Habitat Assessment for a proposed seawater desalination facility in Galveston Bay

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Project Summary

Before developing the proposed Bayshore Desalination Facility in Texas City, Texas, EPCOR requested Texas A&M University at Galveston to evaluate the discharge area for suitable habitat for identified species and to assess the potential impacts (i.e. salinity changes) the proposed discharge may have. The project was established to conduct a habitat assessment for a portion of Galveston Bay that may be impacted by the discharge plume, as well as the intake channel. Requested species to be evaluated included: red drum (*Sciaenops ocellatus*), brown shrimp (*Farfantepenaeus aztecus*), flounder (primarily southern flounder [*Paralichthys lethostigma*]), oysters (primarily eastern oyster [*Crassostrea virginica*]) and seagrass. The proposed intake flow is 82.8 million gallons/day, with a proposed discharge flow of 56.3 million gallons/day and an expected discharge averate salinity of 21.2 ppt to the plume area. The objectives of this project were:

Objective 1: Conduct a literature search to determine if the identified species reside in the area of the desalination plant and if the proposed discharge would impact essential habitat requirements.

A literature search was conducted for all species identified above to determine habitat preferences and environmental requirements. Four species were added to the above identified species: black drum (*Pogonias cromis*), spotted seatrout (*Cynoscion nebulosus*), white shrimp (*Litopenaeus setiferus*) and blue crab (*Callinectes sapidus*). These species were added due to their importance as a recreational or commercial fishery in Galveston Bay. The literature search was also expanded to assess ranges of salinity tolerance and thresholds of osmotic shock for each species.

Key Findings: Each species identified above is present in Galveston Bay. Spawning occurs outside of the bay for red drum, southern flounder, brown shrimp, white shrimp and blue crab, while spotted seatrout, black drum (can also spawn out of bay) and eastern oyster spawn within the bay. All of the above identified species utilize Galveston Bay as a nursery area, with seagrass being an important habitat for newly settled recruits of red drum, southern flounder, spotted seatrout and brown shrimp. Seagrass has not been present in Upper Bay near the proposed discharge and intake area since 1961, with West Bay maintaining the only remaining seagrass in

Galveston Bay. All species are euryhaline and documented to tolerate a wide range of salinities. While salinity ranges varied for peak recruitment and larval development for each species, each optimal salinity range included 17-24 ppt based on the literature review. Further, the optimal salinity range for each of the fish (red drum, southern flounder, spotted seatrout and black drum) and invertebrate (brown shrimp, white shrimp, and blue crab) species included 15-25 ppt, while eastern oyster optimal salinity ranged from 17-24 ppt. Therefore, the expected discharge average salinity of 21.2 ppt falls within the range of documented salinity for larval recruitment and development of the identified species.

Objective 2: Utilize long-term monitoring data from Texas Parks and Wildlife Department (TPWD) to determine abundance of identified species in the proposed discharge and intake area.

TPWD has conducted surveys throughout Galveston Bay since 1982 using bag seines, bay trawls, gill nets, and oyster dredges. Datasets were combined to assess the abundance of the identified species in the proposed discharge and intake area from 1982 through 2024. Further, two timeframes from 1982-2008 and 2009-2024 were evaluated separately to determine if the closure of a power plant (PH Robinson) operating at the same location had a potential impact on the abundance of the identified species. Environmental data recorded during these surveys was examined to determine the range of parameters correlated to each species presence.

Key Findings: For the TPWD surveys, each identified species collected around the discharge and intake area accounted for less than 5% of the overall species collection across the entire Galveston Bay. One exception was eastern oyster, in which collections around the discharge and intake area accounted for 15.5% of the total survey catch in Galveston Bay due to the proximity of the discharge and intake area to oyster reefs. All species were collected in salinities ranging from 0.9 – 27.9 ppt, with some species being collected in salinities as low as 0 ppt or as high as 35 ppt. Thus, the expected discharge salinity of 21.2 ppt falls within the range of salinity the identified species were collected in. Differences were observed in the abundance of certain identified species between 1982-2008 and 2009-2024; however, it does not appear these differences are linked to the closure of the facility but instead to overall declines or increases in population abundance bay wide.

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Introduction

Desalination plants can provide a vital service by using reverse osmosis to produce fresh water from seawater suitable for human consumption, irrigation, and industrial use. This is beneficial in areas heavily impacted by drought. However, this process poses concerns on the effect of the brine discharge to marine ecosystem and the potential to harm marine life during water uptake and discharge. Plans are being made to develop a desalination plant in Texas City, Texas using a discharge and intake channel previously used by the PH Robinson Power Plant that closed in September 2008. The current proposed intake flow is 82.8 million gallons/day, with a proposed discharge flow of 56.3 million gallons/day and an expected discharge average salinity of 21.2 ppt to the plume area.

Galveston Bay is a critical nursery habitat for various fish and shellfish species that are important commercial and recreational fisheries. The top commercial fisheries in Galveston Bay include shrimp (both brown [*Farfantepenaeus aztecus*] and white [*Litopenaeus setiferus*]), eastern oyster (*Crassostrea virginica*), blue crab (*Callinectes sapidus*), and black drum (*Pogonias cromis*). Whereas, the top recreational species in Galveston Bay are red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), and southern flounder (*Paralichthys lethostigma*). An assessment of habitat requirements and salinity tolerances is necessary to determine if the proposed desalination plant would impose any potential impacts to local fish and shellfish species. The above identified species were selected for assessment based on their commercial or recreational importance to the area. Further, it is necessary to determine if any seagrass habitat is available near the proposed desalination site as seagrass provides valuable juvenile habitat for several species. To assess the habitat requirements, salinity tolerances and abundance of the identified species near the proposed desalination site, the following objectives were proposed:

Objective 1: Conduct a literature search to determine if the identified species reside in the area of the desalination plant and if the proposed discharge would impact essential habitat requirements.

Objective 2: Utilize long-term monitoring data from TPWD to determine abundance of identified species in the proposed discharge and intake area.

Methods

A. Literature Review

A literature review was conducted for the species requested: red drum (*Sciaenops ocellatus*), brown shrimp (*Farfantepenaeus aztecus*), flounder (primarily southern flounder [*Paralichthys lethostigma*]), oysters (primarily eastern oyster [*Crassostrea virginica*]) and seagrass to determine habitat preferences and environmental requirements. Due to their commercial and/or recreational importance to Galveston Bay, four additional species were added to the identified species: black drum (*Pogonias cromis*), spotted seatrout (*Cynoscion nebulosus*), white shrimp (*Litopenaeus setiferus*) and blue crab (*Callinectes sapidus*). An excel spreadsheet was created to organize literature review information, including: objective of the manuscript, methods used, key findings, presence in the discharge area and citations of interest.

B. TPWD Long-Term Data

The TPWD Coastal Fisheries Division long-term monitoring program has been conducting bag seine, bay trawl, gill net and oyster dredge surveys throughout Galveston Bay since 1982. Water depth and hydrological data are collected at each sample survey. During bag seine surveys, hydrological data is collected 3.1 m (10 ft) from shore at the surface (0-15 cm). For bay trawls and oyster dredge surveys, hydrological data is collected 0.3 m (12 in) off the sea floor before trawling/dredging begins. For gill net surveys, hydrological data is collected at the offshore end of the gill net from the surface (0-15 cm). How each survey is conducted is briefly described below based on the Marine Resource Monitoring Operations Manual (Martinez-Andrade 2018).

Bag seine surveys are conducted monthly, with the first half of sampling locations to be completed during the 1st through 15th of the month and the second half to be completed from the 16th through the end of the month. Bag seins used by the Coastal Fisheries Division are 18.3 m (60 ft) long and 1.8 m (6 ft) deep with 19 mm (0.75 in) mesh in the wings and 13 mm (0.5 in) mesh in the bag. Sampling occurs half an hour before sunrise and ends half an hour after sunset. When deploying the bag seine, one person remains on shore while the second person pulls the seine perpendicular to the shoreline to the full extent. Both people then proceed to pull the net 15.2 m (50 ft), at which time the person on shore stops and allows the person offshore to

maintain the full extent of the seine while bringing it to shore. Counts of all species are recorded. Lengths are recorded to the nearest mm of up to 19 randomly selected individuals of each species, with total length being the preference. A total of 240 samples were collected each year via bag seine in Galveston Bay, with 20 occurring each month.

Bay trawl surveys are also conducted monthly, with the first half of sampling locations to be completed during the 1st through 15th of the month and the second half to be completed from the 16th through the end of the month. This allows for temporal distribution of the samples. Sampling begins half an hour before sunrise and ends half an hour after sunset. Coastal Fisheries Division is equipped with 6.1 m (20 ft) wide otter trawls consisting of 38 mm (1.5 in) mesh. Galveston Bay is a larger bay system that is stratified into upper and lower bay zones, with half of the monthly trawls conducted in each zone to ensure good spatial distribution of samples. The trawl is towed at 3 mph for 10 minutes in a circular manner. Counts of all species are recorded, 19 individuals for each species is randomly chosen to be measured to the nearest mm. A total of 240 bay trawl samples are collected each year, with 10 occurring in the upper bay and 10 occurring in the lower bay each month.

Gill net sampling is conducted in the spring and the fall, beginning the second full week of April or September, respectively, and continuing for 10 consecutive weeks. The Coastal Fisheries Division is equipped with gillnets that are 182.9 m (600 ft) in length, consisting of four panels of varying mesh sizes (152 mm [6 in], 127 mm [5 in], 102 mm [4 in] and 76 mm [3 in]). Gill nets are placed perpendicular to shore starting one hour before sunset, with the smallest mesh size closest to shore. The nets are then retrieved no sooner than sunrise, with the last gill net retrieved within four hours of sunrise. Counts of all species are recorded. Species length is recorded to the nearest mm of up to 19 randomly selected individuals of each species per mesh size per day. A total of 90 samples are collected each year by gill nets, with 45 occurring each season.

Oyster dredge sampling occurs monthly, with the first half of sampling locations to be completed during the 1st through 15th of the month and the second half to be completed from the 16th through the end of the month. Again, sampling occurs half an hour before sunrise to half an hour

after sunset. Oyster dredges used by the Coastal Fisheries Division consist of a steel rod frame (0.5 m [19.5 in] wide, 0.24 m [9.5 in] high and 1 m [39 in] long) and a bag made with metal rings, s-hooks and nylon rope (0.36 m [14 in] deep with 76 mm webbing). Sampling with oyster dredges occurs in areas where Eastern oysters form consolidated reef/habitat with at least 0.2 m (6 in) or more vertical relief for a continuous distance (at least 91.4 m [300 ft] long by 0.5 m [1.5 ft] wide) and is in water at least 1 m or greater from mean low tide. The dredge is towed at 3 mph for 30 seconds following the contour of the reef. All oysters are counted and 19 oysters are randomly measured if length is greater than 25 mm. Dead oyster shells and fragments greater than 25 mm in length are also counted, and oyster spat is counted in the range of 5-25 mm. Any other species collected is counted and measured up to 19 randomly individuals for each species to the nearest mm. A total of 360 oyster dredge samples are collected annually, with 30 occurring each month.

For Galveston Bay, all data sets for each gear set survey were combined for the years 1982-2024, except gill nets in which the data set was complete through 2023. Coordinates for each sampling survey were added into QGIS to determine where sampling events occurred near the discharge and intake area, in addition to where the various gear types were deployed in that area (Figure 1). Heatmaps of catch abundance were created for each species for all years combined, as well as for 1982-2008 and 2009-2024 to determine if the closure of a previous facility (September 2008) in the area impacted catch of any species. Data points for where each species were collected near the discharge and intake channels were extracted to determine overall catch and salinity ranges of each species in the area. This data was also used to plot overall catch by year and catch by salinity.

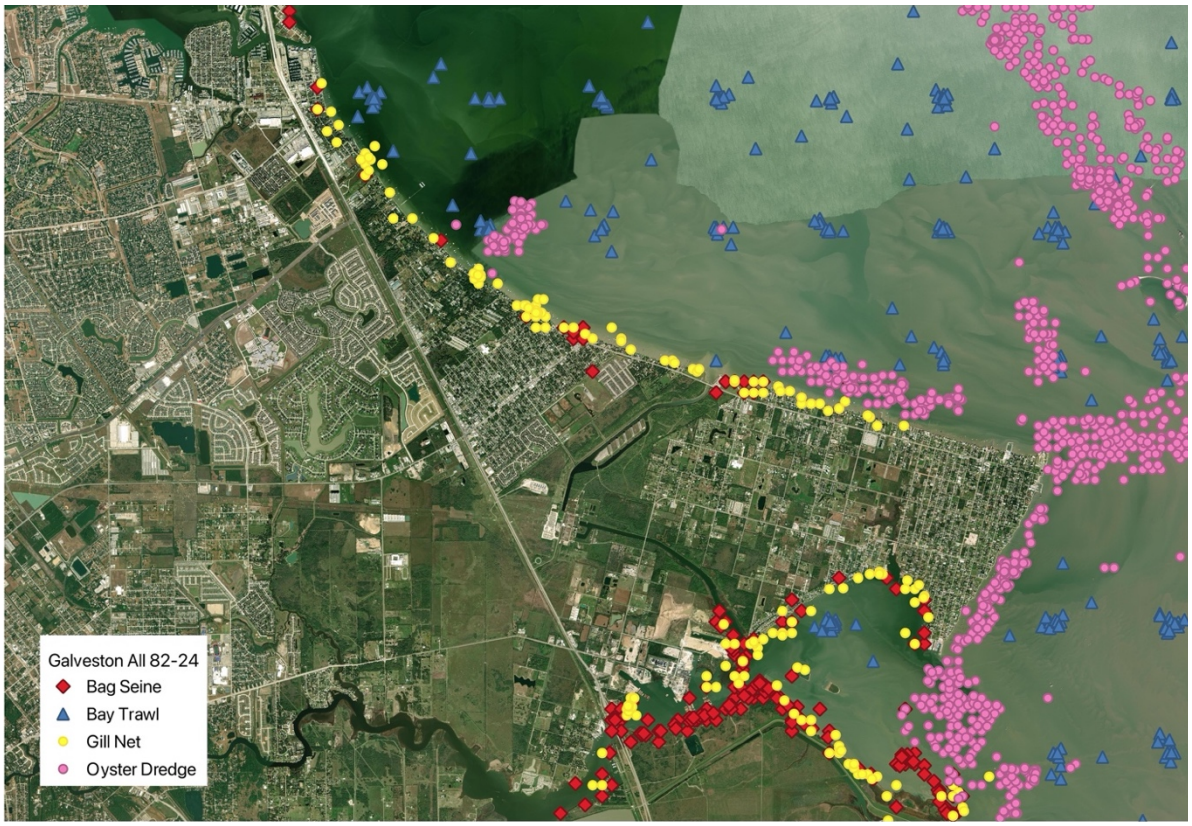


Figure 1. Sampling locations for TPWD long-term monitoring surveys that utilize four gear types near the discharge plume and intake channel.

In addition to the long-term monitoring program, TPWD's Coastal Fisheries Division Habitat Assessment Team applied aerial photography and ground truthing to determine the presence of seagrass in Galveston Bay. Aerial photography was collected on January 16, 2015, and the area was ground truthed for the presence of seagrass in March 2015. Polygons were digitized where areas of seagrass were present and a resulting shapefile was created. This shapefile was updated on March 19, 2025. Likewise, TPWD completed sidescan surveys from 2008-2016 to delineated oyster habitat in Galveston Bay and areas were ground truthed. Local restoration sites were surveyed in 2019, with a total of 117,000 acres scanned. West Bay was surveyed from September 11, 2024 through September 21, 2016, with 39,000 acres scanned. These shapefiles were added to a map in QGIS to display where seagrass and oyster habitat is present in Galveston Bay.

Results and Discussion

This project focused on recreationally and commercially important species that inhabit Galveston Bay. Spawning occurs outside of the bay for most identified species, except spotted seatrout, black drum (can also spawn out of bay) and eastern oyster spawn which spawn within the bay. All of the identified species utilize Galveston Bay as a nursery area, with seagrass being an important habitat for newly settled recruits of red drum, southern flounder, spotted seatrout and brown shrimp. West Bay maintains the only remaining seagrass in Galveston Bay and seagrass has not been present near the proposed discharge and intake area since 1961. While all identified species have been collected in the proposed discharge and intake area, their presence accounted for less than 5% of the entire collection across Galveston Bay from 1982-2024. The exception is eastern oyster, which accounted for 15.5% of the entire Galveston Bay collection due to the proximity of oyster reefs to the discharge and intake area.

All species investigated in the project are euryhaline (tolerate a wide range of salinity), with each species collected over a wide array of salinities ranging from 0.9-27.9 ppt and some species being collected at salinities as low as 0 ppt or as high as 35 ppt. Documented salinity ranges varied for peak recruitment and larval development for each species, with all optimal salinity ranges for each species comprising of 17-24 ppt. Therefore, the expected discharge salinity of 21.2 ppt falls within the range of collection salinities and documented salinities for larval recruitment and development of the identified species. While shifts in abundance were evident for species between 1982-2008 and 2009-2024, these shift do not appear to be linked to the closure of PH Robinson Power Plant but instead due to overall increases or declines in population catches bay wide.

1. Fish Species

i. Red Drum

A total of 1,167 red drum were collected around the discharge and intake area primarily through TPWD gill net surveys (followed by bag seine and then bay trawl surveys) from 1982-2024 (Figure 2). Red drum collected around the discharge and intake area represent 2.5% of the total red drum catch in Galveston Bay (n = 47,614) over the same time period (Supplemental Figure

1). The average total length varied among surveys (gill net: 477 mm [18.8 in], bag seine; 126 mm [5 in], and bay trawl; 47 mm [1.9 in]) due to differences in mesh sizes of the various gear. Adult red drum spawn near tidal passes in coastal waters in the fall, with juveniles then settling into estuarine habitats where they remain through adolescence (~ 3 years [584 mm or 23 in]; Powers 2012). Peak post-settlement of red drum occurs in Galveston Bay from November to December with positive abundance correlated to seagrass coverage (Dance and Rooker 2016). Further, juvenile red drum abundance is typically higher in areas where oyster reef habitat is absent, as this habitat does not provide adequate foraging resources compared to submerged aquatic vegetation (Stunz et al. 2022; Dance and Rooker 2016). Overall red drum collections across the entire Galveston Bay complex were heavily concentrated in West Bay near seagrass habitats (Supplemental Figure 1).

The total number of red drum collected near the discharge and intake area varied from year to year (Figure 3). Red drum were collected in this area with salinity ranging from 0 – 33 ppt and an overall mean salinity of 13.6 ppt (Figure 4). Red drum can tolerate a wide range of salinities, with moderate salinities (15-25 ppt) enhancing growth in juveniles and oxygen consumption is minimal at an intermediate salinity (~20 ppt; Lanier and Scharf 2007). Martin and Esbaugh (2021) transferred juvenile red drum from tanks with 30 ppt of seawater to hypersaline tanks (60 ppt). Red drum exhibited initial increase in plasma osmolality by four hours with decreased muscle water by the four- and 24-hour mark, but recovered to control levels within 72 hours with increase to intestinal water volume. Mild differences were observed between peak abundance areas of red drum collected from 1982-2008 and 2009-2024 around the discharge and intake area (Figure 5). Average salinities at time of collection differed slightly from an average 14.1 ppt (range: 0-33 ppt) for 1982-2008 to an average of 14.0 ppt (range: 0.4-28.1 ppt) for 2009-2024.

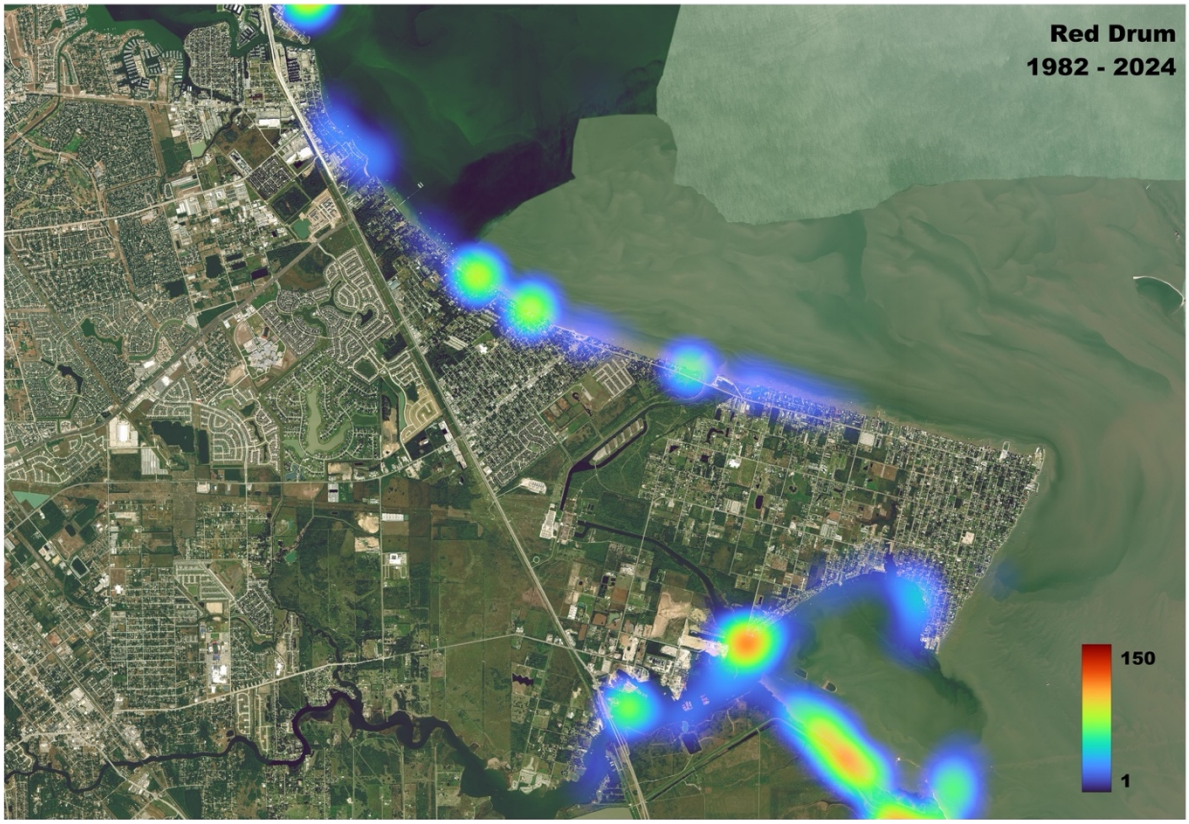


Figure 2. Heatmap of red drum catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0-33 ppt.

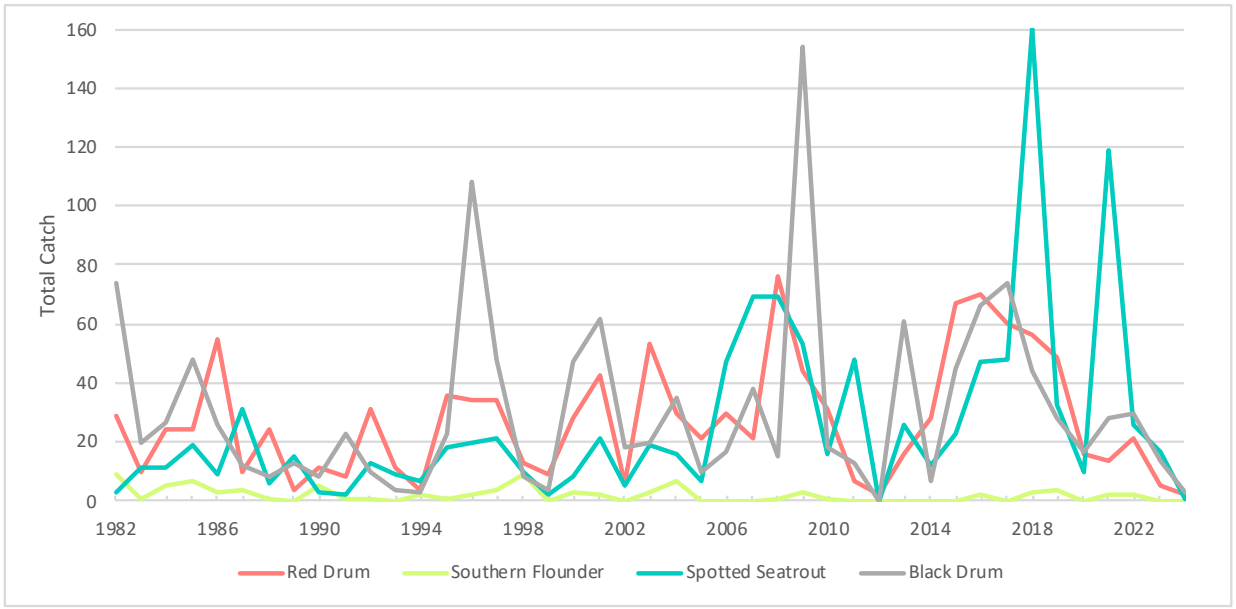


Figure 3. Total catch by year of fish species of interest collected from 1982-2024 during TPWD long-term monitoring surveys conducted near the discharge and intake area.

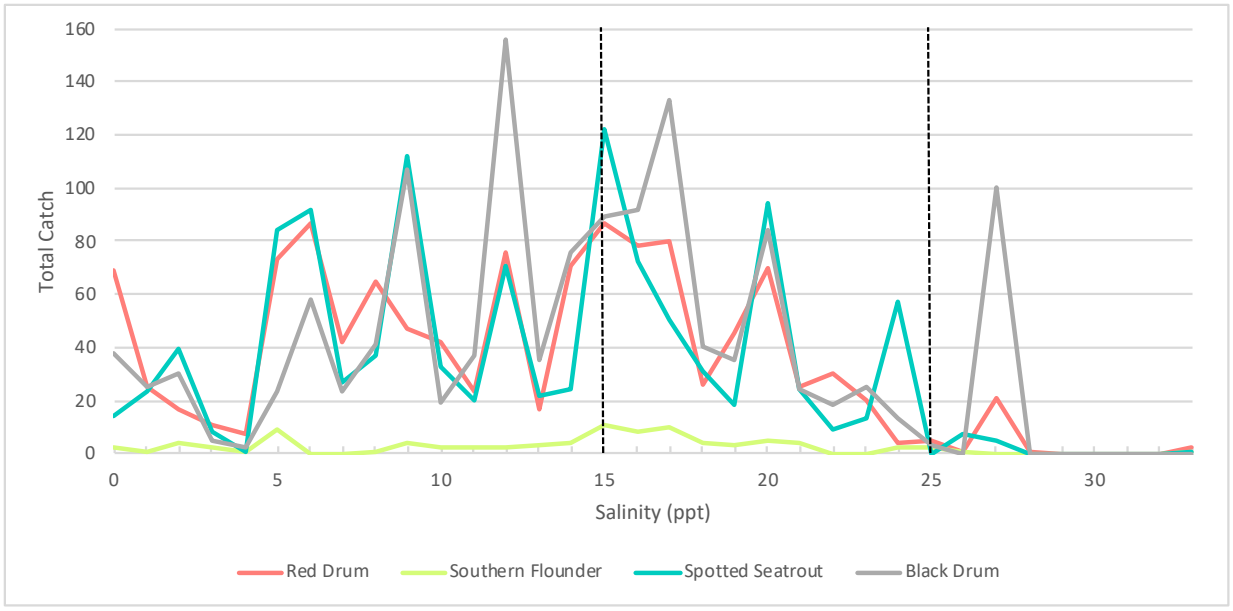


Figure 4. Total catch by salinity of fish species of interest collected from 1982-2024 during TPWD long-term monitoring surveys conducted near the discharge and intake area. While salinity ranges varied for larval development for each species, each optimal salinity range included 15-25 ppt (dashed vertical lines) based on the literature review.

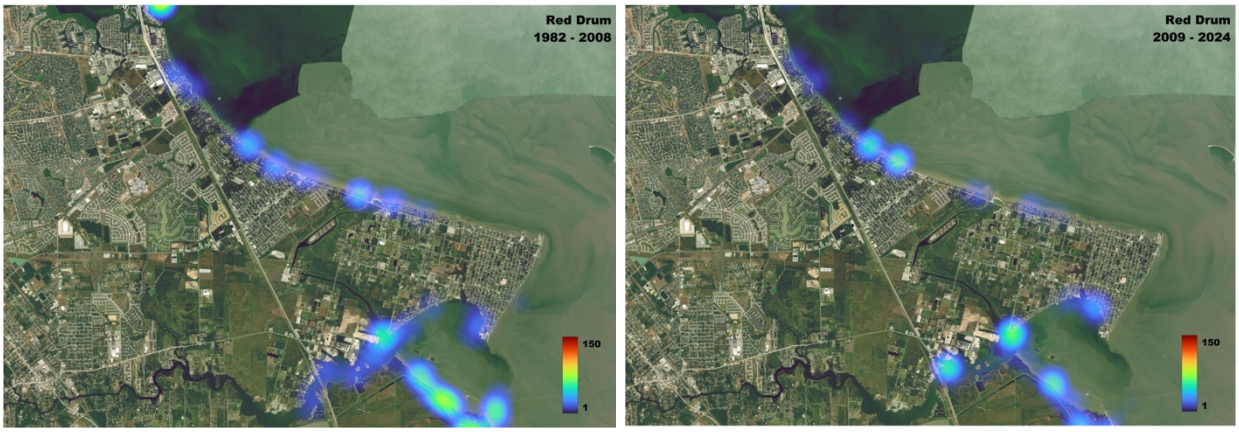


Figure 5. Heatmaps of red drum catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time collection, salinity ranged from 0-33 ppt for 1982-2008 and from 0.4-28.1 ppt 2009-2024.

ii. Southern Flounder

Southern flounder were less prevalent with a total of 88 individuals collected from TPWD surveys around the discharge and uptake area from 1982-2024 (Figure 6). This accounts for 1.7% of the total southern flounder collected in Galveston Bay (n = 5,179) over the same time frame (Supplemental Figure 2). The majority of southern flounder were collected from gill nets (average TL = 336 mm [13.2 in]) followed by bay trawl (average TL = 240 mm [9.4 in]), bag

seine (average TL = 206 mm [8.1 in]) and 1 individual collected in an oyster dredge (TL = 197 mm [7.8 in]). Residents (individuals who overwinter) and migrators (those who leave the tidal pass in the late fall/early winter to spawn [maturity reached at age 2, with females averaging 15 in]) are both present in Galveston Bay (Steffen et al. 2023). Peak recruitment of southern flounder into the estuary occurs in winter or early spring when larvae are transported back into the estuary (Glass et al. 2008), with newly settled flounder more abundant near seagrass beds (Furey and Rooker 2013). Overall southern flounder collections across the entire Galveston Bay complex were largely concentrated in West Bay near seagrass habitats (Supplemental Figure 2).

The total number of southern flounder collected near the discharge and intake area each year was less than 10 individuals (Figure 3). Southern flounder were collected in this area at an average salinity of 14.0 ppt that ranged from 0.9-33 ppt (Figure 4). This species is known to be able to tolerate a wide range of salinities, although eggs and recently metamorphosed fish (50 days old) are less tolerant of fresh water conditions (≤ 10 ppt) as they transition from coastal waters into the estuary. Post-metamorphosis southern flounder are more likely to survive at salinities ranging from 5-30 ppt, with salinity tolerance increasing with age (by 220 days old) to be able to survive lower salinities (0-10 ppt; Smith et al. 1999). Further, Tipsmark et al. (2008) demonstrated that juvenile southern flounder exposed to an abrupt salinity change (freshwater to saltwater [35 ppt] and vice versa) experienced an initial crisis period that alleviated in 1-4 days. Southern flounder populations have been declining along the Texas coast due to overfishing, along with increased water temperatures and decreased freshwater inflows (primarily in southern bay systems; Torres Ceron et al. 2023; Zapp Sluis et al. 2025). This trend is noticeable in the shifts in collection abundance between 1982-2008 and 2009-2024 around the discharge and intake area (Figure 7). Average salinities at time of collection differed from an average 14.7 ppt (range: 2-33 ppt) for 1982-2008 to an average of 11.3 ppt (range: 0.9-21 ppt) for 2009-2024.

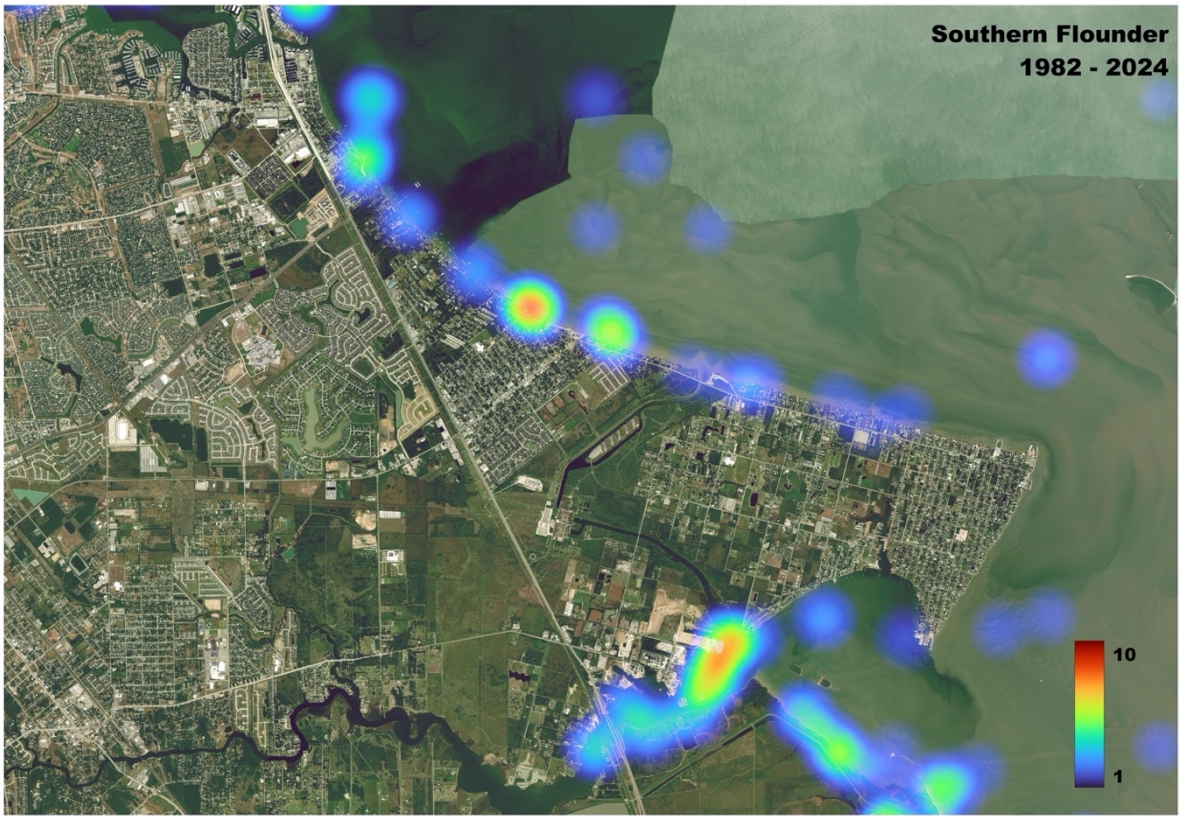


Figure 6. Heatmap of southern flounder catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0.9-33 ppt.

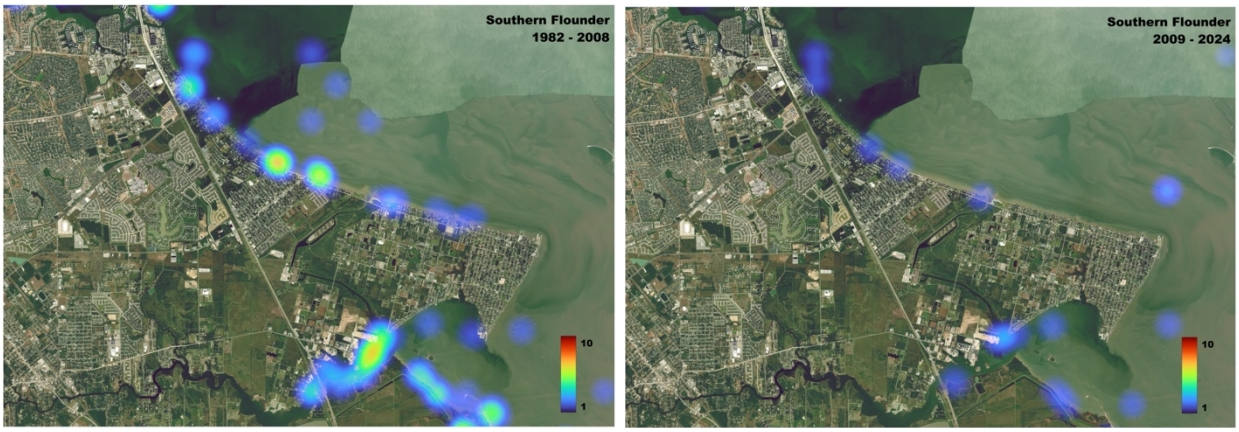


Figure 7. Heatmaps of southern flounder catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time collection, salinity ranged from 2-33 ppt for 1982-2008 and from 0.9-21 ppt 2009-2024.

iii. Spotted Seatrout

A total of 1,110 spotted seatrout were collected from 1982-2024 around the discharge and intake area as part of the TPWD long-term monitoring program surveys (Figure 8). Catch around this

area accounts for 3.3% of the total spotted seatrout collected throughout Galveston Bay (n = 33,154) over the same time period (Supplemental Figure 3). Gill net sampling accounted for the majority of spotted seatrout collections in the area (average TL = 465 mm [18.3 in]), followed by bay seine surveys (average TL = 84 mm [3.3 in]) and bay trawl surveys (average TL = 166 mm [6.5 in]). Spotted seatrout spawn within the estuary from April to October with newly settled individuals present in seagrass habitats (Rooker et al. 1998). The abundance of juvenile spotted seatrout throughout Texas estuaries peaks in October (Froeschke and Froeschke 2011). Overall spotted seatrout collections across the entire Galveston Bay complex were concentrated in East and West Bay (Supplemental Figure 3).

The total number of spotted seatrout collected each year around the discharge and intake area began to increase in 2006 (Figure 3). TPWD began regularly stocking Galveston Bay with spotted seatrout in 1998 (https://tpwd.texas.gov) and additional catch regulations were put into effect in 2003 that may have aided this increase in production. This observed increase in abundance is also evident between collections from 1982-2008 and 2009-2024 around the discharge and intake area (Figure 9). Average salinities during these time frames differed slightly from an average of 13.3 ppt (range: 0-33 ppt) for 1982-2008 and an average of 13.9 ppt (range: 0.7-27.9 ppt) for 2009-2024. The overall average salinity during spotted seatrout collections in this area was 13.6 ppt and ranged from 0-33 ppt (Figure 4). Spotted seatrout have been observed in a wide array of salinities (0.2-75 ppt), as well as spawn in salinities ranging from 21-45 ppt with varying salinities having no effect on hatch size (Kucera et al. 2002).



Figure 8. Heatmap of spotted seatrout catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0-33 ppt.

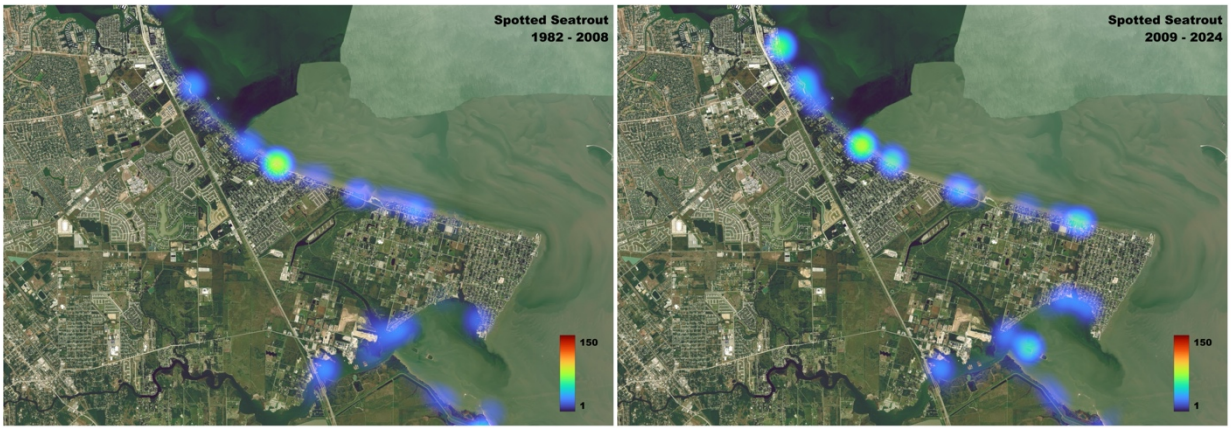


Figure 9. Heatmaps of spotted seatrout catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time of collection, salinity ranged from 0-33 ppt for 1982-2008 and from 0.7-27.9 ppt 2009-2024.

iv. Black Drum

Black drum were the most abundant fish species around the discharge and intake area with a total of 1,331 individuals collected from 1982-2024 as part of the TPWD long-term monitoring program (Figure 10). This accounts for 4.6% of the total black drum samples collected across Galveston Bay (n = 28,800) during the same time period (Supplemental Figure 4). The majority of black drum samples were collected through gill net samples (average TL = 374 mm [14.7 in]), followed by bay trawl surveys (average TL = 474 mm [18.7 in]) and bag seine surveys (average TL = 163 mm [6.4 in]). Black drum spawn in the estuaries, connecting passes or nearshore regions, with spawning primarily occurring from February – April as well as late spawning in June and July. Juvenile black drum are abundant by early summer and commonly found in shallow, muddy creeks (www.tpwd.texas.gov). In fact, black drum are not considered seagrass dependent like other estuarine species (Patillo et al. 1997). Overall black drum collections across the entire Galveston Bay complex were also concentrated in East and West Bay (Supplemental Figure 4).

The total number of black drum collected around the discharge and intake area varied annually with a peak in 1996 and 2009 (Figure 3). Differences in the location peak abundance collection areas are evident between surveys from 1982-2008 and 2009-2024 (Figure 11) correlating to the locations of increased samples collected in 1996 and 2009, respectively. Black drum were collected around the discharge and intake area at an average salinity of 13.5 ppt and ranging from 0-27.9 ppt (Figure 4). From 1982-2008, the average salinity was 13.7 ppt (range: 0-27 ppt) and 14.1 ppt (range: 0.4-27.9 ppt) from 2009-2024. Juvenile black drum in Tampa Bay were collected at a variety of salinities, but were most often found in low to moderate salinities (7-30 ppt) with unvegetated mud bottom (Peters and McMichael 1990). A study in 2014 used acoustic telemetry to track black drum in a hypersaline, reverse estuary (salinities increasing upstream; Baffin Bay) with salinities ranging from 40.2-63.6 ppt. While black drum can tolerate a variety of salinity levels, under these conditions black drum predominately remained in the interior of the bay where food sources were limited and exhibited reduced movement with increased salinity (>35 ppt; Ajemian et al. 2018).

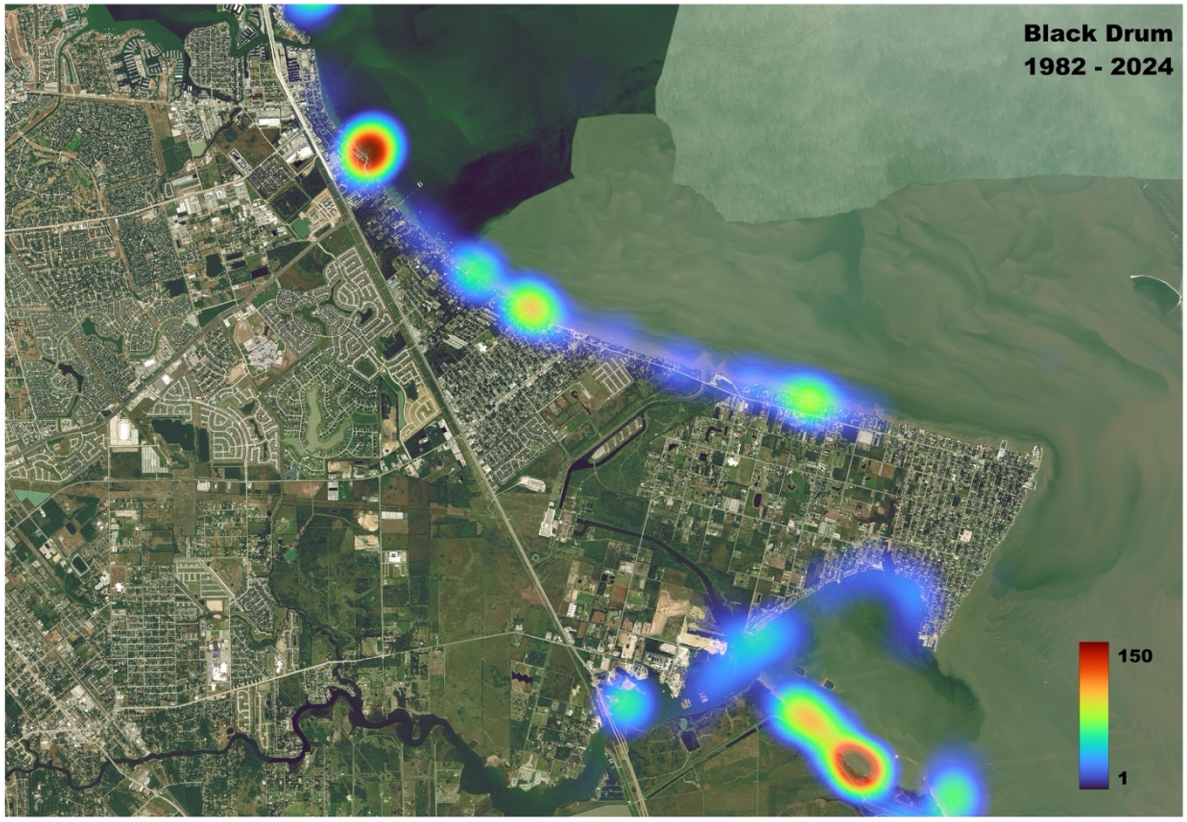


Figure 10. Heatmap of black drum catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0-27.9 ppt.

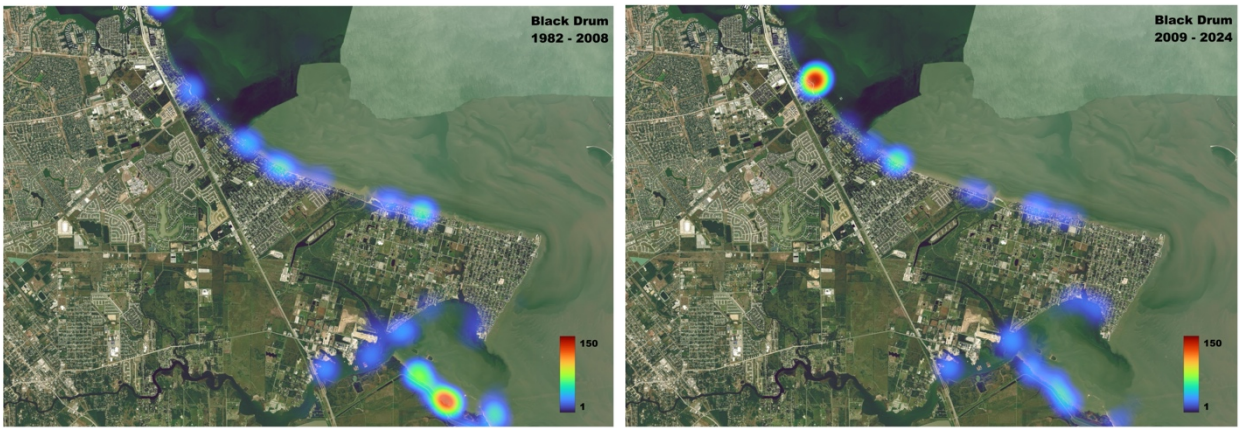


Figure 11. Heatmaps of black drum catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time of collection, salinity ranged from 0-27 ppt for 1982-2008 and from 0.4-27.9 ppt 2009-2024.

2. Invertebrates

i. Brown Shrimp

A total of 4,638 brown shrimp were collected around the discharge and uptake area from 1982-2024 during the TPWD long-term monitoring surveys (Figure 12). This accounts for 2.5% of the total catch of brown shrimp in Galveston Bay (n = 184,789) over the same time period (Supplemental Figure 5). Brown shrimp were predominantly collected during bay trawl surveys (average TL = 89 mm [3.5 in]), followed by bag seine (average TL = 60 mm [2.4 in]) and oyster dredge (average TL = 63 mm [2.5 in]) surveys. Spawning occurs offshore with postlarve settling into estuarine habitats before emigrating back offshore as subadults (Renfro and Brusher 1982). The overall density of brown shrimp in Galveston Bay is highest in the spring and declines throughout the year. Juvenile brown shrimp (<100 mm) are more abundant in lower Galveston Bay where vegetation is more prevalent, preferring seagrass over marsh edge when they co-occur (Clark et al. 2004). Overall brown shrimp collections across the entire Galveston Bay complex were heavily concentrated in West Bay among seagrass habitats and East Bay (Supplemental Figure 5).

The total number of brown shrimp collected near the discharge and intake area varied annually, with peaks occurring in 2015 and 2019 (Figure 13). Brown shrimp can tolerate a wide range of salinities, with collections in this area occurring in salinity ranging from 0 – 30.1 ppt and an overall mean salinity of 14.9 ppt (Figure 14). Juvenile brown shrimp prefer habitats with salinity ranging from 15-25 ppt, and densities on nonvegetated bottom habitats were greatest at salinity >25 ppt and declined as salinity declined (Clark et al. 2004). Doerr et al. (2016) performed experiments in gradient tanks to examine salinity preferences of shrimp and although juvenile brown shrimp where present at all salinity levels, they preferred salinities ranging from 17-35 ppt. From 1982-2008, peak abundance collection sites were evenly spaced throughout the discharge and intake area with salinity averaging 14.3 ppt (range: 0-30 ppt) during this time. From 2009-2024, the peak abundance collection areas are more concentrated near the intake area with salinity averaging 14.4 ppt (range: 0.1-30.1 ppt) during this time (Figure 15). Collections around the discharge and intake area increased to an average of 122 individuals a year between 2009-2024 from an average of 99 individuals a year between 1982-2008. Further, brown shrimp reside in Moses Lake (which borders the Texas City Prairie Preserve) and its inlet to Galveston

Bay is located just south of the intake area. Growth rates of brown shrimp collected in Moses Lake were significantly higher compared to those collected from areas in the Galveston Island State Park due to a higher benthic infauna (important food source) abundance (Leo et al. 2018). Proximity of the intake area to Moses Lake may result in higher collections in this area as shrimp move in and out of the inlet.

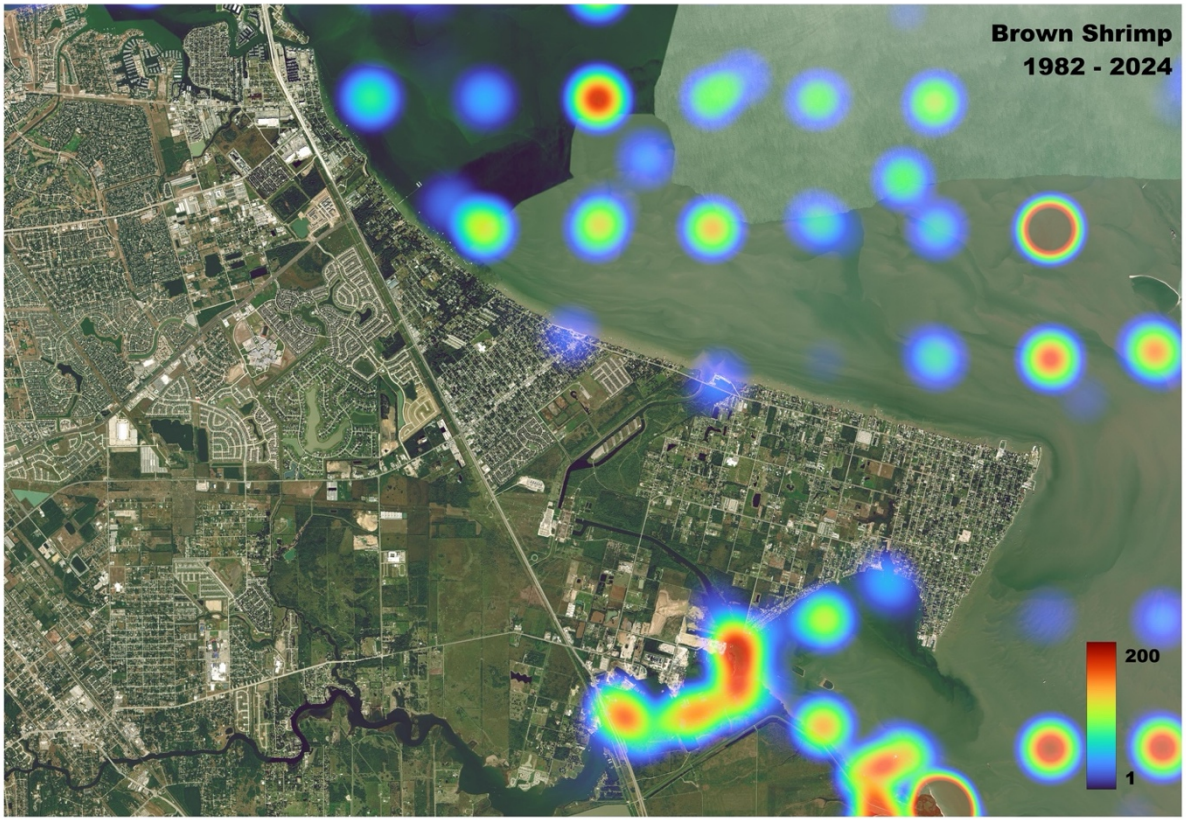


Figure 12. Heatmap of brown shrimp catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0-30.1 ppt.

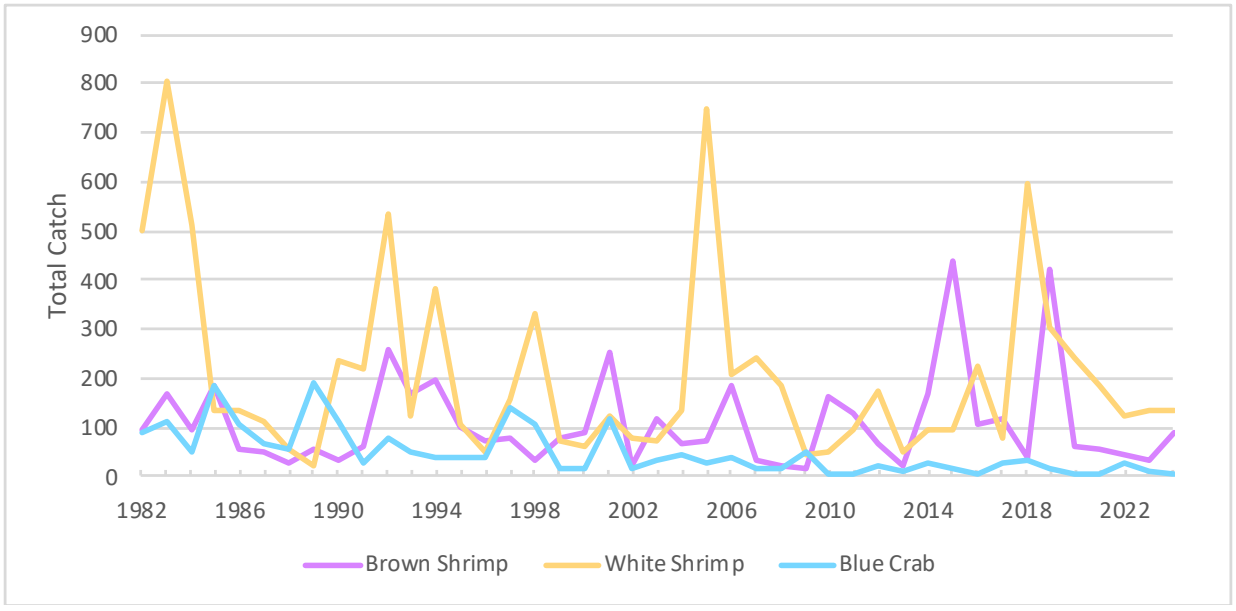


Figure 13. Total catch by year of invertebrate species of interest collected from 1982-2024 during TPWD long-term monitoring surveys conducted near the discharge and intake area.

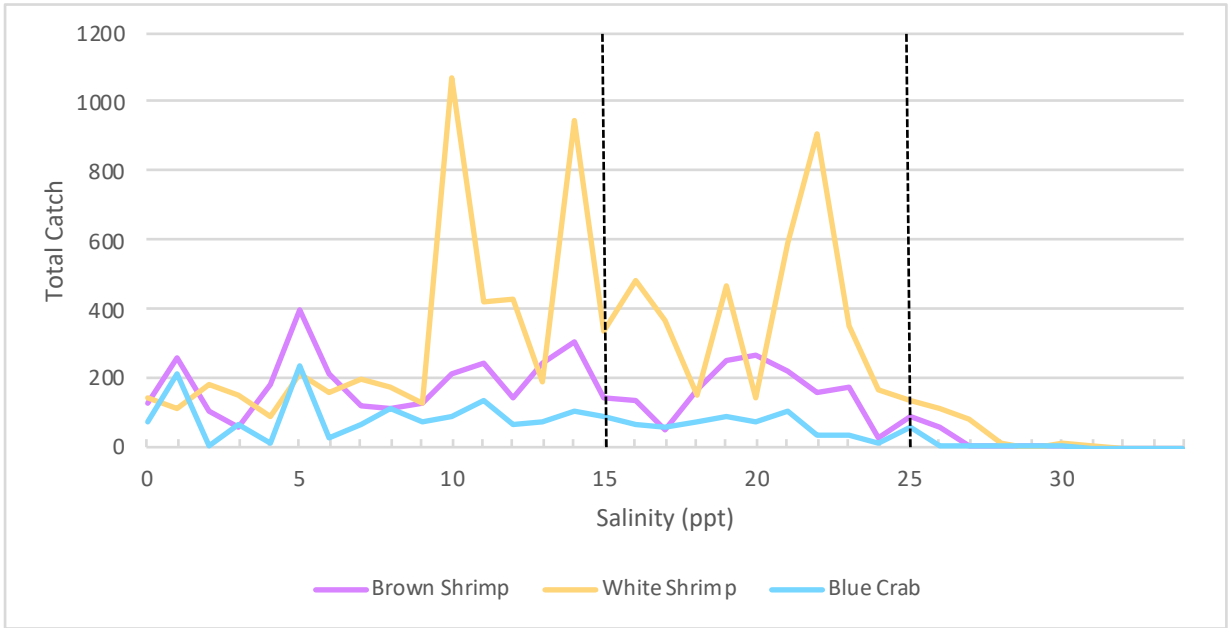


Figure 14. Total catch by salinity of invertebrate species of interest collected from 1982-2024 during TPWD long-term monitoring surveys conducted near the discharge and intake area. While salinity ranges varied for larval development for each species, each optimal salinity range included 15-25 ppt (dashed vertical lines) based on the literature review.

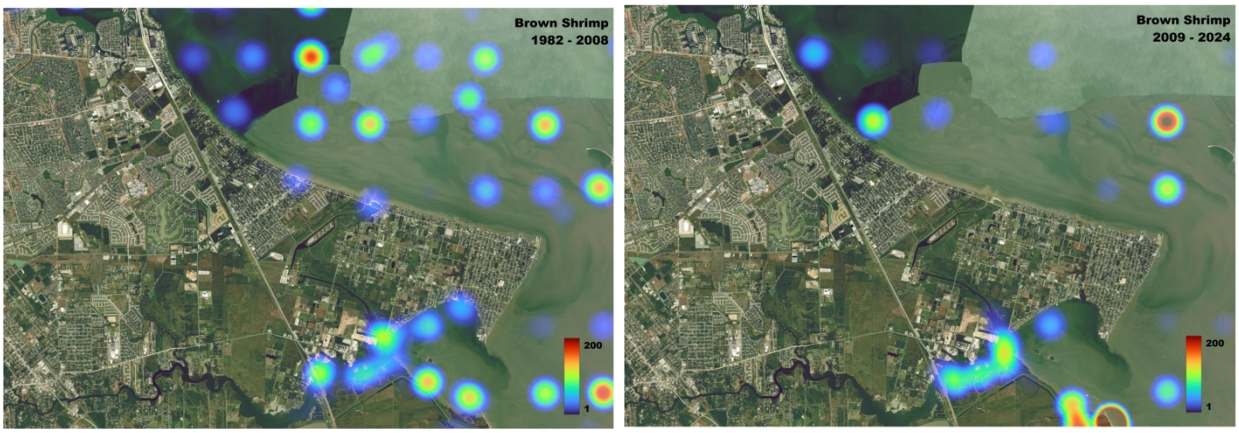


Figure 15. Heatmaps of brown shrimp catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time of collection, salinity ranged from 0-30 ppt for 1982-2008 and from 0.1-30.1 ppt 2009-2024.

ii. White Shrimp

White shrimp were more abundant than brown shrimp collected from TPWD long-term monitoring surveys around the discharge and intake area with a total of 8,969 individuals collected from 1982-2024 (Figure 16). Catch from this area accounts for 2.5% of the total white shrimp collected across Galveston Bay (n = 361,138) for the same time period (Supplemental Figure 6). White shrimp were predominately collected in bay trawl surveys (average TL = 103 mm [4.1 in]), followed by bag seine (average TL = 55 mm [2.2 in]), gill net (average TL = 146 mm [5.7 in]), and oyster dredge (average TL = 94 mm [3.7 in]) surveys. Spawning also occurs offshore, however while brown shrimp recruit to the estuaries in the early spring, white shrimp postlarvae appear in the late spring, early summer, with both continuing recruitment into early fall (Baxter and Renfro 1967) utilizing shallow salt marsh habitats. Subadult shrimp will transition to the open bay before moving offshore (Minello et al. 1989). Overall white shrimp collections across the entire Galveston Bay complex were primarily concentrated in West Bay among seagrass habitats, East Bay, and the southern portion of Trinity Bay (Supplemental Figure 6).

The abundance of white shrimp collected near the discharge and intake area varied annually with peaks occurring in 1983, 2005, and 2018 (Figure 13). White shrimp can also tolerate a wide range of salinities and were collected in the area at an average salinity of 15.3 ppt, ranging from 0-31.5 ppt (Figure 14). Both brown and white shrimp have been reported in salinities of 1-45 ppt

(Zein-Eldin and Renaud 1986). In the same gradient tank experiment as the brown shrimp, juvenile white shrimp did not show a salinity preference and did not avoid lower salinities (Doerr et al. 2016). After 2008, catches of white shrimp in TPWD surveys have been low, other than a spike in 2018. Declines in white shrimp population has been observed bay wide, with warming waters potentially limiting shrimp growth (Olsen et al. 2022). This is evident in differences in catch abundance between 1982-2008 and 2009-2024 (Figure 17). Salinities during these time periods varied slightly from an average of 14.6 ppt (range: 0-30 ppt) in 1982-2008 and to an average of 16.2 ppt (range: 0.5-31.5 ppt) in 2009-2024.

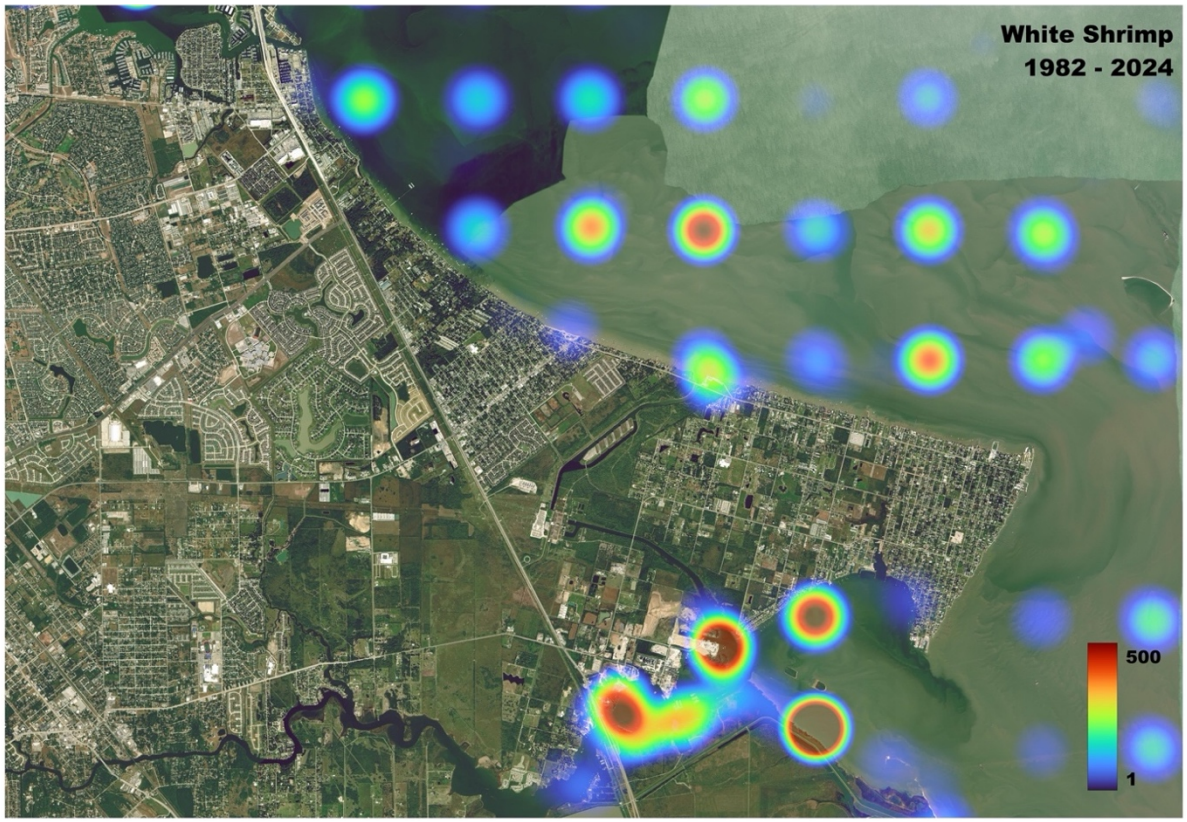


Figure 16. Heatmap of white shrimp catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0-31.5 ppt.

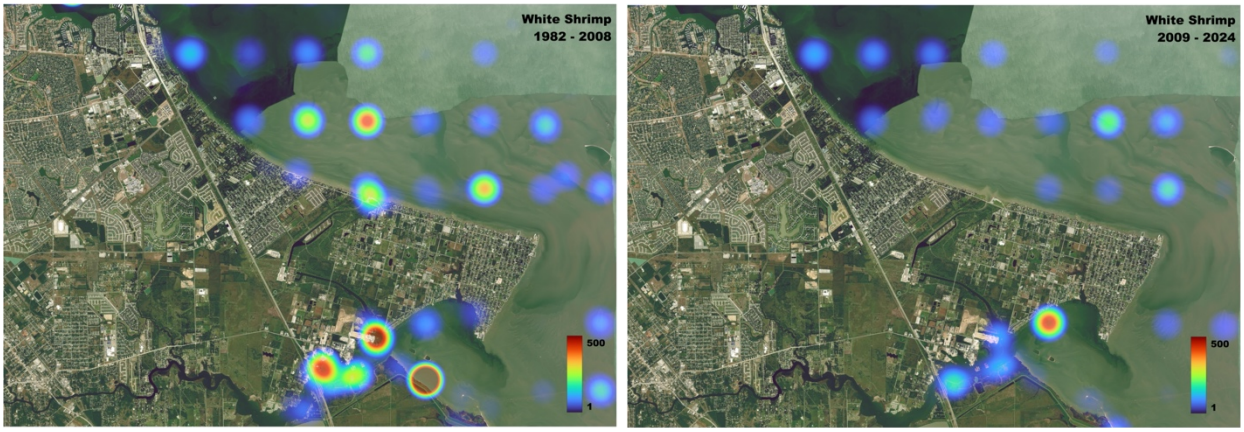


Figure 17. Heatmaps of white shrimp catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time of collection, salinity ranged from 0-30 ppt for 1982-2008 and from 0.5-31.5 ppt 2009-2024.

iii. Blue Crab

A total of 2,108 blue crab were collected around the discharge and intake area from 1982-2024 as part of the TPWD long-term monitoring program. This catch accounts for 4.1% of the overall blue crab catch in Galveston Bay (n = 51,262) during the same time period (Supplemental Figure 7). The majority of blue crab collected in the area was from bay trawl surveys (average TL = 77 mm [3 in]), followed by bag seine (average TL = 47 mm [1.9 in]), gill net (average TL = 137 mm [5.4 in]) and oyster dredge (average TL = 124 mm [4.9 in]). Blue crab megalopae settlement into the estuary peaks in late summer and fall, with adult females spawning offshore (Rabalais et al. 1995). The abundance of juvenile blue crab in lower Galveston Bay was 4.2 times higher in the marsh edge compared to shallow, open water areas (Minello et al. 2008). Overall blue crab collections occurred across the entire Galveston Bay complex with higher collections located just inside the connecting pass to the Gulf (Supplemental Figure 7).

Blue crab collections near the discharge and intake area varied annually and steadily declined after 2001 (Figure 13). Declines in blue crab populations in Galveston Bay have been linked to

overfishing and habitat loss (Rozas et al. 2007). This decline in catch is also evident in abundance heatmaps between 1982-2008 and 2009-2024 (Figure 19). Blue crab collections in the area occurred across a wide range of salinity (0-31.5 ppt), with average catch occurring at 13.4 ppt (Figure 14). The optimal salinity for blue crab to hatch is 23-28 ppt, with megalopae developing the most rapidly at salinities of 15-35 ppt (Tankersely and Forward 2007). Minimal differences in salinities at time of collection occurred from 1982-2008 (average: 13.8; range: 0-30 ppt) and 2009-2024 (average: 13.9; range: 0.4-31.5 ppt).



Figure 18. Heatmap of blue crab catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0-31.5 ppt.

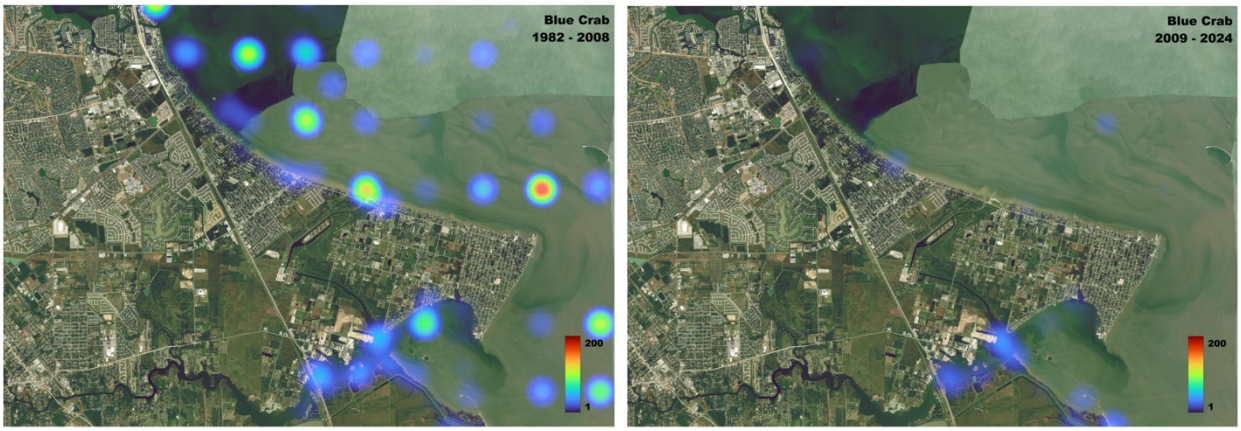


Figure 19. Heatmaps of blue crab catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time of collection, salinity ranged from 0-30 ppt for 1982-2008 and from 0.4-31.5 ppt 2009-2024.

3. Seagrass and Oyster Habitat

i. Seagrass

Seagrass was once present in the Upper Bay of Galveston Bay, with *Ruppia maritima* being the only species to occur near the discharge and intake area. In 1961, Hurricane Carla impacted the area causing extensive damage to the submerged vegetation (SV). By the winter of 1961, all SV disappeared and did not reestablish. Pulich and Write (1991) used historical photos to calculate changes in SV in the Upper Bay from 1956 and 1962. It was concluded that after Hurricane Carla, turbidity and water quality factors potentially contributed to the lack of reestablishment, along with subsidence and shoreline erosion. To date, seagrass is only present in the West Bay of Galveston Bay, with no seagrass present around the proposed discharge and intake area (Figure 20).



Figure 20. Seagrass (yellow) and oyster (pink) habitat locations in Galveston Bay. The light blue square insert highlights the proposed discharge and intake area.

ii. Eastern Oyster

Oyster habitat in Galveston Bay is primarily located in the mid-bay area (Figure 20). Eastern oyster was the most abundant species collected around the discharge and intake area with a total of 43,658 samples collected from 1982-2024 through the TPWD long-term monitoring program (Figure 21). This accounts for 15.5% of the total eastern oyster samples collected throughout Galveston Bay (n = 281,554) during the same time period (Supplemental Figure 8). Eastern oysters were primarily collected by oyster dredge surveys (average TL = 66 mm [2.6 in]), followed by bay trawl (average TL = 70 mm [2.8 in]), bag seine (average TL = 67 mm [2.6 in]), and gill net (average TL = 74 mm [2.9 in]) surveys. Spawning is linked to temperature, occurring in Galveston Bay from late spring to early fall when weather is warmer (www.tpwd.texas.gov). Overall eastern oyster collections across the entire Galveston Bay complex were heavily concentrated in Upper/Mid Bay along known oyster habitat, with a portion of this habitat located near the discharge and intake area (Supplemental Figure 8).

The annual total catch of eastern oyster has steadily declined around the discharge and intake area since 1991 (Figure 22) and this decline has been observed bay wide due to overfishing, habitat loss and weather events (Du et al. 2021). While eastern oysters were collected over a range of salinities (range: 0-35 ppt; average: 16 ppt), this was the only species that displayed a single peak in abundance for a salinity value (20 ppt; Figure 23). Decreases in oyster production are a result of high freshwater inflow as salinity in the primary factor controlling oyster distribution, with higher salinities resulting in increased larval growth rate (Dekshenieks et al. 2000). Stronger recruitment events occur when salinities range from 17-24 ppt and recruitment ceases when salinity drops below 8 ppt (Hofstetter 1983). The decline in eastern oyster abundance is evident when comparing catch between 1982-2008 and 2009-2024 (Figure 24). Salinities varied over these collection periods with salinity averaging 14.5 ppt (range: 0-35ppt) from 1982-2008, and salinity averaging 7.3 ppt (0.5-32.5 ppt) from 2009-2024. Reduction in oyster populations has been linked to overharvesting, hurricanes, and spring flooding events in the upper bay (Dekshenieks et al. 2000).



Figure 21. Heatmap of eastern oyster catch from TPWD long-term monitoring program from 1982-2024 conducted near the discharge and intake area. During the time of collection salinity ranged from 0-35 ppt.

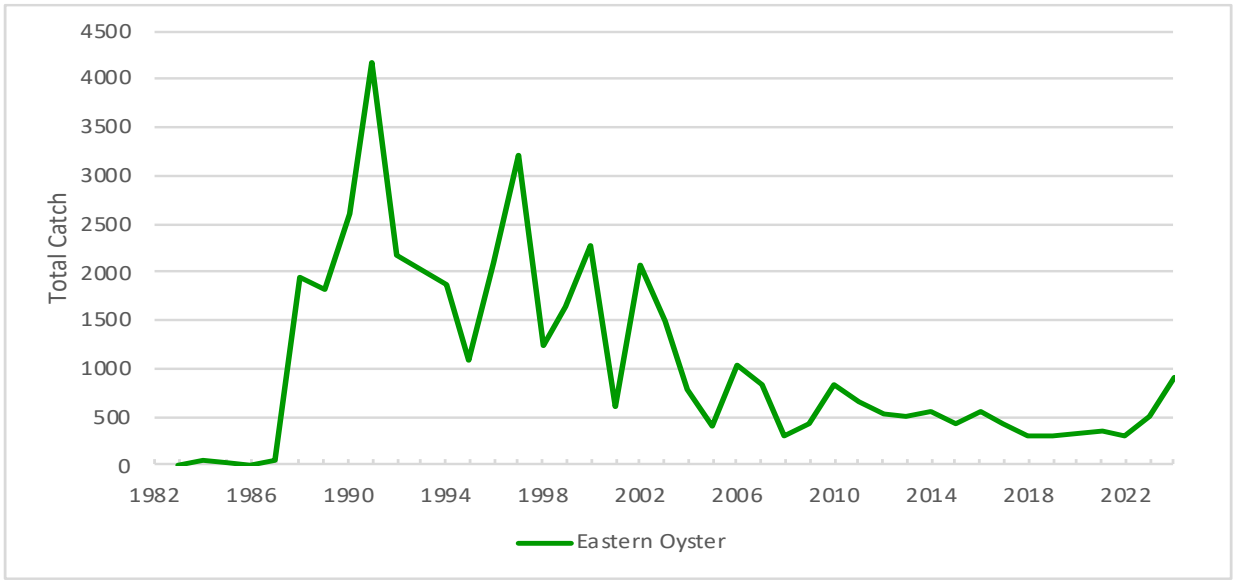


Figure 22. Total catch by year of eastern oyster collected from 1982-2024 during TPWD long-term monitoring surveys conducted near the discharge and intake area.

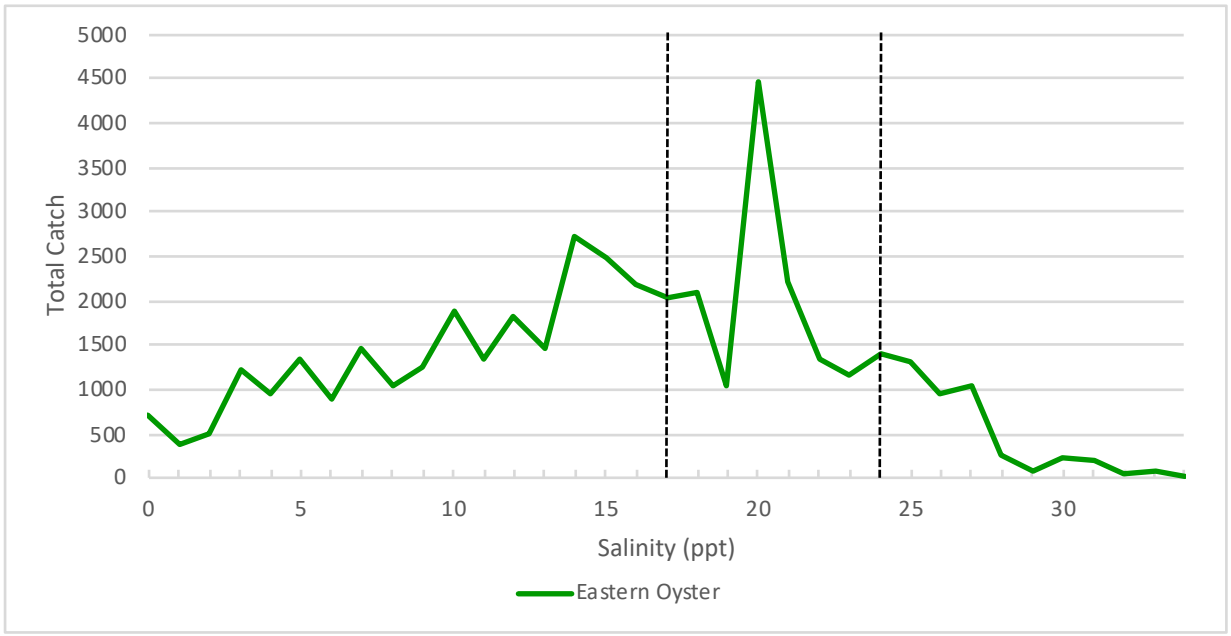


Figure 23. Total catch by salinity of eastern oyster collected from 1982-2024 during TPWD long-term monitoring surveys conducted near the discharge and intake area. The optimal salinity range is 17-24 ppt (dashed vertical lines) based on the literature review.

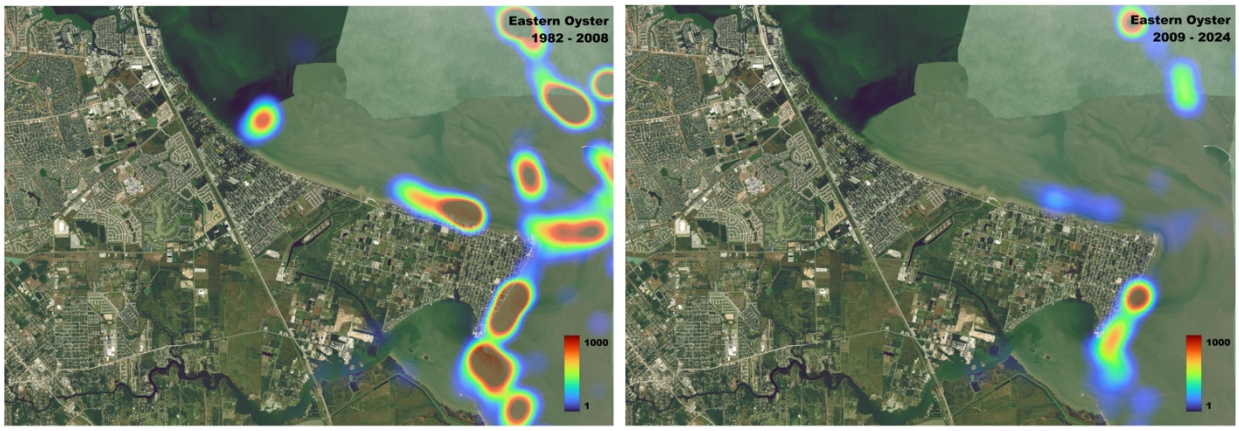


Figure 24. Heatmaps of eastern oyster catch from TPWD long-term monitoring program illustrating differences in catch between 1982-2008 and 2009-2024 conducted near the discharge and intake area. During the time of collection, salinity ranged from 0-35 ppt for 1982-2008 and from 0.5-32.5 ppt 2009-2024.

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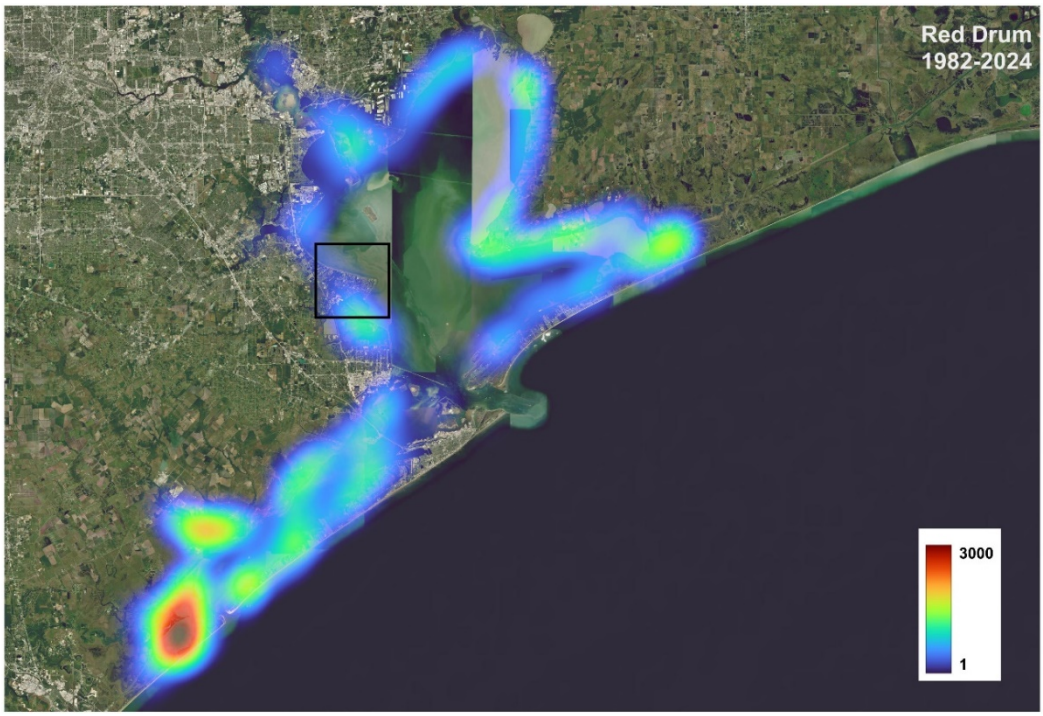
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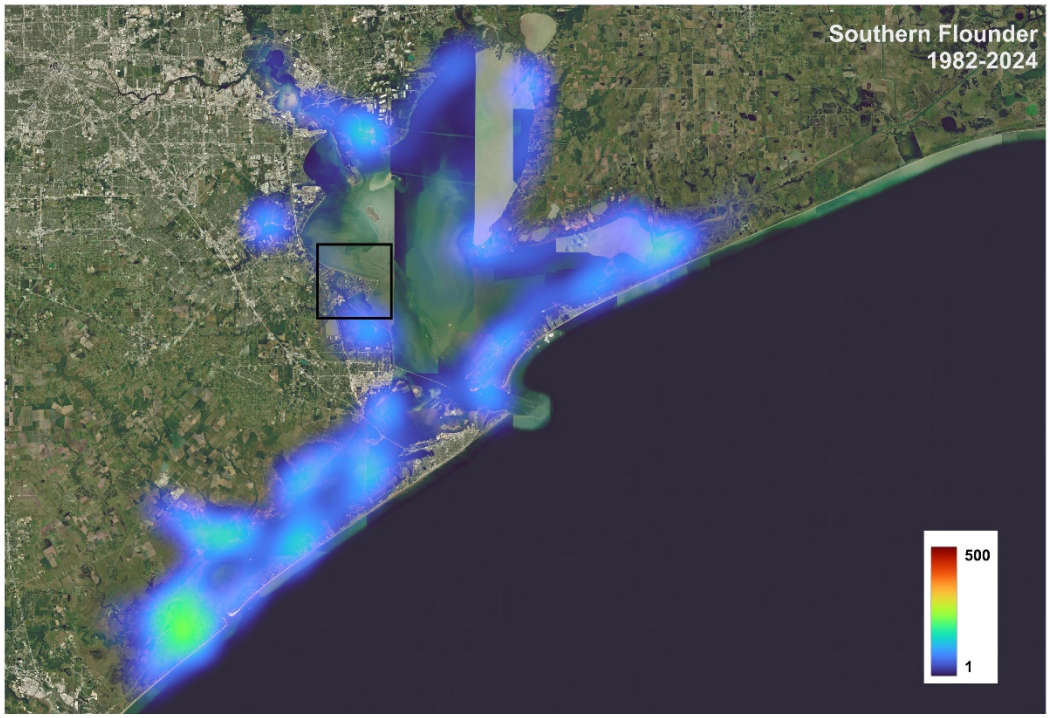
Supplemental Data

Supplemental Table 1. Total catch, salinity, temperature, dissolved oxygen (DO), and turbidity of species collected near the discharge and intake area from 1982-2024 from TPWD long-term monitoring program.

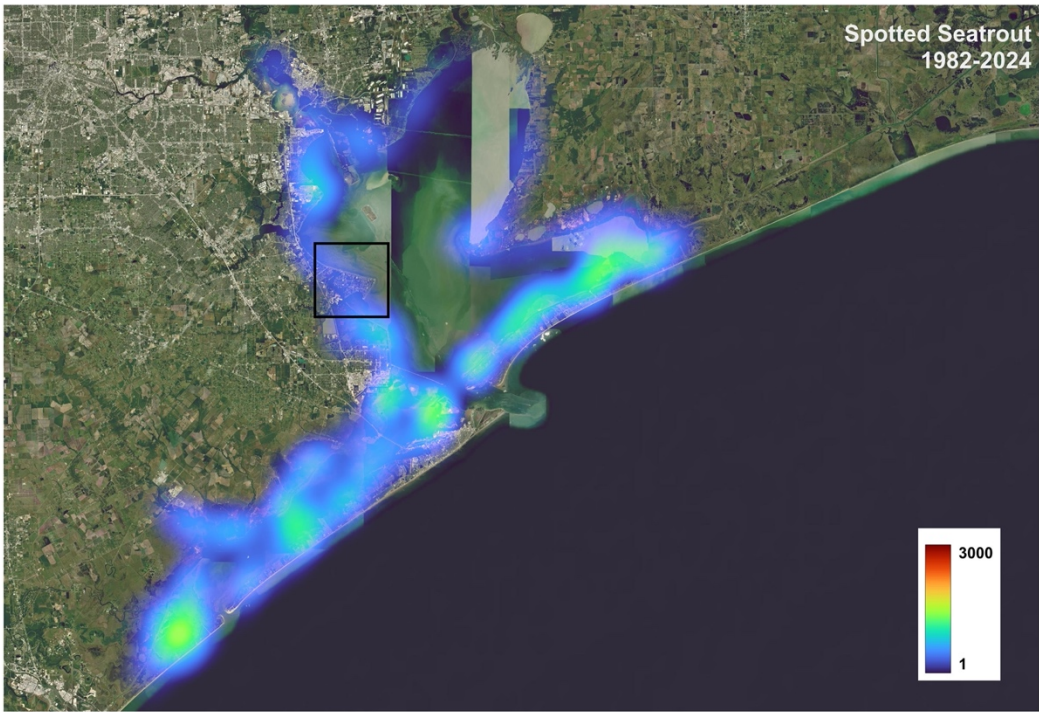
Species	Total Catch	Salinity (ppt)			Temperature (◦C)			DO (ppm)			Turbidity (NTU)		
		Mean	Mode	Range	Mean	Mode	Range	Mean	Mode	Range	Mean	Mode	Range
Red Drum	1,167	13.6	5.0	0-33	24.4	28.0	10-31.7	7.8	8.3	2-14	24.8	11.0	3-170
Southern Flounder	88	14.0	17.0	0.9-33	24.6	25.5	10.2-31.8	7.9	6.6	4.3-14	34.6	24.0	4-170
Spotted Seatrout	1,110	13.6	5.0	0-33	24.5	26.0	8.2-35.2	7.8	8.3	2.5-14	24.2	20.0	3-170
Black Drum	1,331	13.5	15.0	0-27.9	24.8	28.0	8.6-31.9	7.8	8.3	2-14.3	23.6	11.0	1-170
Brown Shrimp	4,638	14.9	11.0	0-30.1	26.4	29.5	11.1-35.2	7.0	8.0	2.3-14	25.9	24.0	1-270
White Shrimp	8,969	15.3	20.0	0-31.5	22.4	23.5	6.0-35.2	7.7	7.0	2.3-17	26.3	24.0	1-270
Blue Crab	2,108	13.4	10.0	0-31.5	23.9	29.0	9.0-35.2	7.7	9.0	2-16	28.6	24.0	1-270
Eastern Oyster	43,658	16.0	20.0	0-35	22.1	29.5	5.3-34.1	7.6	7.1	0.9-20.6	18.8	10.0	0-850



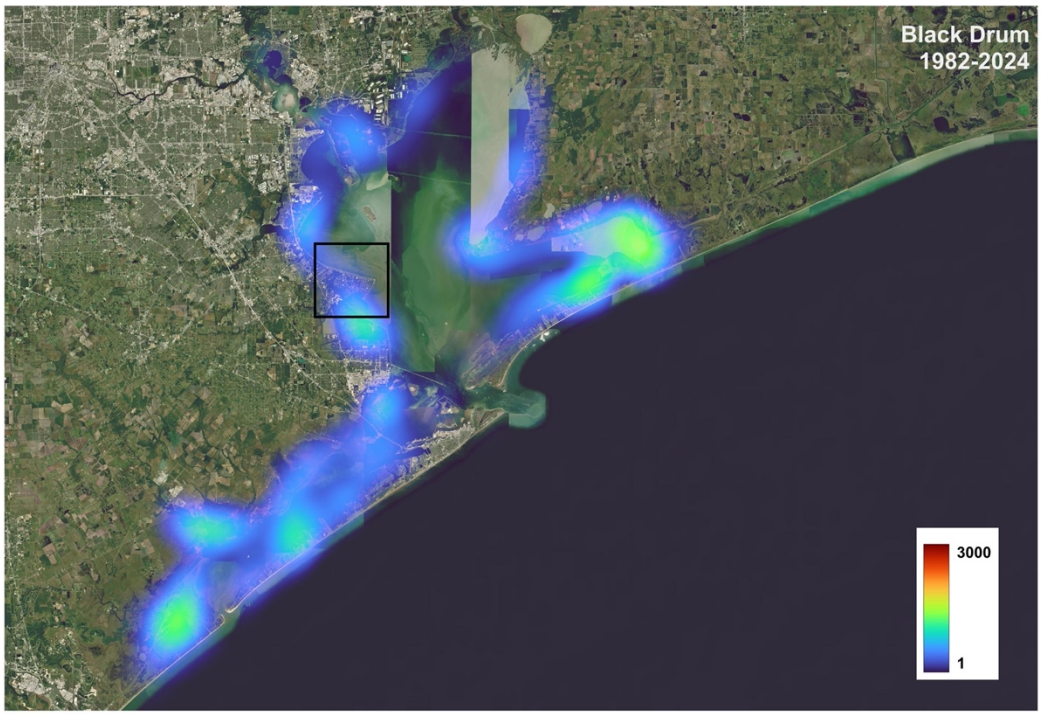
Supplemental Figure 1: Total red drum catch (n = 47,614) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.



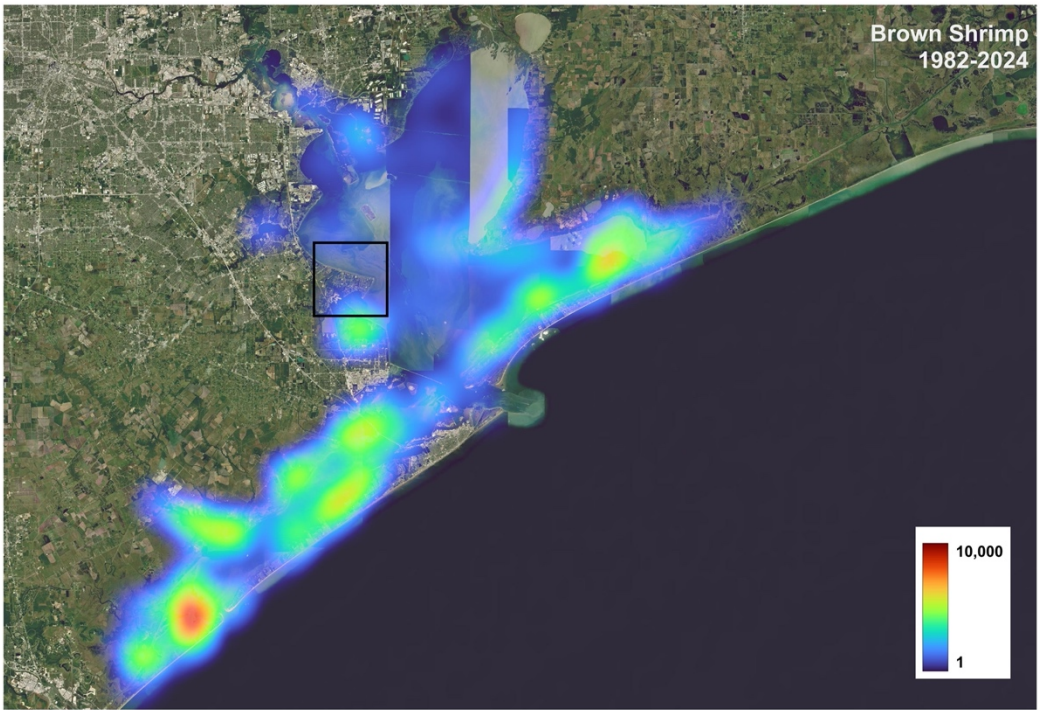
Supplemental Figure 2: Total southern flounder catch (n = 5,179) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.



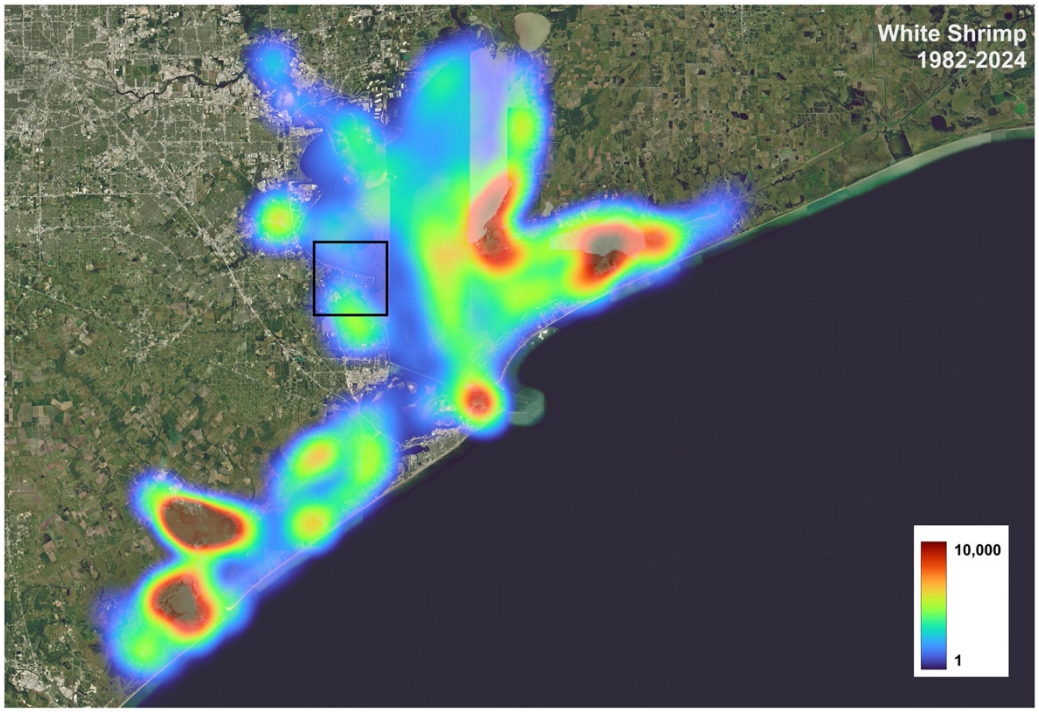
Supplemental Figure 3: Total spotted seatrout catch (n = 33,154) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.



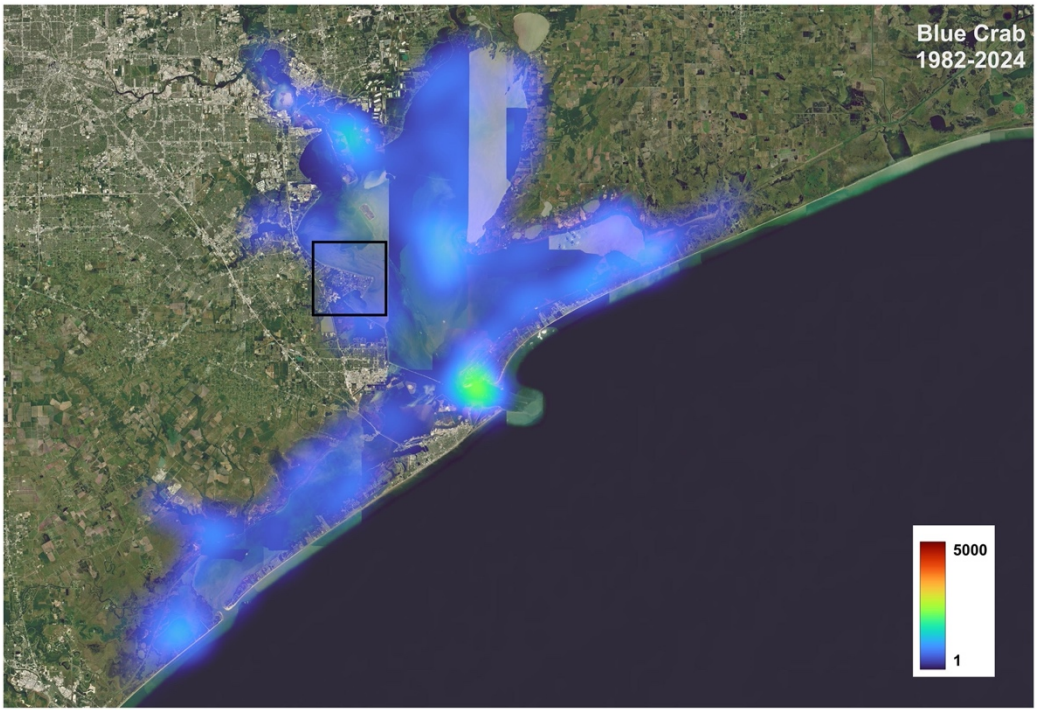
Supplemental Figure 4: Total black drum catch (n = 28,800) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.



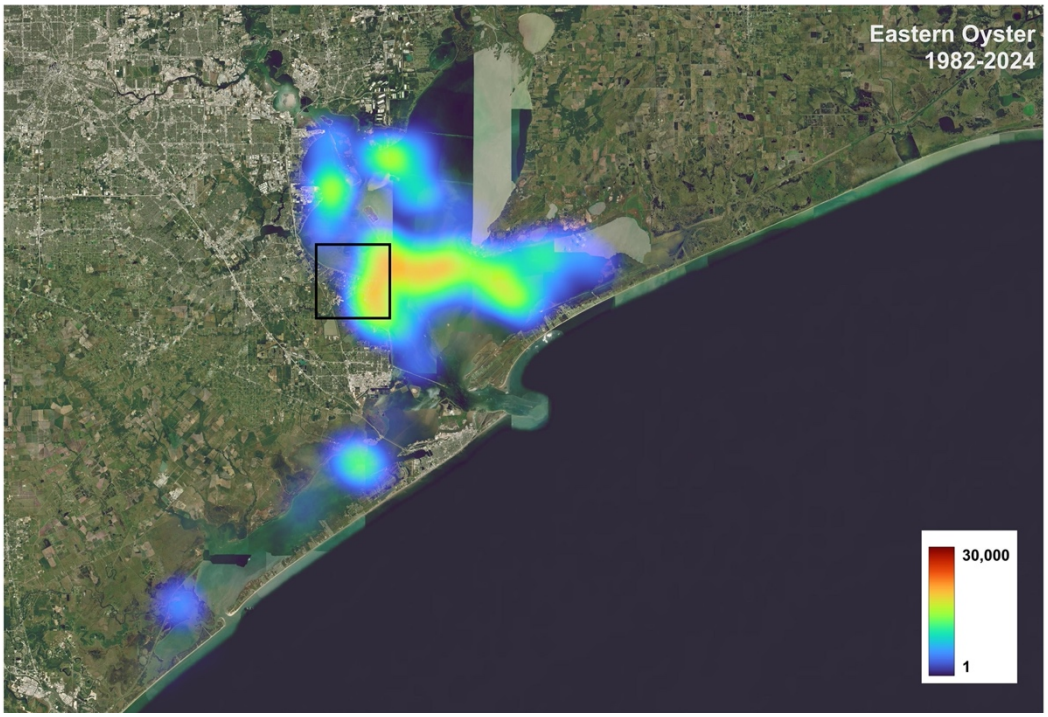
Supplemental Figure 5: Total brown shrimp catch (n = 184,789) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.



Supplemental Figure 6: Total white shrimp catch (n = 361,138) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.



Supplemental Figure 7: Total blue crab catch (n = 51,262) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.



Supplemental Figure 8: Total eastern oyster catch (n = 281,554) across Galveston Bay through the TPWD long-term monitoring program from 1982-2024. Black box highlights proposed intake and discharge area.