitting from reduced shrimping effort.

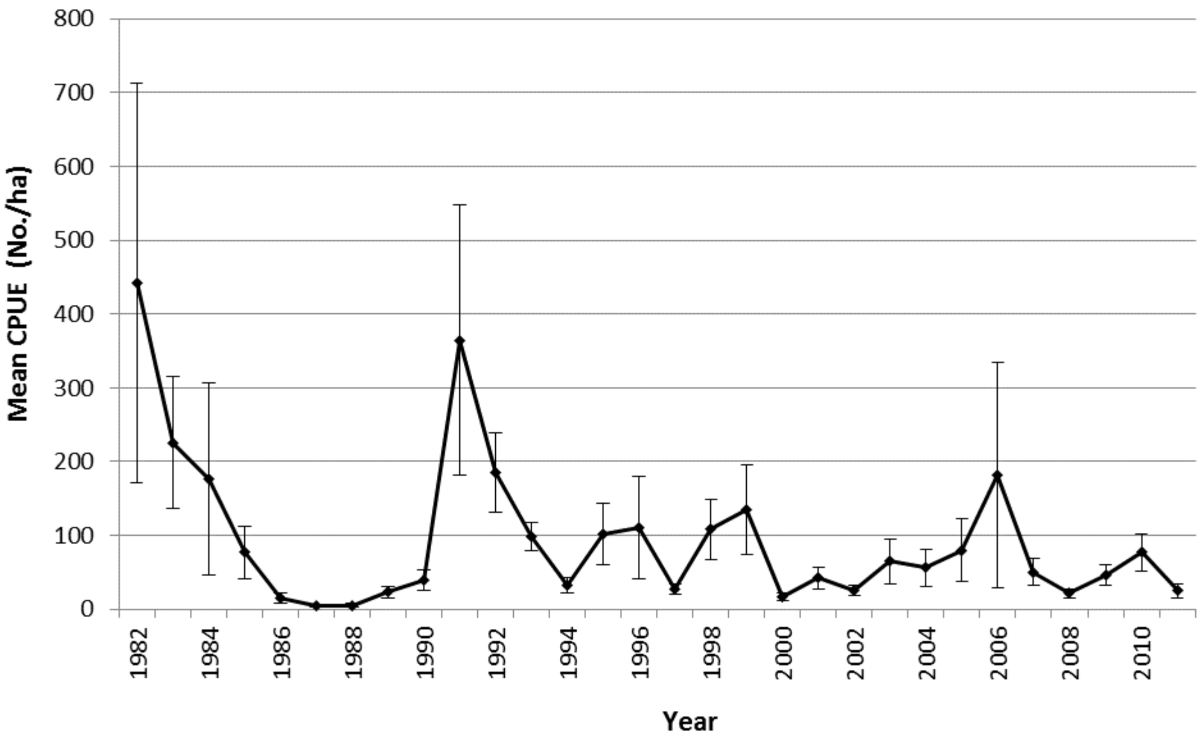


Figure 2.21 Bay anchovy annual mean seine catch rate ± standard error.

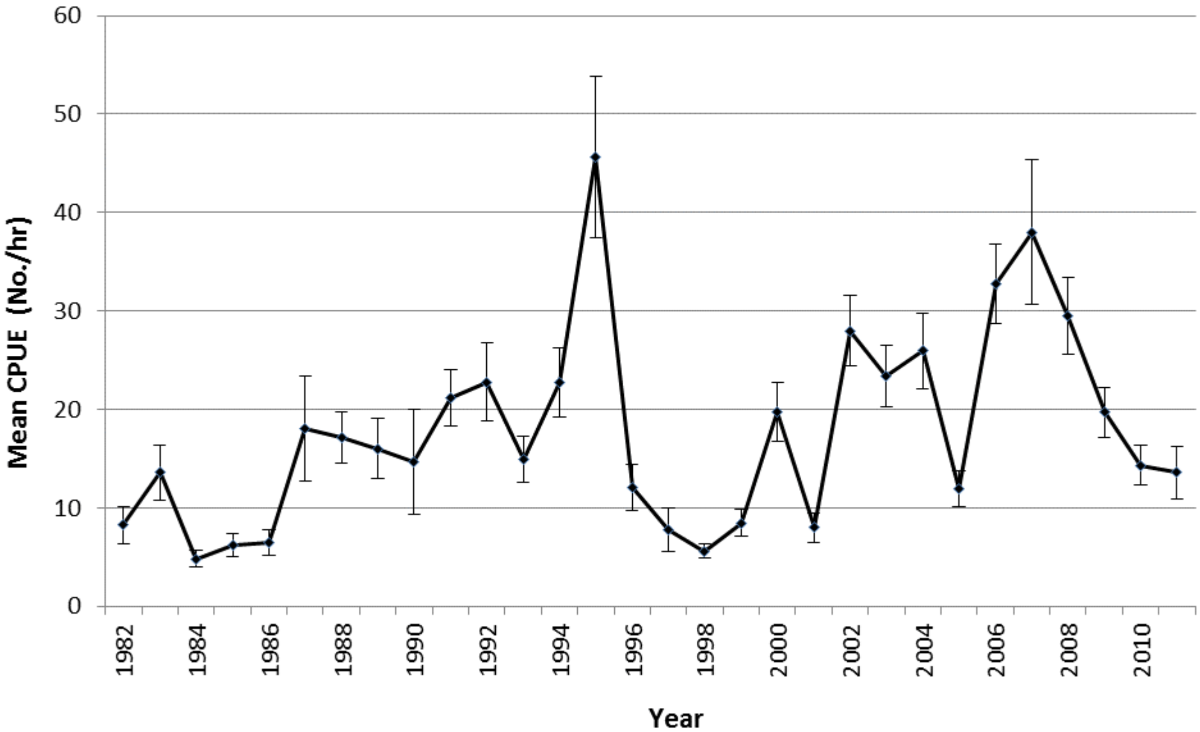


Figure 2.22 Bay anchovy annual mean trawl catch rate ± standard error.

Striped mullet, *Mugil cephalus*, were a common species in seine and gill net samples, occurring in over 29% and 76% of samples, respectively. Mullet comprised less than 2% of the seine catch, while in gill nets they made up 5% of the catch, and exhibited high variability between years (Figures 2.23 and 2.24).

Mullet are harvested commercially for bait and often cast netted by recreational anglers for the same purpose. However, neither activity is as substantial as the bait harvest for shrimp.

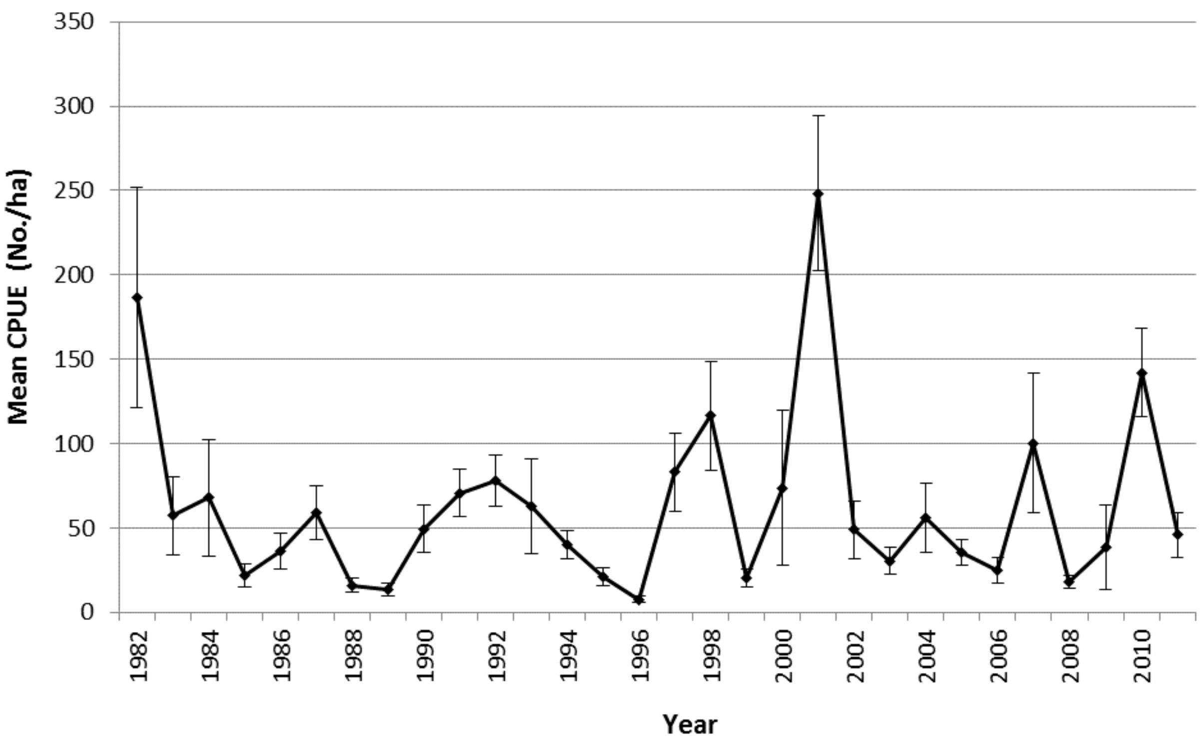


Figure 2.23 Striped mullet annual mean seine catch rate ± standard error.

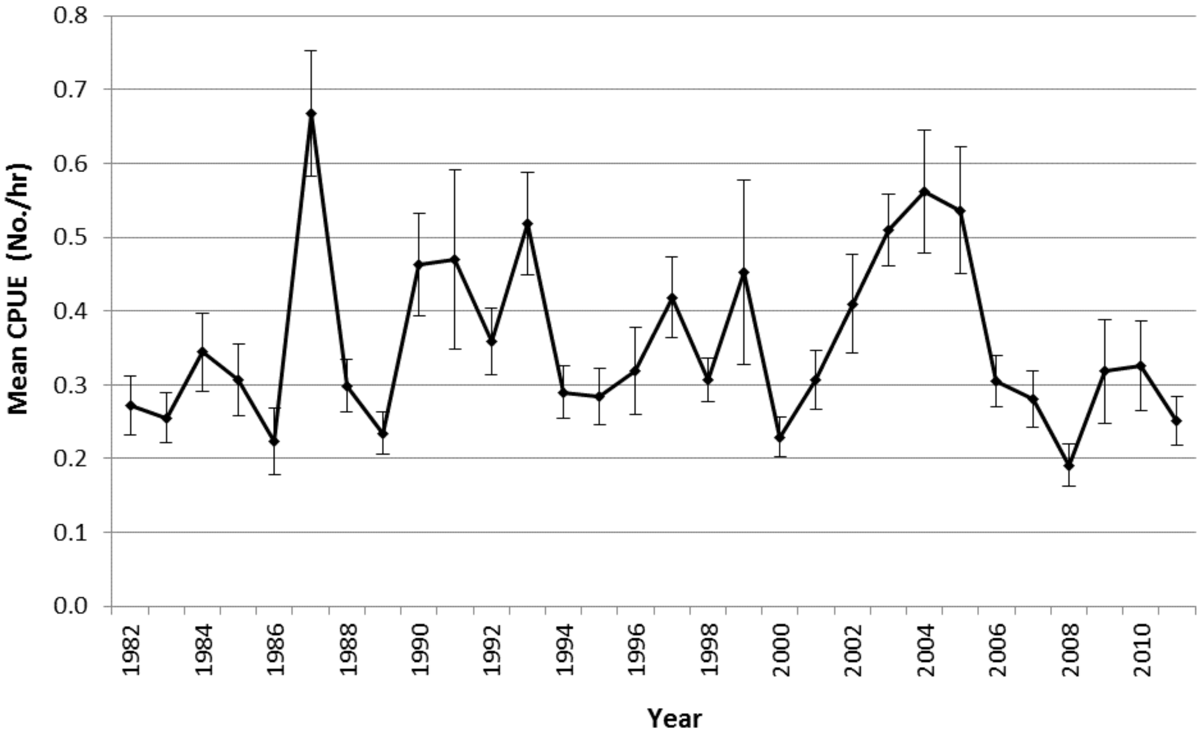
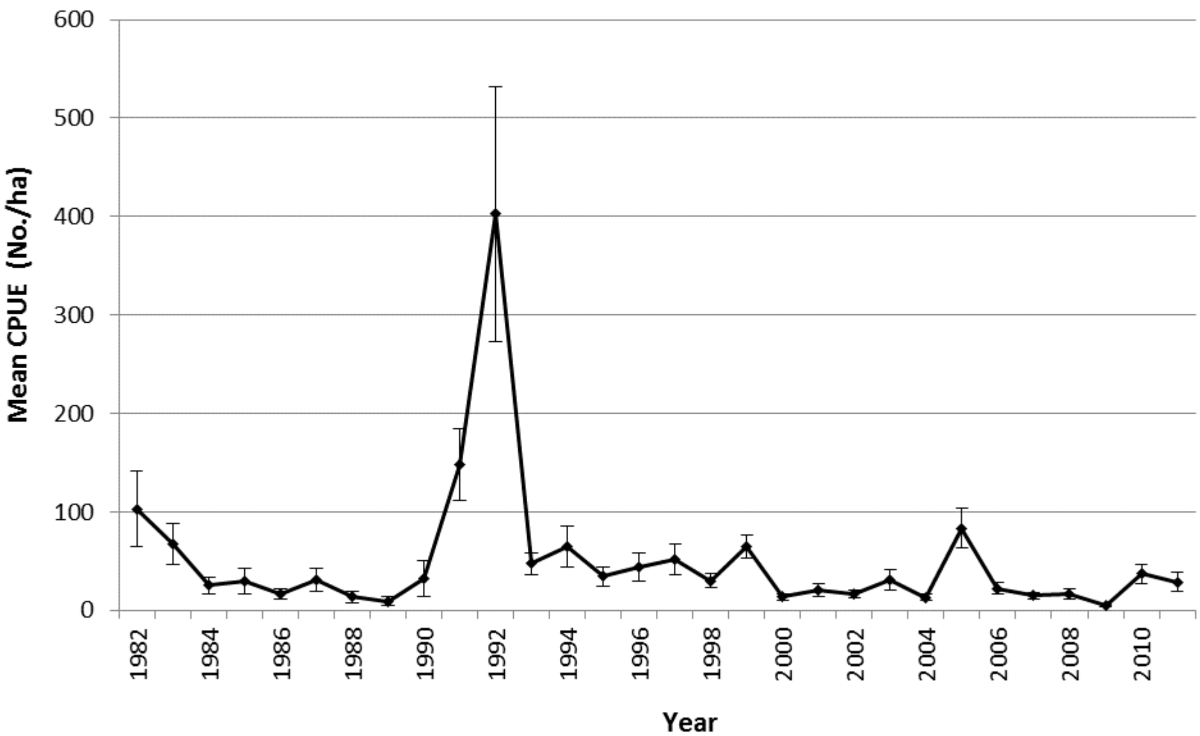


Figure 2.24 Striped mullet annual mean gill net catch rate ± standard error.

Atlantic croaker, *Micropogonias undulatus*, were a common animal in the estuary during late spring and summer months and is harvested commercially for bait, primarily from June through August. One of five species commonly caught in all three gears, croaker occurred in 17%, 59%, and 30% of the seine, trawl, and gill net samples, respectively. They also made up 20% of the catch in trawls. Much like shrimp, croaker are not common or plentiful during the winter but are very numerous during late spring and summer months. Croaker annual seine catches have been remarkably stable with the exception of 1992 (Figure 2.25), the year of record freshwater inflows for SAB. Croaker trawl data were similar to spot data, exhibiting a recovery from shrimp fishery impacts (Figure 2.26). Gill net data were mixed (Figure 2.27).

Atlantic croaker were a substantial component of the shrimping industry bycatch (unintended catch) (Fuls et al 2002). As observed with brown and white shrimp, bay anchovy, and spot, the Atlantic croaker population appears to have benefitted from the decreased shrimping effort during the last decade (Figure 2.26).



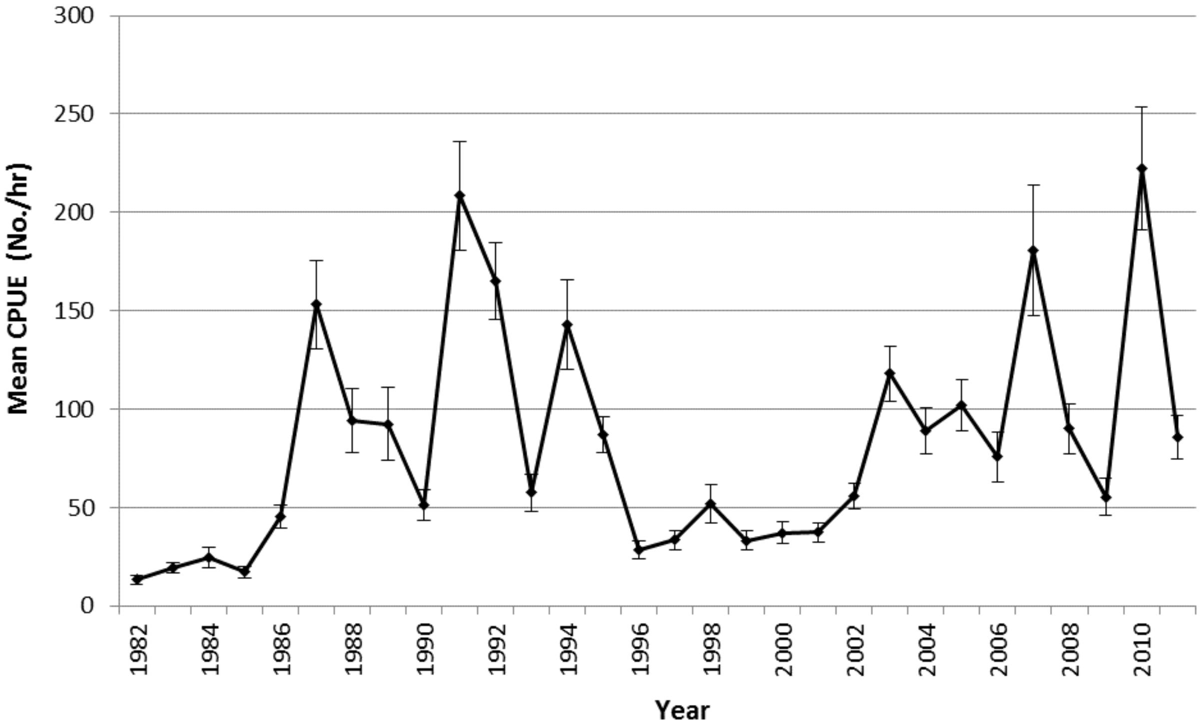


Figure 2.26 Atlantic croaker annual mean trawl catch rate ± standard error.

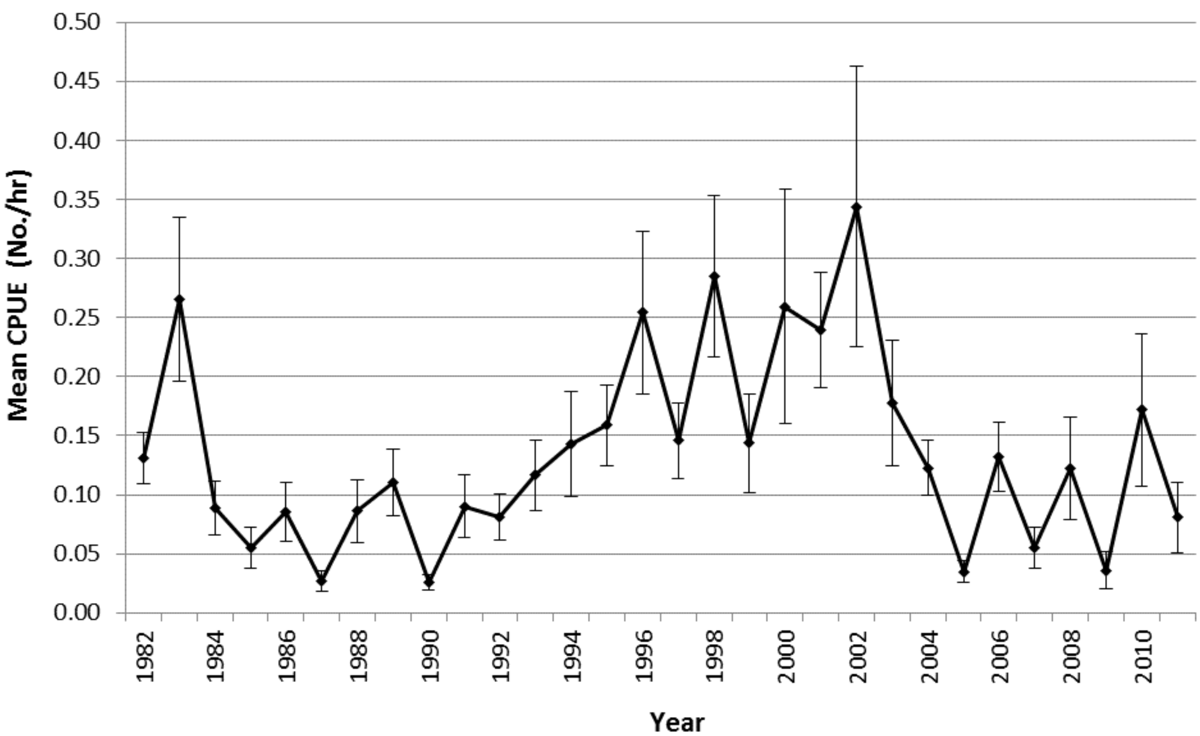


Figure 2.27 Atlantic croaker annual mean gill net catch rate ± standard error.

Blue crab, *Callinectes sapidus*, were common in all three gears occurring in 42%, 59%, and 35% of all samples for seines, trawls, and gill nets, respectively (Figures 2.28, 2.29, and 2.30), though they were numerous in only the trawl samples at 6.5% of the catch. The population trend has declined for all three gears, a phenomenon also reported from other Gulf States. Preliminary analysis by the TPWD indicates that overfishing may be contributing to this decline.

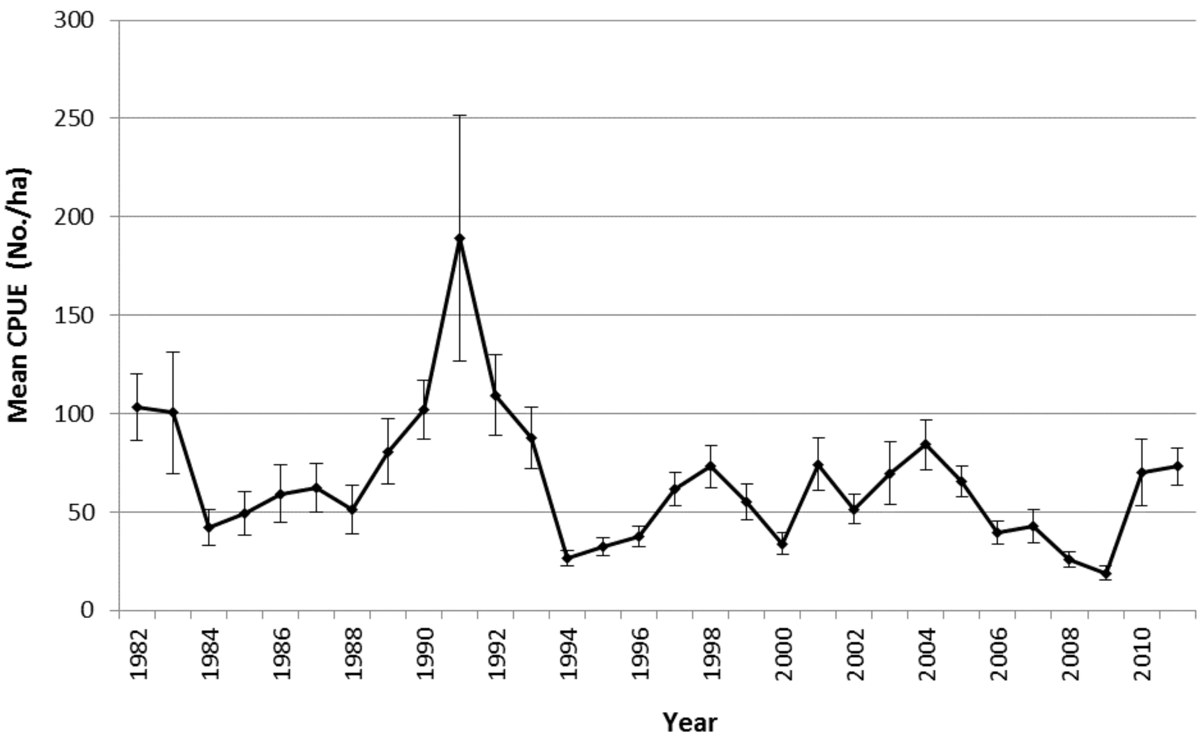


Figure 2.28 Blue crab annual mean seine catch rate ± standard error.

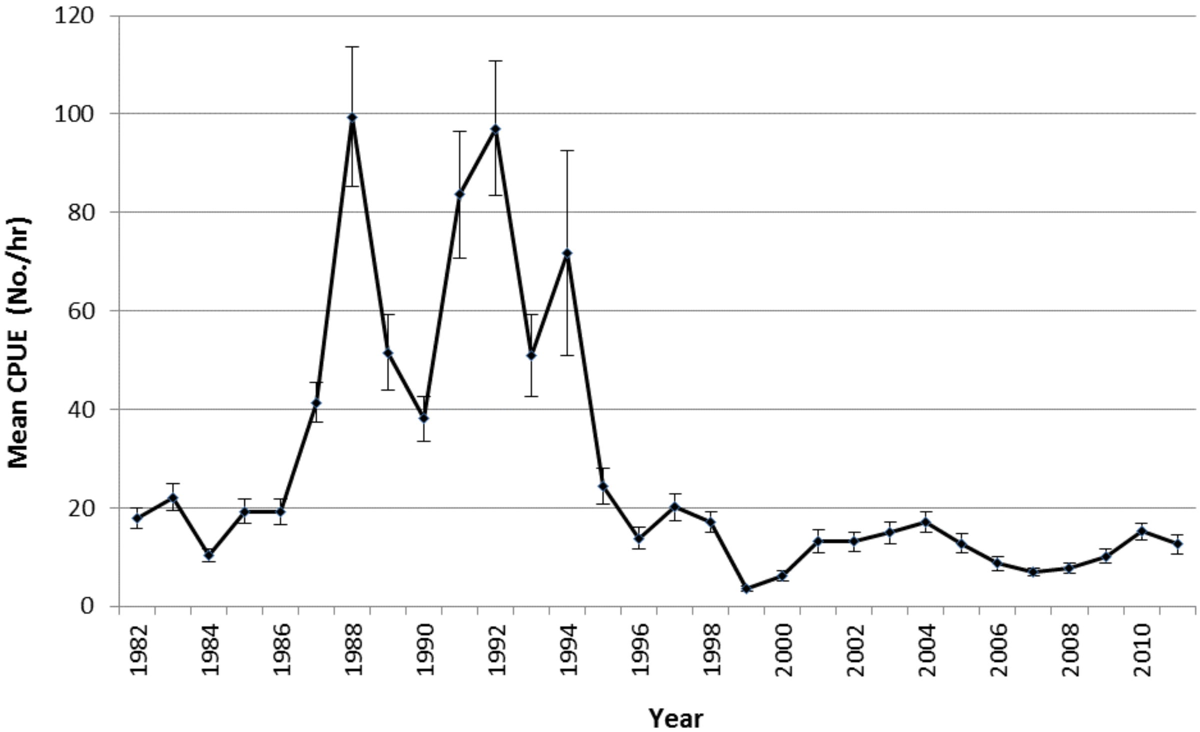


Figure 2.29 Blue crab annual mean trawl catch rate ± standard error.

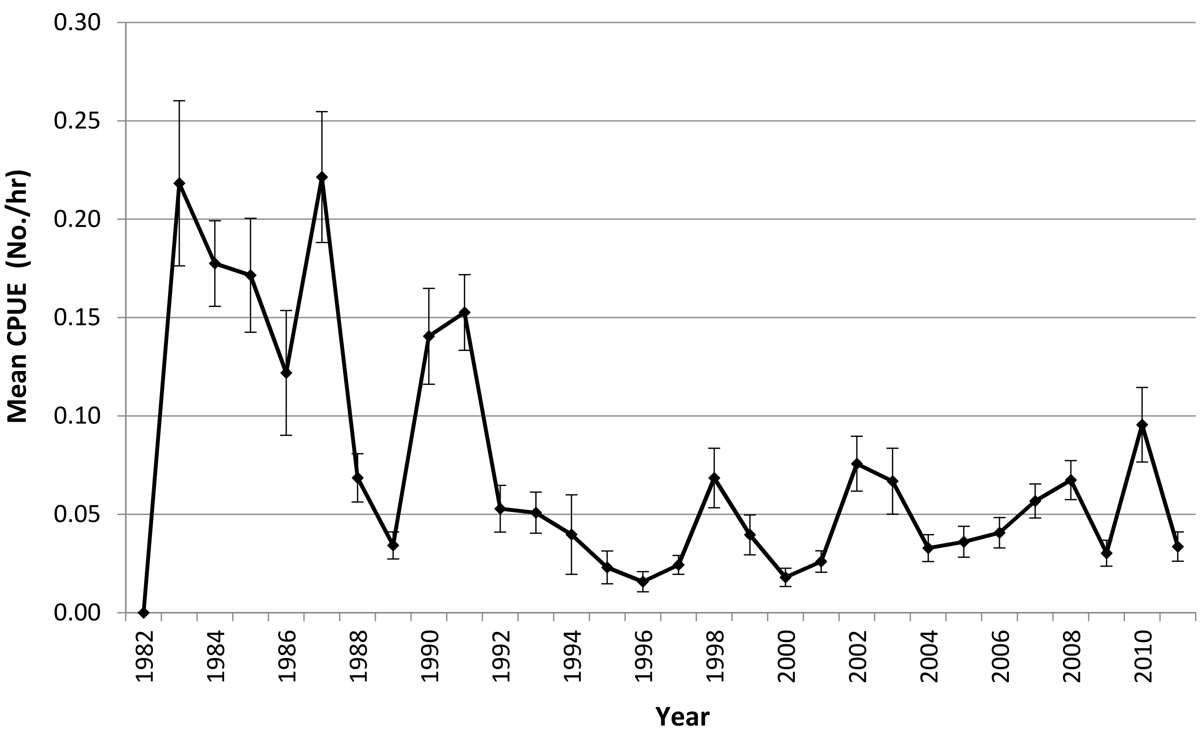


Figure 2.30 Blue crab annual mean gill net catch rate ± standard error.

Red drum, *Sciaenops ocellatus*, were a common component of both seines and gill nets, occurring in 20% and 93% of all samples, respectively. Only hardhead catfish occurred more often in gill nets. Red drum were not only very common in gill net samples, they were also numerous, being almost 15% of the total catch. The seine CPUE trend has been variable but not decreasing (Figure 2.31). The gill net CPUE trend has been increasing (Figure 2.32).

Red drum were the most sought after species by recreational anglers with a daily bag limit of three fish. Historically, red drum were a component of the commercial landings. Due to decreasing recruitment to the wild spawning stock, beginning in 1981 they were designated a game fish and the sale of red drum from Texas waters was prohibited. Seven years later, gill net use was banned in Texas waters. This species is part of the TPWD enhancement program and has been stocked in Texas estuaries since the late 1970s.

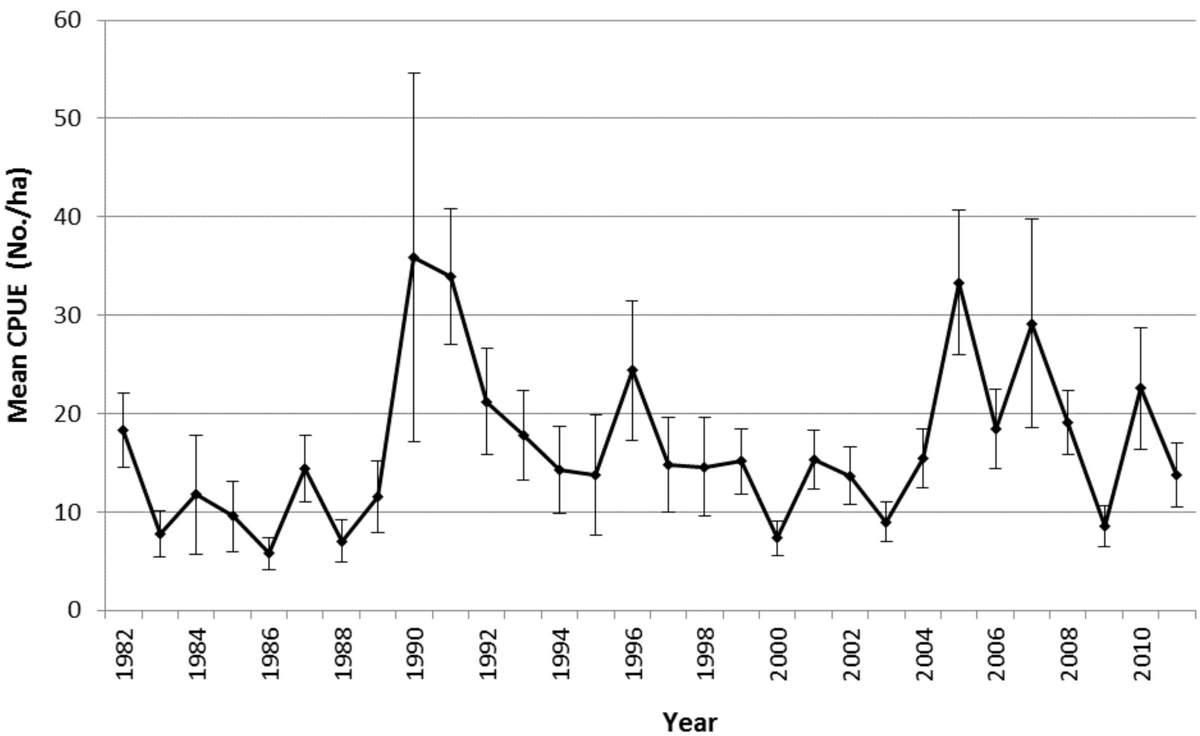


Figure 2.31 Red drum annual mean seine catch rate ± standard error.

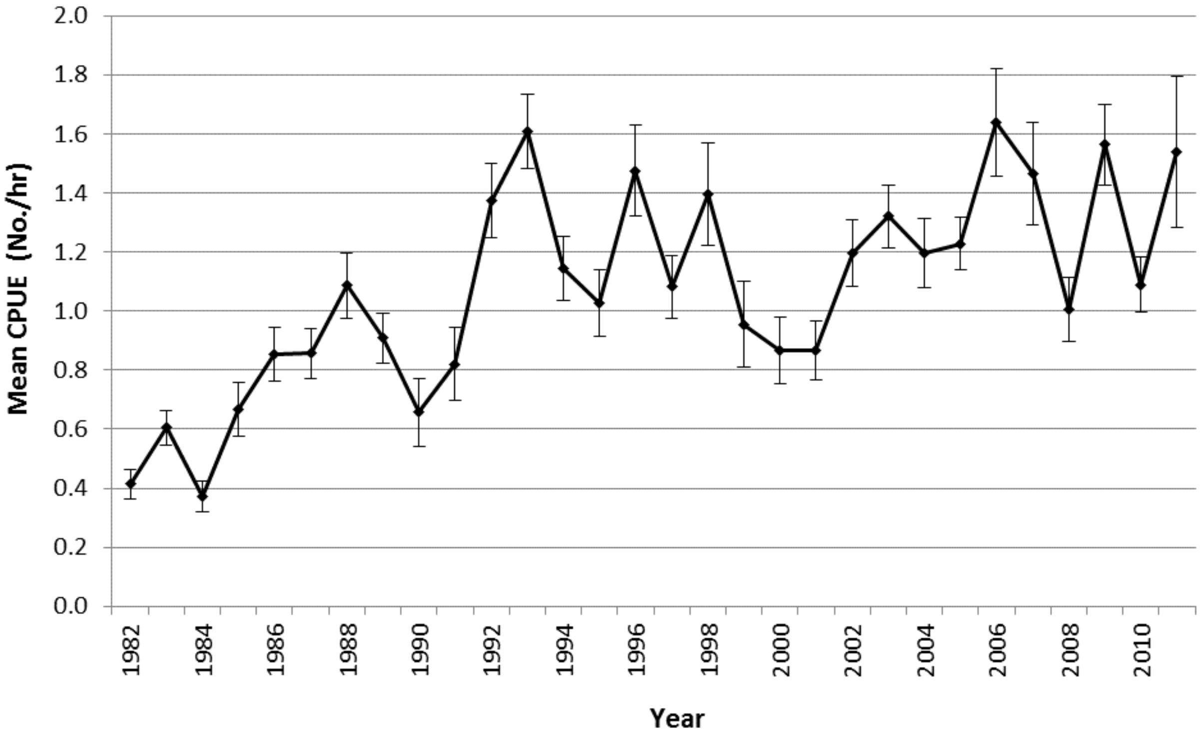


Figure 2.32 Red drum annual mean gill net catch rate ± standard error.

Spotted seatrout, *Cynoscion nebulosus*, were the second most sought after, and most often landed, species by recreational anglers and has a 10 fish daily bag limit. They were a common component of both seines and gill nets occurring in 15% and 87% of samples, respectively. They were also numerous in gill net samples, comprising over 8% of the total catch. The trend for seine catches was variable with peaks in the early 1990s (after the killing freezes of 1989) and the last two years (after the February 2010 freeze) (Figure 2.33). The last two years were the second and fourth highest seine CPUEs during the last 30 years. Gill net catches were also variable with lows in the 1980s, before gill nets were banned in 1988, and then peaked in 1998. Also contributing to the population ascension culminating in the 1998 peak were an increase in the minimum harvest length to 15” in 1991 and increased juvenile recruitment as seen in the record seine catches in 1991 and 1992 indicating large successful spawns.

After the 1998 peak, the spotted seatrout population fluctuated and declined until the last 2 years (Figure 2.34). Contributing to the small uptick in the recent population trend was the substantial increase in juvenile recruitment as measured by seine catches in 2010 and 2011 (Figure 2.33). It is anticipated that gill net catches will continue to increase in the near future, due to these recent near-record recruitment years.

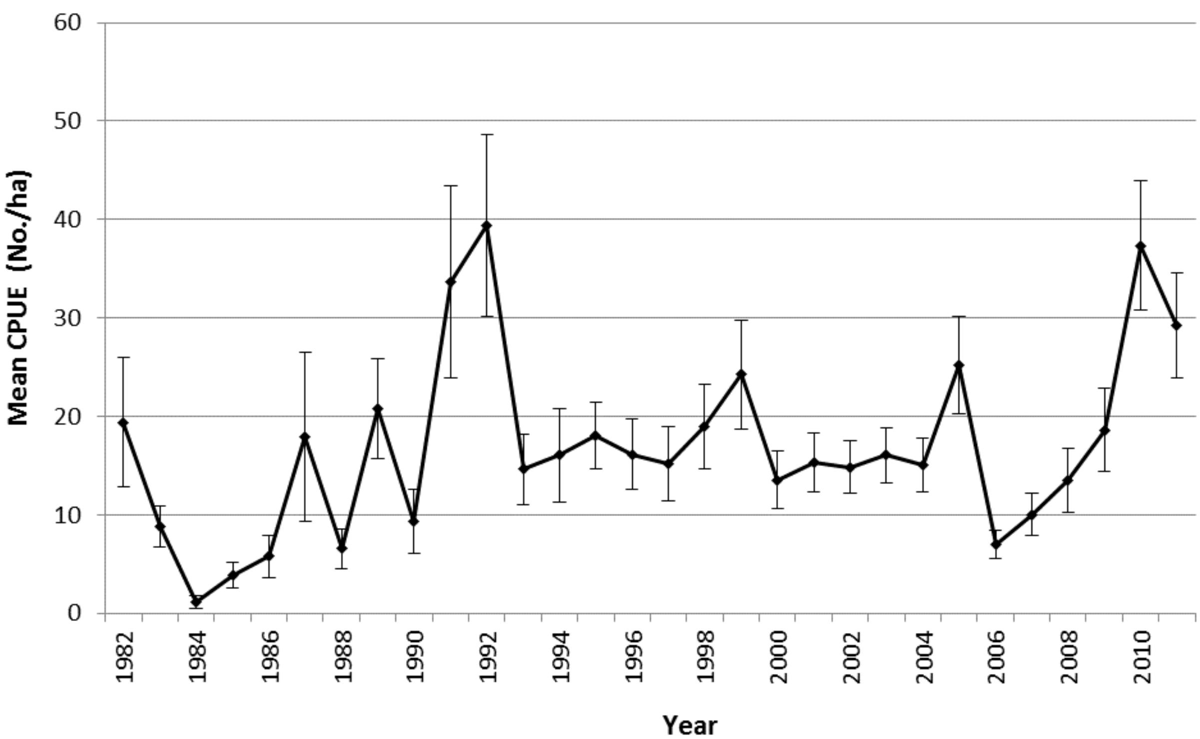


Figure 2.33 Spotted seatrout annual mean seine catch rate ± standard error.

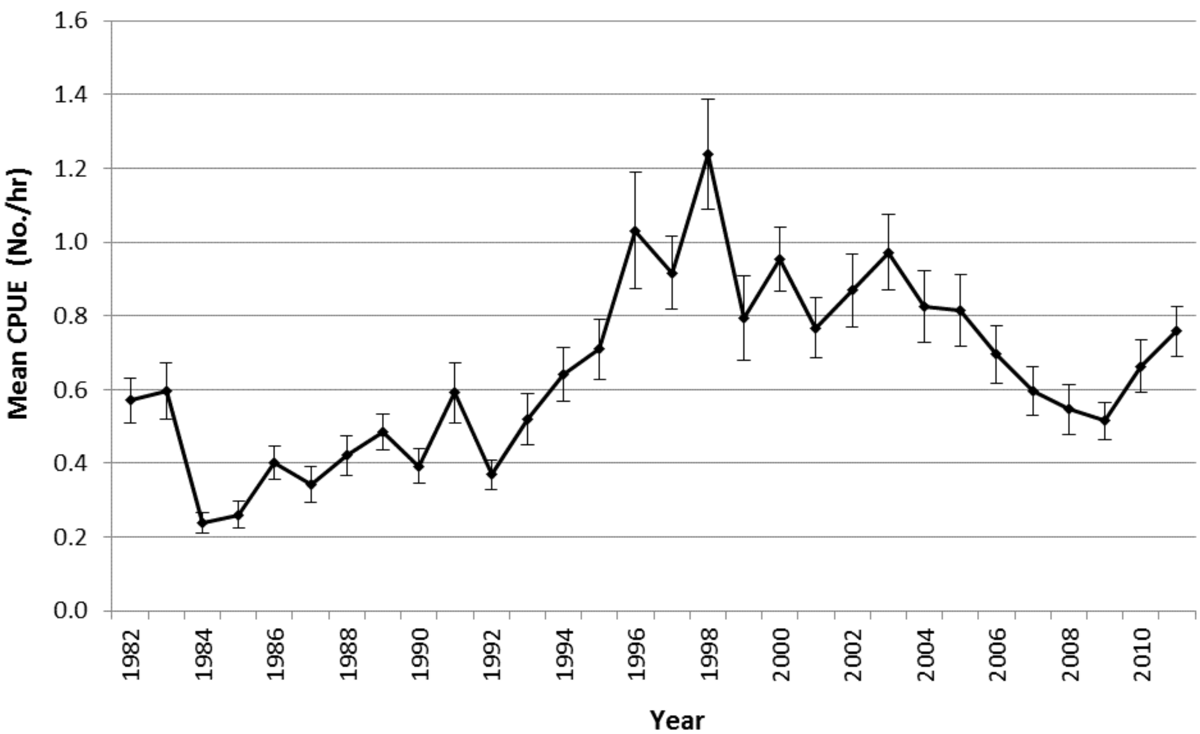


Figure 2.34 Spotted seatrout annual mean gill net catch rate ± standard error.

Gulf menhaden, *Brevoortia patronus*, were common in all three gears, occurring 10%, 35%, and 25% in seine, trawl, and gill net samples, respectively. They were numerous in seine and trawl samples accounting for over 9% and 4% of the catch, respectively. The last decade saw a rebound in gill net catches with the top 3 annual CPUEs occurring in 2002–2004 (Figure 2.35). This would suggest that menhaden also benefitted from reduced shrimping effort. Fuls et al. (2002) also reported menhaden to be a large component of SAB commercial shrimp fishery bycatch. Additionally, 2002 and 2004 also saw large freshwater inflow events which could have impacted menhaden populations.

Menhaden exhibit a patchy distribution across the estuary, meaning that it was not uncommon for a large percentage of the catch to occur in a small percentage of samples. This resulted in the large standard errors seen in Figures 3.35, 3.36, and 3.37. Large standard errors make it difficult to establish a trend with confidence.

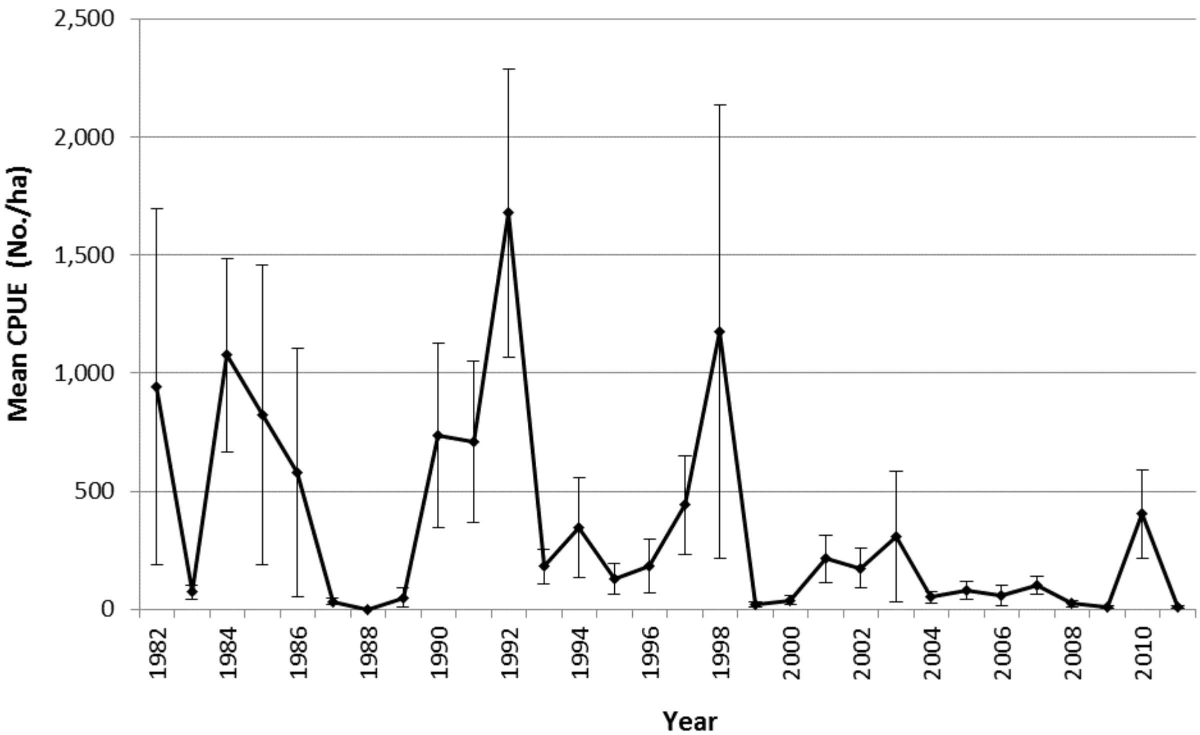


Figure 2.35 Gulf menhaden annual mean seine catch rate ± standard error.

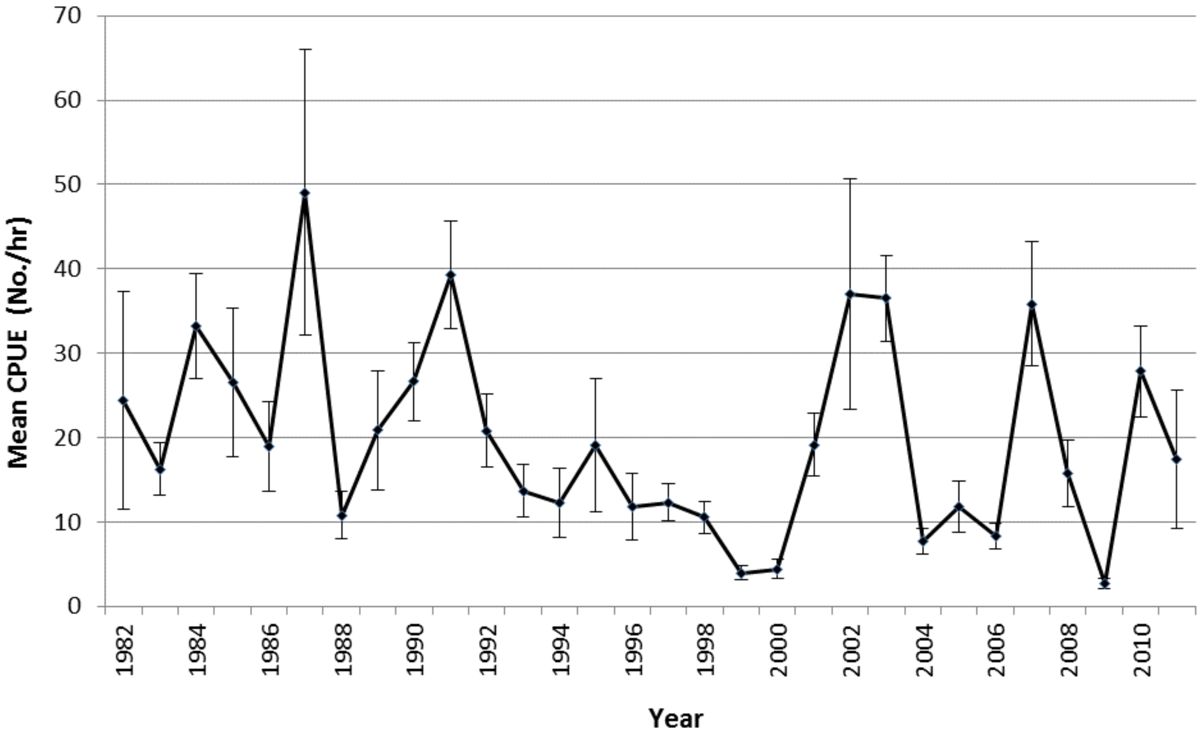


Figure 2.36 Gulf menhaden annual mean trawl catch rate ± standard error.

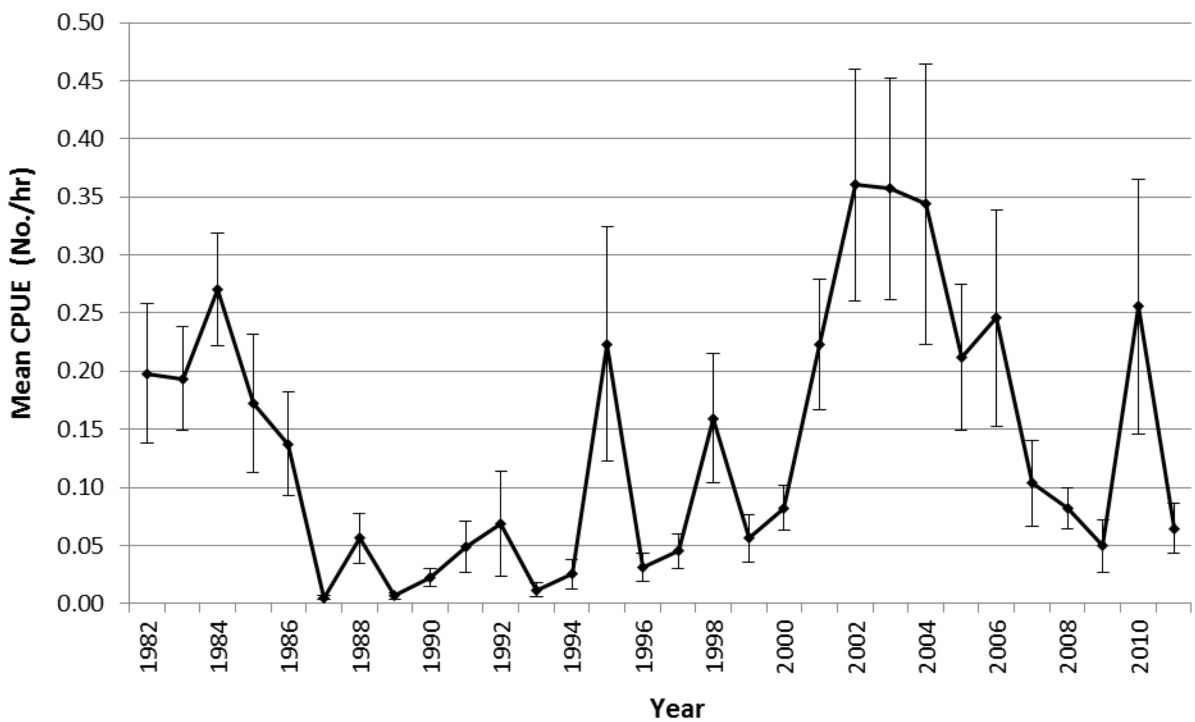


Figure 2.37 Gulf menhaden annual mean gill net catch rate ± standard error.

Gafftopsail Catfish, *Bagre marinus*, are one of two marine catfish species occurring on the Texas coast, and were commonly caught in trawl and gill net samples at 16% and 65% of samples, respectively. They were also plentiful in these two gears making up 2% and 9% of trawl and gill net catch, respectively. Gafftopsail catfish are truly a euryhaline species, being found in all salinities and all areas of the estuary (Figure 2.125). In 1996-97, both hardheads and gafftopsail catfish juveniles were the victims of a virus that occurred on the upper Texas coast including the San Antonio Bay System. The associated mortality may have contributed to the reduced trawl catches for several years afterwards. Gafftop appear to have also benefitted from the reduced shrimping effort in the last decade, exhibiting dramatically increased trawl catches (Figure 2.38). Also, the gill net catch has exhibited an increasing trend since gill nets were banned in 1988 (Figure 2.39). Although gafftop are not often harvested commercially, these data suggest that they were being impacted by both the trawl and gill net commercial fisheries as bycatch. With the gill net ban and the decrease in shrimping effort, the gafftop population has increased.

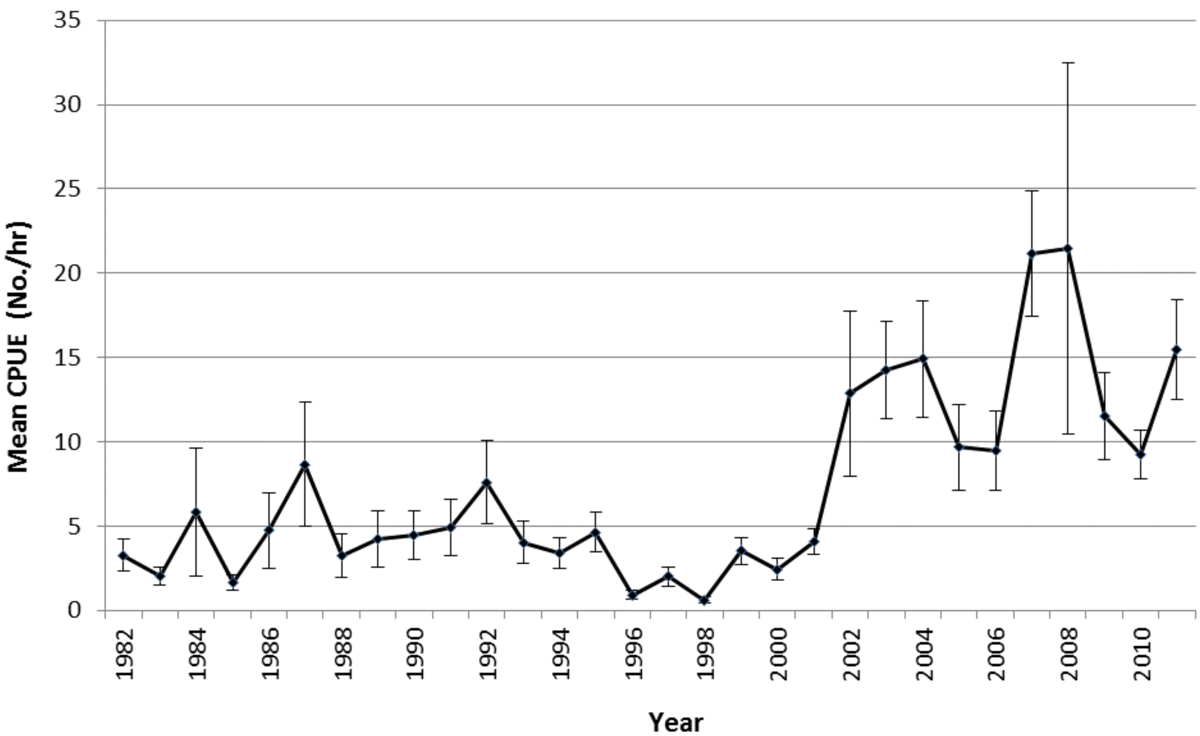


Figure 2.38 Gafftopsail catfish annual mean trawl catch rate ± standard error.

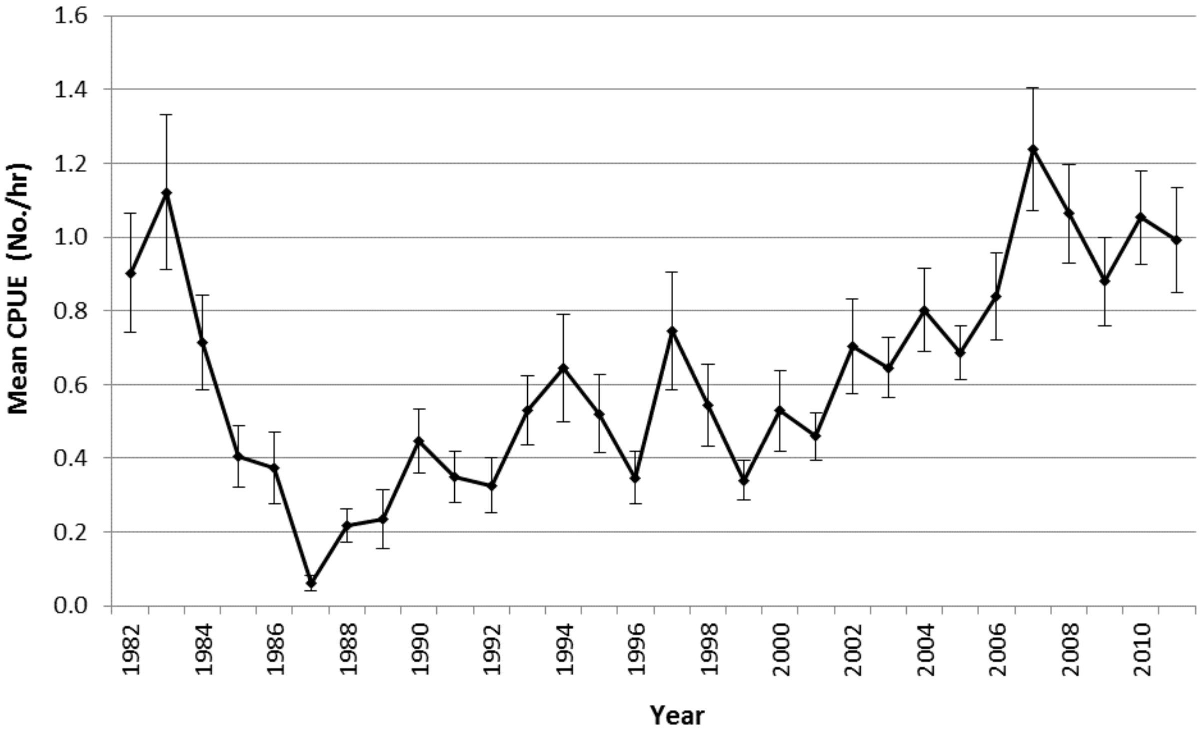


Figure 2.39 Gafftopsail catfish annual mean gill net catch rate ± standard error.

Hardhead Catfish, *Ariopsis felis*, were very common participants in the trawl and gill net sampling, occurring in 37% and 95% of the samples, respectively, and though they were not very numerous in trawl samples at less than 2% of the catch, they dominated the gill net samples with over 22% of the catch. The 22% of the catch and 95% of the samples were the most for any species in any gear.

Considering that hardhead catfish were a substantial component of the gill net catch, it's reasonable to assume they were also impacted by the commercial gill net fishery before nets were banned in 1988. In fact, this was the case as is exhibited by the increased catches immediately after nets were banned in 1988 (Figure 2.41). Also, in 1996-97, both hardheads and gafftopsail catfish juveniles were the victims of a virus that occurred on the upper Texas coast including the San Antonio Bay System. The associated mortality may have contributed to the reduced CPUEs for several years afterwards (Figures 2.40 and 2.41). While both trawl and gill net CPUEs appear to have recovered from the virus-related mortality, gill net catch was still below the 1989-1997 highs.

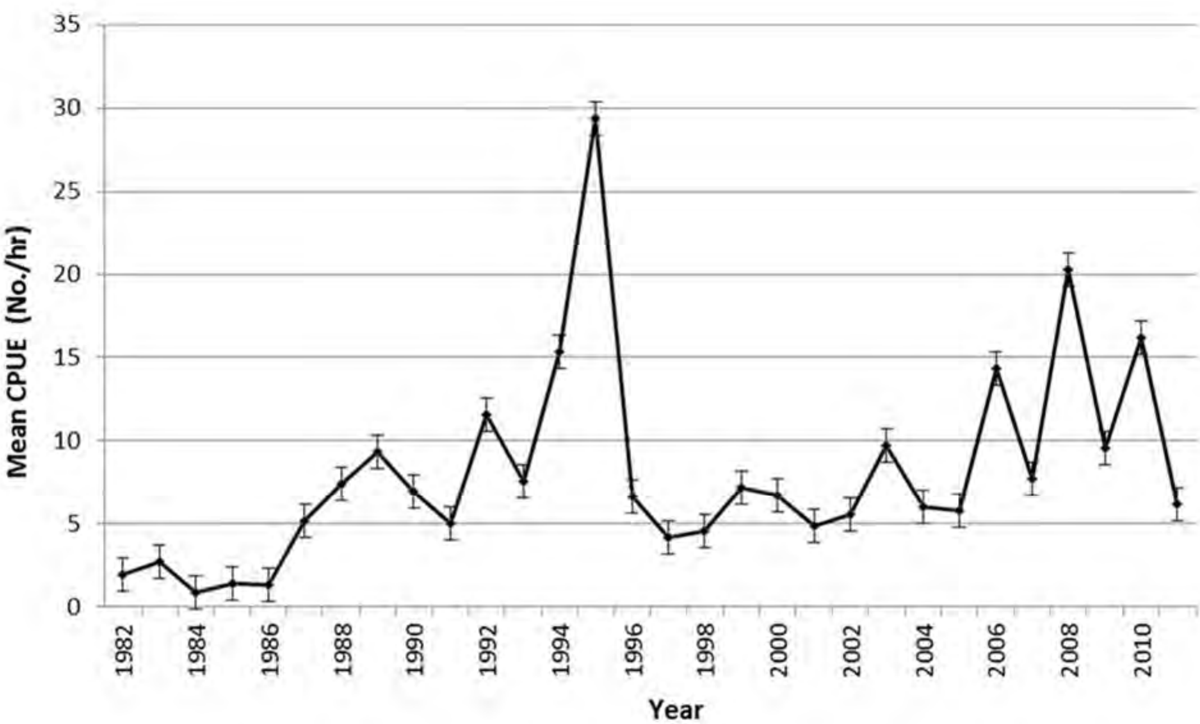


Figure 2.40 Hardhead catfish annual mean trawl catch rate ± standard error.

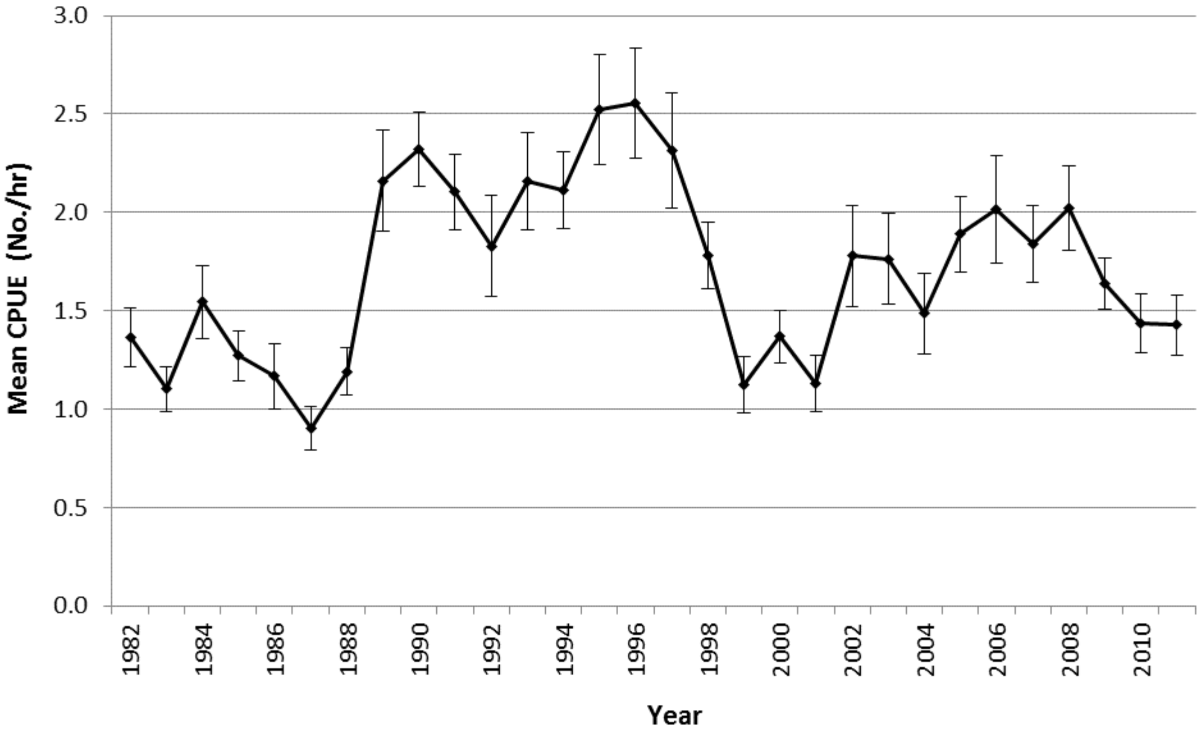


Figure 2.41 Hardhead catfish annual mean gill net catch rate ± standard error.

Atlantic Brief Squid, *Lolliguncula brevis*, were a noteworthy catch only in trawl samples, making up 2% of the catch and occurring in 26% of the samples. The brief squid is one of three squid species found in San Antonio Bay System but the only one that is common. As a common participant in the trawl samples, it is assumed that brief squid were also impacted by the commercial shrimp trawl fishery. The increased catches corresponding with the decreased shrimping effort would seem to support this assumption (Figure 2.42) as does the 1994-95 bycatch study (Fuls et al 2002).

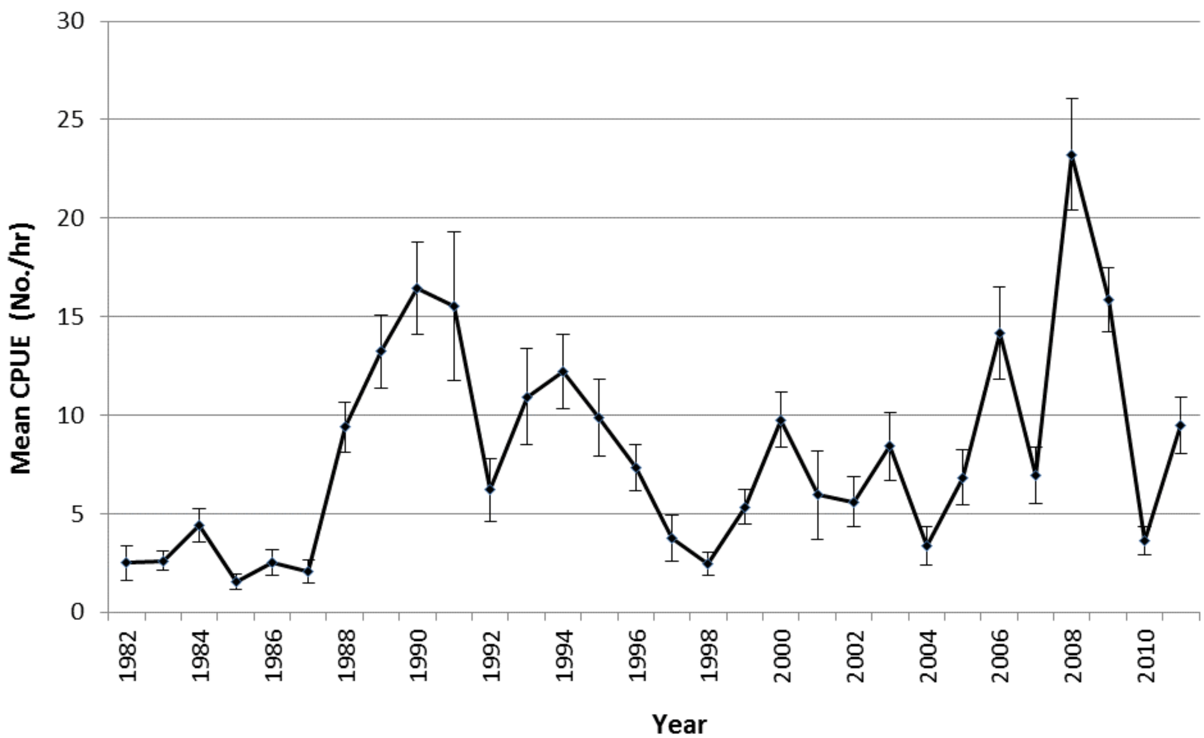


Figure 2.42 Atlantic brief squid annual mean trawl catch rate ± standard error.

Bay whiff, *Citharichthys spilopterus*, small flat-fish, were not numerous in any gear though they occurred in 10% of the trawl samples. Bay whiffs are not harvested commercially or recreationally because of their small size. This small size and their tendency to lay flat on the bottom render them less susceptible to most fishing gears. Their population as indicated by the trawl data was highly variable with no discernible trend (Figure 2.43).

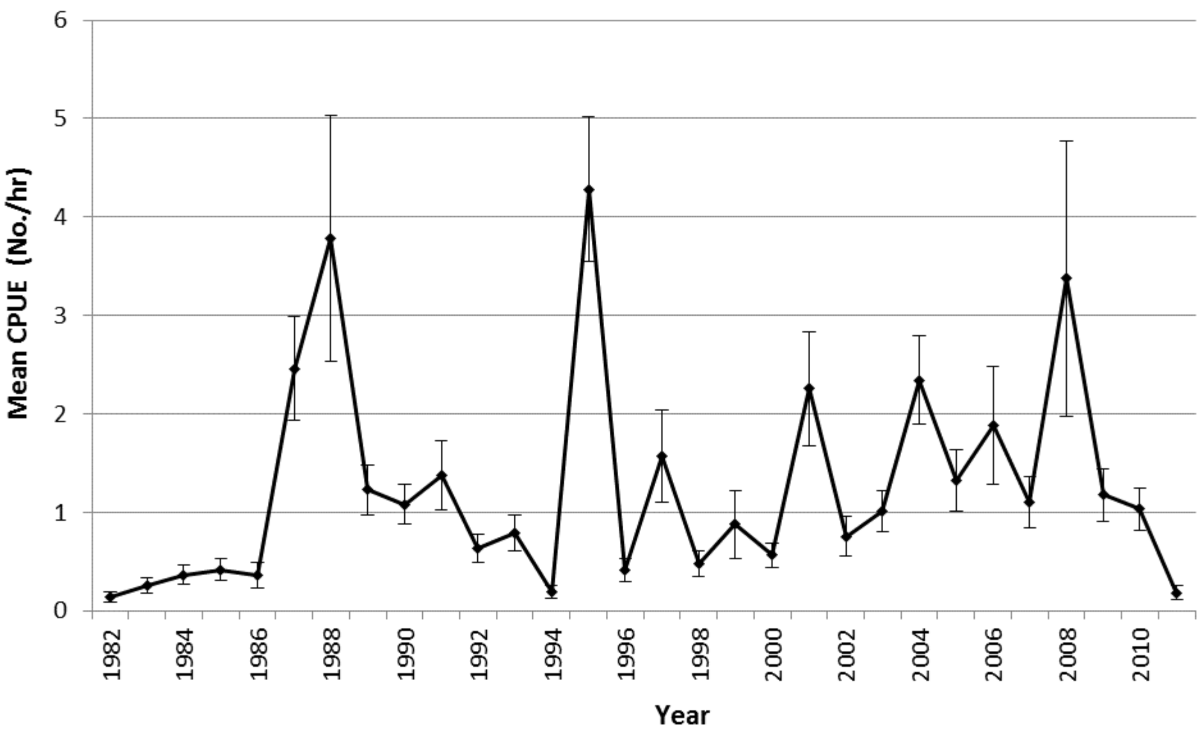


Figure 2.43 Bay whiff annual mean trawl catch rate ± standard error.

Lesser Blue Crab, *Callinectes similis*, were not numerous in any gear and occurred in 13% of the trawl samples. These invertebrates were generally caught in areas of the estuary where salinities were higher (i.e. 1989, 1996, 2000, 2009; Figure 2.129). Their trawl CPUE trend was stable and low other than during high-salinity years when they move into the bay in larger numbers (Figures 2.44 and 2.129).

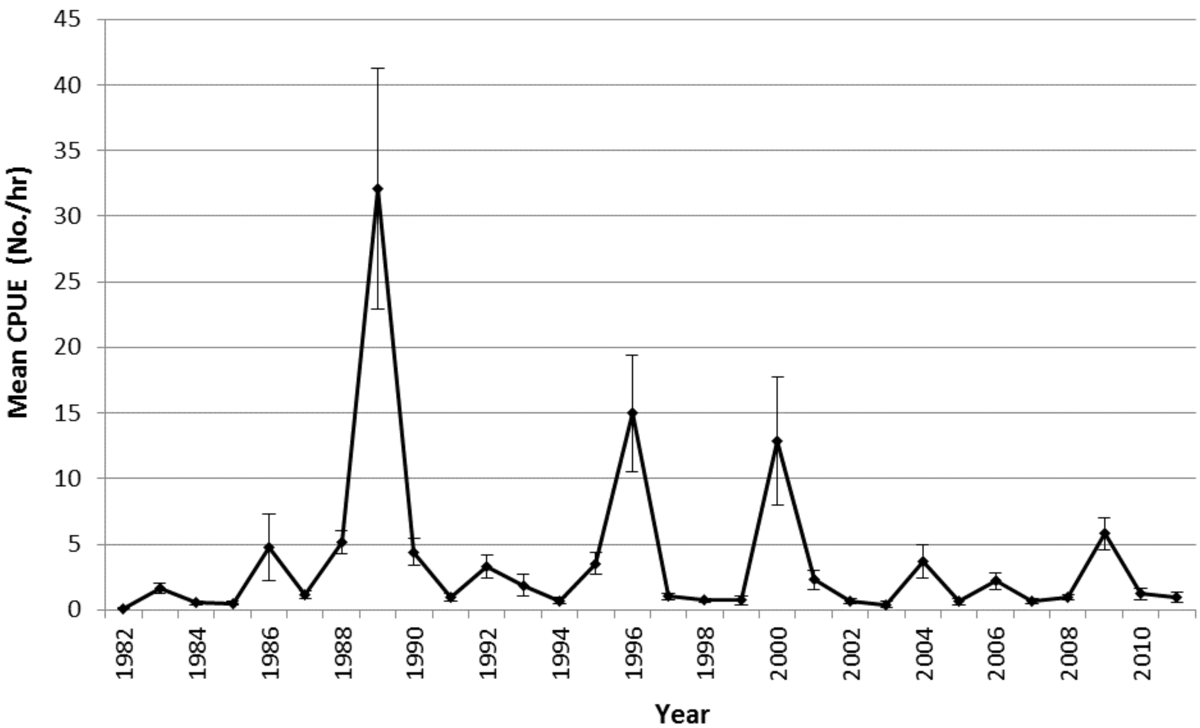


Figure 2.44 Lessor blue crab annual mean trawl catch rate ± standard error.

Pink shrimp, *Farfantepenaeus duorarum*, one of the three commercially harvested shrimp in the estuary, were not numerous in any gear but were present in 19% of the trawl samples. This species is active primarily at night or when the bay waters are very turbid. For this reason the commercial pink shrimp season is the only night time commercial shrimp fishery in Texas waters. Because the TPWD trawl sampling is a daytime program, pink shrimp were not caught in large numbers (Figure 2.45). Their CPUEs were variable and low, while the trend was relatively stable within this variation. Because of the nocturnal nature of their activity and water clarity variability in the estuary, the estuarine population trend is difficult to ascertain. Also, because this species, like the other commercial shrimp species, uses the estuary for only a portion of their life cycle, this estuarine population may not be representative of the Gulf population as a whole.

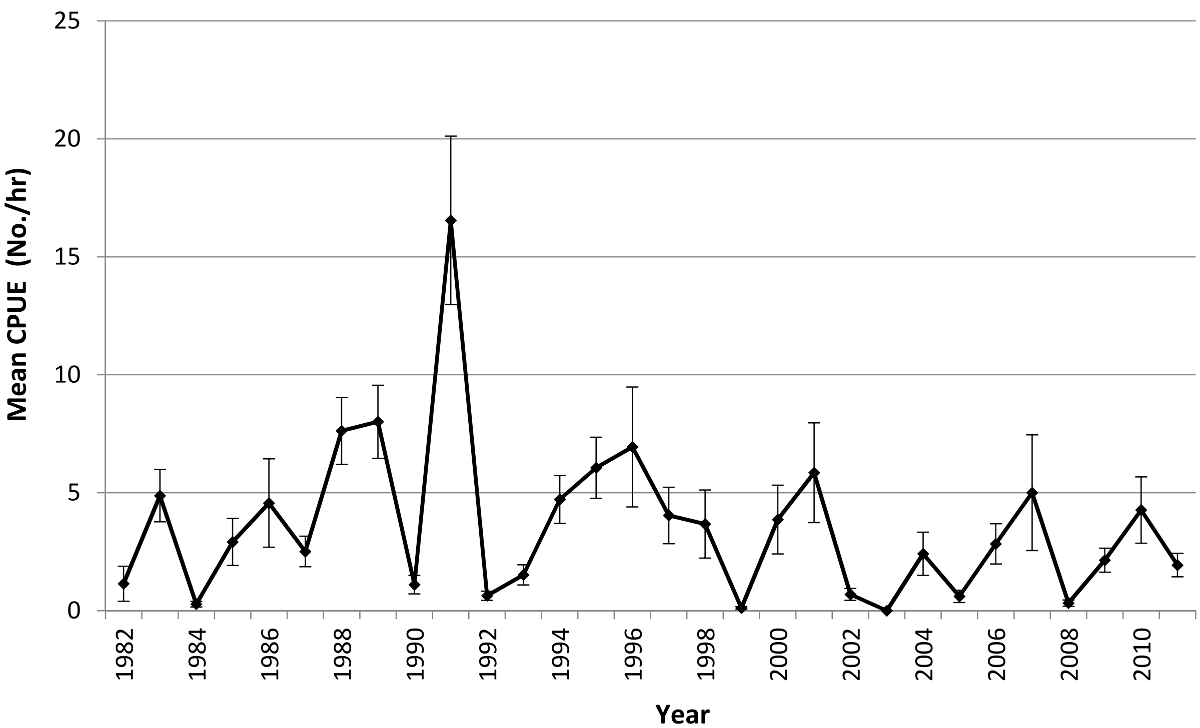


Figure 2.45 Pink shrimp annual mean trawl catch rate ± standard error.

Black drum, *Pogonias cromis*, were a noteworthy component of only gill net samples where they occurred in 87% of all samples and made up 15% of the total catch. Only hardhead catfish were more numerous in this gear, and only hardheads and red drum occurred more frequently. Black drum is one of the more dominant large fish in the estuary and were a major component of the of gill net data assemblage analysis. And despite there being a substantial commercial fishery for black drum from 1994 through about 2008 (Figure 2.74), the population has been increasing since gill nets were banned in 1988 (Figure 2.46). Additionally, with commercial landings greatly reduced by 2010, the only harvest pressure is a small recreational fishery.

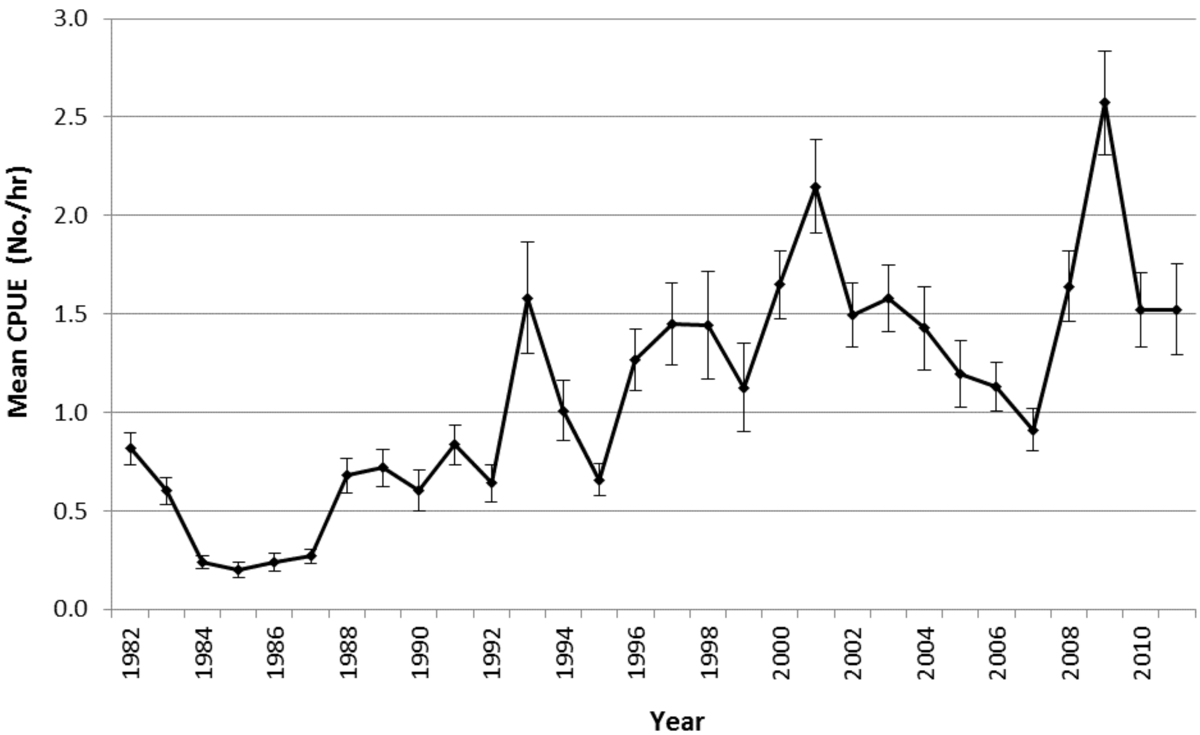


Figure 2.46 Black drum annual mean gill net catch rate ± standard error.

Gizzard Shad, *Dorosoma cepedianum*, comprised over 6% of the gill net catch and were present in over 53% of the samples. Despite being primarily a freshwater fish, gizzard shad were common in the upper half of the estuary (Figure 2.137). Over the last 20 years the CPUE trend has been variable with no discernible direction (Figure 2.47). Because gizzard shad are a primarily freshwater species, consequently the estuarine population trend may not be representative of the entire population.

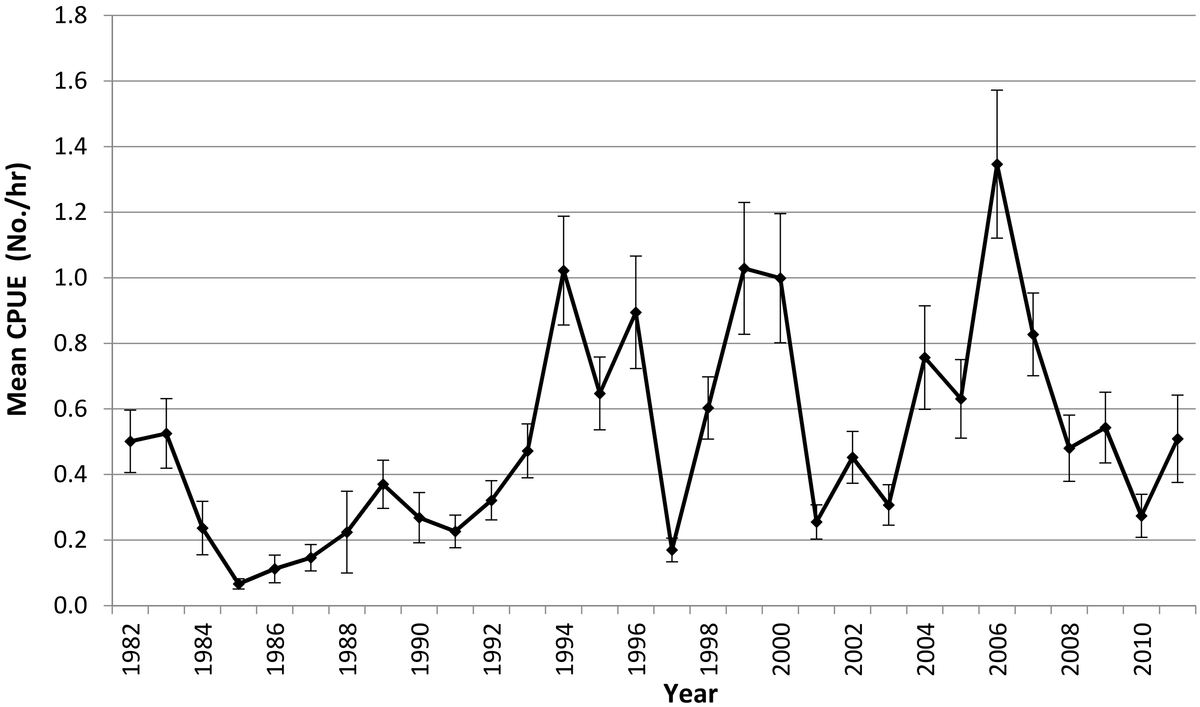


Figure 2.47 Gizzard shad annual mean gill net catch rate ± standard error.

Blue catfish, *Ictalurus, furcatus*, a freshwater catfish, comprised less than 2% of the gill net catch while occurring in over 10% of the samples. “Blue cats,” as they are referred to, were caught primarily in the upper half of the estuary (Figure 2.142) and because this is primarily a freshwater species the overall population trends may not be discernible with only marine samples. There has been very little commercial or recreational interest in blue catfish in SAB; therefore their estuarine numbers were probably a result of fluctuations in the environment and their aversion to higher salinities (Figures 2.48 and 2.142).

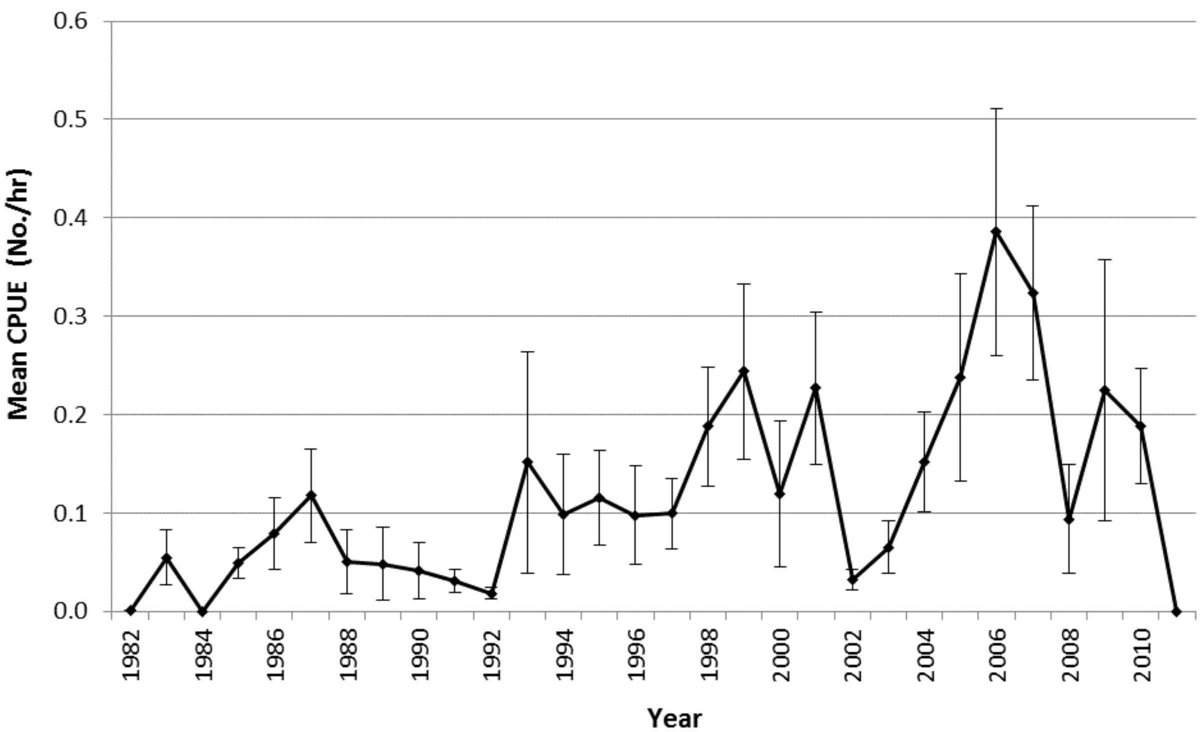


Figure 2.48 Blue catfish annual mean gill net catch rate ± standard error.

Lady fish, *Elops saurus*, a close relative of tarpon, exhibited an amazing population trend as measured by gill net data. Occurring in 32% of all gill net samples and comprising 2% of the catch, the lady fish population increased approximately ten fold during the last decade before ending the decade up about seven fold (Figure 2.49). Prior to the increase, their population had been very stable for over 15 years. There was no recorded commercial or recreational harvest of lady fish and there is no readily identifiable explanation for their dramatic increase in abundance over the last decade. Because this species is very active predator it's possible their population is responding to the increase in other fish populations resulting from reduced shrimping effort. For example, their population increase was coincident with the population declines of longnose killifish, gulf killifish, and sheepshead minnow, known to be part of the lady fish diet (Patillo 1997). These phenomena may be related or stem from a common cause.

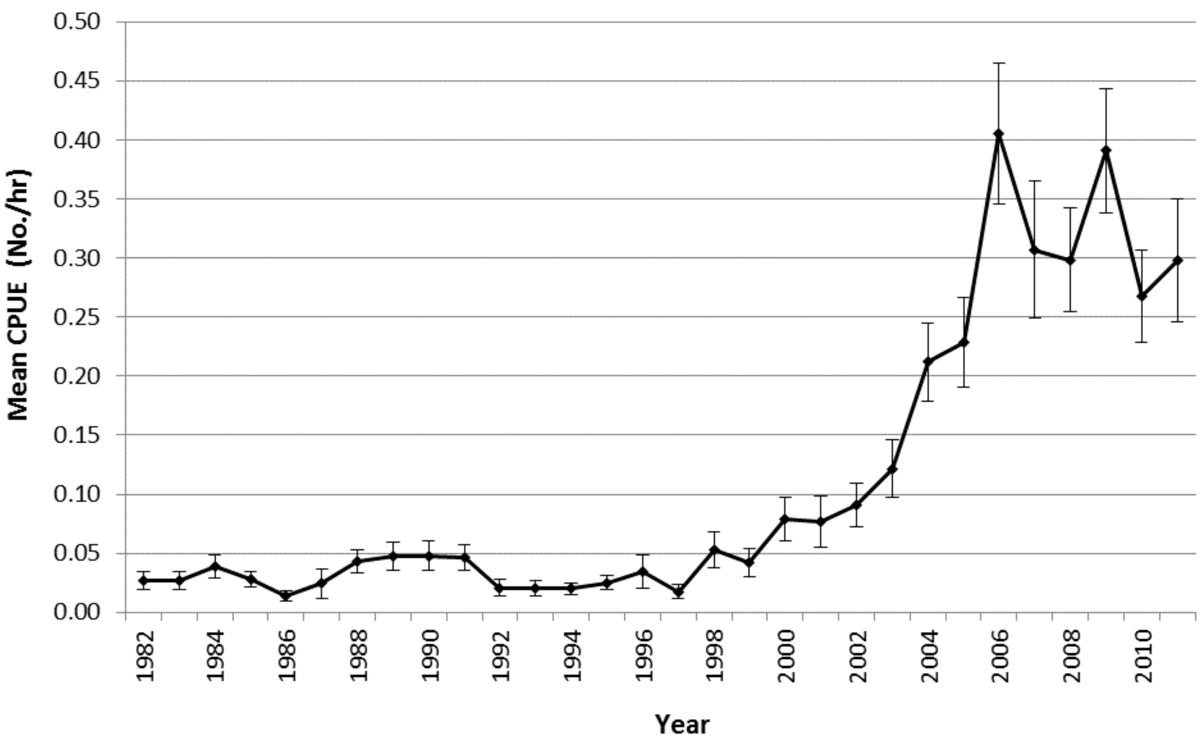


Figure 2.49 Lady fish annual mean gill net catch rate ± standard error.

Alligator gar, *Atractosteus spatula*, primarily freshwater fish, were present in 32% of gill net samples, comprising less than 2% of the catch. Like blue catfish and gizzard shad, alligator gar were caught primarily in the upper half of the estuary (Figure 2.144) where the catch rate was highly variable (Figure 2.50). Alligator gar numbers are thought to be in jeopardy and harvest restrictions have been implemented recently to promote conservation of the species. There was limited commercial and recreational harvest for this species in San Antonio Bay System. This species was a major component in the gill net analysis that demonstrated a significant difference between the Sabine Lake system and the estuarine group including SAB. Considering this is a primarily freshwater species, the overall population trends may not be discernible in estuarine data.

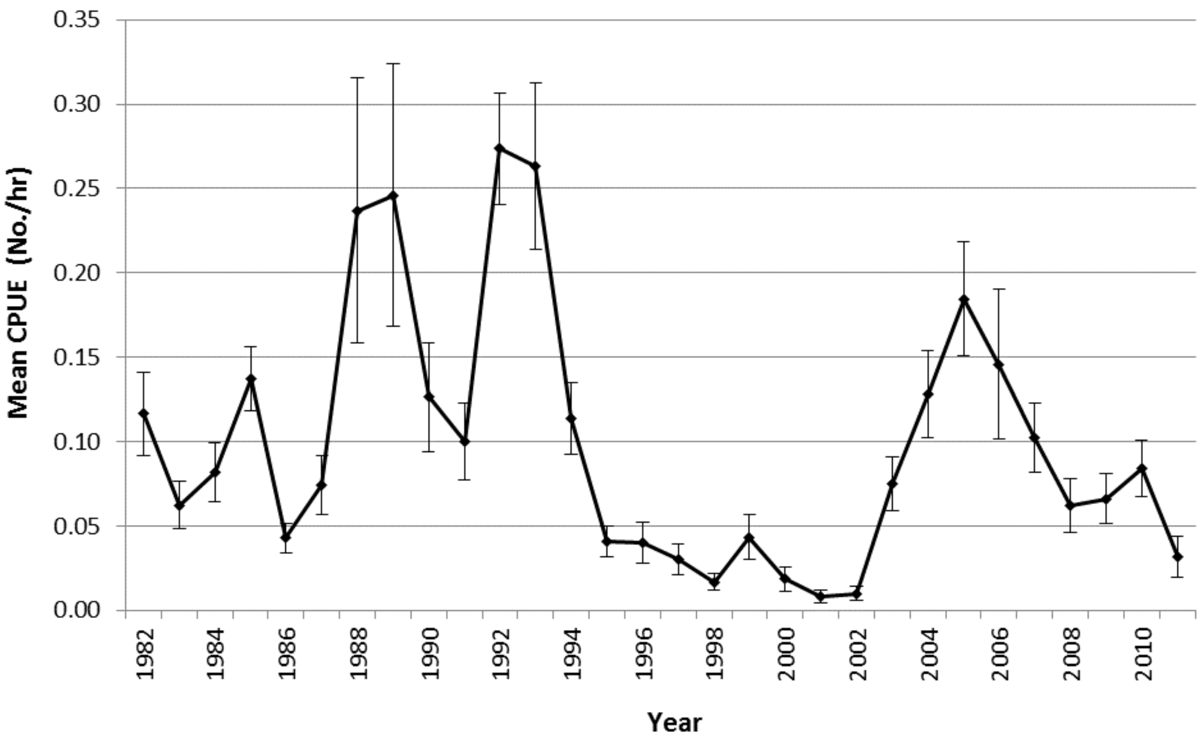


Figure 2.50 Alligator gar annual mean gill net catch rate ± standard error.

Spotted Gar, *Lepisosteus oculatus*, also primarily freshwater fish, were not as numerous or common as alligator gar. Spotted gar were usually caught in very low salinity areas near the river (Figure 2.149) where they were less than 1% of the total gill net catch and present in 10% of the samples. There are no commercial or recreational fisheries, and until recent years their estuarine CPUE had been consistently low (Figure 2.51). As with several other primarily freshwater species, these data from the marine environment may not be representative of the overall population.

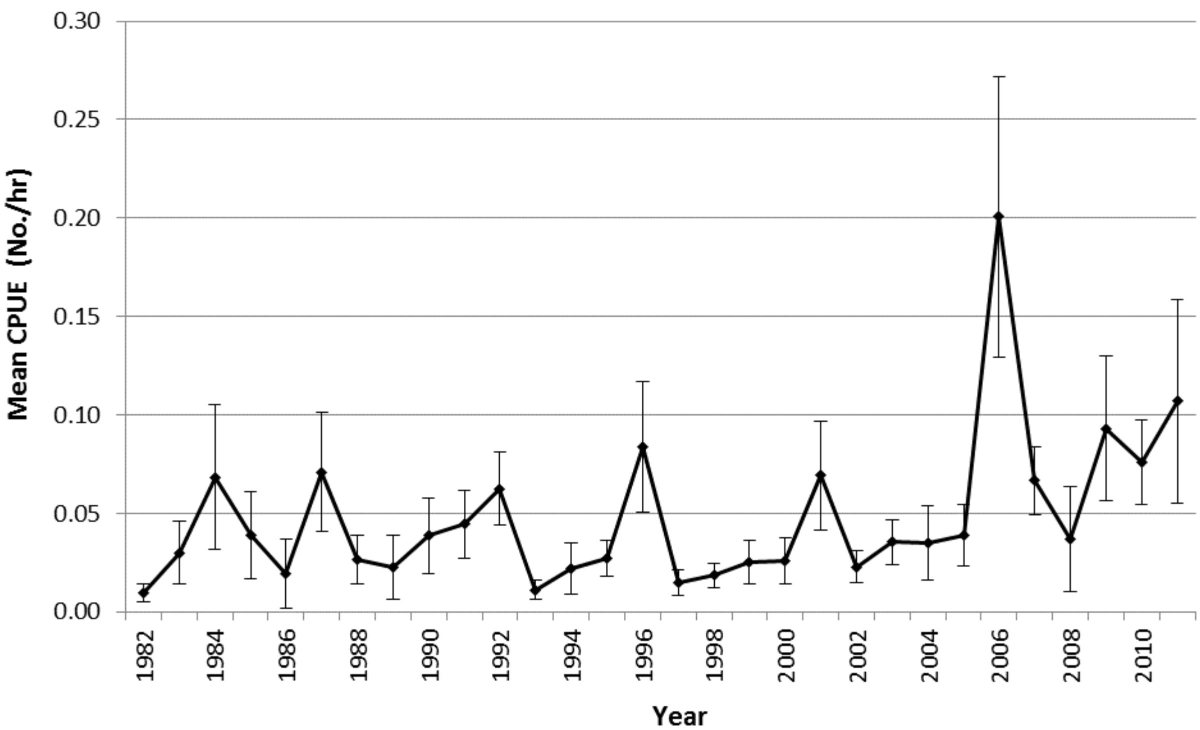


Figure 2.51 Spotted gar annual mean gill net catch rate ± standard error.

Southern flounder, *Paralichthys lethostigma*, appeared in 42% of the gill net samples in low numbers. The population had been trending dramatically downward until recently and has yet to fully recover even though the 2011 gill net catches were the highest since 1999 (Figure 2.52). Flounder are targeted both commercially and recreationally and have been the subject of harvest restrictions on multiple occasions to protect the population and affect recovery. With both warming bay waters and overfishing implicated as contributors to the population decline, recovery is not assured.

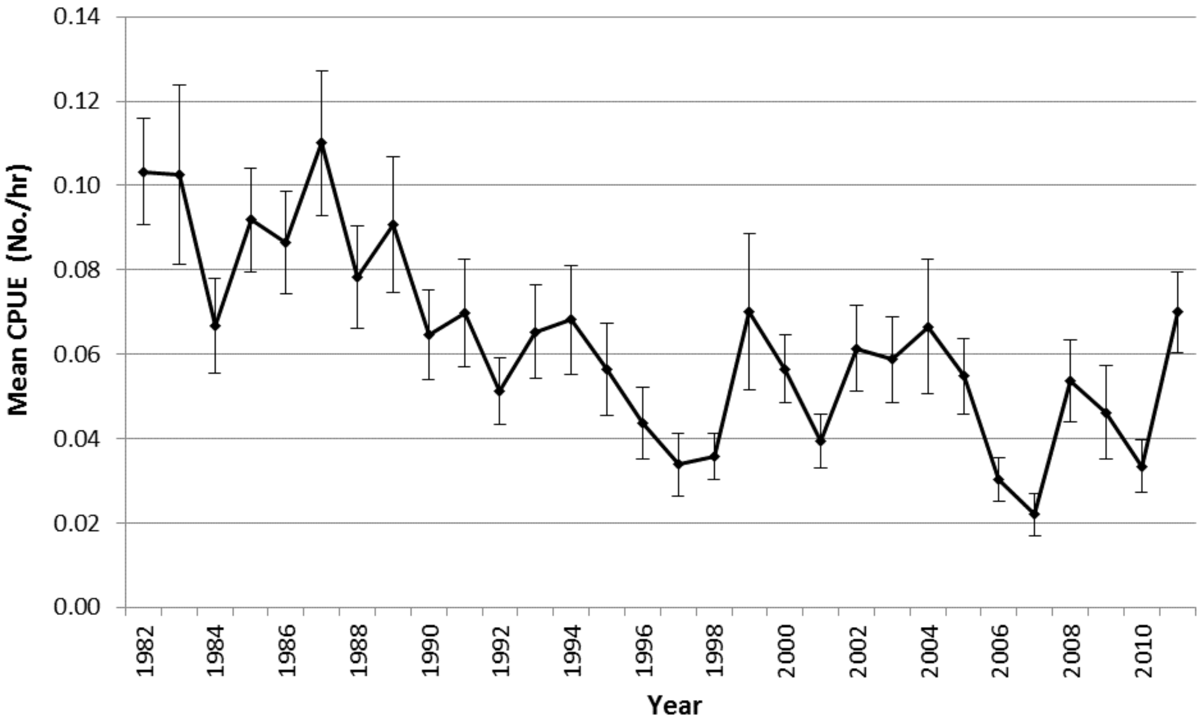


Figure 2.52 Southern flounder annual mean gill net catch rate ± standard error.

Atlantic stingrays, *Dasyatis Sabina*, were present in 10% of the gill net samples in small numbers. Their shape and bottom dwelling behavior, similar to flounder, contributed to very low and variable catch rates, with the highest annual CPUE occurring in 2011 (Figure 2.53).

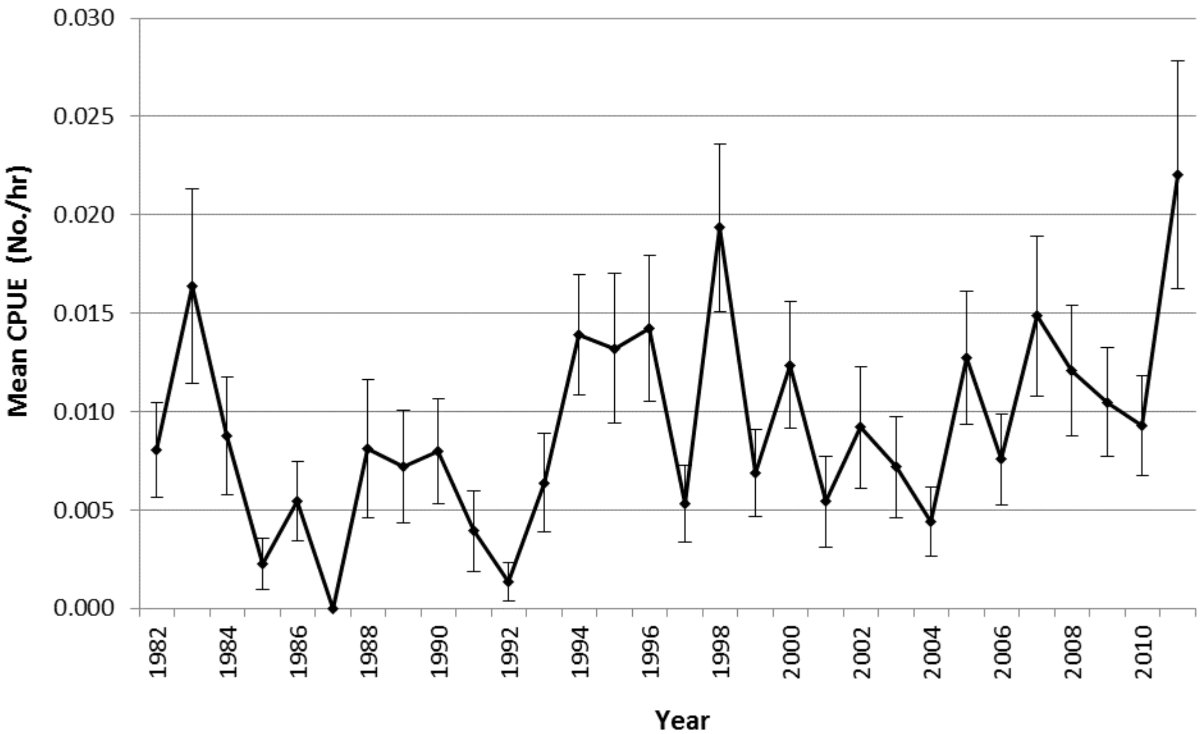


Figure 2.53 Atlantic stingray annual mean gill net catch rate ± standard error.

Bull sharks, *Carcharhinus leucas*, the only common shark in any gear, appeared in 31% of gill net samples in low numbers. Bull sharks caught in the estuary are generally juveniles or young adults and so do not represent the population of adults. The gill net catch rates are stable relative to other species, with no discernible trend (Figure 2.54).

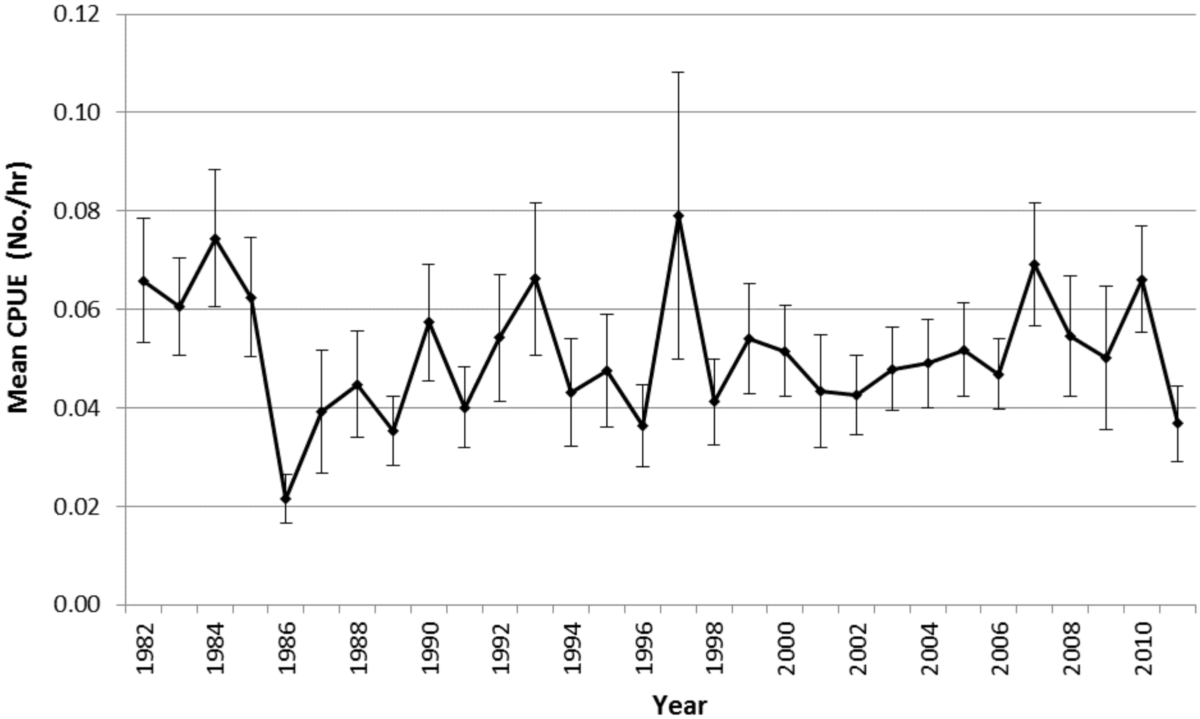


Figure 2.54 Bull shark annual mean gill net catch rate ± standard error.

Sheepshead, *Archosargus probatocephalus*, appeared in almost half of the gill net samples, comprising more than 2% of the catch. Prior to 1995 they were much less commonly caught in gill nets; however, the population increased dramatically between 1994 and 1996 (Figure 2.55). Despite slowly shrinking since the 1996 peak, the population remains substantially above the pre-1995 trend.

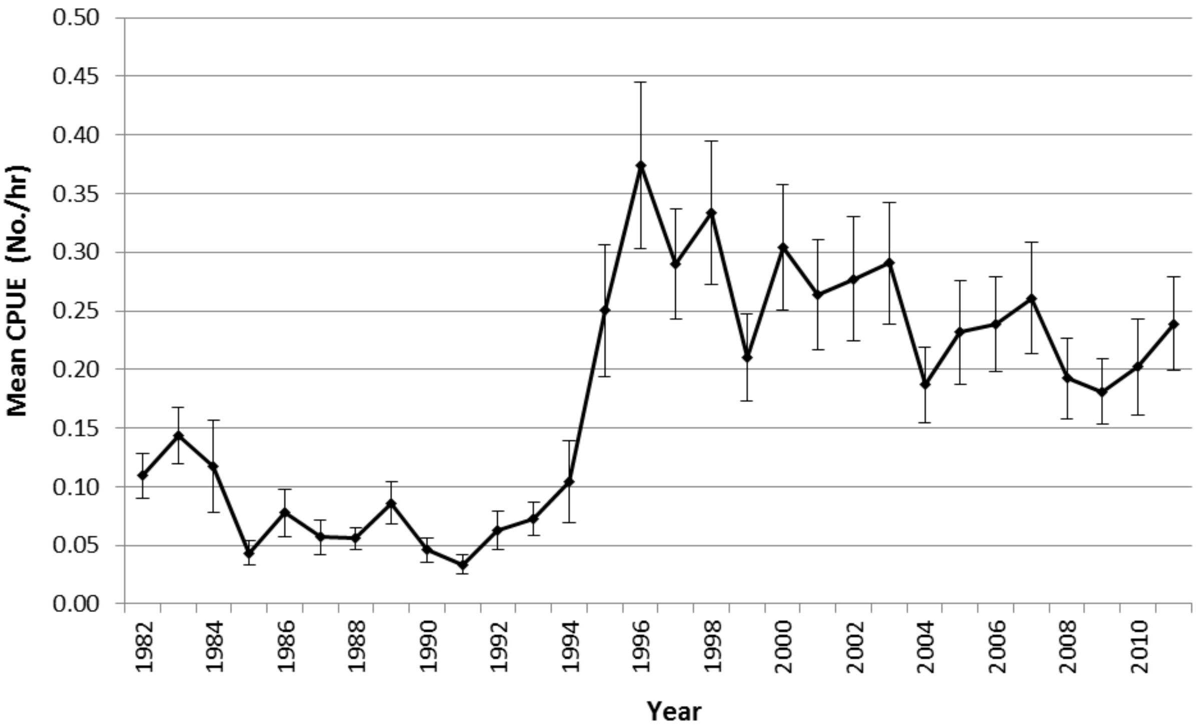


Figure 2.55 Sheepshead annual mean gill net catch rate ± standard error.

Silver perch, *Bairdiella chrysoura*, small predatory fish, were not numerous in any gear but were common in trawls occurring in over 30% of all samples. Their population trend is similar to Atlantic croaker and brown shrimp with increased catches in the last decade (Figure 2.56). Being most often caught in open water indicates they were susceptible to commercial shrimp trawlers. This was confirmed by Fuls et al (2002) who reported that silver perch were a conspicuous component of the San Antonio Bay System shrimp fishery bycatch. Consequently, the reduced effort in this fishery probably contributed to the increased catches seen in the last decade, though the catch rates were very low and variable.

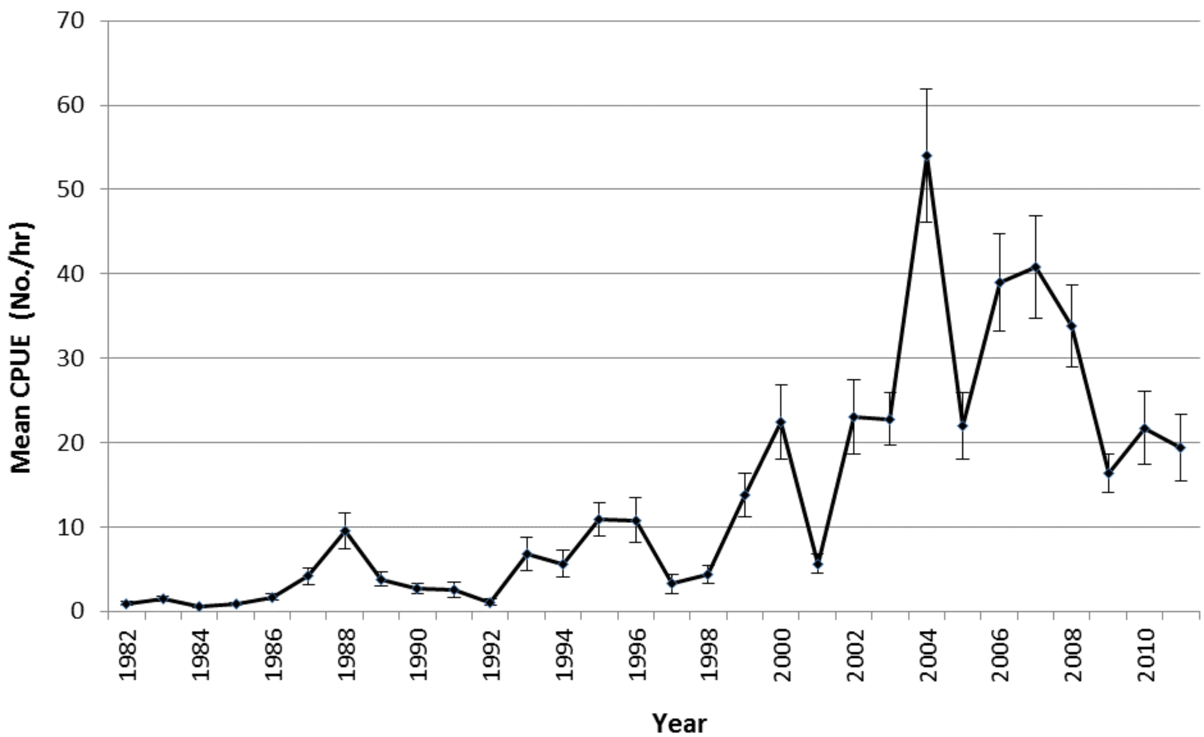


Figure 2.56 Silver perch annual mean trawl catch rate ± standard error.

Gulf stone crab, *Menippe adina*, occurred in 11% of the gill net samples. It was not numerous and generally restricted to higher salinities (Figure 2.57). Their abundance appears to increase during periods of higher salinity. This species is an incidental harvest in the blue crab commercial fishery.

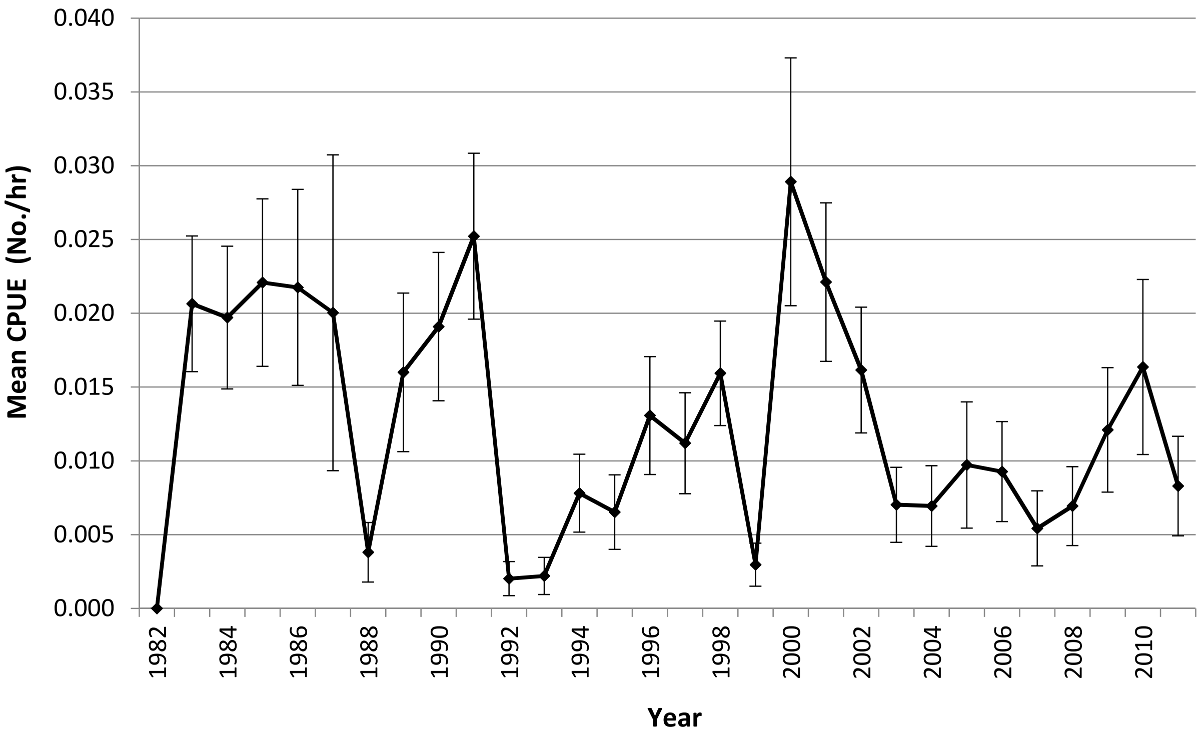


Figure 2.57 Gulf stone crab annual mean gill net catch rate ± standard error.

Fishery Dependent Data

Recreational Harvest

Effort: Recreational fishing effort, both private and party boat activity, has increased in SAB over the last 30 years (Figures 2.58 and 2.59). Though private boat effort decreased markedly after the 1983 and 1989 freezes, due to substantial fish mortality, it has since climbed to an annual average of about 438,000 angler hours over the last 10 years. After the substantial loss of fish to the two 1989 freezes, fishing briefly became less successful, and effort decreased as a result. Party boat effort was very low until 1997-98 when it began to increase rapidly with an increase in fishing guides who were using the Port O'Connor area. This increase in effort was preceded by an increase in spotted seatrout availability (Figure 2.34) accompanied by an increase in party boat landings (Figure 2.61). Over the last 10 years, party boat effort has averaged about 63,000 angler hours per year. The only substantial changes in angler origin over the past 30 years was a 6% decrease and 5% increase in the proportion of Victoria County and Calhoun County anglers, respectively (Figure 2.60).

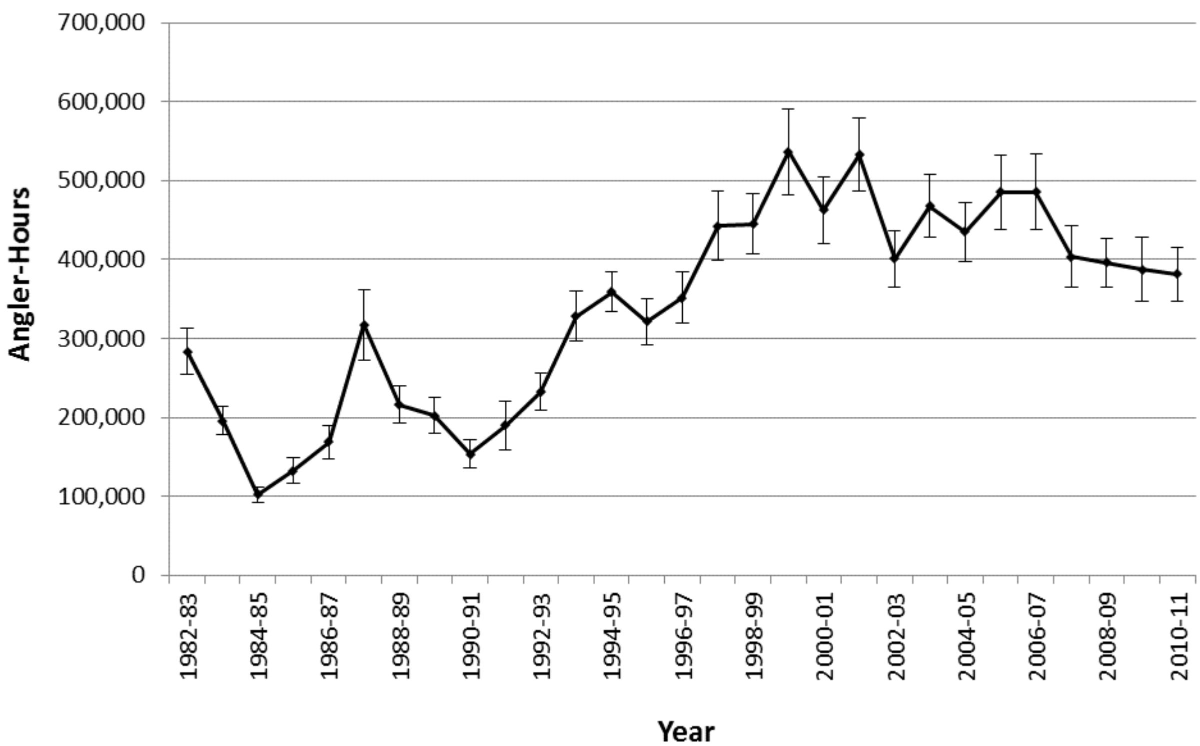


Figure 2.58 Private boat effort ± standard error.

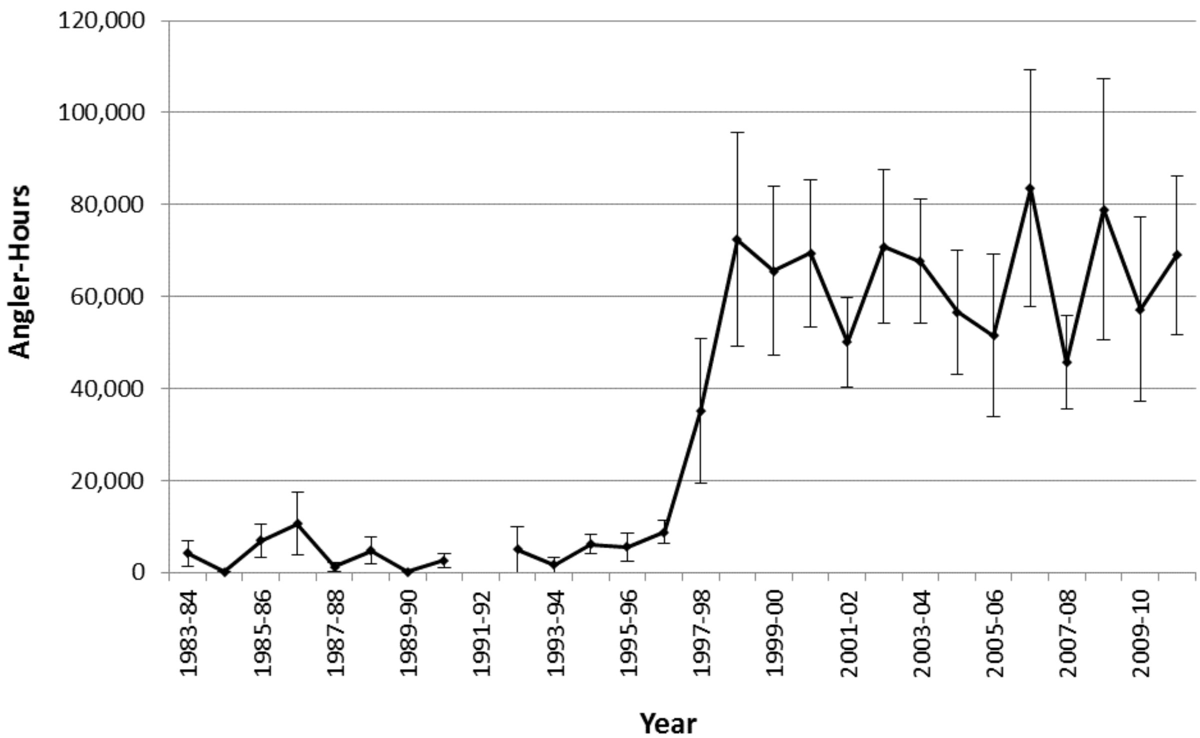


Figure 2.59 Party boat effort ± standard error.

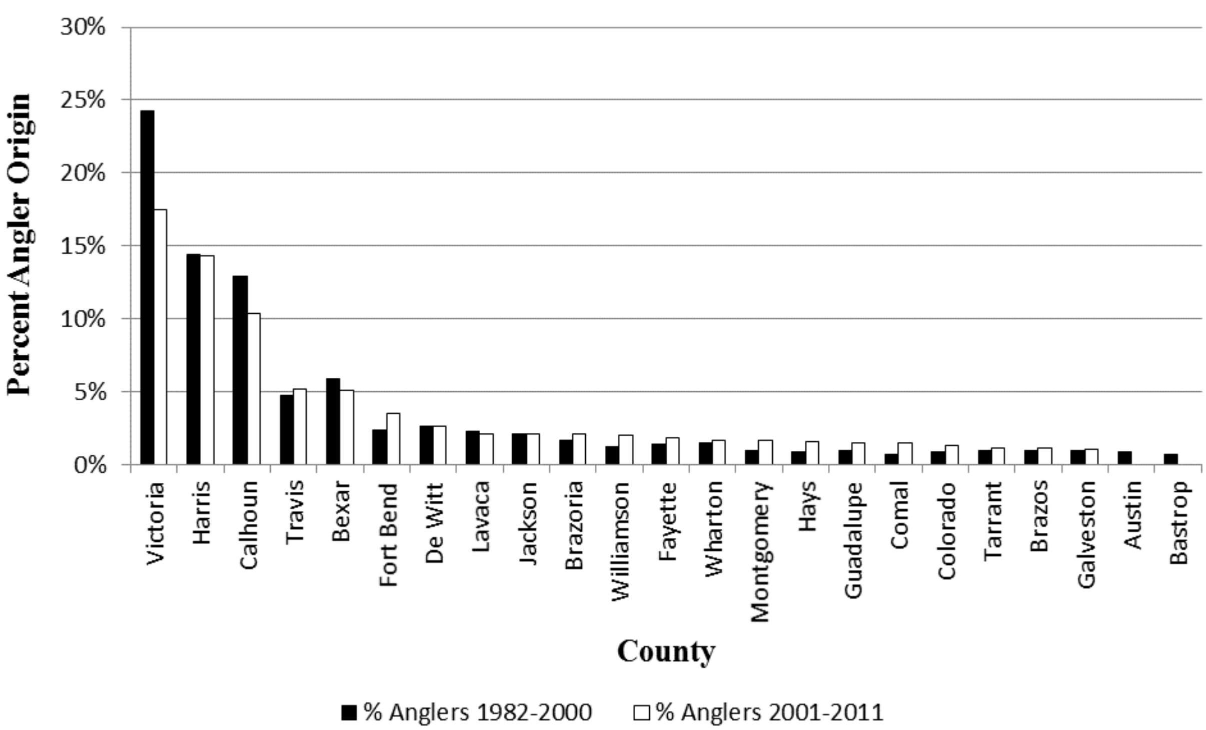


Figure 2.60 Angler origin county 1982-2000 and 2001-2011.

Spotted seatrout were landed by SAB recreational anglers more than any other fish. This is due to having a generous bag limit of 10 fish per day and their reputation for being good sport and table fare. In combination with red drum, they are listed most frequently by anglers during on-site angler surveys as the targeted species.

Private boat landings began to increase in 1991-92 after the 1989 freezes and remained high from the late 1990s through the mid-2000s (Figure 2.62). Initially, party boat landings mirrored the increase in party boat effort in the late 1990s (Figure 2.61). However, as the trout population began to fluctuate and decline (Fig. 34), the landings also declined. Over the last ten years, private and party boat landings have averaged 68,000 and 15,000 fish, respectively. Both the private and party boat annual landings have decreased substantially since their peaks.

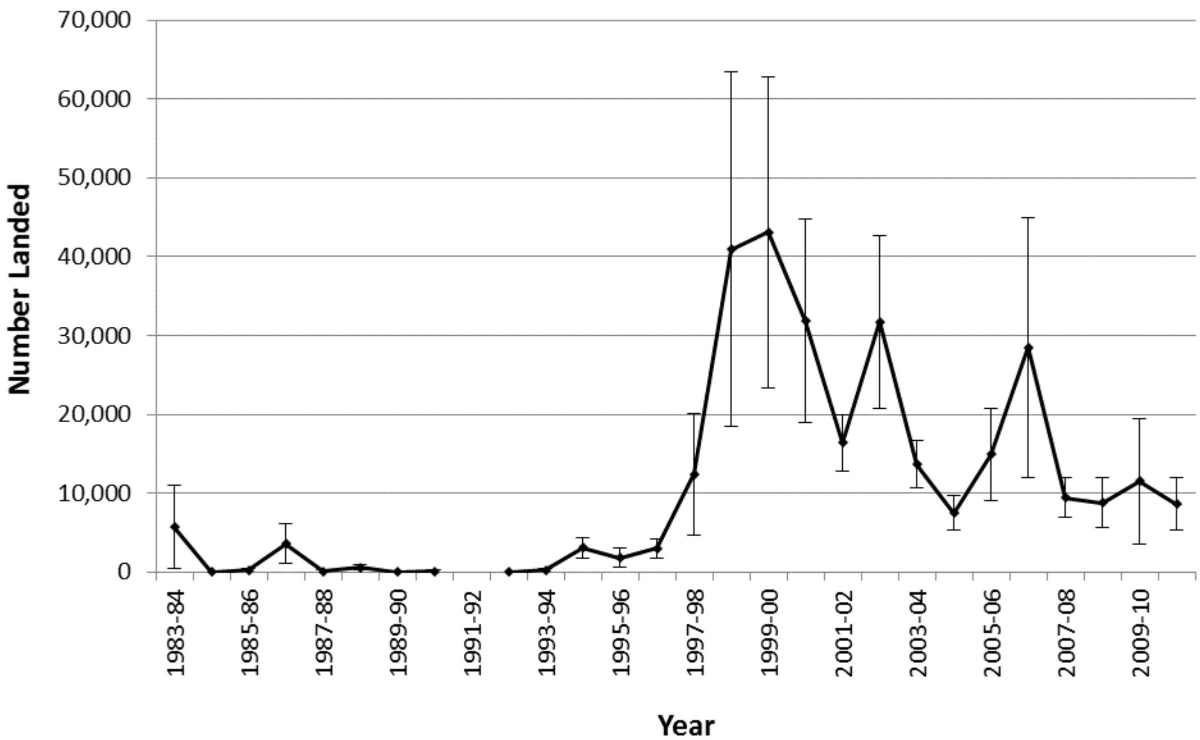


Figure 2.61 Party boat spotted seatrout landings ± standard error.

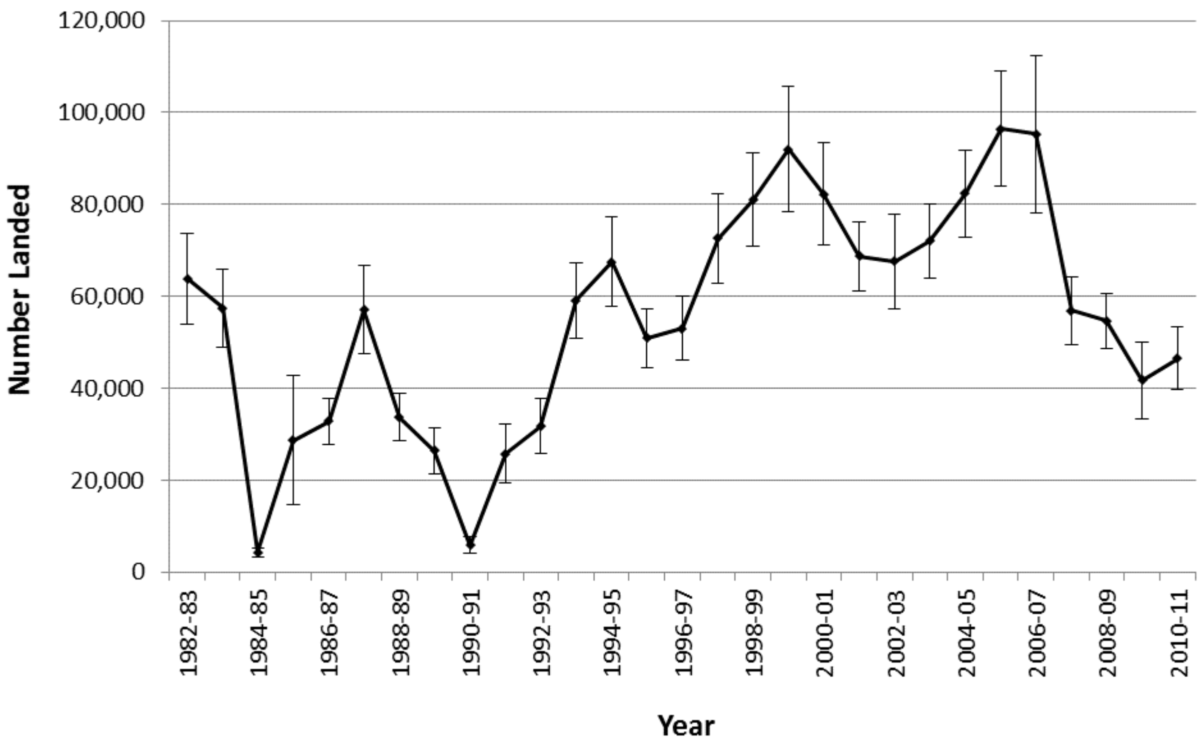


Figure 2.62 Private boat spotted seatrout landings ± standard error.

Red drum in combination with spotted seatrout, were the most sought after species by recreational anglers. With a less generous bag limit of 3 fish per day, both private and party boat landings were less than spotted seatrout but have steadily increased over the last 30 years (Figure 2.63 and 2.64). While the private boat landings have averaged more than 25,000 fish annually over the last 10 survey years; the party boat landings averaged less than 7,000 fish.

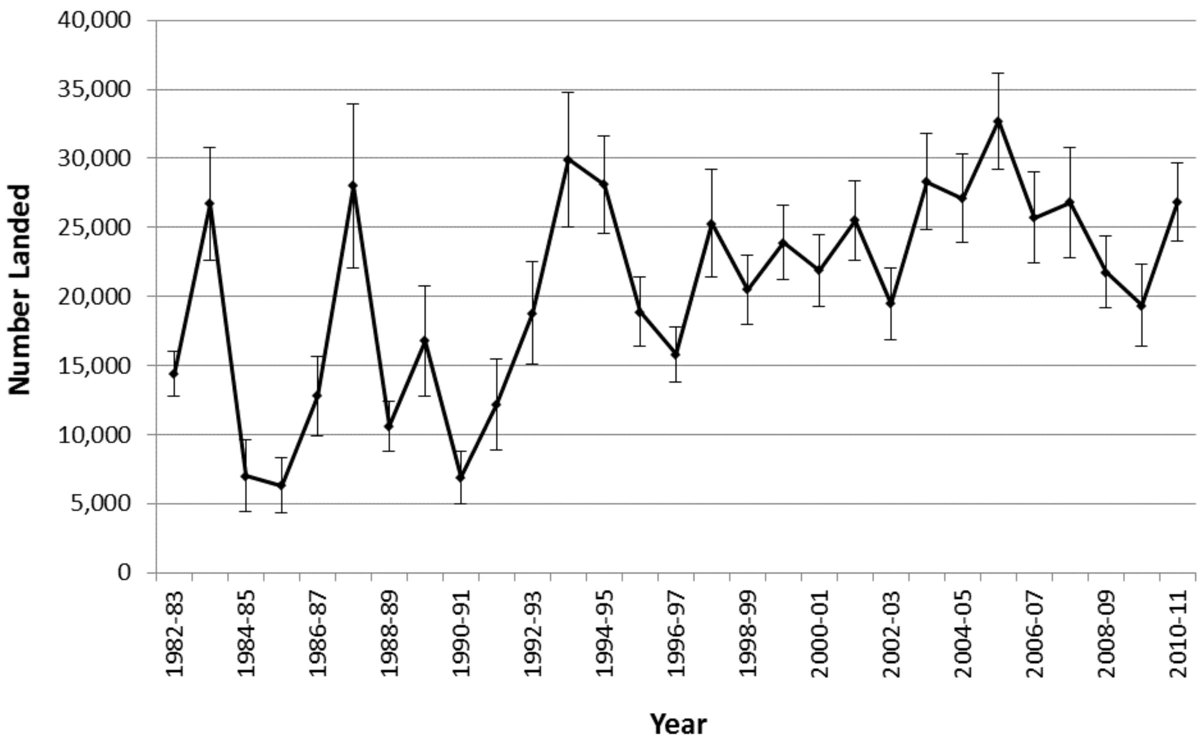


Figure 2.63 Private boat red drum landings ± standard error.

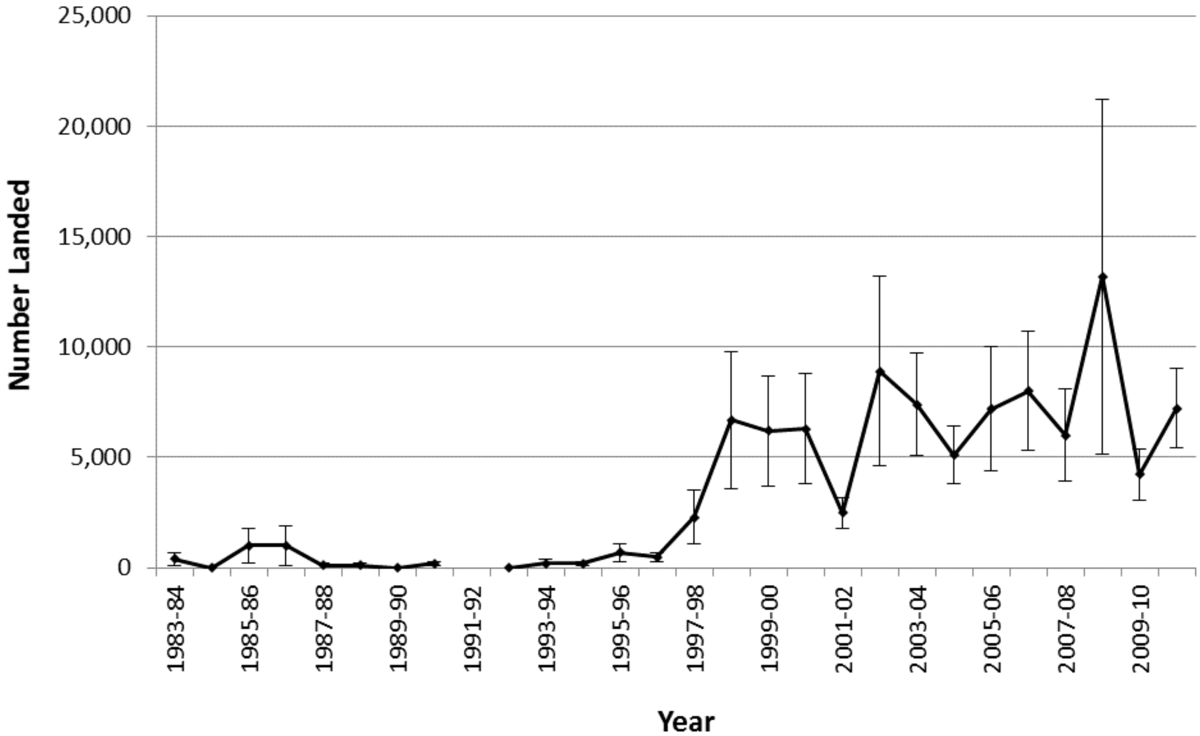


Figure 2.64 Party boat red drum landings ± standard error.

Sheepshead were not highly sought after, and so despite being a common large fish in the estuary, (Figure 2.55) they are not landed in large numbers. Private boat annual landings have averaged over 2,000 over the last 10 years while party boats have averaged less than 1,000 (Figures 2.65 and 2.66).

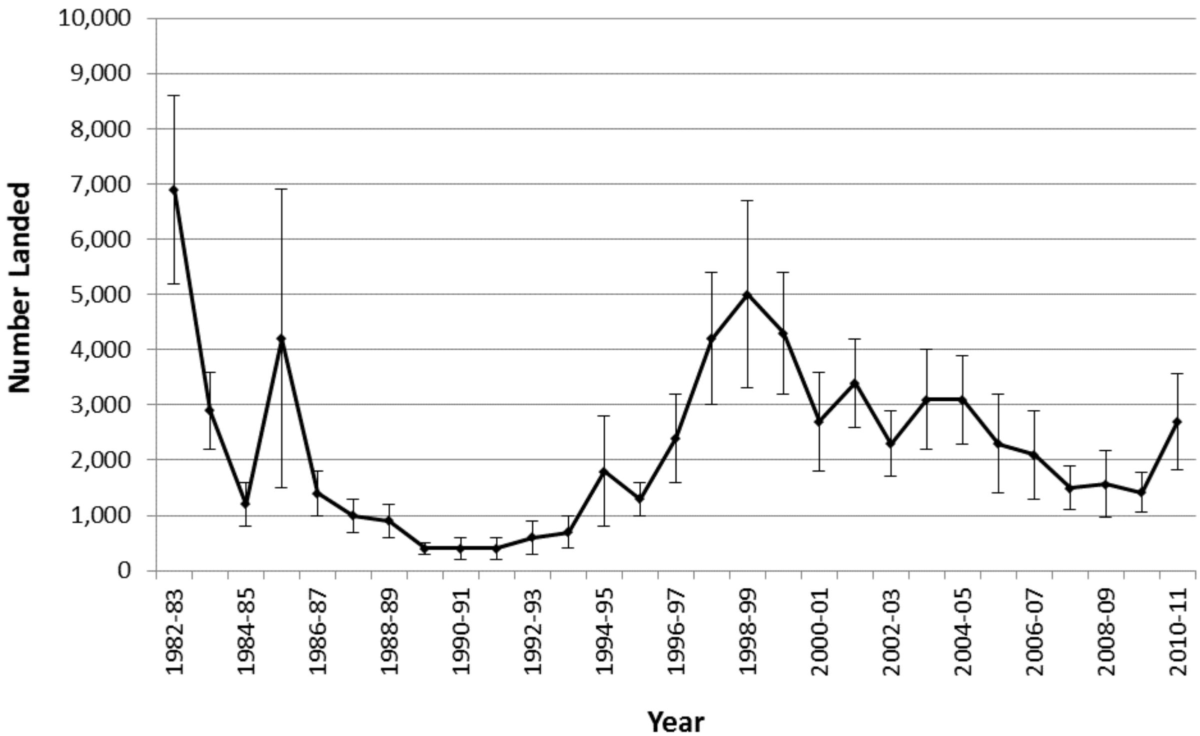


Figure 2.65 Private boat sheepshead landings ± standard error.

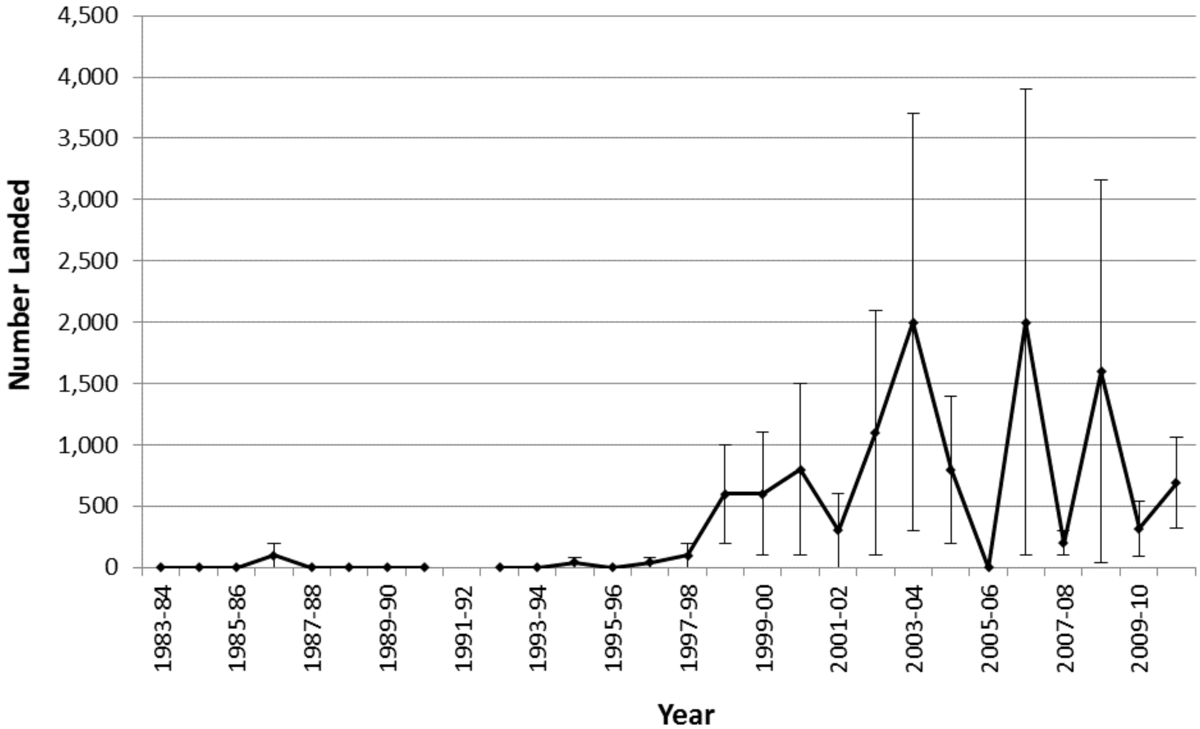


Figure 2.66 Party boat sheepshead landings ± standard error.

Gafftopsail catfish, similar to sheepshead were seldom sought after, and although they were numerous (Figure 2.39) and make good table fare, they were not landed in large numbers (Figures 2.67 and 2.68). Over the last ten years, landings averaged 2,600 and 200 fish annually for private and party anglers, respectively. Their population and angler landings are increasing (Figure 2.125).

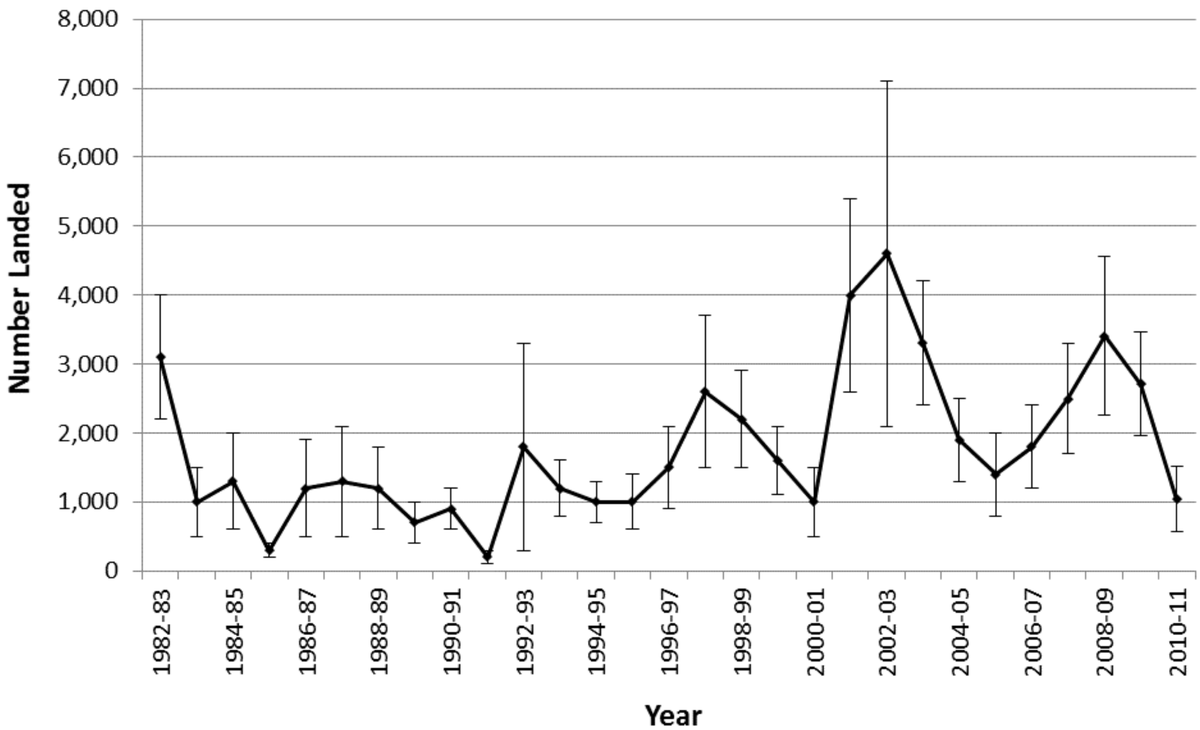


Figure 2.67 Private boat gafftopsail catfish landings ± standard error.

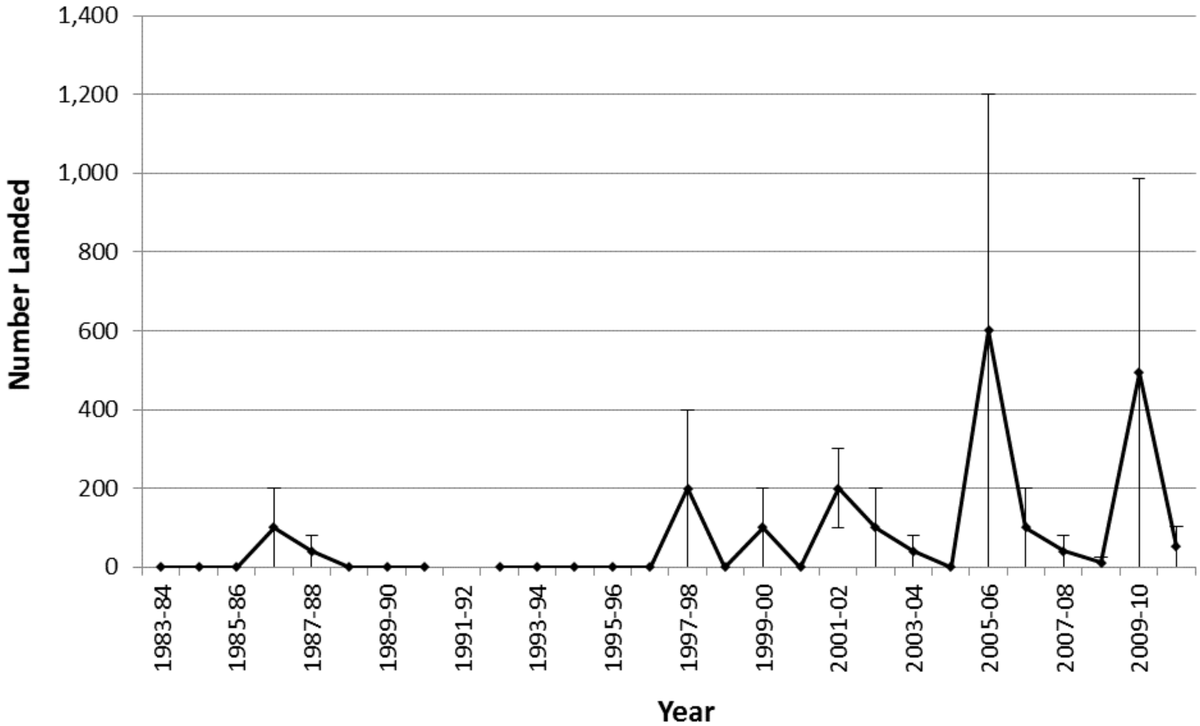


Figure 2.68 Party boat gafftopsail catfish landings ± standard error.

Black Drum were harvested in numbers exceeded by only spotted seatrout and red drum (Figures 2.69 and 2.70). Private boats landed an average of about 4,400 fish per year. Party boats do not typically target black drum and yet still landed an average of about 2,800 fish per year. Anecdotal information indicates than when the usual preferred target species, spotted seatrout and red drum, are difficult to catch, black drum will be retained if caught, or even targeted to ensure that clients take home fish. Both the population and angler landings are increasing within the estuary (Figures 2.46, 2.69, and 2.70).

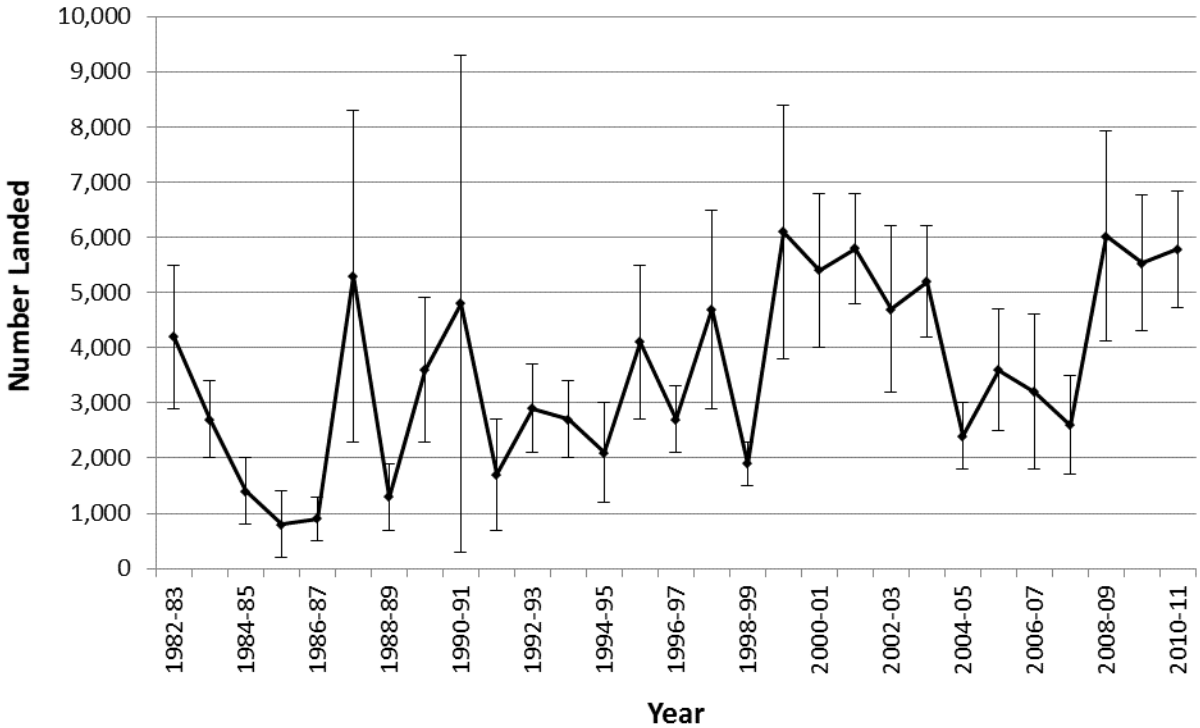


Figure 2.69 Private boat black drum landings ± standard error.

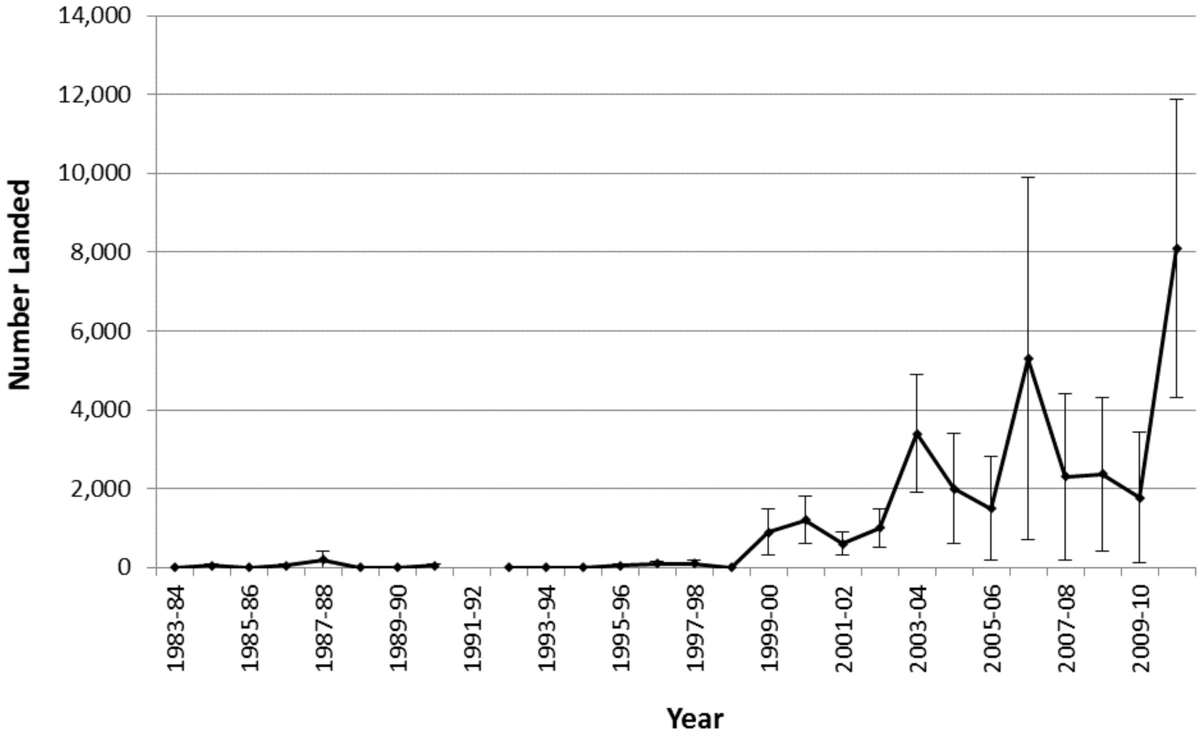


Figure 2.70 Party boat black drum landings ± standard error.

Southern flounder, like black drum, are targeted by both recreational and commercial fishers. Flounder fishers use both rod/reel and gig, with a substantial number being landed by the night-time gig fishery. Because the night-time gig fishery isn't routinely surveyed by the TPWD, recreational landings estimates were based on daytime rod & reel landings and therefore are a conservative estimate (Figures 2.71 and 2.72). Having averaged about 2,400 fish annually over the last 10 years private boat landings have recently declined to less than 1,000 in 2011. Party boat landings were highly variable averaging about 300 fish per year (Figure 2.72). Though highly prized as table fare, flounder are difficult to find and catch so landings were not as numerous as spotted seatrout or red drum. More than one fish per boat was not common with rod and reels.

Because of a declining population, in 1996 and again in 2006 the TPWD implemented harvest restrictions to promote population recovery. Though fishery independent data indicate the beginnings of a recovery (Figure 2.52), the fishery dependent data has yet to exhibit such a recovery (Figures 2.71 and 2.72). Currently, the flounder population remains in a depressed state, although anecdotal information indicates landings may be increasing.

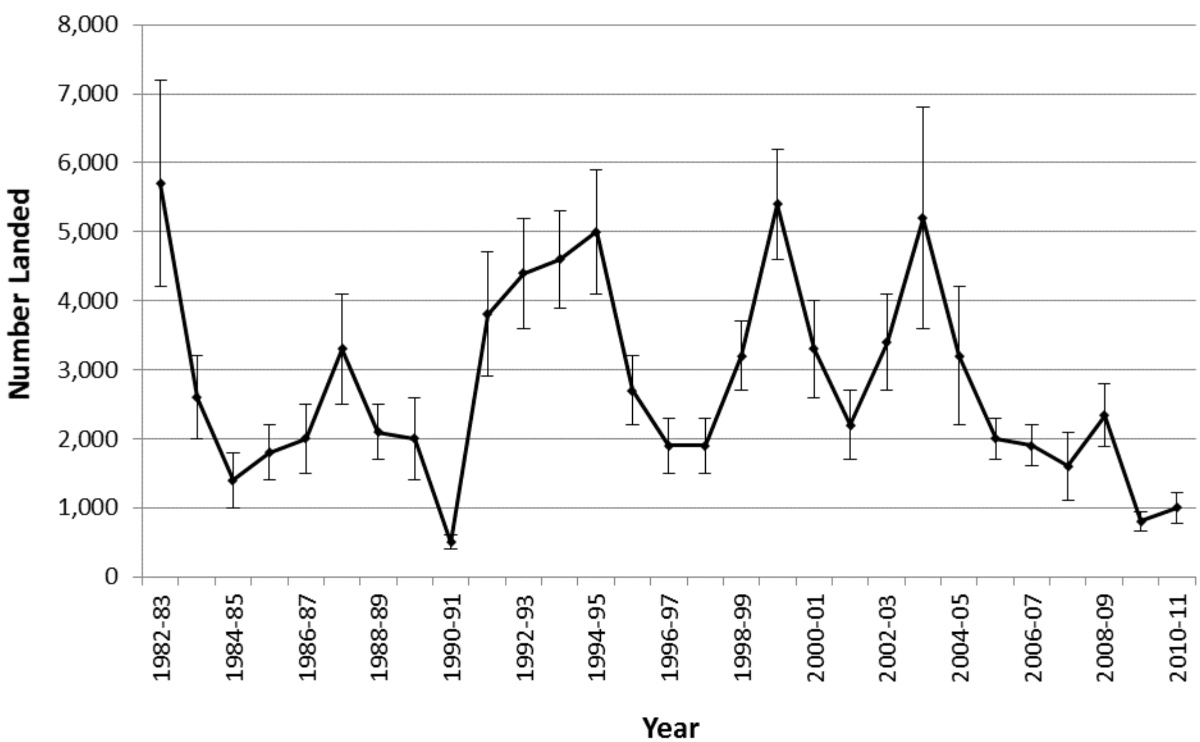


Figure 2.71 Private boat southern flounder landings ± standard error.

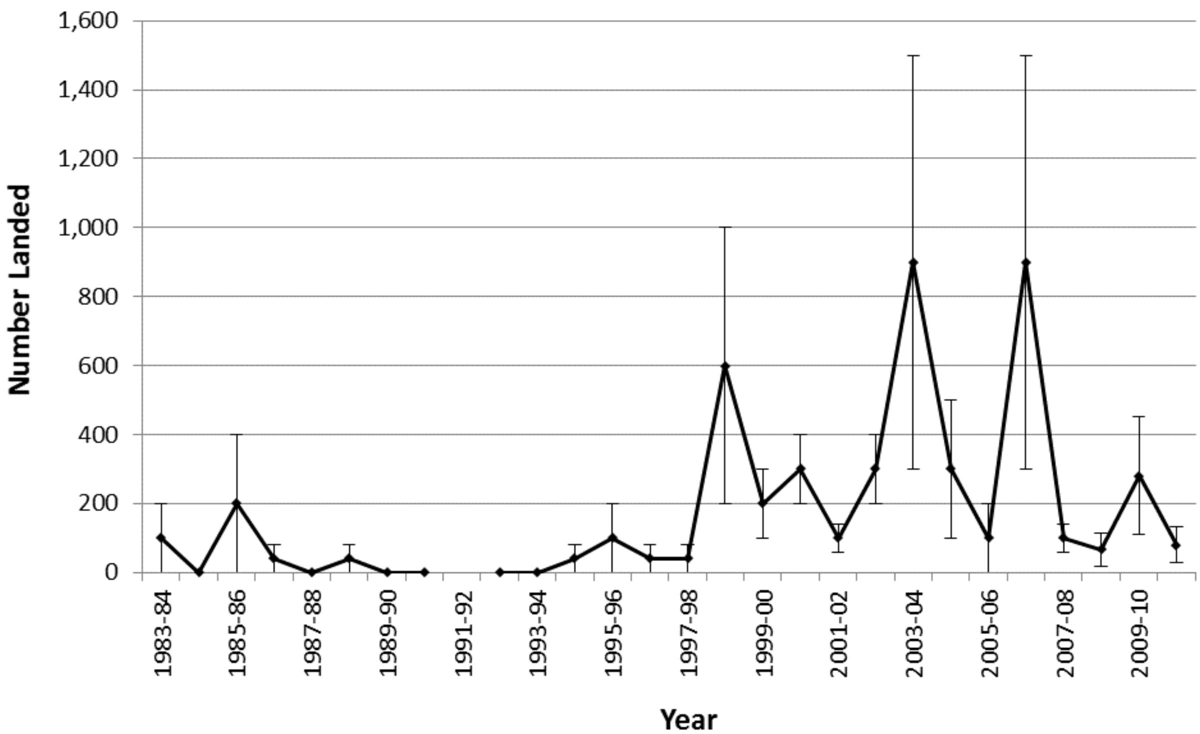


Figure 2.72 Party boat southern flounder landings ± standard error.

Commercial Harvest

From 1981–2010, the total commercial landings from SAB ranged from 701,480 pounds to 6,774,562 pounds (Figure 2.73). The selected species—black drum, southern flounder, sheepshead, blue crab, eastern oyster, and shrimp—comprised 99% of this total, on average. The ex-vessel value of all commercial landings from SAB ranged from $856,953 to $5,988,648 (Figure 2.73). The selected species comprised 98% of this total value, on average.

In 1981, spotted seatrout and red drum were designated game fish, and their commercial harvest from Texas waters was banned. This was followed by the banning of gill nets in 1988. The shrimping license management program previously discussed was duplicated for crab, finfish, and oyster licenses in 1998, 2000, and 2005, respectively. These programs, together with traditional size, area, gear, season, and time restraints, restrict the harvest of commercial species.

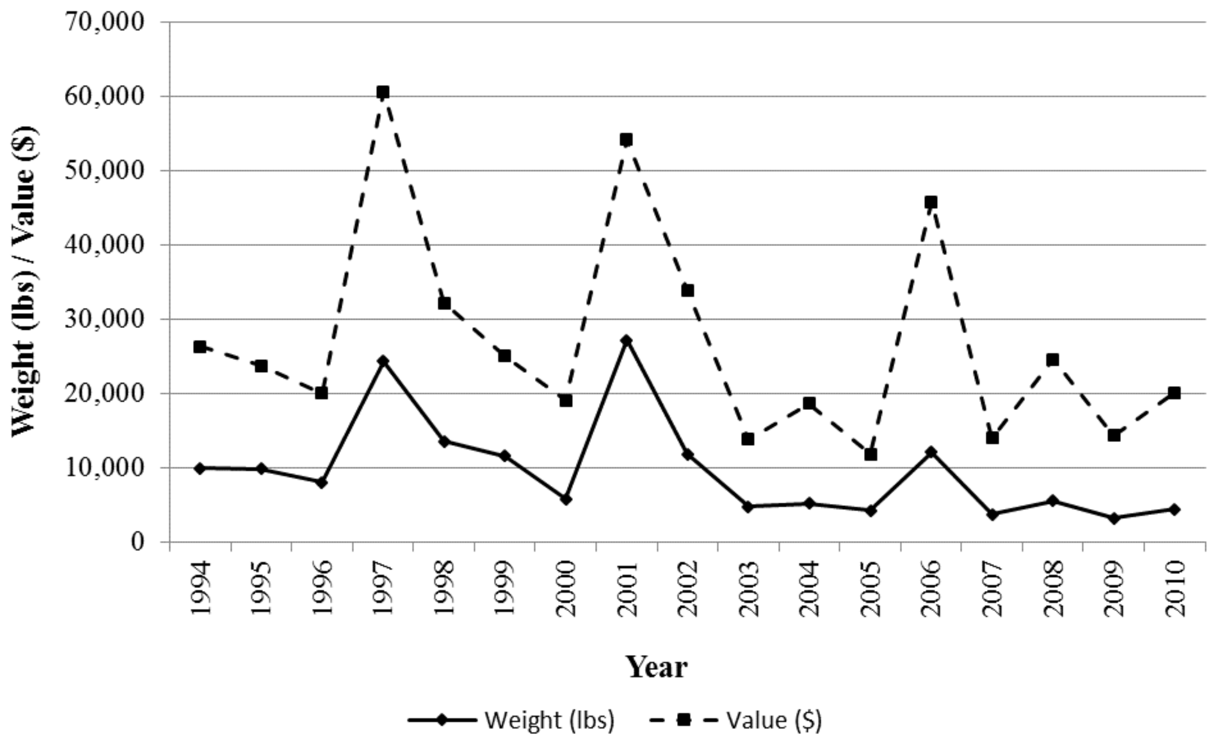


Figure 2.73 Weight and value of bait landings from the Guadalupe Estuary.

Black drum, currently harvested primarily with trotlines, account for more pounds and value than any other finfish species harvested from SAB. Prior to 1994, landings were negligible but rapidly climbed and peaked at over 500,000 pounds in 1997 (Figure 2.74). This trend is similar in other Texas estuaries. In 1996, the TPWD implemented a regulation designed to limit harvest of non-shrimp species associated with shrimp trawling effort. This harvest restriction limited the harvest of non-shrimp species by boats involved in commercial shrimping to 50% of the weight of shrimp on board. Also, in 1999, the TPWD established a license management plan for finfish licenses which are required to commercially harvest fish from Texas marine waters. Since 1999, 43% of all finfish licenses have been bought back by TPWD and retired. Consequently, this restriction combined with reduced shrimping effort has contributed to the rapid decline in black drum landings since 1997. The ex-vessel value mirrored the landings trend (Figure 2.74), and during the peak landings years, the SAB value accounted for up to 16% of the coastwide value of black drum landings (Figure 2.75).

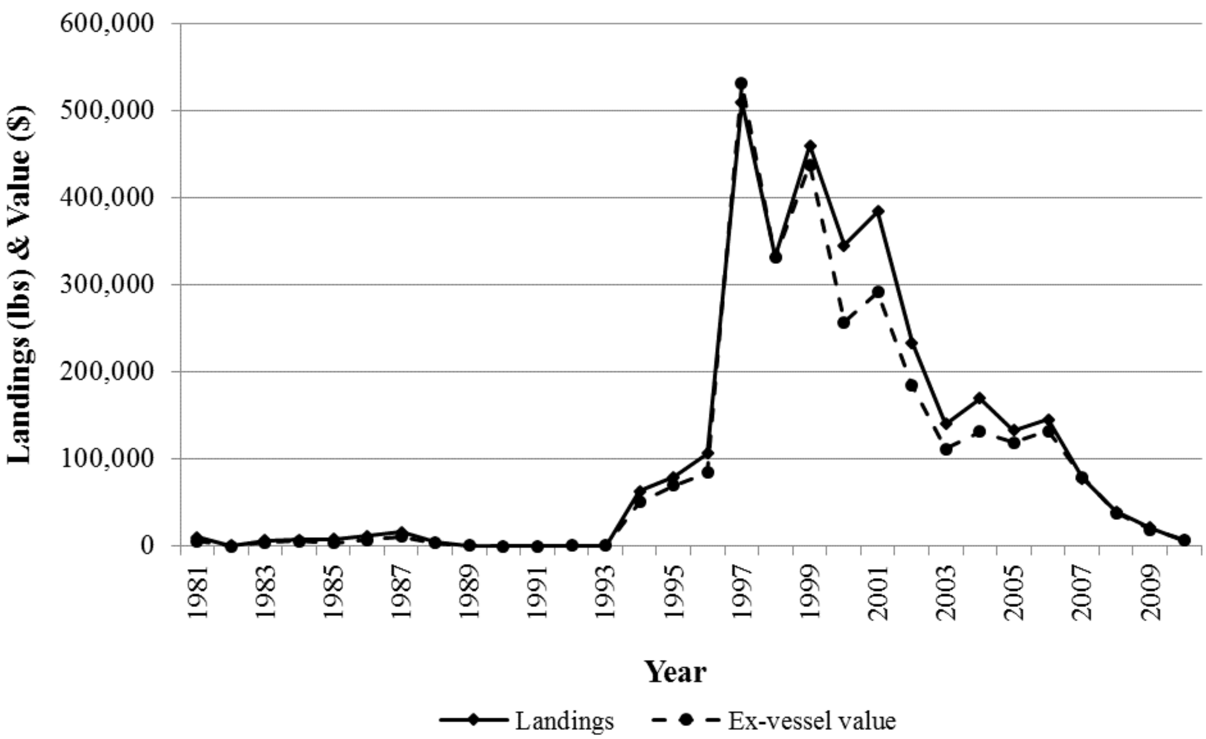


Figure 2.74 Black drum commercial landings and ex-vessel value.

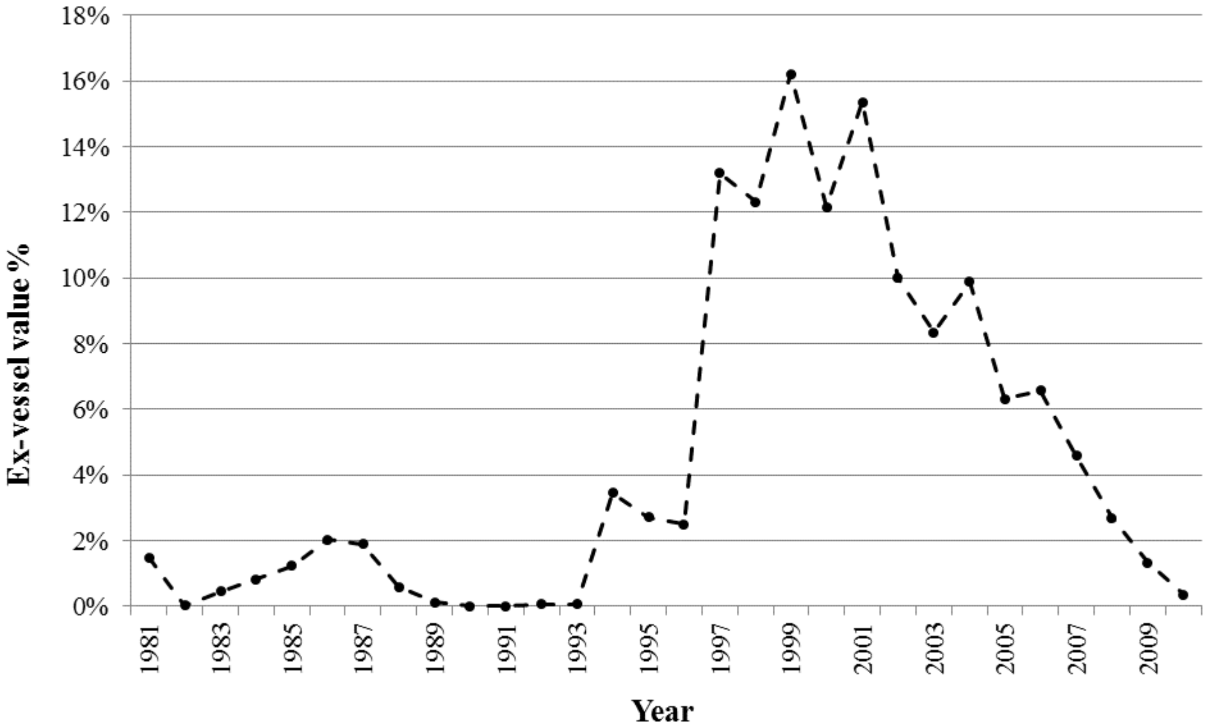


Figure 2.75 Black drum commercial landings ex-vessel value as a percentage of coastwide value.

Flounder were second to black drum in finfish landings from SAB with peak landings in 1999 of 70,423 pounds (Figure 2.76). Because there are more than one species of flounder landed commercially, they are considered as a group, although southern flounder dominated the landings for the group. Historically, SAB flounder landings have comprised an average of 13% of the coastwide value of flounder with a high of almost 30% in 2006 (Figure 2.77).

Flounder were harvested commercially primarily by gigging, with some harvest coming from shrimping activity. Because of coastwide decreasing fishery independent (gill net) catch rates (Figure 2.52), coastwide harvest restrictions have been implemented to reduce both commercial and recreational harvest. Although the anticipated impacts of these restrictions have not had sufficient time to be fully realized, and the population has not recovered yet, the 2011 SAB gill net catch rates were the highest since 1999.

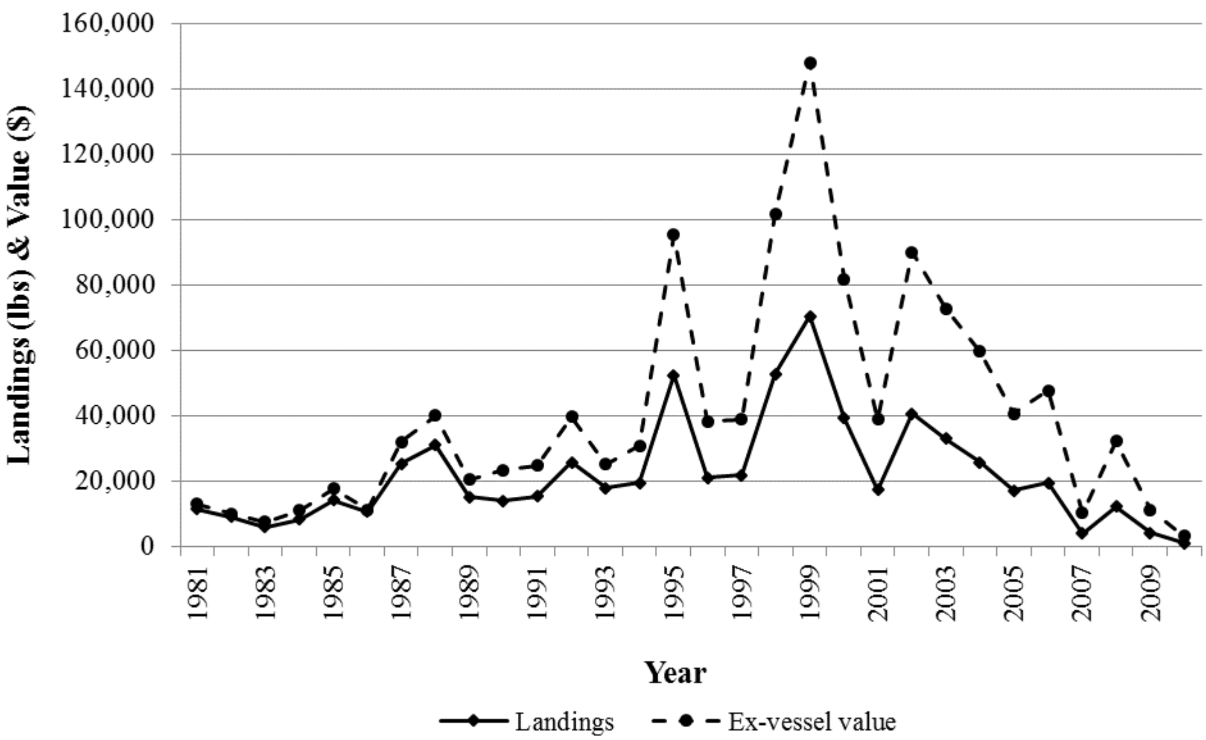


Figure 2.76 Flounder commercial landings and ex-vessel value.

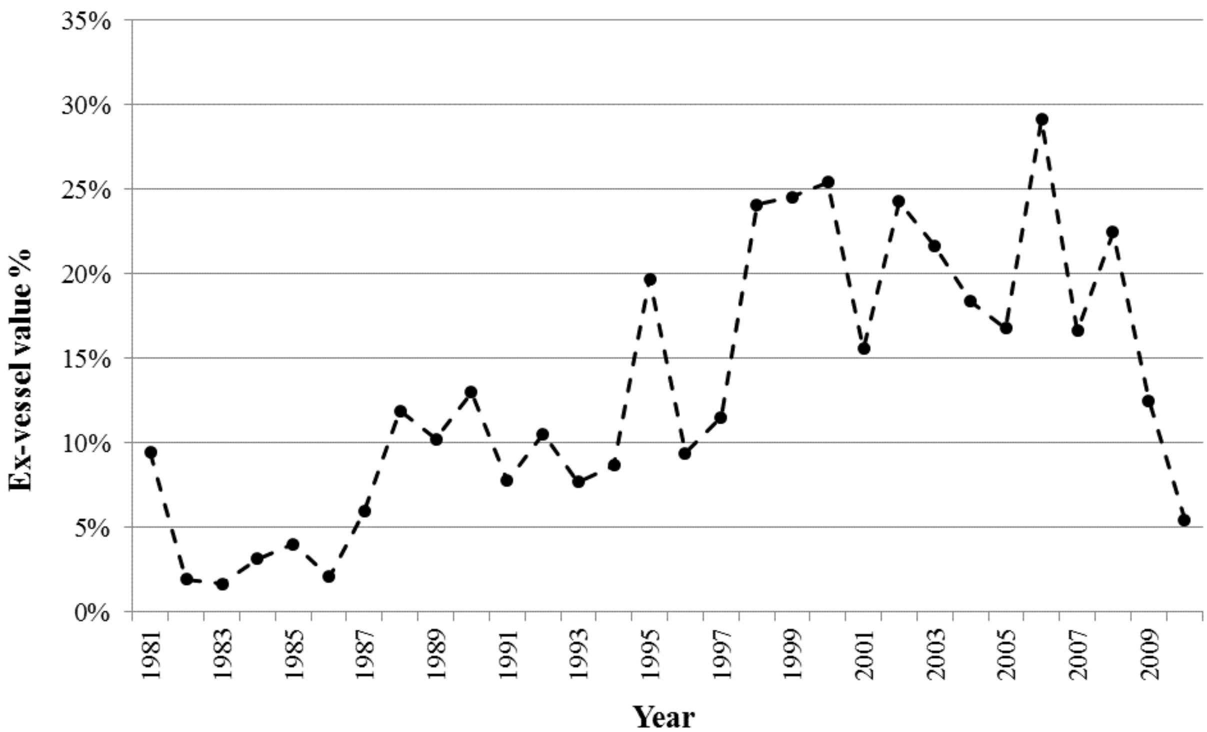


Figure 2.77 Flounder commercial landings ex-vessel value as a percentage of coastwide value.

Sheepshead were the third most often landed commercial fish species from SAB where they historically represent about 15% of the coastwide value for this species (Figure 2.78). Sheepshead were harvested commercially during shrimping activity with some harvest coming from gigging. The fishery peaked in 1999 and has declined coincident with the reduction in shrimping effort (Figure 2.79).

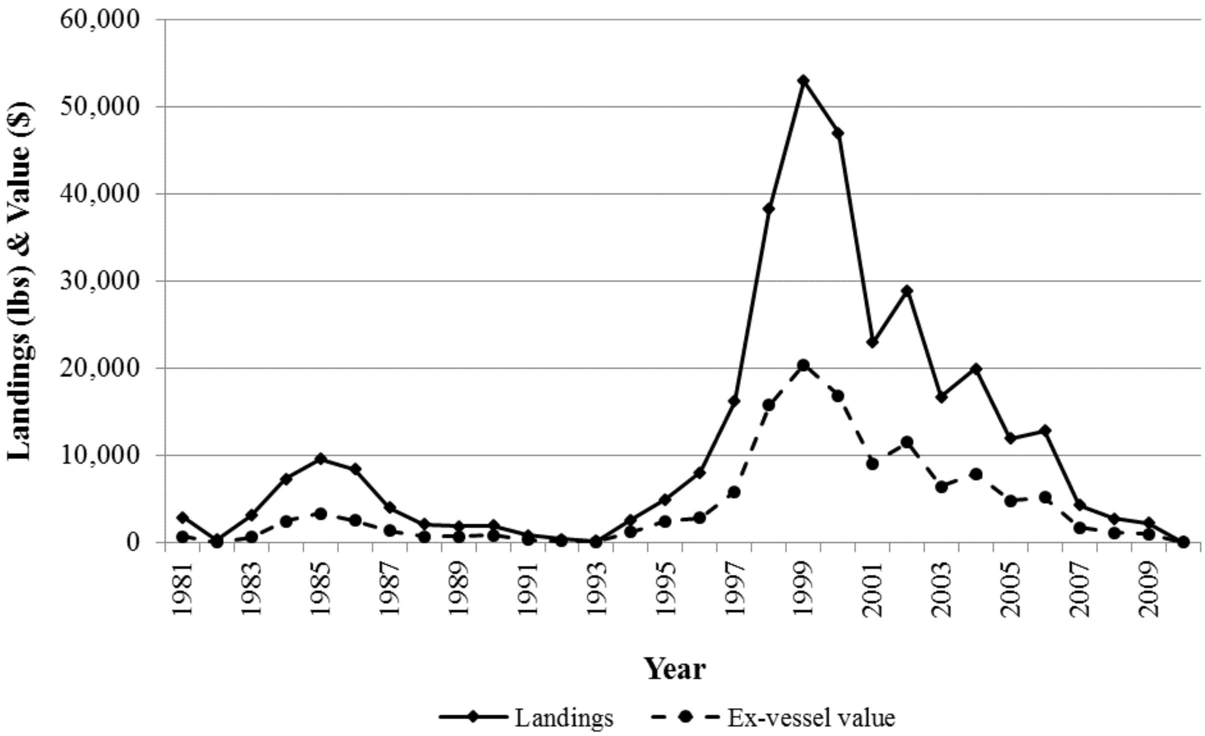


Figure 2.78 Sheepshead commercial landings and ex-vessel value.

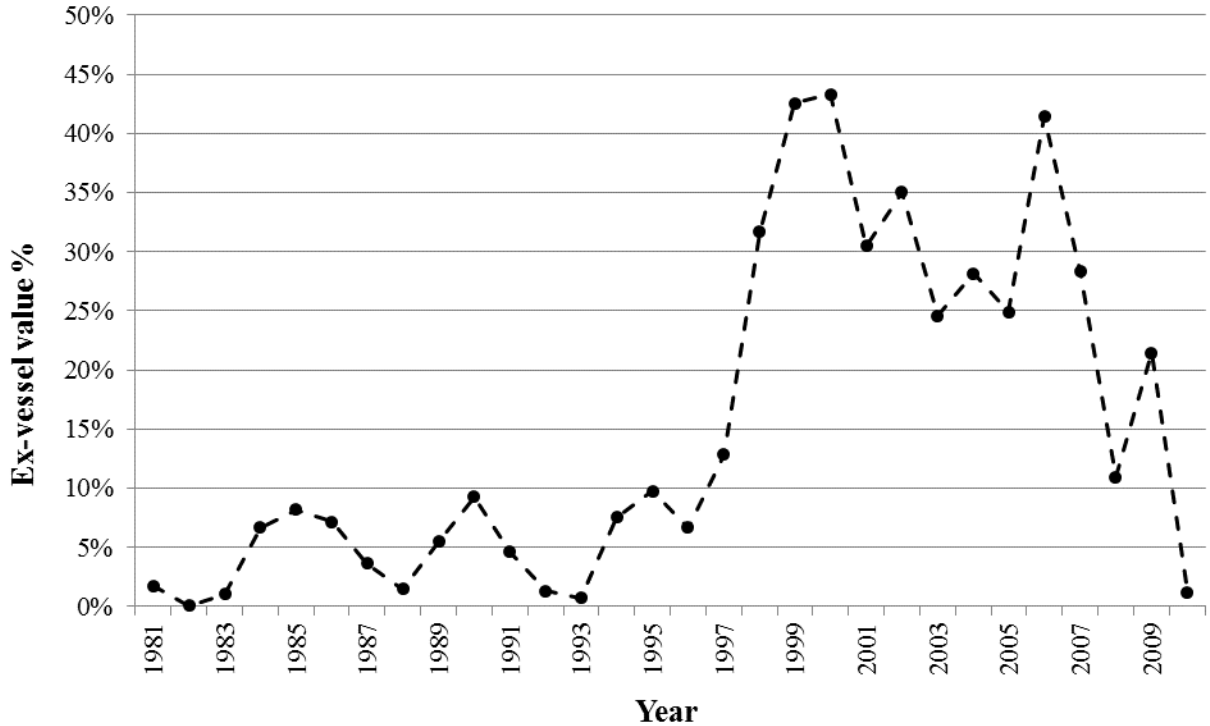


Figure 2.79 Sheepshead commercial landings ex-vessel value as a percentage of coastwide value.

Shrimp landings made up an average 25% and 41% of the total SAB commercial landings and value historically, though it has averaged much lower in recent years. There are three shrimp species commercially harvested from SAB: pink (*Farfantepenaeus duorarum*), brown (*Farfantepenaeus aztecus*), and white (*Litopenaeus setiferus*). Because of the difficulty in distinguishing them apart, brown and pink shrimp are grouped together for commercial reporting. Owing to a morphological characteristic distinguishing them from white shrimp, together they are referred to as "grooved shrimp." Of these two species, brown shrimp dominate the grooved shrimp landings. All three shrimp species are harvested for both food and bait, though historically the bait component of their harvest has been very much smaller in weight and value than the food component (Figures 2.80, 2.81, and 2.82).

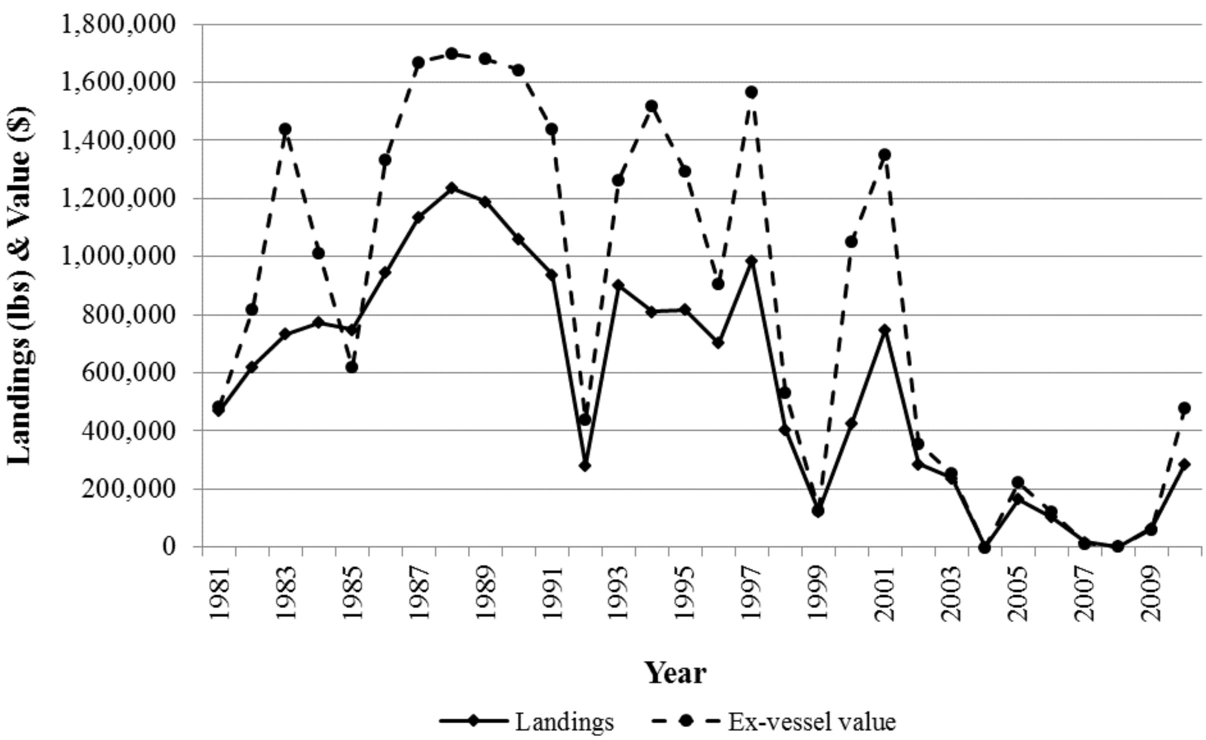


Figure 2.80 Grooved shrimp commercial landings and ex-vessel value.

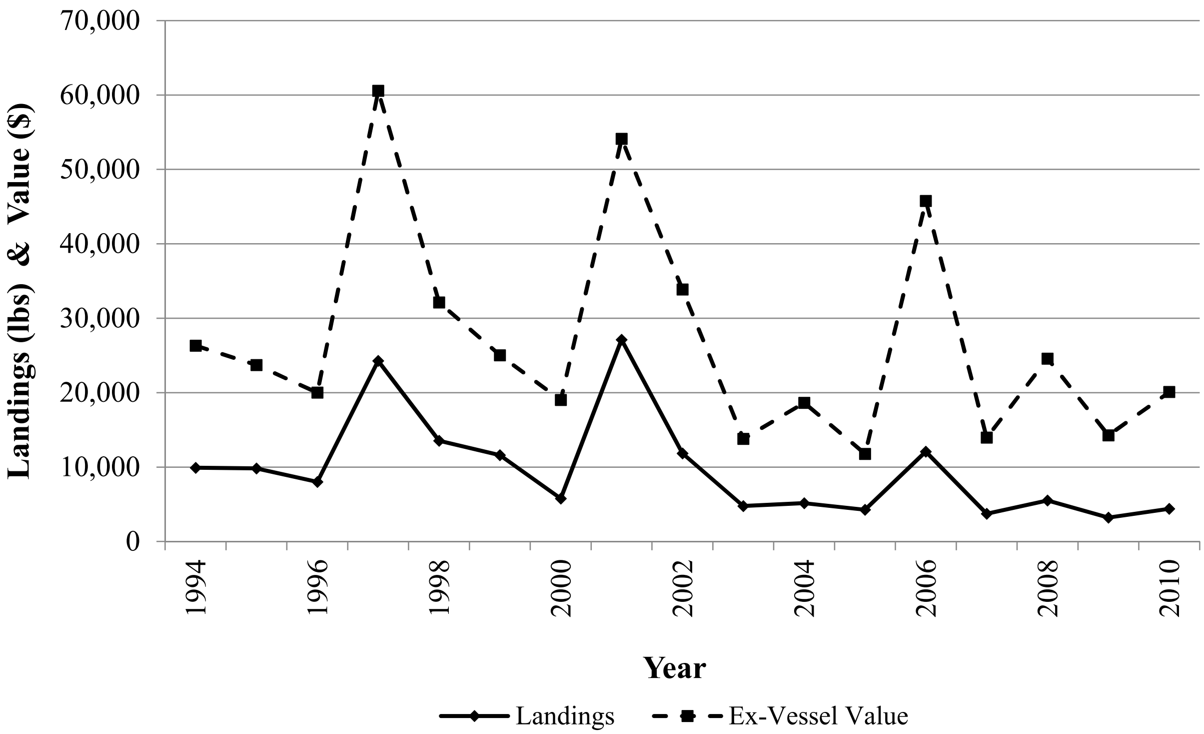


Figure 2.81 Bait shrimp landings and ex-vessel value.

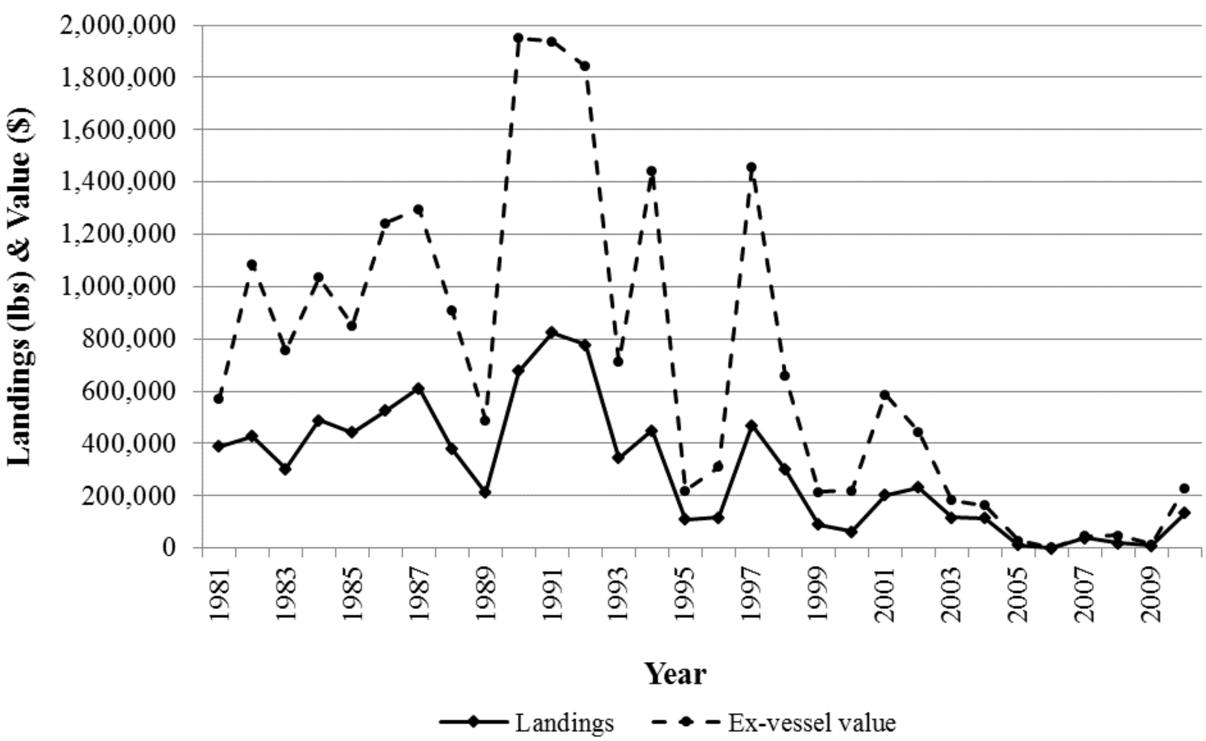


Figure 2.82 White shrimp commercial landings and ex-vessel value.

Although grooved shrimp landings are historically higher than white shrimp, they are typically smaller animals when landed. Because larger shrimp fetch more money per pound, white shrimp are more valuable per pound. Yet grooved shrimp landings are so much higher than white shrimp that their annual crop is worth more historically (Figs. 78 and 80). Compared with total coastwide value, SAB shrimp landings value are small, with grooved shrimp averaging less than 1% of the coastwide harvest and white shrimp about 2% (Figures 2.83 and 2.84).

All three species utilize estuaries as nurseries in that they enter as very small post larvae, mature over several months within the estuary, and then migrate back to the Gulf at a much larger size to complete their life cycle. Pink shrimp come into the bay during the fall and winter and leave the bay in late winter-early spring. Brown shrimp enter the estuary in late winter and begin emigrating offshore in late spring-fall, with many staying throughout the summer and into the fall. White shrimp come into the bay in May and leave September–December. Each species is harvested when it moves to open water and attains a size susceptible to commercial fishing gear. The shrimp harvested in the estuary are primarily young-of-the-year. Because of the timing of their life cycles, the bulk of their harvest occurs at different times for grooved (brown and pink) and white shrimp, with some overlap (Figure 2.85).

The license buy back and economic adversity discussed earlier have played important roles in altering the commercial harvest of shrimp on the Texas coast and in SAB. Landings peaked when effort was high, and when shrimping effort decreased during the last decade, landings also decreased, although by a smaller percentage. This would seem to indicate there were more landings per boat after effort decreased.

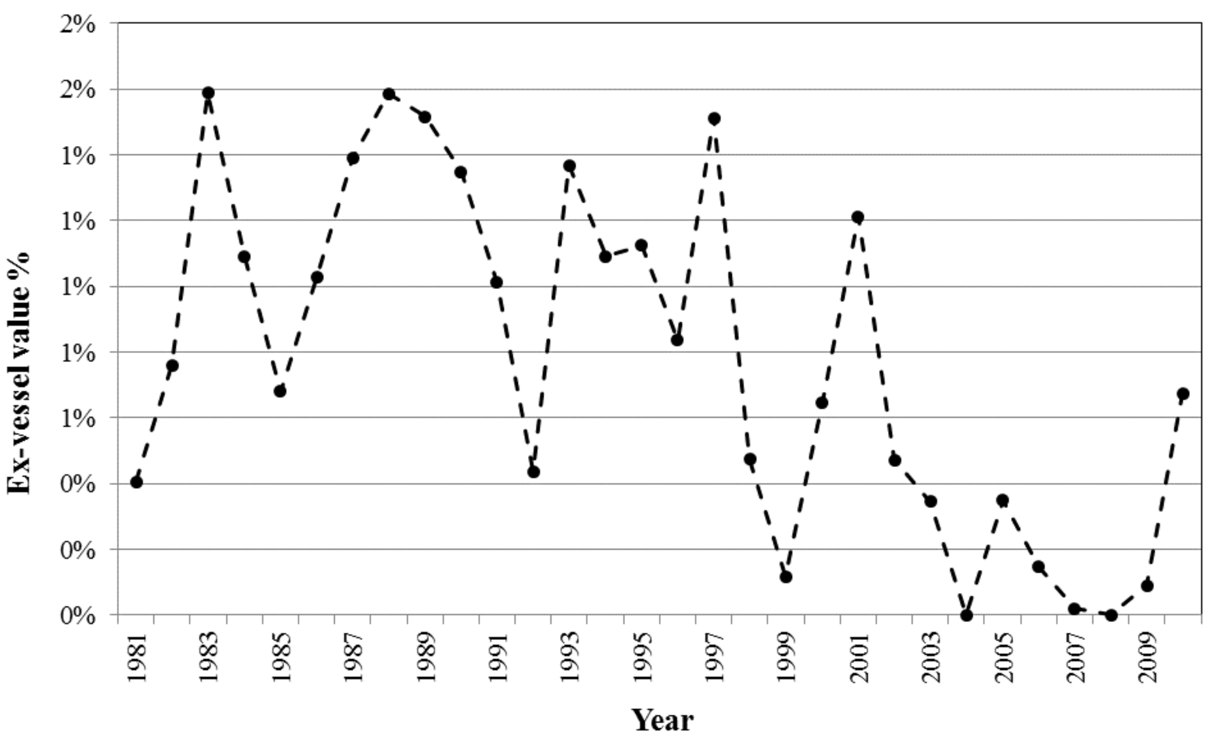


Figure 2.83 Grooved shrimp commercial ex-vessel value as a percentage of coastwide value.

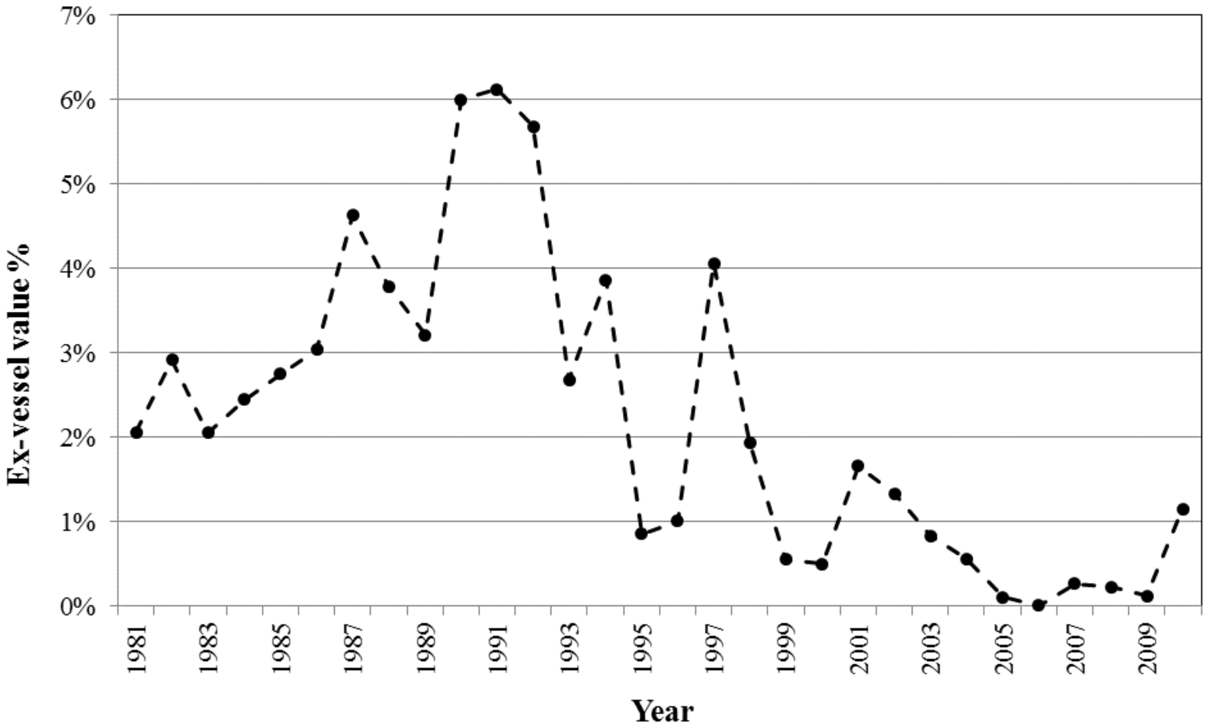


Figure 2.84 White shrimp commercial ex-vessel value as a percentage of coastwide value.

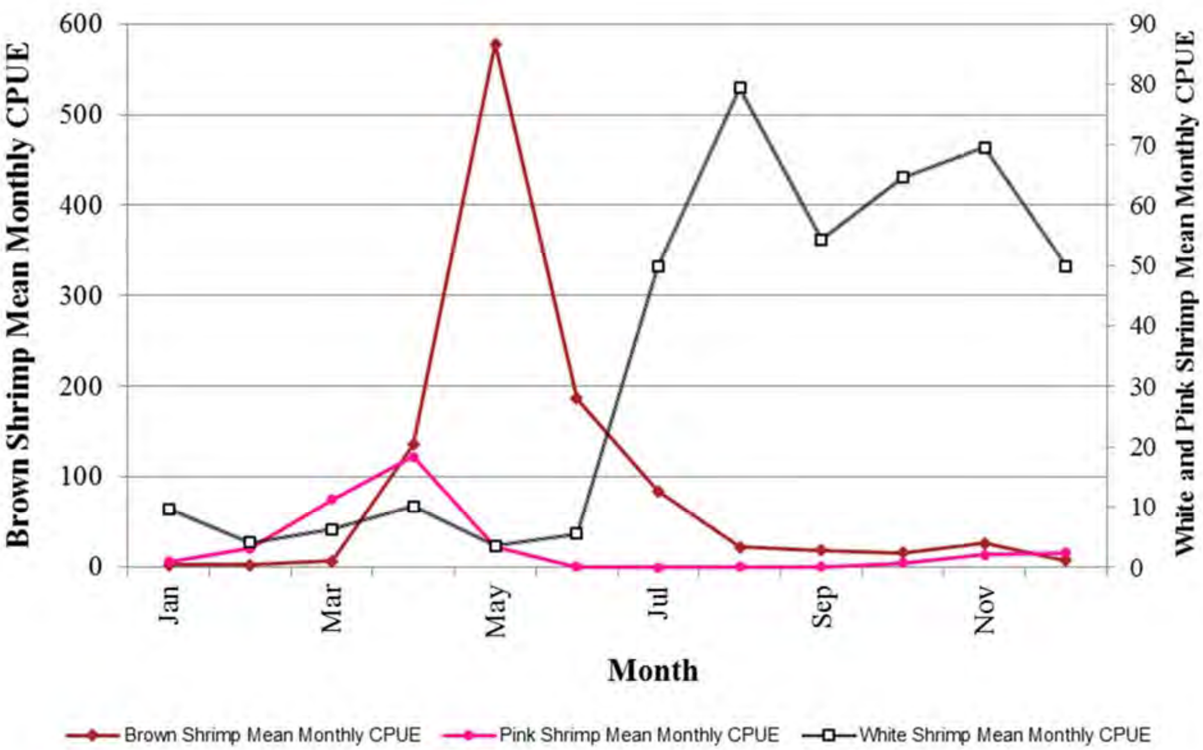


Figure 2.85 Brown, pink, and white shrimp mean monthly CPUEs.

Blue crab commercial landings and value mirrored the fishery independent data. The landings have been decreasing for over 20 years, though the ex-vessel value had remained stable until recently (Figure 2.86). The SAB portion of the coastwide value did not decrease as fast as the landings did (Figure 2.87). In 1998, a license management program was implemented for the blue crab fishery to reduce fishing effort and aid in affecting population recovery.

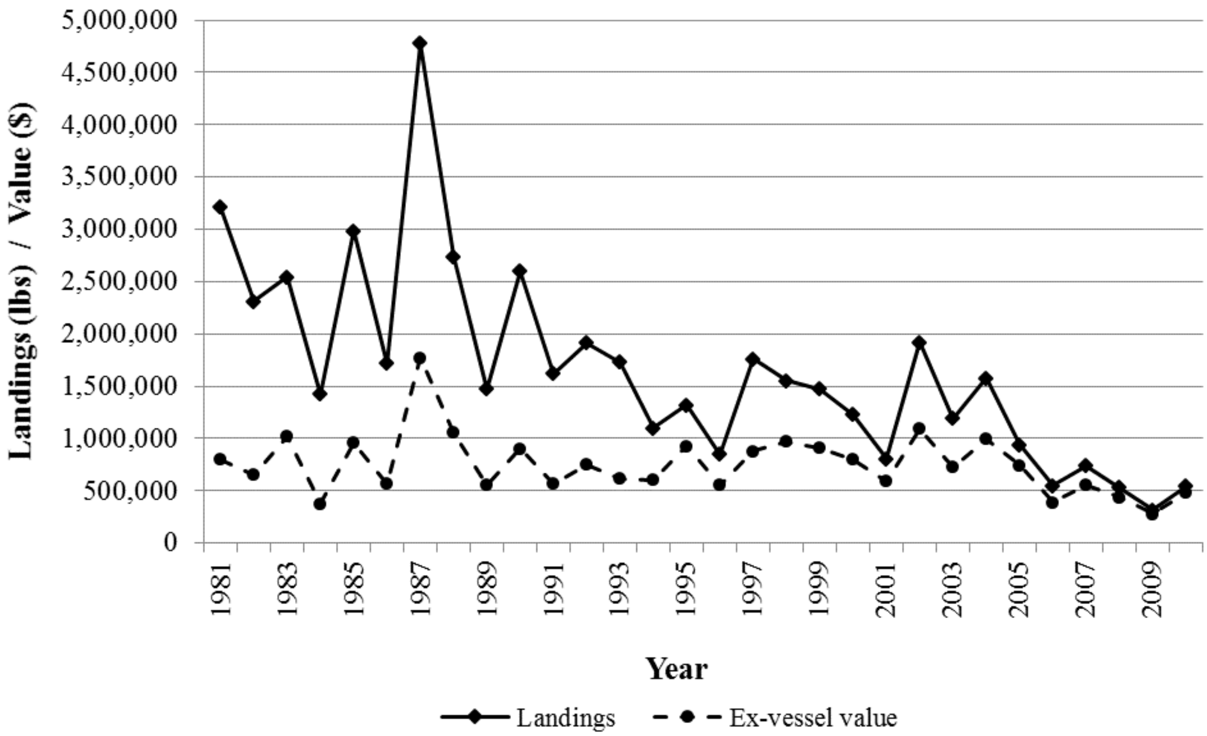


Figure 2.86 Blue crab commercial landings and ex-vessel value.

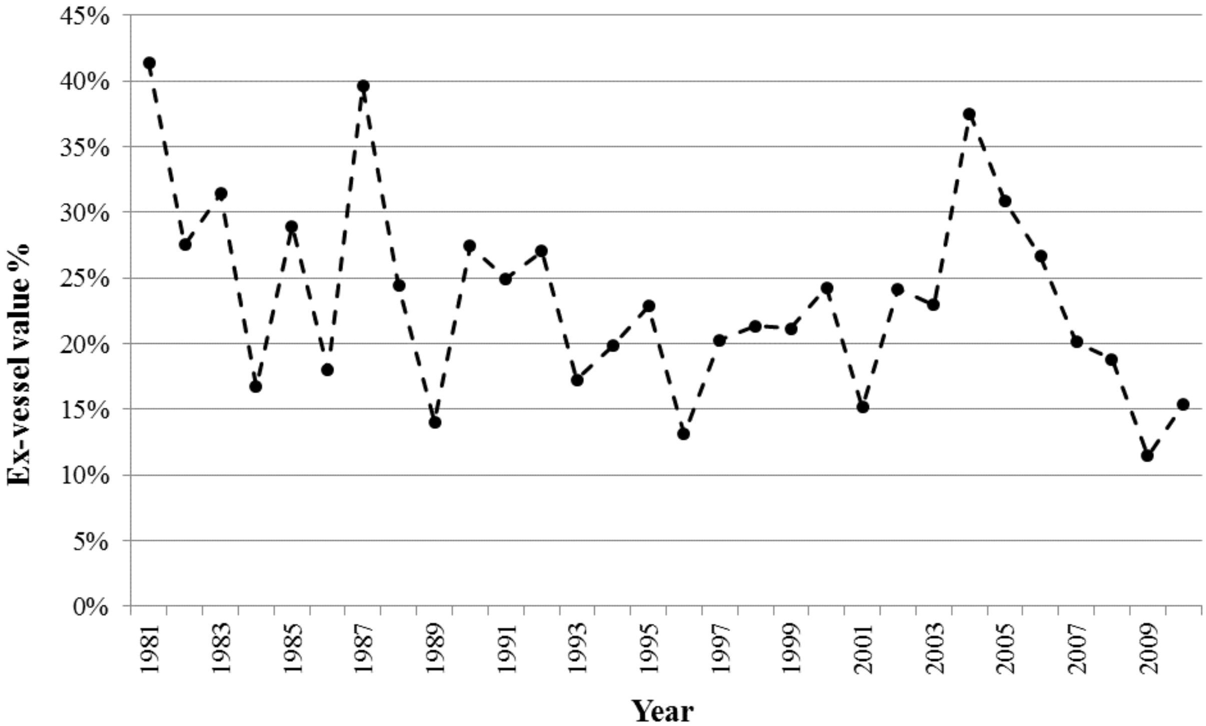


Figure 2.87 Blue crab commercial landings ex-vessel value as a percentage of coastwide value.

Eastern oysters were the third most valuable commercial fishery in SAB averaging $500,000 annually historically with a range of $0 to $4,428,657 (Figure 2.88). Their portion of the coastwide oyster harvest value fluctuated between 0% and 35% (Figure 2.89). Oyster reefs exhibit highly variable oyster populations due to their susceptibility to environmental factors, such as freshwater inflows, parasites, and diseases. This highly variable nature is normal for oysters in SAB and they typically can recover quickly from environmental perturbations. As such, a population trend is not useful for describing the health of the species.

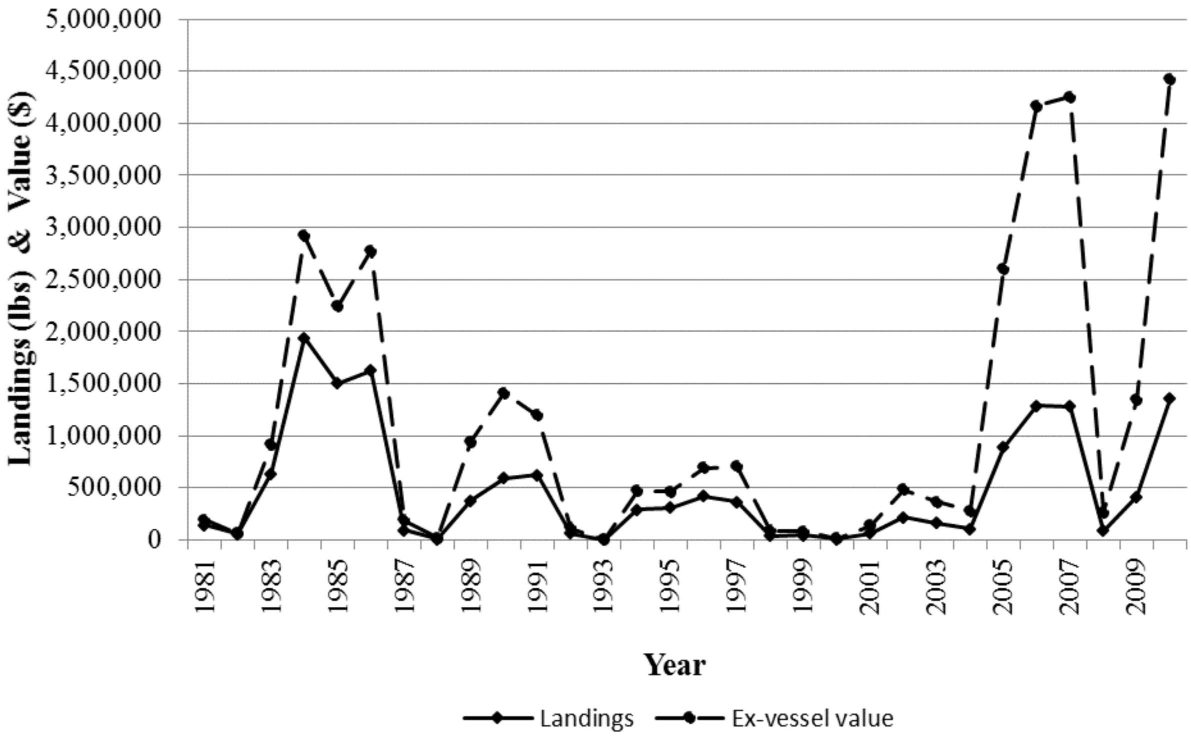


Figure 2.88 Eastern oyster commercial landings and value.

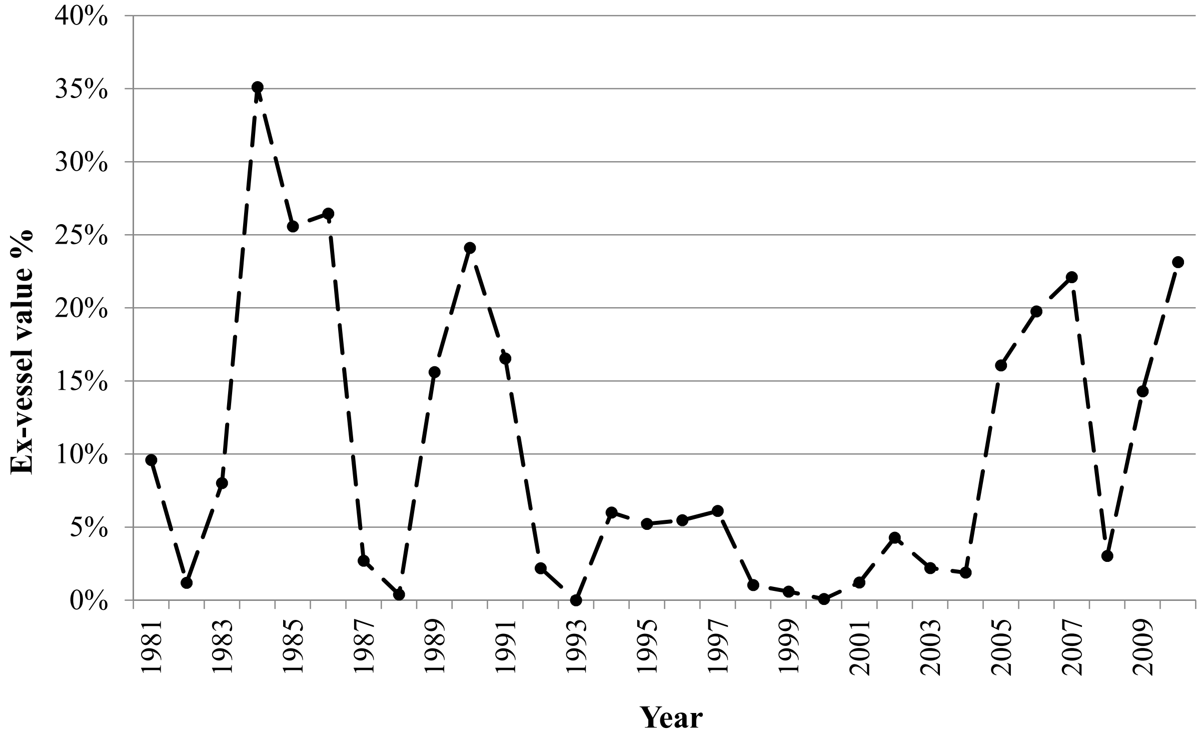


Figure 2.89 Eastern oyster commercial landings ex-vessel value as a percentage of coastwide value.

Assemblage Data

In all gears tested, the species assemblage in San Antonio Bay clustered together with other bays found along the mid-Texas coast. Cluster analysis of samples obtained with bag seines clustered SAB with Aransas/Copano and Corpus Christi bays (Figure 2.90) in terms of species assemblages. Pinfish and brown shrimp were the two highest species in terms of percent of similarity they contributed to the assemblages between SAB, Aransas/Copano Bay, and Corpus Christi Bay (Table 2.1). Gulf menhaden and pinfish were the species contributing the highest proportion of the dissimilarity between SAB group and Sabine Lake (Table 2.2) as well as the Galveston and Matagorda Bay group (Table 2.3). Sheepshead minnow and inland silverside were the two species that contributed the most difference between SAB and Upper Laguna Madre (Table 2.4). Grass shrimp and gulf menhaden were the two species which contributed the most difference between SAB and Lower Laguna Madre (Table 2.5). There is a gradient of hydrological variables along the Texas coast which could account for SAB clustering with bays nearest to it. This was evidenced by the species having a preference for certain salinities, such as gulf menhaden and sheepshead minnow, being the ones that contributed most to the dissimilarity.

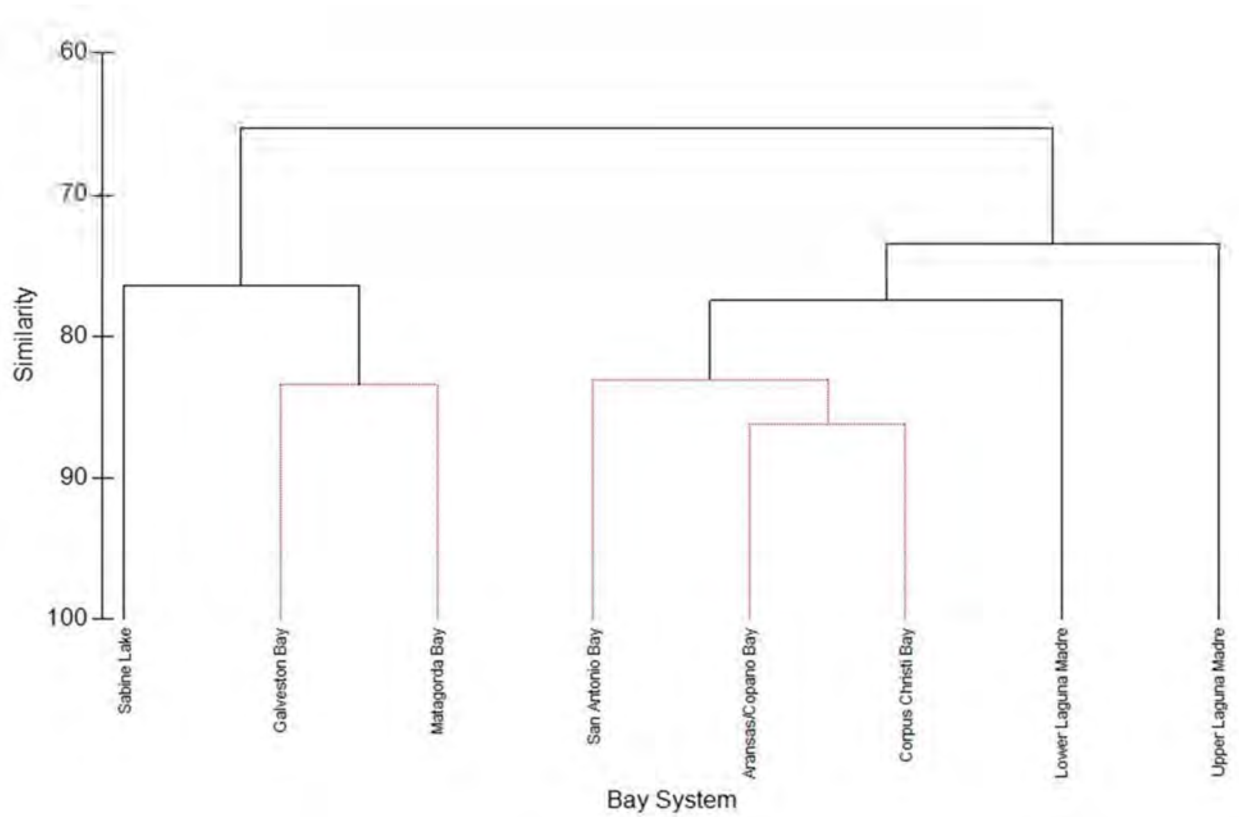


Figure 2.90 Hierarchical clustering of major bays along the Texas coast by similarity of species assemblages for bag seine catches from 1982-2011. Black lines indicate significant differences between bays.

Table 2.1 Species abundances caught by bag seine within cluster group containing San Antonio, Aransas/Copano, and Corpus Christi Bays and their contribution to similarities between these bays. Species contributing at least 1% of similarity are included.

Species	Average Abundance	Contribution %	Cumulative Contribution %
Lagodon rhomboides	4.03	8.22	8.22
Farfantopenaeus aztecus	3.88	7.78	16
Genus Palaemonete	3.95	6.97	22.98
Cyprinodon variegatus	3.11	6.06	29.04
Brevoortia patronus	2.86	5.72	34.76
Leiostomus xanthurus	3.05	5.71	40.47
Litopenaeus setiferus	2.84	5.67	46.14
Mugil curema	1.8	3.6	49.74
Anchoa mitchilli	1.8	3.58	53.31
Menidia beryllina	2.11	3.2	56.51
Fundulus similis	1.65	3.18	59.69
Mugil cephalus	1.64	3.13	62.82
Callinectes sapidus	1.61	3.1	65.92
Fundulus grandis	1.37	2.59	68.5
Micropogonias undulatus	1.21	2.38	70.88
Eucinostomus argenteus	1.01	2.01	72.89
Farfantepenaeus duorarum	1.16	1.73	74.62
Sciaenops ocellatus	0.79	1.59	76.21
Cynoscion nebulosus	0.69	1.26	77.46
Bairdiella chrysoura	0.65	1.15	78.61

Table 2.2 Species abundances caught by bag seine within cluster group containing San Antonio, Aransas/Copano, and Corpus Christi Bays (SAB) and the cluster consisting of Sabine Lake (SL), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance SL	Contribution %	Cumulative Contribution %
Brevoortia patronus	2.86	7.09	11.28	11.28
Lagodon rhomboides	4.03	1.08	7.87	19.15
Cyprinodon variegatus	3.11	0.58	6.76	25.91
Genus Palaemonete	3.95	1.41	6.76	32.67
Litopenaeus setiferus	2.84	4.92	5.55	38.22
Leiostomus xanthurus	3.05	1.37	4.49	42.71
Fundulus similis	1.65	0.06	4.23	46.95
Micropogonias undulatus	1.21	2.72	4.02	50.97
Farfantepenaeus duorarum	1.16	0.04	2.98	53.95
Menidia berylina	2.11	1.19	2.56	56.51
Fundulus grandis	1.37	0.47	2.39	58.91
Mugil curema	1.8	0.91	2.38	61.29
Menidia peninsulae	0.82	0.1	2.07	63.35
Eucinostomus argenteus	1.01	0.32	1.84	65.19
Orthopristis chrysoptera	0.5	0.02	1.29	66.48
Cynoscion arenarius	0.15	0.61	1.24	67.72
Dorosoma petenense	0.06	0.51	1.19	68.91
Bairdiella chrysoura	0.65	0.23	1.13	70.04
Callinectes sapidus	1.61	1.22	1.04	71.08

Table 2.3 Species abundances caught by bag seine within cluster group containing San Antonio, Aransas/Copano, and Corpus Christi Bays (SAB) and the cluster consisting of Galveston and Matagorda Bays (GB/MB), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance GB/MB	Contribution %	Cumulative Contribution %
Brevoortia patronus	2.86	8.01	15.80	15.80
Lagodon rhomboides	4.03	2.02	6.38	22.18
Litopenaeus setiferus	2.84	4.90	6.38	28.56
Micropogonias undulatus	1.21	3.06	5.79	34.36
Cyprinodon variegatus	3.11	1.66	4.57	38.93
Genus Palaemonete	3.95	2.96	3.55	42.48
Farfantepenaeus duorarum	1.16	0.17	3.10	45.58
Menidia peninsulae	0.82	0.18	2.52	48.10
Menidia beryllina	2.11	1.88	2.30	50.40
Cynoscion arenarius	0.15	0.88	2.30	52.70
Fundulus similis	1.65	1.07	1.83	54.53
Leiostomus xanthurus	3.05	2.58	1.70	56.24
Fundulus grandis	1.37	0.87	1.60	57.83
Anchoa mitchilli	1.80	2.14	1.55	59.38
Farfantepenaeus aztecus	3.88	3.70	1.48	60.87
Fundulus chrysotus	1.01	0.64	1.13	61.99
Menticirrhus americanus	0.22	0.57	1.10	63.09
Polydactylus octonemus	0.24	0.58	1.09	64.18
Callinectes sapidus	1.61	1.43	1.03	65.22
Sygnathus scovelli	0.37	0.04	1.03	66.25
Mugil curema	1.80	1.58	1.02	67.27
Ariopsis felis	0.52	0.83	1.00	68.28

Table 2.4 Species abundances caught by bag seine within cluster group containing San Antonio, Aransas/Copano, and Corpus Christi Bays (SAB) and the cluster consisting of Upper Laguna Madre (ULM), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance ULM	Contribution %	Cumulative Contribution %
Cyprinodon variegatus	3.11	5.54	8.98	8.98
Menidia peninsulae	0.82	3.01	8.09	17.06
Litopenaeus setiferus	2.84	1.01	6.78	23.84
Brevoortia patronus	2.86	1.55	4.84	28.68
Pogonias cromis	0.32	1.57	4.63	33.31
Lagodon rhomboides	4.03	3.03	3.69	37.01
Lucania parva	0.35	1.30	3.50	40.51
Menidia berylina	2.11	1.23	3.49	44.00
Genus Palaemonete	3.95	4.39	2.42	46.42
Farfantepenaeus aztecus	3.88	3.27	2.23	48.66
Micropogonias undulatus	1.21	0.62	2.19	50.85
Farfantepenaeus duorarum	1.16	0.90	1.90	52.75
Mugil curema	1.80	1.36	1.65	54.40
Leiostomus xanthurus	3.05	2.82	1.51	55.91
Adinia xenica	0.43	0.06	1.37	57.27
Orthopristis chrysoptera	0.50	0.15	1.28	58.56
Bairdiella chrysoura	0.65	0.31	1.26	59.82
Eucinostomus argenteus	1.01	0.68	1.21	61.03
Callinectes sapidus	1.61	1.28	1.20	62.23
Family Mugilidae	0.26	0.08	1.07	63.30
Harengula jaguana	0.33	0.05	1.05	64.36
Sygnathus scovelli	0.37	0.64	1.00	65.35

Table 2.5 Species abundances caught by bag seine within cluster group containing San Antonio, Aransas/Copano, and Corpus Christi Bays (SAB) and the cluster consisting of Lower Laguna Madre (LLM), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance LLM	Contribution %	Cumulative Contribution %
Genus Palaemonete	3.95	1.49	9.99	9.99
Brevoortia patronus	2.86	1.13	7.04	17.03
Menidia peninsulae	0.82	1.66	5.06	22.08
Menidia beryllina	2.11	1.20	3.90	25.98
Micropogonias undulatus	1.21	1.89	2.76	28.74
Membras martinica	0.31	0.96	2.66	31.39
Anchoa mitchilli	1.80	1.15	2.63	34.03
Farfantepenaeus aztecus	3.88	4.51	2.56	36.59
Fundulus grandis	1.37	0.75	2.54	39.13
Lagodon rhomboides	4.03	3.43	2.47	41.60
Leiostomus xanthurus	3.05	3.65	2.42	44.02
Brevoortia gunteri	0.06	0.60	2.22	46.25
Farfantepenaeus duorarum	1.16	1.68	2.14	48.39
Eucinostomus argenteus	1.01	1.52	2.11	50.49
Cyprinodon variegatus	3.11	3.59	1.96	52.46
Bairdiella chrysoura	0.65	0.21	1.83	54.28
Eucinostomus gula	0.37	0.78	1.69	55.97
Eucinostomus melanopterus	0.13	0.52	1.58	57.55
Adinia xenica	0.43	0.06	1.50	59.05
Mugil cephalus	1.64	2.01	1.49	60.54
Cynoscion nebulosus	0.69	0.33	1.45	61.99
Family Mugilidae	0.26	0.19	1.33	63.31
Orthopristis chrysoptera	0.50	0.18	1.32	64.63
Ariopsis felis	0.52	0.77	1.05	65.68

Analysis of samples collected using bay trawls clustered SAB with Aransas/Copano Bay (Figure 2.91). Atlantic croaker and brown shrimp were the two species that comprised the most similarity of the assemblages between SAB and Aransas/Copano Bay (Table 2.6). Pinfish and brown shrimp were the two species that contributed the most differences between the SAB group and Sabine Lake and Galveston Bay group (Table 2.7), as well as the Matagorda and Corpus Christi Bay group (Table 2.8). Atlantic croaker and spot were the two species which contributed the most differences between SAB and Upper Laguna Madre (Table 2.9). Brown shrimp and spot were the two species that contributed most of the differences between SAB and Lower Laguna Madre (Table 2.10).

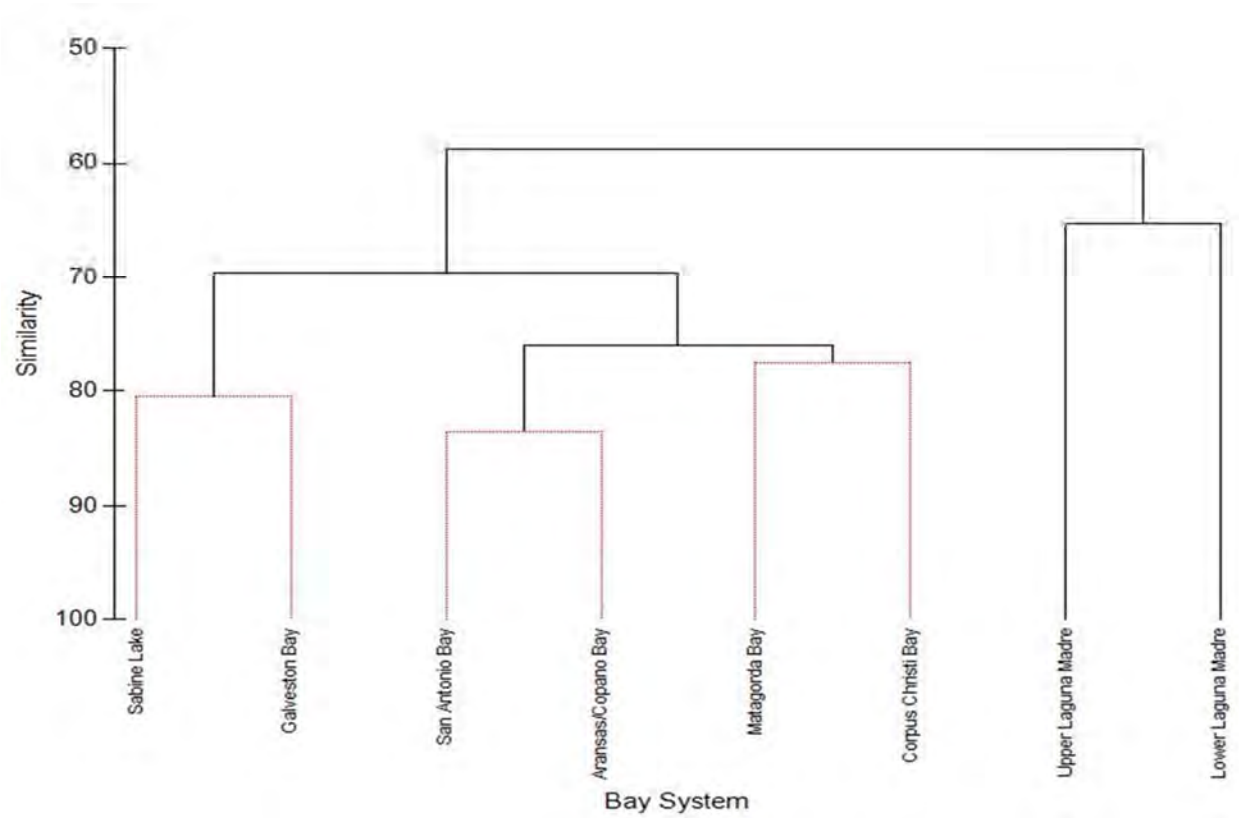


Figure 2.91 Hierarchical clustering of major bays along the Texas coast by similarity of species assemblages for bay trawl catches from 1982-2011. Black lines indicate significant differences between bays.

Table 2.6 Species abundances caught by bay trawl within cluster group containing San Antonio and Aransas/Copano Bays and their contribution to similarities between these bays. Species contributing at least 1% of similarity are included.

Species	Average Abundance	Contribution %	Cumulative Contribution %
Micropogonias undulatus	4.17	10.30	10.30
Farfantepenaeus aztecus	3.88	9.11	19.41
Leiostomus xanthurus	4.04	8.12	27.53
Lagodon rhomboides	3.19	6.32	33.85
Litopenaeus setiferus	2.46	6.15	40.00
Callinectes sapidus	2.22	5.27	45.27
Anchoa mitchilli	2.04	4.59	49.86
Bairdiella chrysoura	1.84	3.95	53.82
Brevoortia patronus	1.73	3.93	57.75
Loligo brevis	1.51	3.31	61.06
Ariopsis felis	1.38	3.05	64.11
Bagre marinus	1.18	2.66	66.77
Farfantepenaeus duorarum	1.05	2.16	68.94
Mugil cephalus	0.77	1.60	70.54
Genus Palaemonete	0.78	1.46	72.00
Chloroscombrus chrysurus	0.62	1.38	73.38
Cynoscion arenarius	0.71	1.30	74.68
Sphoeroides parvus	0.57	1.22	75.89
Orthopristis chrysoptera	0.60	1.21	77.10
Citharichthys spilopterus	0.46	1.09	78.20
Peprilus burti	0.55	1.01	79.21

Table 2.7 Species abundances caught by bay trawl within cluster group containing San Antonio and Aransas/Copano (SAB) and the cluster consisting of Sabine Lake and Galveston Bay (SL/GB), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance SL/GB	Contribution %	Cumulative Contribution %
Lagodon rhomboides	3.19	0.89	9.44	9.44
Farfantepenaeus aztecus	3.88	1.95	8.09	17.52
Leiostomus xanthurus	4.04	2.12	7.85	25.37
Bairdiella chrysoura	1.84	0.54	5.37	30.74
Farfantepenaeus duorarum	1.05	0.10	3.92	34.66
Loligo brevis	1.51	0.76	3.14	37.80
Callinectes sapidus	2.22	1.48	3.13	40.94
Micropogonias undulatus	4.17	3.46	2.94	43.87
Genus Palaemonete	0.78	0.13	2.74	46.61
Bagre marinus	1.18	0.53	2.73	49.33
Litopenaeus setiferus	2.46	3.07	2.51	51.84
Orthopristis chrysoptera	0.60	0.10	2.05	53.89
Anchoa mitchilli	2.04	1.67	1.74	55.63
Cynoscion arenarius	0.71	1.12	1.73	57.36
Stellifer lanceolatus	0.12	0.53	1.71	59.07
Ictalurus furcatus	0.50	0.71	1.66	60.73
Dorosoma petenense	0.25	0.62	1.57	62.30
Ariopsis felis	1.38	1.02	1.49	63.79
Chloroscombrus chrysurus	0.62	0.64	1.28	65.07
Polydactylus octonemus	0.45	0.15	1.23	66.29
Brevoortia patronus	1.73	1.57	1.21	67.51
Peprilus burti	0.55	0.32	1.20	68.71
Pogonias cromis	0.27	0.50	1.08	69.80
Sphoeroides parvus	0.57	0.34	1.04	70.84

Table 2.8 Species abundances caught by bay trawl within cluster group containing San Antonio and Aransas/Copano (SAB) and the cluster consisting of Matagorda and Corpus Christi Bays (MB/CCB), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance MB/CCB	Contribution %	Cumulative Contribution %
Lagodon rhomboides	3.19	3.83	10.49	10.49
Farfantepenaeus aztecus	3.88	2.18	7.58	18.07
Callinectes sapidus	2.22	1.17	4.65	22.72
Loligo brevis	1.51	2.52	4.48	27.20
Chloroscombrus chrysurus	0.62	1.50	3.96	31.16
Leiostomus xanthurus	4.04	3.99	3.63	34.79
Genus Palaemonete	0.78	0.12	2.98	37.77
Litopenaeus setiferus	2.46	1.82	2.81	40.58
Bairdiella chrysoura	1.84	1.25	2.68	43.26
Micropogonias undulatus	4.17	3.57	2.61	45.87
Brevoortia patronus	1.73	1.18	2.44	48.32
Bagre marinus	1.18	0.68	2.20	50.52
Selene setapinnis	0.18	0.62	2.00	52.51
Peprilus burti	0.55	0.97	1.89	54.40
Ictalurus furcatus	0.50	0.27	1.84	56.24
Cynoscion nothus	0.23	0.61	1.70	57.94
Mugil cephalus	0.77	0.39	1.70	59.64
Ariopsis felis	1.38	1.59	1.65	61.29
Farfantepenaeus duorarum	1.05	0.81	1.58	62.87
Orthopristis chrysoptera	0.60	0.67	1.44	64.31
Trichiurus lepturus	0.27	0.55	1.28	65.59
Cynoscion arenarius	0.71	0.96	1.15	66.74
Stellifer lanceolatus	0.12	0.37	1.12	67.86
Polydactylus octonemus	0.45	0.67	1.02	68.87
Dorosoma cepedianum	0.36	0.13	1.01	69.89

Table 2.9 Species abundances caught by bay trawl within cluster group containing San Antonio and Aransas/Copano (SAB) and the cluster consisting of Upper Laguna Madre (ULM), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance ULM	Contribution %	Cumulative Contribution %
Micropogonias undulatus	4.17	1.32	9.23	9.23
Leiostomus xanthurus	4.04	1.48	8.20	17.44
Farfantepenaeus aztecus	3.88	1.86	6.61	24.05
Brevoortia patronus	1.73	0.31	4.65	28.69
Litopenaeus setiferus	2.46	1.18	4.15	32.84
Genus Palaemonete	0.78	1.99	3.90	36.74
Bagre marinus	1.18	0.11	3.49	40.23
Loligo brevis	1.51	0.57	3.03	43.26
Pogonias cromis	0.27	1.15	2.84	46.10
Callinectes sapidus	2.22	1.36	2.80	48.90
Bairdiella chrysoura	1.84	0.99	2.71	51.61
Gobiosoma robustum	0.04	0.87	2.68	54.29
Lucania parva	0.05	0.72	2.19	56.48
Lagodon rhomboides	3.19	2.68	2.11	58.58
Chloroscombrus chrysurus	0.62	0.03	1.92	60.51
Anchoa mitchilli	2.04	1.47	1.84	62.35
Ariopsis felis	1.38	0.83	1.76	64.11
Cynoscion arenarius	0.71	0.17	1.73	65.84
Ictalurus furcatus	0.50	0.00	1.66	67.50
Peprilus burti	0.55	0.05	1.59	69.09
Mugil cephalus	0.77	0.37	1.29	70.39
Opsanus beta	0.20	0.58	1.23	71.61
Dorosoma cepedianum	0.36	0.04	1.03	72.64

Table 2.10 Species abundances caught by bay trawl within cluster group containing San Antonio and Aransas/Copano (SAB) and the cluster consisting of Lower Laguna Madre (LLM), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance LLM	Contribution %	Cumulative Contribution %
Farfantepenaeus aztecus	3.88	1.66	7.64	7.64
Leiostomus xanthurus	4.04	1.82	7.49	15.14
Micropogonias undulatus	4.17	2.27	6.50	21.63
Litopenaeus setiferus	2.46	0.82	5.61	27.25
Brevoortia patronus	1.73	0.23	5.16	32.41
Lagodon rhomboides	3.19	4.33	3.99	36.39
Anchoa mitchilli	2.04	0.99	3.59	39.98
Bagre marinus	1.18	0.16	3.51	43.49
Orthopristis chrysoptera	0.60	1.51	3.13	46.62
Opsanus beta	0.20	1.02	2.80	49.42
Chilomycterus schoepfi	0.12	0.92	2.77	52.19
Loligo brevis	1.51	0.88	2.15	54.33
Mugil cephalus	0.77	0.24	1.81	56.15
Ictalurus furcatus	0.50	0.00	1.75	57.90
Callinectes sapidus	2.22	1.78	1.51	59.40
Ariopsis felis	1.38	1.03	1.20	60.60
Peprilus burti	0.55	0.20	1.18	61.78
Dorosoma cepedianum	0.36	0.06	1.01	62.79

Cluster analysis with samples obtained using gillnets was the largest group, as SAB clustered with Galveston Bay, Matagorda Bay, and Aransas/Copano Bays (Figure 2.92). Hardhead catfish and red drum were the two species that contributed the most in terms of similarity of the assemblages between SAB, Galveston Bay, Matagorda Bay, and Aransas/Copano Bays (Table 2.11). Hardhead catfish and alligator gar were the two species that contributed the most in terms of differences between the SAB group and the Sabine Lake group (Table 2.12). Gafftopsail catfish and gizzard shad were the two species that contributed the most in terms of dissimilarity between the SAB group and the Corpus Christi Bay and Lower Laguna Madre group (Table 2.13). Black drum and gafftopsail catfish were the two species that contributed the most on terms of dissimilarity between the SAB group and Upper Laguna Madre (Table 2.14).

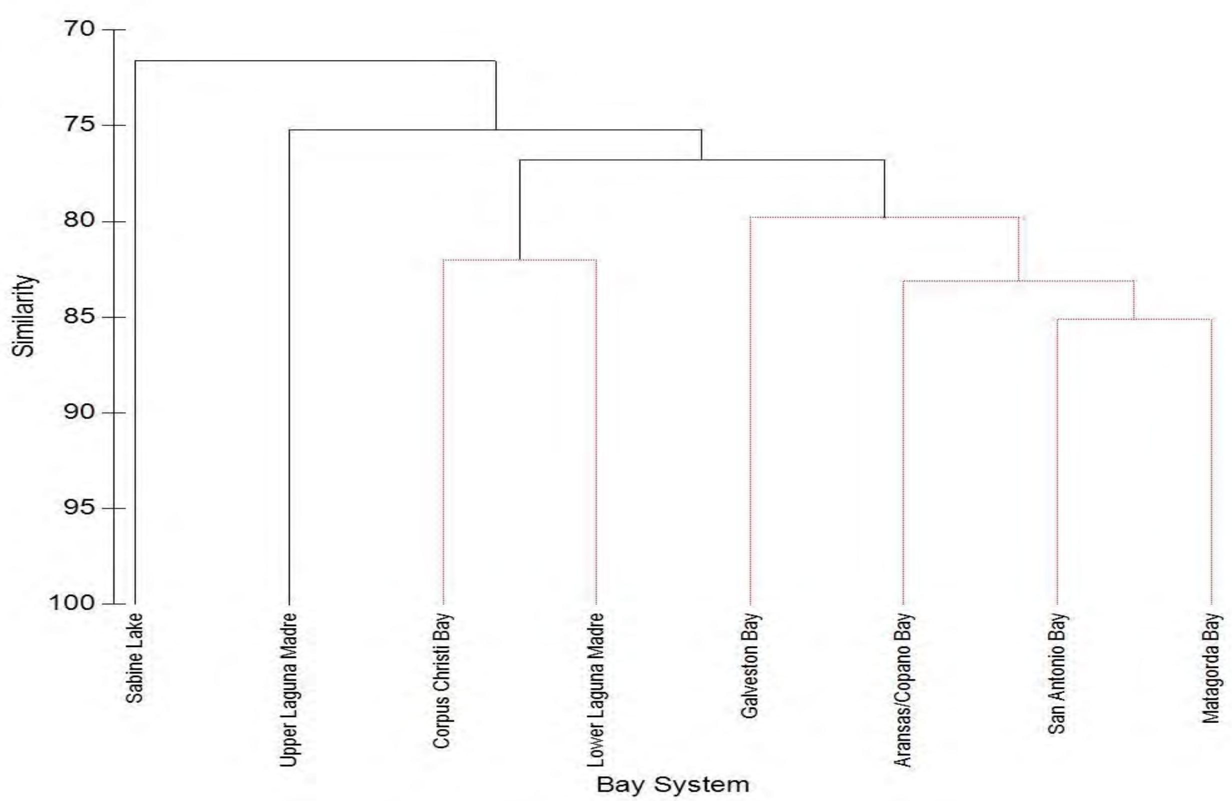


Figure 2.92 Hierarchical clustering of major bays along the Texas coast by similarity of species assemblages for gillnet catches from 1982-2011. Black lines indicate significant differences between bays.

Table 2.11 Species abundances caught by bay trawl within cluster group containing San Antonio, Galveston, Matagorda and Aransas/Copano Bays and their contribution to similarities between these bays. Species contributing at least 1% of similarity are included.

Species	Average Abundance	Contribution %	Cumulative Contribution %
Ariopsis felis	4.35	11.30	11.30
Sciaenops ocellatus	3.41	9.42	20.72
Pogonias cromis	3.27	8.63	29.36
Dorosoma cepedianum	3.04	8.09	37.45
Cynoscion nebulosus	2.67	7.48	44.93
Bagre marinus	2.32	5.79	50.72
Mugil cephalus	2.02	5.58	56.31
Brevoortia patronus	1.98	3.75	60.05
Micropogonias undulatus	1.52	3.59	63.64
Atractosteus spatula	1.18	2.95	66.60
Leiostomus xanthurus	1.08	2.78	69.38
Archosargus probatocephalus	1.11	2.62	72.00
Lepisosteus oculatus	0.95	2.35	74.35
Paralichthys lethostigma	0.85	2.35	76.70
Elops saurus	0.89	2.15	78.85
Ictalurus furcatus	0.83	1.68	80.52
Carcharhinus leucas	0.71	1.66	82.19
Brevoortia gunteri	0.51	1.17	83.36

Table 2.12 Species abundances caught by bay trawl within cluster group containing San Antonio, Galveston, Matagorda and Aransas/Copano Bays (SAB) and the cluster consisting of Sabine Lake (SL), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance SL	Contribution %	Cumulative Contribution %
Ariopsis felis	4.35	2.16	10.56	10.56
Atractosteus spatula	1.18	3.04	9.04	19.60
Brevoortia patronus	1.98	2.84	6.87	26.47
Lepisosteus oculatus	0.95	2.09	5.53	32.00
Dorosoma cepedianum	3.04	3.79	3.65	35.65
Archosargus probatocephalus	1.11	0.48	3.04	38.69
Sciaenops ocellatus	3.41	4.03	3.00	41.70
Elops saurus	0.89	0.30	2.85	44.55
Bagre marinus	2.32	1.87	2.70	47.25
Micropogonias undulatus	1.52	1.78	2.54	49.79
Brevoortia gunteri	0.51	0.00	2.45	52.24
Ictalurus furcatus	0.83	0.33	2.39	54.62
Ictiobus bubalus	0.49	0.05	2.11	56.73
Pogonias cromis	3.27	3.53	2.11	58.83
Morone mississippiensis	0.07	0.50	2.08	60.92
Cynoscion nebulosus	2.67	2.29	1.84	62.76
Leiostomus xanthurus	1.08	1.34	1.46	64.21
Carcharhinus limbatus	0.35	0.05	1.45	65.66
Rhinoptera bonasus	0.32	0.05	1.33	67.00
Dasyatis sabina	0.26	0.03	1.10	68.10
Mugil cephalus	2.02	1.81	1.08	69.18
Cynoscion arenarius	0.42	0.43	1.02	70.19
Lepisosteus osseus	0.33	0.13	1.02	71.21

Table 2.13 Species abundances caught by bay trawl within cluster group containing San Antonio, Galveston, Matagorda and Aransas/Copano Bays (SAB) and the cluster consisting of Corpus Christi Bay and Lower Laguna Madre (CCB/LLM), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance CCB/LLM	Contribution %	Cumulative Contribution %
Bagre marinus	2.32	1.08	6.63	6.63
Dorosoma cepedianum	3.04	1.85	6.50	13.13
Brevoortia patronus	1.98	1.31	4.98	18.10
Lepisosteus oculatus	0.95	0.06	4.73	22.83
Elops saurus	0.89	1.62	3.91	26.74
Ictalurus furcatus	0.83	0.16	3.50	30.24
Atractosteus spatula	1.18	0.54	3.43	33.68
Ariopsis felis	4.35	3.90	3.30	36.98
Cynoscion nebulosus	2.67	3.28	3.29	40.27
Leiostomus xanthurus	1.08	1.63	2.97	43.23
Micropogonias undulatus	1.52	1.84	2.92	46.15
Pogonias cromis	3.27	3.63	2.66	48.81
Ictiobus bubalus	0.49	0.01	2.51	51.31
Carcharhinus leucas	0.71	0.24	2.48	53.79
Lutjanus griseus	0.25	0.66	2.15	55.95
Dorosoma petenense	0.07	0.42	1.88	57.83
Sciaenops ocellatus	3.41	3.60	1.84	59.67
Lagodon rhomboides	0.35	0.66	1.66	61.33
Archosargus probatocephalus	1.11	1.31	1.65	62.98
Mugil cephalus	2.02	1.75	1.59	64.56
Lepisosteus osseus	0.33	0.04	1.47	66.03
Paralichthys albigutta	0.12	0.39	1.42	67.45
Centropomus undecimalis	0.03	0.28	1.33	68.79
Cynoscion arenarius	0.42	0.34	1.11	69.89

Table 2.14 Species abundances caught by bay trawl within cluster group containing San Antonio, Galveston, Matagorda and Aransas/Copano Bays (SAB) and the cluster consisting of Upper Laguna Madre (ULM), as well as their contribution to dissimilarities between groups. Species contributing at least 1% of dissimilarity are included.

Species	Average Abundance SAB	Average Abundance ULM	Contribution %	Cumulative Contribution %
Pogonias cromis	3.27	5.80	13.44	13.44
Bagre marinus	2.32	0.45	9.84	23.28
Ariopsis felis	4.35	3.01	7.01	30.29
Dorosoma cepedianum	3.04	2.01	5.53	35.82
Brevoortia patronus	1.98	1.07	4.73	40.55
Ictalurus furcatus	0.83	0.24	3.08	43.63
Sciaenops ocellatus	3.41	2.84	3.05	46.68
Carcharhinus leucas	0.71	0.17	2.85	49.53
Atractosteus spatula	1.18	0.68	2.68	52.20
Ictiobus bubalus	0.49	0.00	2.55	54.76
Micropogonias undulatus	1.52	1.12	2.12	56.88
Brevoortia gunteri	0.51	0.12	2.06	58.94
Archosargus probatocephalus	1.11	0.77	1.95	60.89
Leiostomus xanthurus	1.08	1.35	1.64	62.53
Carcharhinus limbatus	0.35	0.04	1.62	64.15
Elops saurus	0.89	1.16	1.50	65.65
lepisosteus osseus	0.33	0.06	1.38	67.03
Lepisosteus oculatus	0.95	1.21	1.36	68.39
Cynoscion arenarius	0.42	0.19	1.21	69.60
Scomberomorus maculatus	0.33	0.10	1.21	70.81
Sphyrna tiburo	0.30	0.08	1.13	71.94

Annual Species Assemblages within SAB

In all gears tested, there were species assemblage changes as time progressed. Cluster analysis of samples obtained with bag seines (Figure 2.93), showed that the two main species which contributed the most dissimilarity between the clusters were grass shrimp and gulf menhaden. These two species also happened to be two of the most abundant species caught with bag seines in SAB.

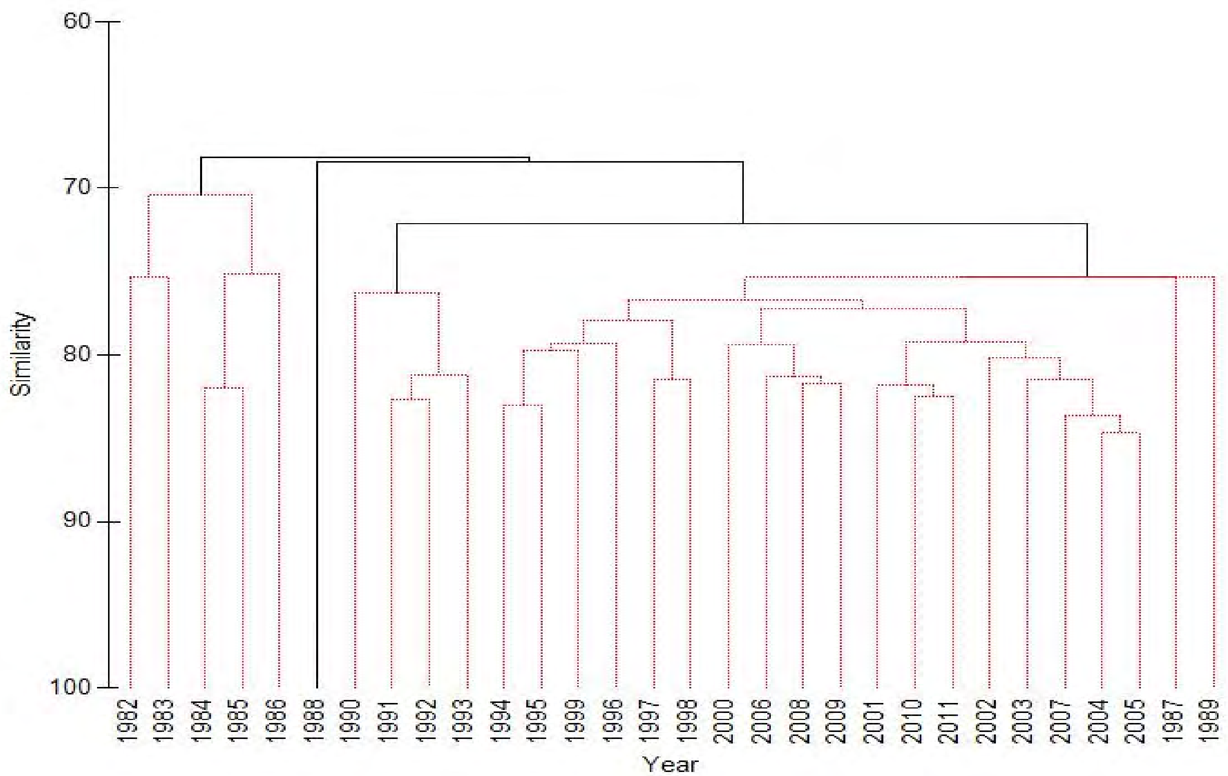


Figure 2.93 San Antonio Bay hierarchical clustering of years by similarity of species assemblages for bag seine catches from 1982-2011. Black lines indicate significant differences between bays.

Cluster analysis of samples obtained with bay trawls (Figure 2.94), showed dissimilarity between clusters with a variety of species, but some common ones that contributed substantial amounts of difference were blue crab, brown shrimp, Atlantic croaker, and spot. While these were some of the most common species showing up in the analysis, there are certain species which cause individual clusters to be significantly different from others, such as Atlantic bumper in 1996 showing elevated abundance or white shrimp in the cluster containing 2007 and 2010. By examining the trends of some of these species over time (see fishery dependent discussion), one can get an understanding of the changes occurring in the assemblages as species composition is altered.

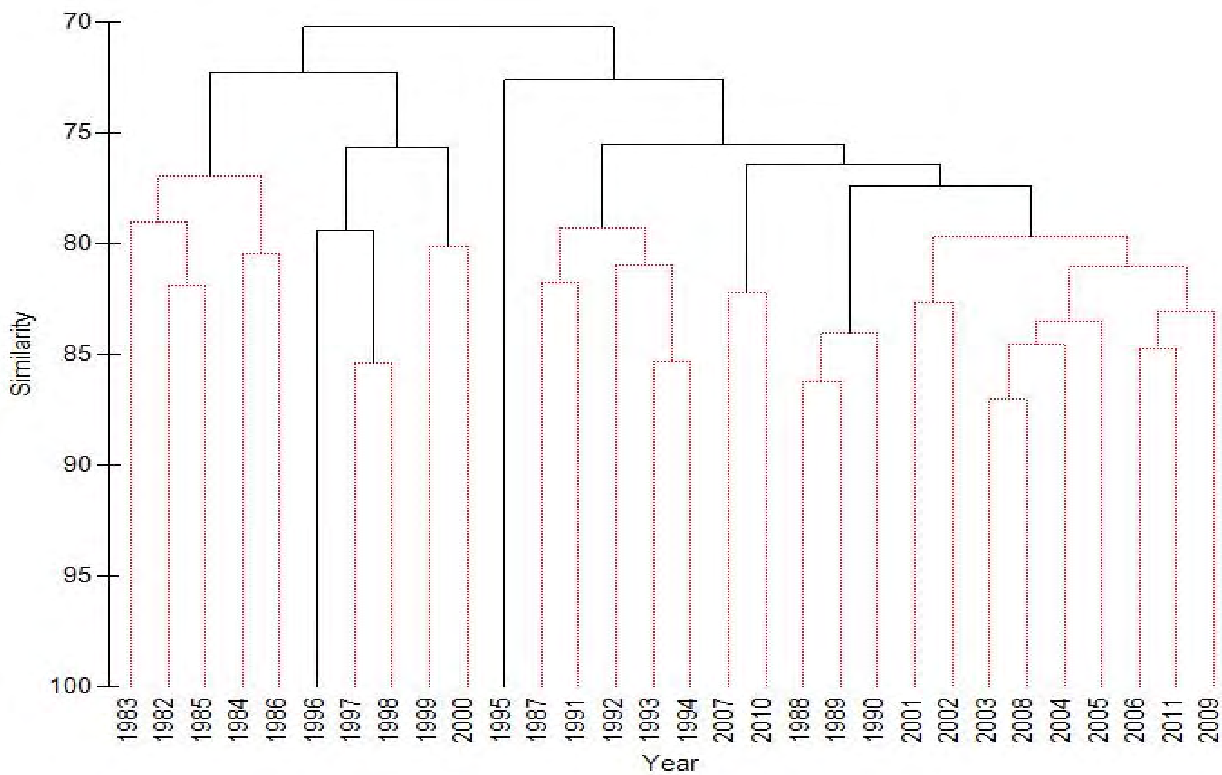


Figure 2.94 San Antonio Bay hierarchical clustering of years by similarity of species assemblages for bay trawl catches from 1982-2011. Black lines indicate significant differences between bays.

Cluster analysis of samples obtained with gillnets (Figure 2.95), showed dissimilarity between clusters with a variety of species, but some of the most common ones that contributed substantial amounts of difference were black drum and red drum. As with the bay trawls, there are certain clusters which differ from all other clusters due to a single species, like the cluster containing 1984 which has an unusually high catch rate for blue catfish or the cluster containing 1985 and 1986 in which gizzard shad is one of the species causing dissimilarity between other clusters. Other species trends when examined throughout the years show the changing of species assemblages, such as the explosion of ladyfish abundance in SAB over the previous 10 years. This species shows up as contributing substantial differences between the clusters from the most recent years and those further back.

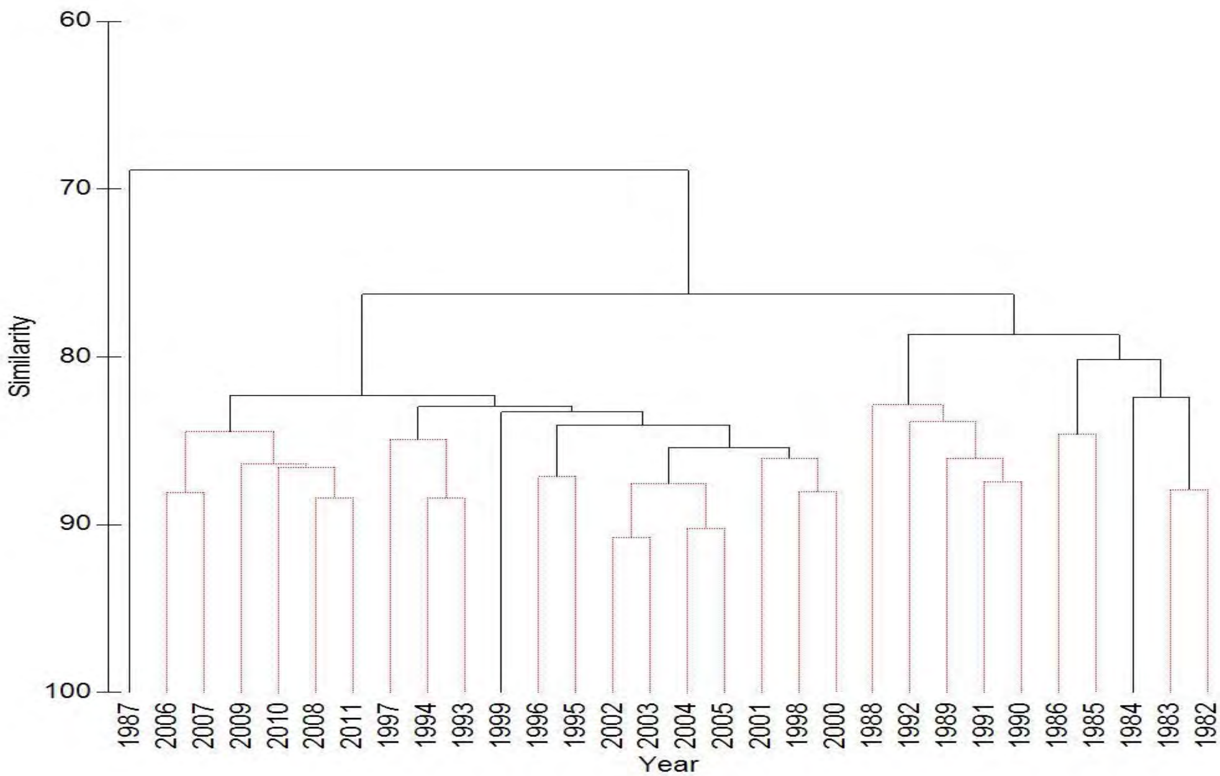


Figure 2.95 San Antonio Bay hierarchical clustering of years by similarity of species assemblages for gillnet catches from 1982-2011. Black lines indicate significant differences between bays.

Spatial Distribution of Species

Bag Seine

Grass Shrimp*, Palaemonete spp.:* Grass shrimp catches in bag seines favored areas with higher salinity in the bays. These locations were Espiritu Santo Bay (ESB), Eastern SAB, and Southern SAB on the Matagorda Island shoreline (Figure 2.96). The mean salinity for grass shrimp samples was 18.6 ppt.

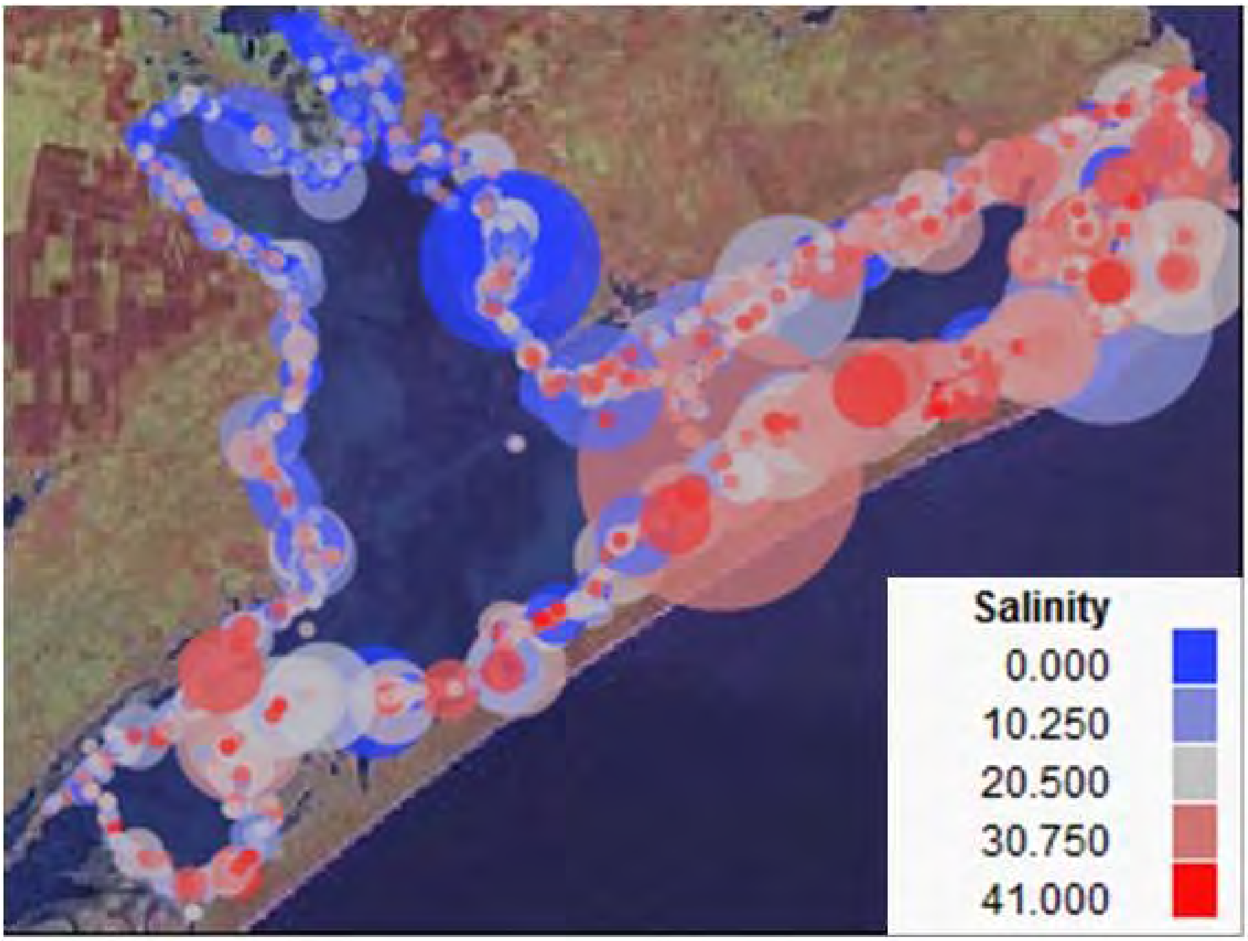


Figure 2.96 Spatial distribution of grass shrimp, Genus *Palaemonete*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection

Brown Shrimp, *Farfantepenaeus aztecus:* Brown shrimp catches showed more tolerance to salinity ranges in the bays, though catches were slightly larger from Espiritu Santo Bay (Figure 2.97). The mean salinity for brown shrimp samples was 19.7 ppt.

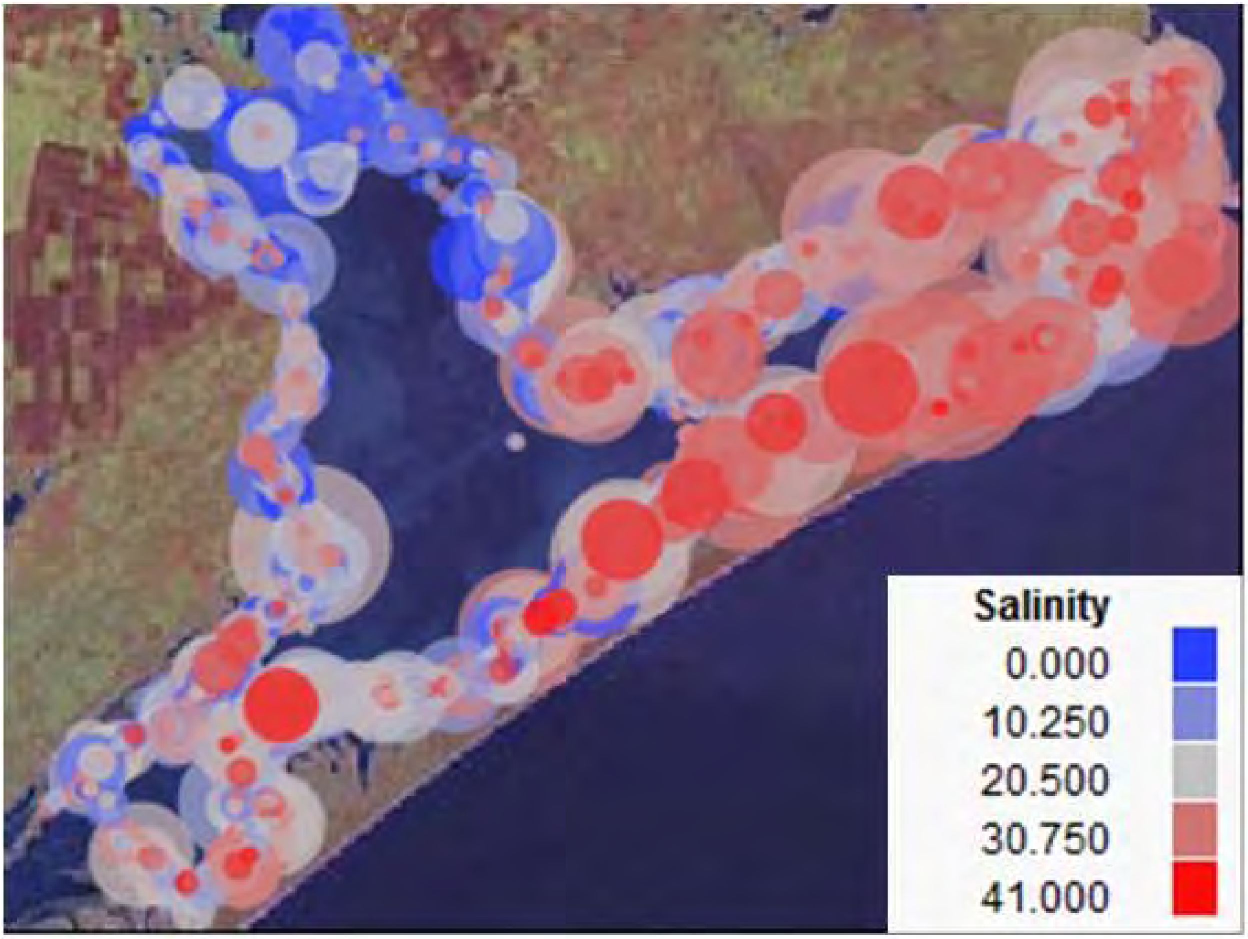


Figure 2.97 Spatial distribution of brown shrimp, *Farfantepenaeus aztecus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Pinfish, *Lagodon rhomboides:* Pinfish catches favored areas with higher salinity in the bays. These locations were ESB, Eastern SAB, and Southern SAB on Matagorda Island shoreline (Figure 2.98). The mean salinity for pinfish samples was 20.8 ppt.

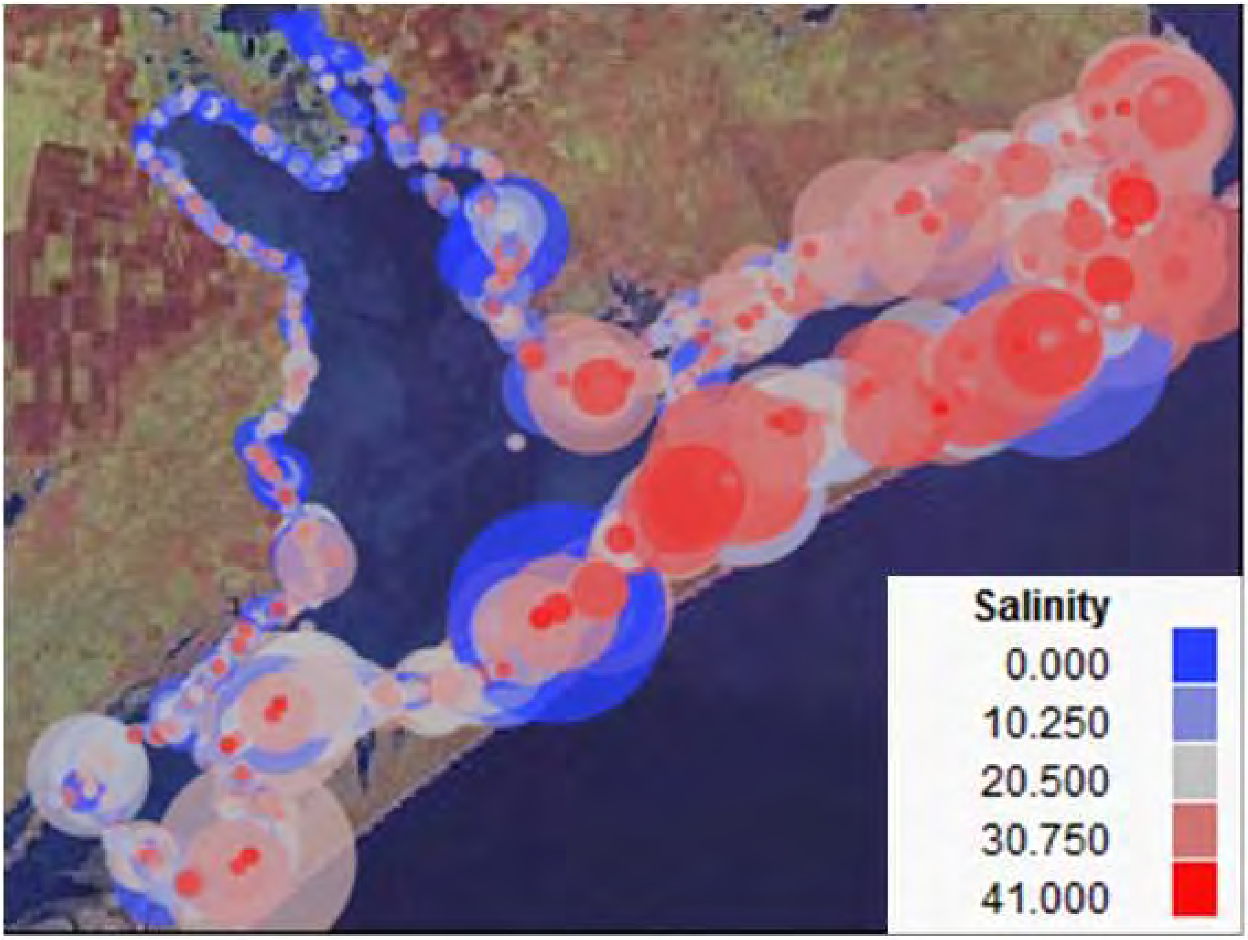


Figure 2.98 Spatial distribution of pinfish, *Lagodon rhomboides*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gulf Menhaden, *Brevoortia patronus:* Gulf menhaden catches favored areas with low salinity in the bays. Catches were centered around upper SAB, Guadalupe, and Hynes Bays (Figure 2.99). There were larger catches in lower SAB and ESB, but these were associated with unusually low salinities than are typical for these areas. The mean salinity for gulf menhaden samples was 9.6 ppt.

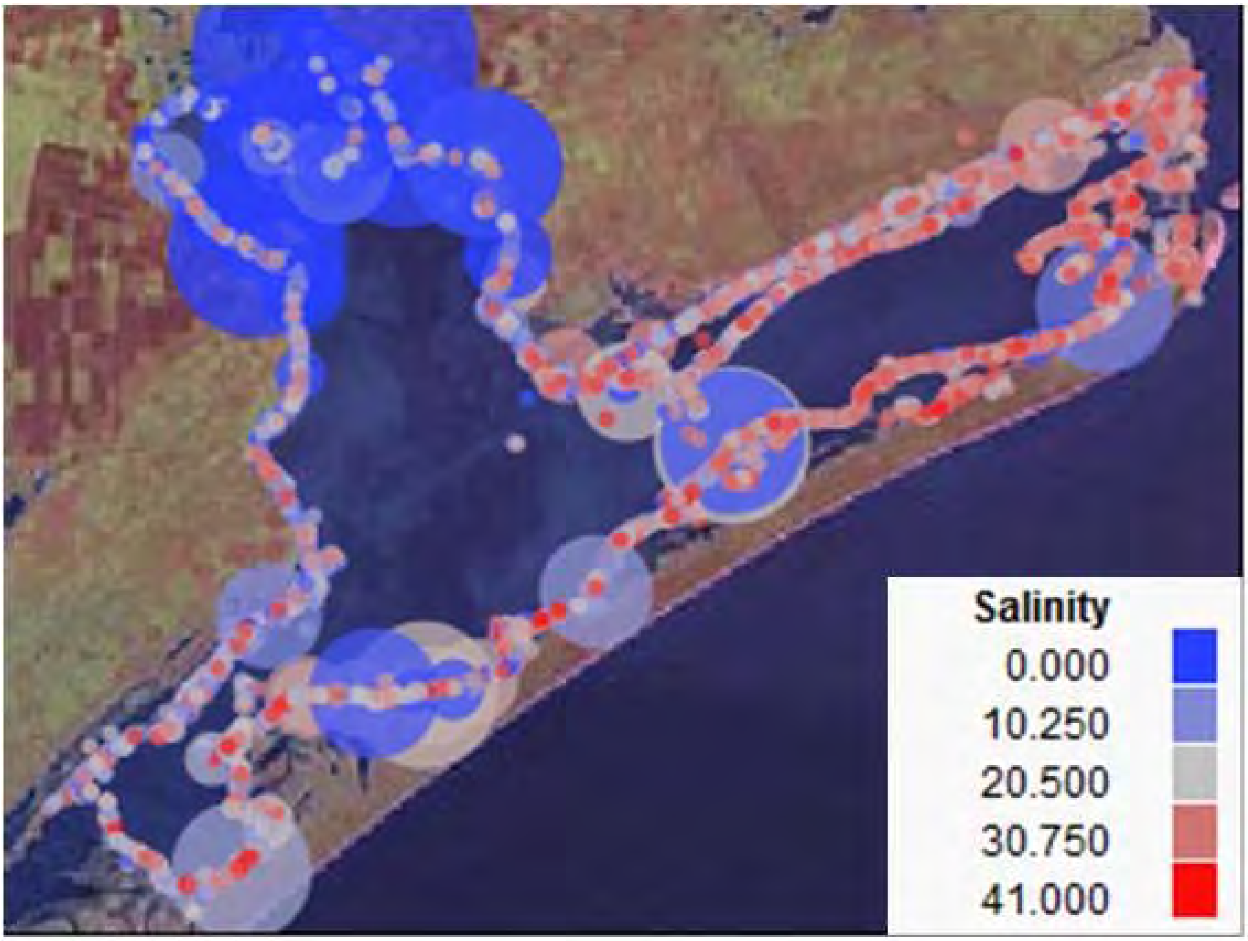


Figure 2.99 Spatial distribution of gulf menhaden, *Brevoortia patronus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Sheepshead Minnow*, Cyprinodon variegates:* Sheepshead minnows did not show a clear preference due to salinity as there were consistently large catches in low, intermediate, and high salinities (Figure 2.100). The catches did show a preference for Upper and Eastern SAB (including Hynes and Guadalupe Bays) as well as ESB. The mean salinity for sheepshead minnow samples was 19.6 ppt.

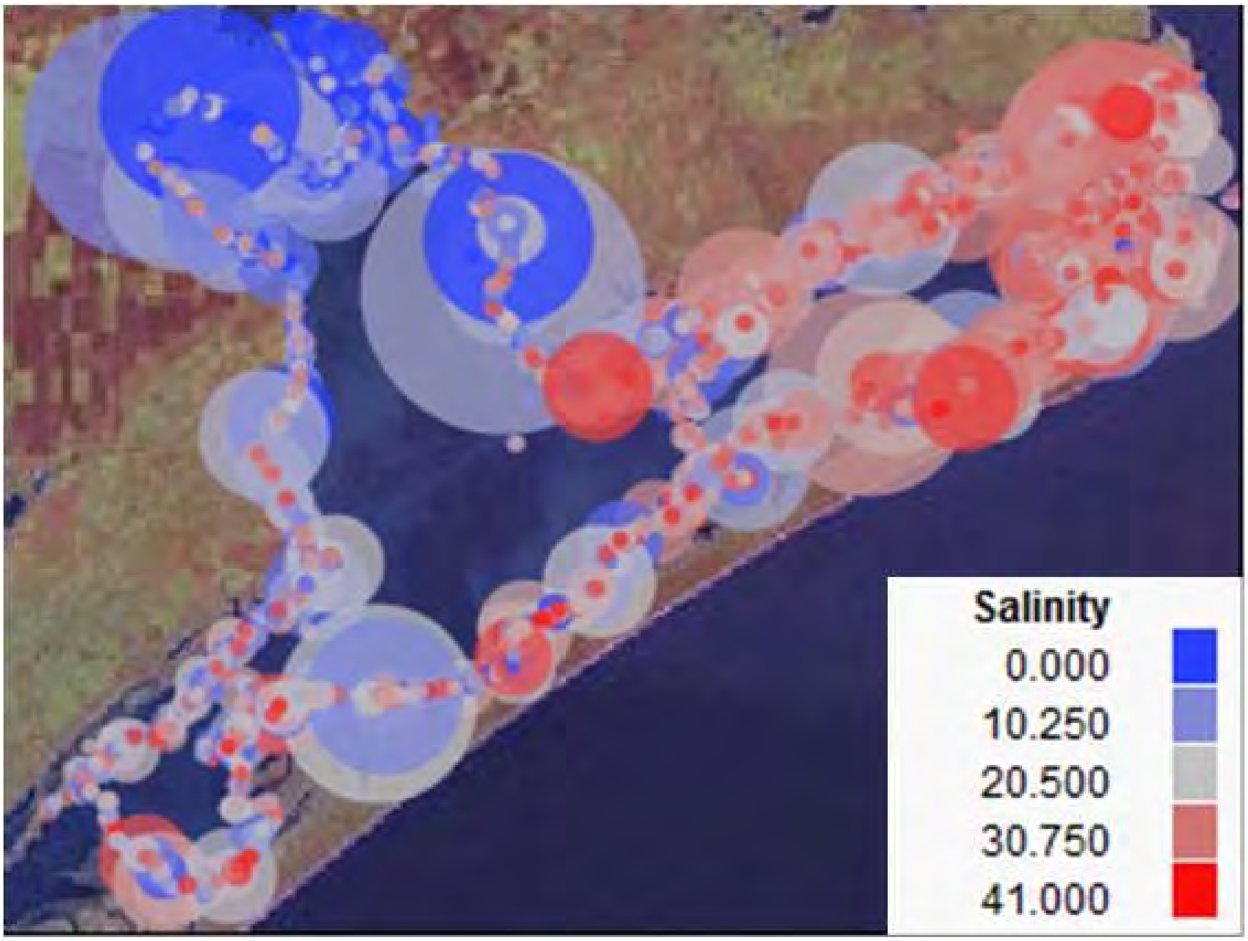


Figure 2.100 Spatial distribution of sheepshead minnow, *Cyprinodon variegatus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

White Shrimp, *Litopenaeus setiferus:* White shrimp catches favored areas with lower salinity in the bays. These locations were upper SAB (including Hynes and Guadalupe Bays). There were catches in Mesquite and ESB, but many of these are smaller or during low salinity events (Figure 2.101), which coincides with a previous study in Texas (Copeland and Bechtel 1974). The mean salinity for white shrimp samples was 17.5 ppt.

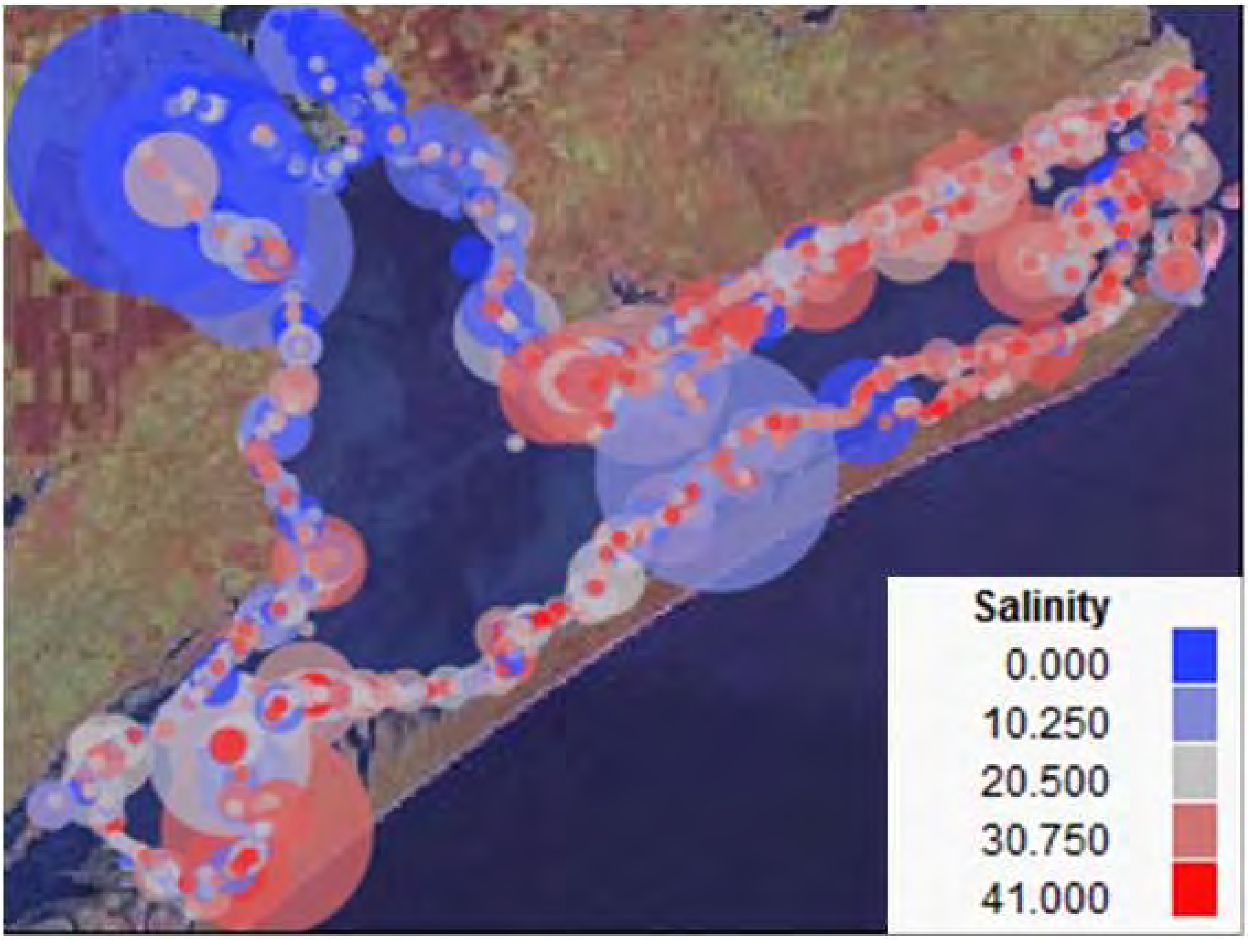


Figure 2.101 Spatial distribution of white shrimp, *Litopenaeus setiferus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Spot, *Leiostomus xanthurus:* Spot catches showed a trend favoring areas with higher salinity in the bays. These locations were ESB, Eastern SAB, and Southern SAB on Matagorda Island shoreline (Figure 2.102). The mean salinity for spot samples was 19.3 ppt.

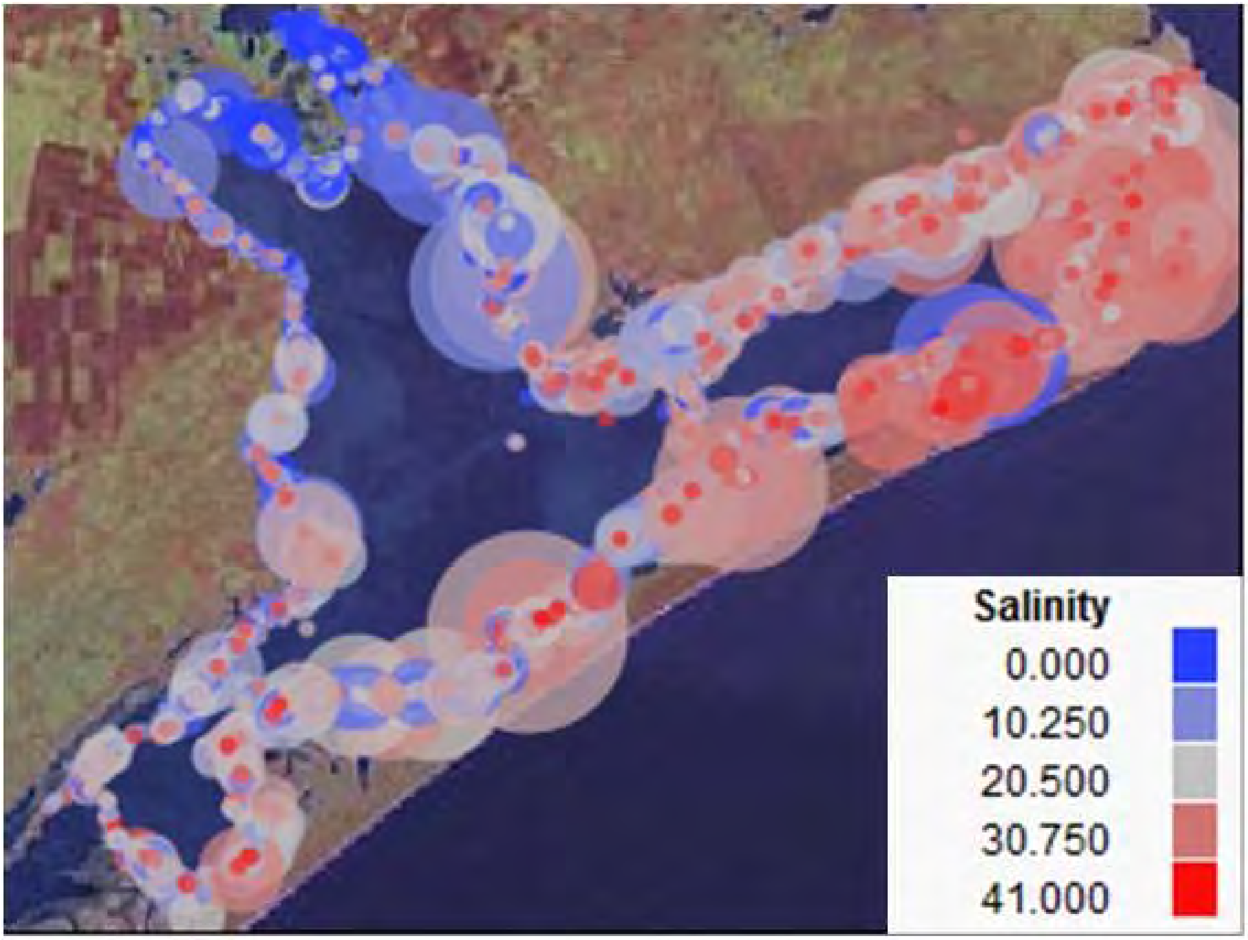


Figure 2.102 Spatial distribution of spot, *Leiostomus xanthurus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Tidewater Silverside, *Menidia peninsulae:* Tidewater silverside catches showed a trend favoring areas with higher salinity in the bays. These locations were ESB, Eastern SAB, and Southern SAB on Matagorda Island shoreline (Figure 2.103). The mean salinity for tidewater silverside samples was 21.4 ppt.

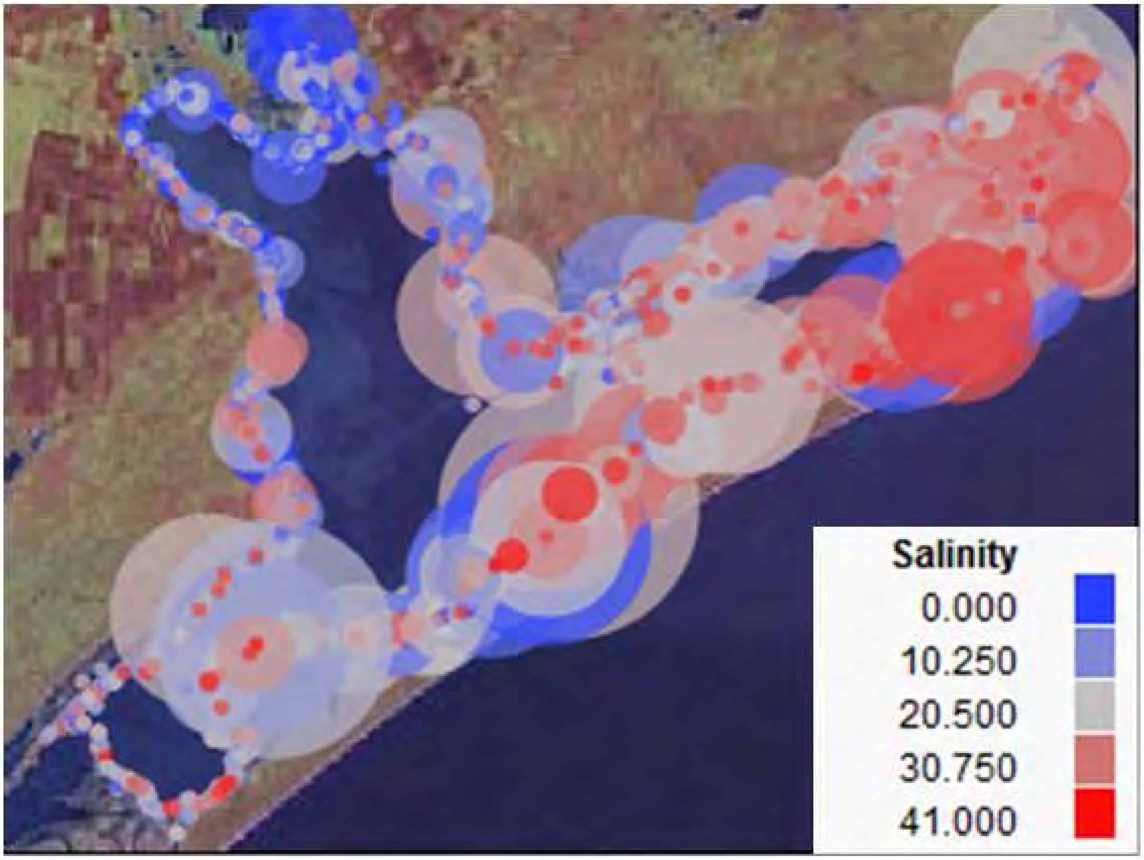


Figure 2.103 Spatial distribution of tidewater silverside, *Menidia peninsulae*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

White Mullet, *Mugil curema:* White mullet catches showed no distinct trend in regards to salinity in the bays. While white mullet were caught throughout the bay, the areas in which the largest numbers were caught were the northern shore of ESB (Figure 2.104). The mean salinity for white mullet samples was 18.7 ppt.

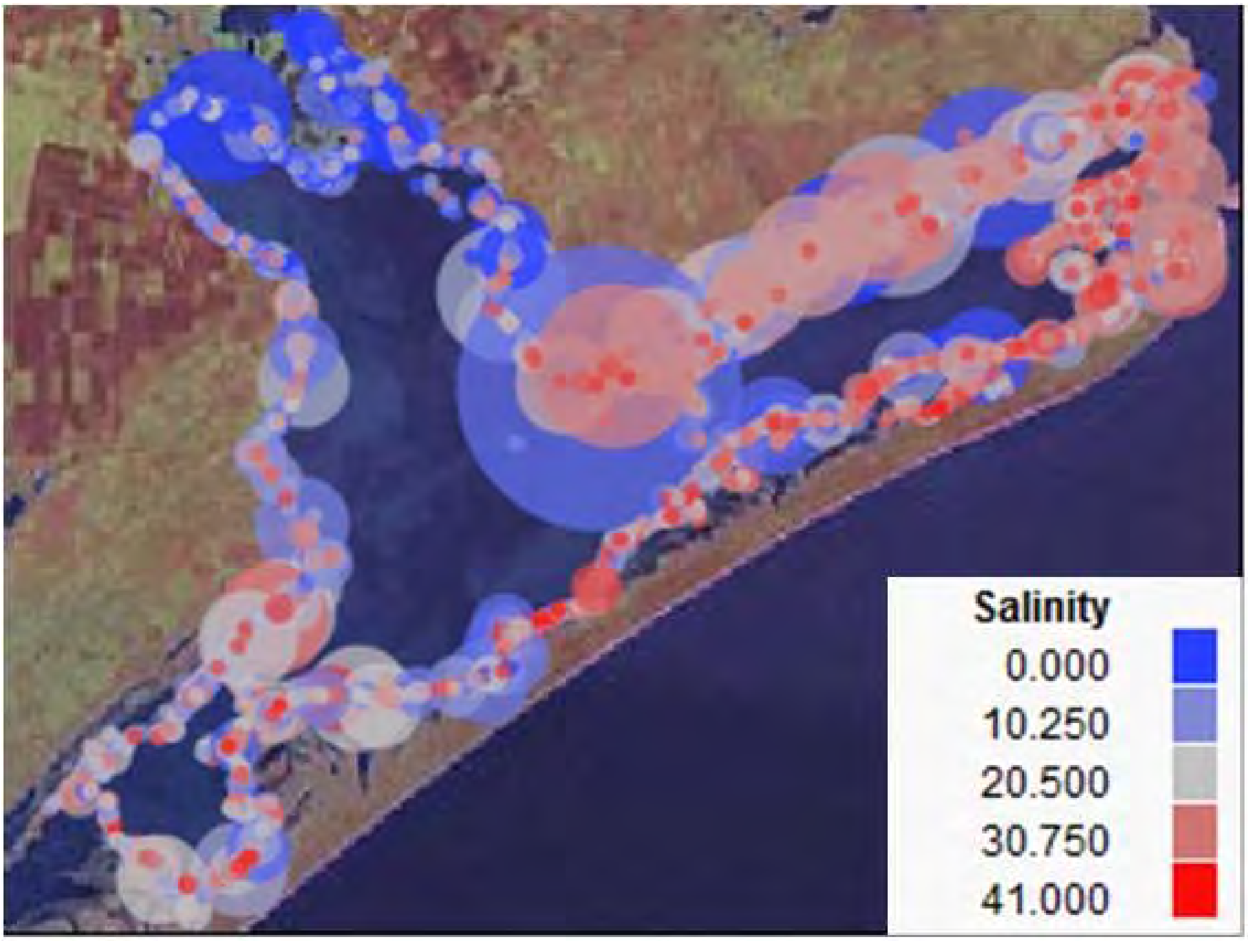


Figure 2.104 Spatial distribution of white mullet, *Mugil curema*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Bay Anchovy, *Anchoa mitchilli:* Bay anchovy catches showed a trend favoring areas with higher salinity. While bay anchovies were caught throughout the bay, the areas in which the largest numbers were caught were in eastern ESB (Figure 2.105). The mean salinity for bay anchovy samples was 16.5 ppt.

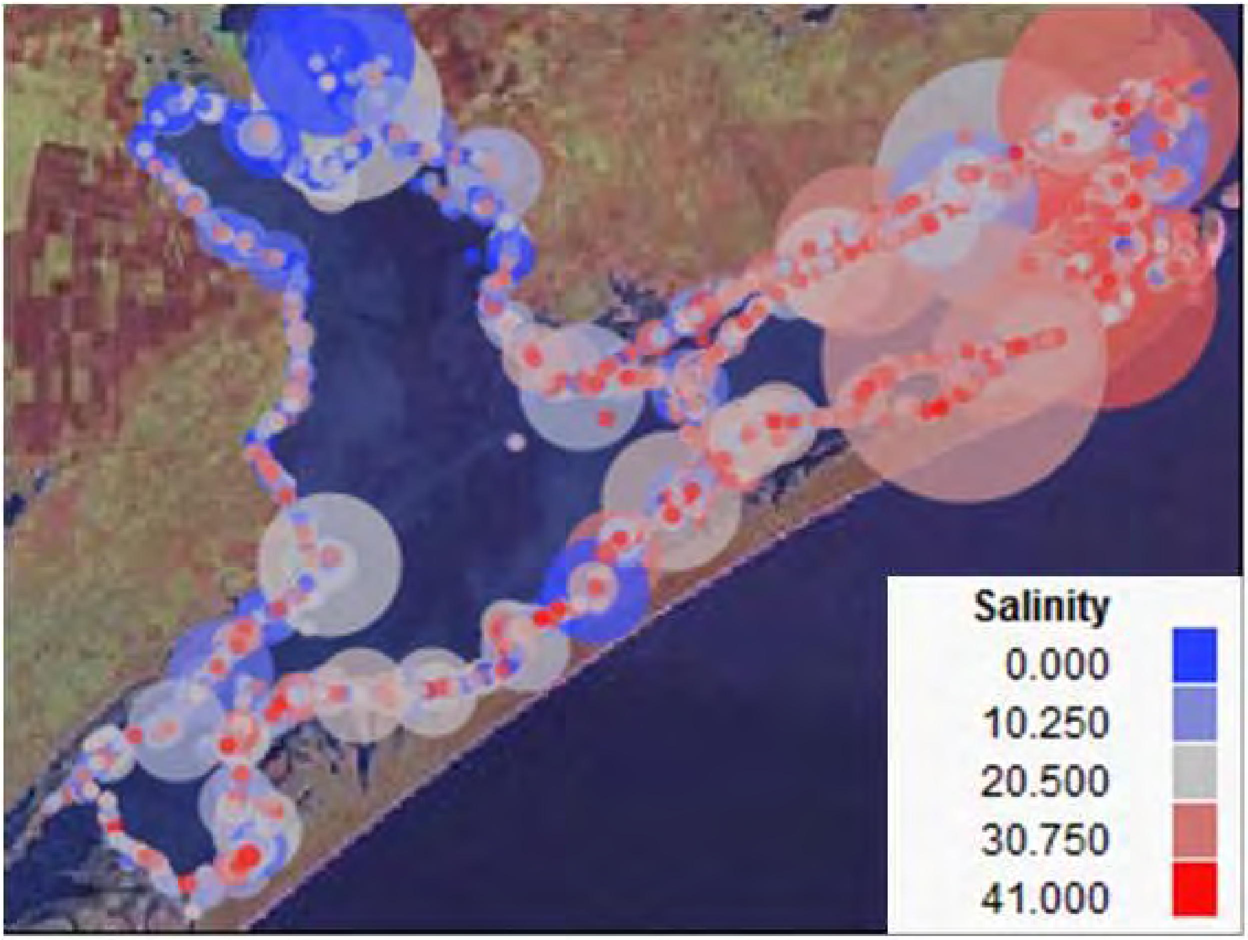


Figure 2.105 Spatial distribution of bay anchovy, *Anchoa mitchilli*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Striped Mullet, *Mugil cephalus:* Striped mullet catches showed a trend favoring areas with lower salinity in the bays. While striped mullet were caught throughout the bay, the areas in which the largest numbers were caught were in upper SAB and northern ESB, at salinities below the mean (Figure 2.106). The mean salinity for striped mullet samples was 14.5 ppt.

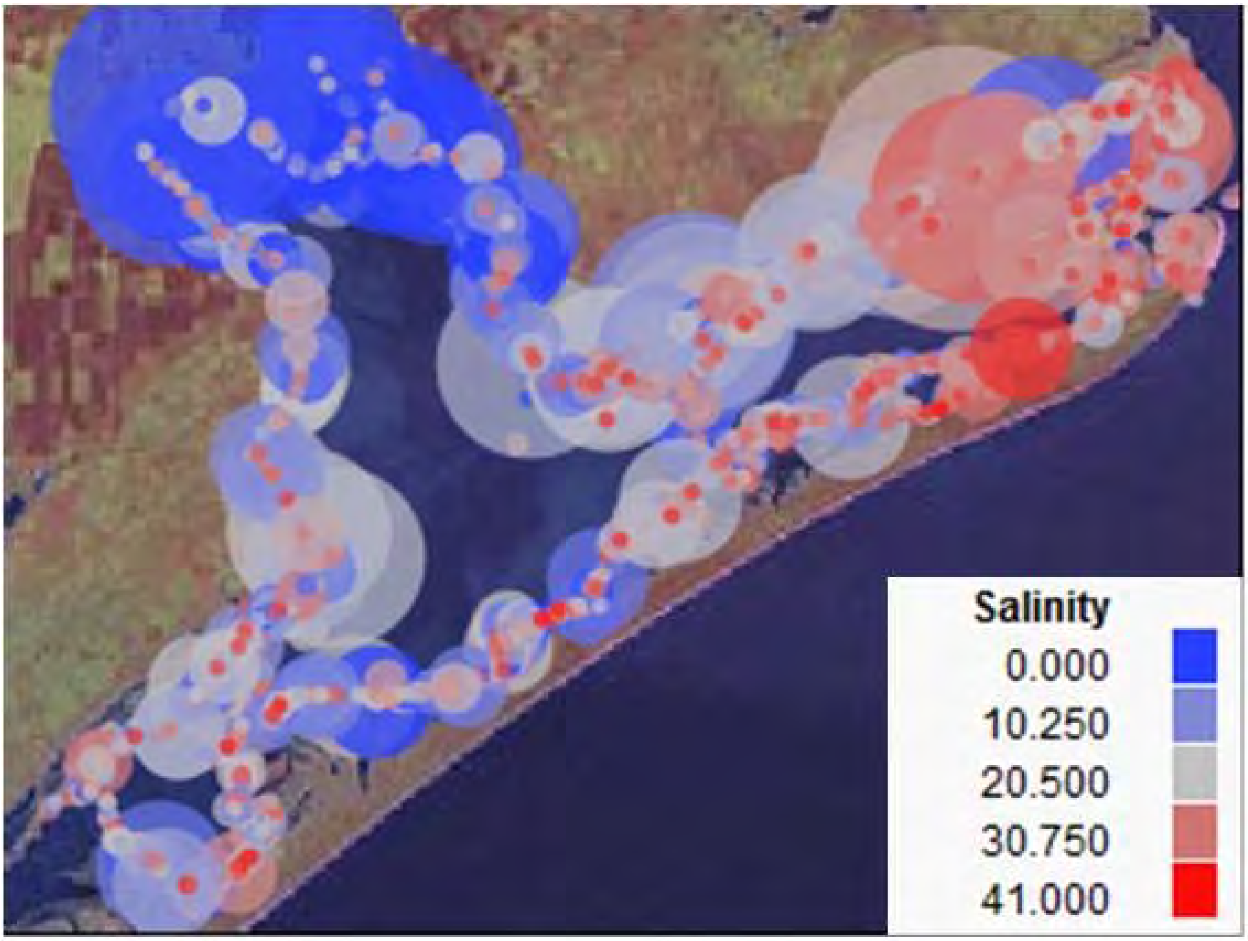


Figure 2.106 Spatial distribution of striped mullet, *Mugil cephalus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Longnose Killifish, *Fundulus similis:* Longnose killifish catches showed a trend favoring areas with higher salinity in the bays. The locations of the most abundant catches were in southern ESB, southern SAB, and Mesquite Bay (Figure 2.107). The mean salinity for longnose killifish samples was 22.0 ppt.

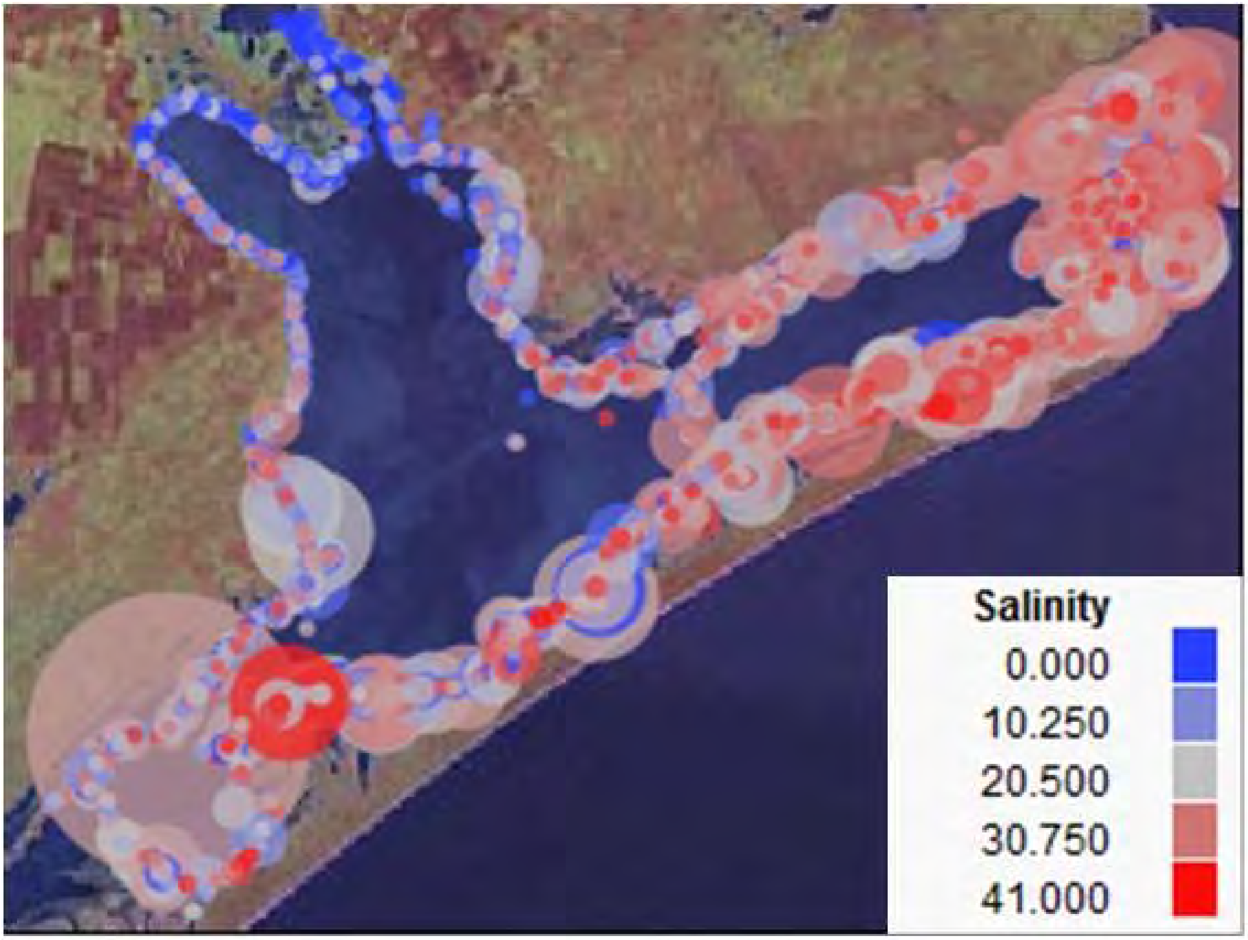


Figure 2.107 Spatial distribution of longnose killifish, *Fundulus similis*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Blue Crab*, Callinectes sapidus:* While blue crabs were caught throughout the bay, the areas with the largest abundance were in SAB (Figure 2.108). Catches showed a trend favoring areas with lower salinity, but as stated above, correlation does not indicate causation, as there could be many variables acting on species distribution. The mean salinity for catches of blue crab was 18.5 ppt.

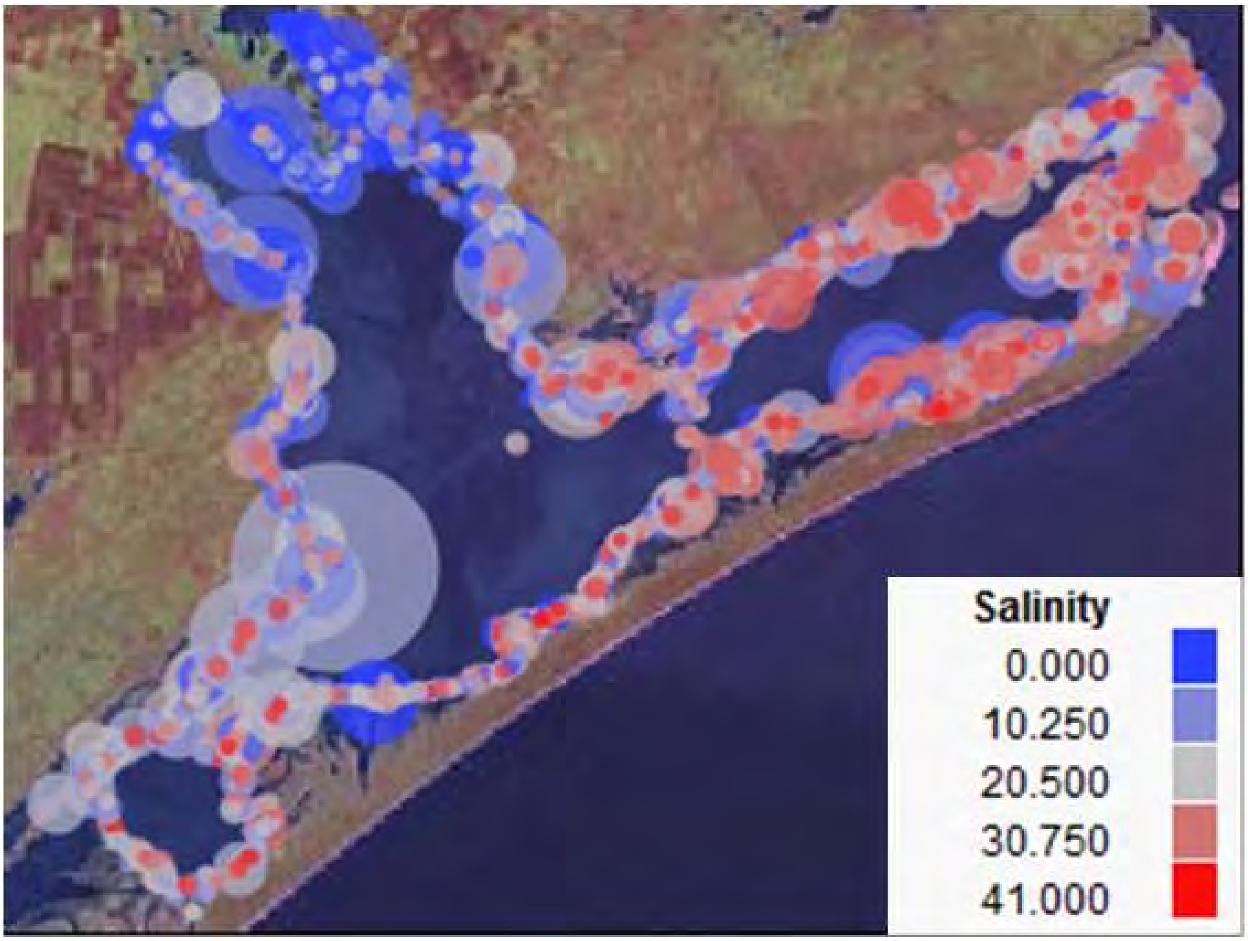


Figure 2.108 Spatial distribution of blue crab, *Callinectes sapidus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Atlantic Croaker*, Micropogonias undulatus:* While Atlantic croaker were caught throughout the bay, the areas with the largest abundance were in upper SAB, including Hynes and Guadalupe Bays (Figure 2.109). Catches showed a trend favoring lower salinity, which coincides with previous work descriptions along the coast of Texas (Ward and Armstrong 1980). The mean salinity for Atlantic croaker samples was 13.7 ppt.

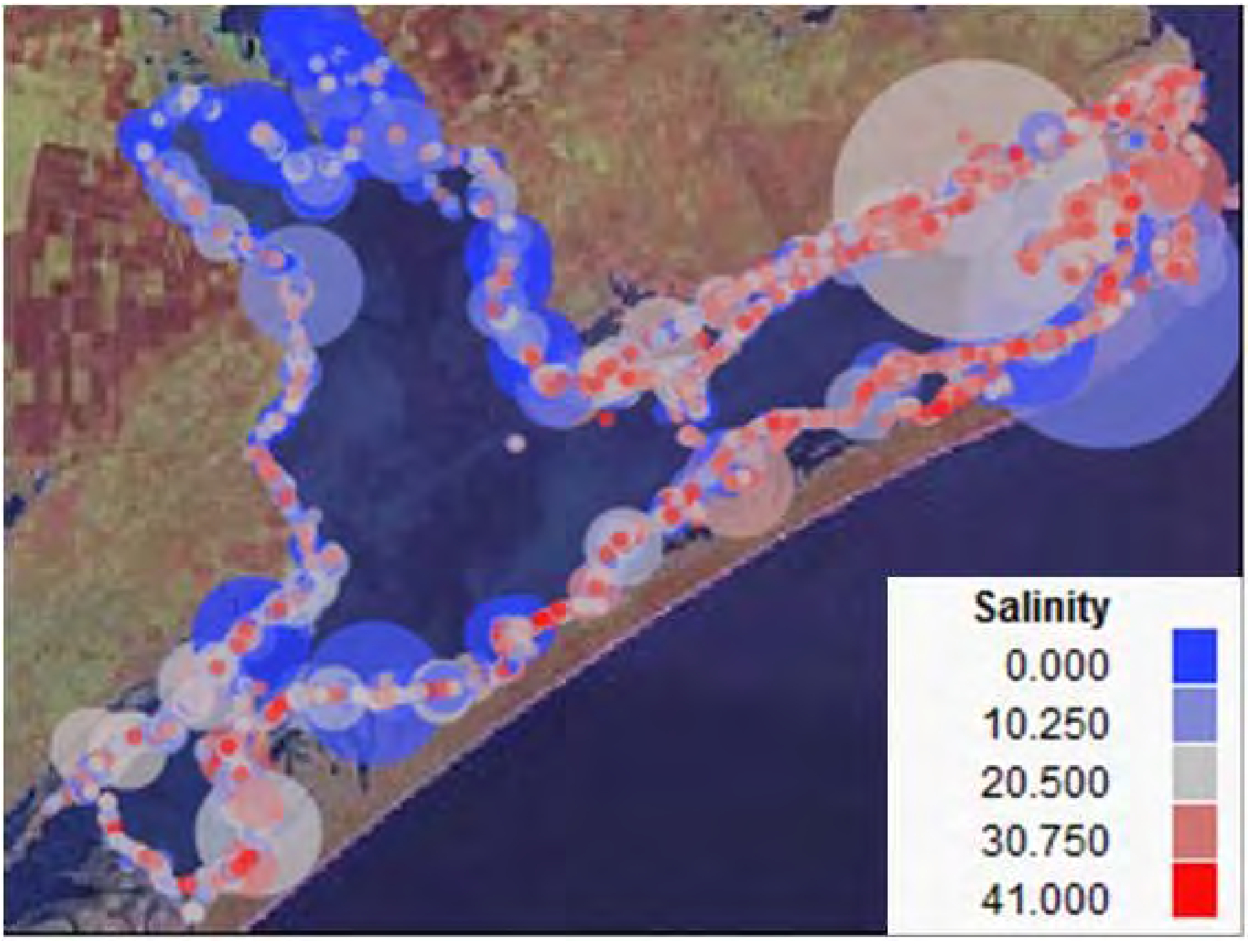


Figure 2.109 Spatial distribution of Atlantic croaker, *Micropogonias undulatus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gulf Killifish, *Fundulus grandis:* Gulf killifish were caught throughout the bay, and did not show much salinity preference. The only area that showed relatively low abundance was in Guadalupe Bay (Figure 2.110). The mean salinity for gulf killifish samples was 19.9 ppt.

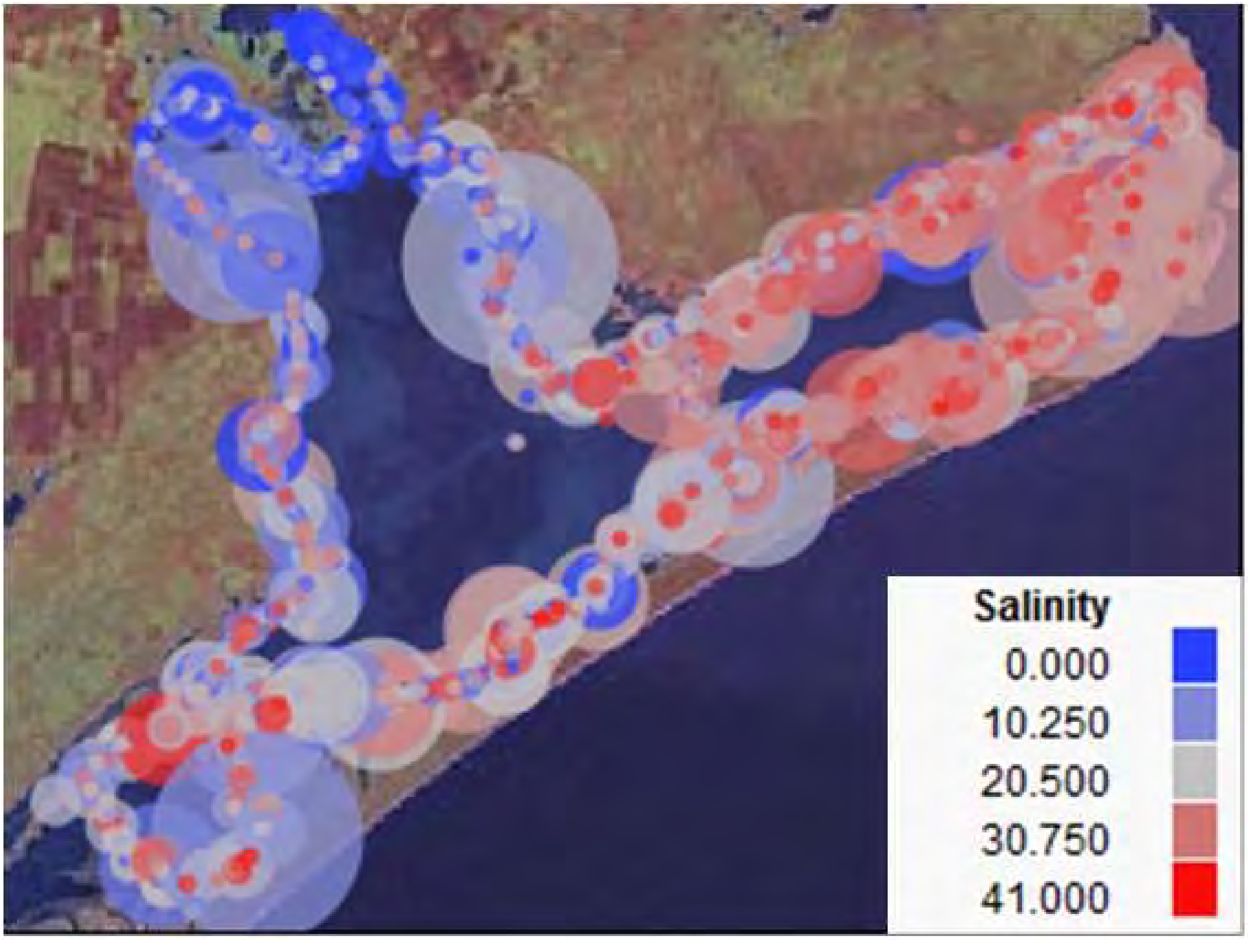


Figure 2.110 Spatial distribution of gulf killifish, *Fundulus grandis*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Inland Silverside, *Menidia beryllina:* Inland silverside were caught throughout the bay, and showed a slight preference for higher salinity (Figure 2.111). Abundance was higher along Matagorda island in ESB, SAB, and Mesquite Bay. The mean salinity for inland silverside samples was 18.4 ppt.

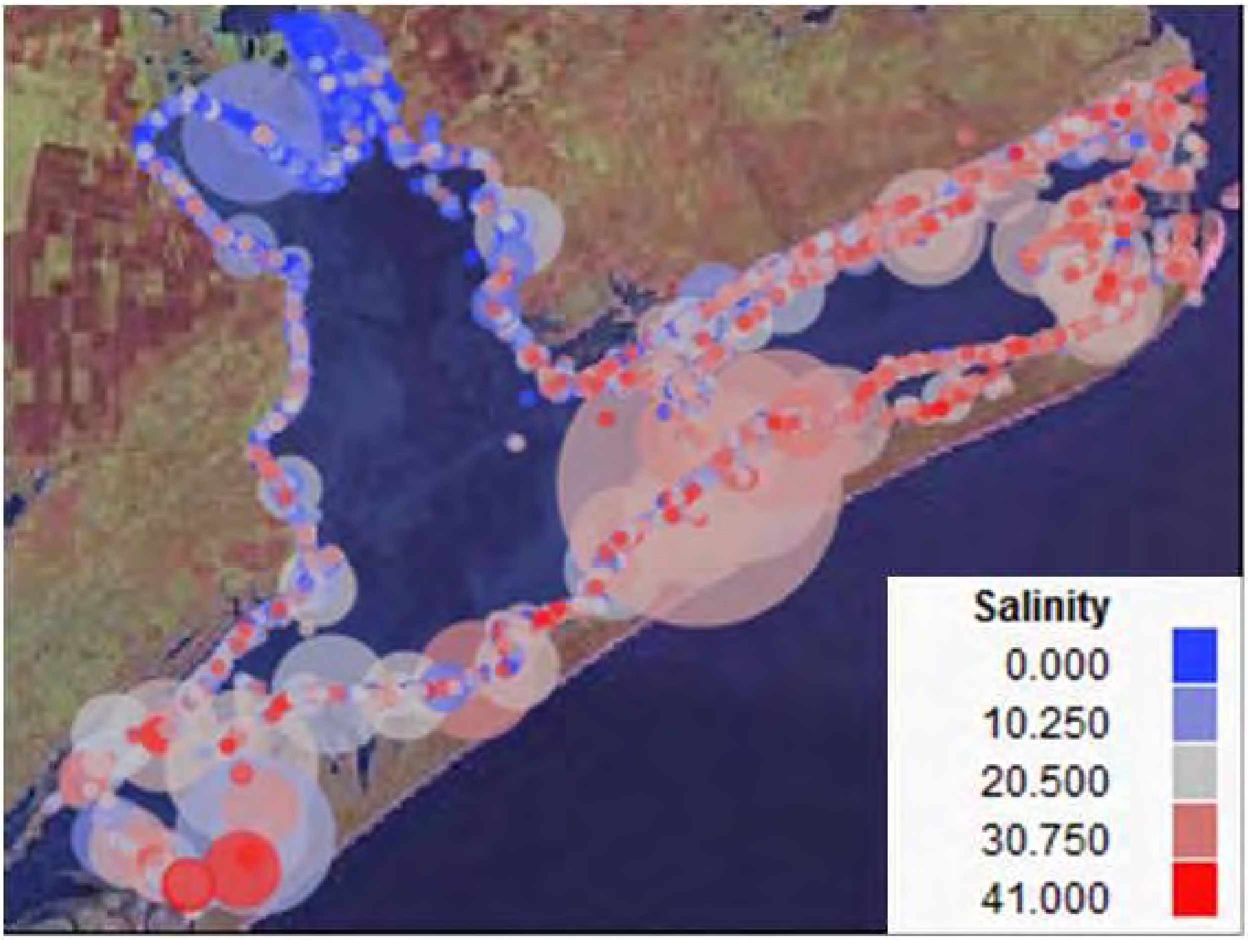


Figure 2.111 Spatial distribution of inland silverside, *Menidia beryllina*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Spotfin Mojarra*, Eucinostomus argenteus:* Spotfin mojarra showed a preference for higher salinity (Figure 2.112). Abundance was highest in ESB and the mean salinity for catches was 24.1 ppt.

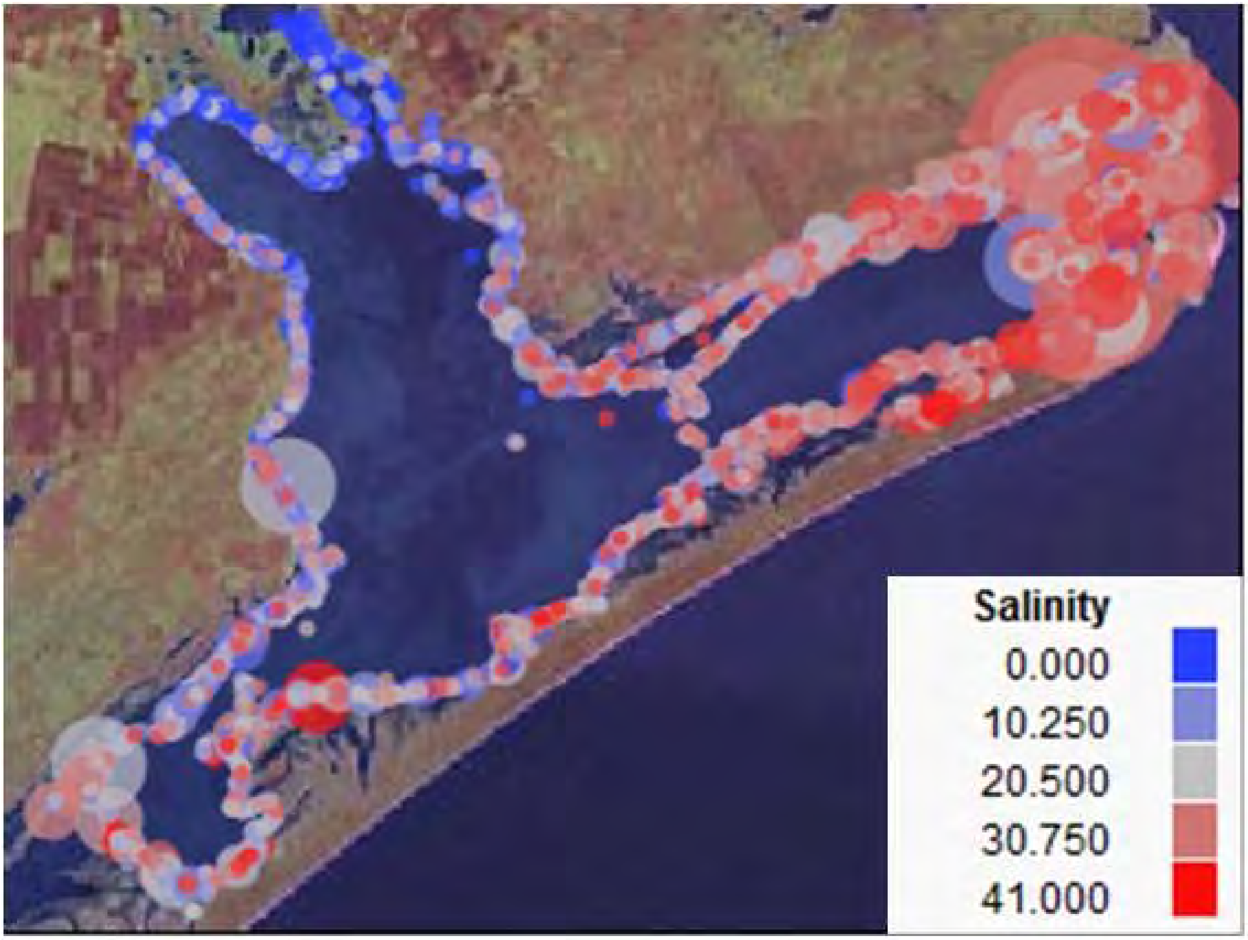


Figure 2.112 Spatial distribution of spotfin mojarra, *Eucinostomus argenteus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Red Drum, *Sciaenops ocellatus:* Red drum were caught throughout the bay and showed no preference for salinity (Figure 2.113), as expected due to their ability to efficiently osmoregulate (Crocker *et. al* 1981). Mesquite Bay and ESB had slightly higher abundance than SAB. The mean salinity for red drum samples was 18.0 ppt.

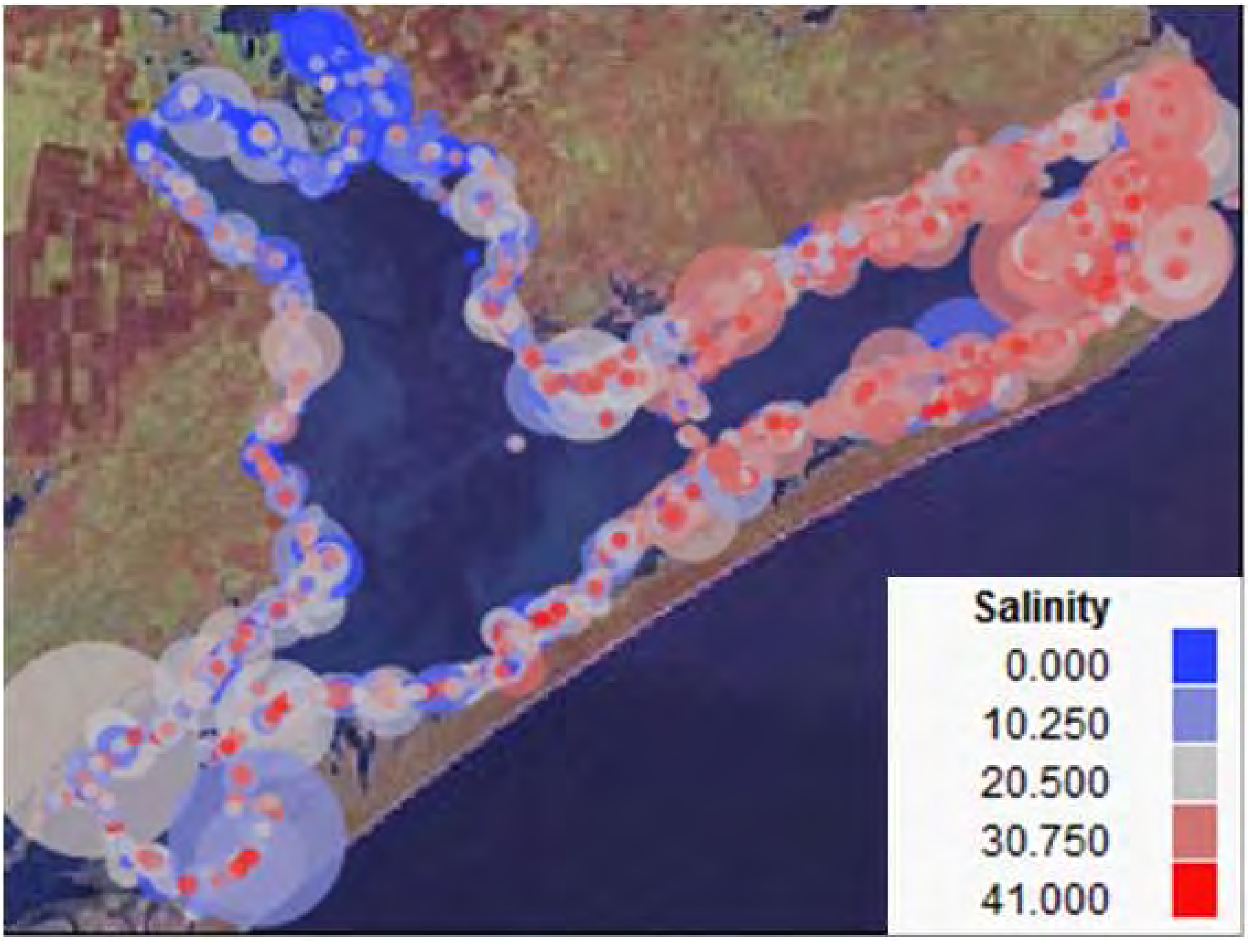


Figure 2.113 Spatial distribution of red drum, *Sciaenops ocellatus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Spotted Seatrout*, Cynoscion nebulosus:* Spotted seatrout were caught throughout the bay and showed some preference for higher salinity (Figure 2.114). The only region that showed reduced abundance was western SAB. The mean salinity for spotted seatrout samples was 20.0 ppt.

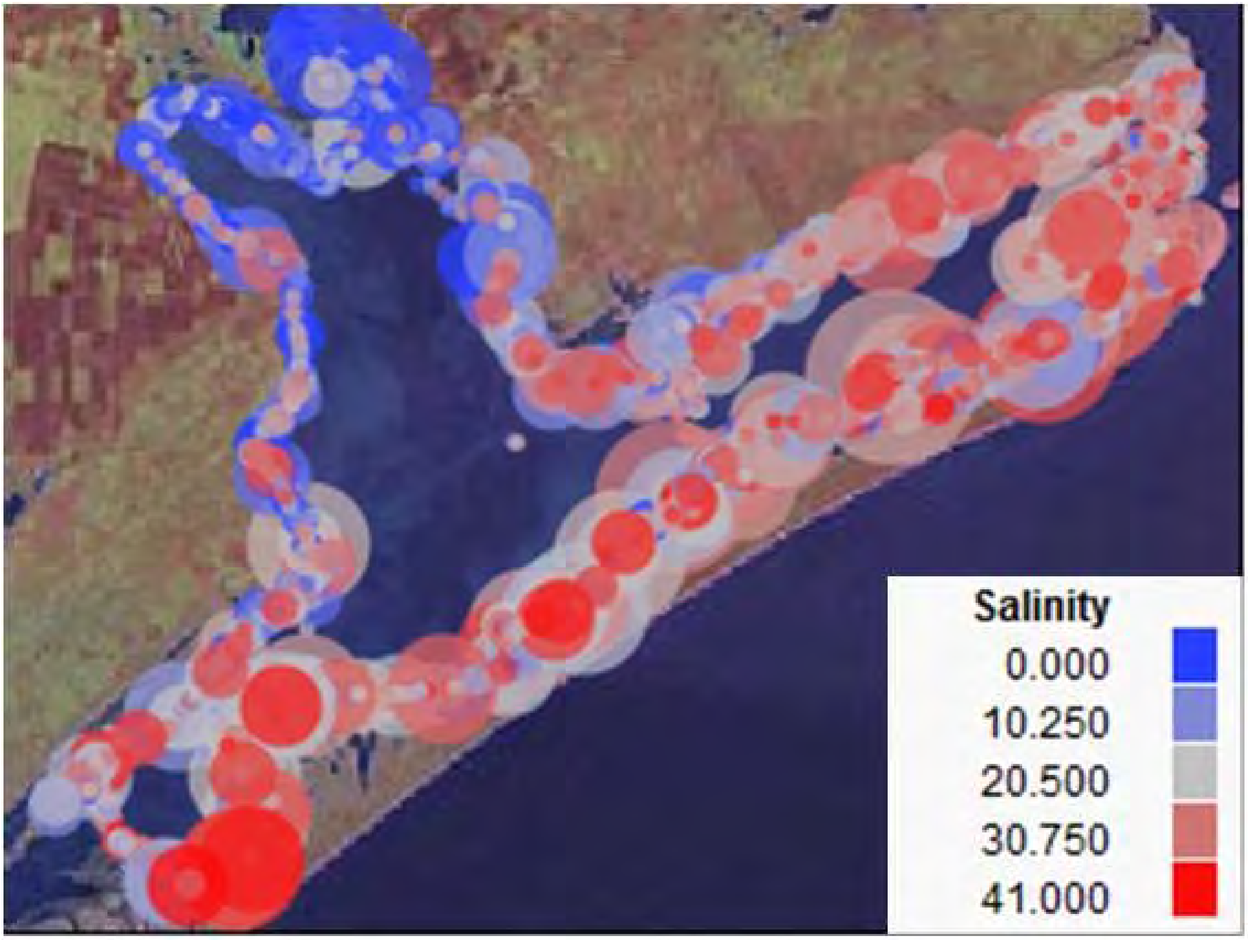


Figure 2.114 Spatial distribution of spotted seatrout, *Cynoscion nebulosus*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Silver Perch*, Bairdiella chrysoura:* Silver perch showed a slight preference for salinity within the bay, and distinct locations of absence were apparent (Figure 2.115). There was minimal catch in central SAB, with larger catches in lower SAB and ESB. The mean salinity for silver perch samples was 18.4 ppt.

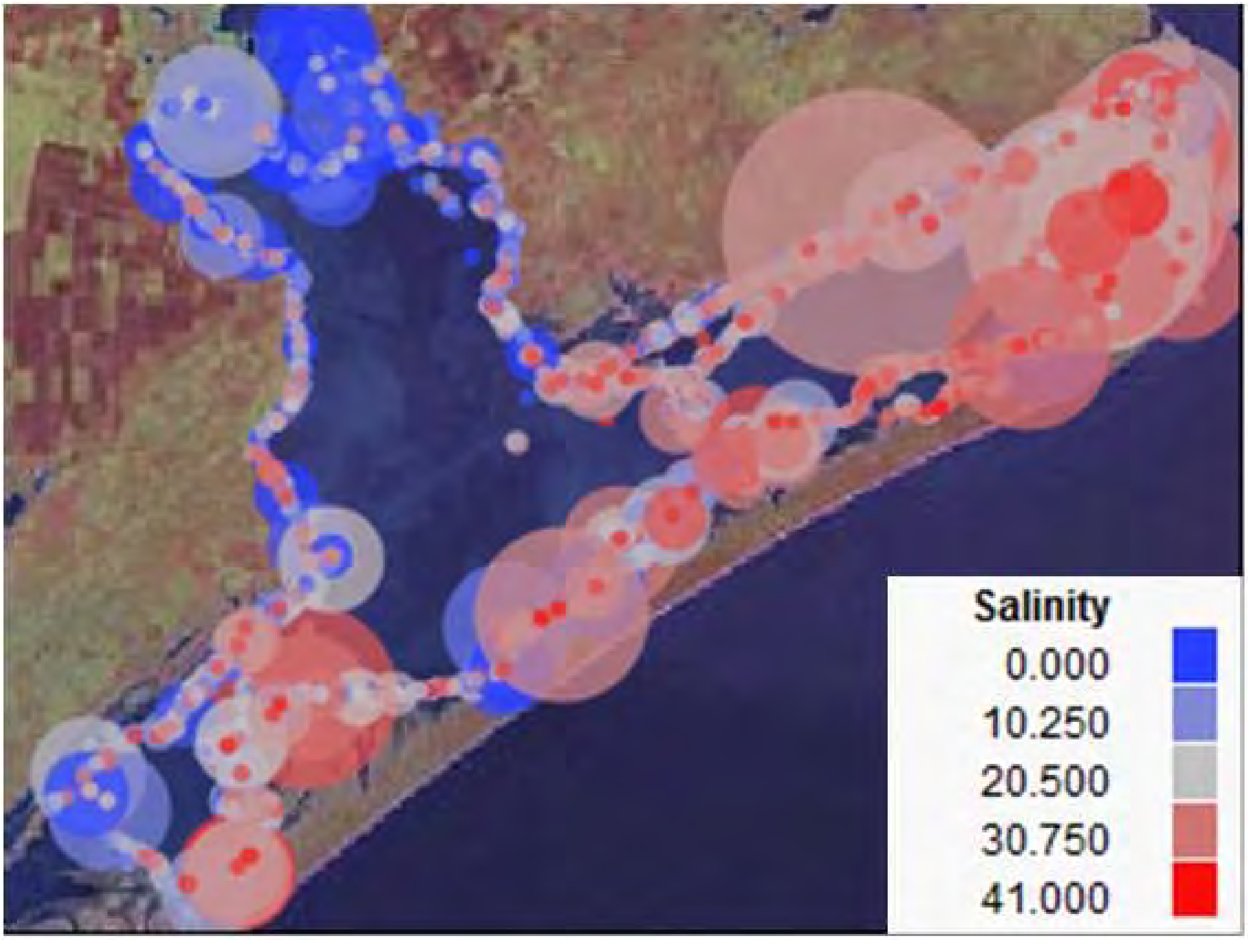


Figure 2.115 Spatial distribution of silver perch, *Bairdiella chrysoura*, bag seine catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Bay Trawl

Brown Shrimp, *Farfantepenaeus aztecus*: As opposed to the catch rates from bag seines, brown shrimp trawl catches showed preference for lower salinity ranges in the bays with minimal catches from ESB (Figure 2.116). The mean salinity for catches of brown shrimp was 17.4 ppt.

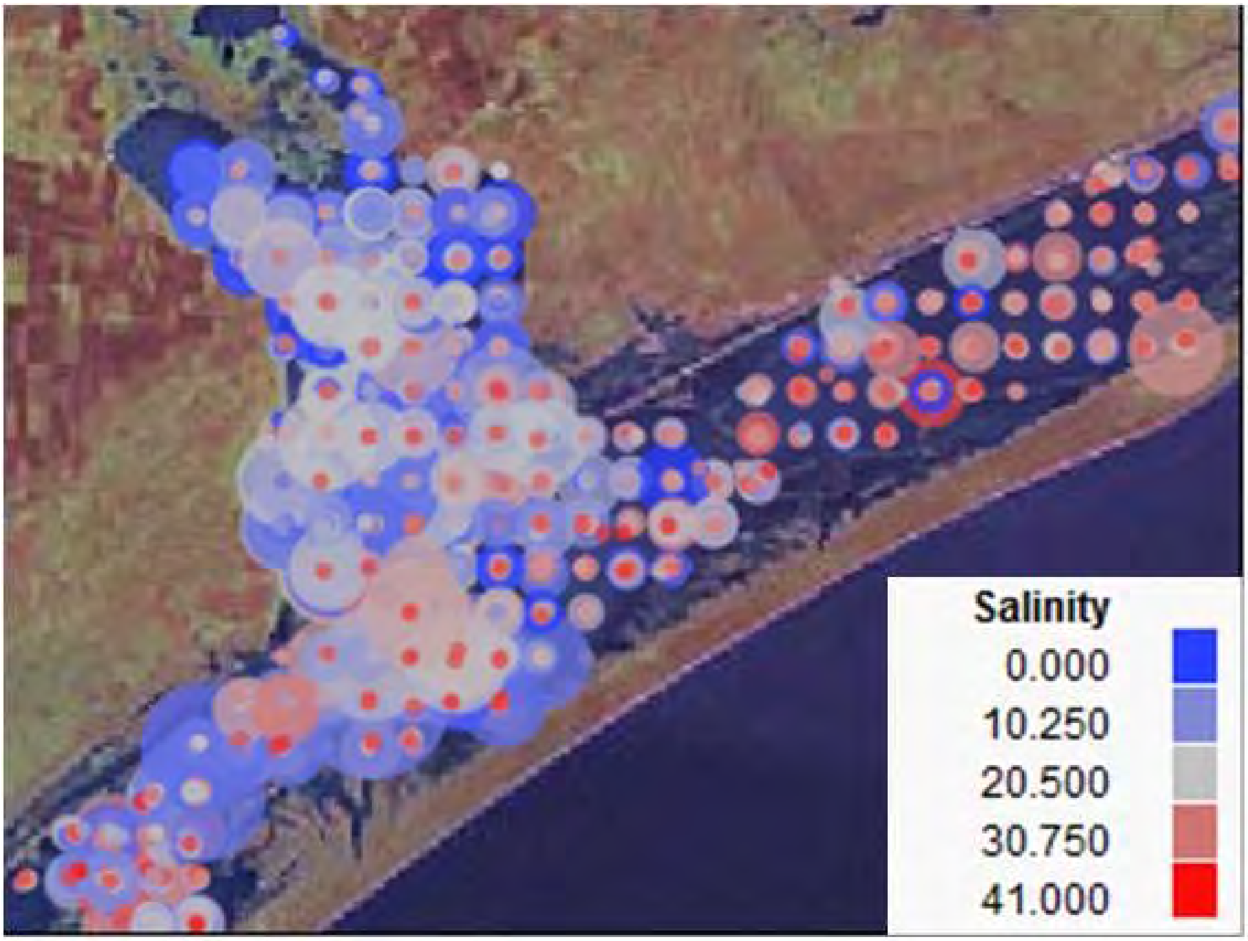


Figure 2.116 Spatial distribution of brown shrimp, *Farfantepenaeus aztecus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Atlantic Croaker, *Micropogonias undulatus*: Atlantic croaker were caught throughout SAB while showing a trend favoring lower salinities (Figure 2.117), which coincides with previous work descriptions along the coast of Texas (Ward and Armstrong, 1980). Catches in ESB were less frequent than SAB and Mesquite Bay. The mean salinity for catches of Atlantic croaker was 15.4 ppt.

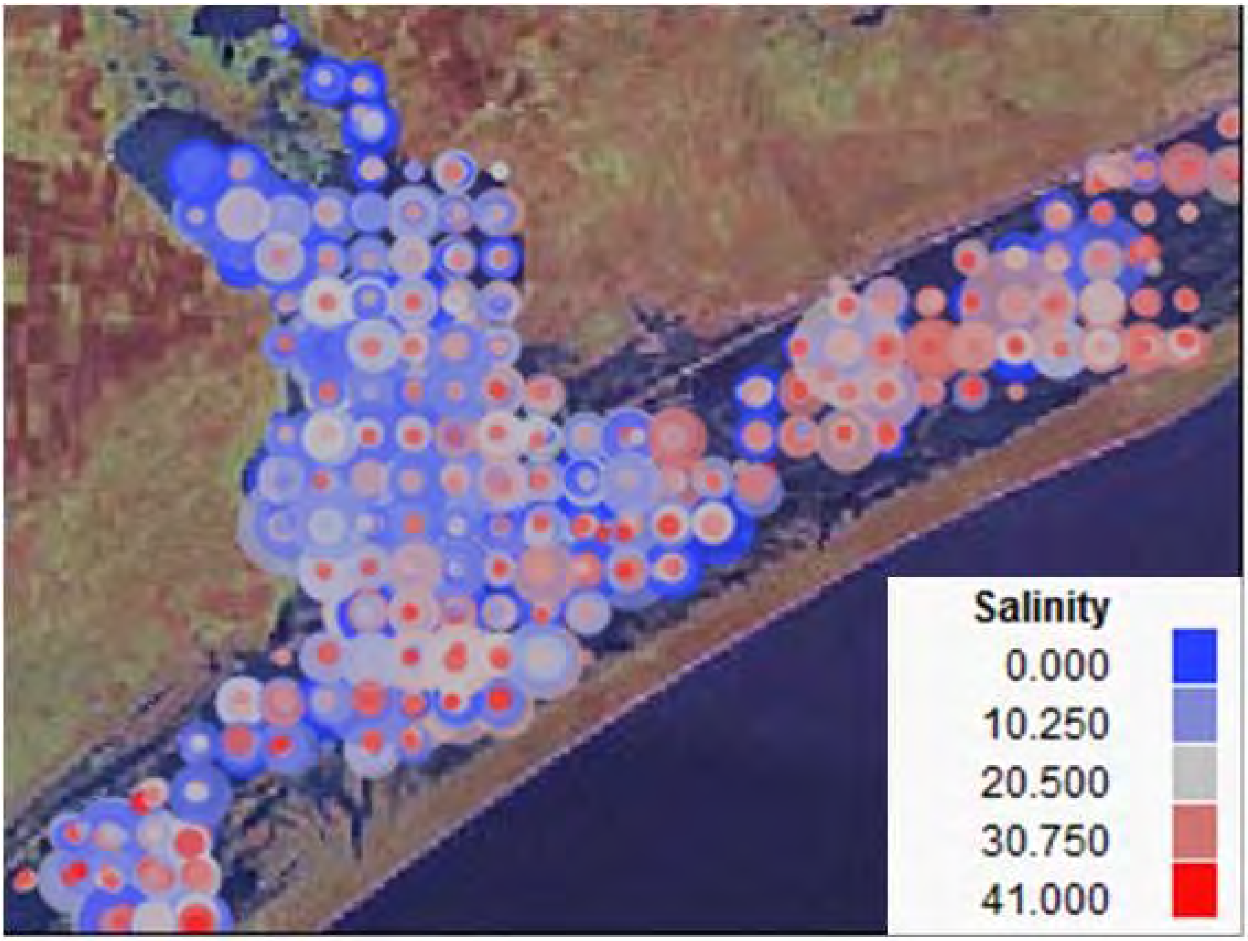


Figure 2.117 Spatial distribution of Atlantic croaker, *Micropogonias undulatus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Spot, *Leiostomus xanthurus*: Similar to the bag seine catch rates, spot trawl catches showed a trend favoring areas with higher salinity. These locations were lower SAB near the Matagorda Island shoreline, ESB, and Mesquite Bay (Figure 2.118). The mean salinity for catches of spot was 18.6 ppt.

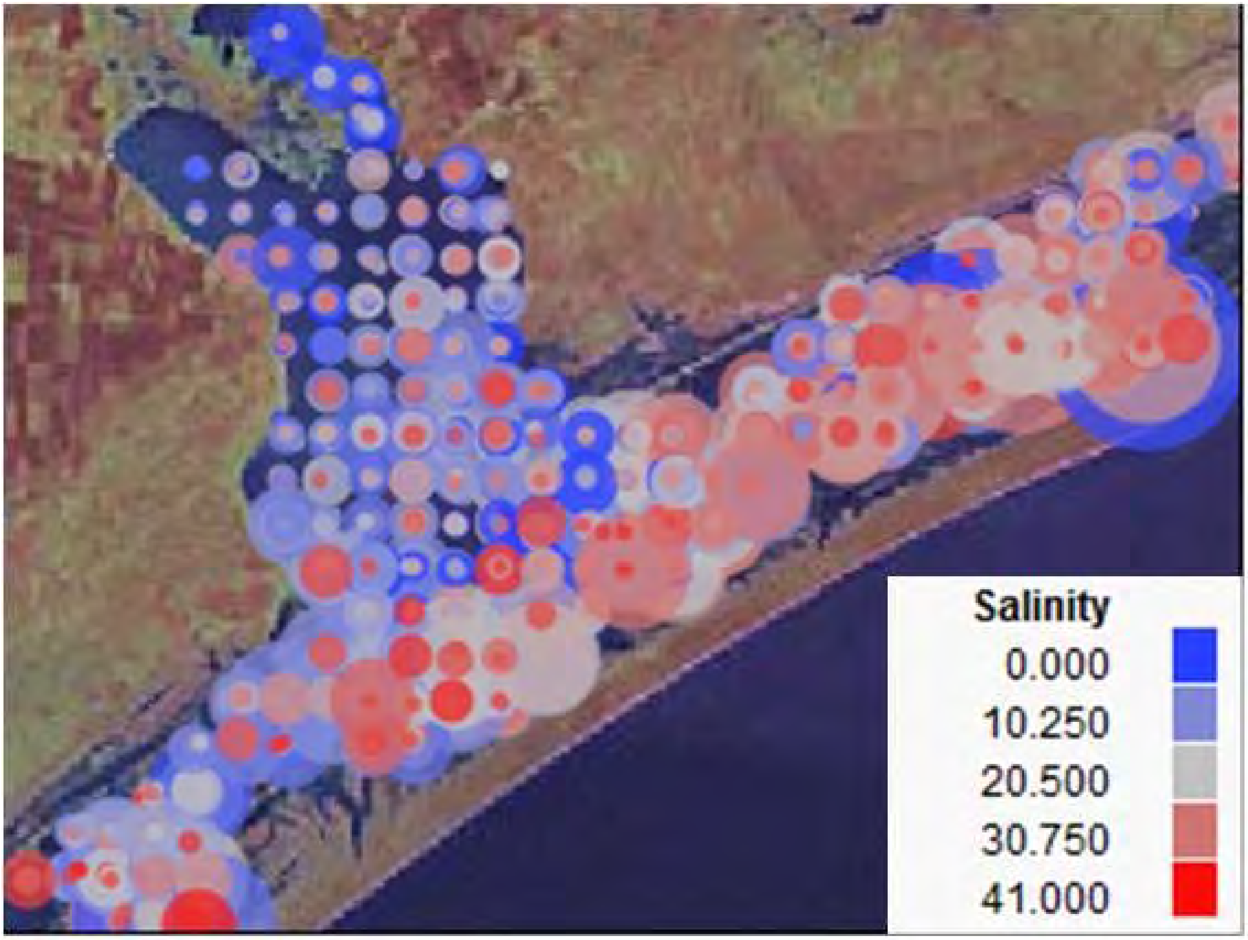


Figure 2.118 Spatial distribution of spot, *Leiostomus xanthurus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Pinfish, *Lagodon rhomboides*: Similar to bag seine catch rates, pinfish trawl catches favored areas with higher salinity in the bays. These locations were ESB and to a lesser extent Southern SAB near Matagorda Island shoreline and Mesquite Bay (Figure 2.119). The mean salinity for catches of pinfish was 20.2 ppt.

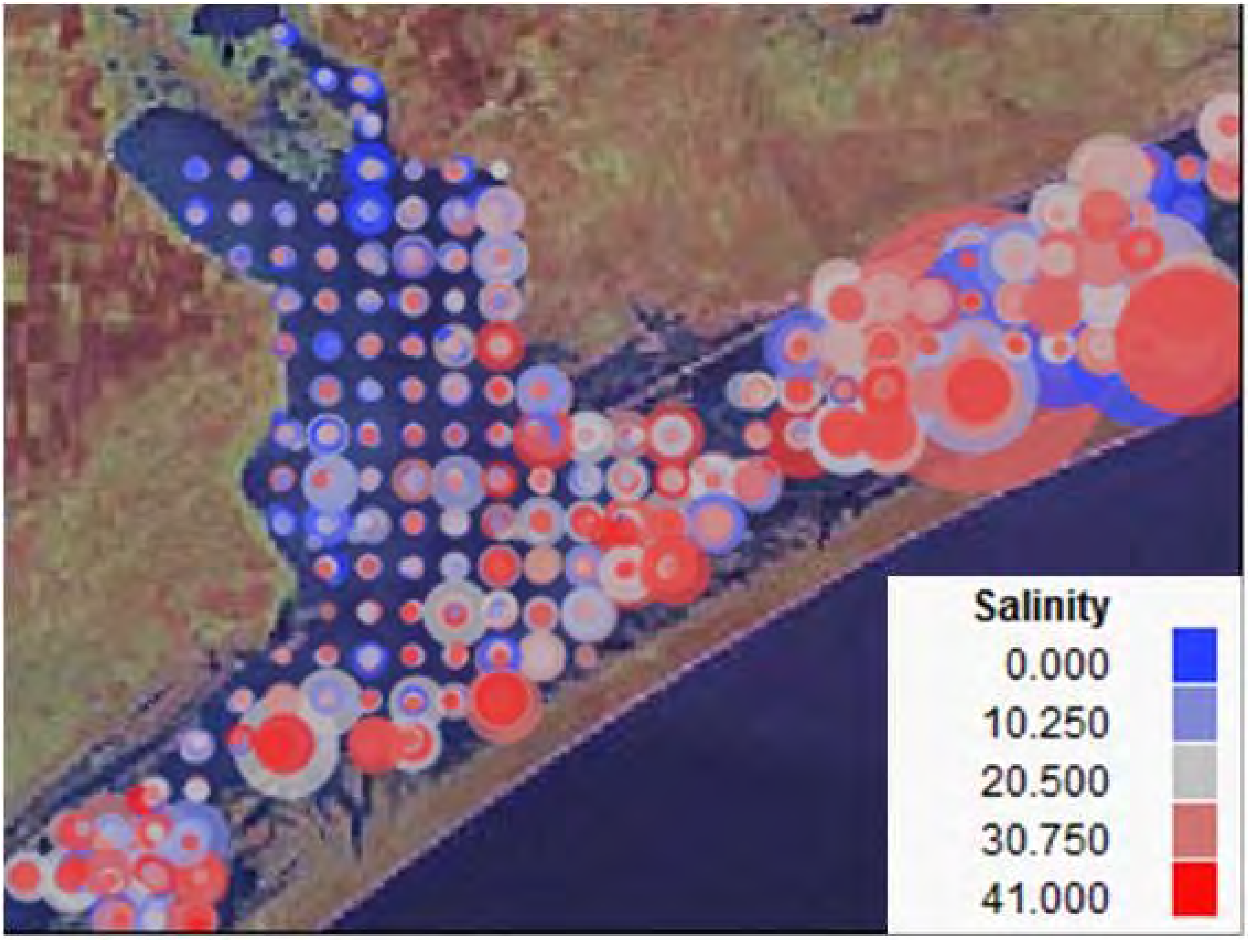


Figure 2.119 Spatial distribution of Pinfish, *Lagodon rhomboides*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

White Shrimp, *Litopenaeus setiferus*: White shrimp trawl catches favored areas with lower salinity in the bays, even more so than the catch rates for bag seines. This coincides with a previous study in Texas (Copeland and Bechtel, 1974). These locations were all of SAB and Mesquite Bay, with the largest catches typically occurring in upper SAB (Figure 2.120). The mean salinity for catches of white shrimp was 14.5 ppt.

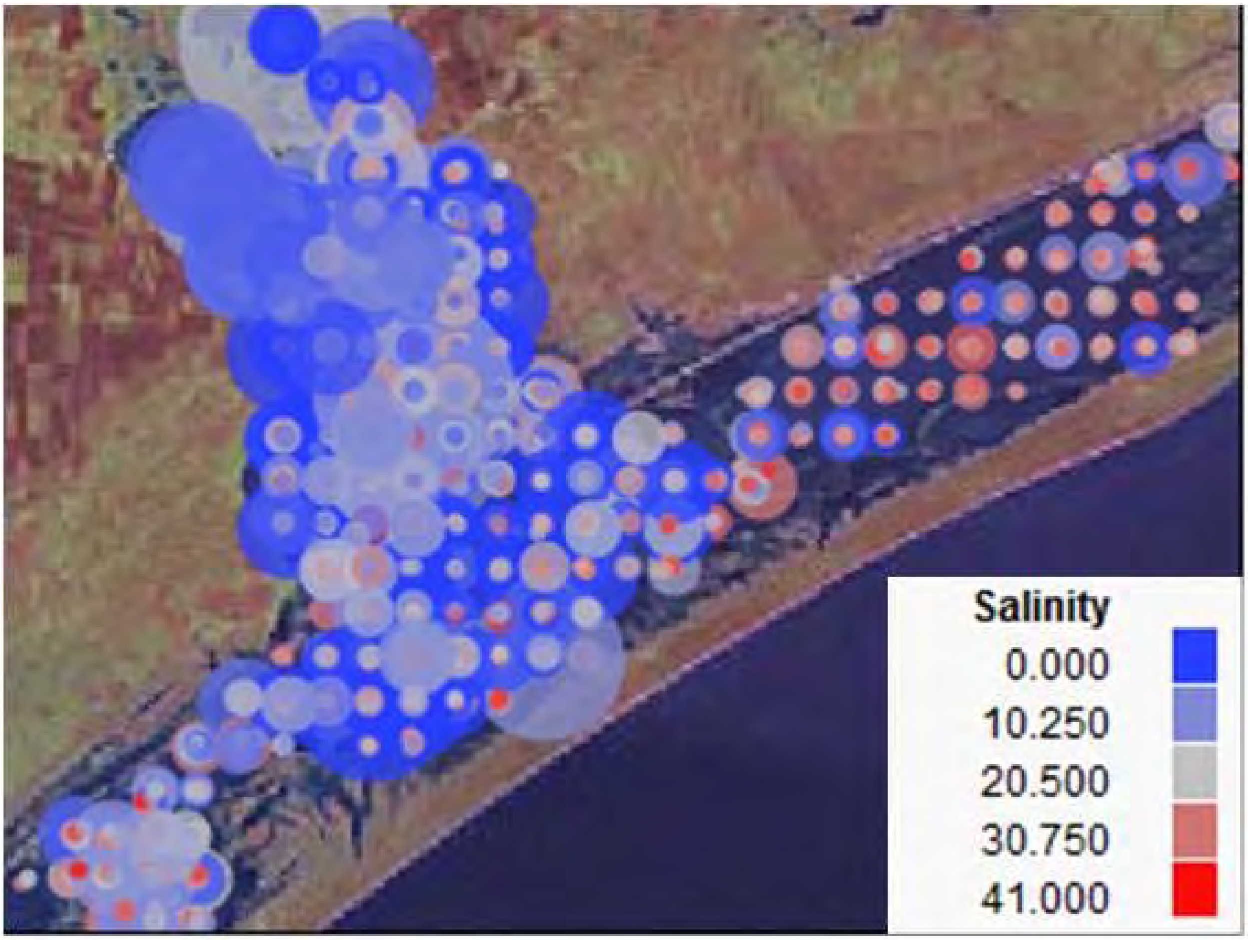


Figure 2.120 Spatial distribution of white shrimp, *Litopenaeus setiferus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Blue Crab, *Callinectes sapidus*: Similar to the catch in bag seines, blue crab were caught throughout the bay in trawl samples, mainly avoiding areas with the highest salinity, such as ESB (Figure 2.121). The mean salinity for catches of blue crab was 15.4 ppt.

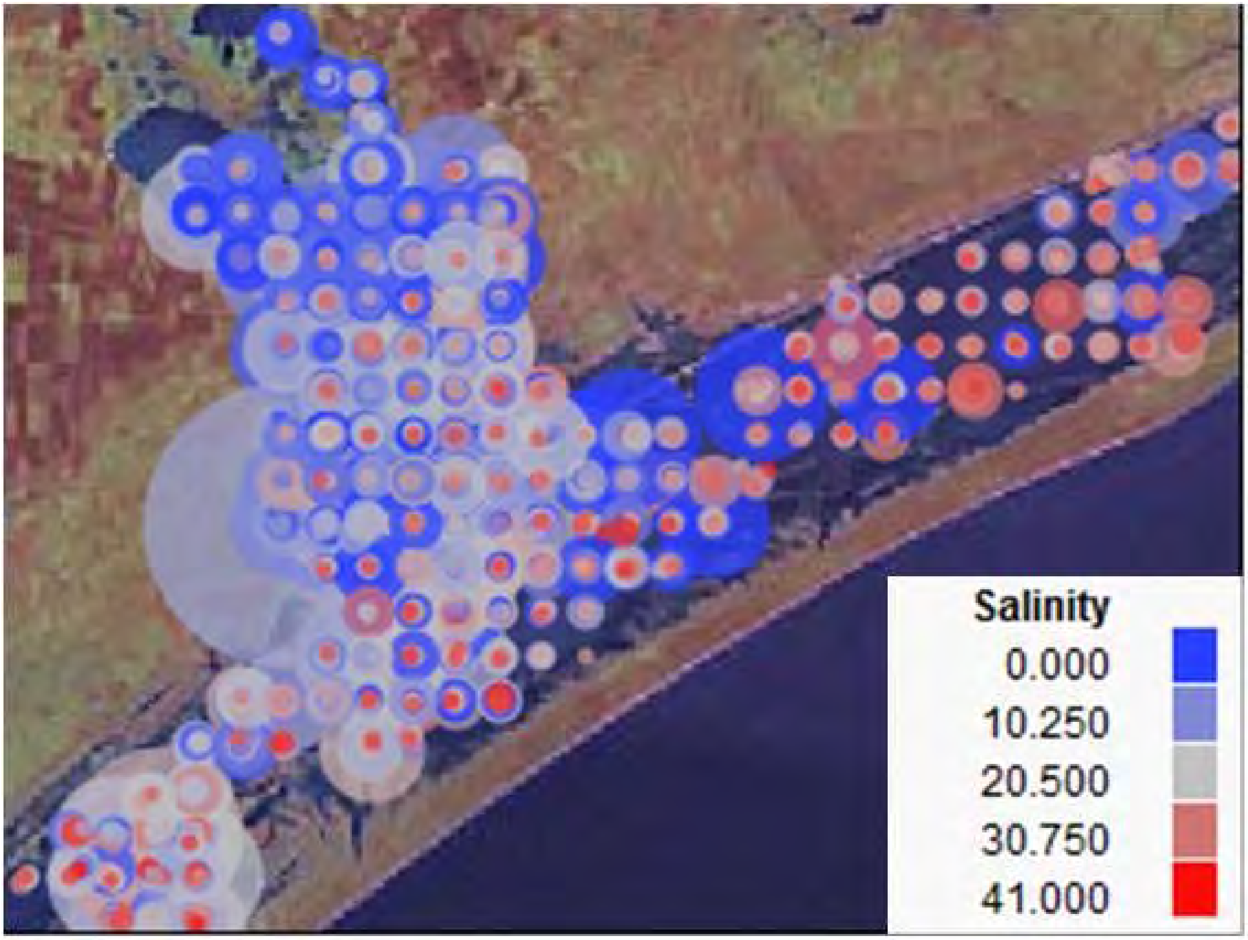


Figure 2.121 Spatial distribution of blue crab, *Callinectes sapidus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gulf Menhaden, *Brevoortia patronus*: As with the bag seine catch rates, gulf menhaden trawl catches favored areas with low salinity in the bays, but not to the same extent. The gulf menhaden caught in bay trawls showed relatively more tolerance to higher salinities, thus were caught in more locations, but they were predominantly caught in areas with lower salinity (Figure 2.122). There were lower catch rates in ESB in general and the larger catches in this bay were during times of unusually low salinity. The mean salinity for catches of gulf menhaden was 13.5 ppt.

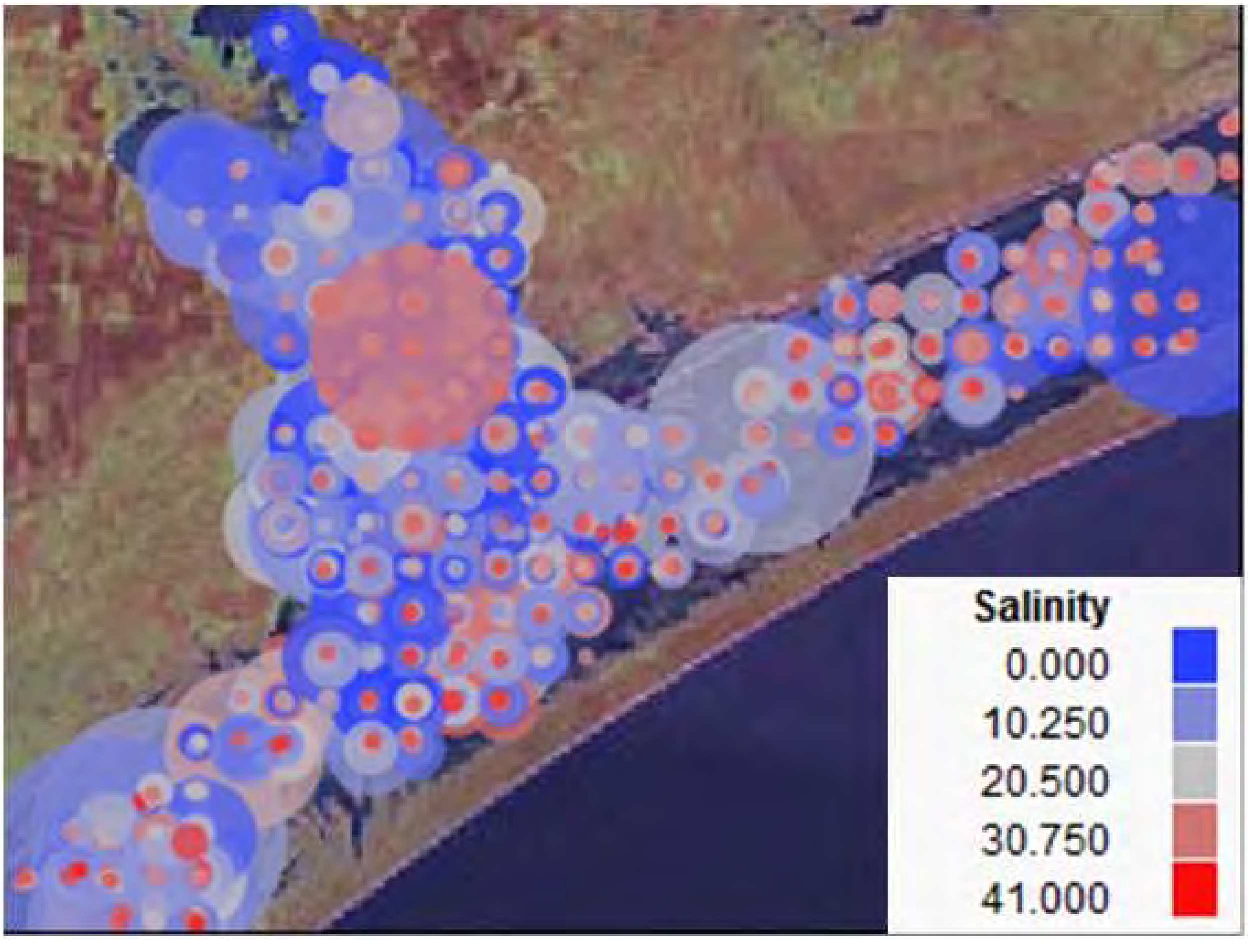


Figure 2.122 Spatial distribution of gulf menhaden, *Brevoortia patronus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Bay Anchovy, *Anchoa mitchilli*: The bay trawl catch rate of bay anchovy catches showed no preference for salinity. While bay anchovies were caught throughout the bay, the areas in which the largest numbers were caught were in eastern ESB (Figure 2.123). The mean salinity for catches of bay anchovy was 17.8 ppt.

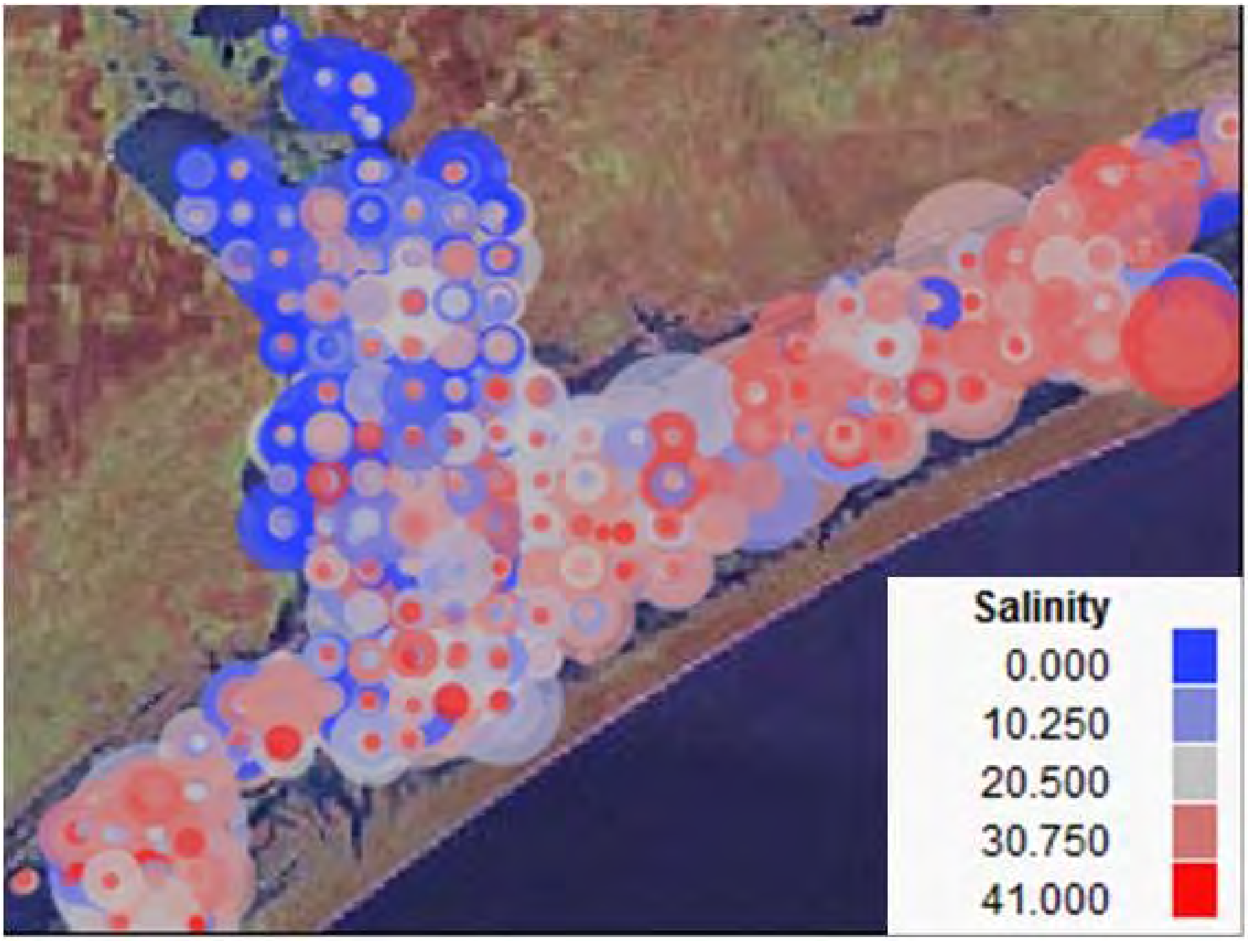


Figure 2.123 Spatial distribution of bay anchovy, *Anchoa mitchilli*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Silver Perch, *Bairdiella chrysoura*: Silver perch trawl catch showed no preference for salinity, as with the catch rates from bag seines (Figure 2.124). There is fairly even catch within the entire bay, but the lowest abundance is in lower SAB. The mean salinity for catches of silver perch was 18.1 ppt.

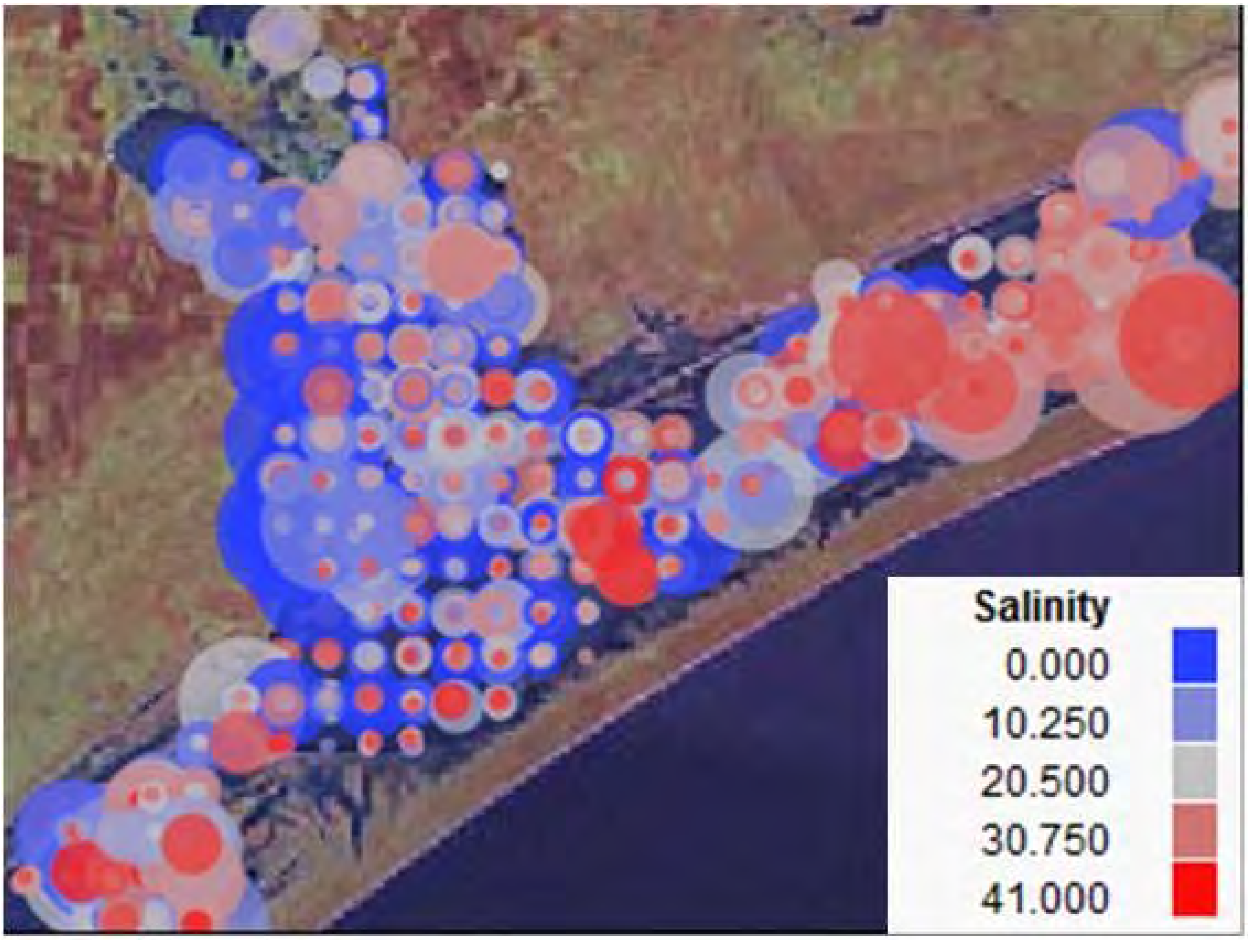


Figure 2.124 Spatial distribution of silver perch, *Bairdiella chrysoura*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gafftopsail Catfish, *Bagre marinus*: Gafftopsail catfish were caught throughout the bay, with slightly lower catch in ESB, but they showed no preference for salinity (Figure 2.125). The mean salinity for catches of gafftopsail catfish was 18.1 ppt.

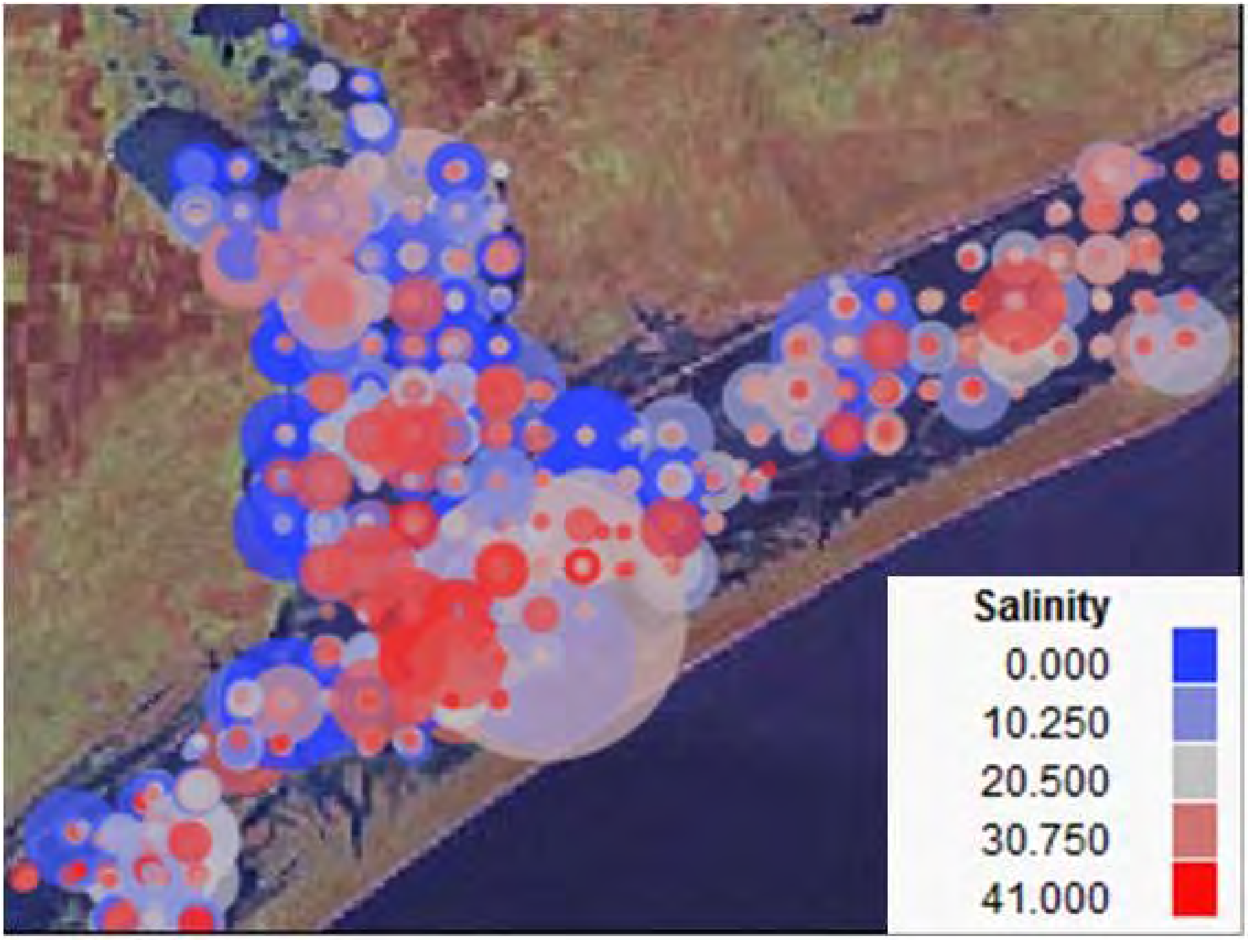


Figure 2.125 Spatial distribution of gafftopsail catfish, *Bagre marinus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Atlantic Brief Squid, *Loligo brevis*: Atlantic brief squid were caught throughout most of the bay, but the areas in which there were catches clearly shows a preference for higher salinity (Figure 2.126). The mean salinity for catches of Atlantic brief squid was 26.0 ppt.

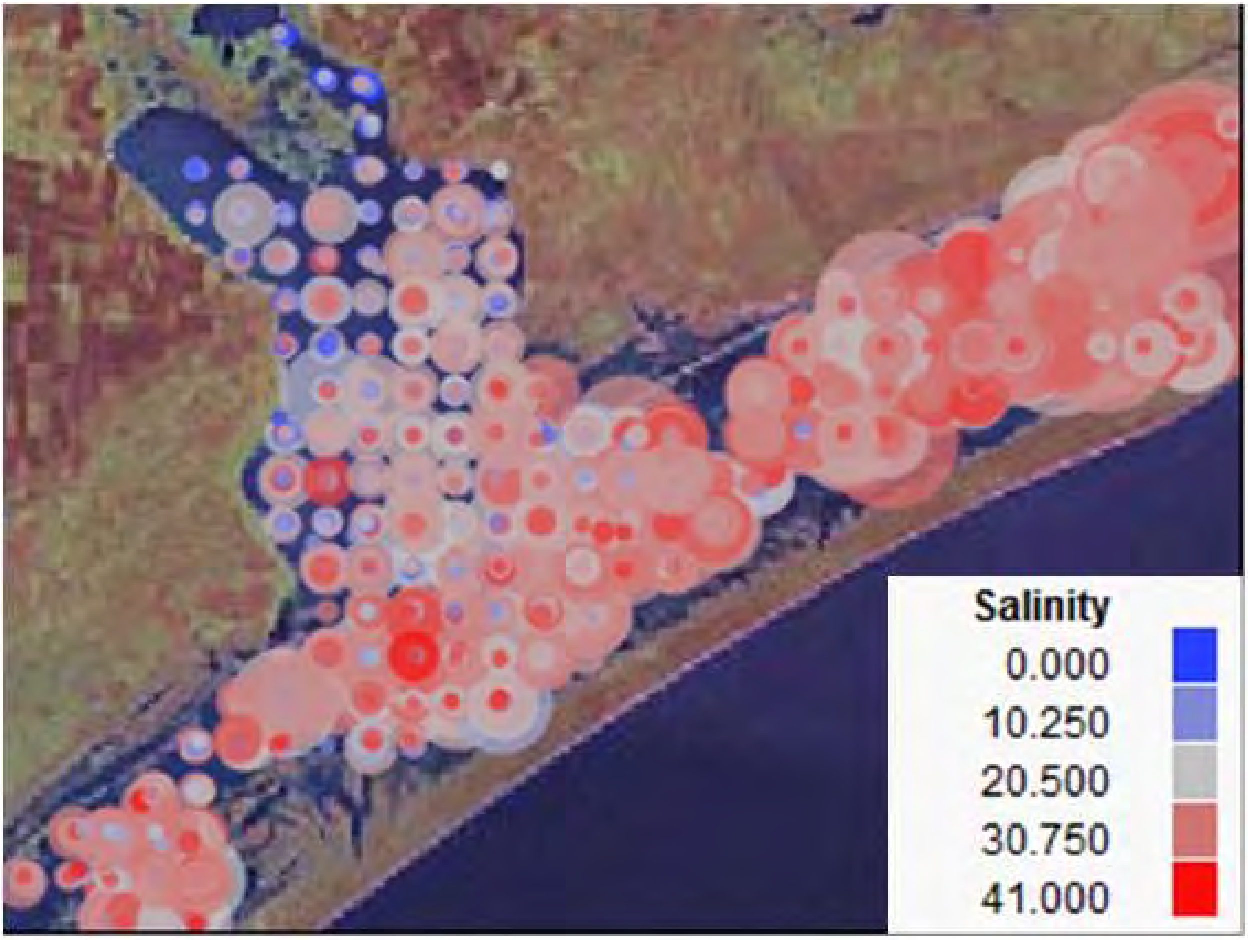


Figure 2.126 Spatial distribution of brief squid, *Loligo brevis*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Hardhead Catfish, *Ariopsis felis*: Hardhead catfish were caught throughout the bay with no apparent preference for salinity (Figure 2.127). The mean salinity for catches of hardhead catfish was 16.9 ppt.

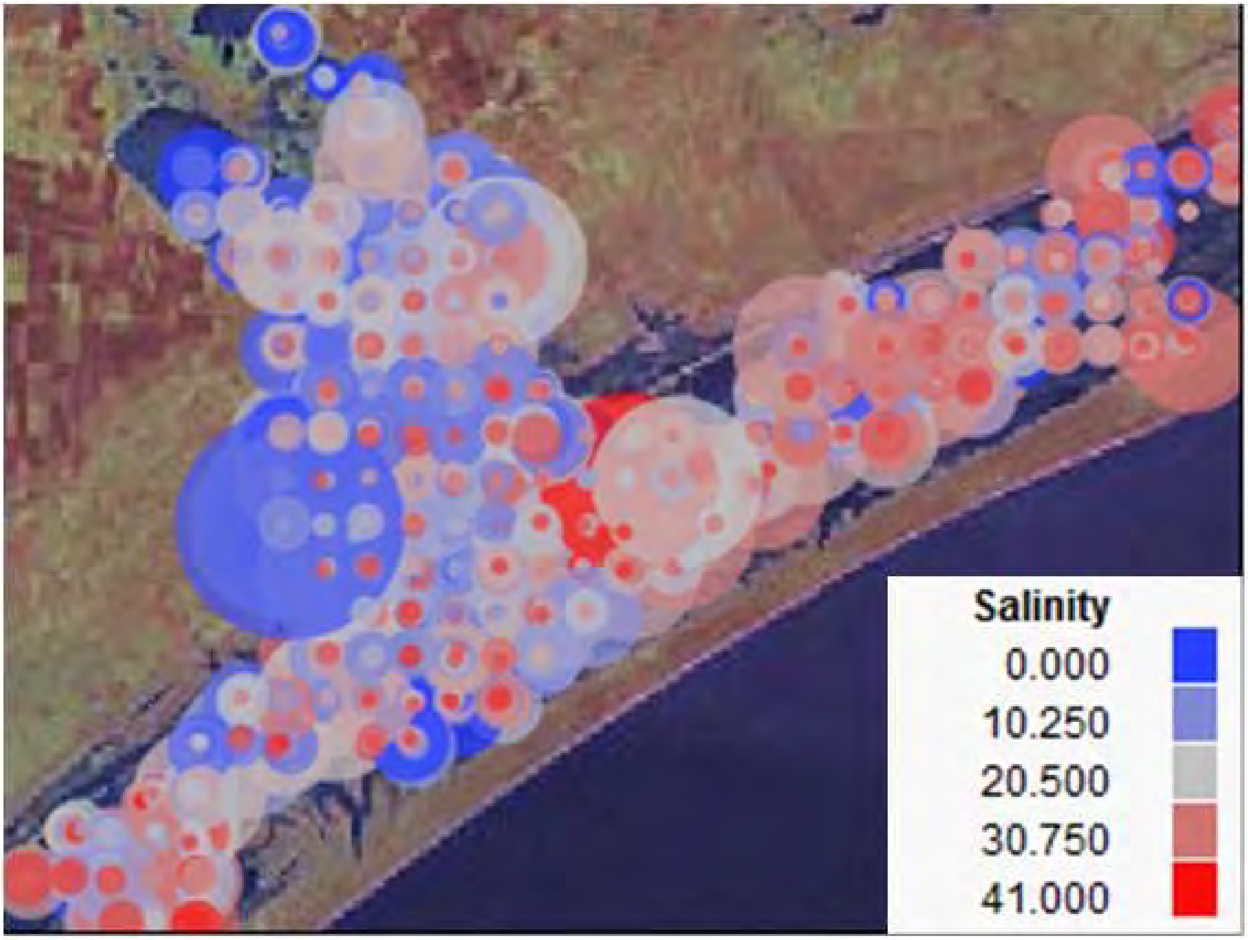


Figure 2.127 Spatial distribution of hardhead catfish, *Ariopsis felis*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Pink Shrimp, *Farfantepenaeus duorarum*: Pink shrimp catches showed preference for intermediate salinity ranges in the bays (Figure 2.128) as has been shown by a previous study in Texas (Copeland and Bechtel, 1974). Areas with typically very low or high salinities such as upper SAB (including Hynes and Guadalupe Bays) and ESB, respectively, had reduced abundance or absence of pink shrimp. The mean salinity for catches of pink shrimp was 20.6 ppt.

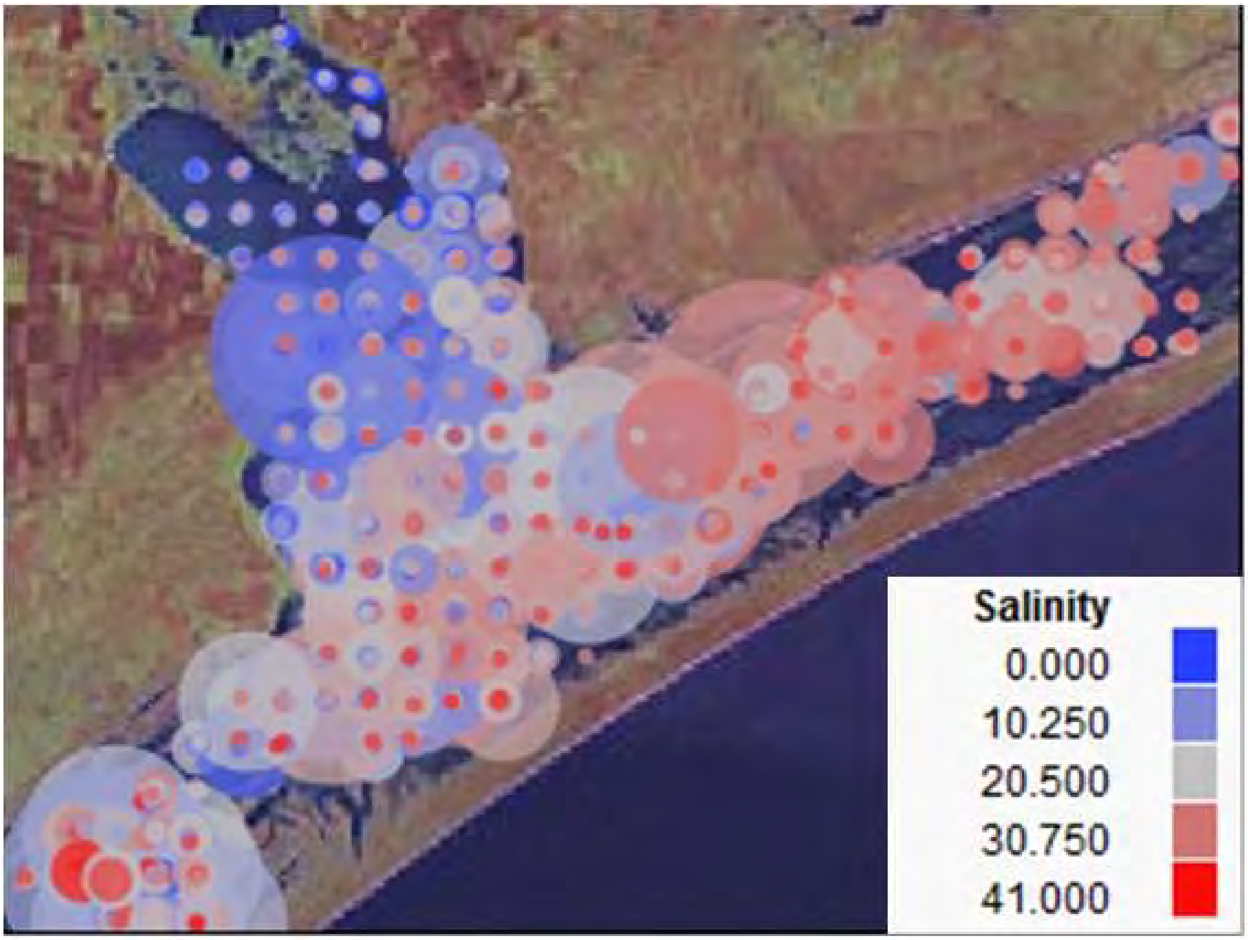


Figure 2.128 Spatial distribution of pink shrimp, *Farfantepenaeus duorarum*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Lesser Blue Crab, *Callinectes similis*: Lesser blue crabs showed a preference for areas and periods that typically had higher salinities, such as lower SAB, ESB, and Mesquite Bay (Figures 2.129 and 2.44). They were not abundant in these areas at the highest salinities though. The mean salinity for catches of lesser blue crab was 23.5 ppt.

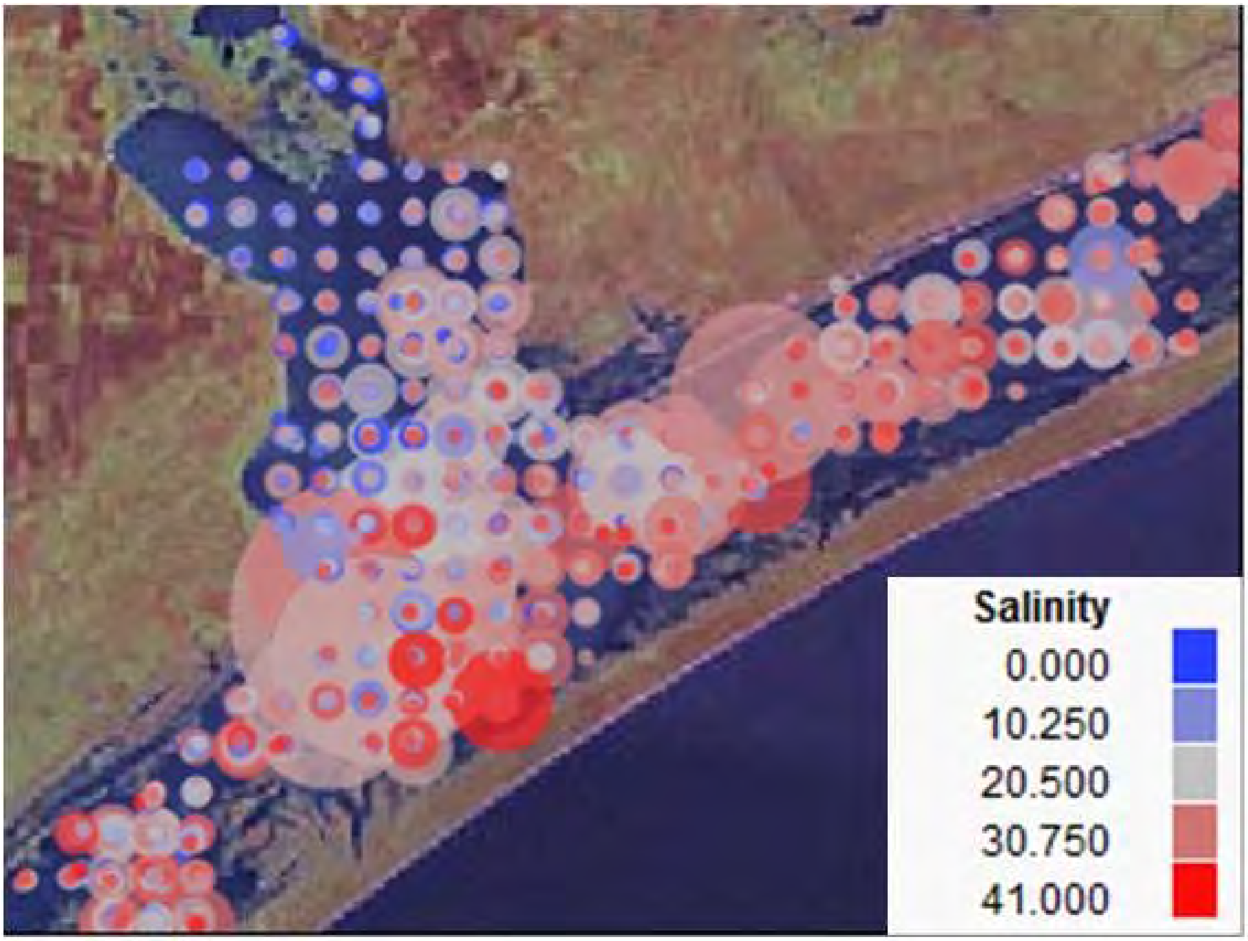


Figure 2.129 Spatial distribution of lesser blue crab, *Callinectes similis*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Bay Whiff, *Citharichthys spilopterus*: Bay whiff were caught throughout the bay and did not show any preference for salinity (Figure 2.130). The mean salinity for catches of bay whiff was 16.7 ppt.

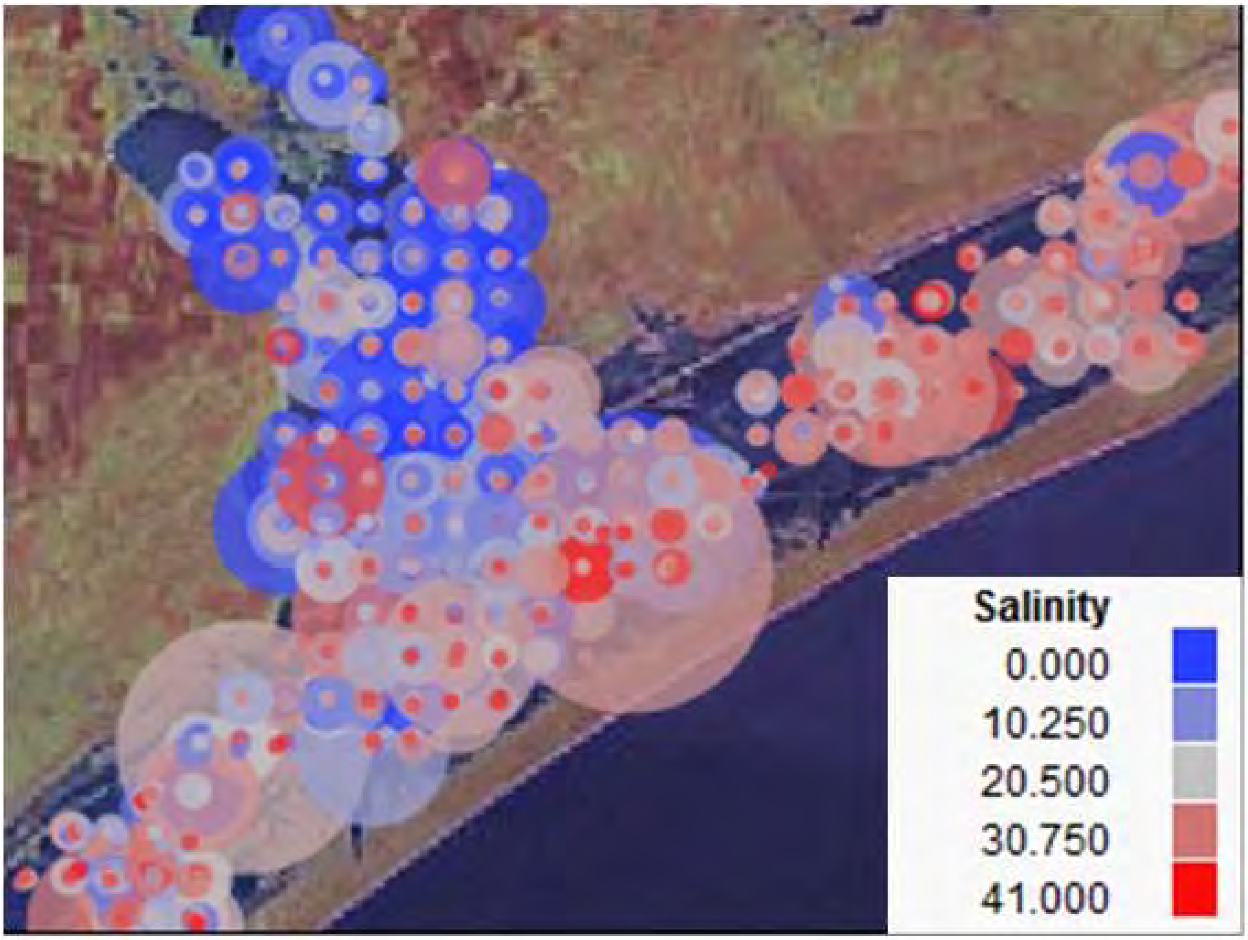


Figure 2.130 Spatial distribution of bay whiff, *Citharichthys spilopterus*, bay trawl catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gillnet

Spotted Seatrout, *Cynoscion nebulosus*: Spotted seatrout were caught throughout the bay but showed a preference for higher salinity, such as along Matagorda Island shoreline in ESB, SAB, and Mesquite Bay (Figure 2.131). This differed from the bag seine catches which showed no preference for salinity. The mean salinity for catches of spotted seatrout was 21.0 ppt.

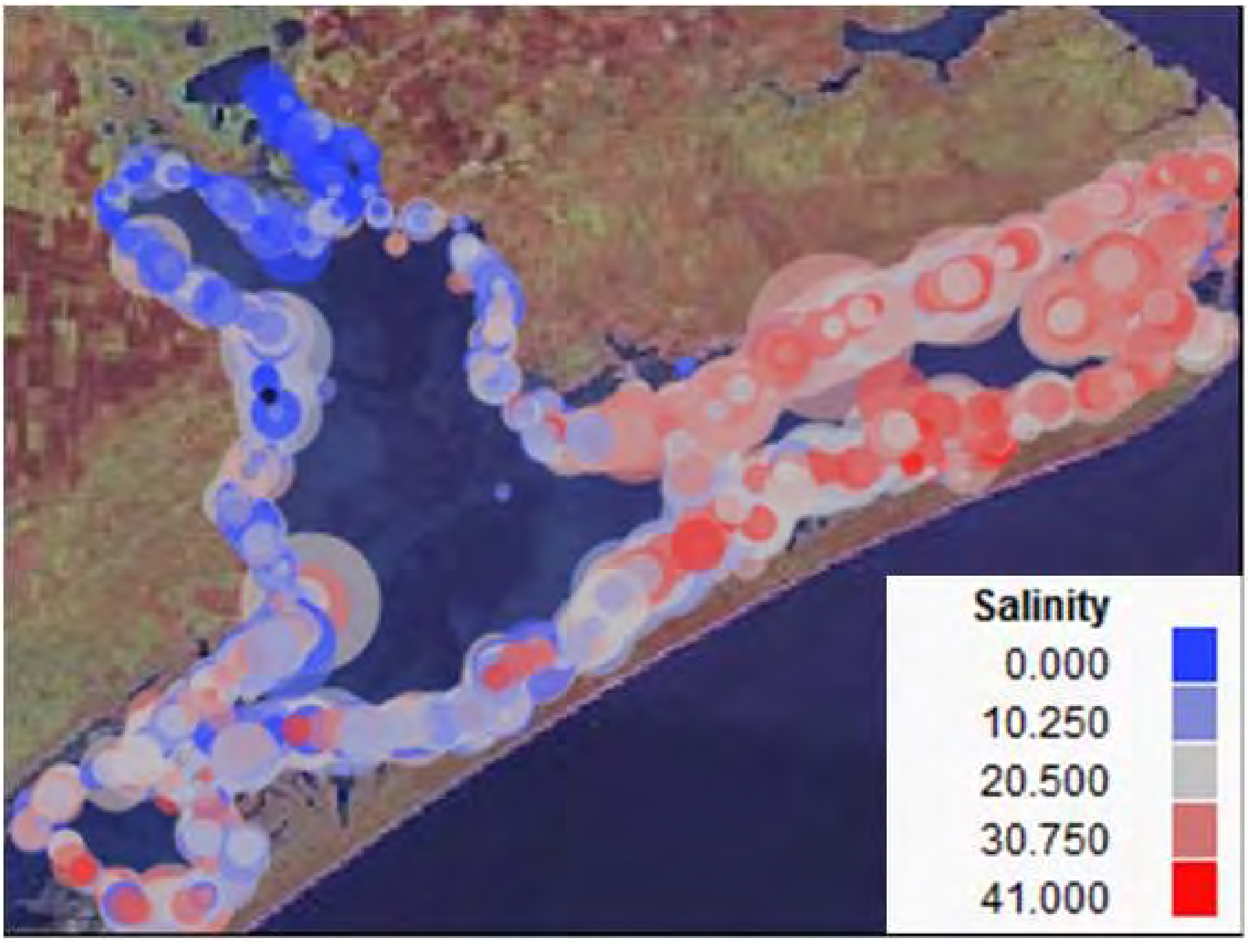


Figure 2.131 Spatial distribution of Spotted seatrout, *Cynoscion nebulosus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Red Drum, *Sciaenops ocellatus*: Similar to the bag seine catches, red drum were caught in gillnets throughout the bay and showed no preference for salinity (Figure 2.132), as expected due to their ability to efficiently osmoregulate (Crocker et. al, 1981). The mean salinity for catches of red drum was 19.9 ppt.

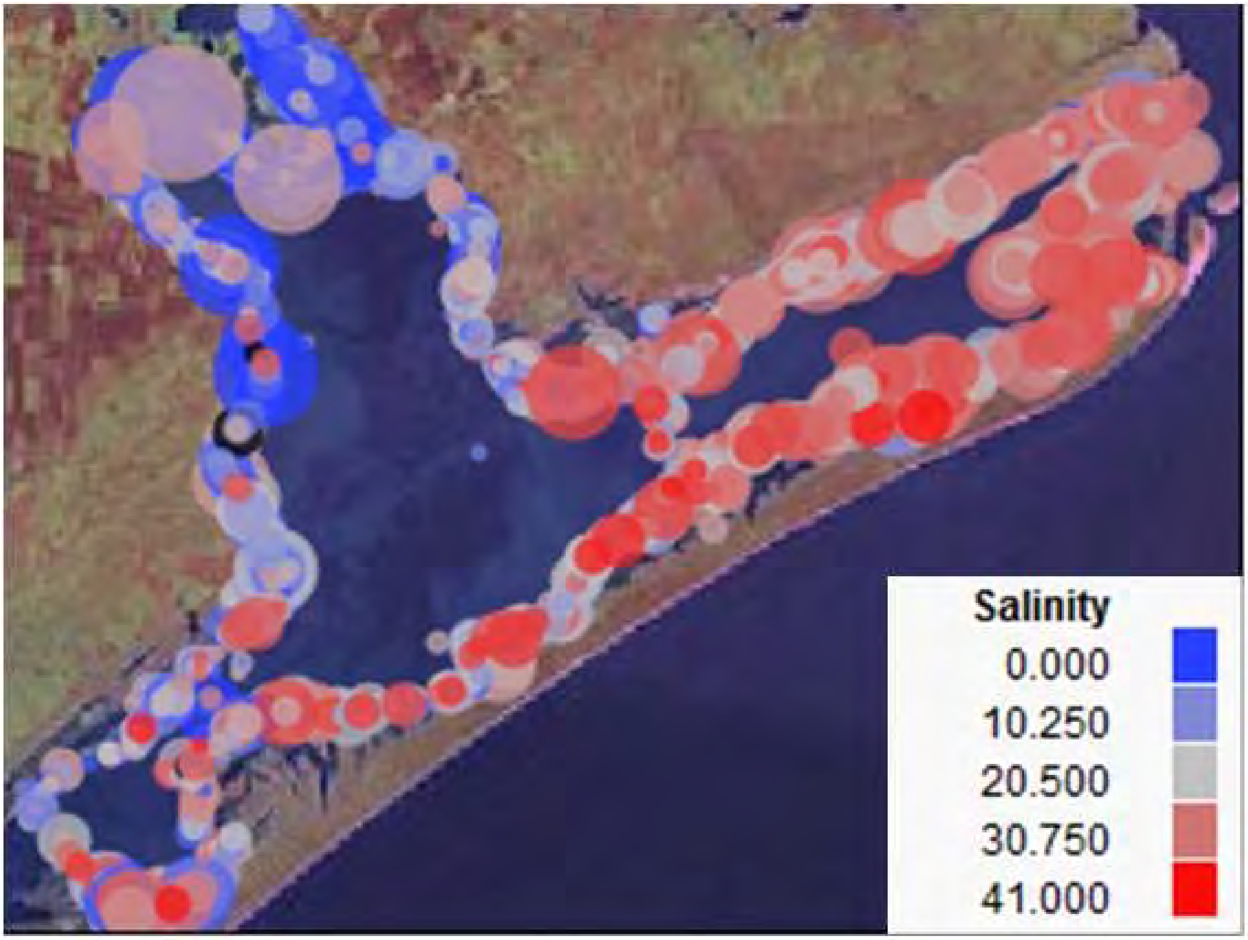


Figure 2.132 Spatial distribution of red drum, *Sciaenops ocellatus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Southern Flounder, *Paralichthys lethostigma*: Southern flounder were caught throughout the bay but showed higher abundance in areas with higher salinity, such as ESB (Figure 2.133), as expected with their preference for higher salinities as adults (Ward and Armstrong, 1980). The mean salinity for catches of southern flounder was 21.7 ppt.

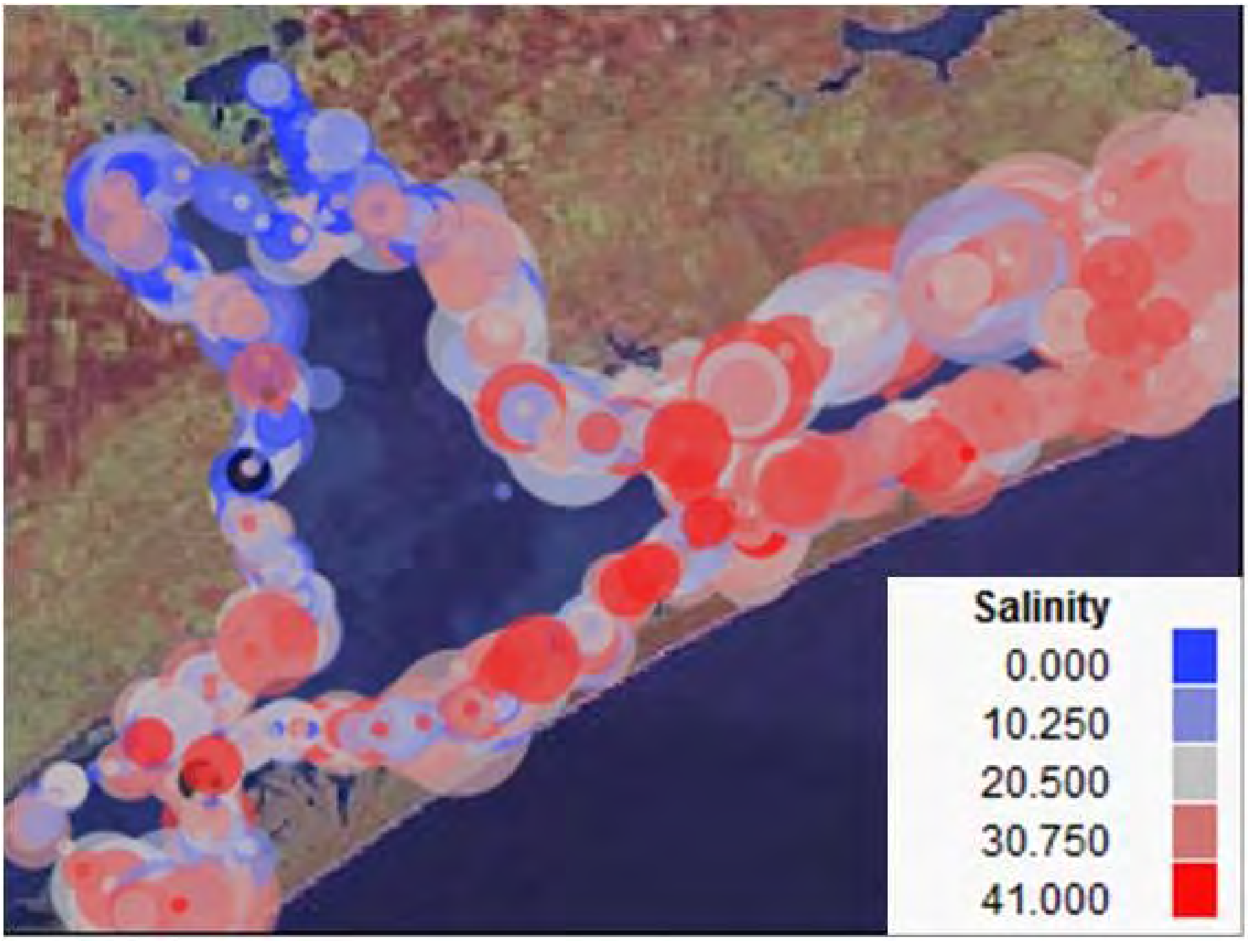


Figure 2.133 Spatial distribution of southern flounder, *Paralichthys lethostigma*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Hardhead Catfish, *Ariopsis felis*: As shown in trawl catches, hardhead catfish were caught throughout the bay using gillnets with no apparent preference for salinity (Figure 2.134). The mean salinity for catches of hardhead catfish was 20.3 ppt.

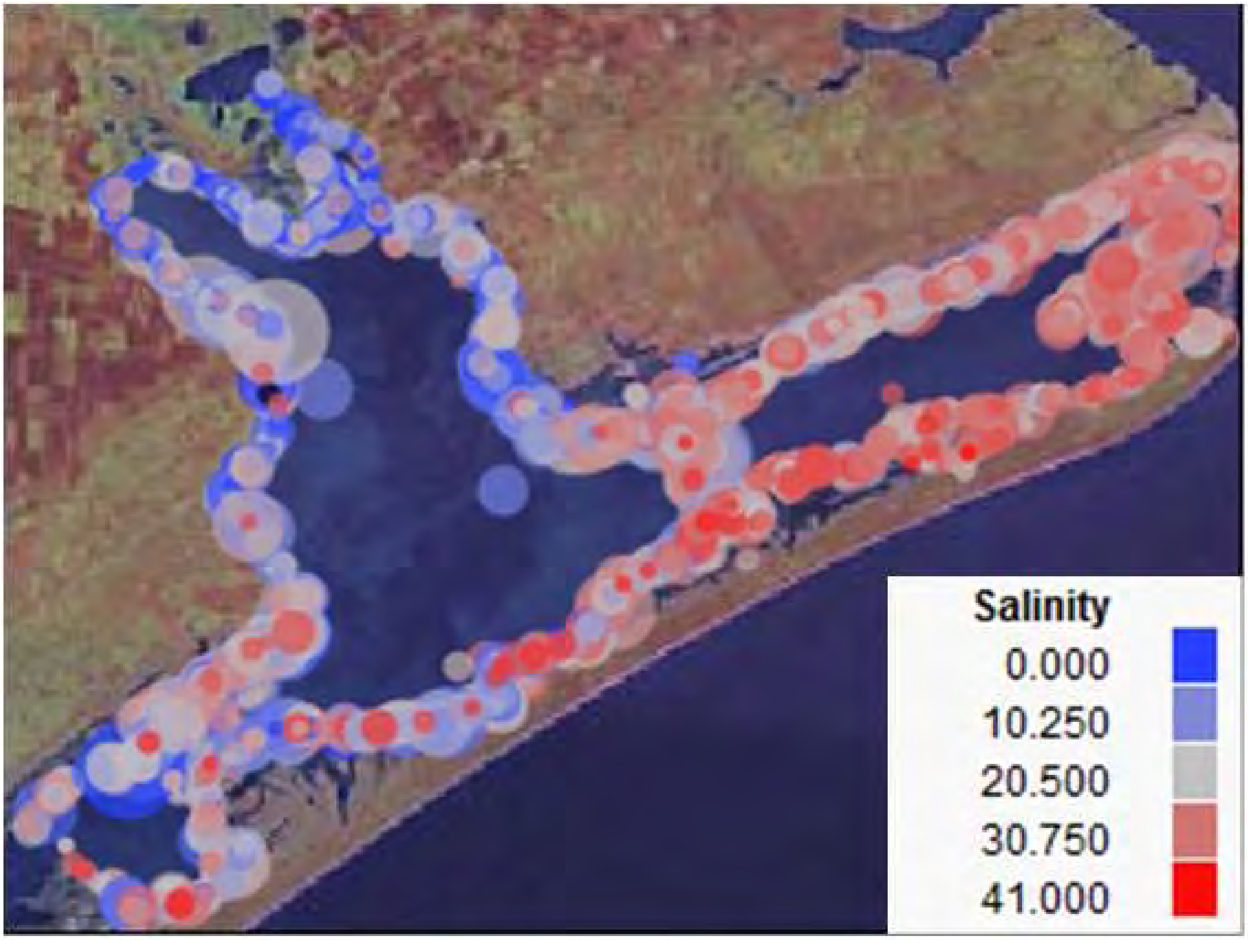


Figure 2.134 Spatial distribution of hardhead catfish, *Ariopsis felis*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Black Drum, *Pogonias cromis*: Black drum were caught throughout the bay and showed no preference for salinity (Figure 2.135). The mean salinity for catches of black drum was 20.0 ppt.

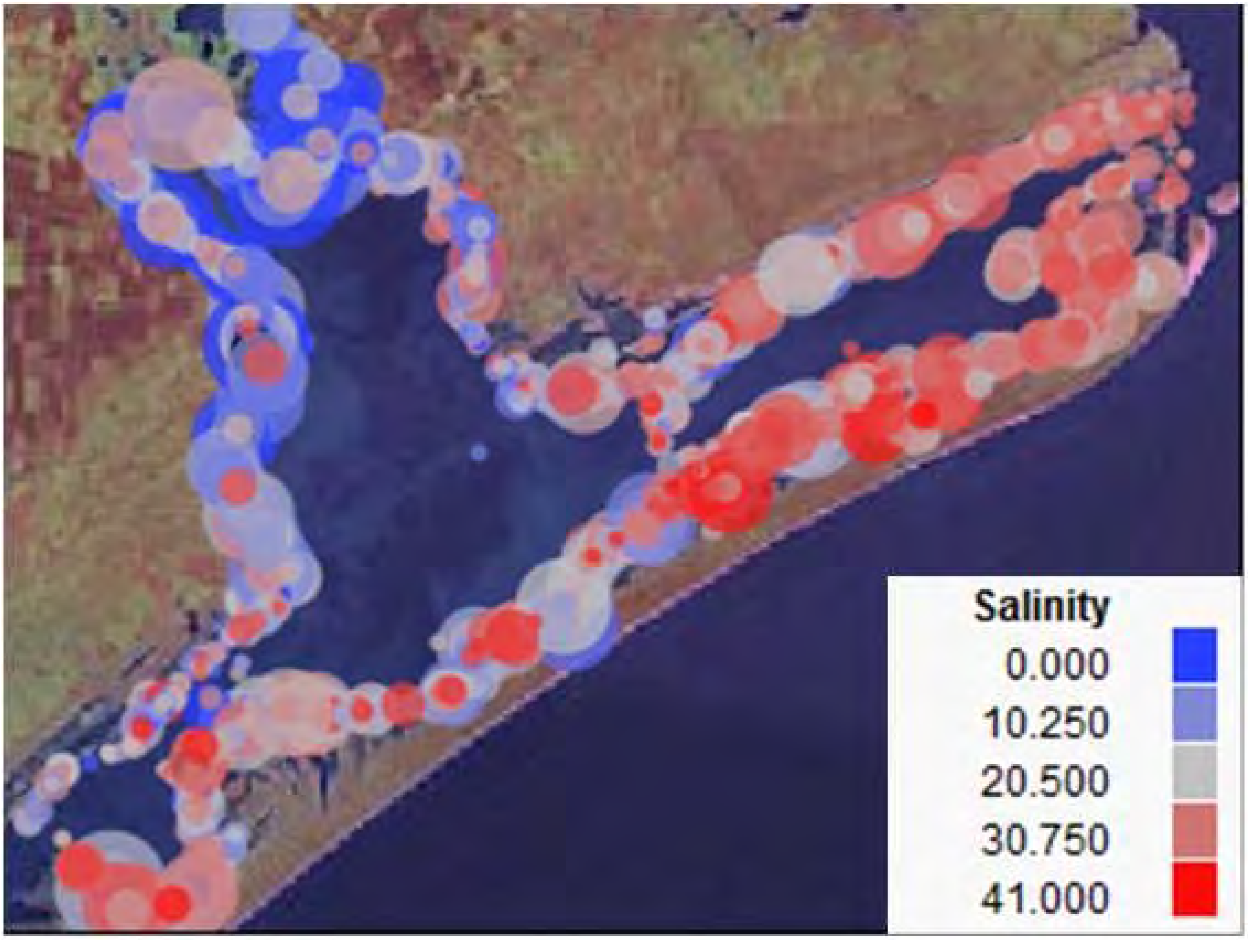


Figure 2.135 Spatial distribution of black drum, *Pogonias cromis*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gafftopsail Catfish, *Bagre marinus*: Similar to bag seine catch, gafftopsail catfish were caught throughout the bay using gillnets showed no preference for salinity (Figure 2.136). The mean salinity for catches of gafftopsail catfish was 19.6 ppt.

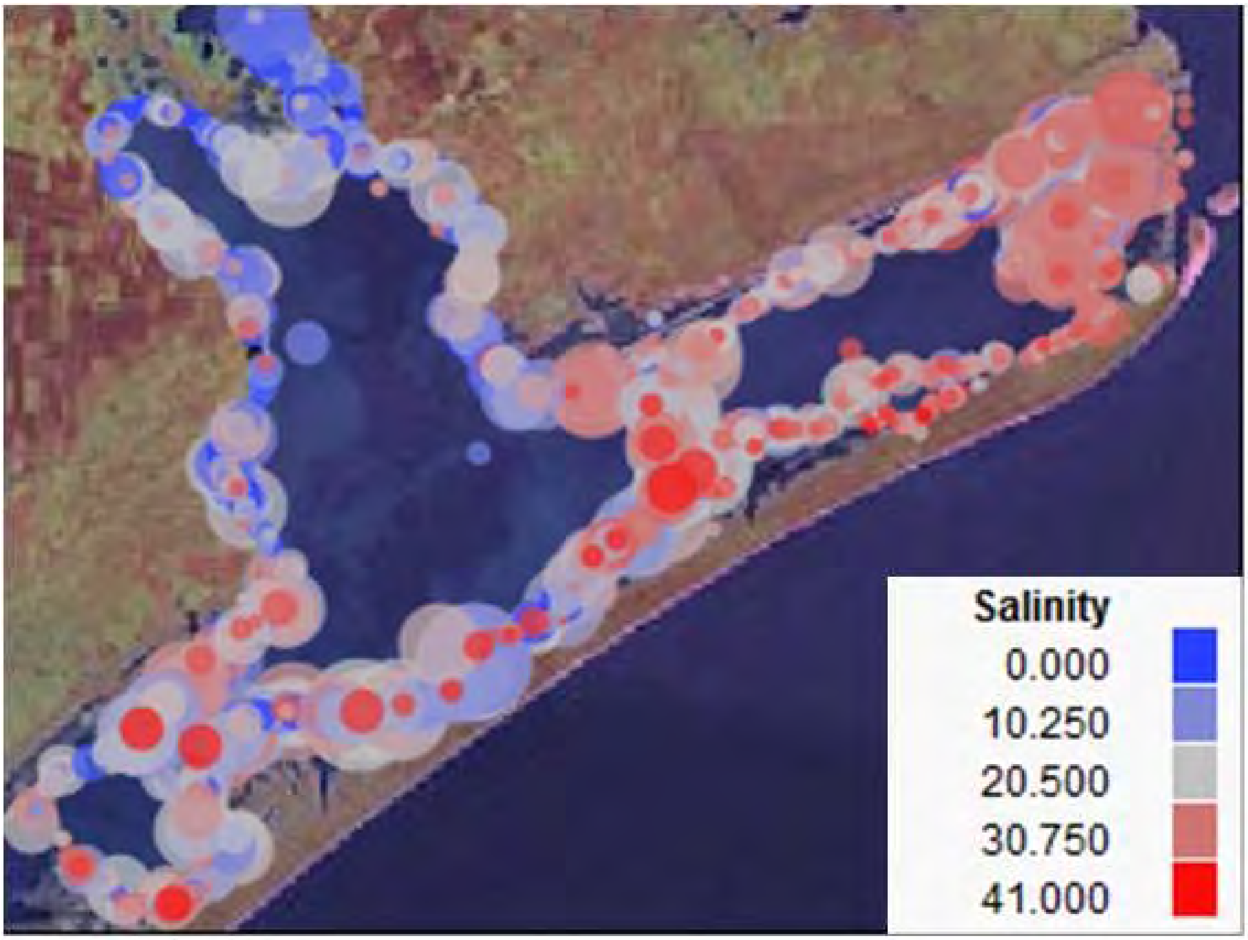


Figure 2.136 Spatial distribution of gafftopsail catfish, *Bagre marinus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gizzard Shad, *Dorosoma cepedianum*: Gizzard shad distribution showed a preference for lower salinity and areas of the bay in which these salinities typically occur (Figure 2.137). Lower SAB and ESB have lower catches except for times during which the salinity is lower than normal. These were not surprising data considering that gizzard shad are primariliy freshwater fish. The mean salinity for catches of gizzard shad was 16.1 ppt.

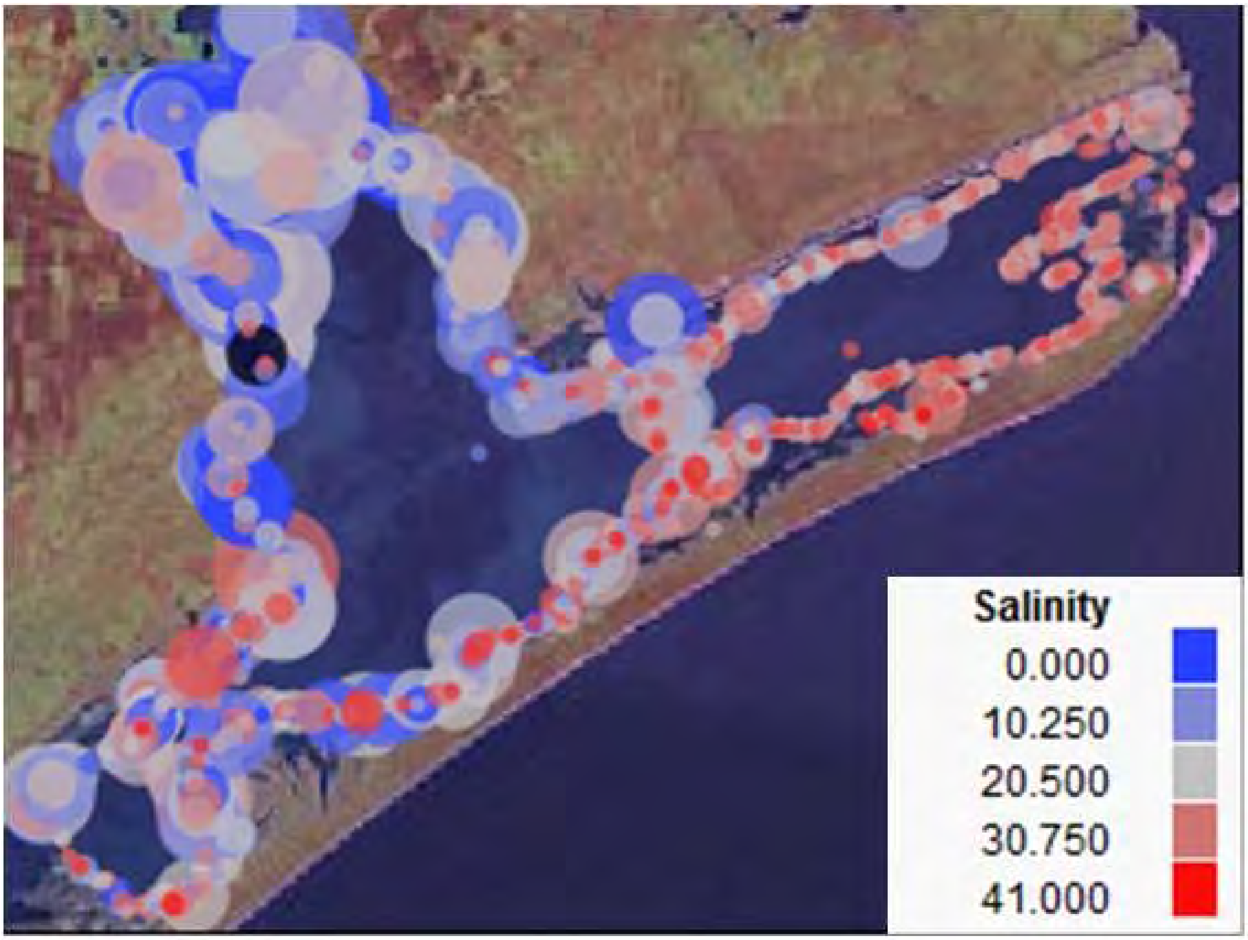


Figure 2.137 Spatial distribution of gizzard shad, *Dorosoma cepedianum*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Striped Mullet, *Mugil cephalus*: Striped mullet gillnet catches showed a trend favoring areas with lower salinity in the bays, as shown with bag seine catch as well. While striped mullet were caught throughout the bay, the areas in which the largest numbers were caught were in upper SAB (Figure 2.138). The mean salinity for catches of striped mullet was 19.6 ppt.

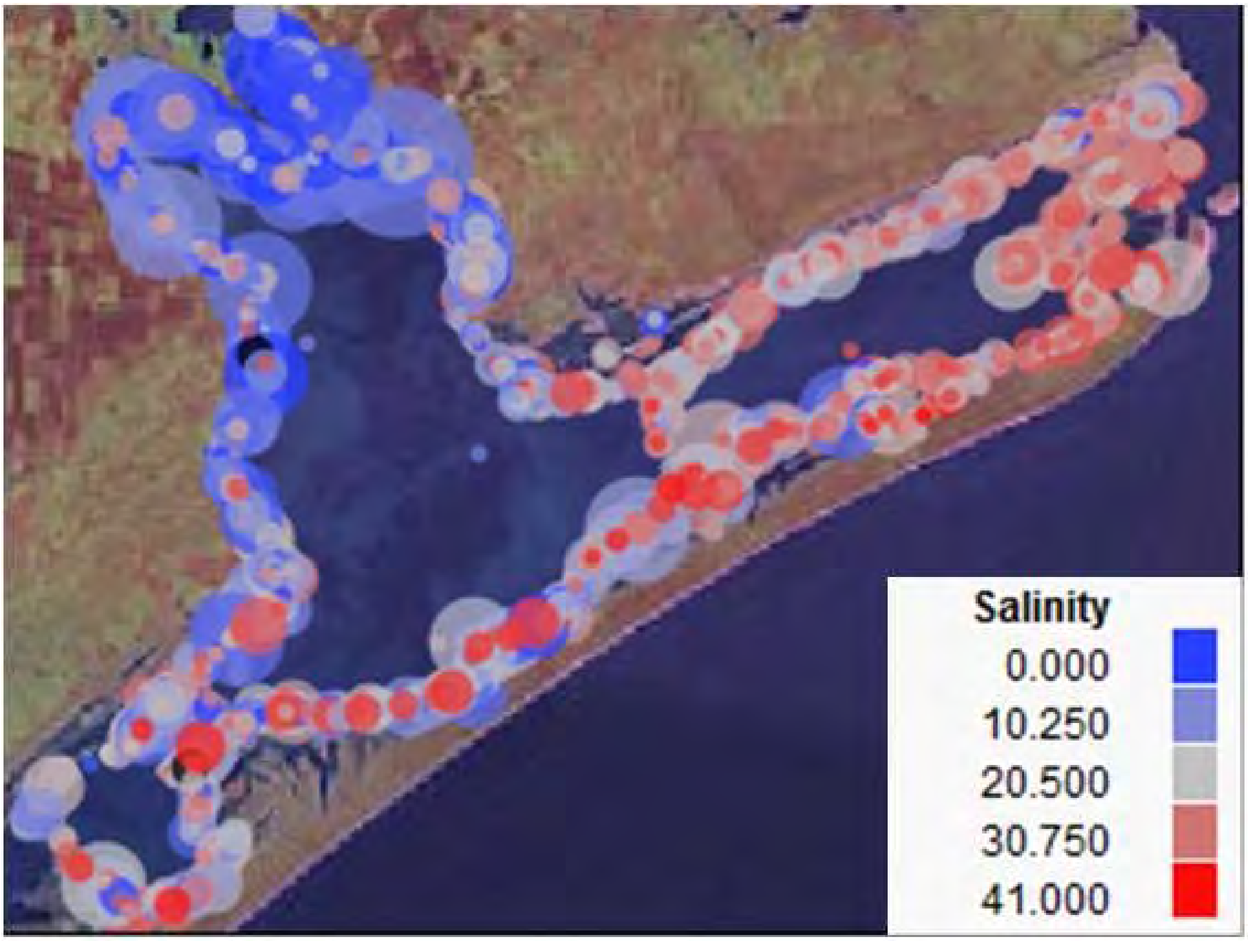


Figure 2.138 Spatial distribution of striped mullet, *Mugil cephalus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Sheepshead, *Archosargus probatocephalus*: Sheepshead were caught throughout the bay but showed a preference for higher salinity, such as in ESB and Mesquite Bay (Figure 2.139). The mean salinity for catches of sheepshead was 21.7 ppt.

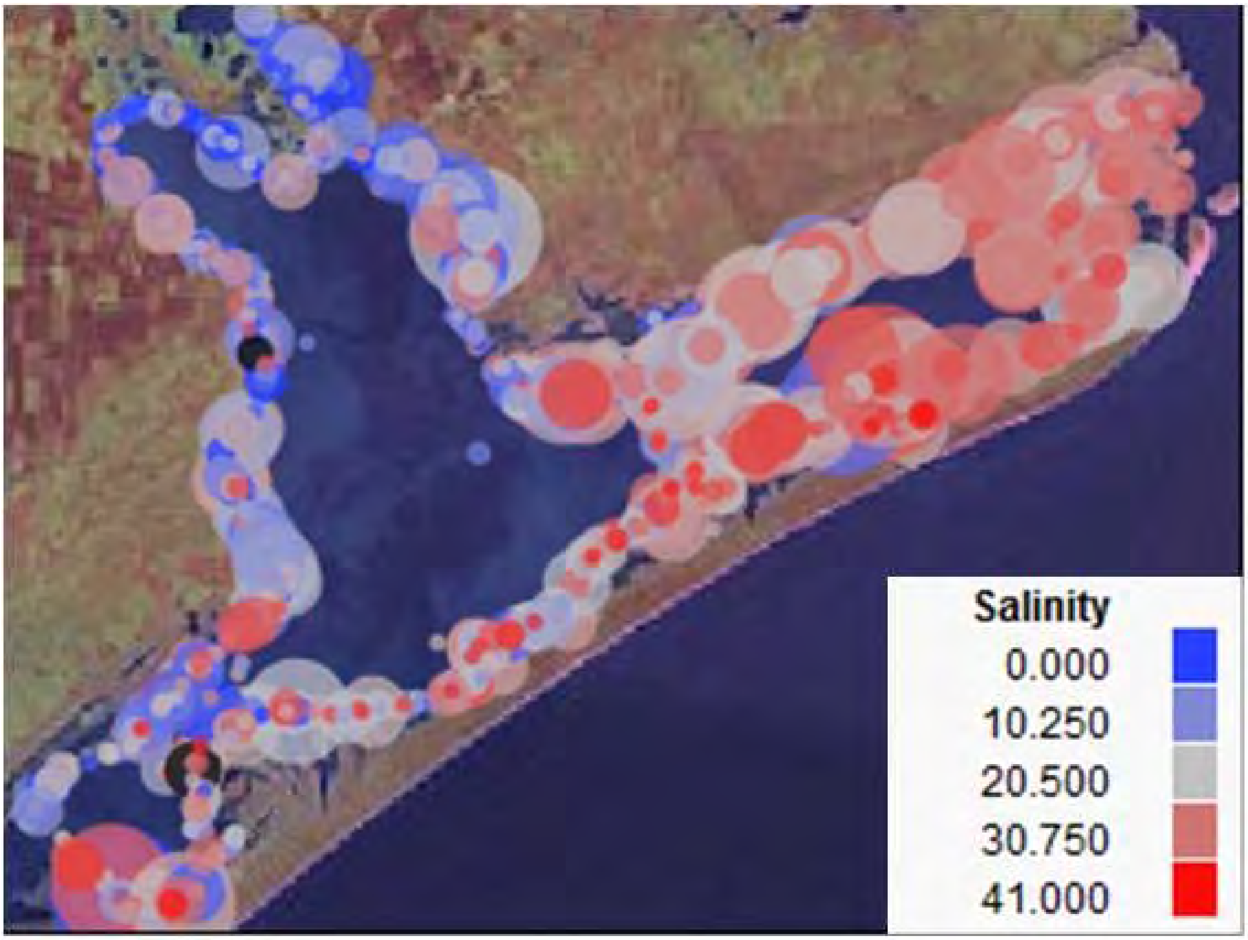


Figure 2.139 Spatial distribution of sheepshead, *Archosargus probatocephalus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Atlantic Croaker, *Micropogonias undulatus*: Atlantic croaker were sparsely caught throughout SAB while showing a slight trend favoring lower salinities (Figure 2.140), which coincides with previous work descriptions along the coast of Texas (Ward and Armstrong, 1980). The mean salinity for catches of Atlantic croaker was 20.8 ppt.

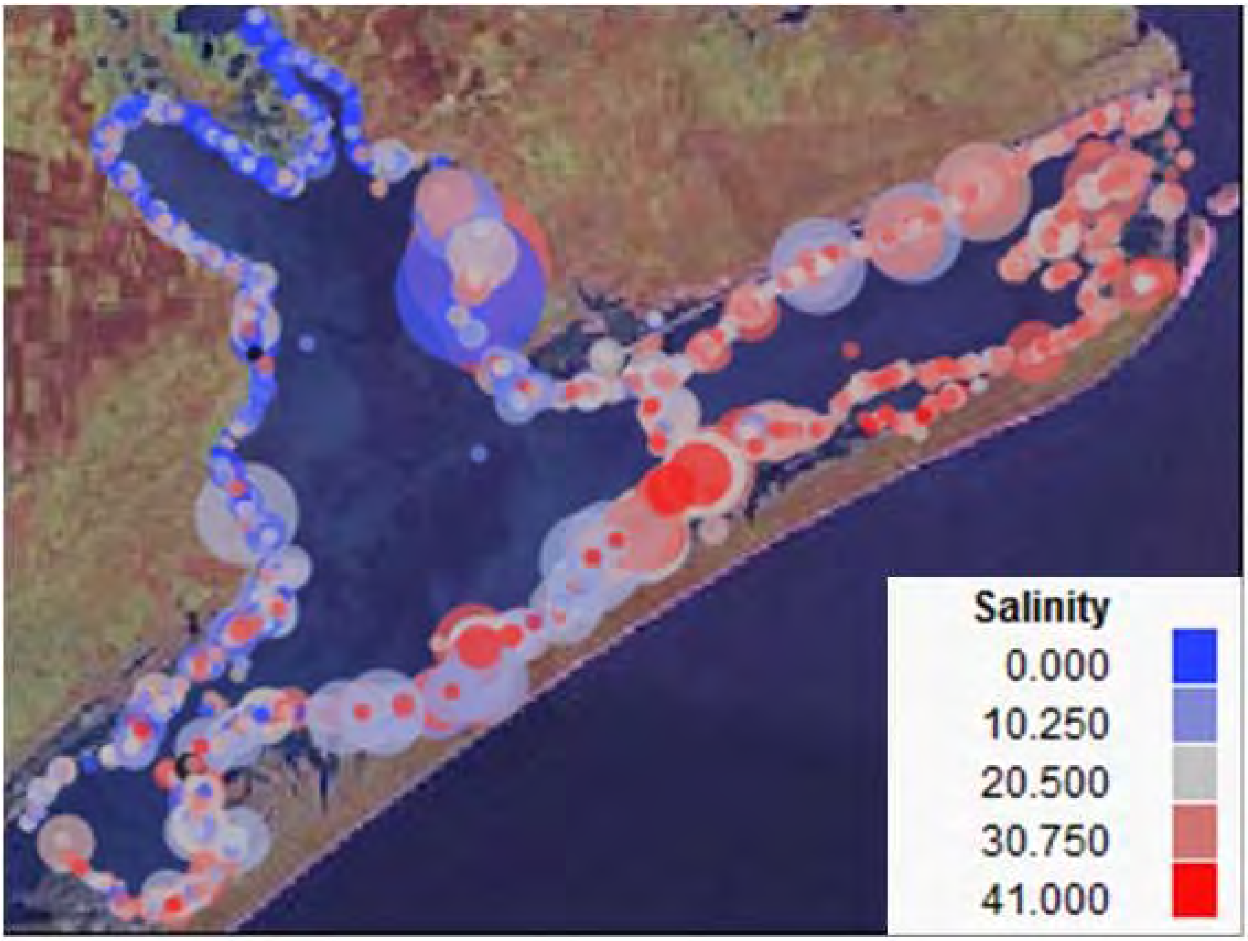


Figure 2.140 Spatial distribution of Atlantic croaker, *Micropogonias undulatus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Gulf Menhaden, *Brevoortia patronus*: As with the bag seine and bay trawl catch rates, gulf menhaden gillnet catches favored areas with low salinity in the bays, but not to the same extent. The gulf menhaden caught in gillnets showed relatively more tolerance to higher salinities (Figure 2.141). The mean salinity for catches of gulf menhaden was 20.8 ppt.

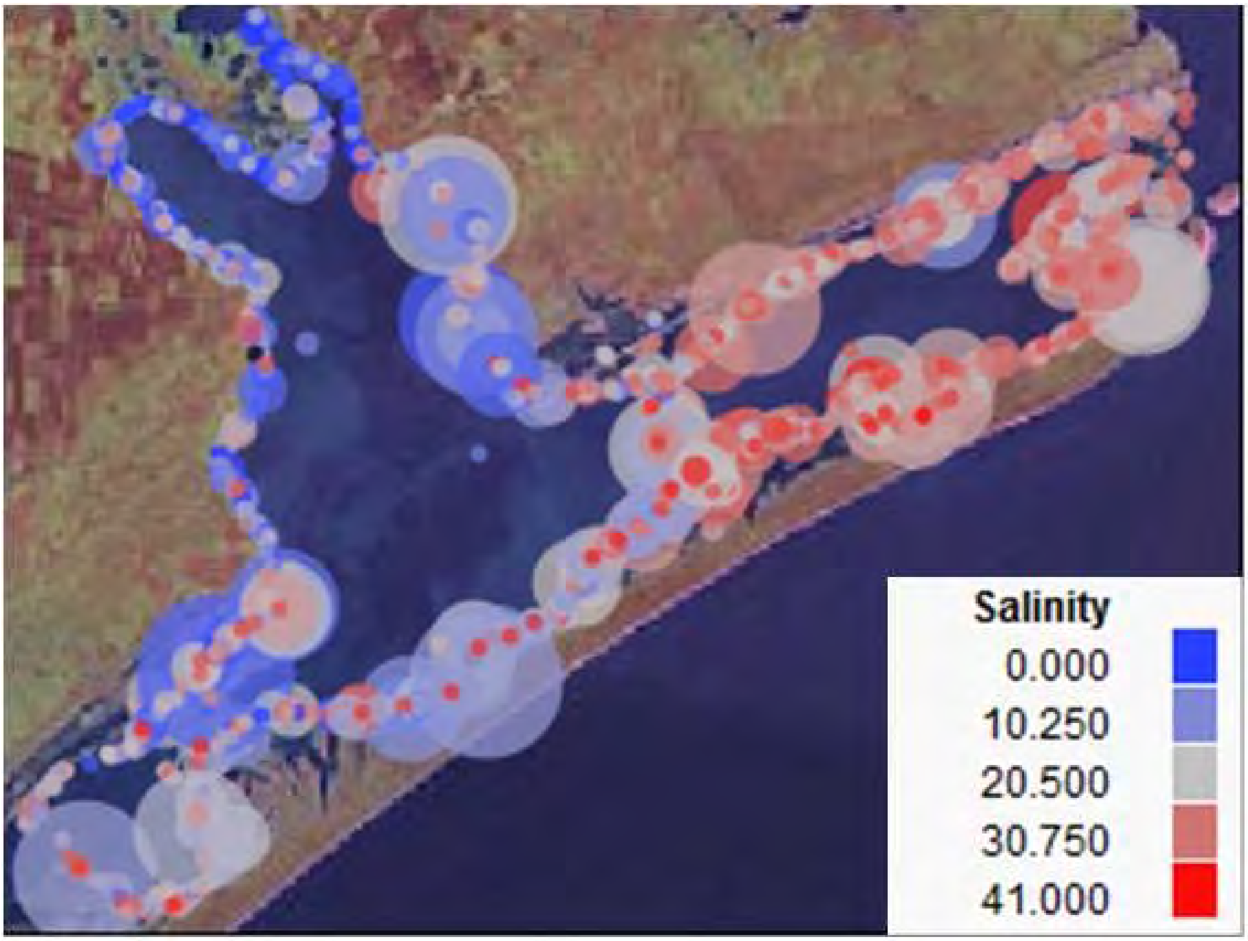


Figure 2.141 Spatial distribution of gulf menhaden, *Brevoortia patronus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Blue Catfish, *Ictalurus furcatus*: Blue catfish, primarily a freshwater fish, showed a strong preference for low salinities, with catches occurring mainly in upper SAB (including Guadalupe and Hynes Bays) (Figure 2.142). These areas typically have lower salinities than other areas within the bay. The mean salinity for catches of blue catfish was 2.5 ppt.

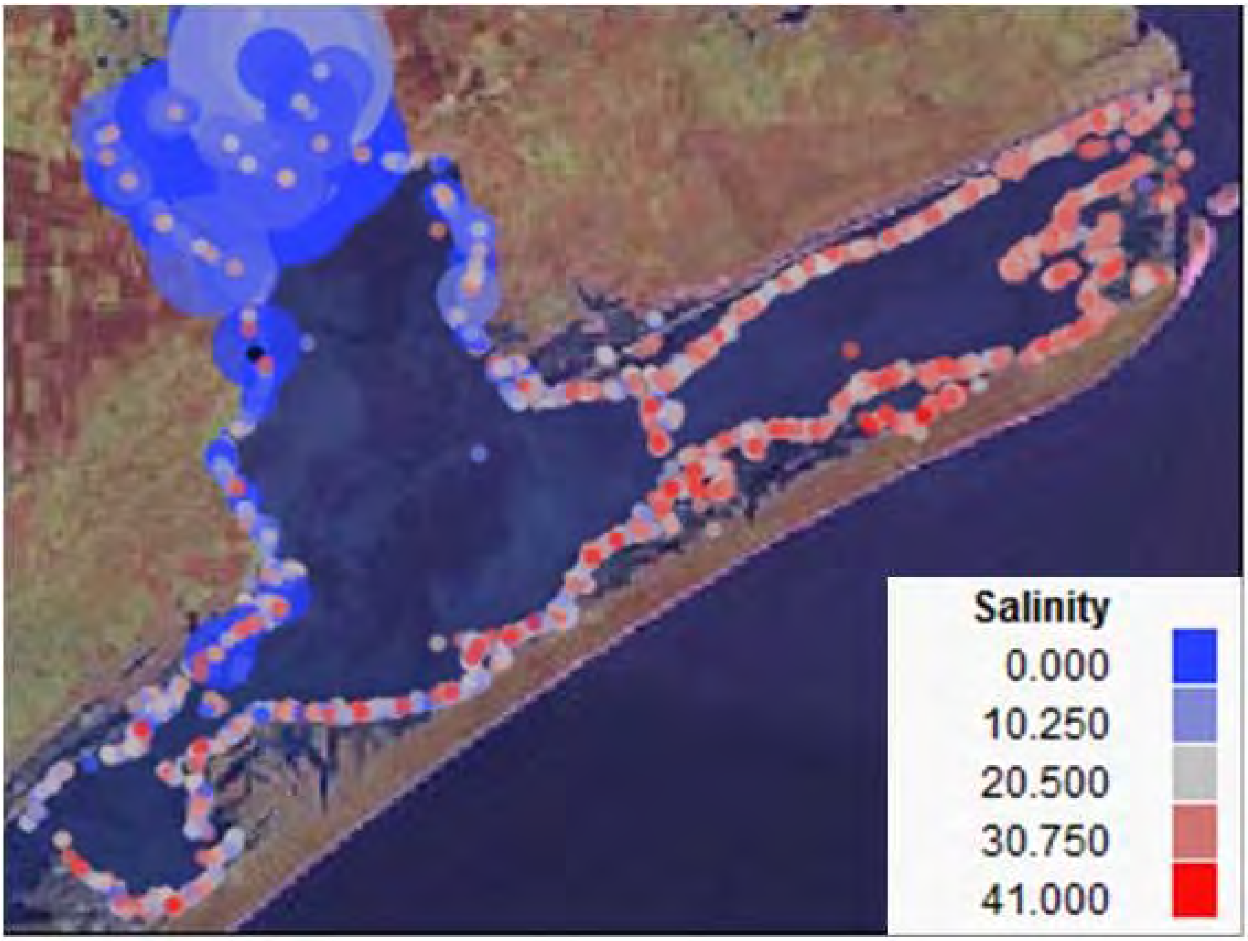


Figure 2.142 Spatial distribution of blue catfish, *Ictalurus furcatus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Ladyfish, *Elops saurus*: Ladyfish showed a strong preference for areas in lower SAB, ESB, and Mesquite Bay (Figure 2.143). These areas typically have high salinities, but there have been high catch rates at times when the salinities were lower than normal. The mean salinity for catches of ladyfish was 22.7 ppt.

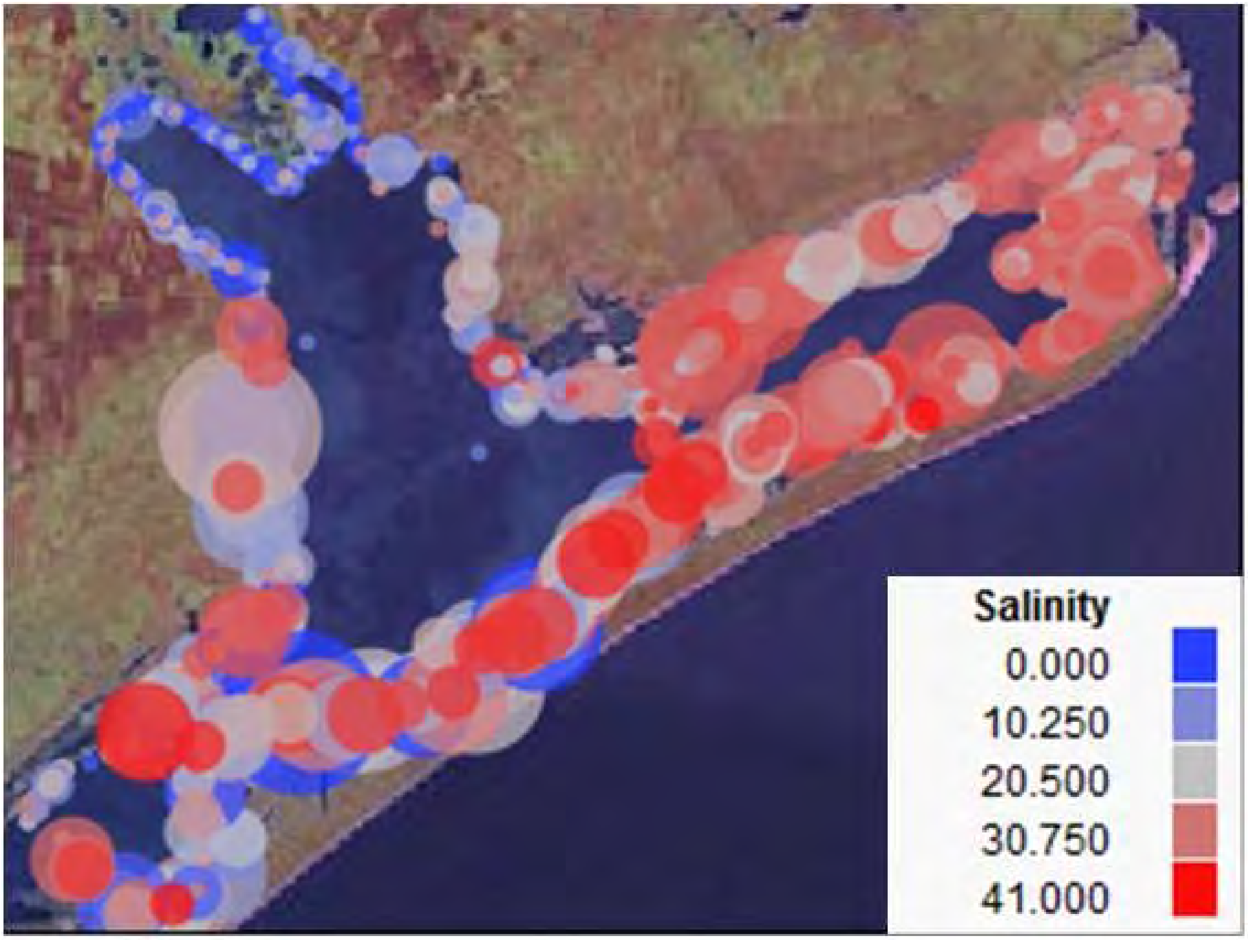


Figure 2.143 Spatial distribution of ladyfish, *Elops saurus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Alligator Gar, *Atractosteus spatula*: While alligator gar were caught throughout the bay, they showed a preference for low salinities, with larger catches typically occurring in upper and western SAB (including Guadalupe and Hynes Bays) (Figure 2.144). These areas typically have lower salinities than other areas within the bay. Again, these are not surprising data considering that alligator gar are primarily freshwater fish. The mean salinity for catches of alligator gar was 13.0 ppt.

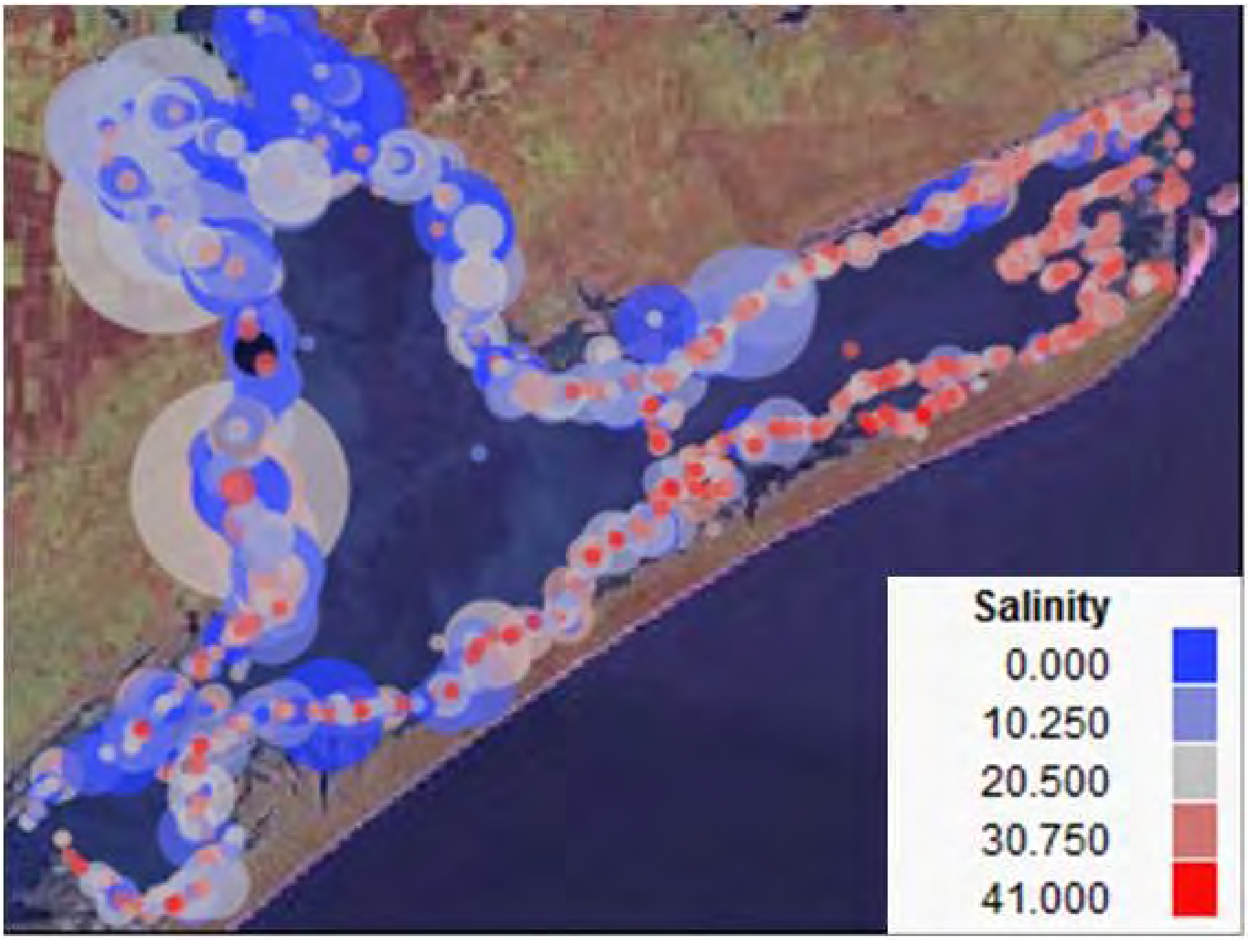


Figure 2.144 Spatial distribution of alligator gar, *Atractosteus spatula*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Spot, *Leiostomus xanthurus*: Similar to the bag seine and bay trawl catch rates, spot catches in gillnets showed a trend favoring areas with higher salinity. These locations were lower SAB near the Matagorda Island shoreline, Espiritu Santo Bay, and Mesquite Bay (Figure 2.145). The mean salinity for catches of spot was 23.7 ppt.

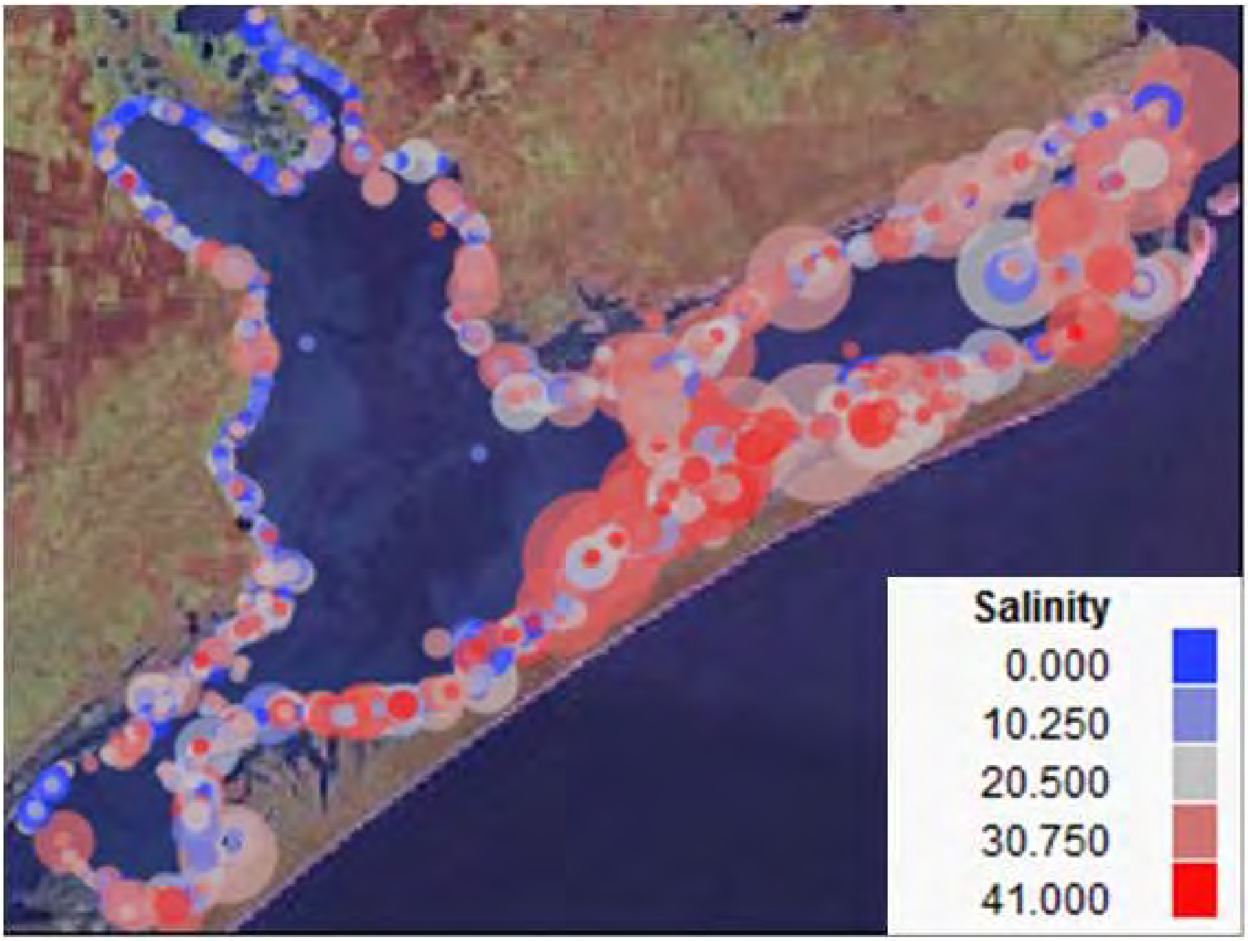


Figure 2.145 Spatial distribution of spot, *Leiostomus xanthurus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Smallmouth Buffalo, *Ictiobus bubalus*: Smallmouth buffalo, primarily a freshwater fish, showed a strong preference for low salinities, with catches occurring mainly in upper SAB (including Guadalupe and Hynes Bays) and extending south to western SAB (Figure 2.146). These areas typically have lower salinities than other areas within the bay. The mean salinity for catches of smallmouth buffalo was 1.7 ppt.

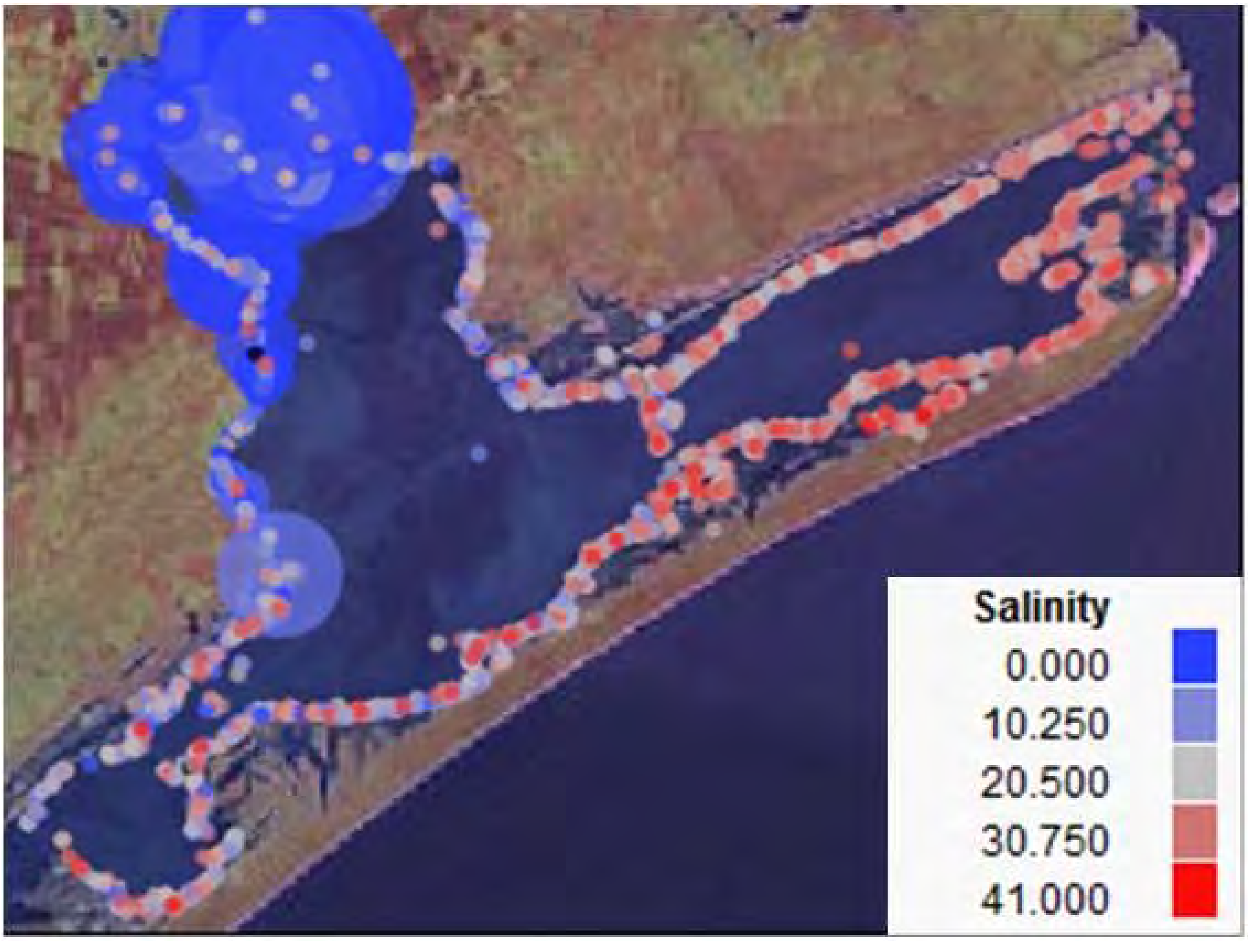


Figure 2.146 Spatial distribution of smallmouth buffalo, *Ictiobus bubalus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Blue Crab, *Callinectes sapidus*: Similar to the catch in bag seines and bay trawls, blue crab were caught throughout the bay, showing no preference for salinities (Figure 2.147). The mean salinity for catches of blue crab was 21.1 ppt.

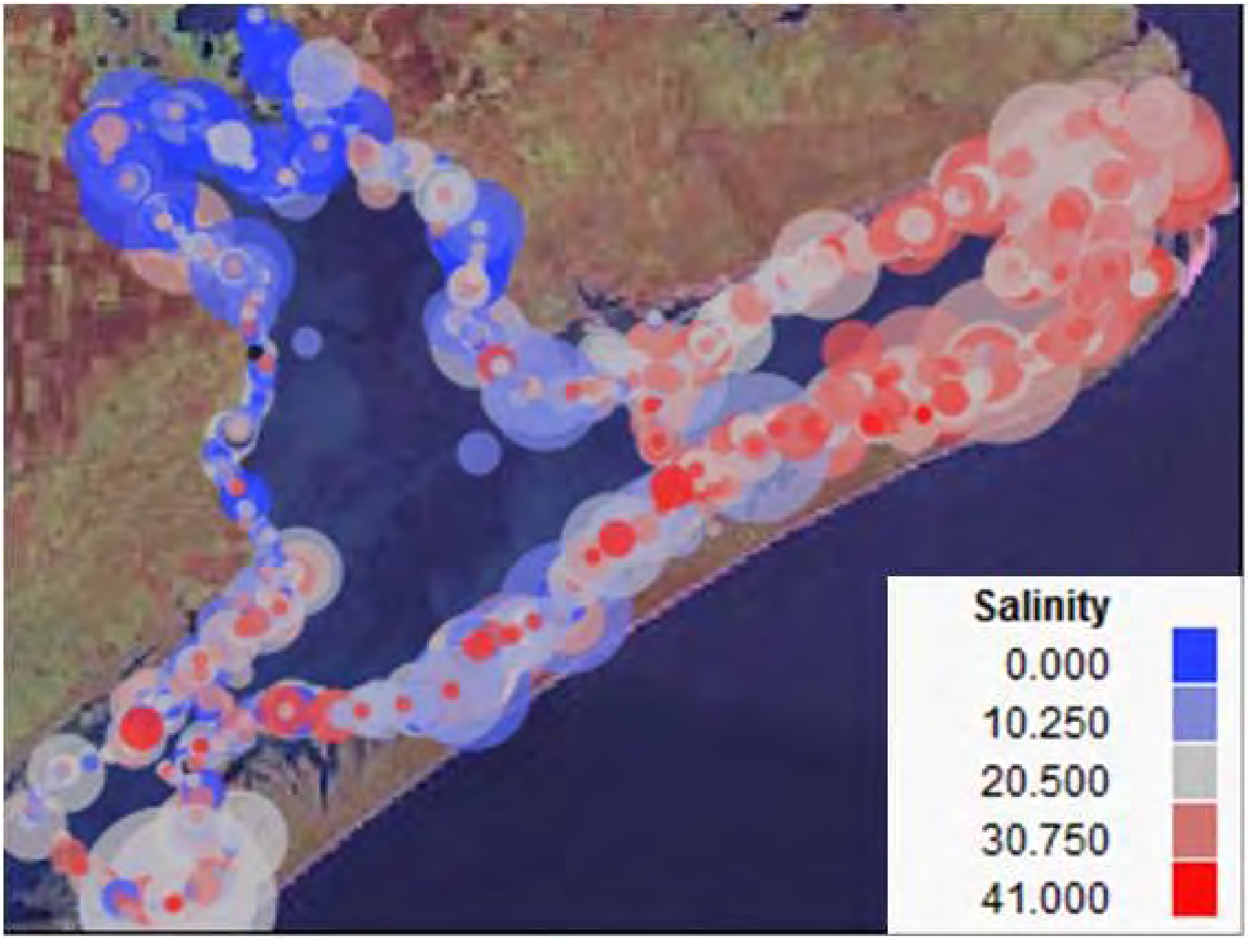


Figure 2.147 Spatial distribution of blue crab, *Callinectes sapidus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Bull shark, *Carcharhinus leucas*: Bull shark were caught throughout the bay, showing no preference for salinities (Figure 2.148). The mean salinity for catches of bull shark was 19.8 ppt.

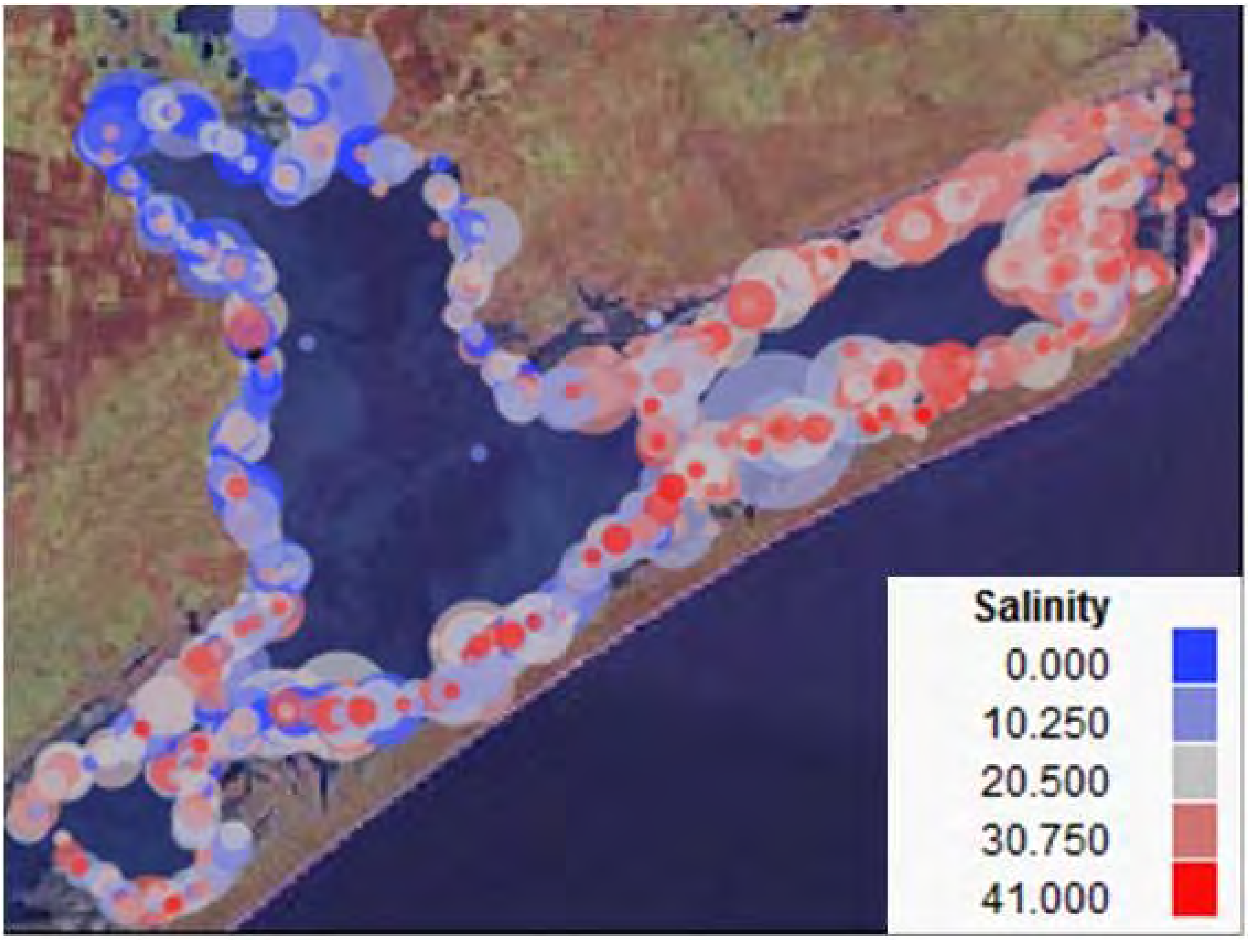


Figure 2.148 Spatial distribution of bull shark, *Carcharhinus leucus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Spotted Gar, *Lepisosteus oculatus*: Spotted gar, another primarily freshwater gar species, showed a strong preference for low salinities, with catches occurring mainly in upper SAB (including Guadalupe and Hynes Bays) (Figure 2.149). These areas typically have lower salinities than other areas within the bay. The mean salinity for catches of spotted gar was 5.2 ppt.

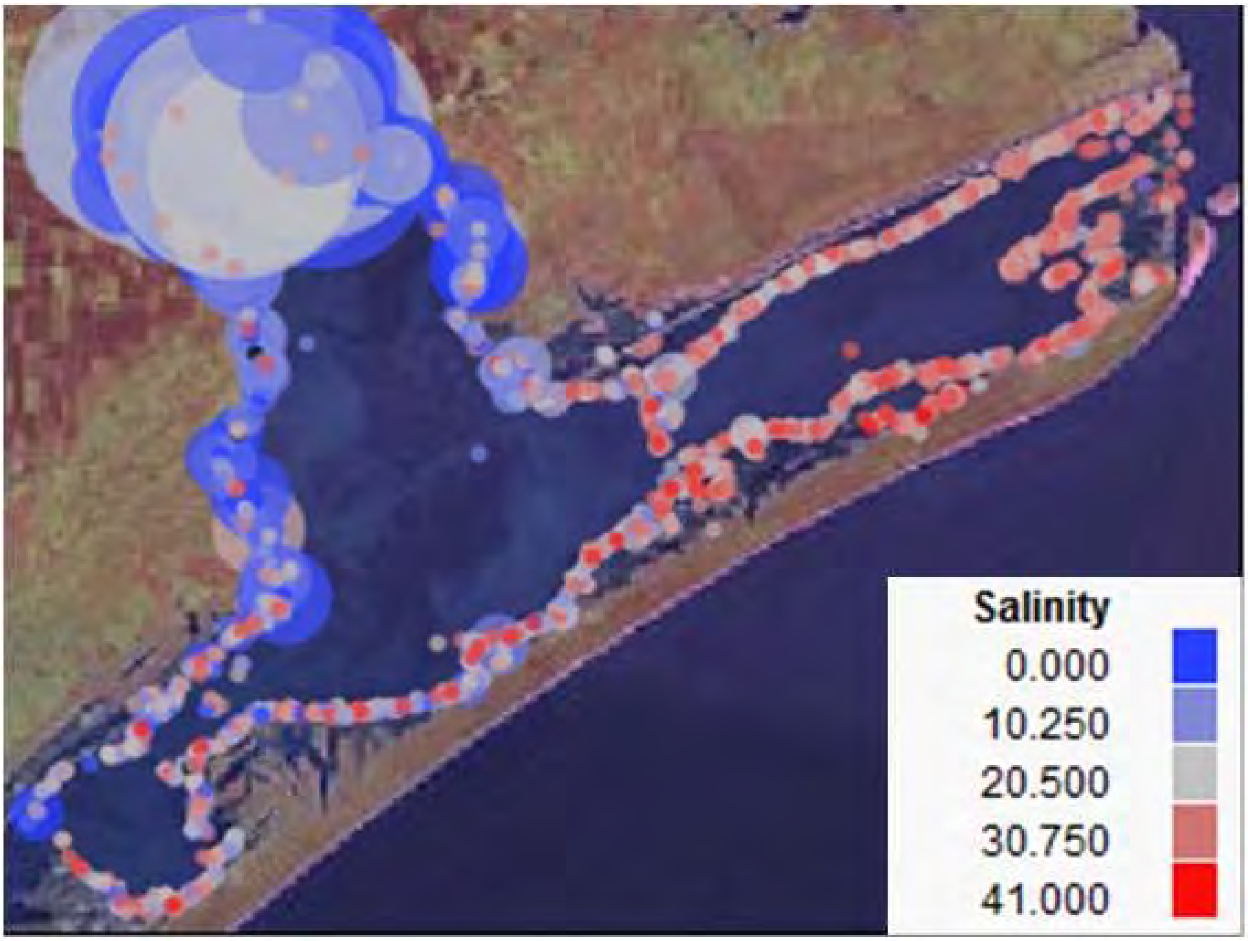


Figure 2.149 Spatial distribution of spotted gar, *Lepisosteus oculatus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Longnose Gar, *Lepisosteus osseus*: Longnose gar, similar to the other freshwater gar species, showed a strong preference for low salinities, with catches occurring mainly in upper SAB (including Guadalupe and Hynes Bays) (Figure 2.150). These areas typically have lower salinities than other areas within the bay. The mean salinity for catches of longnose gar was 2.6 ppt.

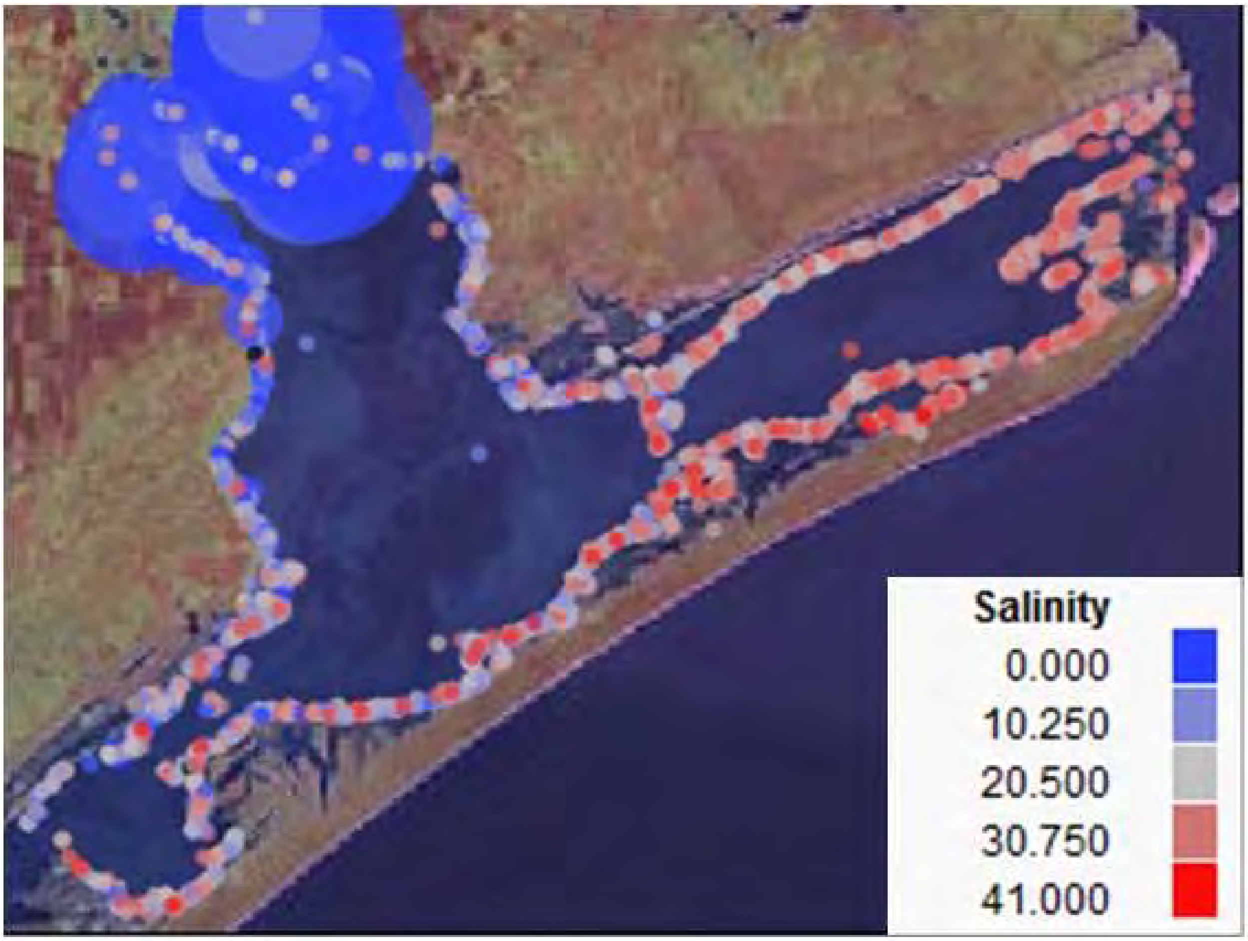


Figure 2.150 Spatial distribution of longnose gar, *Lepisosteus osseus*, gillnet catch in San Antonio Bay from 1982 – 2011. Relative catch per unit effort (CPUE) is indicated by circle size. Circle color is indicative of salinity measured at collection.

Species Diversity

Diversity indices for catches with all gears in SAB, while varying, showed an overall level trend, while species richness increased (Figure 2.151). With all gear types, SAB had a slightly higher diversity and species richness compared to the coast average. Diversity indices and species richness coastwide excluding SAB in bag seine and gillnet catch showed similar relative trends over the same time period (Figure 2.152). Bay trawl diversity and species richness coastwide decreased over this time period, which differed from SAB catch. There are similar shorter time scale trends that are apparent between SAB and coastwide catch, with the most apparent being the decrease in diversity in gillnets from the 1990's. Bay trawl catches also showed a distinct jump in 1995 in both SAB and coastwide.

In bay trawl catch over all years in SAB, the average diversity was 2.37, while the average species richness was 67. Coastwide diversity with bag seine catch over all years was 2.31 and average species richness was 60.

In bag seine catch over all years in SAB, the average diversity was 2.55, while the average species richness was 68. Coastwide diversity with bay trawl catch over all years was 2.31 and average species richness was 59.

In gillnet catch over all years in SAB, the average diversity was 2.42, while the average species richness was 48. Coastwide diversity with bay trawl catch over all years was 2.22 and average species richness was 37.

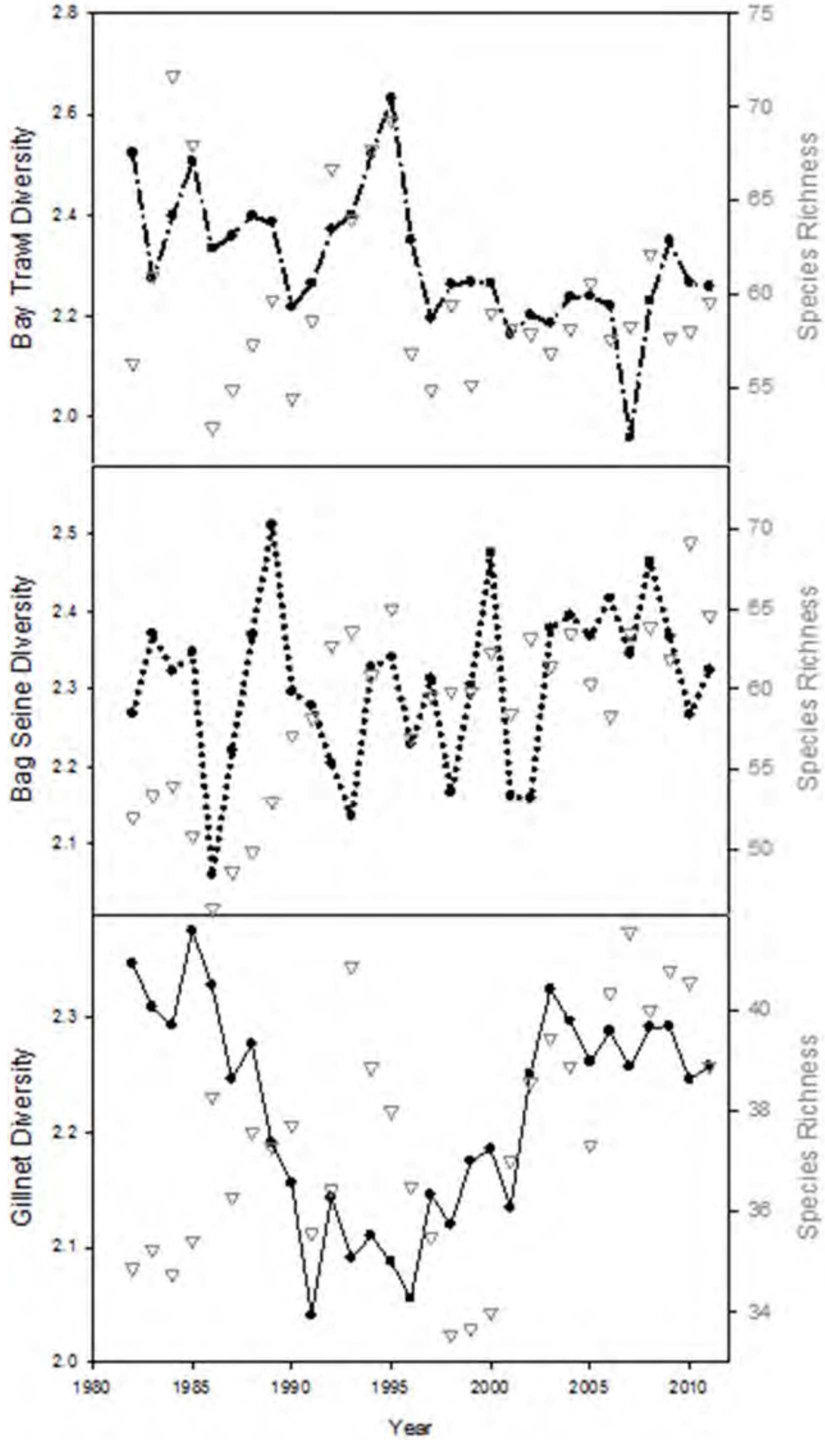


Figure 2.151 Average yearly diversity (represented by points and lines) along Texas coast excluding San Antonio Bay for gillnet, bag seine, and bay trawl catches. Species richness is denoted by gray triangle symbols.

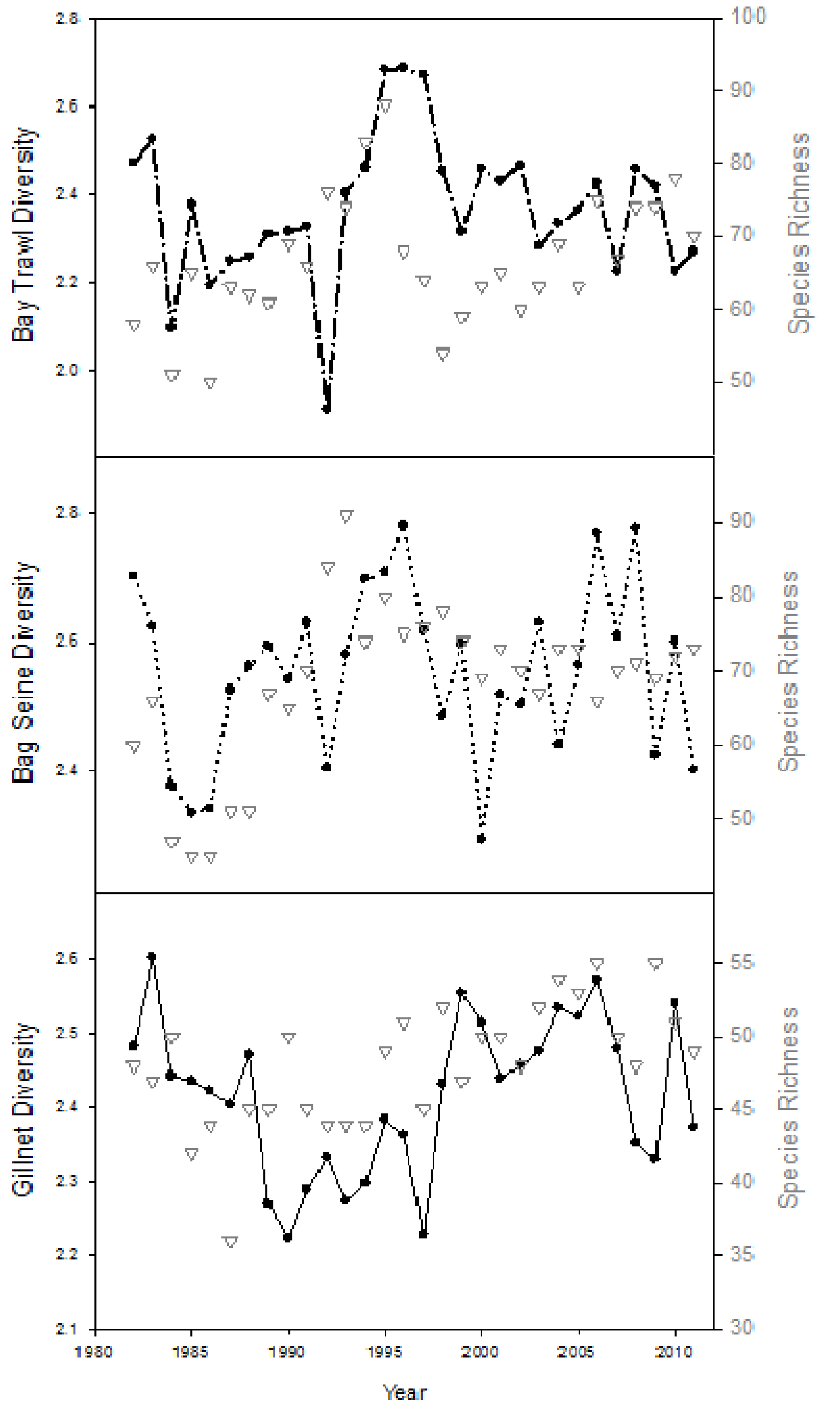


Figure 2.152 Yearly diversity (represented by points and lines) in San Antonio Bay for gillnet, bag seine, and bay trawl catches. Species richness is denoted by gray triangle symbols.

DISCUSSION

It is clear from these analyses that the species populations, and therefore the assemblages, are not static. Almost by definition estuarine systems and the biota within are dynamic. To begin understanding such systems requires years of systematically collected population trend data and knowledge of natural and unnatural mortality. The data used in these analyses meet these requirements.

Species assemblage and trend data revealed two major variables affecting marine fauna in SABS over the past 30 years: (1) the commercial shrimp fishery and (2) an east-west clinal change in rainfall and thus river inflows. The reduction in shrimping effort during the last decade was coincident with catch rate increases for several species including brown and white shrimp, Atlantic croaker, bay anchovy, Atlantic brief squid, gafftopsail catfish, and silver perch. Because these species have also been found to be a components of the SAB shrimp fishery bycatch it is probable that the reduced shrimping effort has allowed their populations to expand. Rainfall declines from east to west resulting in higher freshwater inflows to estuaries on the northern Texas coast relative to those on the southern coast. As a result estuaries on the upper coast exhibit lower salinities, on average, that those on the lower coast. These salinity variations affect the abundance of those species particularly sensitive to salinity.

Other variables such as episodic environmental events and the north-south clinal change in temperatures have also impacted species abundance. By way of changing distribution and abundance trends in species which are abundant, environmental changes in the form of freshwater inflow events and droughts affected the character of SAB and how the estuary compared with other Texas estuaries.

It is noteworthy that SAB was not found to be significantly different from the Aransas/Copano Bay system in any analysis. Species which contributed to the similarity of these two estuarine systems included pinfish, brown shrimp, Atlantic croaker, hardhead catfish and red drum. The similarity between these two estuarine systems goes past the species assemblages; they also share a freshwater inflow source, the Guadalupe River. During low and medium flow conditions the waters from the Guadalupe River enter SAB through Guadalupe Bay and course southwest through Mesquite Bay into Aransas Bay. In this way the Guadalupe River provides nutrients, sediments, and salinity modification to both estuaries.

Also noteworthy is that SAB didn't group with the Laguna Madre system during species assemblage analyses. Because the Laguna Madre receives limited freshwater inflows and is sometimes hyper-saline, it is likely that the inter-basin differences are due in large part to salinity differences. Other contributing causes could be Gulf connections and temperature differences. Several species were important in this separation of mid and lower coast bay systems including sheepshead minnow, Gulf menhaden, Atlantic croaker, spot, gafftopsail catfish, and black drum.

Non-native species

Relative to some estuaries SAB hosts a limited number of non-native marine faunal species. Those which have been collected by the TPWD Fishery-Independent sampling program include common carp, *Cyprinus carpio*, and suckermouth catfish, *Hypostomus plecostomus.* The San Marcos River is known to harbor a substantial population of suckermouth catfish, and other exotics.

Anglers have provided specimens of grass carp, *Ctenopharyngodon idella*, and red-bellied pacu, *Piaractus brachypomus,* from the Guadalupe River just above the estuary. Recently tiger shrimp, *Penaeus monodon,* have been captured in the Trinity-Neches (Sabine Lake) and Mission-Aransas (Aransas Bay) estuaries. However none of these species have been reported from SAB.

Future Threats/Considerations

- Reduced freshwater inflows
- Overfishing
- Non-native species

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REPORT 3: Colonial Nesting Waterbirds

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DATA	Annual Colonial Nesting Waterbird Surveys (primarily conducted by the Texas Colonial Waterbird Society): • Number of adults • Numbers of nests • Estimated number of breeding pairs
TIMEFRAME	1973-2009

INTRODUCTION

The San Antonio Bay Partnership (SABP) is a regional, non-profit, stakeholder-driven planning and management program for the San Antonio Bay/Guadalupe Estuary, which is located on the middle Texas coast. The purpose of the San Antonio Bay Partnership is to create and sustain a working partnership of committed stakeholders in order to protect, restore and enhance the natural resources of the San Antonio Bay/Guadalupe Estuary for the benefit of the ecosystem and its human uses.

Recently the SABP began a project to develop a comprehensive management plan for the San Antonio Bay/Guadalupe Estuary. As one of the first steps in developing the management plan a series of status and trends reports was developed. This colonial nesting waterbird status and trend report is one in that series.

The San Antonio Bay/Guadalupe Estuary is one of seven major estuaries along the Texas coast. It is a large (531 km^2) estuarine complex located between Matagorda and Aransas Bay and at the terminus of the San Antonio/Guadalupe River watersheds. The average depth within the bay is approximately 4 feet and the maximum natural depth is 7 feet (Davis and Smith 2011). The San Antonio Bay Partnership planning area (referred to as the San Antonio Bay System) is composed of Espiritu Santo Bay, Hynes Bay, Guadalupe Bay, Mesquite Bay, Carlos Bay, Ayres Bay, Mission Lake, and Pringle Lake (Figure 3.1).

Figure 3.1 San Antonio Bay Partnership planning area and analysis area for this status and trends report of colonial nesting waterbirds.

METHODS

Data used to develop colonial waterbird status and trends comes from the annual surveys of colonial nesting waterbirds coordinated by the Texas Colonial Waterbird Society (TCWS). The TCWS is a scientific group dedicated to monitoring colonial nesting waterbirds in Texas. The TCWS is made up of staff from Texas Parks and Wildlife Department (TPWD), Texas General Land Office, Texas A&M University, U.S. Fish and Wildlife Service, Audubon, Coastal Bend Bays & Estuaries Program, The Nature Conservancy, and Welder Wildlife Foundation.

The TCWS has been organizing and reporting survey results continually since 1973. The surveys are conducted each year during the last week of May and the first week of June. Participation of the various groups has varied annually depending on staff interest, availability and budgets. TWCS members have surveyed nearly all colonies in Texas bays annually. These in-bay colonies, for the most part, occur on islands of various sizes. Small islands are surveyed from a boat while large colonies that cannot be seen from a boat are surveyed by foot. TPWD conducted aerial surveys of inland near-coastal colonies from 1973 through 1992. Annual aerial surveys were discontinued after 1992 and replaced with biennial surveys through 2004 (Ortego et al., 2011). Data collected during the annual census includes: number of adults, numbers of nests, and estimated number of breeding pairs.

The status and trends data used for these analyses includes only the estimated number of breeding pairs reported in the Texas Colonial Waterbird Database for the San Antonio Bay System for 1973 through 2009. Inland colonies surveyed by ground and aerially by TPWD are used for comparison purposes and are not included in the status and trends analyses. The known colony locations for the San Antonio Bay system are depicted in Table 3.1. Colonies in some cases are comprised of multiple islands in close proximity. In recent years these individual islands within a colony have been designated as subcolonies within the database. The current analysis is conducted at the colony level which includes all subcolonies. For the project area, the TCWS database includes data for 24 in-bay colonies and three inland colonies. Data for two additional inland colonies were provide by TPWD (Table 3.1).

Table 3.1 Colonial waterbird colonies located within the SABP planning area.

Colony Code	County	Name	Latitude	Longitude
	Calhoun	GDWMA	-96.82990	28.46470
	Calhoun	Carbide	-96.78900	28.50500
609-181	Calhoun	Welder Ranch	-96.88778	28.59278
609-260	Calhoun	Green lake	-96.86083	28.49500
609-261	Calhoun	Kenyon Island	-96.79861	28.44833
609-280	Calhoun	Seadrift Island	-96.74000	28.39778
609-281	Calhoun	Seadrift Harbor	-96.70500	28.40278
609-300	Matagorda	Chester Island	-96.34583	28.45278
609-301	Matagorda	Matagorda Island Heron Colony	-96.64350	28.23107
609-320	Calhoun	Turnstake / Turnstake Spoil	-96.68389	28.30889
609-321	Calhoun	Big Bird Island	-96.73583	28.27694
609-322	Calhoun	San Antonio Bay Spoil	-96.71083	28.36778
609-324	Calhoun	Corey Cove	-96.61988	28.27192
609-340	Calhoun	Steamboat Island and Spoil	-96.62000	28.31000
609-360	Calhoun	Matagorda Island Airbase	-96.46278	28.32389

Table 3.1 (cont'd) Colonial waterbird colonies located within the SABP planning area.

Colony Code	County	Name	Latitude	Longitude
609-401	Aransas	Bludworth Island Spoil	-96.86400	28.17290
609-420	Calhoun	False Live Oak Point	-96.77583	28.23889
609-421	Aransas	Aransas Refuge Spoil	-96.83278	28.19194
609-422	Aransas/Calhoun	Second Chain of Islands	-96.81500	28.19278
609-423	Aransas/Calhoun	Matagorda Spit	-96.81389	28.17694
609-424	Aransas	Third Chain of Islands	-96.87278	28.14889
609-425	Aransas	Salada Mill	-96.83575	28.22475
609-426	Calhoun	Observation Tower Colony	-96.79865	28.12563
609-427	Aransas	2 Ring Island	-96.81306	28.20947
609-440	Calhoun	Panther Reef	-96.70500	28.21889
609-441	Calhoun	Cedar Lake Island	-96.66444	28.23167
609-507	Aransas	Black Skimmer Strip	-96.93337	28.11465
609-504	Aransas	Cape Carlos Dugout Island	-96.92600	28.11085
609-520	Aransas	Cedar Bayou	-96.84889	28.07694

RESULTS

Colonies

Although there are 27 colonies in the database in most years, only about seven are active. The number of active colonies is remarkably stable over time. The minor fluctuation is, for the most part, due to survey effort and the occasional occurrence of temporary non-persistent colonies (Figure 3.2).

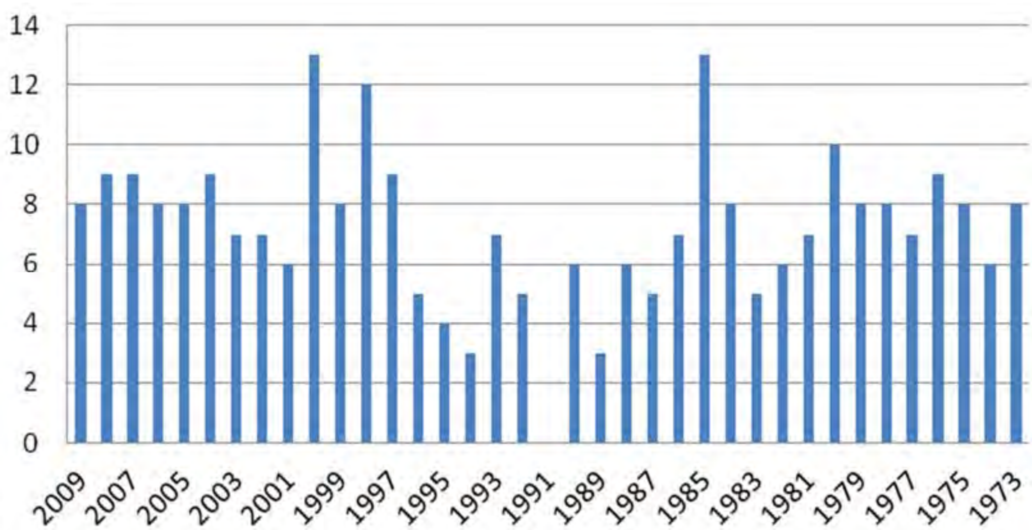

Figure 3.2 Number of active colonies within the SABP planning area.

Of the active in-bay colonies, Chester Island by far has the most species richness and diversity. A total of 585,782 breeding pairs of colonial waterbirds were found in the San Antonio Bay System from 1973 through 2009 of which 82.4% were reported from Chester Island (Figure 3.3). Chester Island is located in

Matagorda Bay at the far eastern end of the SABP planning area. Many birds nesting on Chester Island probably rely on San Antonio Bay habitats for feeding and provisioning young.

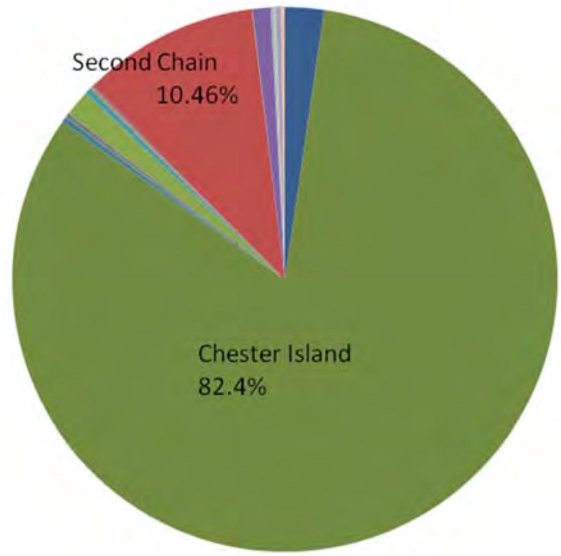

Figure 3.3 Proportion of total number of colonial waterbirds in the San Antonio Bay System (excluding inland colonies) using Chester Island.

Excluding Chester Island, in-bay island colonies in the San Antonio Bay system contributed a total of 102,745 breeding pairs of colonial waterbirds during the same time period. The breeding birds excluding Chester Island were, for the most part, found in four colonies, Second Chain of Islands (59.6%), Seadrift Island (13.2%), Steamboat Island (9.9%), and Third Chain of Islands (6.1%) (Figure 3.4).

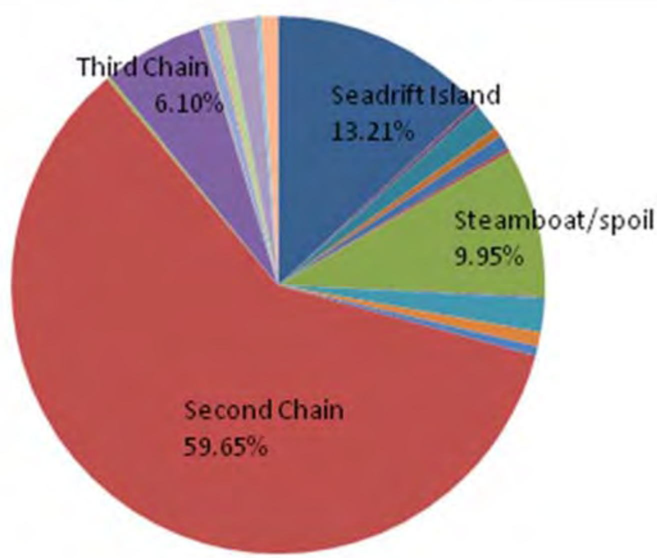

Figure 3.4 Proportion of total number of colonial waterbirds nesting on in-bay colonies within the San Antonio Bay System excluding Chester Island.

A total of 104,114 breeding pairs were counted within inland colonies from 1973 to 2009. This represents a large number of cattle egrets as well as other wading birds. Although the inland colonies were not surveyed with enough consistency to develop long term trends the surveys do indicate the importance of these colonies to wading birds within the San Antonio Bay System. The inland colonies within the SABP planning area are within the Guadalupe and San Antonio rivers flood plains. Ortego et al. (2011) found a high correlation between the number of active colonies and the amount of area flooded below the colonies. In dry years the colonies may be inactive while in wet years the numbers of wading birds in inland colonies can far surpass those of in-bay colonies.

Individual Species

In the individual species data presented below whenever Chester Island or Inland colonies significantly affect total system abundance, graphs depicting this importance are shown (i.e., individual graphs for total in-bay colonies, in-bay colonies excluding Chester Island, and inland colonies are shown).

Brown Pelican: The Brown Pelican was nearly extirpated from Texas prior 1970 due to the pesticide DDT (Chaney et al., 1996). It was listed as endangered in 1970. After the ban of DDT and much conservation work the pelican made a strong recovery and was removed the endangered species list in 2009. The Brown Pelican has an increasing trend over time.

However, nearly all of the Brown Pelicans are located on Chester Island. They are nearly absent from the rest of the San Antonio Bay System (Figures 3. 5 and 3.6). There are currently no islands within the system with sufficient size, elevation, distance from shore, and vegetation structure to support brown pelicans within San Antonio Bay.

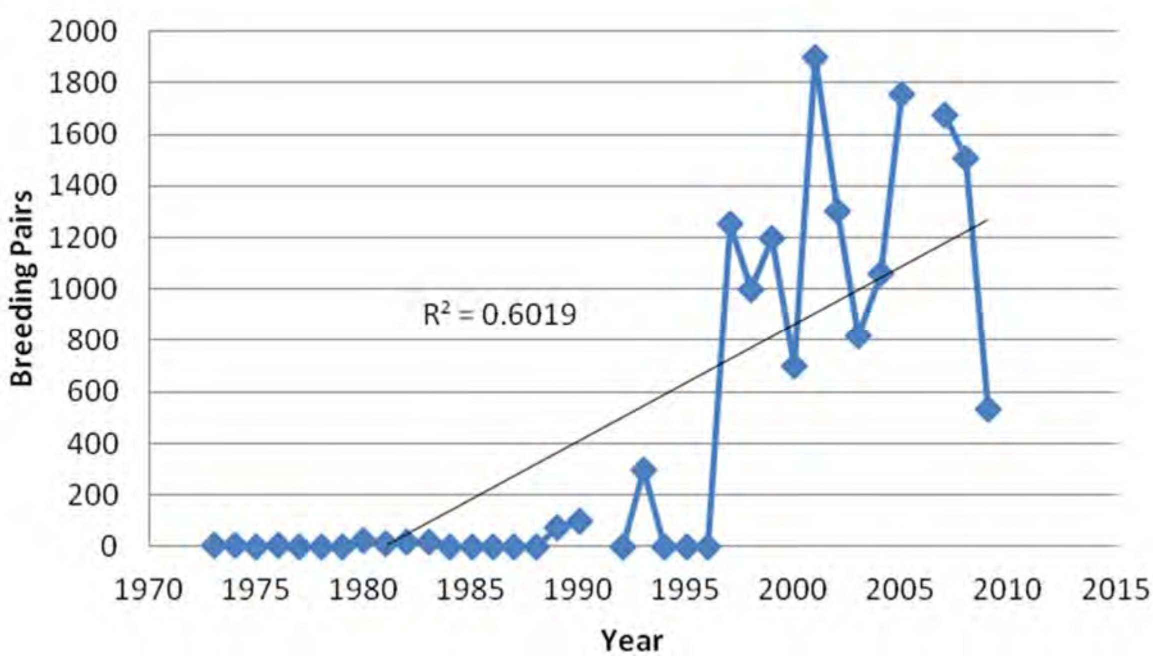

Figure 3.5 Trend in Brown Pelican breeding pairs within the San Antonio Bay System.

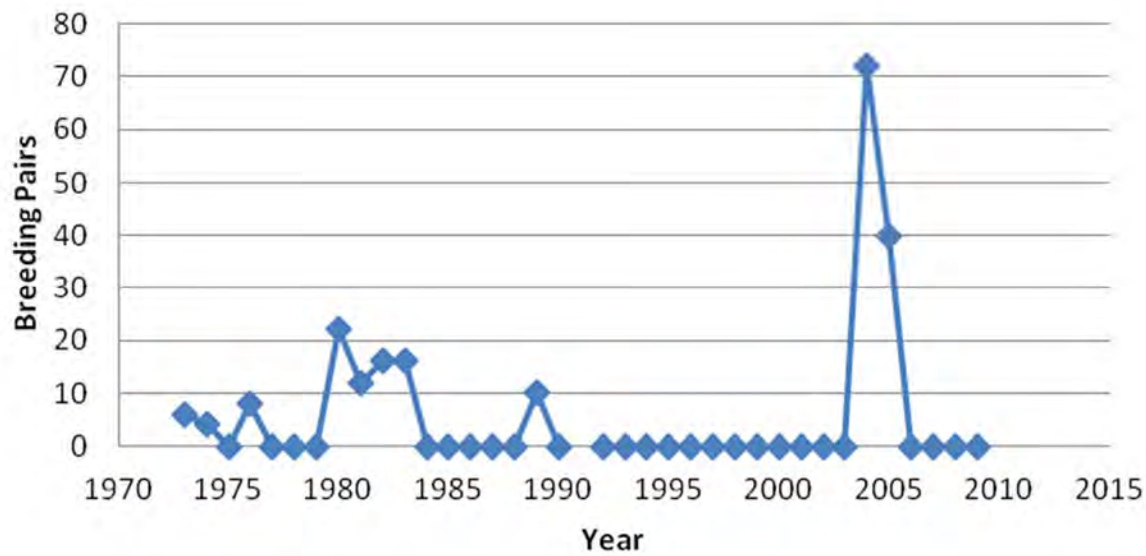

Figure 3.6 Trend in Brown Pelican breeding pairs within the San Antonio Bay System excluding Chester Island.

Great Blue Heron: This ubiquitous species is found throughout the bay system. Trends indicate a declining population within the San Antonio Bay System (Figures 3.7 and 3.8). In the past Second Chain of Islands, Turnstake Island, Steamboat Island, Seadrift Island and Chester Island have all been important for Great Blue Herons. Currently, only Second Chain of Islands and Chester Island regularly support substantial populations of Great Blue Herons (> 20 pairs). The inland colonies are highly variable with respect to Great Blue Heron abundance, but they often have densities equal to or greater than those found in the rest of the System (Figure 3.9).

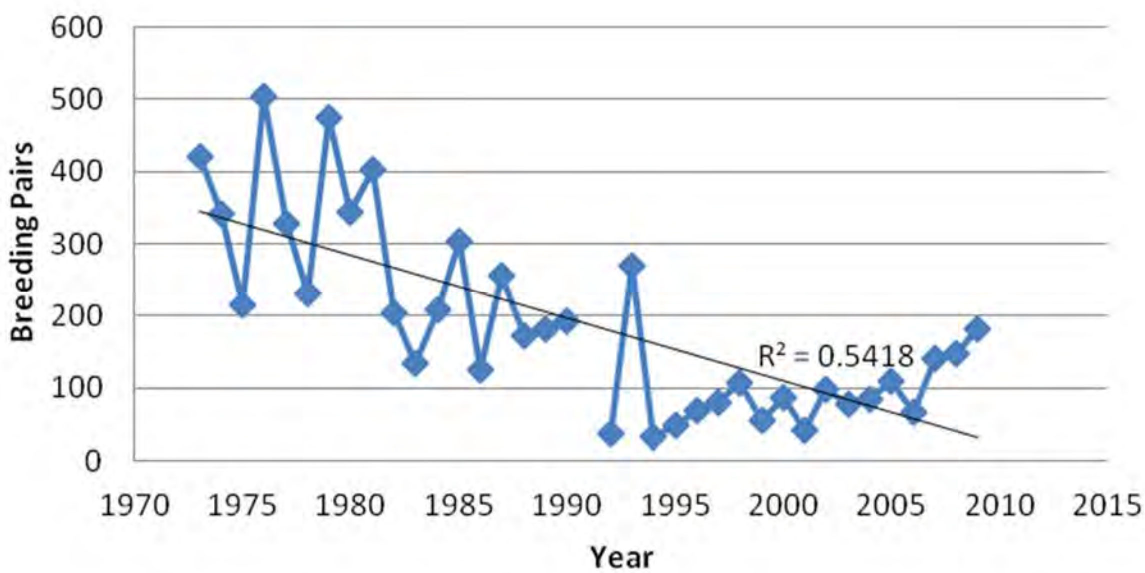

Figure 3.7 Trend in Great Blue Heron breeding pairs within the San Antonio Bay System.

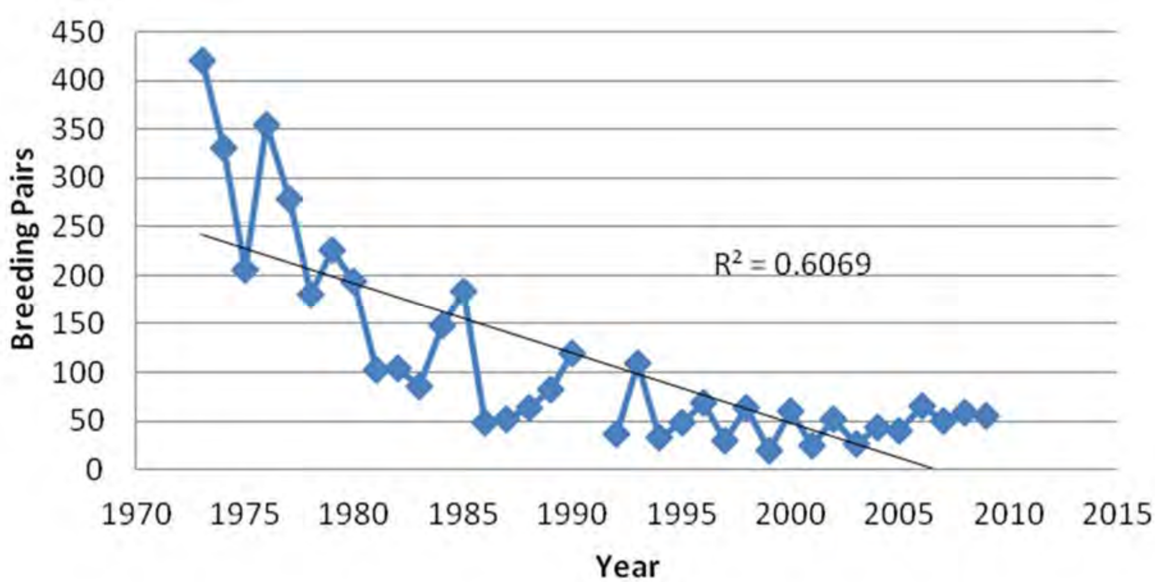

Figure 3.8 Trend in Great Blue Heron breeding pairs within the San Antonio Bay System excluding Chester Island.

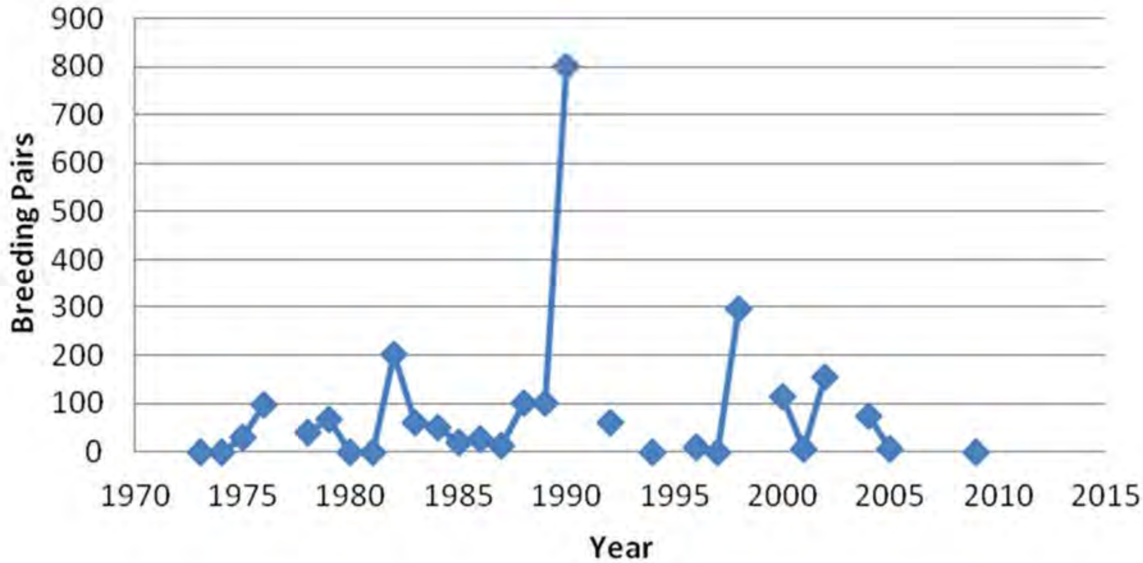

Figure 3.9 Trend in great blue heron breeding pairs for inland colonies within the SABP planning area.

Great Egret: A common species that like the previous is showing a declining trend within the San Antonio Bay System (Figures 3.10 and 3.11). In the past Chester Island, Second Chain of Islands, Steamboat Island, and Seadrift Island all supported abundant great egret populations. Currently on Chester Island Second Chain of Islands and Seadrift Island support significant populations >20 pair. Steamboat Island has had no nesting great egrets since 1999. Great egrets are also found in large numbers within the inland colonies. Often the number breeding on inland colonies is equal to or greater than on in-bay colonies (Figure 3.12).

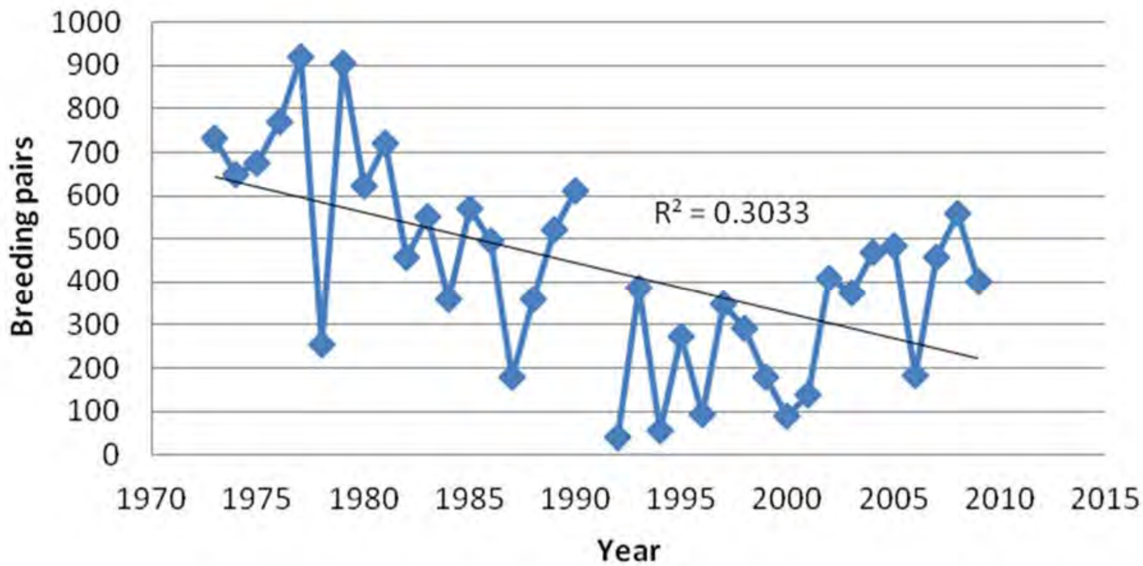

Figure 3.10 Trend in great egret breeding pairs within the San Antonio Bay System.

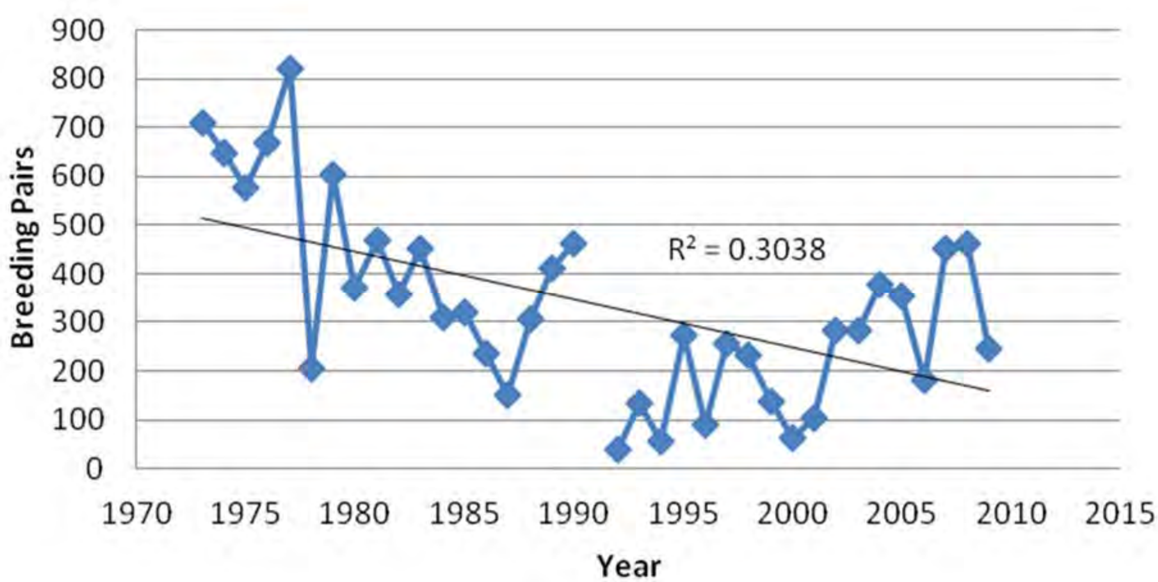

Figure 3.11. Trend in great egret breeding pairs within the San Antonio Bay System excluding Chester Island.

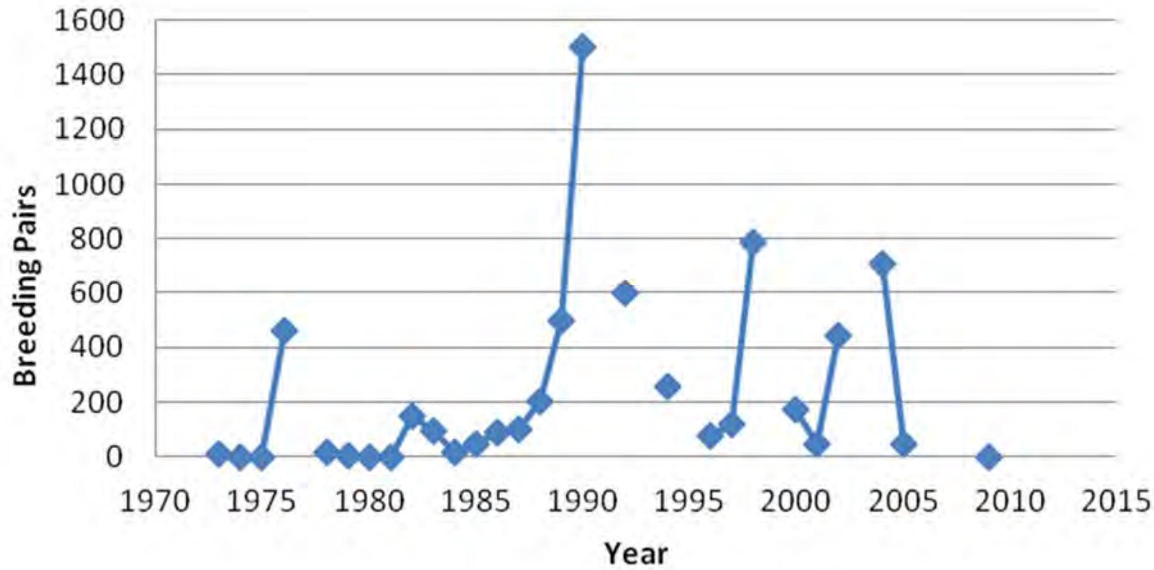

Figure 3.12 Trend in great egret breeding pairs for inland colonies within the SABP planning area.

Snowy Egret: This small white egret with yellow feet is common throughout the area. However, it is also showing signs of a slight decline (Figures 3.13 and 3.14). Important islands for this species include Chester Island, Second Chain of Islands, and Seadrift Island. The decreasing trend is mostly the result of declines at Second Chain of Islands and Seadrift Island. Snowy Egrets in inland colonies are highly variable but can be found in great numbers far exceeding those of in-bay colonies (Figure 3.15).

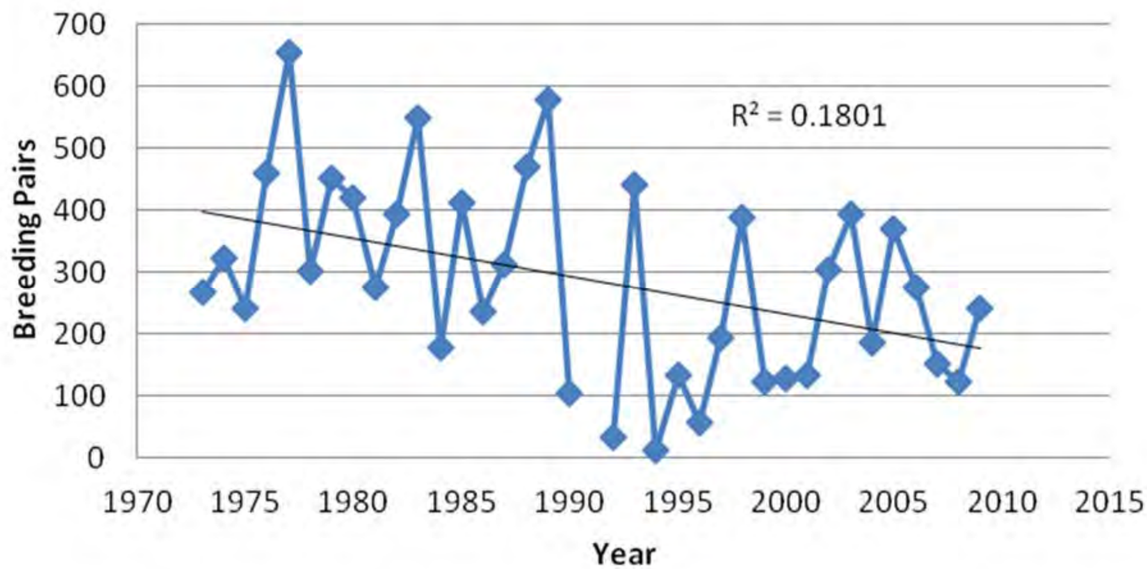

Figure 3.13 Trend in Snowy Egret breeding pairs within the San Antonio Bay System.

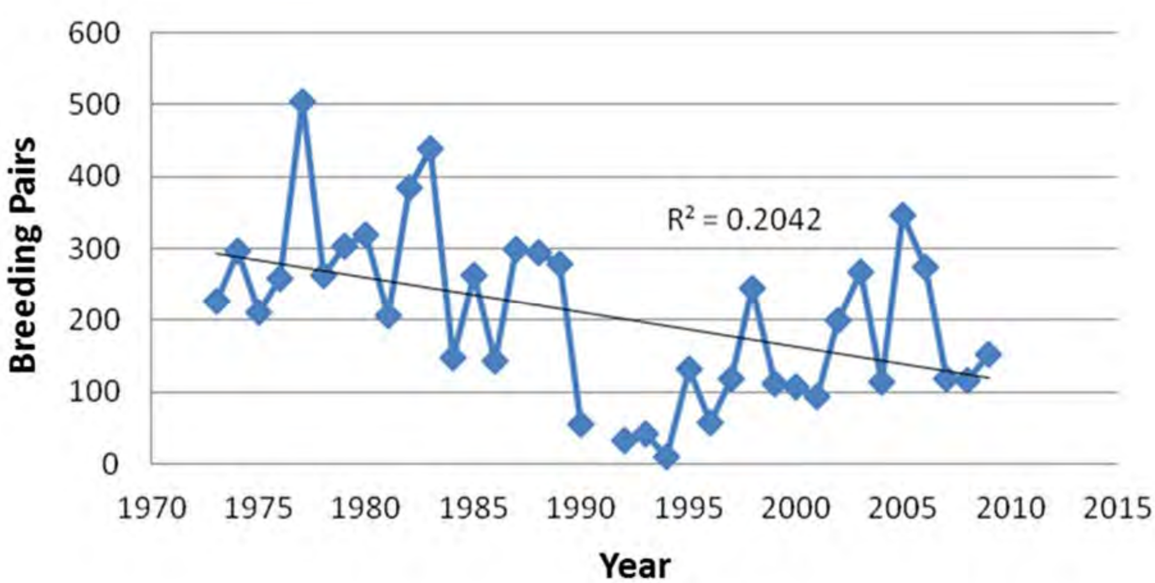

Figure 3.14 Trend in Snowy Egret breeding pairs within the San Antonio Bay System excluding Chester Island.

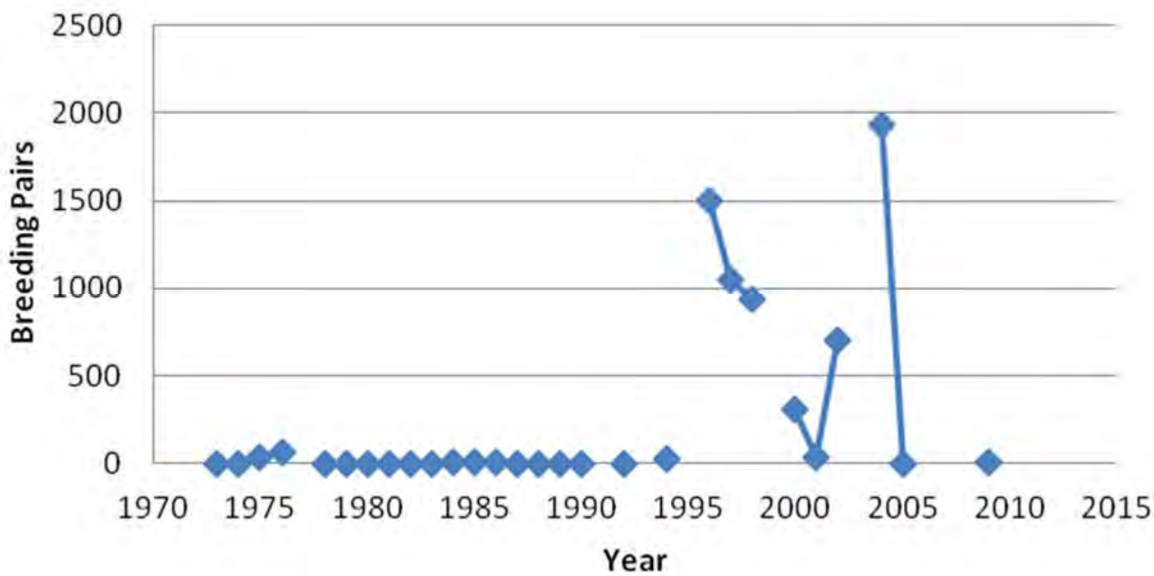

Figure 3.15 Trend in Snowy Egret breeding pairs for inland colonies within the SABP planning area.

Little Blue Heron: This heron is mostly uncommon in coastal waters and prefers inland lakes, streams, and rivers. There has been a slight rise in the trend of this species on the coastal islands within the SABP planning area. The abundance, however, is low and highly variable, and for the most part, breeding pairs of Little Blue Herons are restricted to Chester Island. This species is much more abundant on the inland colonies; however the abundance data is highly variable (Figures 3.16 and 3.17).

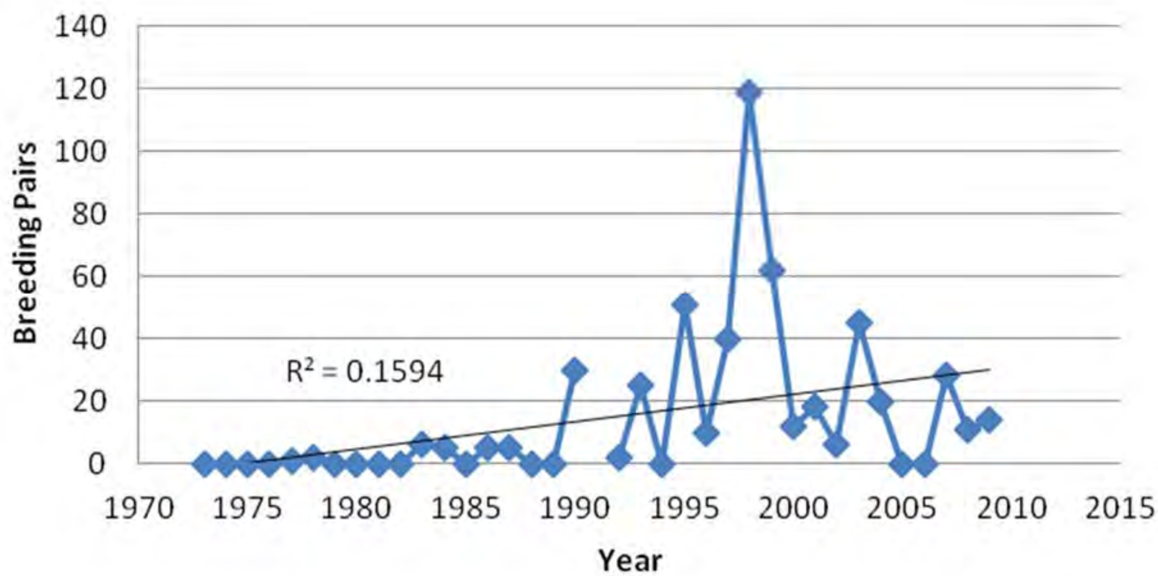

Figure 3.16 Trend in Little Blue Heron breeding pairs within the San Antonio Bay System.

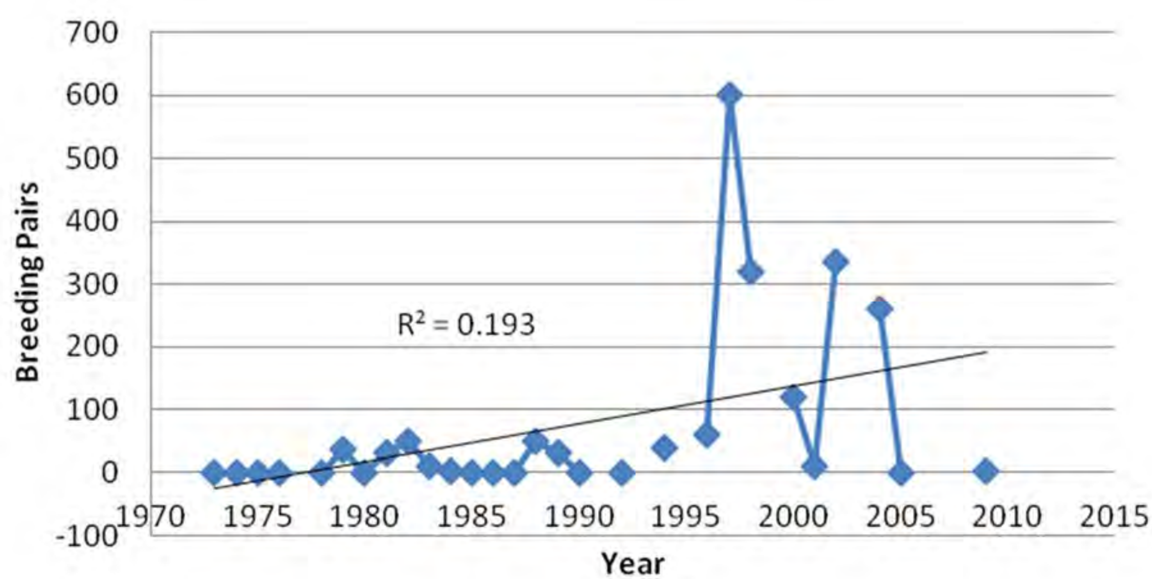

Figure 3.17 Trend in Little Blue Heron breeding pairs for inland colonies within the SABP planning area.

Tricolored Heron: This is a common heron within the coastal areas. It prefers to nest in low vegetation on islands. Within the San Antonio Bay System, Chester Island, Second Chain of Islands, and Seadrift Island have been important islands for this species. Chester Island, on average, supports nearly two times as many Tricolored Herons as the rest of the System combined (Figures 3.18 and 3.19). The inland colonies have low abundance of this species.

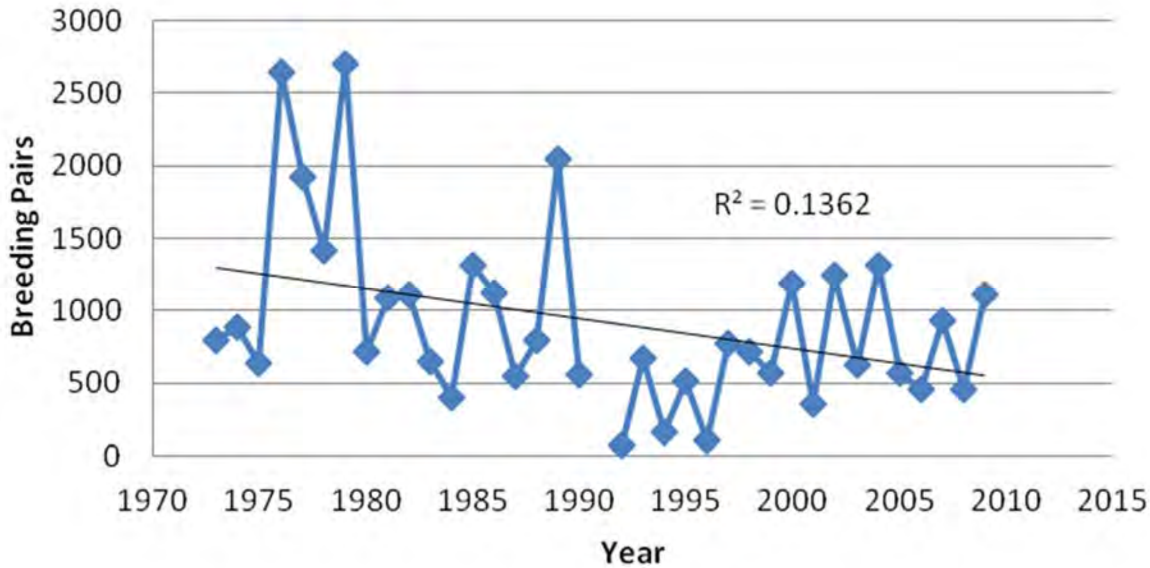

Figure 3.18 Trend in Tricolored Heron breeding pairs within the San Antonio Bay System.

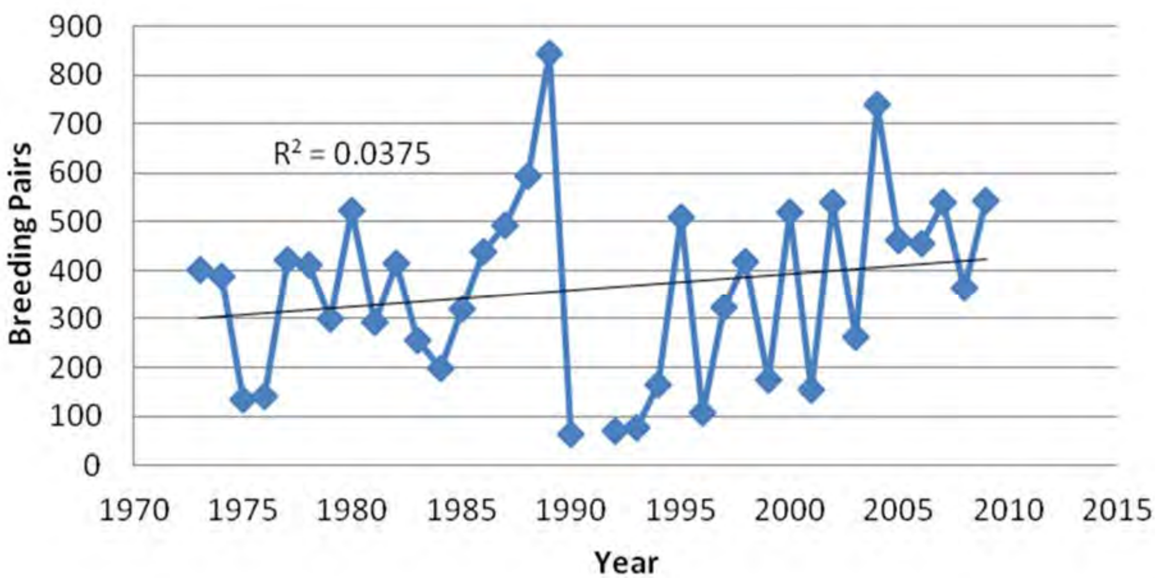

Figure 3.19 Trend in Tricolored Heron breeding pairs within the San Antonio Bay System excluding Chester Island.

Reddish Egret: This coastal egret is listed in Texas as Threatened and is a focal species for the Gulf Coast Joint Venture. Data from the TCWS indicates the population is nearly stable within the San Antonio Bay System (Figures 3.20 and 3.21); however, the abundance is low and generally less than 200 pairs. Important islands within the SABP planning area for Reddish Egrets include Chester Island and Second Chain of Islands.

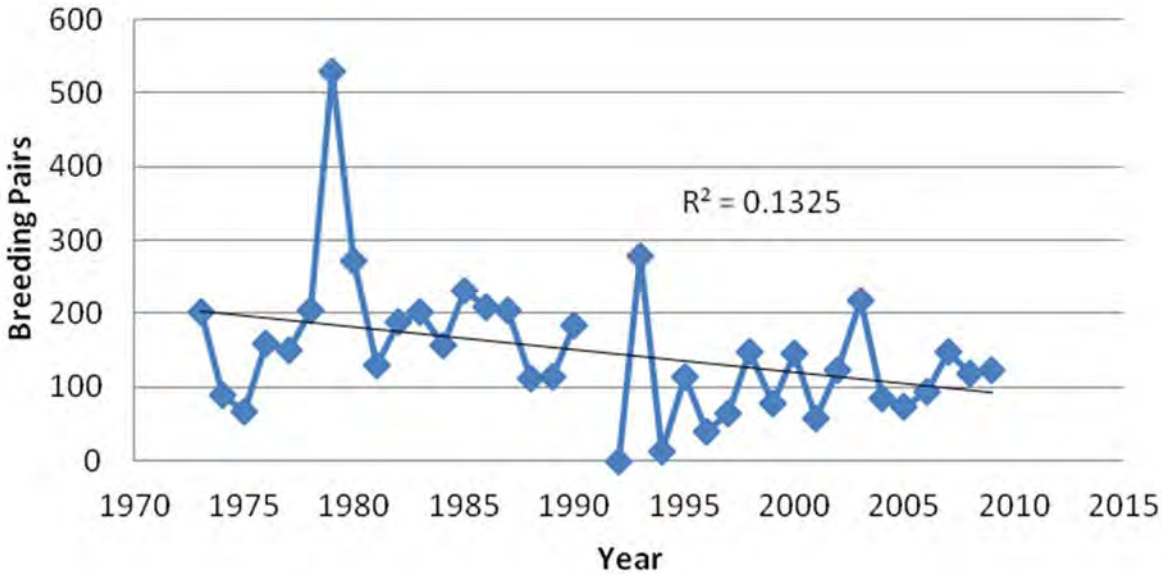

Figure 3.20 Trend in Reddish Egret breeding pairs within the San Antonio Bay System.

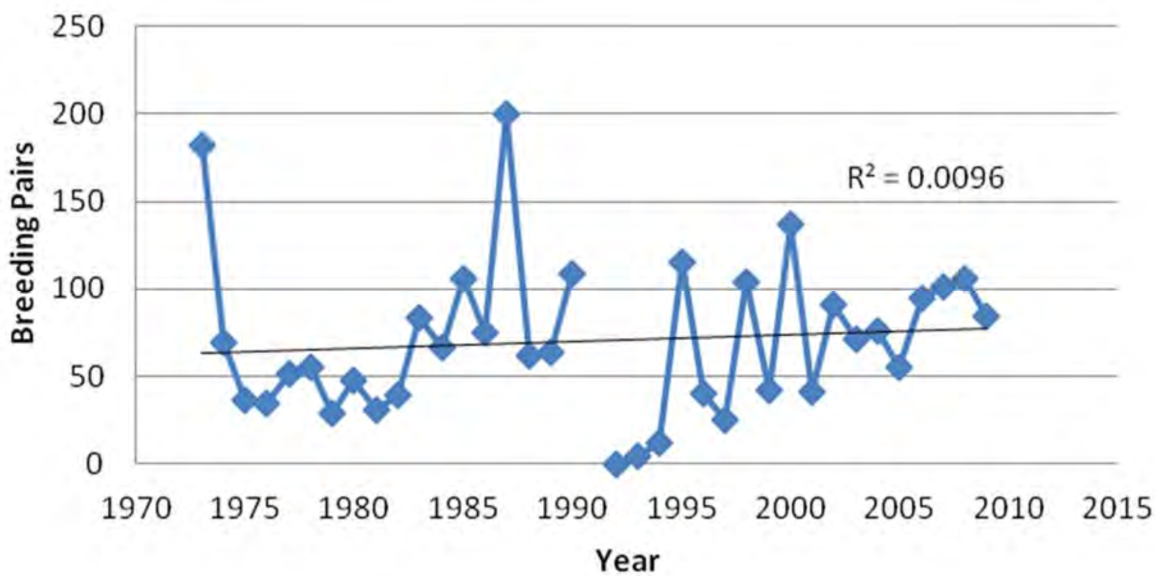

Figure 3.21 Trend in reddish egrets breeding pairs within the San Antonio Bay System excluding Chester Island.

Cattle Egret: This non-native species is common, especially at inland sites. It is less common on coastal islands. The TCWS data is highly variable for both inland and coastal colonies but may show a slight decline within in-bay colonies. This slight decline appears to be related to decreases on Chester Island. It should be noted that the inland colonies often support more than ten times as many Cattle Egrets as the coastal islands (Figures 3.22 and 3.23).

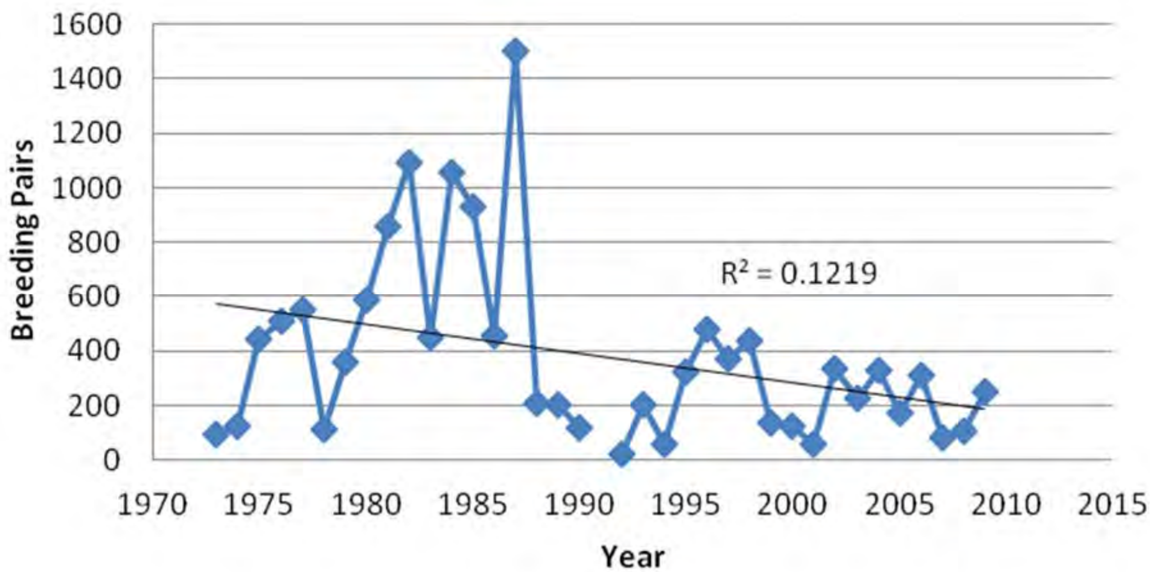

Figure 3.22 Trend in Cattle Egret breeding pairs within the San Antonio Bay System.

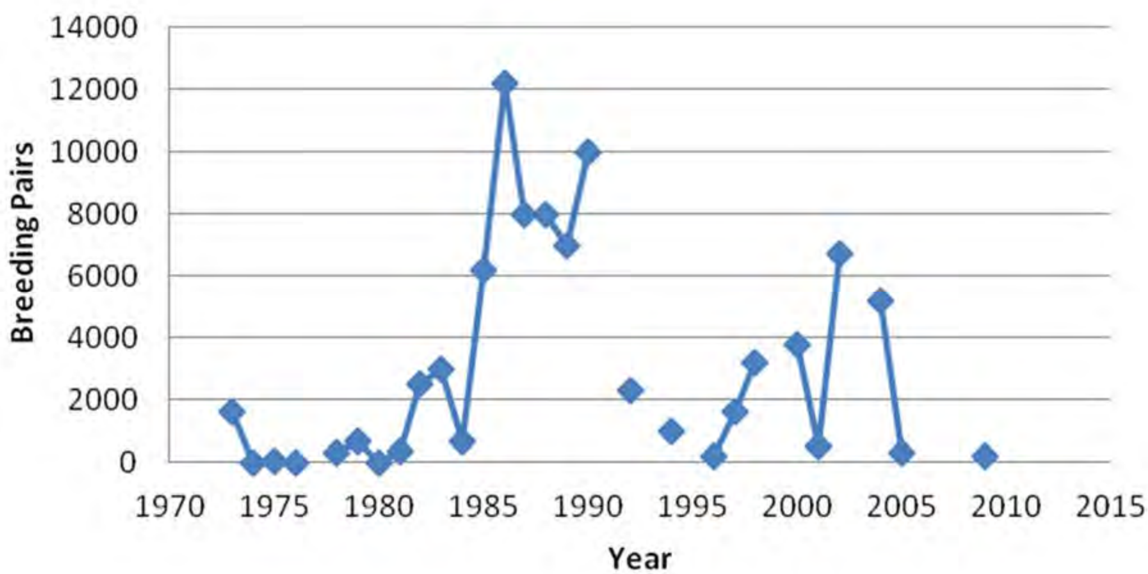

Figure 3.23 Trend in Cattle Egret breeding pairs for inland colonies within the SABP planning area.

Black-crowned Night-Heron: This common year round resident is present throughout the SABP planning area. Because it nests in dense understory it is probably not accurately counted. Within the SABP planning area, Black-crowned Night Herons are primarily counted on Chester Island and Second Chain of Islands. There is a slight decline in the number of breeding pairs within the San Antonio Bay System, excluding Chester Island; however, for the whole System the population appears stable (Figures 3.24 and 3.25).

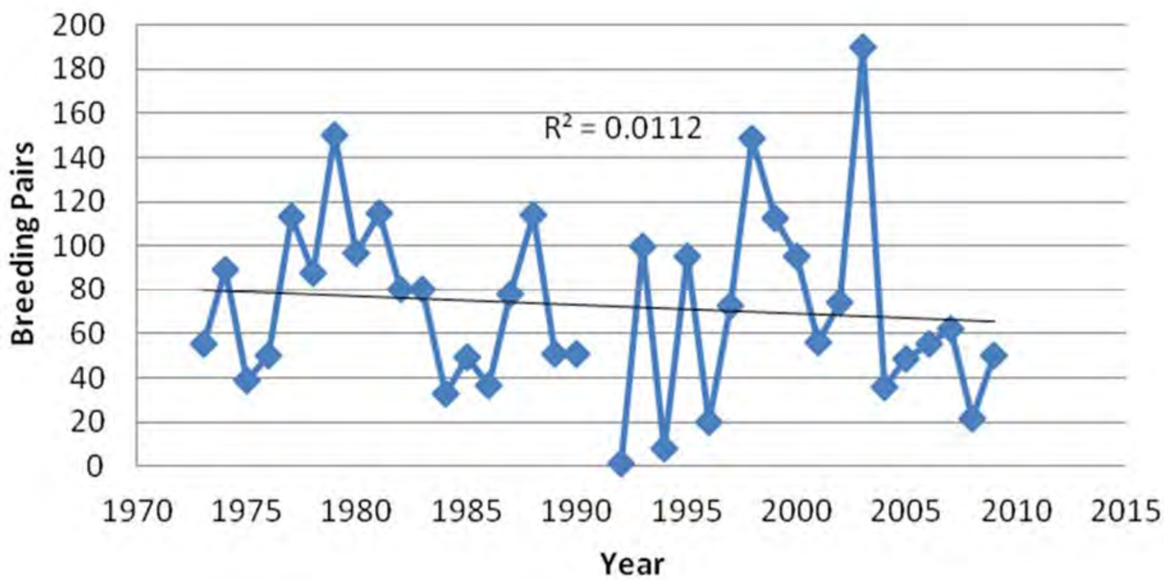

Figure 3.24 Trend in Black-crowned Night Heron breeding pairs within the San Antonio Bay System.

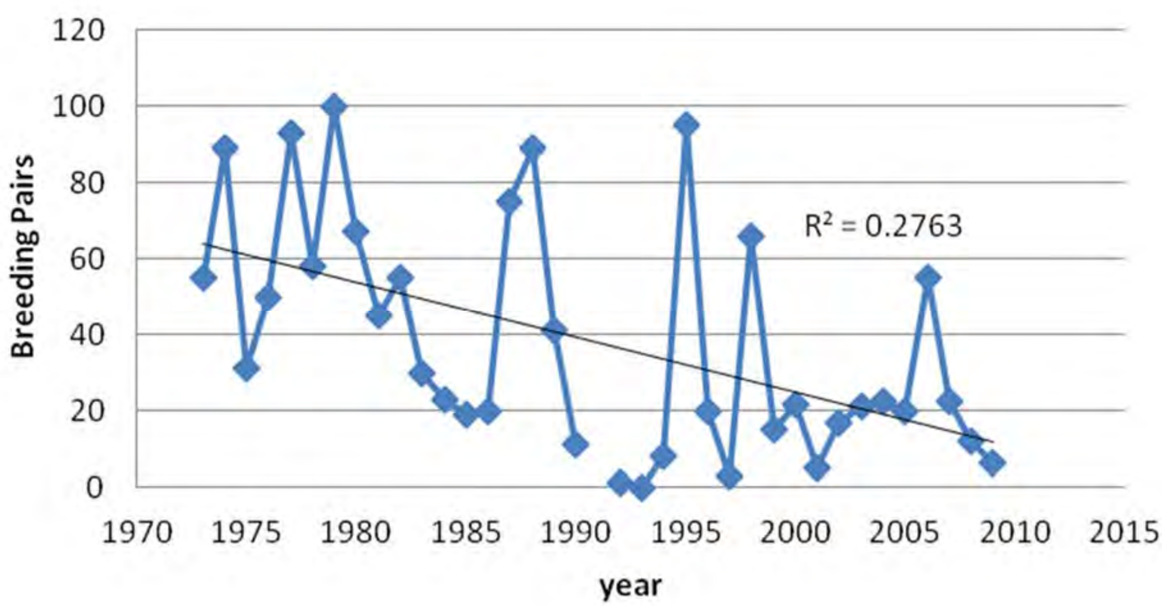

Figure 3.25 Trend in Black-crowned Night Heron breeding pairs within the San Antonio Bay System excluding Chester Island.

White Ibis: Within the SABP planning area this species has primarily been found consistently only on Chester Island, though a small colony has been present at Second Chain of Islands starting in 1998 (Figures 3.26 and 3.27). White Ibis is found sporadically at inland colonies (Figure 3.28).

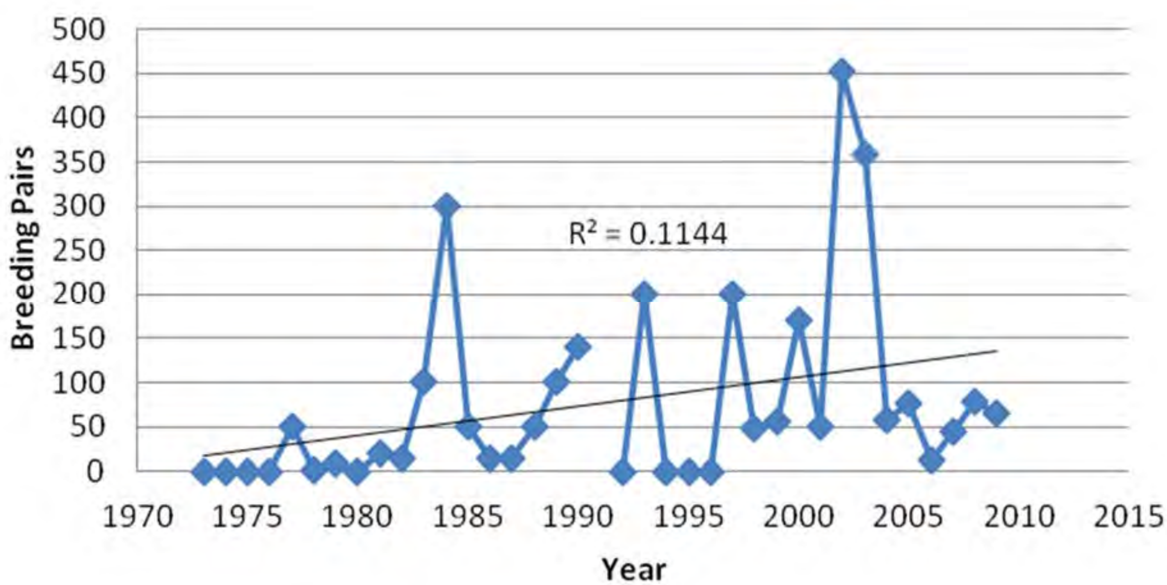

Figure 3.26 Trend in White Ibis breeding pairs within the San Antonio Bay System.

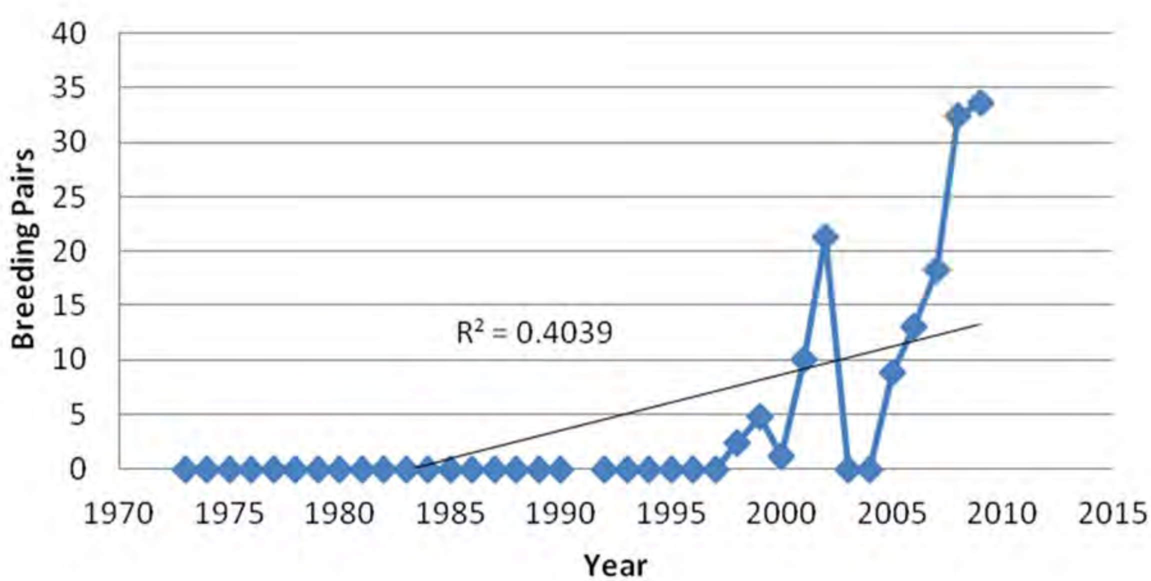

Figure 3.27 Trend in White Ibis breeding pairs within the San Antonio Bay System excluding Chester Island.

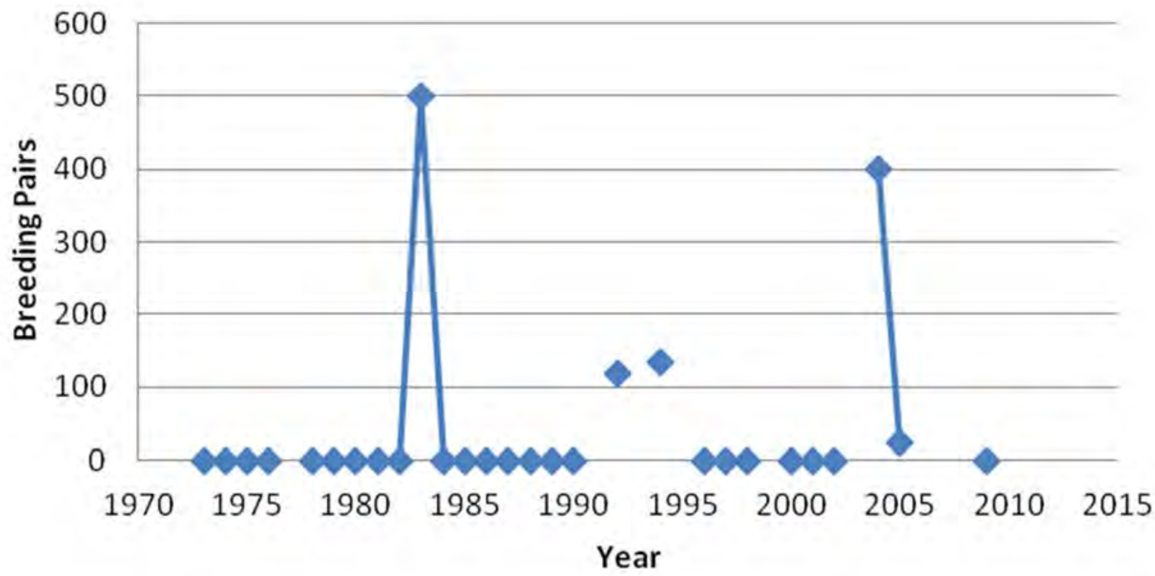

Figure 3.28 Trend in White Ibis breeding pairs for inland colonies within the SABP planning area.

White-faced Ibis: This species is listed as Threatened in Texas. It was primarily found at Chester Island within the SABP planning area. It appears to be experiencing a decline at this location (Figure 3.29). It was found in 2003 nesting at Second Chain of Islands and in 1989 and 1997 nesting at inland colonies.

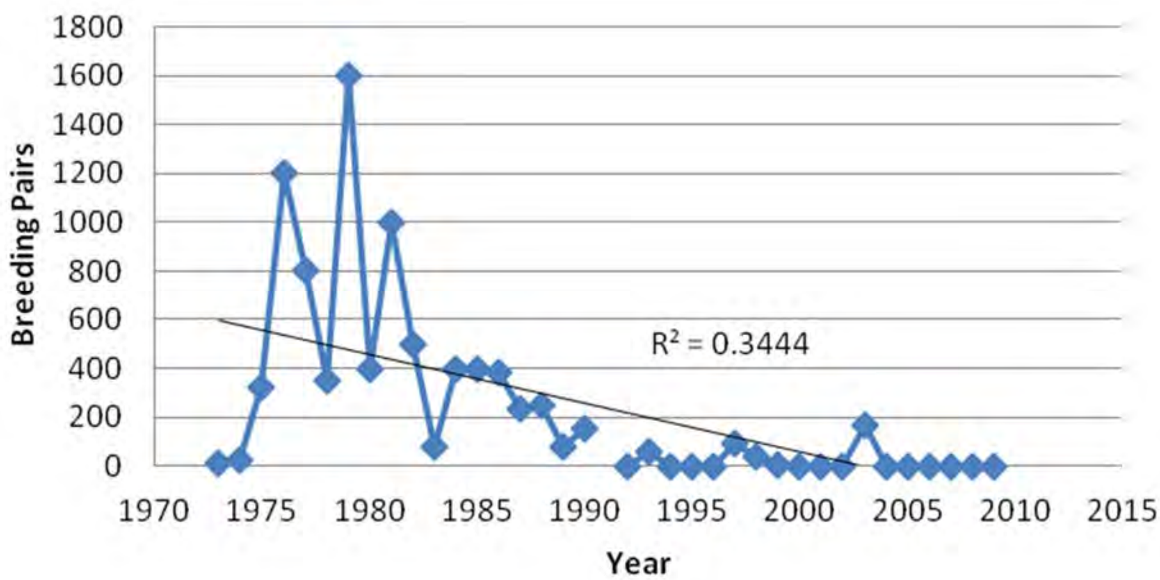

Figure 3.29 Trend in White-faced Ibis breeding pairs within the San Antonio Bay System. Note that it is completely absent from the system after 2003.

Roseate Spoonbill: This species is primarily found nesting on Chester Island, Second Chain of Islands, and at inland colonies within the SABP planning area. Roughly half of in-bay nesting occurs on Chester Island with the other half at Second Chain of Islands. There does not appear to be any increasing or decreasing trend within the planning area (Figures 3.30, 3.31, and 3.32).

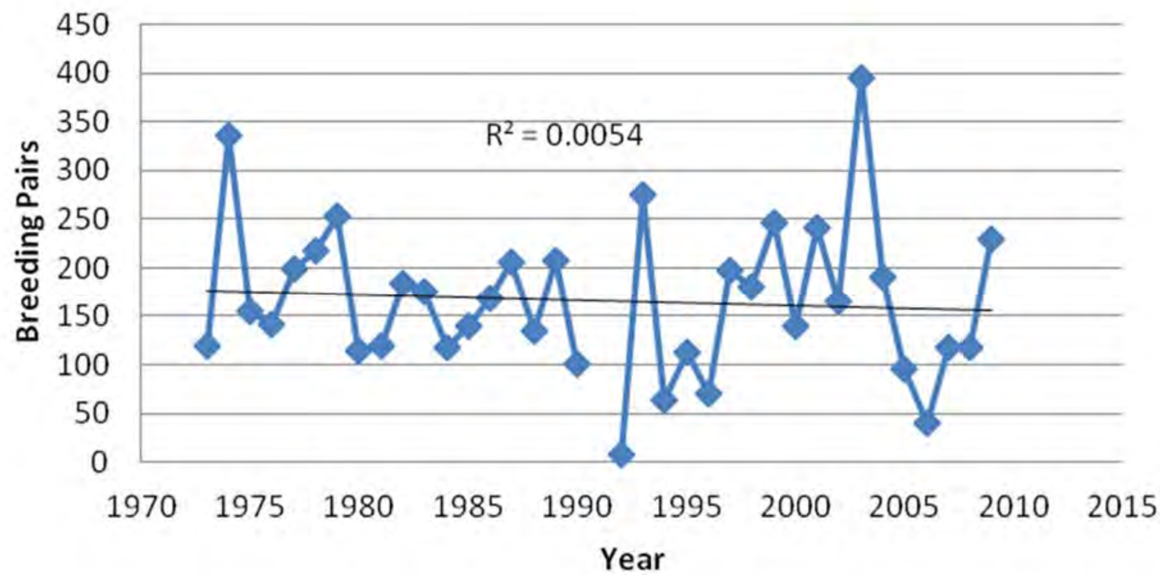

Figure 3.30 Trend in Roseate Spoonbill breeding pairs within the San Antonio Bay System.

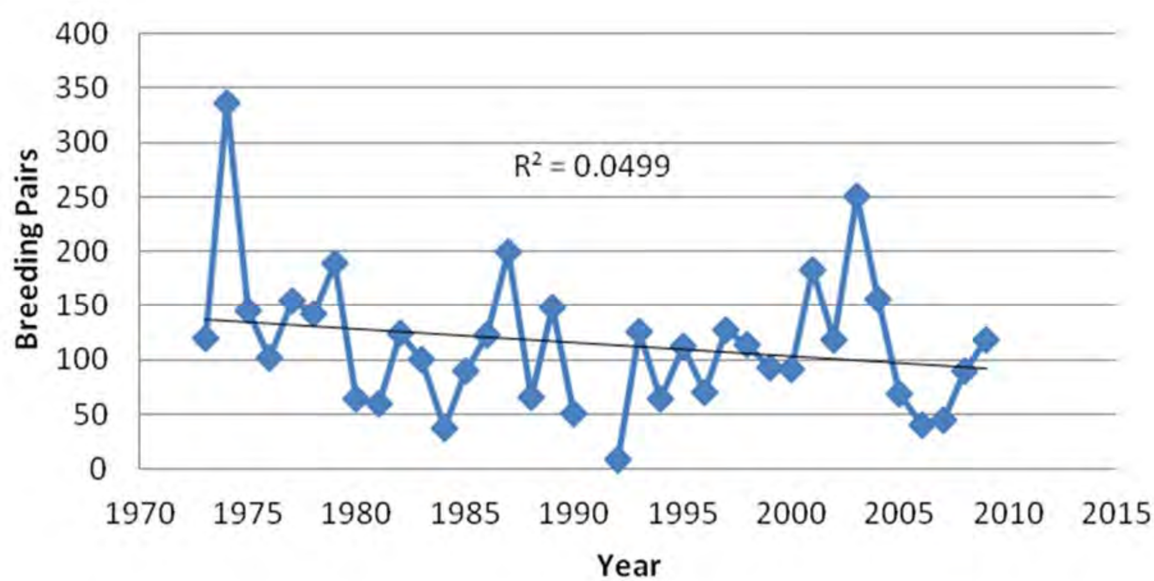

Figure 3.31 Trend in Roseate Spoonbill breeding pairs within the San Antonio Bay System excluding Chester Island.

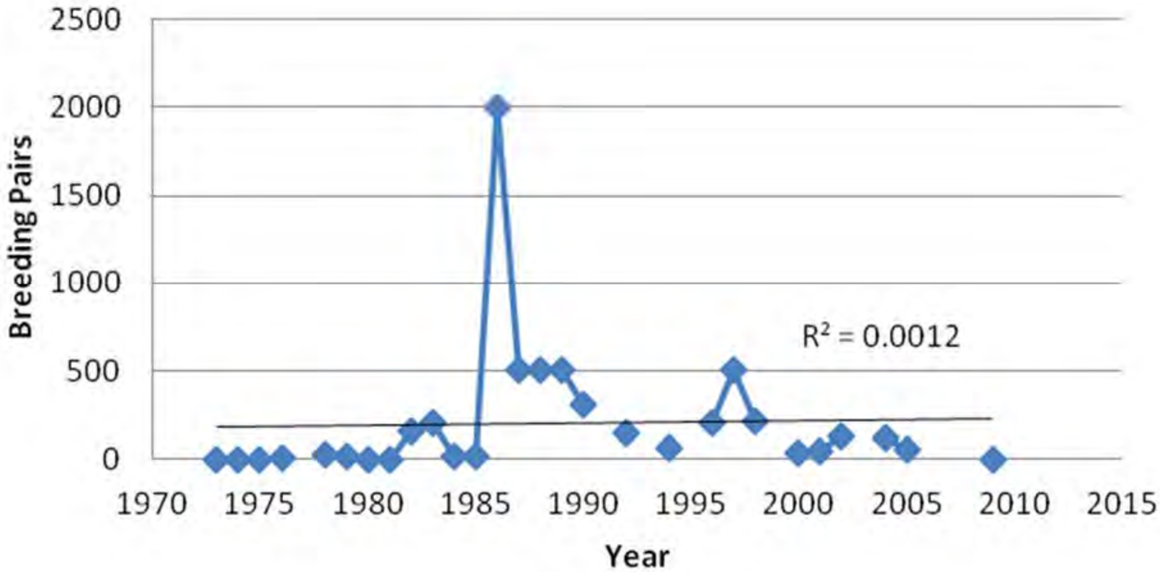

Figure 3.32 Trend in Roseate Spoonbill breeding pairs for inland colonies within the SABP planning area.

Laughing Gull: The Laughing Gull is a common year-round resident within the SABP planning area. This is the only gull species that nests on the Texas coast. This adaptable species can thrive in locations with high human use. Food resources at urban landfills have been implicated in increased abundance of gulls in North America (Patton, 1988). Within the SABP planning area approximately 85% of the gulls can be found nesting on Chester Island, while most others nest on Second Chain of Islands and Steamboat Island. The populations on Chester Island appear stable while there is a slight increasing trend within the rest of the system (Figures 3.33 and 3.34).

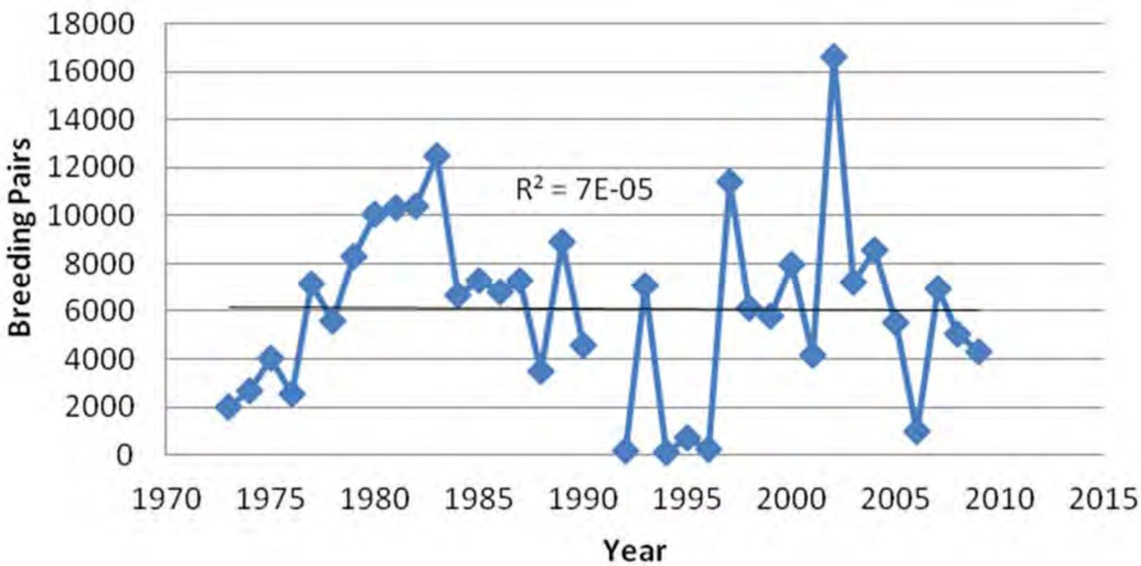

Figure 3.33 Trend in Laughing Gull breeding pairs within the San Antonio Bay System.

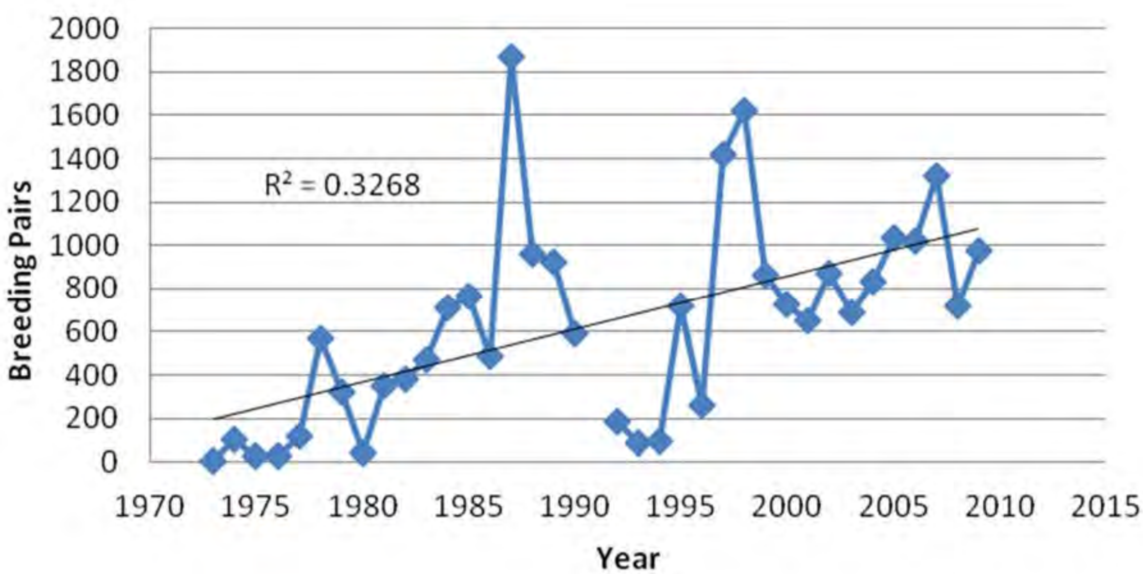

Figure 3.34 Trend in Laughing Gull breeding pairs within the San Antonio Bay System excluding Chester Island.

Gull-billed Tern: This tern nests on coastal islands usually in close association with Black Skimmers. It prefers to nest in open shell bare ground with sparse low vegetation. This species is impacted by human disturbance, and like most terns, requires private areas that are also free of predators. Most of these terns nest on Second Chain of Islands and Third Chain of Islands and sporadically on a few other islands within the System. The Gull-billed Tern population within the SABP planning area appears stable (Figure 3.35).

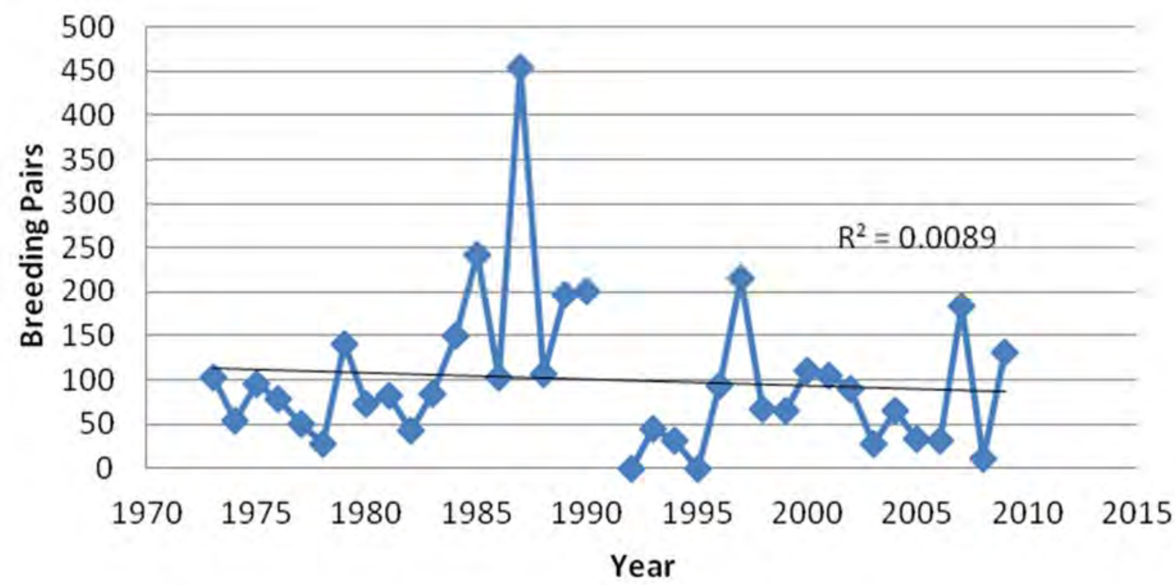

Figure 3.35 Trend in Gull-billed Tern breeding pairs within the San Antonio Bay System.

Caspian Tern: This is the largest tern that nests within the SABP planning area. It is considered a common permanent resident that usually nest in less dense aggregations than other terns. Colonies of greater than 200 pairs are rare. Within the SABP planning area Caspian terns nest primarily on Second Chain of Islands, and more recently on 2-ring Island. The populations appears to be stable (Figure 3.36).

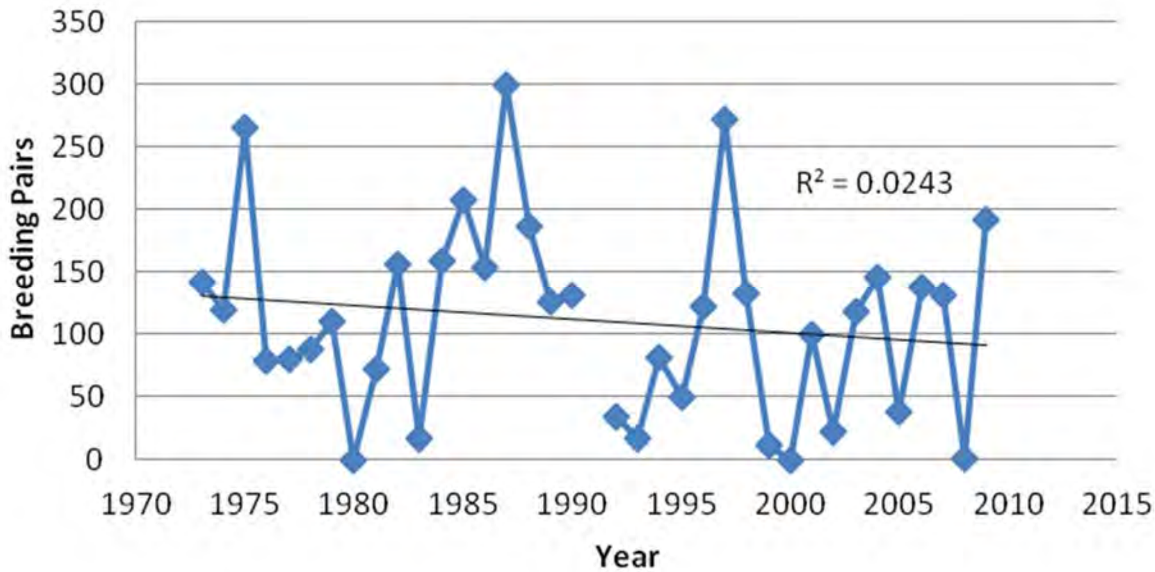

Figure 3.36 Trend in Caspian Tern breeding pairs within the San Antonio Bay System.

Royal Tern: This tern nests in dense aggregations and usually in association with Sandwich Terns. Royal Terns are primarily found on Chester Island within the SABP planning area. In recent years, approximately 200 can be found nesting on small islands throughout the system. There appears to be a very slight decreasing trend on Chester Island (Figures 3.37 and 3.38).

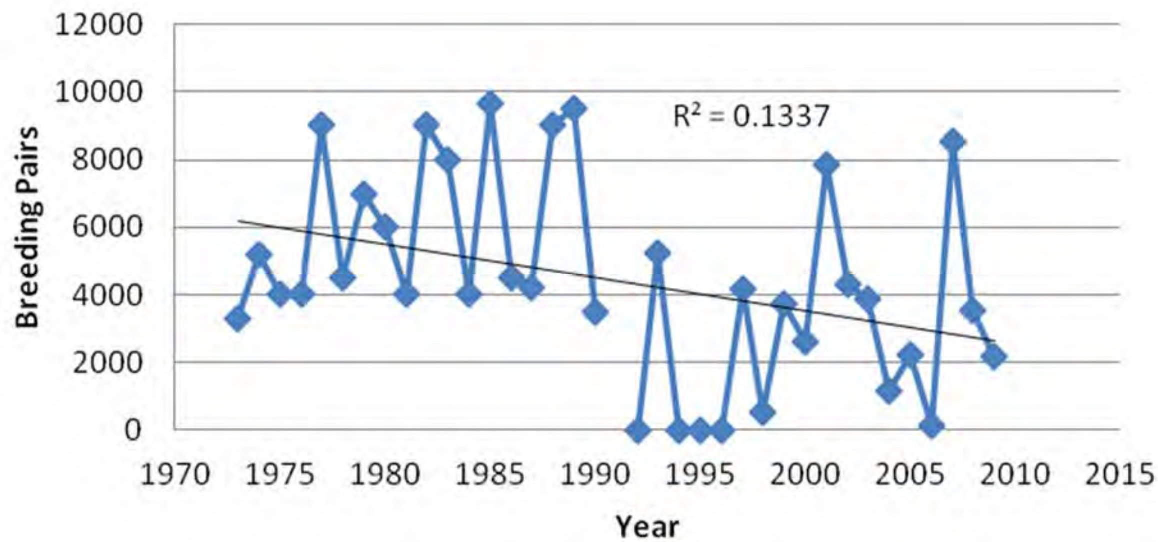

Figure 3.37 Trend in Royal Tern breeding pairs within the San Antonio Bay System.

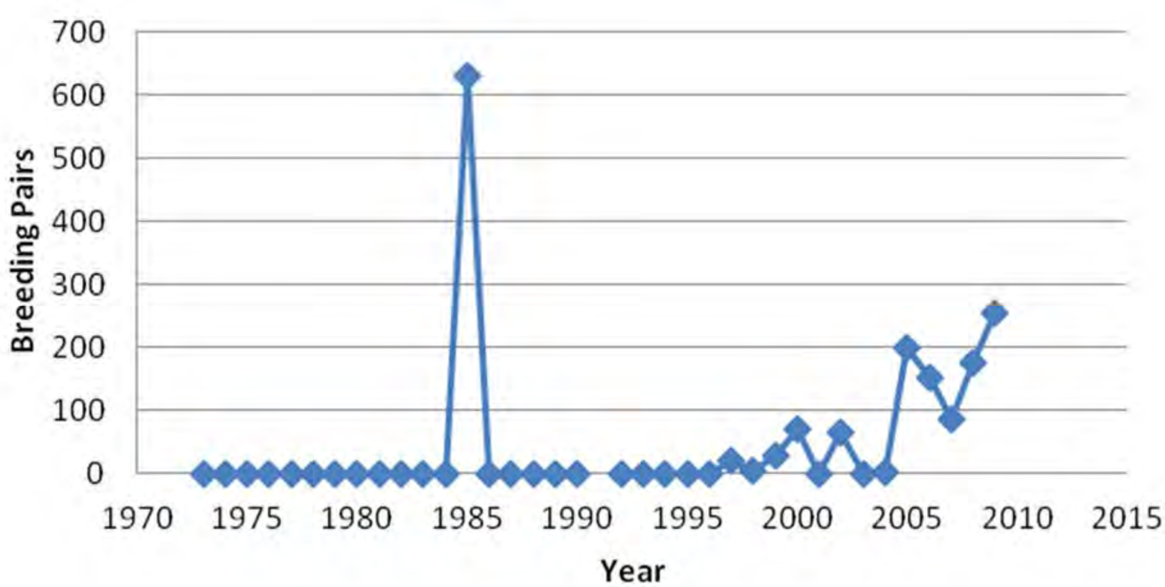

Figure 3.38 Trend in Royal Tern breeding pairs within the San Antonio Bay System excluding Chester Island.

Sandwich Tern: This tern, like the previous, nest in dense aggregations and are usually associated with Royal Terns. Within the SABP planning area Sandwich Terns are found primarily on Chester Island. Like the Royal Tern, in recent years they have been found in much small numbers on islands within the System. There appears to be a slight decreasing trend at Chester Island (Figures 3.39 and 3.40).

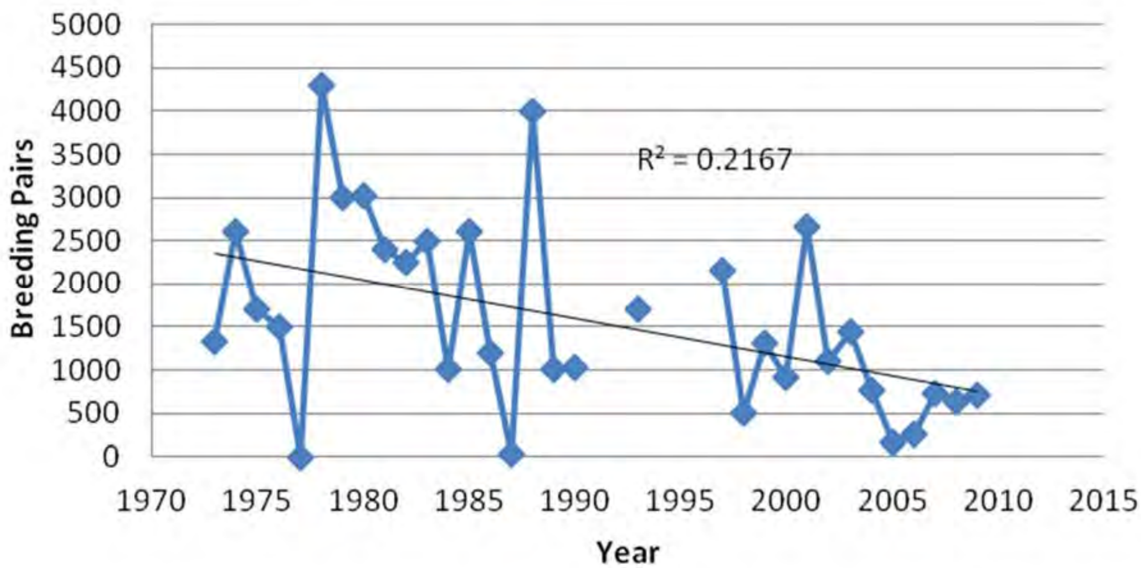

Figure 3.39 Trend in Sandwich Tern breeding pairs within the San Antonio Bay System.

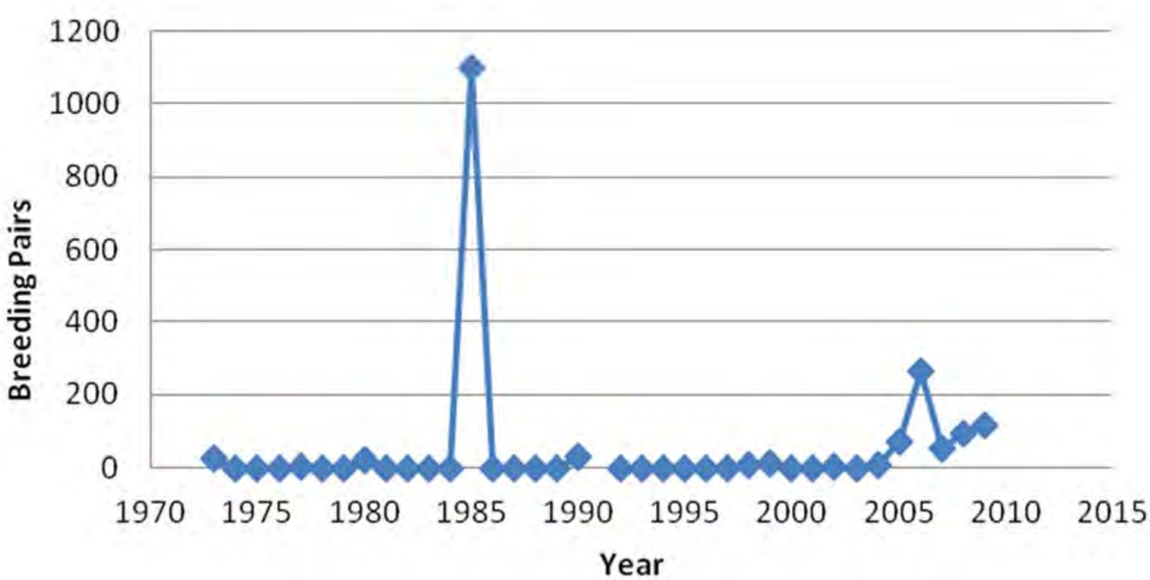

Figure 3.40 Trend in Sandwich Tern breeding pairs within the San Antonio Bay System excluding Chester Island.

Forster's Tern: This common year-round resident nests primarily in isolation from other species and usually in low vegetation or marsh wrack. Due to their preference of isolation they are usually found on Chester Island. They are also primarily found on isolated islands within the Second Chain of Islands, Third Chain of Islands, and on Seadrift Island. There may be a slight decreasing trend in this species however it is masked by large numbers found in 1996 and 1997 (Figure 3.41).

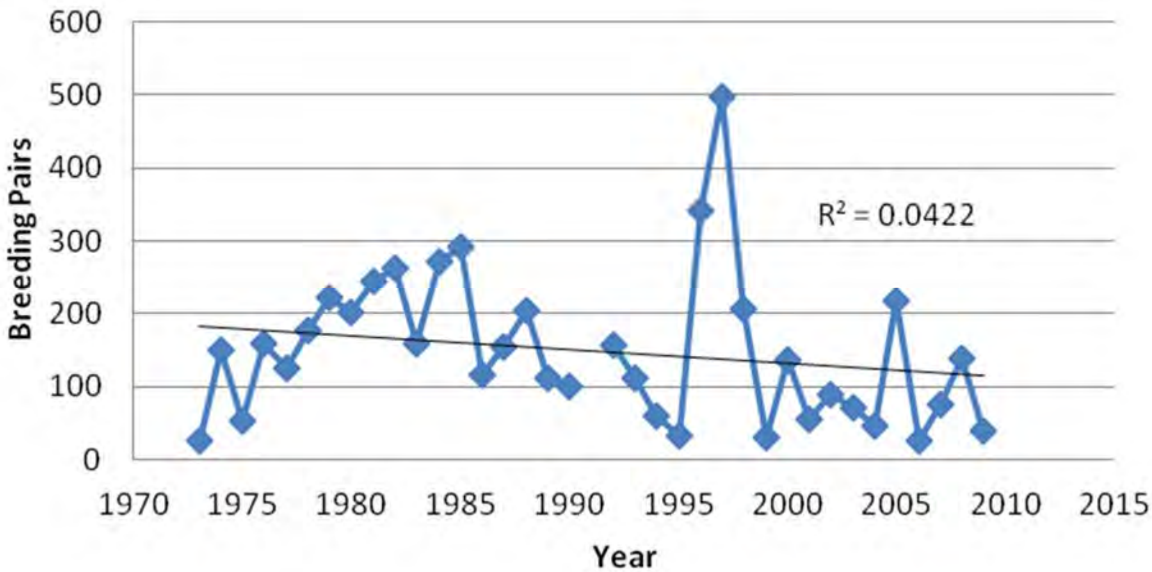

Figure 3.41 Trend in Forster's Tern breeding pairs within the San Antonio Bay System.

Black Skimmer: This species requires sparsely vegetated shell or sandy open areas free of predation and disturbance to persist. They typically nest in association with Gull-billed Terns. They appear to have high site fidelity even to the point of returning to nest at sites with high disturbance and where nest success is generally low. Black Skimmers often nest on the lowest elevation of islands making them subject to flooding during high tides. Within the SABP planning area about half the skimmers usually nest on Chester Island while the rest have been scattered on several islands through the system. There appears to be a slight declining trend over time within the System (Figures 3.42 and 3.43).

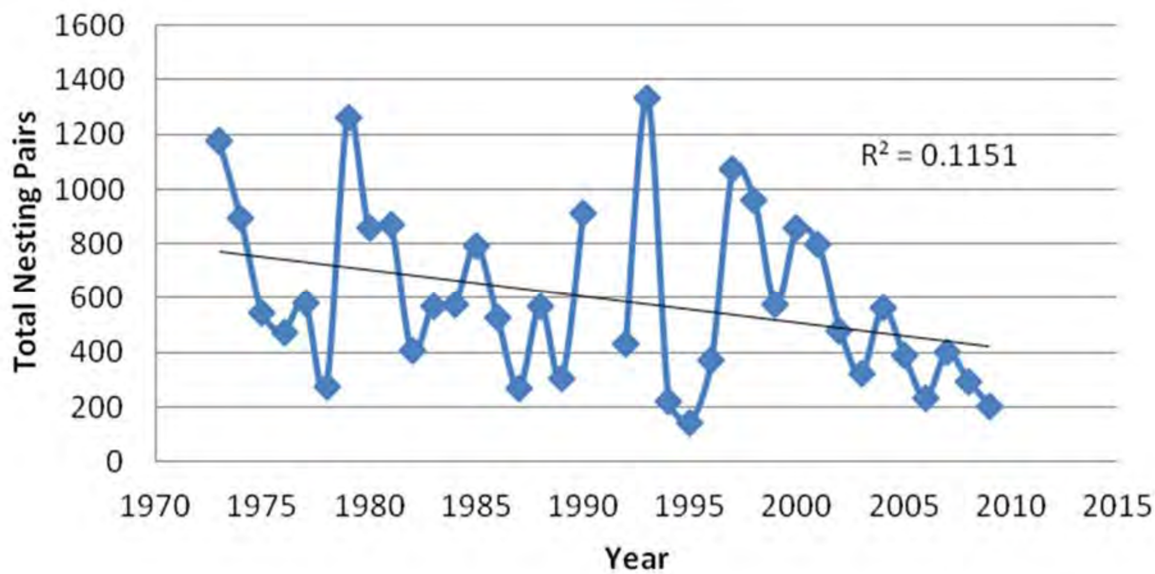

Figure 3.42 Trend in Black Skimmer breeding pairs within the San Antonio Bay System.

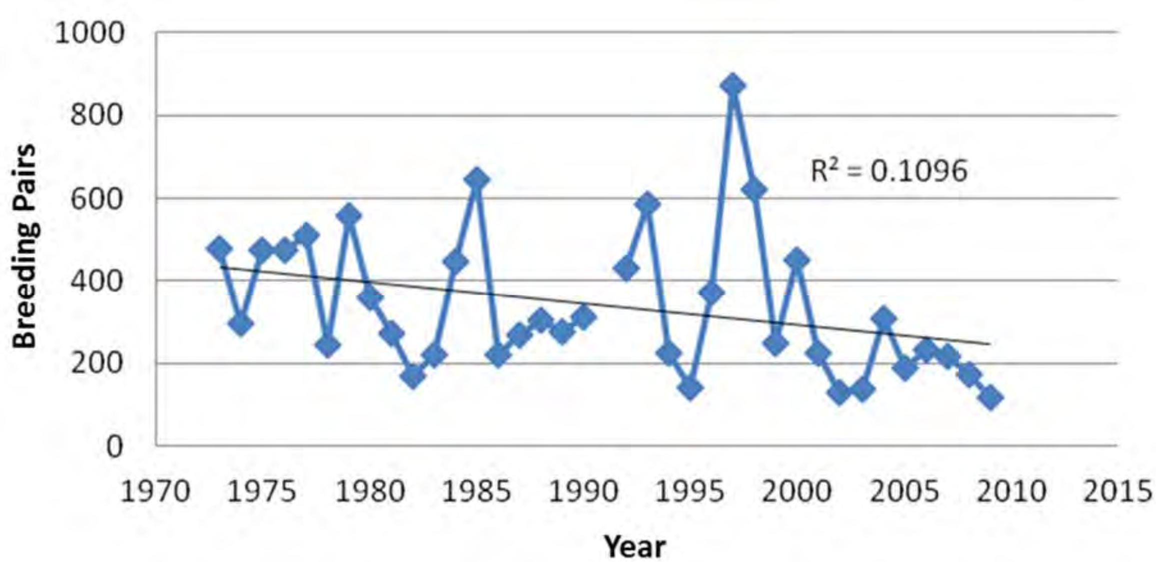

Figure 3.43 Trend in Black Skimmer breeding pairs within the San Antonio Bay System excluding Chester Island.

DISCUSSION

Throughout the survey period (1973-2009) approximately 24 in-bay colonies have been identified within the TCWS database. However, only four consistently have nesting birds. These four are: Chester Island, Second Chain of Islands, Steamboat Island, and Seadrift Island. All of these islands suffer from erosion, human disturbance, and predation. If Chester Island is excluded from the analyses the rest of the San Antonio Bay System has very few nesting waterbirds.

The five inland colonies can be very important for herons, egrets and spoonbills in years when the river flood plain is inundated. Based on the data presented here, the availability of inland colony sites does not appear to "pull" birds from bay colonies. Abundance of the most common inland breeding species (Great Blue Heron, Great Egret, Cattle Egret, Roseate Spoonbill) do not show declines at bay colony sites in years when inland colonies are flourishing. In fact, abundance of most of these species is near or above the trendline at bay colonies in most years when large numbers are present at inland colonies, suggesting that rainfall and associated inflow to the bay probably benefit bay colonies as well as making inland colonies available.

Restoration/conservation actions associated with provision of nesting habitat will likely be beneficial to either bay colonies or inland colonies depending on where they are targeted, while actions focusing on ecosystem processes would likely benefit colonies in both locations. Because of the importance of inland colonies to herons and egrets within the SABP planning area, it is recommended that partners work with private landowners to manage colonies and seek funding to restore and enhance wetlands that support the colonies.

Lack of islands, erosion of existing islands, human disturbance, and predators are implicated as most problematic for colonial waterbirds within the SABP planning area (Chaney and Blacklock, 2005; Coste and Skoruppa, 1989). San Antonio Bay has extensive wetlands and should be capable of supporting large numbers of colonial waterbirds if there was suitable nesting habitat. When new areas become available they are quickly colonized. Black Skimmer Strip, a beneficial use island was constructed in 2004 to accommodate dredge disposal for the Gulf Intracoastal Waterway and build marsh for Whooping Cranes. This island has a small area suitable for colonial nesting birds and currently provides habitat for as many as ten different species. Although construction of a rookery island was not the intent of project, because a small portion of the area has sufficient elevation it was quickly colonized.

With the exception of Brown Pelicans, most colonial waterbird populations show signs of varying degrees of decline in the system. Great Blue Heron and Great Egret show signs of steep decline, and these declines have mostly taken place at Second Chain of Islands. These steep declines are likely the result of erosion, human disturbance, and predation. In the past, red imported fire ants and raccoons have been identified as causes for decline on Second Chain of Islands (Chaney and Blacklock, 2005)

Recently, the Gulf Coast Joint Venture (GCJV) identified Reddish Egret, Little Blue Heron, Gull-billed Tern, and Black Skimmer as priority focal species. Currently, the GCJV has developed a Reddish Egret Conservation Plan which outlines population goals and habitat objectives (Vermillion and Wilson, 2009). The GCJV is in the process of developing the same type of plan for Gull-billed Terns and Black Skimmers. The Conservation Plan identifies management and protection of the primary nest sites (i.e., Chester and Second Chain of Islands) as critical to at least prevent further declines, but stability or increase of this species in the San Antonio Bay system will be most benefited by the creation of a new island nesting site.

Colony by colony assessments and management recommendations for most in-bay rookeries within the SABP planning area was conducted in two previous colonial waterbird management plans (Chaney and Blacklock, 2005; Coste and Skoruppa, 1989). Based on these rookery island management plans and the Reddish Egret Conservation Plan, the primary recommendation for the San Antonio Bay System would be to create new islands. Chaney and Blacklock (2005) identified the need to re-create Big Bird Island, Seadrift Island, and to build an island near Third Chain of Islands in Carlos Bay. Of note in this status and trends report is low numbers of terns and skimmers nesting in San Antonio Bay. This is due to the lack of suitable nesting islands.

Chester Island, in Matagorda Bay, often supports approximately 4,000 nesting pairs of terns and skimmers that are utilizing a small (less than 3 acre) portion of the larger island. In Corpus Christi Bay, Shamrock Island supports approximately 3,000 nesting pairs of terns and skimmers on approximately 14 acres of sandy beaches. Based on these two examples it should be possible to increase the numbers of nesting terns and skimmers within San Antonio Bay to approximately 3,000 pairs by creating 15 acres of suitable island habitat. Island creation can be very costly (approximately $1,000,000.00/acre); therefore, it will be important for the SABP to work with numerous partners to develop and implement rookery island restoration and creation projects.

Other important recommendations are to enhance existing islands by:

1. Conducting predator control including red imported fire ants, raccoons, coyotes, and feral pigs on islands that have supported colonial waterbird nesting in the past.
2. Managing vegetation on existing islands to promote areas for tree and shrub nesters as well as bare ground nesters.
3. Posting signs and performing education and outreach to limit human disturbance of colonies during the nesting season.

Recommendations for additional research include:

1. Understanding the relationship between inland and in-bay colonies is needed.
2. Understanding the influence of freshwater inflows and rainfall to productivity of waterbirds in the System.
3. Understanding the decline in Great Blue Heron and Great Egret and the near total loss of White-faced Ibis in the System.
4. Research to help managers understand the effects of climate change and sea level rise to these coastal-dependent waterbirds.

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REPORT 4: Whooping Crane

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DATA	U.S. Fish and Wildlife Service
TIMEFRAME	Winter 1938-39 to Winter 2011-2012

INTRODUCTION:

The Whooping Crane is America's most endangered large bird and is the most endangered crane in the world. The only natural wild flock of Whooping Cranes nests in Wood Buffalo National Park in the Northwest Territories of Canada during the summer months and then flies nearly 2,500 miles from Canada to their wintering grounds on the shorelines of Aransas and San Antonio bays (CWS and USFWS, 2007; Environment Canada, 2007). Therefore, the flock is known as the Aransas Wood-Buffalo Park (AWBP) flock.

They travel as a single pair, family group, or in small flocks, and they sometimes accompany Sandhill Cranes. They migrate during daylight hours and make regular stops along the way. By December, all or nearly all, of the AWBP flock have reached the marshes in and around Aransas National Wildlife Refuge (NWR) where they feed on blue crabs, wolfberries, crayfish, frogs, large insects, and acorns. As spring arrives and the days get warmer and longer, the cranes prepare for the trip back to Wood Buffalo by increasing their food intake to fatten up for the long return flight (CWS and USFWS, 2007; Environment Canada, 2007).

The endangered whooping crane is a flagship species for the wildlife conservation movement, symbolizing the struggle for survival that characterizes endangered species worldwide. The AWBP flock has come back from a low of only 14 adult birds in 1942 to reach 242 adults in 2010 (CWS and USFWS, 2007; Stehn, 2010). Historically, population declines were caused by shooting and destruction of nesting habitat in the prairies from agricultural development. The species was listed because of low population numbers, slow reproductive potential (sexual maturity is delayed and pairs average less than one chick annually), cyclic nesting and wintering habitat suitability, a hazardous 4,000-km migration route that is traversed twice annually, and many human pressures on the wintering grounds. Current threats to wild cranes include collisions with manmade objects such as power lines and fences, shooting, chemical spills along the Intracoastal Waterway that bisects its winter habitat, predators, disease, habitat destruction, severe weather, and a loss of two thirds of the original genetic material (CWS and USFWS, 2007; Environment Canada, 2007).

METHODS

Population Size and Mortality

There are efforts in place to monitor Whooping Cranes at both the northern and southern extents of their range. The methodology for censusing the AWBP flock while on their wintering grounds, however, changed in the winter of 2011-2012. Prior to this time, the methodology was to attempt to locate and count every crane multiple times during the winter season. This method was changed to a sampling process identified as "Distance Sampling" in the winter 2011-2012. This change in methodology precludes differentiating juvenile from basic plumaged cranes. This method also does not allow an estimate of the mortality occurring in the South Texas habitat. At the time this report was written, the final 2011-2012 report had not been released, but a news release was issued in June 2012. This release stated that there were an estimated 245 cranes present in the Aransas National Wildlife Refuge (NWR) survey area during the winter. Whooping Cranes were reported at various locations outside the Aransas NWR survey area that were not included in the report. For this report, wintering grounds census data for the AWBP flock was plotted for the period of 1938-39 to 2010-2011 (CWS and USFWS, 2007; Stehn, 2008, 2009, 2010, 2011), excluding the most recent winter's data when census methodology change. This allowed juvenile birds to be plotted separately from adult birds. However, a closer examination of the most recent ten years of data was also conducted and included the winter 2011-2012 estimate of 245 birds.

For the purposes of assessing the status of the Whooping Cranes, mortality data from April 1989 to April 2010 was also examined. Mortality data was collected from annual final reports written by Tom Stehn, former Whooping Crane Biologist at Aransas NWR (Stehn, 2008, 2009, 2010, 2011). Winter mortality data shows the cranes that were lost while on their wintering ground from November to April. Mortality data from April through November was also plotted to show the number of cranes lost from the time they leave their wintering grounds in Texas until they return the following fall. Winter mortality and Apr-Nov mortality were then combined to show total losses for the entire 12-month period (April to April). The change in flock size data is again taken April to April, so it includes the sum of losses and production for that 12 month period.

RESULTS

Population Size

Based on the Winter 1938-1939 to Winter 2010-2011 census data collected in the vicinity of the Aransas NWR, the Whooping Crane population is steadily increasing. The second order polynomial trend lines show a constant growth in the population of both adult and juvenile Whooping Cranes since about 1960 (Figure 4.1). Upon closer examination of the most recent ten years of data (assuming the 2011-2012 Distance Sampling estimate of 245 birds is representative of the resident population), it seems that the population growth is tending to flatten (Figure 4.2). Both graphs highlight the fact that recent drought years (2008-2009, 2011-2012) were accompanied by a drop in the population of Whooping Cranes present in the Aransas NWR survey area for those years (Figures 4.1 and 4.2).

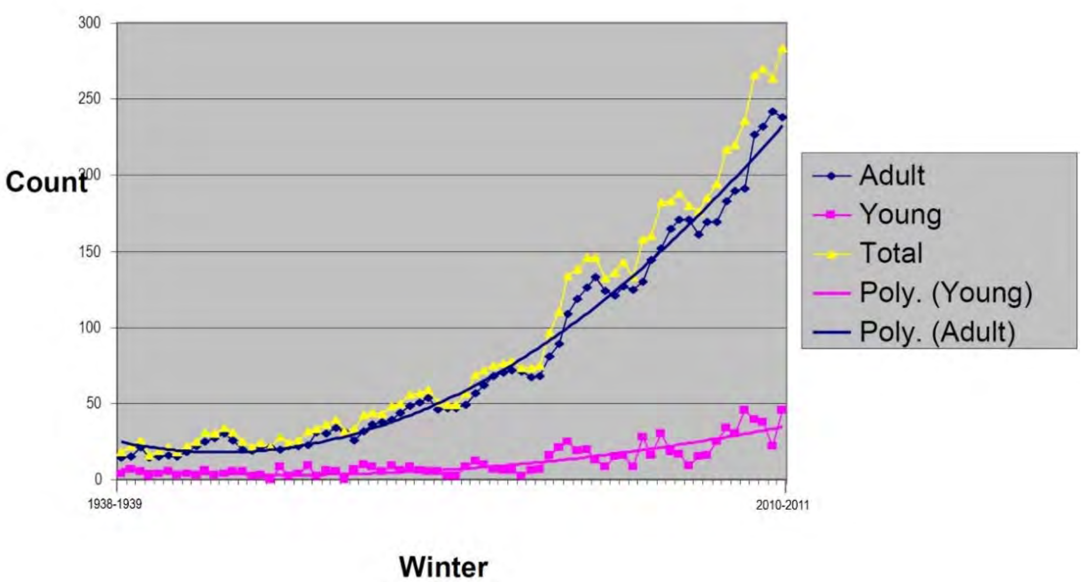

Figure 4.1 Census data for the AWBP Whooping Crane flock from Winter 1938-39 to Winter 2010-2011. Second order polynomial trend lines are shown separately for juveniles (pink) and adults (blue), as well as combined (yellow).

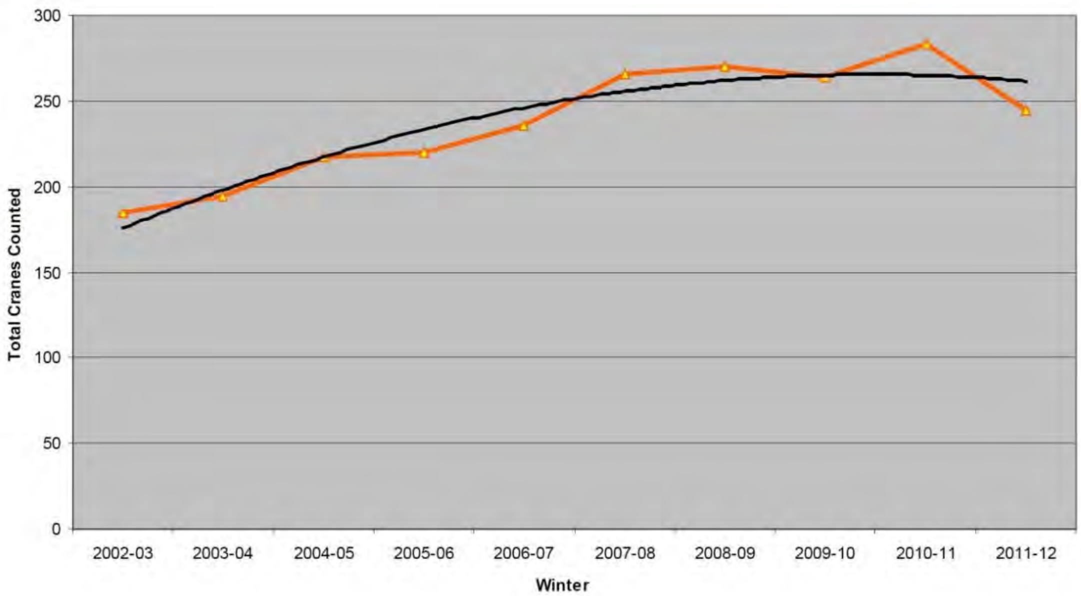

Figure 4.2 AWBP flock population estimate in recent years (Winter 2002-03 to Winter 2011-2012).

A straight-line average of the population change for the 72 years for which we have population numbers is approximately 3% per year. This is somewhat lower than the 4.5% published in a report by Environment Canada (2007). In an effort to understand this difference, the mortality data reported between 1989 and 2010 was examined. The trend of mortality at the AWBP flock winter grounds dropped through the 1990's, but has climbed in the present decade (Figure 4.3). This upward trend is heavily influenced by the high mortality of the winter of 2008-2009 (Figure 4.4). This trend does not include any mortality that occurred during the winter of 2011-2012.

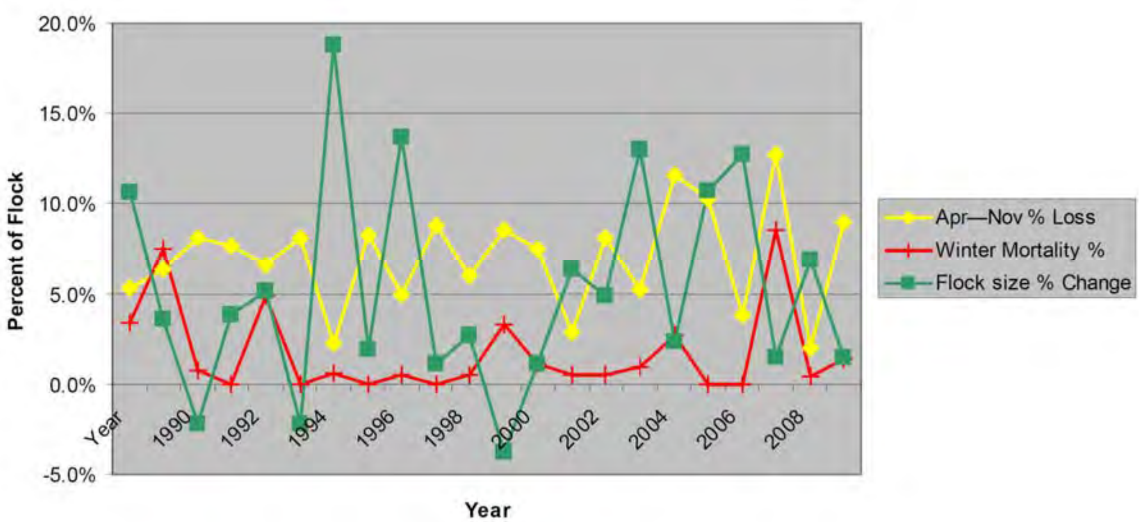

Figure 4.3 Flock mortality and flock size change as a percentage of flock size April 1989 through April 2010. Winter mortality (red) and Apr-Nov mortality (yellow) are shown separately. The change in flock size for each 12 month period (Apr-Apr) is also shown (green).

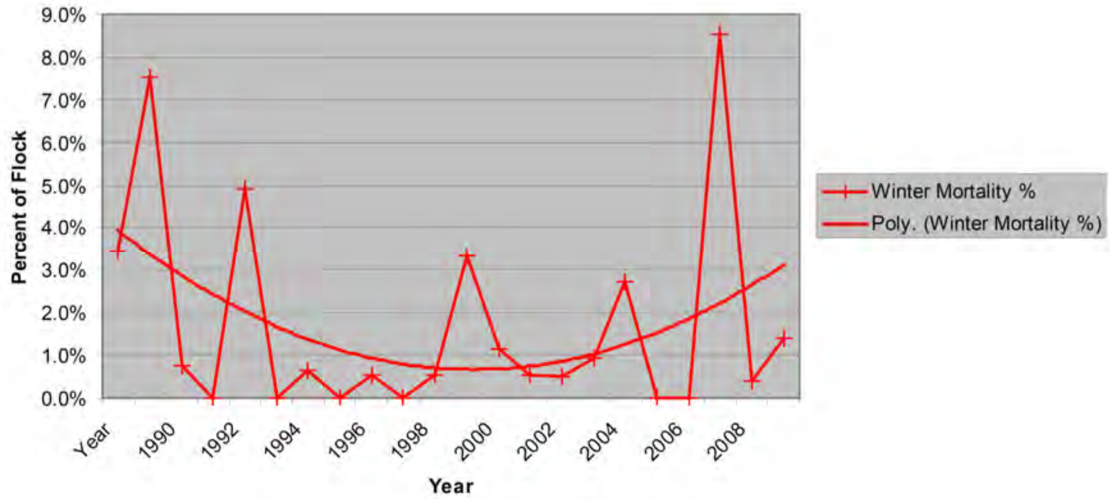

Figure 4.4 Winter mortality 1989-1990 through 2009-2010 with polynomial trend line.

There is some evidence that Whooping Crane mortality is related to blue crab abundance. Pugesek, et al. (2013) stated that "Hunt and Slack (1989) reported that crabs constituted 42.9% and 40.1% of the total mean volume of winter food consumed by Whooping Cranes during the winters of 1983-1984 and 1984-1985. Chavez-Ramirez (1996) found that crabs made up a mean of 90.2% (62–98%) and 61.5% (18.4–97.6%) of their daily energy uptake during the winters of 1992–1993 and 1993–1994." In their comparison of blue crab abundance and Whooping Crane mortality of the Aransas NWR, Pugesek et al. (2013) observed that significant non-linear increases in both juvenile and adult mortality were related to decreasing crab abundance. Their results suggest that some threshold of crab abundance exists in which Whooping Cranes have higher survival on their wintering grounds.

In testimony before the United States District Court for the Southern District of Texas, Corpus Christi Division (Montagna, 2011), Dr. Paul Montagna stated: "The analysis (of the impact of salinity on Blue crabs in Nueces Bay) uses data from bag seines deployed along shoreline taken by the Texas Parks and Wildlife Department, which is the same habitat where Whooping Cranes forage. I asked Dr. Froeschke to perform a similar analysis for San Antonio Bay. In San Antonio Bay, the preferred salinity range for blue crab is approximately 10 - 25 psu, so current conditions in San Antonio Bay are frequently very good for blue crab. The BRT (boosted regression tree) model predicts that if salinity is decreased 10 psu from the mean (as would happen if inflow increased), the abundance of blue crabs will increase up to 10% throughout the bay margins. In contrast, when the salinity is increased 10 psu from the mean (as would happen if inflow is decreased) then blue crab abundance will decrease up to 5%. Increasing salinity (decreasing freshwater inflow) by 5 psu and 10 psu from the long-term average greatly reduces the likelihood of blue crab capture along the bay margins where Whooping Cranes forage."

Dr. Montagna further stated: "Blue crab populations in Texas are clearly at risk and this is demonstrated by the long-term decline in abundance coast-wide. Populations at risk cannot withstand additional stressors. Low salinity is very important to blue crabs during the planktonic stages of its life cycle. High salinities promote higher disease rates by parasites. If salinity increases occur as a result of reductions in freshwater inflows, it is my professional opinion that this would have negative impacts on the San Antonio

Bay System in general, and blue crab abundance and availability within the San Antonio-Aransas-Mission Bay complex would be negatively impacted in particular. If blue crabs are an essential protein source for Whooping Cranes, then it is reasonable to conclude that there would be a connection between low inflow into San Antonio Bay and Whooping Crane mortality."

DISCUSSION

Threats

Probably the most significant factor impacting the future growth of the AWBP flock of Whooping Cranes is the availability of consistent supply of appropriate food for the flock, and on its wintering grounds, the most significant food supply factor for the flock is the availability of blue crabs in the shallow waters around the perimeter of San Antonio Bay and adjoining bays. Since the abundance of blue crabs has declined in recent history (Sutton and Wagner, 2007), some action needs to be taken to ensure the maintenance of this source of food for the cranes. One action might be to reduce the number of crabs taken by humans within the bay system during the time when Whooping Cranes are present in the estuary. A second action (and probably more significant action) is to insure adequate freshwater inflow to San Antonio Bay from the Guadalupe watershed.

The second significant factor is the availability of suitable estuarine habitat for the expanding flock of Cranes. Adult cranes form pairs and almost always return to the same territories each winter, with pairs aggressively excluding other Whooping Cranes from their territory (Pugesek et al., 2013). Census flights were used to delineate territories where a pair of birds was found every week without other cranes close by. Figure 4.5 depicts the habitat used by the mated pairs of Whooping Cranes during the winter of 2009-2010. This is the latest habitat usage data available to the author at the time this report was drafted.

Figure 4.5 Whooping Crane territories during the Winter 2009-10.

It is clear that Whooping Cranes have extended outside the boundaries designated as "Critical Habitat" (Figures 4.5 and 4.6, black line). There appears to be some room for flock expansion within the "Available Habitat" boundary (green shading Figure 5), but much of that the birds have designated less desirable. If the flock is to expand to the size required for "down listing", it is clear that more territory will be required. Figure 4.6 shows the predicted territory needed to accommodate that size of flock.

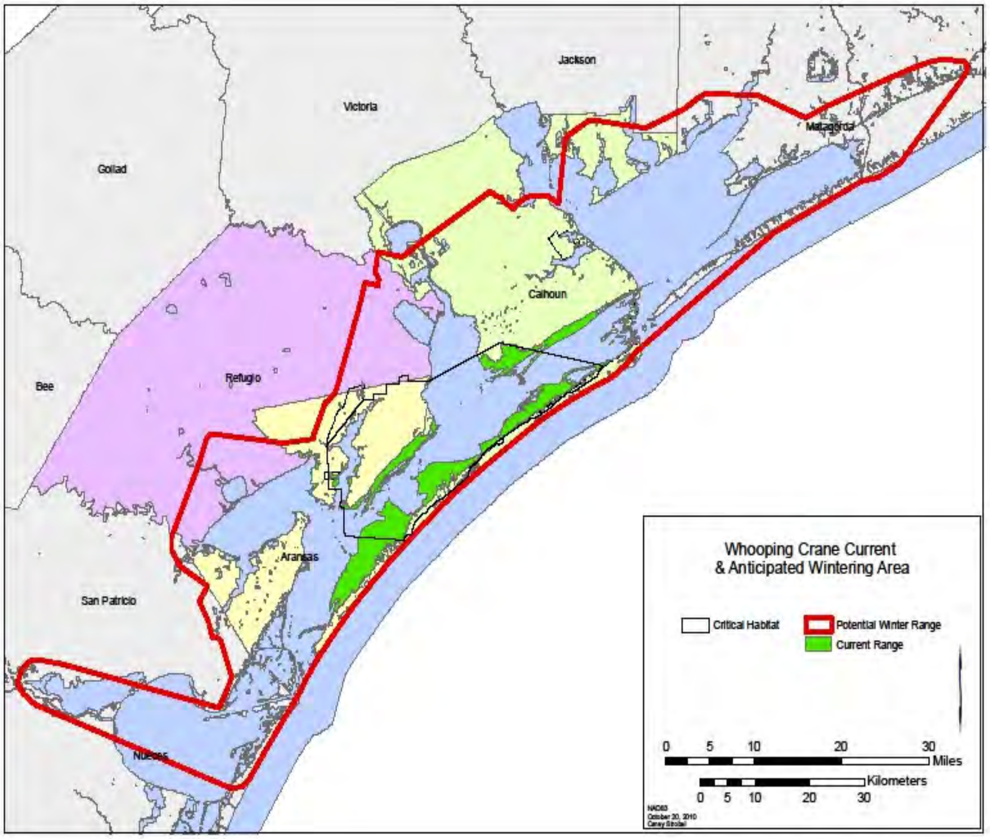

Figure 4.6 Potential winter range of AWBP flock (red line) shown in relation to current range (green area) and critical habitat area (black line).

It is obvious from Figures 4.5 and 4.6 that the current extent of the Whooping Crane wintering grounds has greatly exceeded the designated critical habitat. As the flock continues to expand, they will occupy more estuarine habitat. This expansion will place the birds in direct conflict with development of human habitat in those areas not protected by the "critical habitat" designation.

Recommended Management Actions

At the time this report was written, the Texas Commission on Environmental Quality (TCEQ) was considering the question of how much water is required to keep San Antonio Bay healthy. The recommendations from the *Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Expert Science Team* (GSA BBEST) were that inflows to the Guadalupe Estuary exceed 50,000 acre-feet during the period of July through September at least 69% of the time with flows of at least 450,000 acre-feet at least 12% of the time (GSA BBEST, 2011). This recommendation did not consider inflows during the period October through March, the period when

Whooping Cranes are present in the estuary nor did it consider the requirements for freshwater inflows to support the blue crab population. However, it does provide the best estimate of inflow requirements currently available. These recommendations did not obtain consensus by the *Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Area Stakeholders Committee* (GSA BBASC). This lack of consensus puts the minimum inflow decision in the hands of the TCEQ. The SABP should support acceptance of the BBEST recommendations by the TCEQ, as well as additional future efforts to ensure freshwater inflows to the bays.

In 2009, personnel from Texas Parks and Wildlife Department (TPWD) Fisheries and Regulatory divisions and Aransas NWR met several times and developed a proposal to expand the crab closure zone to all marshes currently used by wintering Whooping Cranes (Figure 4.7). A closure 300 feet from the marshes in the shallow parts of the bays where Whooping Cranes may forage was also proposed. The proposed closure was to be seasonal in nature only for when the Cranes are on the Texas Coast (October 15 - April 15). However, TPWD personnel decided not to present this matter to the Commission.

The SABP should request that TPWD re-consider this matter and bring it before the Commission. The closure would affect only a handful of commercial crabbers licensed on the Texas coast. A seasonal closure would reduce the problem of crab traps being placed in the shallow marshes and later abandoned when tides become too low to check traps. A seasonal closure would also reduce disturbance to Whooping Cranes, an issue of increasing concern as more and more people are able to access even the shallowest of marshes with kayaks and airboats.

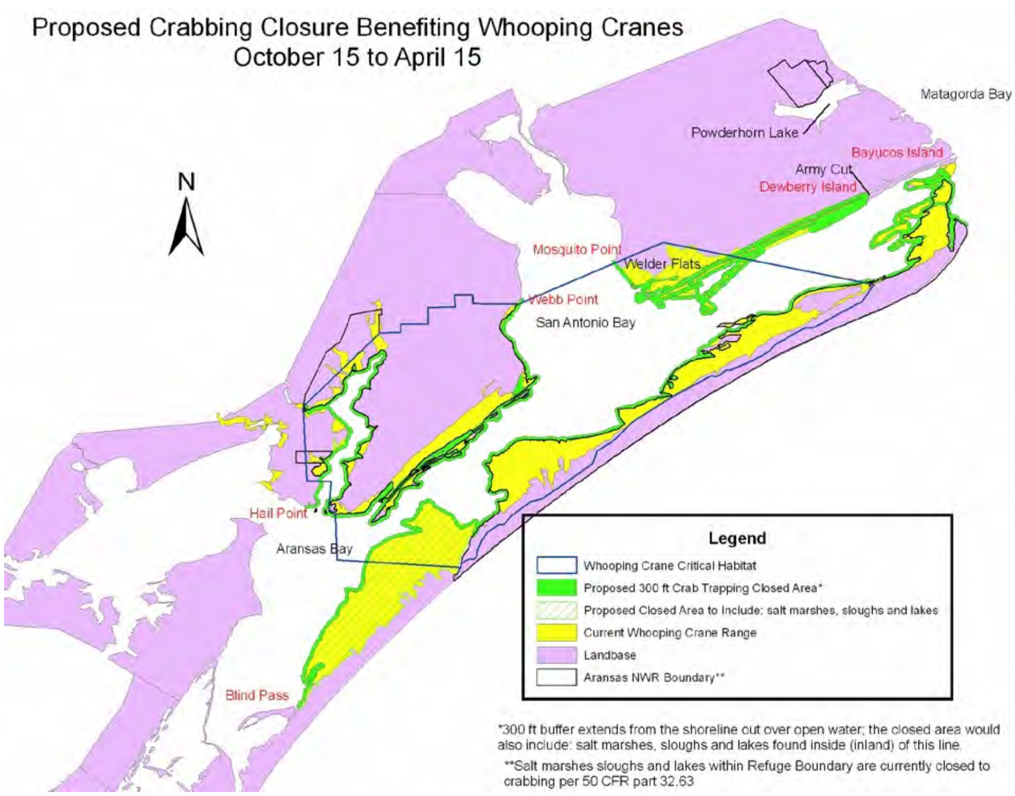

Figure 4.7 Map showing the proposed crabbing closure that would benefit Whooping Cranes.

Future Threats and Considerations

- Sea level rise
- Increased human population densities in the watershed

Summary

Historically, the efforts to restore the Whooping Crane flock have been a great success. The flock has grown from a low of 14 adult birds in 1942 to a high of 242 adults in 2010 (Stehn, 2010). The objective of increasing the AWBP flock size to allow for down-listing of the species (CWS and USFWS, 2007) is in danger, however, if steps are not taken to increase the size of protected habitat, provide for the continued abundance of their food supply, and understand future threats.

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REPORT 5: Upland Birds

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DATA	U.S. Geological Survey, Breeding Bird Surveys National Audubon Society, Christmas Bird Counts Texas Parks and Wildlife Department, Bald Eagle Surveys
TIMEFRAME	Breeding Bird Surveys: 2006-2011 Christmas Bird Counts: 2004-2011 Bald Eagle Surveys: 1974-2005

TEXAS PARKS & WILDLIFE

INTRODUCTION

The Calhoun County vicinity is one of the most diverse regions for birds in Texas. Over 430 species of birds have been documented to occur in Calhoun County by Brush Freeman in 2011 (Brush Freeman, personal communication). The San Antonio Bay System makes up a significant part of the diversity of this region. A more detailed checklist of the birds present in this area, along with habitat preferences of each species, was prepared by Texas Parks and Wildlife Department for the lands on and in the immediate vicinity of Guadalupe Delta Wildlife Management Area (Ortego, 1999). The area represented by this second checklist covers most of the northern portion of the San Antonio Bay System (i.e., north of the mouth of the Guadalupe River), but it does not include avian data from the bays, islands, and lands to the south.

METHODS

To date, no comprehensive study has been conducted on the status and population trends of birds of the entire planning area. Available data that will help describe the avian communities are presented below:

1. The U.S. Geological Survey Breeding Bird Survey (http://www.pwrc.usgs.gov/BBS/about/) is a network of randomly located 25-mile routes where breeding birds are surveyed annually in the United States along public roads. One hundred and ninety five routes are located in Texas and two of these adjoin the planning area (U.S. Department of Interior et al., 2001).

2. Data on wintering birds is best represented by the Guadalupe River Delta \ McFaddin Family Ranches Christmas Bird Count (CBC). The CBC is coordinated by National Audubon Society and is held annually during the mid-winter (http://birds.audubon.org/christmas-bird-count). There are roughly 2000 CBCs conducted in the United States and over 100 CBC sites are located in Texas. Each CBC location is 15-miles in diameter and birds are surveyed during one calendar day between Dec 14 and Jan 5 each winter. The center of the CBC in the San Antonio Bay System (National Audubon Society, 2010) is located near the northwest corner of Green Lake and was designed to survey the lower 15 miles of the Guadalupe River.

3. The Bald Eagle used to be listed as Endangered, but the population has recovered enough to be taken off of the Endangered Species List. The Texas Parks and Wildlife Department began monitoring the species in Texas during 1974 and aerial surveys continued through 2005 (Ortego et al., 2009).

RESULTS

1. U.S. Geologic Survey Breeding Bird Surveys: Population trends from the 194 routes surveyed in Texas from 1966 to 2009 for those species which breed in the planning area, occurred on at least 14 routes, and had a relative abundance of at least one bird per route are shown in U.S. Department of Interior et al. (2010). Species colored in red have a significant negative population trend and those colored in blue have a significant positive population trend. Of the 78 species which met the sample size requirements, 20 species showed significant population declines, and 33 species showed significant population increases. Most of the species showing population declines were associated with grasslands and wetlands, while those showing increases were mostly associated with forested areas. Adjoining to the planning area, two breeding bird survey routes were conducted from 2006-2011 (U.S. Department of Interior et al., 2001). The Goliad route

occurred in areas of mostly native grasslands while the McFaddin Route occurred in areas of mostly brush in former native grasslands. Both of these routes are representative of the upland habitats which occur in the planning area and the density of birds on these routes are typical for that habitat setting.

2. Christmas Bird Count: The Guadalupe River Delta \ McFaddin Family Ranches CBC is the second most diverse count in the United States. It has been conducted from 2004 to 2011, and over 280 species have been reported during those eight days (National Audubon Society, 2010).
3. TWPD Bald Eagle Monitoring: When TPWD began surveying for Bald Eagle nests in 1974, there was one breeding territory known to occur in the San Antonio Bay System. When TPWD stopped surveying in 2005, there were nine territories in this relatively small area (Ortego et al., 2009), which represents one of the highest nesting densities of this species in Texas. Bald eagles primarily nest in large trees in forested areas in close proximity to wetlands, and the high density of wetlands in this area explains the presence of large numbers of birds in this area. However, densities of nesting eagles could conceivably be increased to one eagle nest per mile of river frontage if quality of wetlands and forested areas are maintained or enhanced.

DISCUSSION

Grasslands

Almost all of the uplands were occupied by grasslands that were savannahs historically. Human occupation has converted most of the uplands to farm land or pasturage with introduced exotic grasses. Future projects should consider maintaining existing native grasslands in prairie or savannah conditions to benefit grassland dependent species.

Riparian Forest

Most of the riparian forests in the San Antonio Bay System were cleared for agriculture. Riparian forests are important for Bald Eagles, forest dwelling species, and neotropical migrant songbirds. It is important to maintain and expand forested riparian areas at suitable sites for these species and also to maintain wildlife diversity in the planning area.

Wetlands

Wetlands within the Guadalupe and San Antonio River flood plains have been greatly modified. They are very productive for wildlife and have been shown to support large concentrations of shorebirds and colonial waterbirds (2011 Guadalupe River Delta Christmas Bird Count (Ortego, 2010; Ortego et al., 2012)). Future projects should focus on ecosystem restoration and enhancing key foraging and nesting areas of focal wildlife species.

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REPORT 6: Attwater's Prairie Chicken

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DATA	Attwater's Priarie Chicken Recovery Plan, Second Revision Lehmann
TIMEFRAME	Attwater's Priarie Chicken Recovery Plan: 2010 Lehmann: 1941

INTRODUCTION

According to Lehmann (1941), the grasslands in the San Antonio Bay System are part of the Attwater's Prairie Chicken (APC) former range (Figure 6.1). However, the APC has been long-extirpated from the area (>70 years). Little bluestem-dominated grasslands within the San Antonio Bay System may once have supported prairie chickens at relatively high densities (1 bird per 10-50 ac.), but dense gulf cordgrass-dominated grasslands were probably little-used by prairie chickens except to a limited extent in the winter (Lehmann, 1941).

Figure 6.1 Land use within the Refugio-Goliad County, Texas priority management zone for the Attwater's Prairie Chicken. Orange line indicates historic booming ground range within the San Antonio Bay System (taken from *Attwater's Prairie Chicken Recovery Plan* [USFWS, 2010]).

For at least 10 years (1998 to 2008), no brood survival was documented among wild APC or those birds released from captivity. During this period Attwater's occurrence in the wild was due entirely to captive-reared APC releases at the Attwater's Prairie Chicken National Wildlife Refuge, the Nature Conservancy's Texas City Prairie Preserve, and a private ranch in Goliad County. No one knows for certain the cause(s) for this high or total brood mortality. A small number of theories have been considered, including:

1. Artificial selection - It may be that pressures that select for traits enabling wild brood-survival have been removed from the captive population, so that few captive-reared birds possess traits needed to raise broods in the wild. Little has been done to test this theory.
2. Red imported fire ants - It may be that red imported have reduced the abundance of small insects critical to Attwater's wild brood survival. This theory is being tested on Attwater's Prairie Chicken release sites at the Attwater Prairie Chicken National Wildlife Refuge and on private ranches in Goliad and Refugio Counties. Results are pending.

The two theories mentioned above are not mutually exclusive. It may be that artificial selection, red imported fire ants, and other causes have reduced APC wild brood survival to varying degrees. Since 2008 a few broods have been documented to survive to independence at Attwater Prairie Chicken National Wildlife Refuge, the Nature Conservancy's Texas City Prairie Preserve, and a private ranch in Goliad County.

DISCUSSION

Habitat Management

According to the *Attwater's Prairie Chicken Recovery Plan* (USFWS, 2010), the following actions should be undertaken to maintain and expand grasslands for APC:

1. APC management areas should be ≥33%, and preferably ≥50% grassland
2. Priority for management should be given to habitats within 1mile (1.6 km) of existing and historical booming grounds.
3. Mowing in APC habitat should not occur before 1 July.
4. Prescribed burning should be completed in APC habitat by 1 February.
5. Availability of grasslands for nesting and brood rearing cover most often limit APC populations. As such:
    a. No more than 33% to 60% of grassland habitat managed for *T. cupido* should be burned on an annual basis.
    b. Patches of unburned cover should be as large as possible, but at least 80 to 618 ac.
    c. More than 50% of grassland residual cover (still standing from growth of previous seasons) should be 10-39 inches in height during spring. Cover with OV values averaging 10 inches (25 cm) should be readily available and well distributed within grasslands as nesting sites.
    d. Cover which becomes rank (>39 inches [1 m] tall, >25% horizontal litter cover) should be disturbed by burning, grazing, or mowing.
    e. Brush must be carefully controlled to prevent excessive encroachment into grassland habitats, and trees, especially near booming grounds, should be cut down. Less than 25% of the landscape should be wooded, with woodlands in scattered blocks. In order to support booming grounds, open grasslands must be as large as possible. At a minimum, open grasslands of >1,480 ac (600 ha), and preferably >2,175 ac (880 ha), should be maintained.

Reintroduction

Three areas within the San Antonio Bay System could potentially provide habitat for Attwater's Prairie Chicken reintroductions:

1. McFaddin grasslands - The approximately 15,000 acres of grasslands east of Hwy. 77 between the Guadalupe and San Antonio Rivers could potentially support 300 to 1,500 Attwater's Prairie Chickens. However, brush densities in these grasslands exceed Attwater's Prairie Chicken habitat requirements, so extensive brush management would be required before this area could support these birds.
2. Welder-LaSalle grasslands - The approximately 15,000 acres of grasslands on Calhoun County's mainland south of Hwy. 185 between the Seadrift and Port O'Connor could potentially support about 300 Attwater's Prairie Chickens. However, brush densities in these grasslands exceed Attwater's Prairie Chicken habitat requirements, so extensive brush management would be required before this area could support these birds. There are approximately 3,500 acres of grasslands in the Welder Flats area that are already protected by conservation easements held by the USDA and the Nature Conservancy. Most of the remaining grasslands belong to a company that developed a canal subdivision on part of their property near Port O'Connor. The subdivision has sold a 3,600-acre easement to USDA's Wetlands Reserve Porgram, and approximately 1,400 acres of the easement is uplands. However, this area is also heavily infested with brush, and therefore, extensive brush management would be needed before this area could support Attwater's Prairie Chickens.
3. They are likely planning residential development for their remaining property. Efforts should be made to purchase a conservation easement on this property so that reintroductions could be considered for this area.
4. Matagorda Island- There is approximately 45,000 acres of grasslands on Matagorda Island National Wildlife Refuge that could potentially support about 900 Attwater's Prairie Chickens. Vegetation surveys should be conducted on Matagorda Island to determine if the islands grasslands fit the habitat model described in the recovery plan. Surveys for fire ants should also be conducted in order to compare Matagorda Island with other potential release areas. If the vegetation and fire ant survey results indicate that the island's grasslands could be managed to provide habitat for these birds, then Attwater's Prairie Chicken releases on Matagorda Island should be considered.

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REPORT 7: Aplomado Falcon

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DATA	Northern Aplomado Falcon Recovery Plan Peregrine Fund Annual Reports Northern Aplomado Falcon Restoration Report
TIMEFRAME	Northern Aplomado Falcon Recovery Plan: 1990 Peregrine Fund Annual Reports: 2003-2008 Northern Aplomado Falcon Restoration Report: 2008

INTRODUCTION

The Northern Aplomado Falcon once ranged from Trans-Pecos Texas, southern New Mexico, and southeastern Arizona to Chiapas and the northern Yucatan along the Gulf coast of Mexico. Because of uneven collecting effort, it is difficult to determine the former abundance of the falcon in the U.S. However, observers prior to 1930 considered it to be quite common. Collectors found Northern Aplomado Falcons nesting in the U.S. each year from 1892 to 1914. After 1914, pairs of flacons or nests were discovered nearly every year until 1930. The last Aplomado Falcon specimen in the United States was collected in 1949 on the King Ranch. They continued to be sited in south Texas until the mid-1950's (USFWS, 1990).

The Northern Aplomado Falcon was listed as endangered in 1986. It was believed to be extirpated from the United States in the 1950's. The reason for this decline has been attributed to (1) brush encroachment and agricultural development on much of the grasslands, (2) egg collecting around 1900, and (3) pesticide contamination. Aplomado Falcons were once considered common in coastal Texas. In fact, Aplomado Falcon egg sets collected 1890-1915 in south Texas outnumbered egg sets of the White-tailed Hawk and Crested Caracara in the same area and period (USFWS, 1990).

Northern Aplomado Falcons occur in yucca-studded patches of coastal prairie and tidal flats at least 2,000 acres in size, with no live oak mottes in sight. Tidal flats dominated by shoregrass (*Monanthochloe littoralis*), gulf cord grass (*Spartina spartinae*), salt grass (*Distichlis spicata*), saltwort (*Batis maritima*), marsh hay cordgrass (*Spartina patens*), glasswort (*Salicornia* sp.), and sea ox-eye (*Borrichia frutescens*), low-growing (<5 feet tall) black mangrove (*Avicennia germinans*) brush provide adequate habitat, while coastal prairie dominated by gulf cord grass (*Spartina spartinae*), seacoast bluestem (*Schizachyrium scoparium* var. *littoralis*), gulf dunes paspalum (*Paspalum monostachyum*), and sea oats (*Uniola paniculata*) are also used by the birds.

DISCUSSION

Habitat Management

It is estimated that 93% of the 6 million acres of coastal prairie in Texas had been lost by 1937. In 1991, only one percent of the original coastal prairie was thought to remain in fairly pristine condition. The loss of the coastal prairie has been attributed to conversion to crop land, development, fire suppression and over grazing. Currently there are State and Federal programs in place to help maintain existing coastal prairie and to begin to reverse these declines. To assists in this effort the U.S. Fish and Wildlife Service is in the process of entering into an agreement with the Coastal Bend Bays & Estuaries Program to enhance coastal prairie in the Coastal Bend. This project is to work on public and private lands to enhance 3,000 acres of coastal prairie to benefit Aplomado Falcon, Attwater's Prairie Chicken, Whooping Crane, and Mottled Duck. Most prairie enhancement work will include brush control using chemical and mechanical methods, as well as planning and implementing prescribed fire and grazing management. In addition planting of native yucca in strategic locations to provide appropriate nesting cover for Aplomado Falcons may be conducted. Partners in the project include:

- U.S. Fish and Wildlife Service: Provide funding and assistance in identifying and developing site specific projects.
- Coastal Bend Bays and Estuaries Program: Provide funding and will enter into contracts with

landowners and manager to complete prairie enhancement activities.

- Texas Parks and Wildlife Department: Will assist with prescribed fire activities at Mustang Island State Park and allow Aplomado Falcon releases.
- The Peregrine Fund: Will carry out releases of Aplomado Falcons in the Coastal Bend, monitor for nesting success, and enter into Safe Harbor agreements with landowners.

Landowners and managers who enter into these programs have varied interest. Some are grazers who are looking for assistance in improving range conditions, others are seeking assistance to improve habitat for quail. Where their interests overlap with the partners mentioned above, is where assistance can provided to meet their needs and provide habitat for endangered species and other grassland birds.

Reintroduction

In an effort to recover the species the Peregrine Fund began releasing Aplomado Falcons in 1986 at Laguna Atascosa National Wildlife Refuge. In 1995, their efforts resulted in the first observations of wild breeding Aplomado Falcons in the United States since 1952. Releases on the Texas coast continued through 2004 on Matagorda Island National Wildlife Refuge and in south Texas. Currently there are approximately 30 breeding pairs in coastal Texas. Thirteen of these breeding pairs occur within the San Antonio Bay System. The downlisting criteria are 60 breeding pairs in the United States. Since 2004, the Peregrine Fund has focused their release efforts in west Texas and New Mexico. Those efforts have for the most part failed due to avian predators and long-term drought. The Peregrine Fund is now going to refocus their efforts on the Texas coast where they have had previous success in establishing populations. At the time this report was drafted, the Peregrine Fund was already planning releases in the Texas coastal bend at Mustang Island State Park (Peregrine Fund, 2004, 2005, 2006, 2007, 2008, 2009a, 2009b, personal communication).

Two areas within the San Antonio Bay Partnership's geographic boundary could potentially provide habitat for Aplomado Falcon reintroductions.

1. Welder-LaSalle grasslands - The approximately 15,000 acres of grasslands and 25,000 acres of marsh on Calhoun County's mainland south of Hwy. 185 between the Seadrift and Port O'Connor could potentially support about 20 Aplomado Falcons. However, live oak distribution and abundance currently prevents Aplomado Falcons from occupying this area, so extensive brush management would be required before this area could support these birds. There are approximately 3,500 acres of grasslands and 10,000 acres of marsh in the Welder Flats area protected by conservation easements held by the USDA and the Nature Conservancy. Most of the remaining grasslands belong to a company that developed a canal subdivision on part of their property near Port O'Connor. The subdivision has sold a 3,600-acre easement to USDA's Wetlands Reserve Program, and approximately 1,400 acres of the easement is uplands. However, this area is also heavily infested with brush, and therefore, extensive brush management would be needed before this area could support Aplomado Falcons.
2. Matagorda Island- There are approximately 45,000 acres of grasslands and 15,000 acres of marsh on Matagorda Island National Wildlife Refuge that currently supports 13 Aplomado Falcon pairs, and could potentially support about 17 more. Efforts should be made to establish 17 more Aplomado Falcon pairs on Matagorda Island.

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