CAERNARVON FRESHWATER DIVERSION PROJECT

ANNUAL REPORT 2003

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1. INTRODUCTION

The Caernarvon Freshwater Diversion Project was authorized by the U.S. Congress under the Flood Control Act of 1965 and the Water Resources Development Act of 1974, 1986, and 1996. The structure is located on the east bank of the Mississippi River (mile 82) in Plaquemines Parish near Braithwaite. It is designed to re-introduce up to 8,000 cubic feet per second (cfs) of freshwater, sediments, and nutrients into the marshes and bays of the Breton Sound estuary. The objectives of the project are to enhance emergent marsh vegetation growth, reduce marsh loss, and increase the productivity of significant commercial and recreational fish and wildlife. The project was constructed between 1988 and 1991 and began operations in August 1991. To evaluate the project effectiveness, the monitoring consists of a 3-year preconstruction phase, a 4-year post-construction phase and a 46-year long-term monitoring phase. Below is a summary of the primary monitoring elements. All fisheries and wildlife data are collected by the Louisiana Department of Wildlife and Fisheries. Some data presented are provisional. The reporting period for this report is October 2002 through September 2003.

2. OPERATIONAL DATA

Discharge (Figures 1-2, Tables 1-2)

Caernarvon discharge for the reporting period (October 2002-September 2003) averaged 2,211 cfs when the structure was operational and 1,241 cfs including non-operational periods. The 12-year average for discharge is 1,741 cfs when the structure was operational and 1,108 cfs including non-operational periods. Discharge was highest between January and March, averaging in the 3,500-4,500 cfs range and lowest in the fall months when low river stage precludes operating the structure for significant periods. Although the structure was closed for 36% of the time for a variety of reasons, this was slightly greater than the long-term average of 35%. Closures resulted from low stage on the river, tropical activity in the Gulf of Mexico or high tidal events. On February 17- March 2, 2003 and on March 17-March 31, 2003 the structure was opened to 6,500 cfs for the LSU PULSE study. The high pulse of two weeks is contrasted with low flows of 0 cfs on February 10-February 17, 2003, March 3-March 16, 2003, and on April 1-April 10, 2003. As can be seen in figure 2, Caernarvon yearly discharge has been fairly consistent in the past several years and the long-term average is 21% of the capacity of the structure.

3. PHYSICAL DATA

Rainfall (Figure 3)

Rainfall data are obtained from the LSU Southern Regional Climate Center from stations located at Chalmette, New Orleans, Audubon, and LSU Citrus. The 30 year long-term average is from New Orleans, Audubon station.

The total rainfall for the time period was 70 inches which was 6 inches above the long-term average. Much of the time period rainfall was below the long term-average; the surplus was made during June-August due to tropical storm activity. Cumulative rainfall graphs from the Southern Regional Climate Center indicate a surplus of precipitation in the latter half of 2003 and a deficit for the first half of 2003. Tropical storm Bill impacted the Caernarvon area in June-July 2003.

River Stage (Figure 4)

Mississippi River stage data are obtained from the U.S. Army Corps of Engineers at the Carrollton gauge in New Orleans.

The average annual river stage of 6.3 ft, NGVD was slightly below the 65-year long-term average of 6.8 ft, NGVD. The mean monthly stage deviated from the long-term average between February and June 2003. In March and June 2003, river stage was above the long-term average, and in February, April, and May 2003, river stage was below the long-term average. Stage was unusually low in February and April 2003.

Wind (Figure 5)

Wind data are obtained from the LDNR data collection platform in Bay Gardene. Resultant wind speed and direction are calculated from an algorithm provided by the Southern Regional Climate Center.

Wind direction was primarily out of the northeast during the winter months, largely due to frontal passage and out of the southeast during the spring and summer months. Southerly and easterly winds can increase water stage in the Breton Sound estuary while northerly winds decrease stage. Highest winds were noted in May and September.

Salinity (Figures 6-7)

Four real-time Data Collection Platforms (DCPs) are located strategically in Breton Sound estuary to monitor salinity levels. These platforms assist active operation and management of the Caernarvon structure. The Bay Gardene gauge has been operational since 1992, the Cow and Crooked Bayou gauges since 1997 and the Reggio Canal gauge since 1999. Cow and Crooked Bayou gauges are located on the post-construction 5 ppt line.

All gauges exhibited a similar pattern between October 2002 and September 2003. Reggio Canal, which is located at the top of the estuary and nearest the diversion structure, exhibited little variation throughout the time period and remained below 2 ppt. However, even at the top of the basin, Reggio Canal can show increased salinities in the fall when the diversion is usually closed due to backflow conditions. In past years, salinity has reached as high as 7 ppt at Reggio Canal in October 1999.

Cow Bayou was inoperable all of the year. This gauge has been repeatedly knocked over by boats. A more substantial platform will be installed in early 2004. Crooked Bayou is also missing data for a variety of reasons. A more substantial platform will also be installed for Crooked Bayou.

Salinities at Bay Gardene, Crooked Bayou and Reggio Canal show a generally similar pattern in that peaks and troughs. However the pattern is puzzling for salinity during the time period considering data on freshwater inputs. At Bay Gardene, salinity decreased from October 2002 to January 2003, then exhibited a variable up and down period until July 2003, then increased precipitously in August 2003. At Crooked Bayou, low salinities also start in October 2002 and persist until July 2003 with increases similar to Bay Gardene. Salinities remained below 5 ppt almost all year. According to rainfall data from the LSU Southern Regional Climate Center, New Orleans exhibited a rainfall deficit for all of 2002 and until July 2003. Mississippi River levels were near normal for the reporting period. Caernarvon freshwater inputs were below average for October 2003-December 2002, above average for January to March 2003 and below average for the rest of 2003. Despite this relative lack of freshwater input, Crooked Bayou remained below 5 ppt for much for much of the reporting period.

4. WILDLIFE DATA

Alligator (Figures 8-9)

Alligators (Alligator mississippiensis) are most abundant in fresh/intermediate marshes. Their numbers are reduced in more saline habitats; however, they do occur in brackish marshes. The alligator population in the Breton Sound estuary is surveyed annually by the Louisiana Department of Wildlife and Fisheries (LDWF) via aerial nest inventories conducted in late June or early July after nesting is complete. The north-south transect lines are illustrated in figure 8.

Counts of alligator nests conducted during the pre and post operational period are presented in figure 9. Although the Caernarvon structure became operational in 1991, the structure was operated minimally due to excessive rainfall that year. Since the opening of the Caernarvon structure counts of alligator nests have increased 153%. Prior to 2000, alligator nests occurred mostly in brackish marsh. Since 2000, nests in intermediate marsh have substantially increased. Nests in fresh marsh have been documented in 1999 for the first time since 1987 when data collection started. The shift from brackish environment to intermediate environments is due both to a shift in habitat from brackish to intermediate but also alligator nest are being found in more southerly areas. Discussion with landowners who conduct alligator and egg harvest also indicate an increase in alligators since Caernarvon started operation. Alligator production is expected to increase as more habitat becomes available and food resources favorable to alligators continue to increase with diversion operation.

Addendum to the 2002 alligator graph: Two files were used in that report that included duplicate data from 1998-2002. As a result, some numbers were double counted in that graph. That error has been fixed in the current graph.

Waterfowl (Figures 10-11)

LDWF conducts waterfowl surveys along three transects within the Breton Sound estuary. These surveys are flown monthly from September through February and the numbers of each waterfowl species observed are estimated and recorded when the transect is flown.

Year to year number of waterfowl counted is variable but shows a generally increasing trend, particularly since 1998. Overall, waterfowl increased 100% during the post-operation period. In the pre-operation period about 67% of ducks counted occurred in brackish and intermediate marsh whereas in the post-operation period it is 88%. Waterfowl counts are highly variable due to weather and other conditions; however, habitat and food resources for waterfowl in the upper basin remain favorable for waterfowl.

5. FISHERIES DATA

Meter Square (Figures 12-14)

Meter square sampling of seed, sack, and dead oysters (Crassostrea virginica) is conducted at 27 stations within the Breton Sound estuary to monitor the effects of the Caernarvon freshwater diversion on oyster productivity.

Seed and sack oysters increased substantially during the post-operation period. Although dead oysters increased also, dead oysters constitute a much higher percentage during pre-operation than post-operation. The highest percentage mortality occurred in 1991 at 56% and the lowest was 2% in 2000 and the overall percentage mortality dropped from 36% pre-operation to 7% post-operation. All stations with the exception of station 25, which is furthest from the diversion in Breton Sound, had higher oyster abundance during post-operation. Meter square sampling for the post-operational period is five times higher than the preceding 18 years (Laiche et. al. 2002). It is unclear what caused the decrease in oysters in 1997 through 1999. It may be related to a decrease in discharge that was initiated in 1997 with a new operational plan. However a dermo (Perkinsus marinus) outbreak occurred in 1996 which affected spat numbers. Oyster productivity then rebounded in 2000 and decreased in 2001-2003. Oyster production on the public seed grounds has remained consistently high since Caernarvon opened. Compared to the pre-Caernarvon production, it is quite remarkable (Figure 14).

Boarding Surveys (Figure 15)

Oyster harvest is monitored by boarding and estimating the number of oysters on boats dredging in Breton Sound. Average production of sack oysters increased 280 % over the pre-operation period. Oyster harvest is also more consistent and reliable in the post-operation period. The greatest average harvest occurred in 2002 and the least in 1990.

Nestier Trays (Figures 16-17)

Nestier trays (plastic trays to which oysters are attached) are used to assess mortality and growth rates of oysters throughout the basin. Fourteen stations are chosen throughout the basin. Trays are deployed in January and are checked at the end of each month for mortality.

Overall, survival between the 2002 and 2003 was similar. Survival was somewhat higher earlier in the year of 2003 compared to 2002. Overall survival in 2002 and 2003 was about 24%. This compares to an overall survival in the post-operation period of 35%. Overall survival in the pre-operation period was 65%. In both years, 54% of stations sampled experienced 0% survival by the end of the year. In both years, at stations where oysters did survive the entire year, survival was generally high. In both years, survival north of the 5 ppt line was much lower than south of the line. Low salinities from October 2002 to August 2003 likely contributed to low survival above the 5 ppt line.

Finfish Data (Figures 18-19)

To simplify presentation, data on 6-foot and 16-foot trawls are combined and presented as “Trawl” data and data on seines and gill nets are combined and are presented as “Seine” data. Data are presented as catch per unit effort (CPUE) for stations above and below the 5 ppt line. Data are presented for Black Bass (Micropterus salmoides), Red Drum (Sciaenops ocellatus), Spotted Seatrout (Cynoscion nebulosus), Blue Crab (Callinectes sapidus), Brown Shrimp (Farfantepenaeus aztecus) and White Shrimp (Litopenaeus setiferus).

BLACK BASS (Figures 20-21)
Black bass is primarily a freshwater species that can also be found in brackish environments. Few bass were caught in trawls during the pre or post operational period. However catch was about 85 % higher in the post-operational period in the seine data. Almost all bass were caught above the 5 ppt line. Bass were caught during almost all months post-operation as opposed to few times pre-operation.

RED DRUM (Figures 22-23)
Adult red drum live in the nearshore and offshore Gulf of Mexico and spawn near the mouths of tidal passes. The juveniles spend the first 1-3 years in the inshore estuaries and marshes.

Red drum catch was 22% higher during the post-operational period in the seine data. Fish were caught both below and above the 5 ppt line. The catch appeared relatively consistent across years of post-operation with peak catches in 1995 and 1998. Peak catches occurred above the 5 ppt line. Catch in the trawl data was light for both periods. This pattern was expected to continue.

SPOTTED SEATROUT (Figures 24-25)
Spotted seatrout are widely distributed in coastal estuaries and utilize tidal marshes and creeks as nursery grounds. In trawls, catch was 36% higher in the post-operation period than pre-operation. Spotted seatrout were caught more frequently above and below the 5 ppt line in the post-operation period. Catch above and below the 5 ppt line post-operation is similar. In the seine data, catch was 26% more prevalent in the post-operation period. Catch was even above and below the 5 ppt line in the pre-operation period, but 46% higher above the 5 ppt line in the post-operation period.

BLUE CRAB (Figures 26-27)
In trawls, the mean blue crab catch was about 45% greater in the pre-operation period than the post-operation. This appears to be due to an exceptionally abundant catch in 1990. Catch of crabs in trawls was much more prevalent below the 5 ppt line in the pre-operation period; in the post-operation period the catch below the 5 ppt line is only slightly higher than below the line. Crab trapping was introduced in the monitoring in 2001 and is reflected in the higher numbers caught in 2001 and 2002 in seines. In seines, mean catch was about 18% higher during the post-operation period and more crabs are caught below the 5 ppt line. Much of the increase appears to be since 1998. Reports from fishers indicate a very good crab harvest for 2002.

BROWN SHRIMP (Figures 28-29)
Mean brown shrimp catch in trawls was about 6% greater in the pre-operation time period. Catch below the 5 ppt was higher in the pre-operation period with catch above the 5 ppt line being higher in the post-operation period. The catch above the 5 ppt line in the post-operation period almost equals the catch below the 5 ppt line in the pre-operation period. Catch is primarily in April-June and appears to be increasing since 2000. This is likely due to drier weather and lower river stage during that time period.

In seines, mean catch is about 30% greater in the pre-operation period. Mean catch of brown shrimp remained greater below the 5 ppt line in both pre and post operation periods. Since operation, mean catch above the 5 ppt line has dropped about 50% in seines.

WHITE SHRIMP (Figures 30-31)
Mean white shrimp catch in trawls was about 40% greater in the post-operation period. In the post-operation period, mean catch increased above and below the 5 ppt line compared to the pre-operation period. Catch is primarily in September-October and appears to increase since 1998. Mean catch in seines was slightly greater in the post-operation period. Mean catch was greatest below the 5 ppt line for both time frames. Reports from fishers indicate a very good harvest for 2002.

6. VEGETATION (Figure 32)

Changes in habitat are monitored by periodic surveys of vegetation across the Breton Sound basin. Vegetation transects are flown from which vegetation habitat maps are created. Fresh marsh is nonexistent in 1978; by 2000, 628 acres were documented in the surveys. Since 1978, intermediate marsh area increased by 10,582 acres; whereas, brackish marsh and saline marsh decreased.

7. DISCUSSION

Management of the Caernarvon freshwater diversion consists of two interlinked components: enhancement of coastal marshlands and enhancement of commercial and recreational fish and wildlife resources. Historically, the Mississippi River was a major source of freshwater, sediment, and nutrients which created and sustained Louisiana's estuaries. During the past 7,000 years, different deltas of the river created 14,000 mi^2 of wetlands (Frazier 1967). Loss of these wetlands has ecological consequences. Net primary productivity (NPP) has been documented to decrease as marsh changes to open water (Bahr et al. 1982). For example, NPP in Barataria basin has been shown to decrease 26% in the last 30 years (Day et al. 1997). Since coastal fisheries harvest and production have been linked to NPP by numerous authors (Nixon 1988, Rozas and Reed 1993), coastal erosion can have severe effects on local economic systems.

Salinity Implications

The Caernarvon freshwater diversion is designed to return a more historical salinity pattern the Breton Sound estuary. Project planners and biologists felt that the with-project 5 ppt and 15 ppt lines represented a more beneficial and historical salinity pattern for the basin which would benefit commercial and recreational wildlife and fisheries resources.

Interpretation of salinity data is confounded by numerous causes of salinity change. Winds, tides, rainfall, evapotranspiraton, overflow from the river, higher river flow, groundwater, fastlands pumping and Caernarvon operation can affect salinities in the basin. Earlier analysis of salinities by Dr. James Geaghan, under contract to LDNR, indicates that stations closer to the diversion structure and under the influence of the Mississippi River exhibited lower salinities. The stations further from the structure but closer to the river are more effected by freshwater from overbanking of the river than Caernarvon discharge. Overall, the structure influences salinity at stations closer to the structure and the river influences salinity in the lower part of the basin. However, analysis of isohaline diagrams indicates that at higher flows, the river can influence salinity over much of the basin. Rainfall affects salinity primarily through more extreme wet or dry events. Wind, tide and frontal events can substantially change salinities for short periods of time. The Caernarvon operational plan seeks to achieve a yearly average of around 5 ppt at the with-project 5 ppt line near Cow and Crooked Bayous as indicated by the EIS. Monitoring indicates that since 1997 when recorders were placed on the 5 ppt line, the yearly mean salinity at these stations was 6 ppt for 1997, 5 ppt for 1998, 7.6 for 1999, 9.8 ppt for 2000, 5.6 for 2001 and 4.2 for 2002. It appears that the diversion structure can generally maintain historical salinities in the upper basin.

The lower 5 ppt average for 2002 is mainly due to missing data at Cow Bayou and several tropical storms with heavy rainfall during the hurricane season. Salinities at the 5 ppt line remained below 5 ppt from around October 2002-July 2003. Caernarvon input was generally low except for the pulse period, rainfall was generally below normal, and the river was at average stage during this period. Thus these extended low salinities are paradoxical. It is possible that rainfall from October 2002 tropical storms and Caernarvon input may stay in the basin for extended periods and not flush out and be replaced regularly with marine waters. Low tides associated with frontal passage may then freshen the basin from this upper basin reservoir of freshwater. It appears that the diversion structure can generally maintain historical salinities in the upper basin.

Fish and Wildlife Implications

Wildlife

Before the Caernarvon diversion, habitats in the Breton Sound Estuary were comprised almost completely of brackish and saline vegetation which resulted in lower species diversity. Herpetological diversity is inversely related to water salinity as many species do not possess adaptations for salt exclusion or excretion. Alligators are most abundant in intermediate marshes and generally will not nest in brackish marsh with salinity greater the 10 ppt (Chabreck 1988). Also previous monitoring had shown increases in muskrat populations, a primary food source for alligators. As a result of increasing intermediate habitat and food resource, alligators are expected to remain plentiful in the area.

Situated at the southern end of the Mississippi Flyway, Louisiana marshes provide overwintering habitat for 70% of migrating ducks and geese using this route.

Waterfowl hunting contributes more than $10 million annually to the local economy and is an important cultural and recreational activity in the region. Waterfowl, particularly dabbling ducks, generally prefer fresh to brackish environments. Manipulation of water levels and salinities is needed to maintain plant species desirable to waterfowl (Chabreck 1988). While waterfowl numbers are dependent on weather and food conditions across the flyway which may keep ducks in more northerly areas, observations from hunters in the Caernarvon area indicate that food in duck ponds is generally good in the upper part of the Breton Sound estuary. Waterfowl production in the Caernarvon estuary is subject to variability in weather, however food for waterfowl has remained abundant in the upper basin. If some of these benefits extend further down the basin, waterfowl production could increase in the area.

Oyster

One goal of the Caernarvon freshwater diversion is to enhance commercial and recreational fisheries in the Breton Sound estuary. A main impetus, historically, for the freshwater diversion at Caernarvon has been enhancement of oyster (Crassostrea virginica) production and mitigation of losses due to predation and disease as a result of saltwater encroachment (Galigano et al. 1995, Pollard 1973). Landward movement of the 15 ppt isohaline and subsequent increase in oyster predation by oyster drills (Thais haemastoma) are the putative causal agents in the loss of productive oyster grounds. The purpose behind the freshwater diversion was to push the 5 ppt and 15 ppt isohalines seaward to enlarge the distance between the two lines thereby maintaining an expanded productive zone for oysters (USACE 1984).

Oyster production on the public seed grounds, from boarding surveys, or meter-square sampling have all increased substantially and remained sustained since the opening of the Caernarvon diversion. Review of isohaline maps and stations where increased production occurs suggest that export of nutrients and detritus from upstream production may be a factor. Caernarvon diversion may increase productivity in the historically fresh marsh and increase allochthonous input to the estuary. Some of the decreases seen in 1997-1999 and 2002-2003 may be related to dermo infestations on seed oyster stock that reduced sack oysters in subsequent years. Low recruitment and high harvest in 2001 may also have contributed to low production in 2002 (LDWF personal communication). Dermo is mitigated by lower salinities so Caernarvon discharge in warmer months when dermo is more problematic may be beneficial to oysters. Oyster survival in 2001 and 2002 is consistent with previous post-construction years. Survival in 2003 is lower than previous years probably due to prolonged low salinities from October 2002-August 2003. Most of the oyster mortality is north of the 5 ppt line, an expected occurrence.

Oyster productivity rebounds after freshets from the river or Caernarvon diversion (Figure 14). Wilber (1992) indicated that current year river flows correlated negatively with oyster catch per unit effort but positively with catch 2-3 years later.

Livingston et al (2000) observed that river flow reduction could have serious adverse consequences on oyster productivity. He observed that oyster productivity is higher in areas with a convergence of river and saline waters. Also LaPeyre et al. (2003) have suggested the exposure to short term freshwater inputs significantly reduces Dermo infection intensities without lasting detriment to the oysters. While the benefits of a sustained oyster resource in the Breton Sound estuary from the Caernarvon diversion are likely to continue, occasional pulses of different magnitude, timing, or duration may be needed to facilitate the freshet effect.

Fisheries

The effect of the Caernarvon diversion on fisheries will reflect the motility of fish species, the variation in flow patterns of the diversion, and biotic and abiotic patterns from the diversion such as food availability and salinity. Coastal fisheries production is heavily dependent on energy and primary production in estuaries. Martin's (2002) emergy analysis estimated a greater primary production and consequent fishery production at Caernarvon and Davis Pond with diversion compared to no diversion. At Caernarvon, overall finfish biomass increased 62% post-operation substantiating the emergy speculations (JY Ko, pers. comm.)

Caernarvon has become known as a premier bass fishing locale. However, LDWF biologists have indicated that lack of consistent discharge from Caernarvon limits bass habitat and productivity. Heavy fishing pressure can also be detrimental. Bass were not caught during some months during the drought but numbers appeared consistent to past catch. Caernarvon is closed, on average, about 35% of the time for a variety of reasons, usually low flow in the river. A minimum discharge, which is allowed by the operational plan, should be utilized as is practical during low river situations to keep a freshwater head in the upper part of the basin.

On balance, blue crab productivity appears better post-operation. Trawl data are down, but seine and harvest data are generally higher. One concern with the trawl data is that crabs may be utilizing the submerged aquatic vegetation for refuge which is more abundant post-operation. Low numbers of crabs caught in trawls make this data somewhat unreliable. This will make crabs harder to catch as trawling is generally not done in aquatic vegetation. Crab trapping is showing higher catch and a possible different pattern of catch with year, although more years are needed to substantiate this possibility. Blue crabs can tolerate a wide range of salinities and are caught both above and below the 5 ppt line consistently.

Given that spotted seatrout and red drum are considered saltwater species, they might be expected to decrease post-operation. Catch for both of these species is higher post-operation. Catch did not appear to be exclusively related to salinity in that high catches sometimes occurred in low salinity areas near the diversion. Spotted seatrout are caught more often above the 5 ppt line post-operation. This may reflect juvenile fish using the marsh areas. Flow from the diversion and diversion-mediated food availability are not evenly distributed, even at higher flows. These patterns may explain catch pattern better than simply looking at salinity.

Brown and white shrimp show seasonal patterns of catch. Brown shrimp are caught in greater numbers in April-June and white shrimp are caught more from August-October. Brown shrimp catch has been down post-operation but not dramatically, in fact the overall difference for pre-post changed from 20% greater in pre-operation to 6% greater pre-operation. Some shrimpers indicate brown shrimp has decreased dramatically since Caernarvon opened; however, others say the decrease is moderate. In trawls, brown shrimp were caught at almost the same levels above the 5 ppt line post-operation as they were below the 5 ppt line pre-operation. A small increase in trawl abundance since 2000 may be related to lower river levels and increased water temperatures seen during the drought. The big spike in catch in trawls in 1993 was due to a big tide that pushed shrimp into the estuary. Due to these environmental conditions, it is unclear whether changes to lower flows during the spring, made at the request of the shrimping industry, have helped the shrimp harvest. White shrimp have increased in both trawls and seines. Some shrimpers indicate that catch has increased substantially and the season lasts longer. A study of brown shrimp distributional patterns near the diversion was conducted in 2001 (Rozas and Minello 2002). The objective was to assess brown shrimp recruitment and distributional patterns during the spring. This study found no relationship between brown shrimp and salinity. No evidence was found that the operation of the Caernarvon structure affected distribution of brown shrimp in May 2001. Brown shrimp densities were as high in areas that received Caernarvon discharge than those that did not. Winter and early spring operations did not negatively affect shrimp populations.

Vegetative Implications

Coastal marsh loss has many causes, natural and anthropogenic. Saltwater intrusion from subsidence and sea-level rise is a primary factor. River re-introduction mitigates these wetland stressors by reducing salinity and plant stress, and providing sediment and nutrients which help balance the accretion deficit through sedimentation and increased plant growth (Nyman et al. 1993, Twilley 2002, DeLaune 2002).

Biomass

Two studies investigating marsh biomass were conducted at Caernarvon by LSU and ULL researchers (Twilley 2002, DeLaune 2002, DeLanue and Pezeshki 2003, DeLaune et al. 2003.). The LSU study conducted a gradient analysis of the impact of the diversion on mineral and organic matter accumulation and plant biomass. The measured accretion was sufficient to offset water level rises due to subsidence. Mineral sediment input was greatest near the diversion and minimal further from the diversion. But the lower salinity at the distal sites reduced the mineral need for maintaining brackish marsh. Plant biomass increased due to nutrient addition and lower salinity and consequently enhanced marsh stability. Plant biomass also supplied matter for accretion to keep pace with subsidence. A marsh soil accretion model indicated that the marsh should remain stable for the next 100 years. The study concluded that Caernarvon diversion is stabilizing marshes and can slow or reduce marsh loss.

The ULL study investigated the significance of reduced salinity stress and increased nutrient availability at promoting soil organic matter production and promoting marsh soil formation at upstream and downstream sites. Porewater nutrients, salinity, bulk density and phosphate decreased further from the diversion. The lowered salinity and increased nutrients should slowly increase biodiversity. Controlled experiments indicated that salinity reduction alone did not increase biomass. Sediment additions increased total biomass production under conditions of low salinity. The operation of the diversion needs to deliver resources like sediment and nutrients and reduce stressors like salinity to produce optimal conditions for plant growth.

PULSES

The PULSES project is a multi-investigator project investigating the hydrologic, physical, ecological, and social impacts of restored flood inputs from the Mississippi River into the coastal marshes of the Breton Sound estuary. The Caernarvon diversion delivered sediment to the northern estuary, but southerly winds moderated freshwater and sediment delivery to the lower portion of the estuary. High Caernarvon pulses resulted in about 30% of the discharge flowing over the marsh, while low pulses remained in channels. Sediment deposition decreased with distance from the structure and pulses provided similar sediment deposition as marine pulsing. However, providing sediment to interior marsh sites further than 6 km from the structure requires higher water levels associated with set-up from frontal passages. During the pulses removal rate for nitrate was 57% while phosphate was reduced by 23% and silicate by 38%. Stable isotope analysis showed that nitrogen and carbon are being incorporated into the biota such as shrimp. Socio-economic surveys showed a wide variety of opinions regarding the diversion and that some feel that diversions are not the appropriate solution to coastal loss (Day et al. 2003, Wheelock 2003).

In the Breton Sound basin, there was very little fresh and intermediate marsh habitat prior to the Caernarvon diversion. Caernarvon operations have succeeded in returning fresh and intermediate marsh to the upper Breton Sound estuary. Some shallow open water ponds are being reestablished with fresh marsh (Figures 33-34). Experience from operating the diversion indicates that water needs to sheet flow over the marsh to be beneficial. This requires 2,500-3,000 cfs at minimum. Higher flows could reach a greater area for a larger footprint of benefits. Also aerial photo analysis indicates that even at high flows, water does not affect all areas equally. Some areas more conducive to flow may be receiving greater benefits that others and account for some of the variation seen in fisheries and land loss data. Pulsing of high discharge may be a strategy to maximize benefits.

8. ADDITIONAL SOURCE OF INFORMATION

Data collected as part of the Caernarvon monitoring program is available at www.saveLAwetlands.org.

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Table 1. Caernarvon Freshwater Operational Plan January 2003

CAERNARVON FRESHWATER DIVERSION OPERATIONAL PLAN
January 2003

Month	Flow Range (cfs)[1]
January	3000-4000 [2]
February	3000-4000 [2]
March	500-4000 [5]
April	500-4000 [5]
May	500-4000 [3]
June	1000-4000 [3]
July	1000-2000 [4]
August	1000-2000 [4]
September	1000-2000 [4]
October	1000-2000 [4]
November	1000-2000 [4]
December During Duck Season Split	2500 [2] 5600[1,2]

[1] Notwithstanding these flow range targets, operational procedures relating to emergencies, closure of the structure or reduction of flow to reduce the threat of coastal flooding or high water levels reflected by monitoring and operational procedures pertaining to low Mississippi River stage or drought conditions shall all remain in effect. The structure will be closed if the water level measured by a real-time gauge at Reggio Canal reads above 3.1 NGVD.
[2] Salinity at Bay Gardene will be monitored to stay above 3 ppt.
[3] For oyster production, the salinities at the Bay Gardene station will be monitored during these months. The structure will be operated at the lower discharge levels. If the Bay Gardene station moves to 9 ppt based on a two-week average, Caernarvon discharge will be increased, but will not exceed 4000 cfs, to decrease the average to 9 ppt. Water levels gauges will be added to certain sites and monitored.
[4] Seek to maintain annual average 5 ppt line, based on a yearly average, and monitor salinities as to promote enhancement of oyster production in the public seed grounds and to achieve other stated benefits of the project, up to 2000 cfs.
[5] Seek to maintain annual average 5 ppt line, based on a yearly average, and monitor salinities as to promote enhancement of oyster production in the public seed grounds and to achieve other stated benefits of the project, up to 4000 cfs.

Table 2. Caernarvon Operational Summary
2002-2003
Prepared by the Louisiana Department of Natural Resources
Coastal Restoration Division

Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Serpas	10/1/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.1	2.3	
Serpas	10/2/2002	9:00	0.0	0.0	0.0	0.0	0.0	4.0	3.0	
R	10/3/2002	8:00	0.0	0.0	0.0	0.0	0.0	5.0	4.4	
Serpas	10/4/2002	6:00	0.0	0.0	0.0	0.0	0.0	6.0	5.8	
R	10/5/2002	8:00	0.0	0.0	0.0	0.0	0.0	5.4	5.3	
R	10/6/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.7	4.7	
Serpas	10/7/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.1	4.2	
Serpas	10/8/2002	8:00	0.0	0.0	0.0	0.0	0.0	3.3	4.0	
Serpas	10/9/2002	8:00	0.0	0.0	0.0	0.0	0.0	3.1	3.5	
Serpas	10/10/2002	6:00	0.0	0.0	0.0	0.0	0.0	3.0	3.0	
Serpas	10/11/2002	6:00	0.0	0.0	0.0	0.0	0.0	3.0	2.5	
R	10/12/2002	8:00	0.0	0.0	0.0	0.0	0.0	2.9	2.4	
R	10/13/2002	8:00	0.0	0.0	0.0	0.0	0.0	2.9	2.3	
Serpas	10/14/2002	9:00	0.0	0.0	0.0	0.0	0.0	2.8	2.2	
Serpas	10/15/2002	6:00	0.0	0.0	0.0	0.0	0.0	3.0	1.8	
Serpas	10/16/2002	8:00	0.0	0.0	0.0	0.0	0.0	3.0	1.5	
Serpas	10/17/2002	6:00	0.0	0.0	0.0	0.0	0.0	3.0	1.4	
Serpas	10/18/2002	6:00	0.0	0.0	0.0	0.0	0.0	2.8	1.4	
R	10/19/2002	8:00	0.0	0.0	0.0	0.0	0.0	2.8	1.4	
R	10/20/2002	8:00	0.0	0.0	0.0	0.0	0.0	2.8	1.3	
Serpas	10/21/2002	9:00	0.0	0.0	0.0	0.0	0.0	2.8	1.3	
Serpas	10/22/2002	8:00	0.0	0.0	0.0	0.0	0.0	3.1	1.5	
Serpas	10/23/2002	10:00	0.0	0.0	0.0	0.0	0.0	4.1	1.3	
Serpas	10/24/2002	9:00	0.0	0.0	0.0	0.0	0.0	4.5	1.5	
Serpas	10/25/2002	9:00	0.0	0.0	0.0	0.0	0.0	4.4	1.4	
R	10/26/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.4	2.4	
R	10/27/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.4	3.4	
Serpas	10/28/2002	6:00	0.0	0.0	0.0	0.0	0.0	4.4	1.4	
Serpas	10/29/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.3	1.4	
Serpas	10/30/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.4	1.3	
Serpas	10/31/2002	8:00	0.0	0.0	0.0	0.0	0.0	4.3	1.4	
Serpas	11/1/2002	6:00	0	0	0	0	0	4.5	1.2	
R	11/2/2002	9:00	0	0	0	0	0	4.5	1.2	
R	11/3/2002	8:00	0	0	0	0	0	4.5	1.2	
Serpas	11/4/2002	9:00	0	0	0	0	0	4.5	1.2	
Serpas	11/5/2002	8:00	0	0	0	0	0	4.4	1.1	
Serpas	11/6/2002	9:00	0	0	0	0	0	4.2	1	
Serpas	11/7/2002	8:00	0	0	0	0	0	4	1	
Serpas	11/8/2002	6:00	0	0	0	0	0	3.3	0.8	
R	11/9/2002	8:00	0	0	0	0	0	3.3	0.7	
R	11/10/2002	8:00	0	0	0	0	0	3.3	0.6	
Serpas	11/11/2002	9:00	0	0	0	0	0	3.2	0.5	
Serpas	11/12/2002	6:00	0	0	0	0	0	3.1	0.2	
Serpas	11/13/2002	8:00	0	0	0	0	0	3.1	0.3	
Serpas	11/14/2002	9:00	0	0	0	0	0	3	0.2	
Serpas	11/15/2002	8:30	0	0	0	0	0	2.5	0.3	
R	11/16/2002	8:00	0	0	0	0	0	2.6	0.3	
R	11/17/2002	8:00	0	0	0	0	0	2.7	0.3	
Serpas	11/18/2002	6:30	0	0	0	0	0	2.8	0.3	
Serpas	11/19/2002	8:00	0	0	0	0	0	2.6	0.2	FIELD TRIP OPENED TO 3000 CFS FOR 10 MINUTES
Serpas	11/20/2002	14:40	3.3	3.3	3.3	3.3	3.3	2.5	0.3	OPENED TO 2000 CFS
Serpas	11/21/2002	8:00	2.9	2.9	2.9	2.9	2.9	2.5	1.3	SET AT 1500 CFS PER DNR
Serpas	11/22/2002	8:30	2.6	2.6	2.6	2.6	2.6	2.9	1.3	
R	11/23/2002	8:00	2.6	2.6	2.6	2.6	2.6	2.9	1.3	
R	11/24/2002	8:00	2.6	2.6	2.6	2.6	2.6	2.9	1.2	
Serpas	11/25/2002	6:30	2.5	2.5	2.5	2.5	2.5	3.4	1.2	
Burton	11/26/2002	10:00	2.7	2.7	2.7	2.7	2.7	3.1	1.2	
Burton	11/27/2002	8:13	2.7	2.7	2.7	2.7	2.7	3.1	1.2	
R	11/28/2002	8:00	2.7	2.7	2.7	2.7	2.7	2.9	1.1	
R	11/29/2002	8:00	2.7	2.7	2.7	2.7	2.7	2.7	1	
R	11/30/2002	8:00	2.7	2.7	2.7	2.7	2.7	2.2	1	
R	12/1/2002	8:00	2.7	2.7	2.7	2.7	2.7	2.1	1	
Serpas	12/2/2002	9:00	3.7	3.7	3.7	3.7	3.7	1.9	0.9	
Serpas	12/3/2002	13:00	3.7	3.7	3.7	3.7	3.7	1.8	0.8	
R	12/4/2002	8:00	3.7	3.7	3.7	3.7	3.7	1.9	0.9	
Serpas	12/5/2002	13:00	3.7	3.7	3.7	3.7	3.7	2	1	
Serpas	12/6/2002	13:00	3.7	3.7	3.7	3.7	3.7	2	1	
R	12/7/2002	8:00	3.7	3.7	3.7	3.7	3.7	2.2	1	
R	12/8/2002	8:00	3.7	3.7	3.7	3.7	3.7	2.4	1	
Serpas	12/9/2002	12:30	0	0	0	0	0	2.5	1	CLOSED FOR FIELD TRIP

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Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Serpas	12/10/2002	7:15	2.4	2.4	2.4	2.4	2.4	3.4	1	REOPEN AT 1500 CFS
Kimble	12/11/2002	8:55	3.5	3.5	3.5	3.5	3.5	3.4	1	
Kimble	12/12/2002	8:56	3.5	3.5	3.5	3.5	3.5	2	0.9	
Serpas	12/13/2002	10:40	3.5	3.5	3.5	3.5	3.5	2.5	1.4	
R	12/14/2002	8:00	3.5	3.5	3.5	3.5	3.5	2.2	1.2	
R	12/15/2002	8:00	3.5	3.5	3.5	3.5	3.5	2	1	
Serpas	12/16/2002	14:00	3.5	3.5	3.5	3.5	3.5	1.9	0.8	
Serpas	12/17/2002	13:00	4.4	4.4	4.4	4.4	4.4	1.6	0.9	
Serpas	12/18/2002	13:15	4.4	4.4	4.4	4.4	4.4	1.9	1.2	
Kimble	12/19/2002	7:27	4.4	4.4	4.4	4.4	4.4	1.9	1.2	
Serpas	12/20/2002	8:30	4.4	4.4	4.4	4.4	4.4	2	1.3	
R	12/21/2002	8:00	4.4	4.4	4.4	4.4	4.4	2.2	1.5	
R	12/22/2002	8:00	4.4	4.4	4.4	4.4	4.4	3.1	1.6	
R	12/23/2002	8:00	4.4	4.4	4.4	4.4	4.4	3.9	1.7	
Serpas	12/24/2002	11:00	1.6	1.6	1.6	1.6	1.6	4.2	1.8	RESET FLOW TO 1000 CFS DUE TO RISING RIVER
R	12/25/2002	8:00	1.6	1.6	1.6	1.6	1.6	4.9	1.8	
Serpas	12/26/2002	8:30	1.3	1.3	1.3	1.3	1.3	5.3	1.8	
Serpas	12/27/2002	13:00	1.1	1.1	1.1	1.1	1.1	6	1	
R	12/28/2002	8:00	1.1	1.1	1.1	1.1	1.1	6.3	1	
R	12/29/2002	8:00	1.1	1.1	1.1	1.1	1.1	6.7	0.9	
Serpas	12/30/2002	7:40	1	1	1	1	1	6.9	0.9	
Serpas	12/31/2002	13:00	1	1	1	1	1	7.4	1.4	
Rodrigue	1/1/2003	9:40	1.0	1.0	1.0	1.0	1.0	7.6	1.1	
Rodrigue	1/2/2003	9:30	1.0	1.0	1.0	1.0	1.0	7.5	1.0	
Rodrigue	1/3/2003	13:20	1.0	1.0	1.0	1.0	1.0	7.3	0.8	
Rodrigue	1/4/2003	13:00	1.0	1.0	1.0	1.0	1.0	7.3	0.9	
Rodrigue	1/5/2003	8:50	1.0	1.0	1.0	1.0	1.0	7.2	0.8	
Rodrigue	1/6/2003	14:09	2.5	2.5	2.5	2.5	2.5	7.2	0.8	Set to 2,500 CFS
Rodrigue	1/7/2003	7:30	2.5	2.5	2.5	2.5	2.5	7.4	1.2	
Rodrigue	1/8/2003	9:20	2.5	2.5	2.5	2.5	2.5	7.3	1.0	
Rodrigue	1/9/2003	9:40	2.5	2.5	2.5	2.5	2.5	7.2	1.2	
Rodrigue	1/10/2003	7:40	2.5	2.5	2.5	2.5	2.5	7.1	1.1	
Rodrigue	1/11/2003	13:10	2.5	2.5	2.5	2.5	2.5	6.8	1.1	
Rodrigue	1/12/2003	9:50	2.5	2.5	2.5	2.5	2.5	6.6	1.2	
Rodrigue	1/13/2003	8:00	2.7	2.7	2.7	2.7	2.7	6.4	1.2	
Rodrigue	1/14/2003	14:00	5.7	5.7	5.7	5.7	5.7	6.0	2.0	Opened to 5000 CFS
Rodrigue	1/15/2003	13:20	6.1	6.1	6.1	6.1	6.1	5.9	2.4	
Rodrigue	1/16/2003	14:40	4.9	4.9	4.9	4.9	4.9	5.9	2.4	Adjusted to 4000 CFS due to high water
Rodrigue	1/17/2003	8:00	4.9	4.9	4.9	4.9	4.9	5.7	2.2	
Rodrigue	1/18/2003	13:00	4.9	4.9	4.9	4.9	4.9	5.5	2.2	
Rodrigue	1/19/2003	13:30	4.9	4.9	4.9	4.9	4.9	5.2	2.1	
Rodrigue	1/20/2003	8:30	4.9	4.9	4.9	4.9	4.9	4.6	2.0	
Rodrigue	1/21/2003	9:00	6.5	6.5	6.5	6.5	6.5	4.0	2.0	
Rodrigue	1/22/2003	12:30	8.1	8.1	8.1	8.1	8.1	3.5	2.2	
Rodrigue	1/23/2003	13:40	10.3	10.3	10.3	10.3	10.3	3.0	2.2	
Rodrigue	1/24/2003	9:50	13.0	13.0	13.0	13.0	13.0	2.7	2.2	
Rodrigue	1/25/2003	8:00	13.0	13.0	13.0	13.0	13.0	2.3	2.0	
Rodrigue	1/26/2003	9:30	13.0	13.0	13.0	13.0	13.0	2.0	1.8	
Rodrigue	1/27/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.8	1.6	
Rodrigue	1/28/2003	8:27	14.5	14.5	14.5	14.5	14.5	1.6	1.5	
Rodrigue	1/29/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.5	1.4	
Rodrigue	1/30/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.4	1.3	
Rodrigue	1/31/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.4	1.3	
Rodrigue	2/1/2003	12:50	14.5	14.5	14.5	14.5	14.5	1.4	1.3	
Rodrigue	2/2/2003	9:00	14.5	14.5	14.5	14.5	14.5	1.3	1.2	
Rodrigue	2/3/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.4	1.3	
Rodrigue	2/4/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.5	1.2	
Rodrigue	2/5/2003	9:50	14.5	14.5	14.5	14.5	14.5	1.3	1.2	
Rodrigue	2/6/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.4	1.2	
Rodrigue	2/7/2003	13:00	14.5	14.5	14.5	14.5	14.5	1.5	1.2	
Rodrigue	2/8/2003	9:00	14.5	14.5	14.5	14.5	14.5	1.4	1.3	
Rodrigue	2/9/2003	10:10	14.5	14.5	14.5	14.5	14.5	1.4	1.2	
Rodrigue	2/10/2003	6:50	0.0	0.0	0.0	0.0	0.0	1.3	1.2	Closed for pulse
Rodrigue	2/11/2003	10:40	0.0	0.0	0.0	0.0	0.0	1.4	1.0	
Rodrigue	2/12/2003	8:30	0.0	0.0	0.0	0.0	0.0	1.3	0.9	
Rodrigue	2/13/2003	7:20	0.0	0.0	0.0	0.0	0.0	1.2	0.8	
Rodrigue	2/14/2003	12:30	0.0	0.0	0.0	0.0	0.0	1.2	0.7	
Rodrigue	2/15/2003	13:00	0.0	0.0	0.0	0.0	0.0	1.3	1.1	
Rodrigue	2/16/2003	13:00	0.0	0.0	0.0	0.0	0.0	1.8	0.9	
Rodrigue	2/17/2003	13:30	0.0	0.0	0.0	0.0	0.0	2.0	0.5	

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2002-2003
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Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Rodrigue	2/18/2003	7:00	14.5	14.5	14.5	14.5	14.5	2.6	0.4	Opened to 6500 for pulse
Rodrigue	2/19/2003	7:30	14.5	14.5	14.5	14.5	14.5	2.6	2.2	
Rodrigue	2/20/2003	10:00	14.5	14.5	14.5	14.5	14.5	2.7	2.3	
Rodrigue	2/21/2003	13:00	14.5	14.5	14.5	14.5	14.5	3.2	2.8	
Rodrigue	2/22/2003	10:40	9.4	9.4	9.4	9.4	9.4	4.7	3.5	Lowered b/c high water
Rodrigue	2/23/2003	9:15	6.5	6.5	6.5	6.5	6.5	4.7	3.5	
Rodrigue	2/24/2003	14:40	5.5	5.5	5.5	5.5	5.5	6.5	3.0	
Rodrigue	2/25/2003	7:00	6.5	6.5	6.5	6.5	6.5	6.5	3.0	
Rodrigue	2/26/2003	7:20	6.1	6.1	6.1	6.1	6.1	7.0	2.8	
Rodrigue	2/27/2003	7:50	6.1	6.1	6.1	6.1	6.1	7.6	3.0	
Rodrigue	2/28/2003	13:00	5.5	5.5	5.5	5.5	5.5	8.4	3.2	
Rodrigue	3/1/2003	10:40	0.0	0.0	0.0	0.0	0.0	8.9	3.2	Closed for pulse
Rodrigue	3/2/2003	10:00	0.0	0.0	0.0	0.0	0.0	9.4	3.1	
Rodrigue	3/3/2003	7:30	0.0	0.0	0.0	0.0	0.0	9.7	3.0	
Rodrigue	3/4/2003	13:00	0.0	0.0	0.0	0.0	0.0	9.9	3.2	
Rodrigue	3/5/2003	8:30	0.0	0.0	0.0	0.0	0.0	10.0	2.8	
Rodrigue	3/6/2003	15:30	0.0	0.0	0.0	0.0	0.0	10.3	2.7	
Rodrigue	3/7/2003	9:00	0.0	0.0	0.0	0.0	0.0	10.2	2.5	
Rodrigue	3/8/2003	7:00	0.0	0.0	0.0	0.0	0.0	10.5	2.1	
Rodrigue	3/9/2003	10:00	0.0	0.0	0.0	0.0	0.0	10.5	2.1	
Rodrigue	3/10/2003	13:10	0.0	0.0	0.0	0.0	0.0	10.2	2.0	
Rodrigue	3/11/2003	13:20	0.0	0.0	0.0	0.0	0.0	10.3	1.9	
Rodrigue	3/12/2003	13:40	0.0	0.0	0.0	0.0	0.0	9.9	1.9	
Rodrigue	3/13/2003	7:00	0.0	0.0	0.0	0.0	0.0	9.8	1.8	
Rodrigue	3/14/2003	9:50	0.0	0.0	0.0	0.0	0.0	9.9	1.7	
Rodrigue	3/15/2003	7:50	0.0	0.0	0.0	0.0	0.0	9.8	1.9	
Rodrigue	3/16/2003	13:00	0.0	0.0	0.0	0.0	0.0	9.7	2.1	
Rodrigue	3/17/2003	15:30	5.5	5.5	5.5	5.5	5.5	9.5	2.2	Opened to 6500 CFS
Rodrigue	3/18/2003	7:30	5.8	5.8	5.8	5.8	5.8	9.2	2.7	
Rodrigue	3/19/2003	8:30	5.9	5.9	5.9	5.9	5.9	9.2	3.0	
Rodrigue	3/20/2003	13:50	6.2	6.2	6.2	6.2	6.2	8.8	3.2	
Rodrigue	3/21/2003									Data missing
Rodrigue	3/22/2003									
Rodrigue	3/23/2003									
Rodrigue	3/24/2003									
Rodrigue	3/25/2003									
Rodrigue	3/26/2003									
Rodrigue	3/27/2003									
Rodrigue	3/28/2003									
Rodrigue	3/29/2003									
Rodrigue	3/30/2003									
Rodrigue	3/31/2003									
Rodrigue	4/1/2003									
Rodrigue	4/2/2003									
Rodrigue	4/3/2003									
Rodrigue	4/4/2003									
Rodrigue	4/5/2003									
Rodrigue	4/6/2003									
Rodrigue	4/7/2003									
Rodrigue	4/8/2003									
Rodrigue	4/9/2003									
Rodrigue	4/10/2003									
Rodrigue	4/11/2003									
Rodrigue	4/12/2003									
Rodrigue	4/13/2003									
Rodrigue	4/14/2003									
Rodrigue	4/15/2003									
Rodrigue	4/16/2003									
Rodrigue	4/17/2003									
Rodrigue	4/18/2003									
Rodrigue	4/19/2003									
Rodrigue	4/20/2003									
Rodrigue	4/21/2003									
Rodrigue	4/22/2003									
Rodrigue	4/23/2003									
Rodrigue	4/24/2003									
Rodrigue	4/25/2003									
Rodrigue	4/26/2003									
Rodrigue	4/27/2003									
Rodrigue	4/28/2003									

Table 2. Caernarvon Operational Summary
2002-2003
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Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Rodrigue	4/29/2003									
Rodrigue	4/30/2003									
Rodrigue	5/1/2003									
Rodrigue	5/2/2003									
Rodrigue	5/3/2003									
Rodrigue	5/4/2003									
Rodrigue	5/5/2003									
Rodrigue	5/6/2003									
Rodrigue	5/7/2003									
Rodrigue	5/8/2003									
Rodrigue	5/9/2003									
Rodrigue	5/10/2003									
Rodrigue	5/11/2003									
Rodrigue	5/12/2003									
Rodrigue	5/13/2003									
Rodrigue	5/14/2003									
Rodrigue	5/15/2003									
Rodrigue	5/16/2003									
Rodrigue	5/17/2003									
Rodrigue	5/18/2003									
Rodrigue	5/19/2003									
Rodrigue	5/20/2003									
Rodrigue	5/21/2003									
Rodrigue	5/22/2003									
Rodrigue	5/23/2003									
Rodrigue	5/24/2003									
Rodrigue	5/25/2003									
Rodrigue	5/26/2003									
Rodrigue	5/27/2003									
Rodrigue	5/28/2003									
Rodrigue	5/29/2003									
Rodrigue	5/30/2003									
Rodrigue	5/31/2003									
Rodrigue	6/1/2003									
Rodrigue	6/2/2003									
Rodrigue	6/3/2003									
Rodrigue	6/4/2003	18:20	0.8	0.8	0.8	0.8	0.8	10.8	0.5	Opened Structure
Rodrigue	6/5/2003	9:35	0.6	0.6	0.6	0.6	0.6	10.6	1.2	River gauge hard to read
Rodrigue	6/6/2003	18:50	0.6	0.6	0.6	0.6	0.6	10.6	1.1	
Rodrigue	6/7/2003	18:00	0.6	0.6	0.6	0.6	0.6	10.4	1.2	
Rodrigue	6/8/2003	17:20	0.6	0.6	0.6	0.6	0.6	10.5	1.1	
Rodrigue	6/9/2003	19:05	0.7	0.7	0.7	0.7	0.7	10.5	1.0	
Rodrigue	6/10/2003	18:55	0.6	0.7	0.6	0.7	0.6	9.0	1.0	
Rodrigue	6/11/2003	17:35	0.6	0.7	0.6	0.7	0.6	8.6	1.1	
Rodrigue	6/12/2003	18:30	0.6	0.7	0.6	0.7	0.6	8.4	1.1	
Rodrigue	6/13/2003	12:45	0.7	0.7	0.7	0.7	0.7	8.0	1.0	
Rodrigue	6/14/2003	10:30	0.7	0.7	0.7	0.7	0.7	7.7	1.0	
Rodrigue	6/15/2003	18:00	0.7	0.7	0.7	0.7	0.7	7.2	1.0	
Rodrigue	6/16/2003	18:10	0.7	0.7	0.7	0.7	0.7	7.3	1.1	
Rodrigue	6/17/2003	17:45	0.7	0.7	0.7	0.7	0.7	7.3	0.9	
Rodrigue	6/18/2003	17:10	0.7	0.7	0.7	0.7	0.7	7.4	0.9	
Rodrigue	6/19/2003	17:00	0.7	0.7	0.7	0.7	0.7	7.6	1.0	
Rodrigue	6/20/2003	17:15	0.7	0.7	0.7	0.7	0.7	7.5	1.0	
Rodrigue	6/21/2003	19:20	0.7	0.7	0.7	0.7	0.7	7.4	1.1	
Rodrigue	6/22/2003	17:35	0.7	0.7	0.7	0.7	0.7	7.5	0.9	
Rodrigue	6/23/2003	17:30	0.7	0.7	0.7	0.7	0.7	7.6	0.8	
Rodrigue	6/24/2003	19:05	0.7	0.7	0.7	0.7	0.7	7.8	1.2	
Rodrigue	6/25/2003	18:50	0.7	0.7	0.7	0.7	0.7	7.8	1.2	Flow has been stable at around 1000 cfs.
Rodrigue	6/26/2003	17:00	0.7	0.7	0.7	0.7	0.7	7.9	1.4	
Rodrigue	6/27/2003	18:50	0.7	0.7	0.7	0.7	0.7	8.2	1.6	
Rodrigue	6/28/2003	18:00	0.7	0.7	0.7	0.7	0.7	8.3	1.9	
Rodrigue	6/29/2003	17:55	0.0	0.0	0.0	0.0	0.0	8.4	2.0	Closed structure for tropical storm Bill.
Rodrigue	6/30/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/1/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/2/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/3/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/4/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/5/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/6/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/7/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	

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Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Rodrigue	7/8/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/9/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/10/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/11/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/12/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/13/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/14/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/15/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/16/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/17/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/18/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/19/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/20/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/21/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/22/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/23/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/24/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/25/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/26/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/27/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/28/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/29/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/30/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	7/31/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/1/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/2/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/3/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/4/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/5/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/6/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/7/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/8/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/9/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/10/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/11/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/12/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/13/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/14/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/15/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/16/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/17/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/18/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/19/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/20/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/21/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/22/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/23/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/24/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/25/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/26/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/27/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/28/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/29/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/30/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	8/31/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/1/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/2/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/3/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/4/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/5/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/6/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/7/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/8/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/9/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/10/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/11/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/12/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/13/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/14/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/15/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	

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Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Rodrigue	9/16/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/17/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/18/2003	8:00	0.0	0.0	0.0	0.0	0.0	8.4	2.0	
Rodrigue	9/19/2003	10:20	1.8	1.8	1.8	1.8	1.8	4.4	1.6	Opened structure after maintenance by ACOE
Rodrigue	9/20/2003	15:15	2.0	2.0	2.0	2.0	2.0	3.6	1.6	
Rodrigue	9/21/2003	17:30	2.0	2.0	2.0	2.0	2.0	3.5	1.5	
Rodrigue	9/22/2003	16:15	2.0	2.0	2.0	2.0	2.0	3.4	1.7	
Rodrigue	9/23/2003	18:00	2.0	2.0	2.0	2.0	2.0	3.3	1.9	
Rodrigue	9/24/2003	18:00	3.4	3.4	3.4	3.4	3.4	3.2	2.0	
Rodrigue	9/25/2003	17:30	3.4	3.4	3.4	3.4	3.4	3.1	2.1	
Rodrigue	9/26/2003	18:00	4.2	4.2	4.2	4.2	4.2	3.0	2.2	
Rodrigue	9/27/2003	11:45	4.4	4.4	4.4	4.4	4.4	3.1	2.3	
Rodrigue	9/28/2003	16:15	4.8	4.8	4.8	4.8	4.8	2.8	2.0	
Rodrigue	9/29/2003	18:36	5.6	5.6	5.6	5.6	5.6	2.6	2.0	
Rodrigue	9/30/2003	16:55	6.4	6.4	6.4	6.4	6.4	2.5	2.3	

* "R" in the operator column indicates that no physical measurements for marsh or river stage were taken on that day by Plaquemines Parish Government (PPG) or DNR and reported values were either calculated and/or interpolated from the surrounding data set or taken from another source.
** Gate setting reflects the predominant position throughout the day.

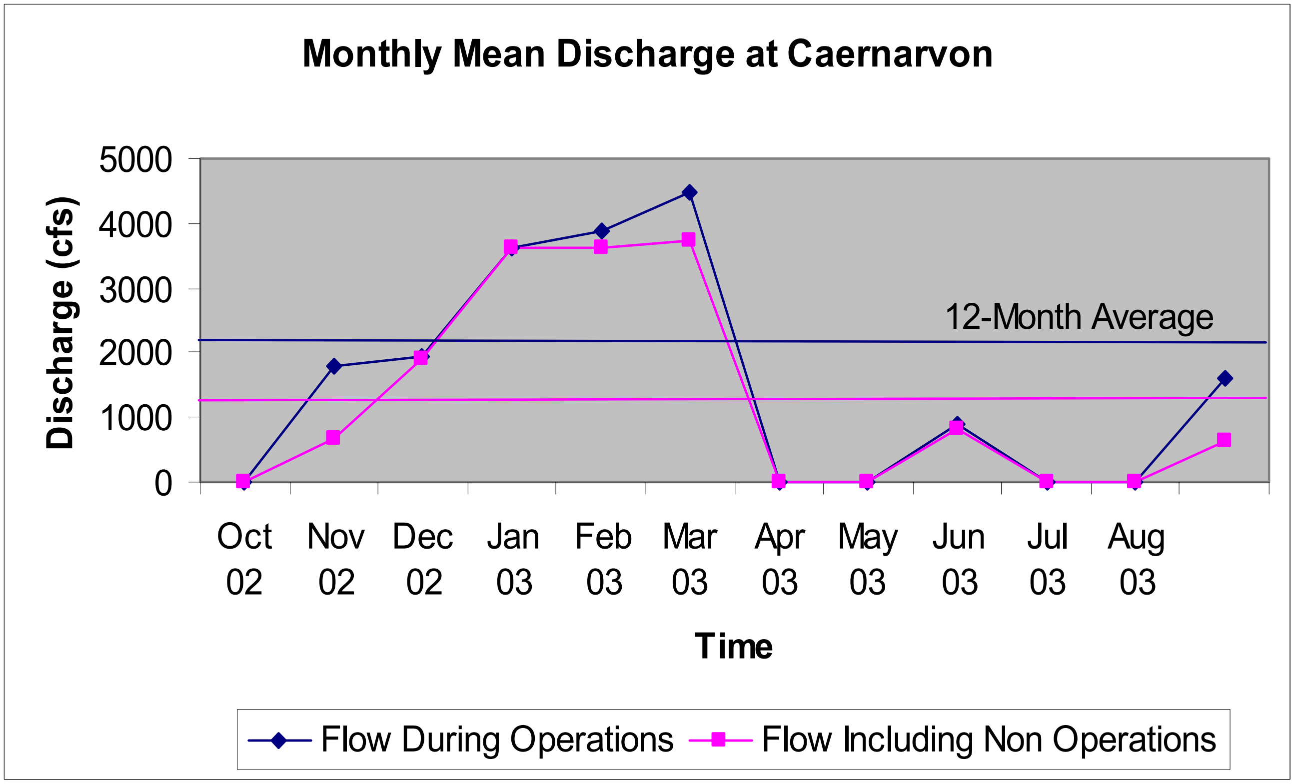

Figure 1. Monthly Mean Discharge at Caernarvon (USGS).

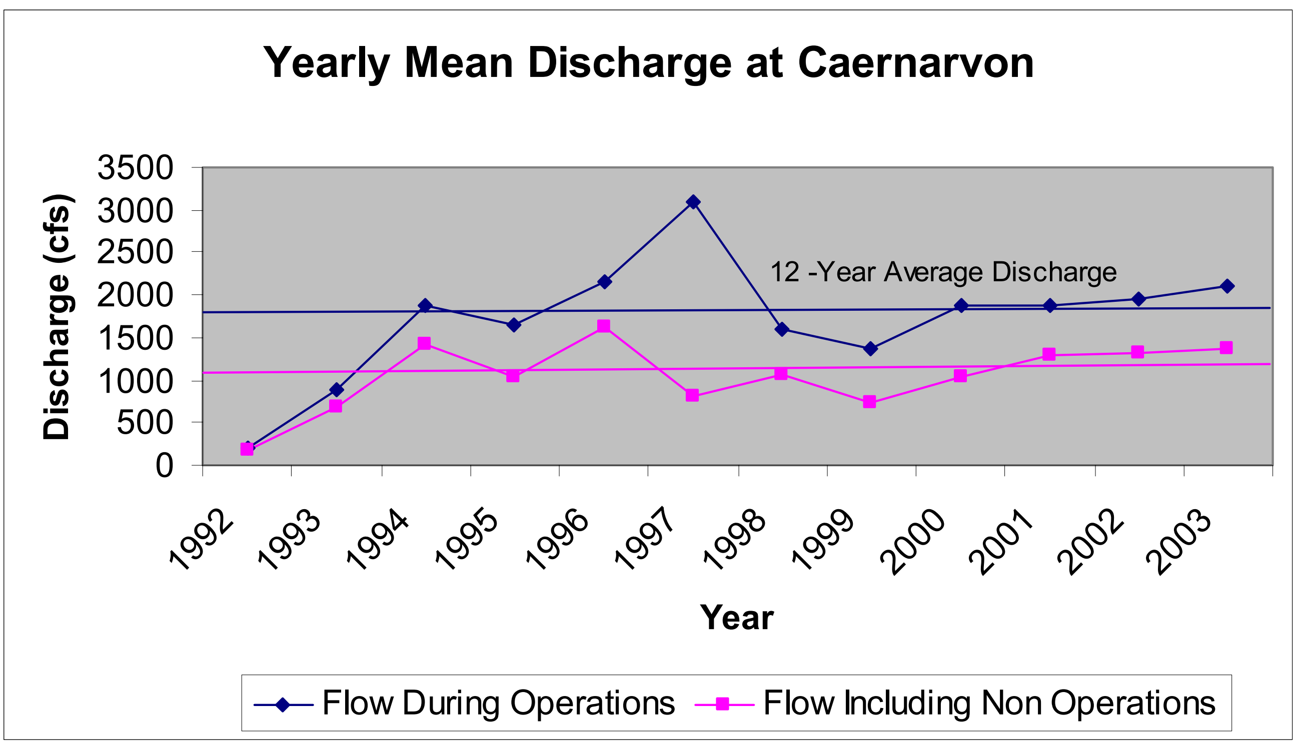

Figure 2. Yearly Mean Discharge at Caernarvon (USGS).

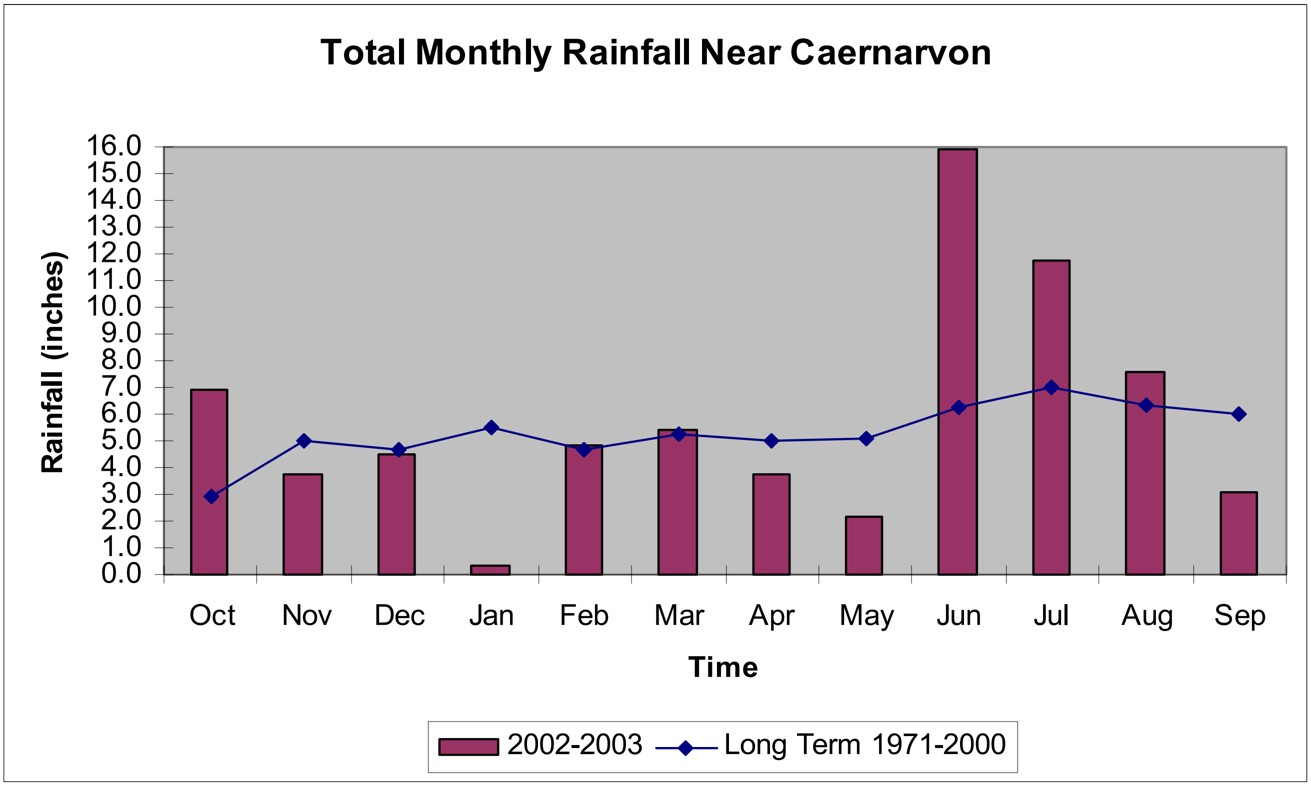

Figure 3. Total Monthly Rainfall Near Caernarvon (LSU Southern Regional Climate Center).

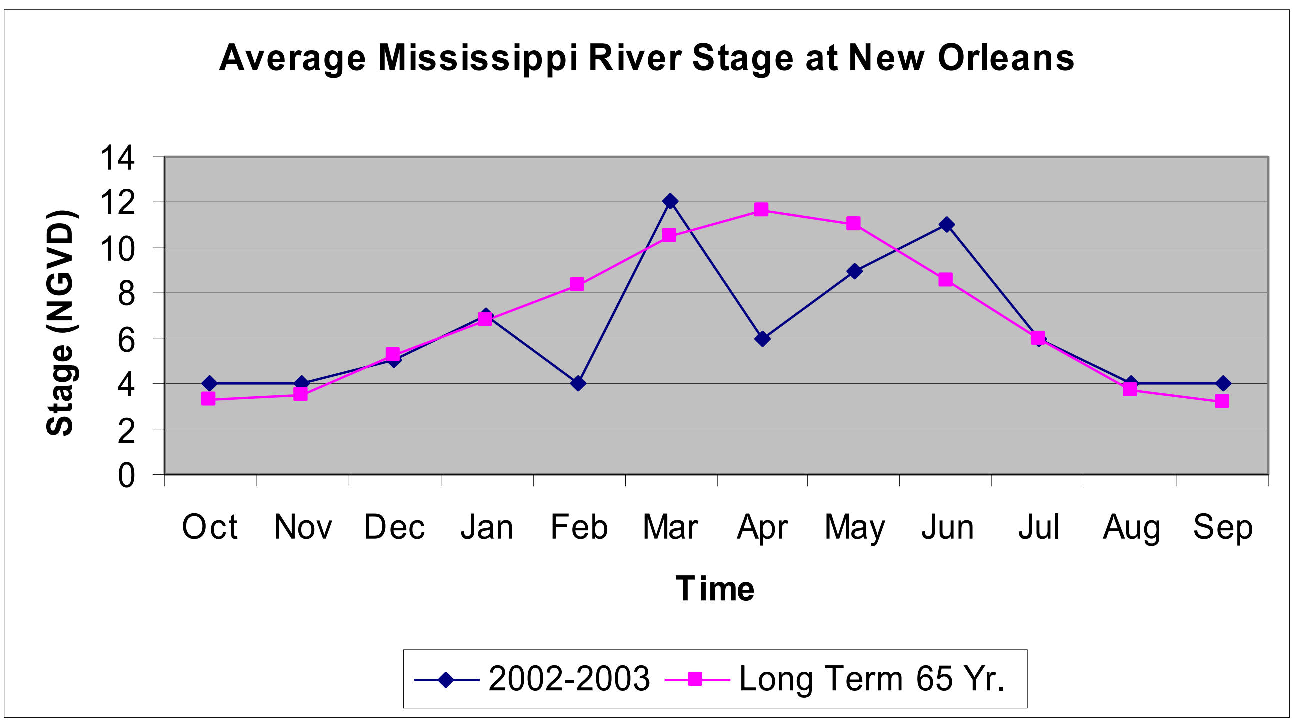

Figure 4. Average Mississippi River Stage at New Orleans (USACE).

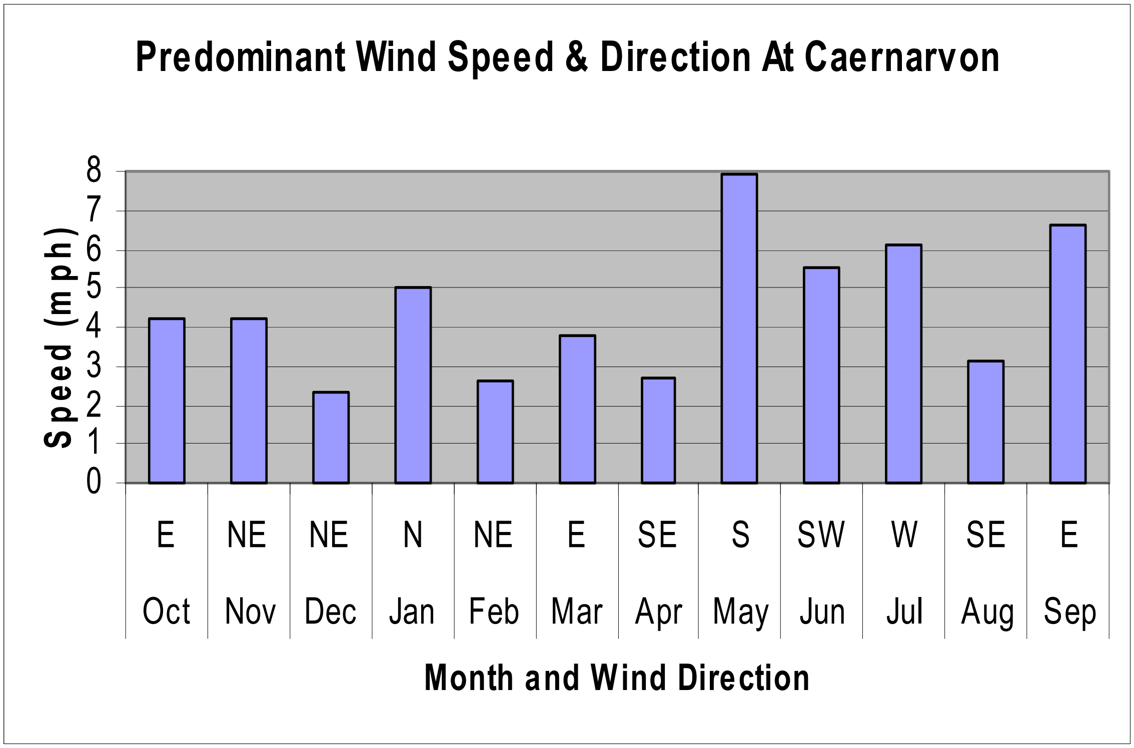

Figure 5. Predominant Wind Speed and Direction at Caernarvon (USGS).

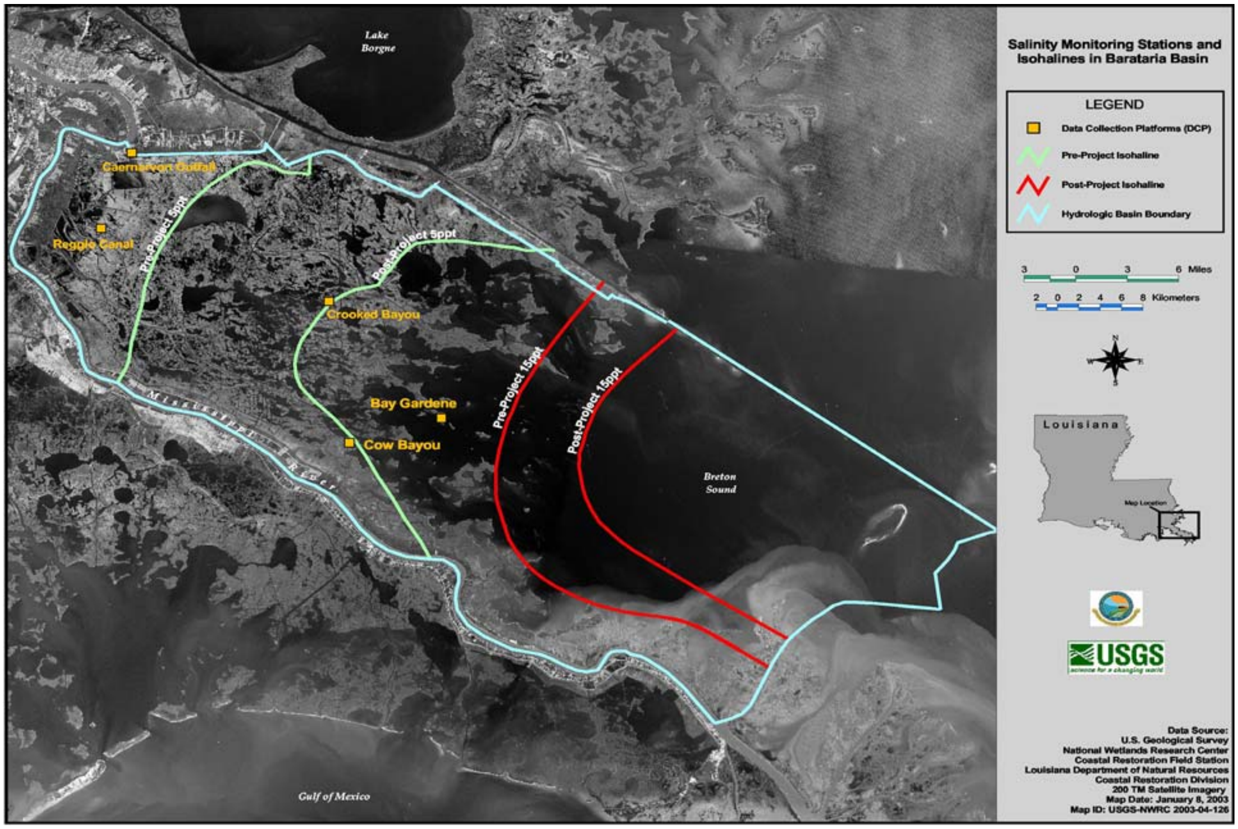

Figure 6. Location of Data Collection Platforms and pre-post construction isohalines for Breton Sound.

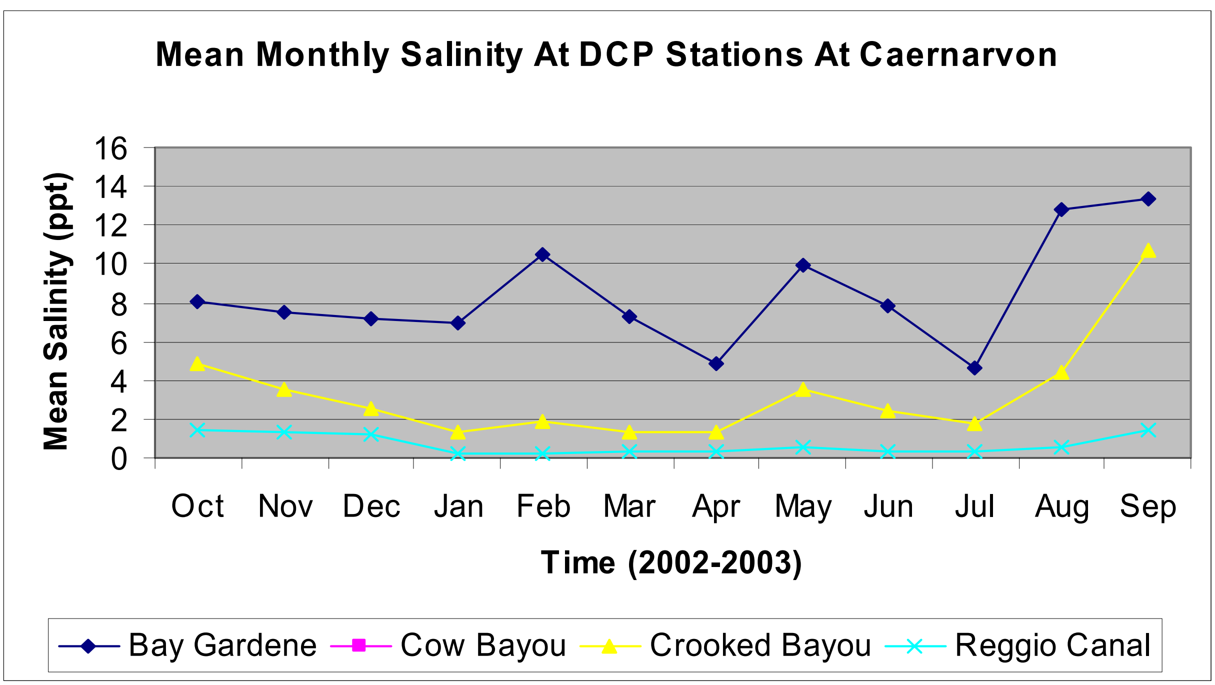

Figure 7. Mean Monthly Salinity at DCP Stations at Caernarvon (USGS).

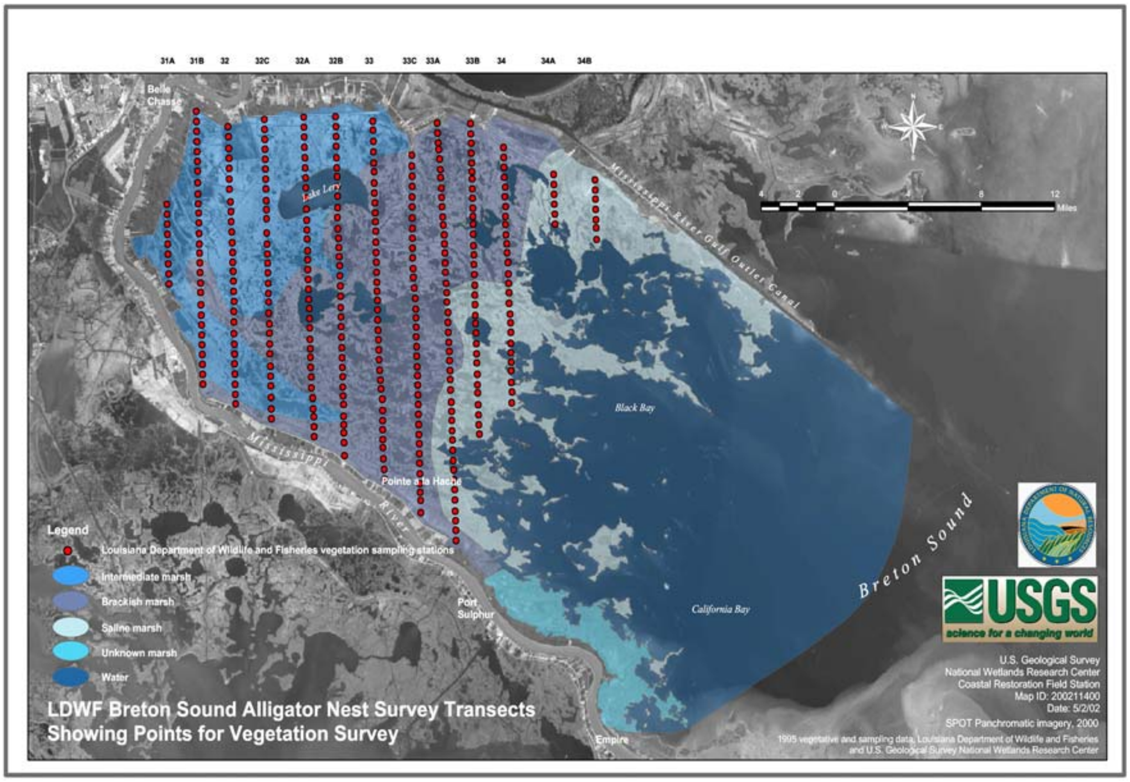

Figure 8. Location of wildlife and vegetation transects at Caernarvon.

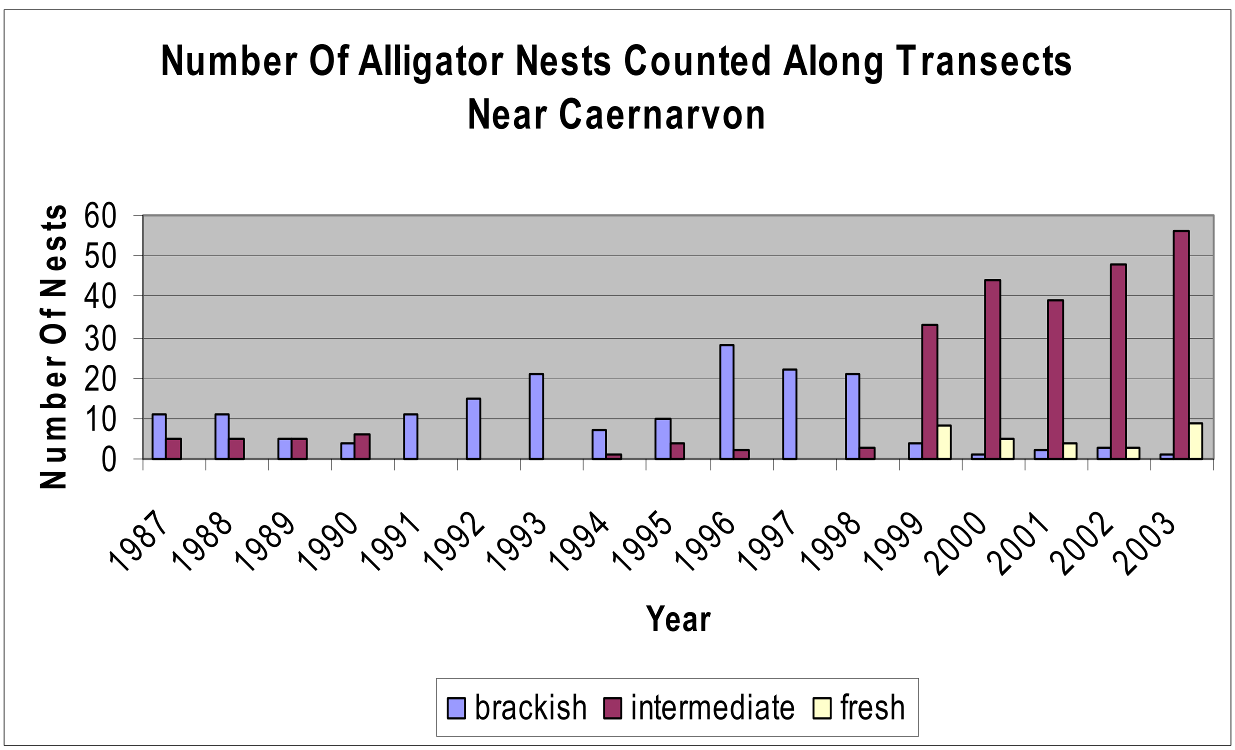

Figure 9. Number of alligator nests counted along transects at Caernarvon (LDWF).

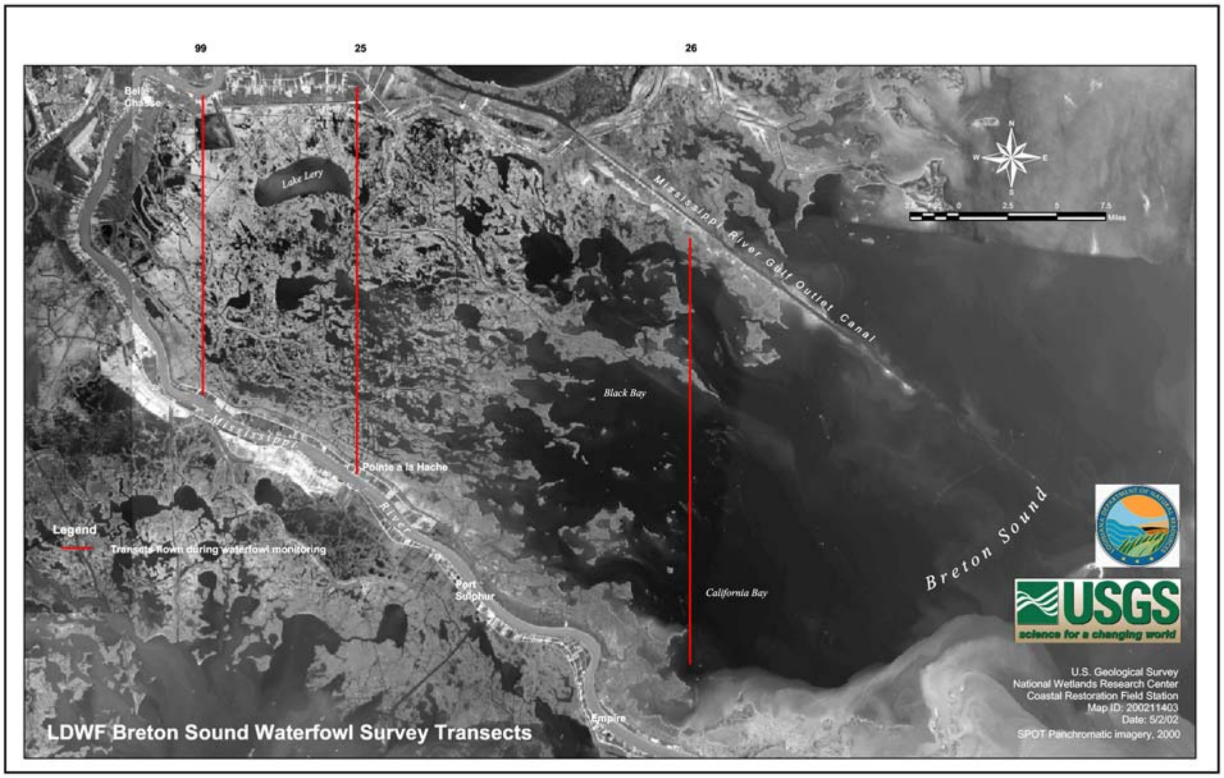

Figure 10. Location of waterfowl transects at Caernarvon.

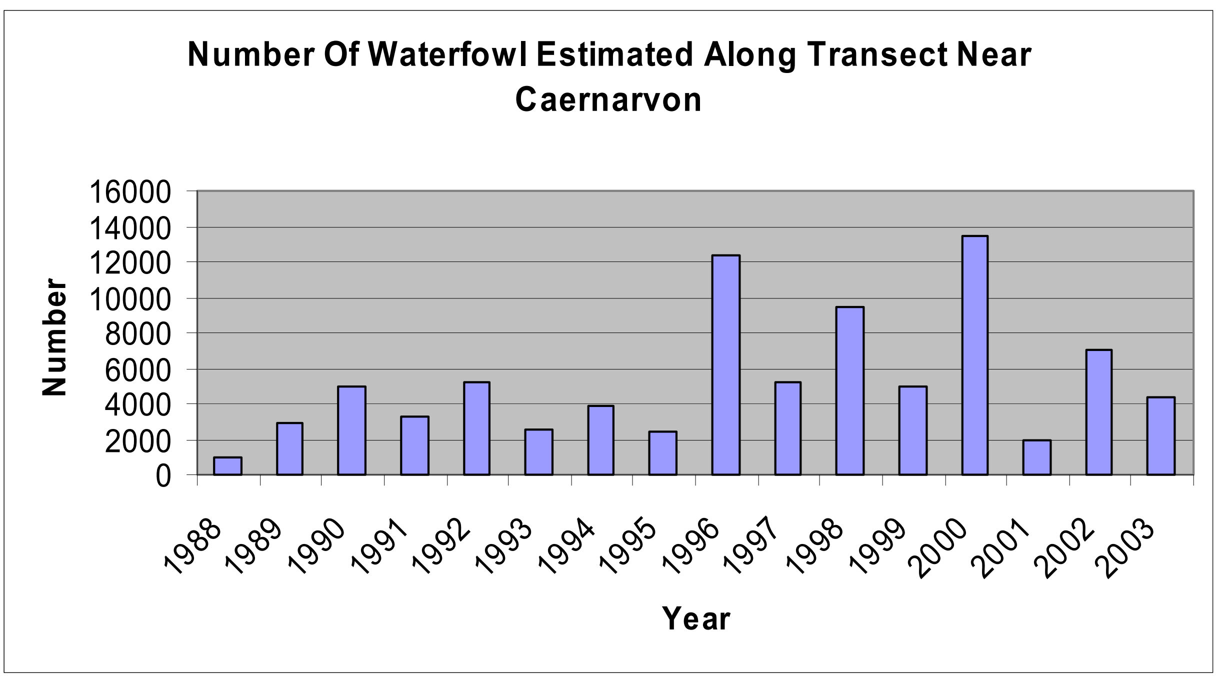

Figure 11. Number of waterfowl estimated along transects at Caernarvon (LDWF).

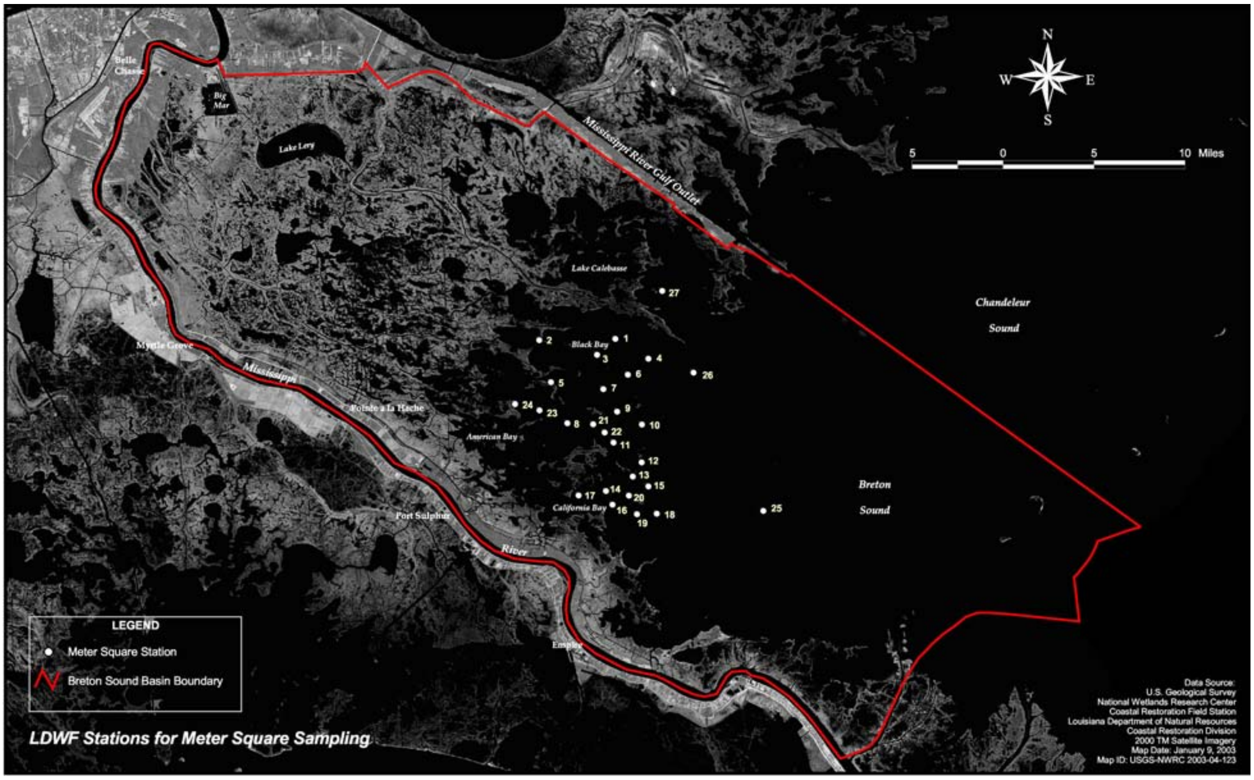

Figure 12. Location of meter square stations at Caernarvon.

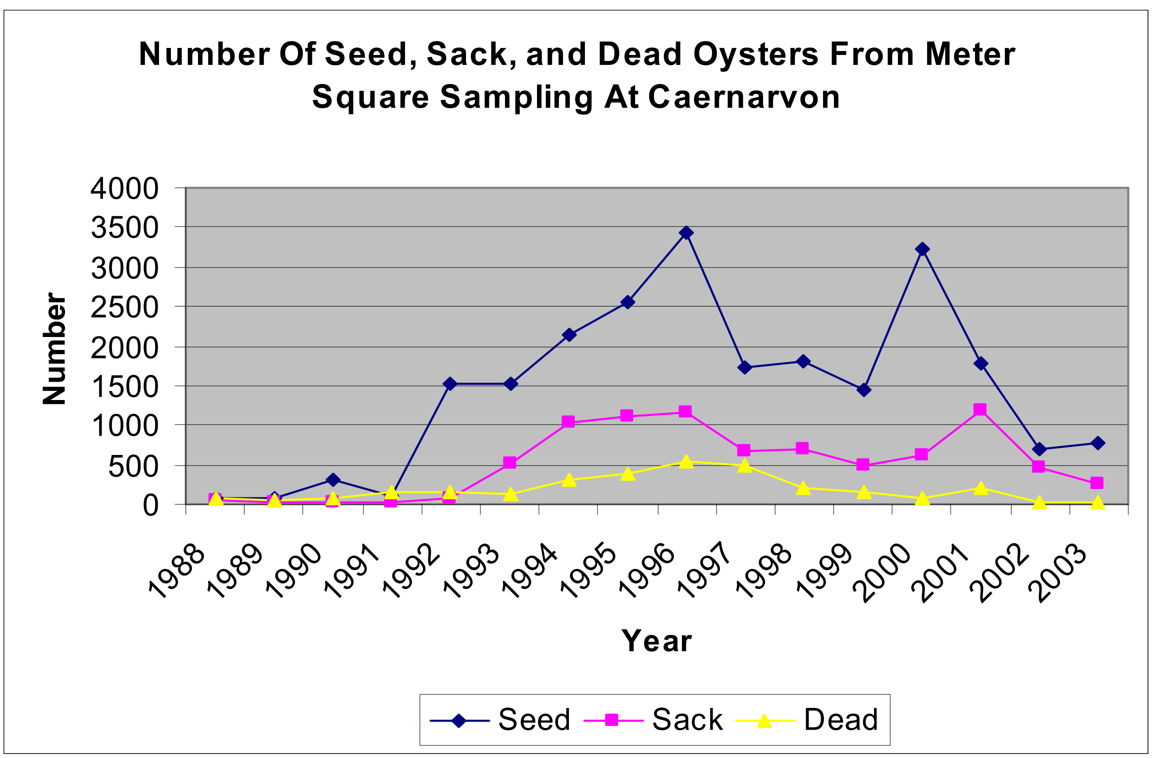

Figure 13. Number of seed, sack and dead oysters from meter square sampling at Caernarvon (LDWF).

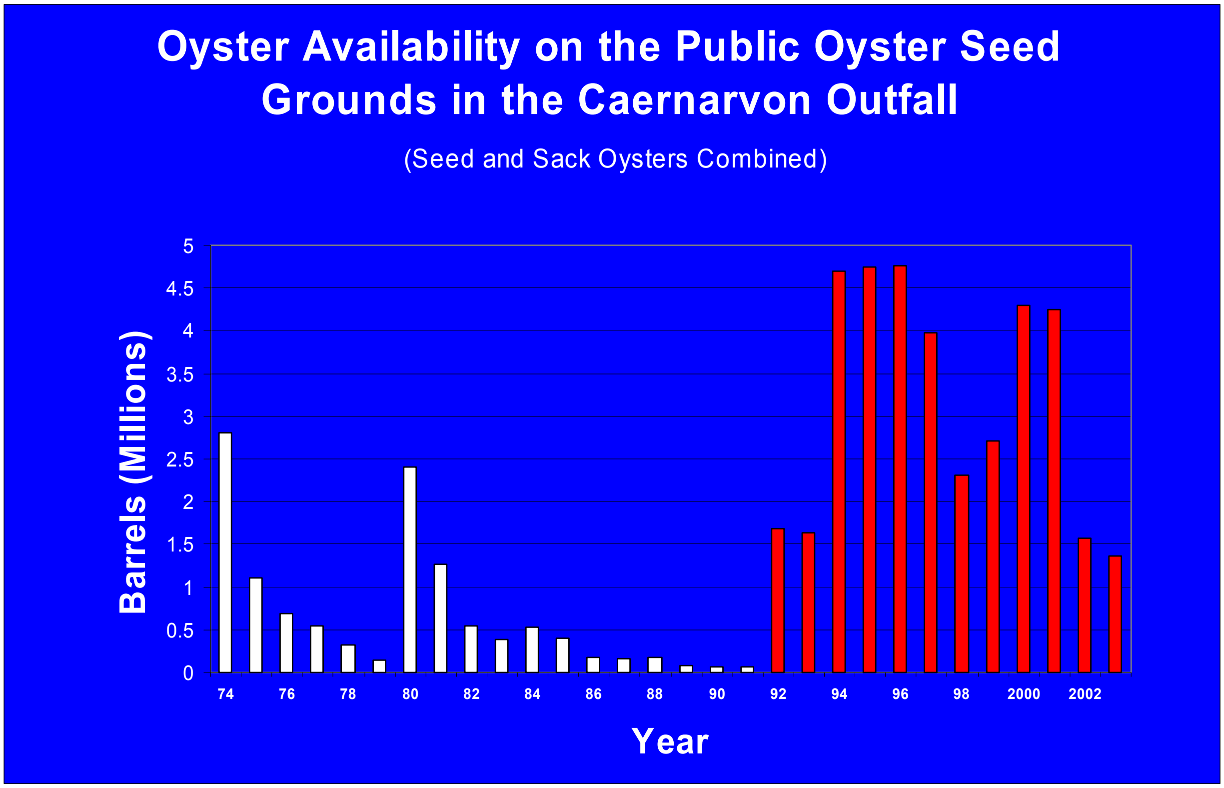

Figure 14. Oyster availability on the public seed grounds at Caernarvon (LDWF).

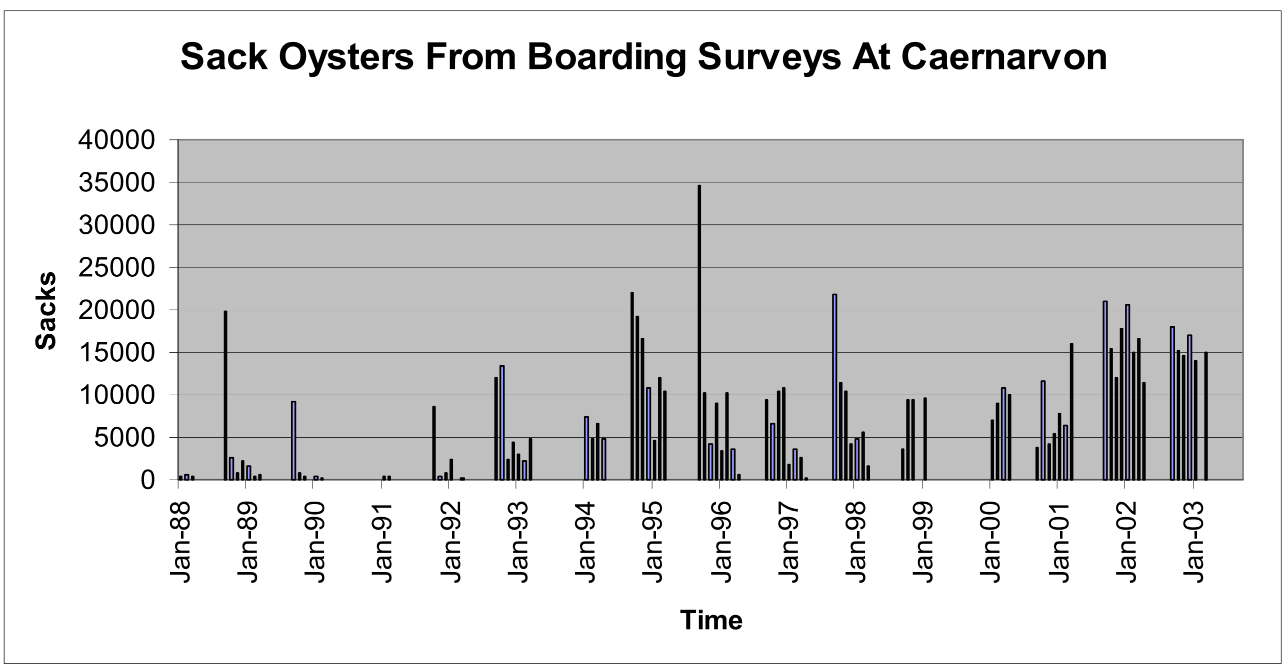

Figure 15. Sack oysters from boarding surveys at Caernarvon (LDWF).

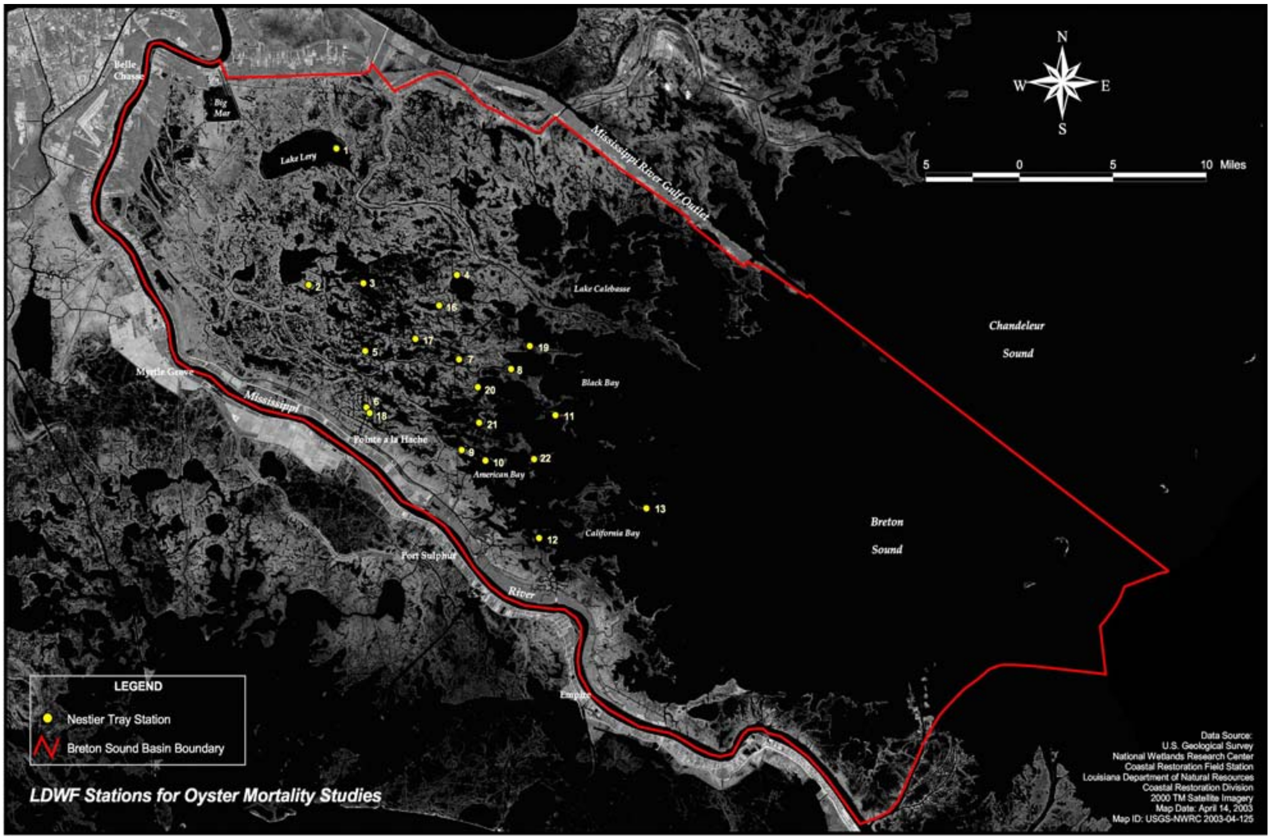

Figure 16. Location of nestier tray stations at Caernarvon.

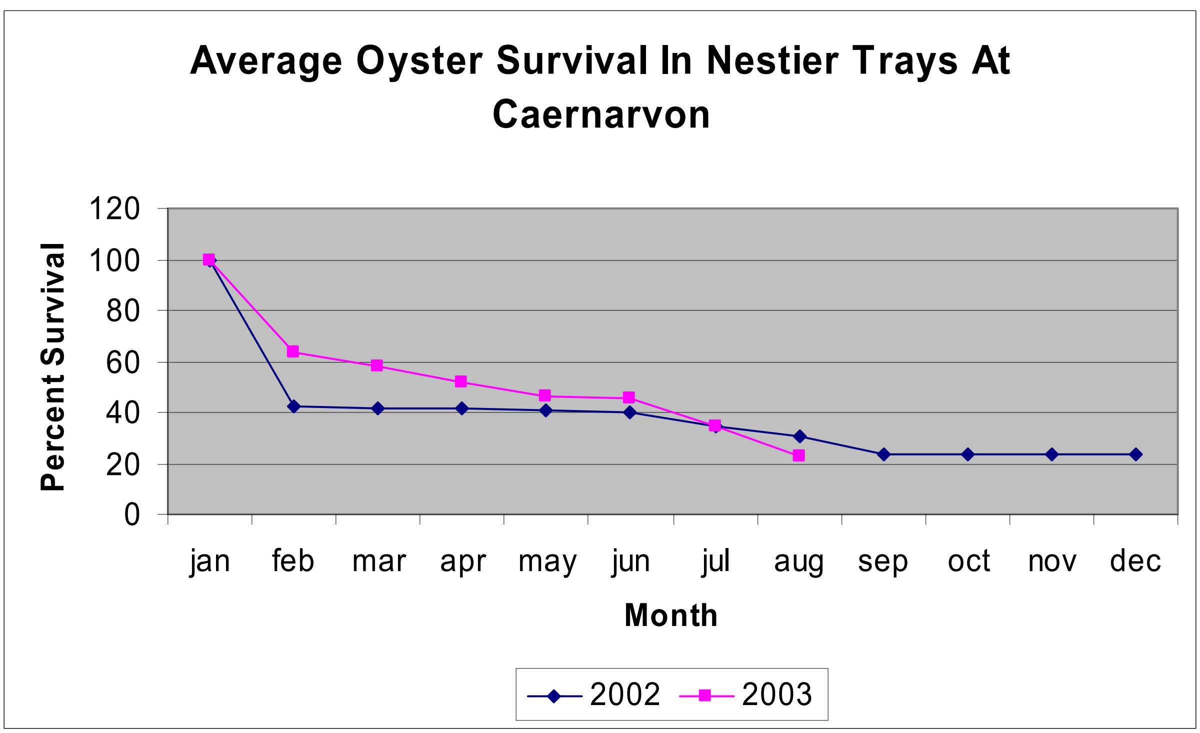

Figure 17. Average oyster survival in nestier trays at Caernarvon (LDWF).

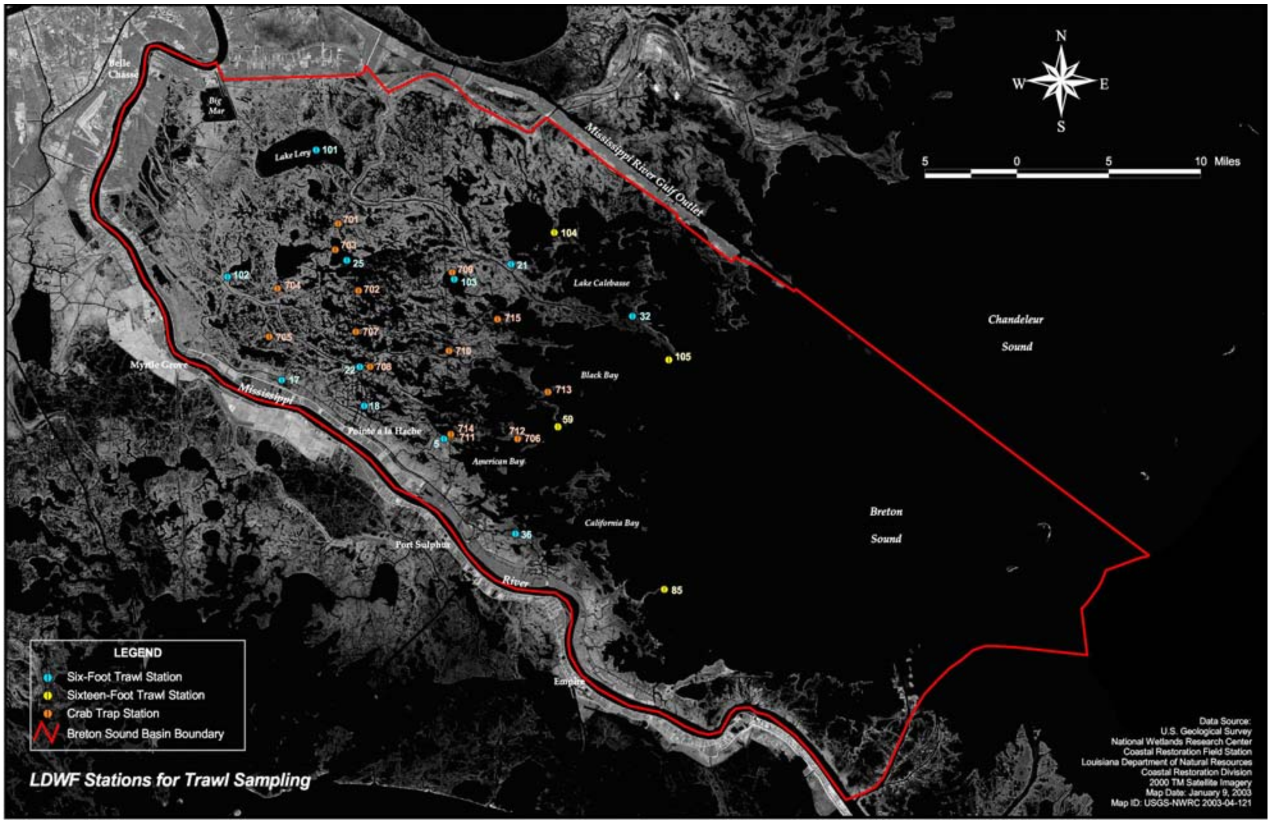

Figure 18. Location of trawl stations at Caernarvon.

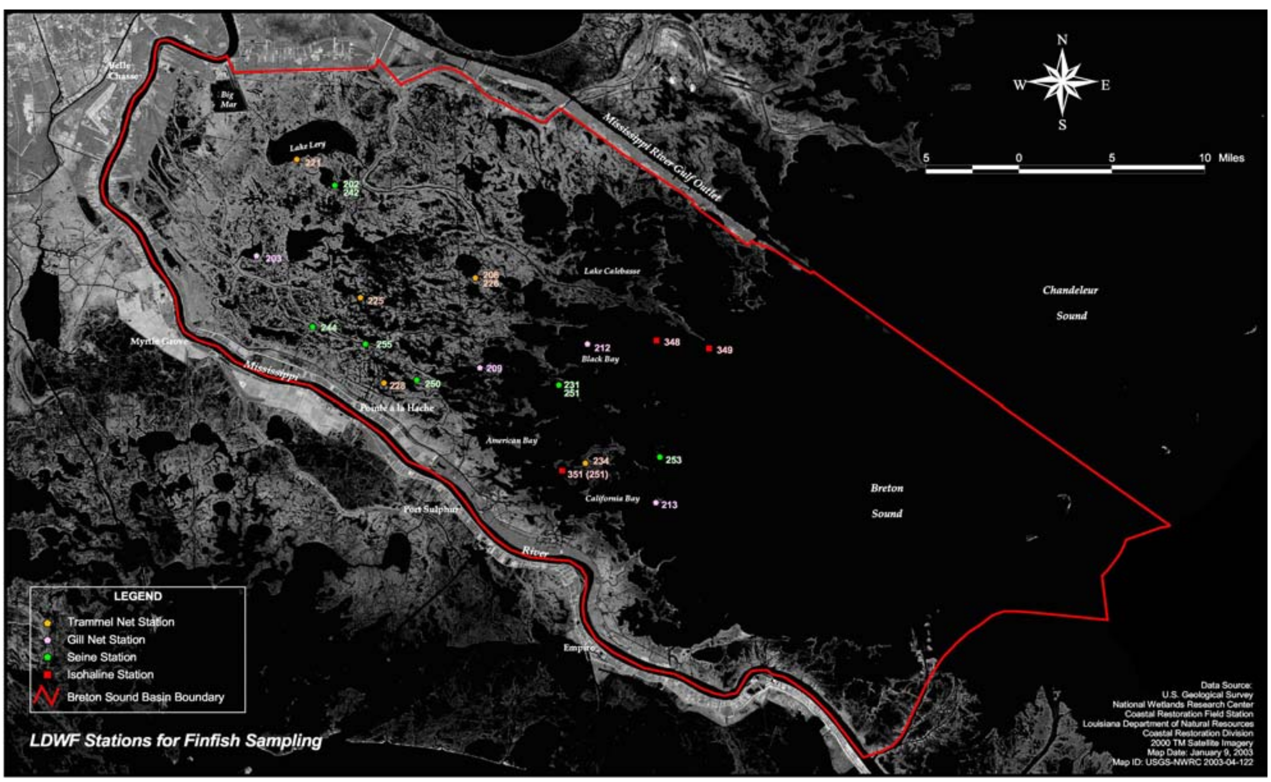

Figure 19. Location of finfish stations at Caernarvon.

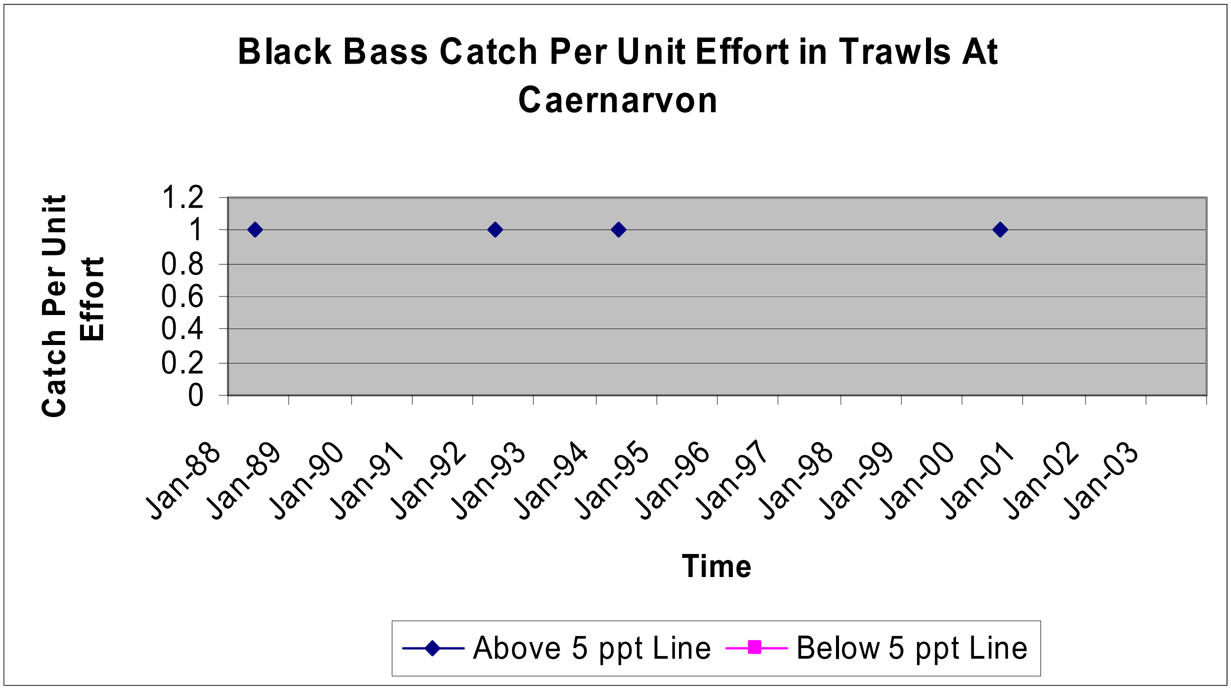

Figure 20. Black bass catch per unit effort in trawls at Caernarvon (LDWF).

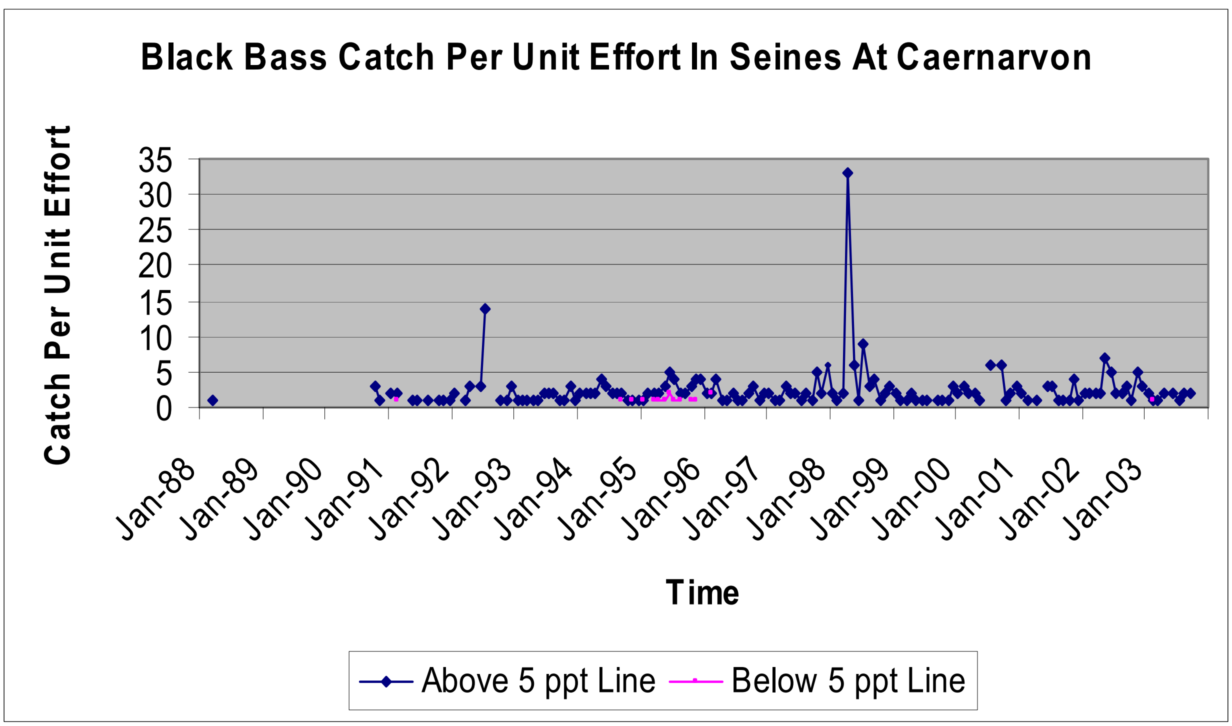

Figure 21. Black bass catch per unit effort in seines at Caernarvon (LDWF).

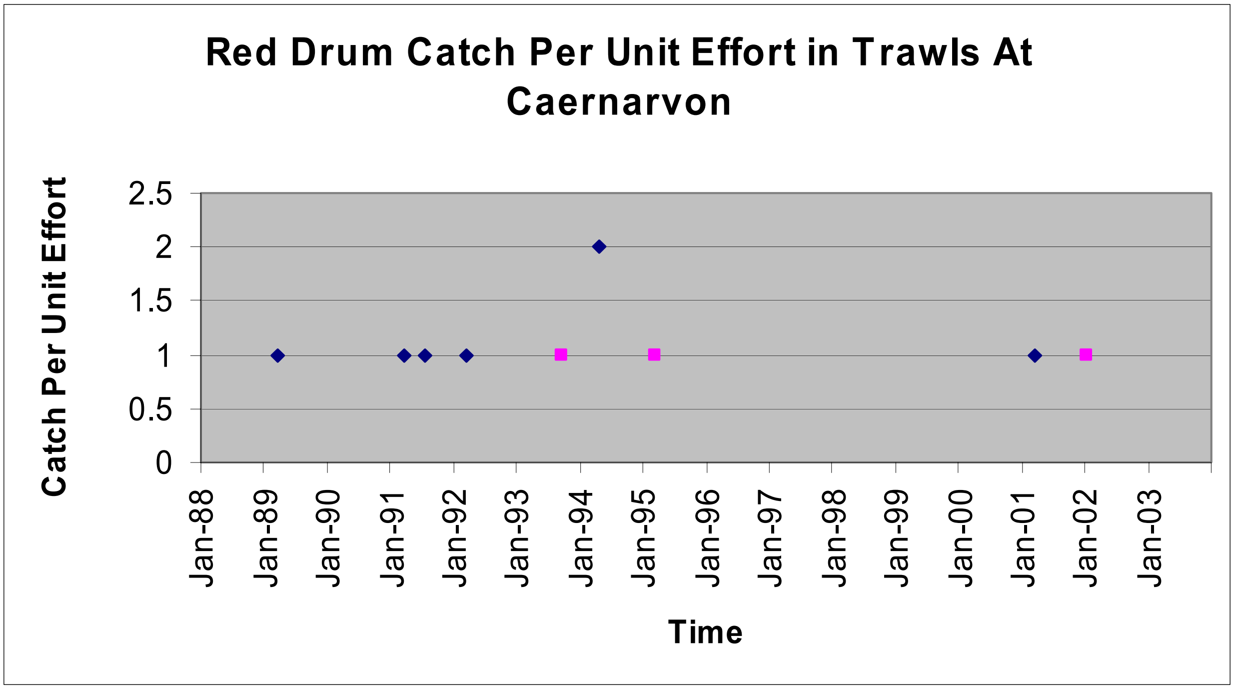

Figure 22. Red drum catch per unit effort in trawls at Caernarvon (LDWF).

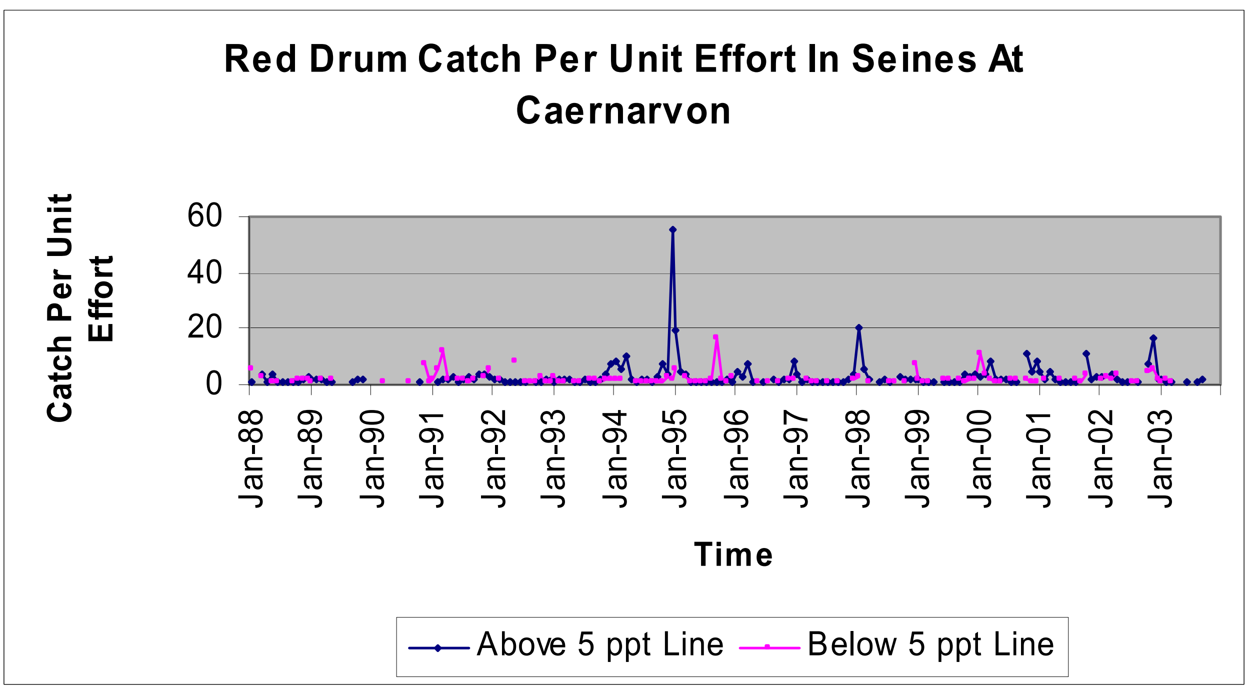

Figure 23. Red drum catch per unit effort in seines at Caernarvon (LDWF).

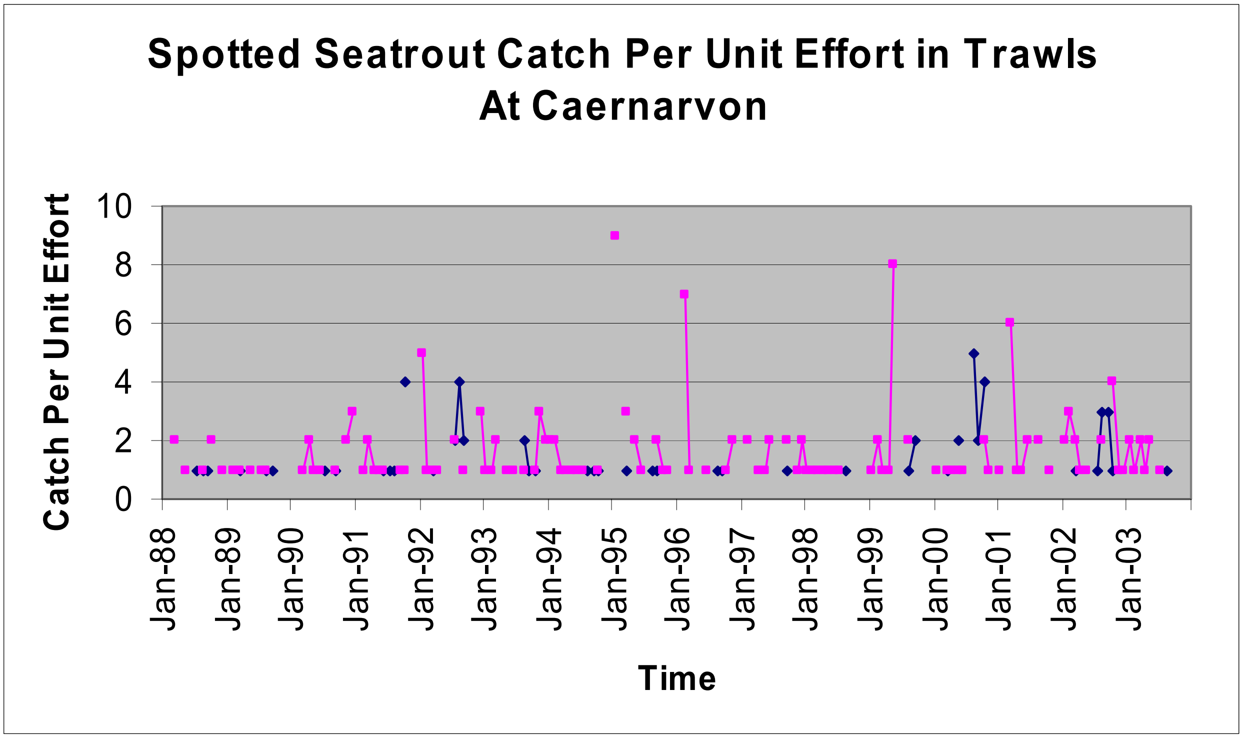

Figure 24. Spotted seatrout catch per unit effort in trawls at Caernarvon (LDWF).

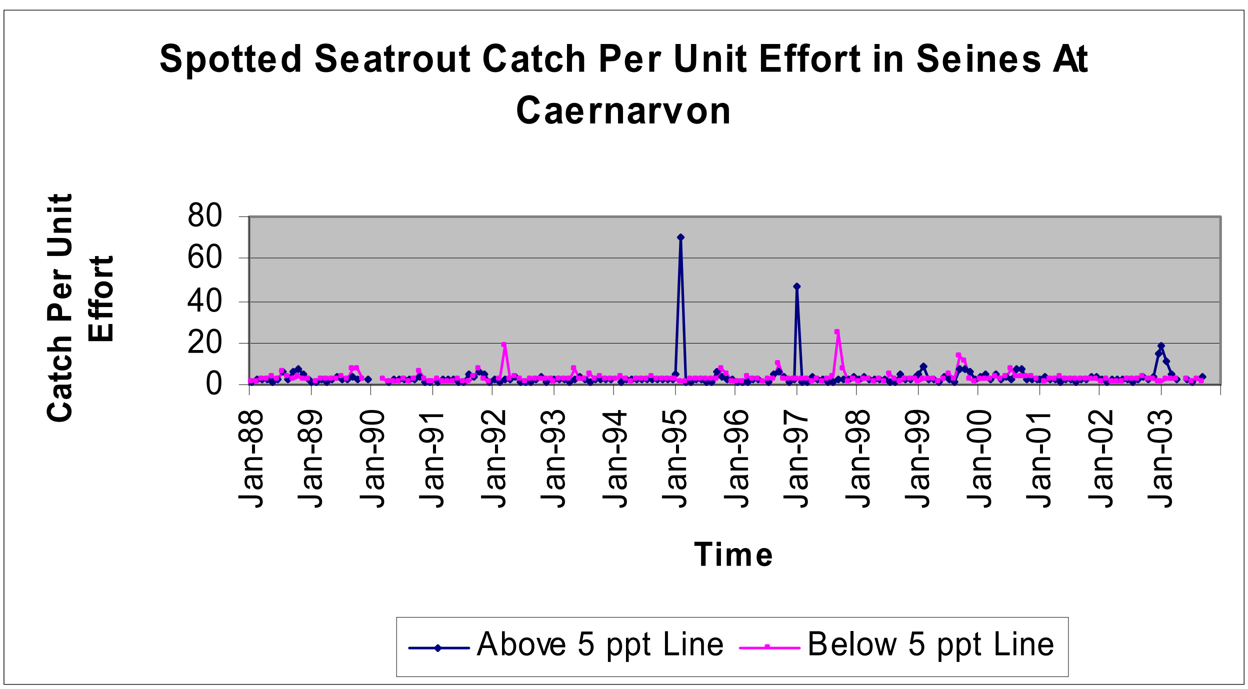

Figure 25. Spotted seatrout catch per unit effort in seines at Caernarvon (LDWF).

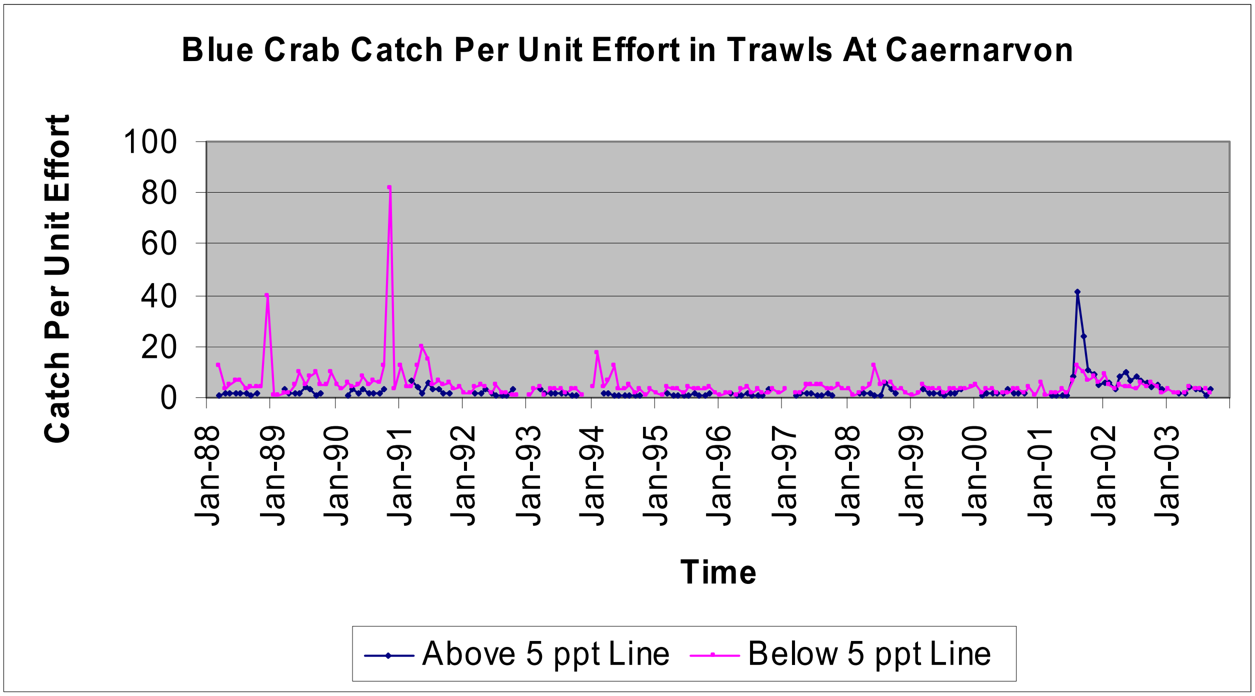

Figure 26. Blue crab catch per unit effort in trawls at Caernarvon (LDWF).

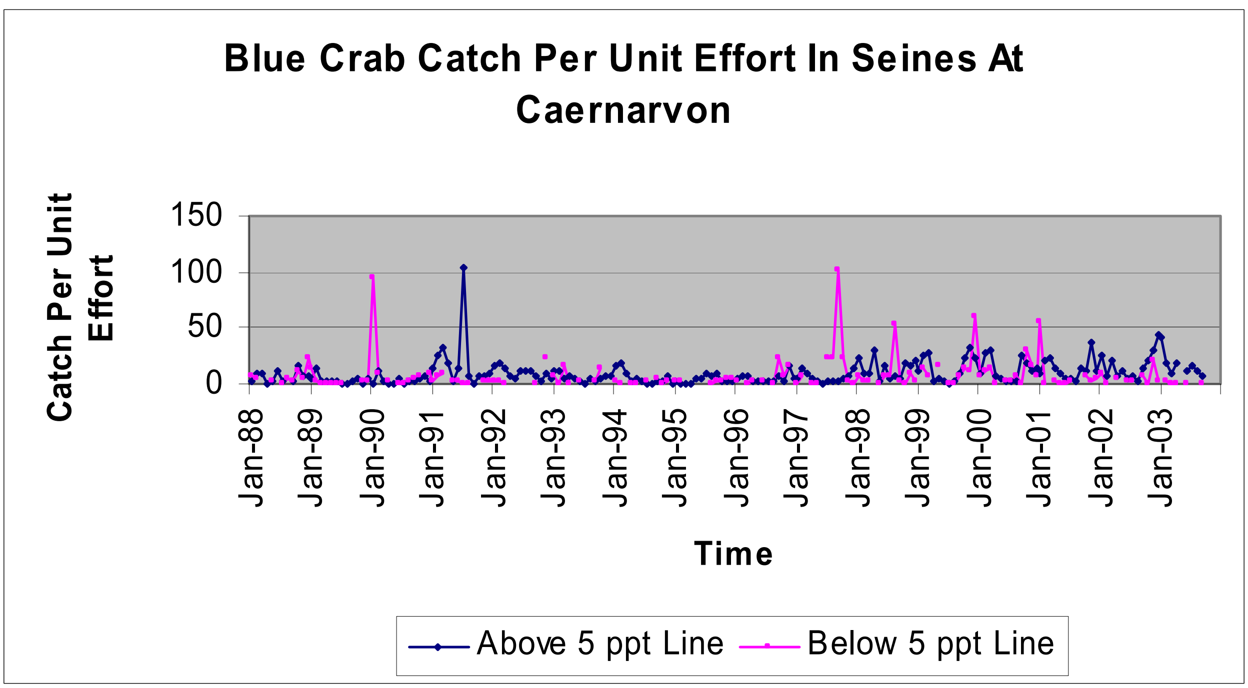

Figure 27. Blue crab catch per unit effort in seines at Caernarvon (LDWF).

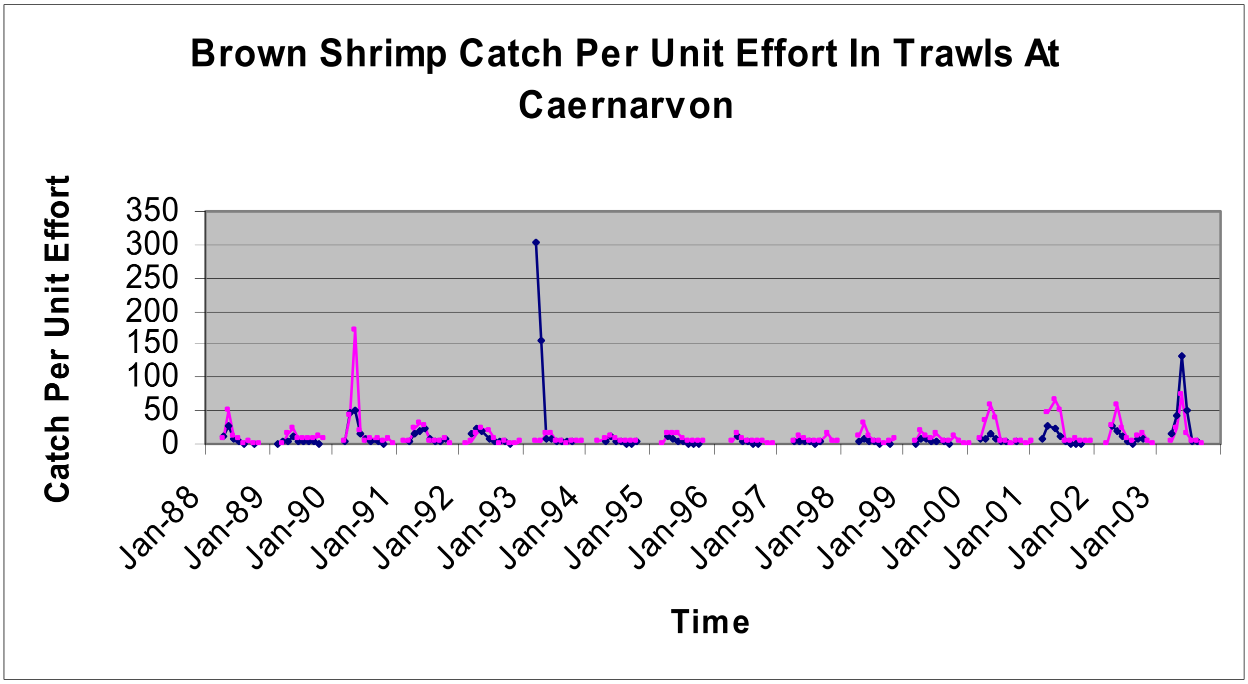

Figure 28. Brown shrimp catch per unit effort in trawls at Caernarvon (LDWF).

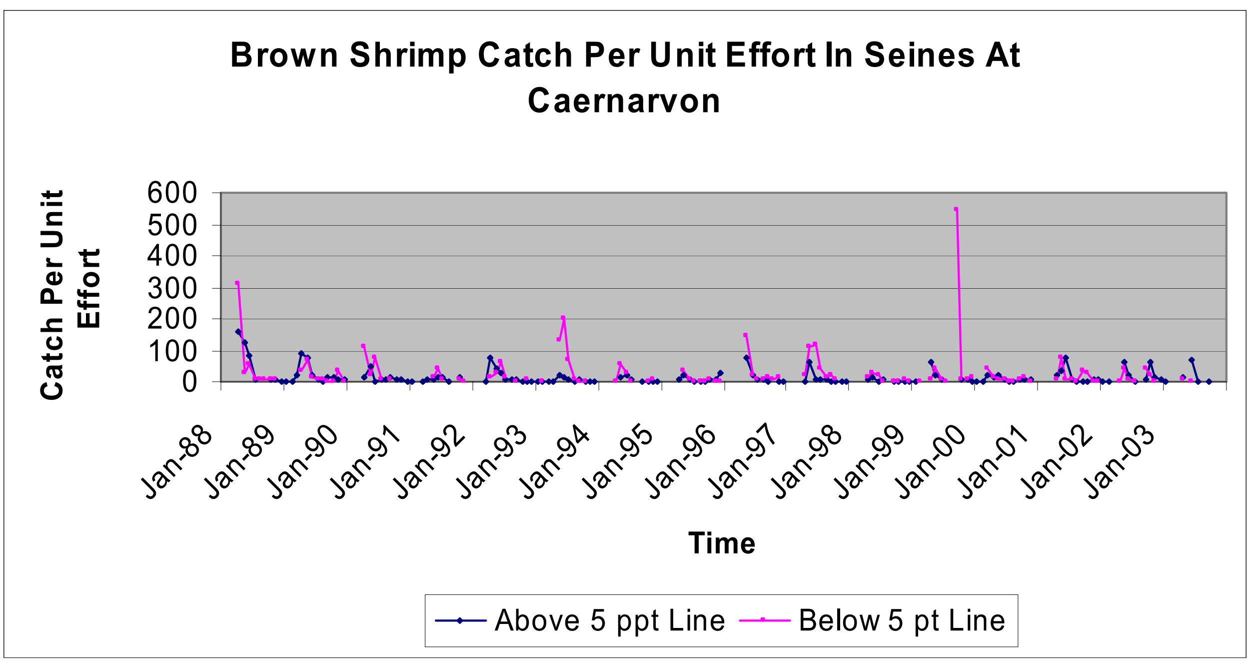

Figure 29. Brown shrimp catch per unit effort in seines at Caernarvon (LDWF).

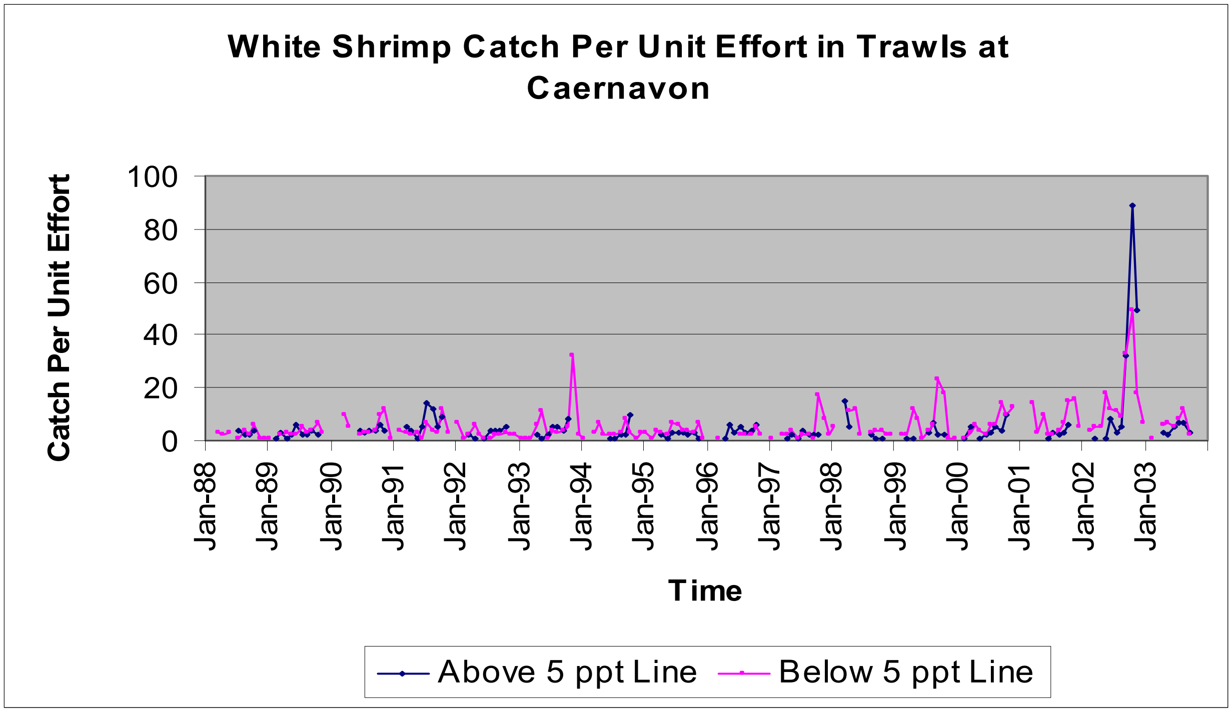

Figure 30. White shrimp catch per unit effort in trawls at Caernarvon (LDWF).

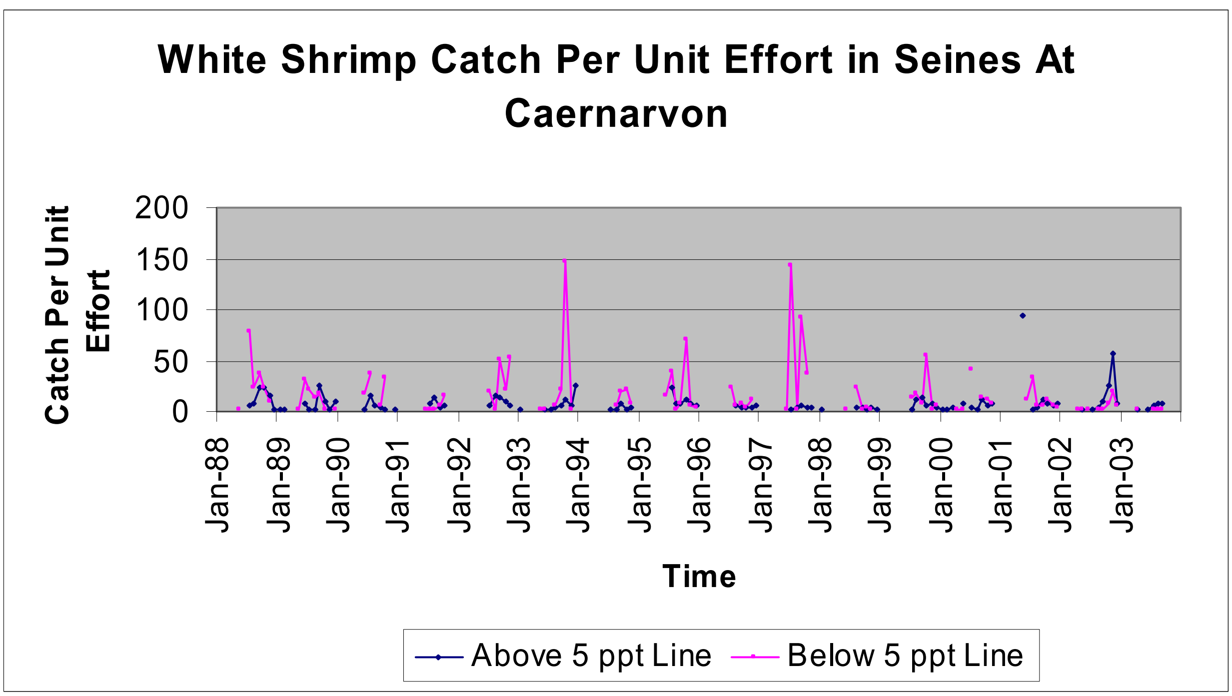

Figure 31. White shrimp catch per unit effort in seines at Caernarvon (LDWF).

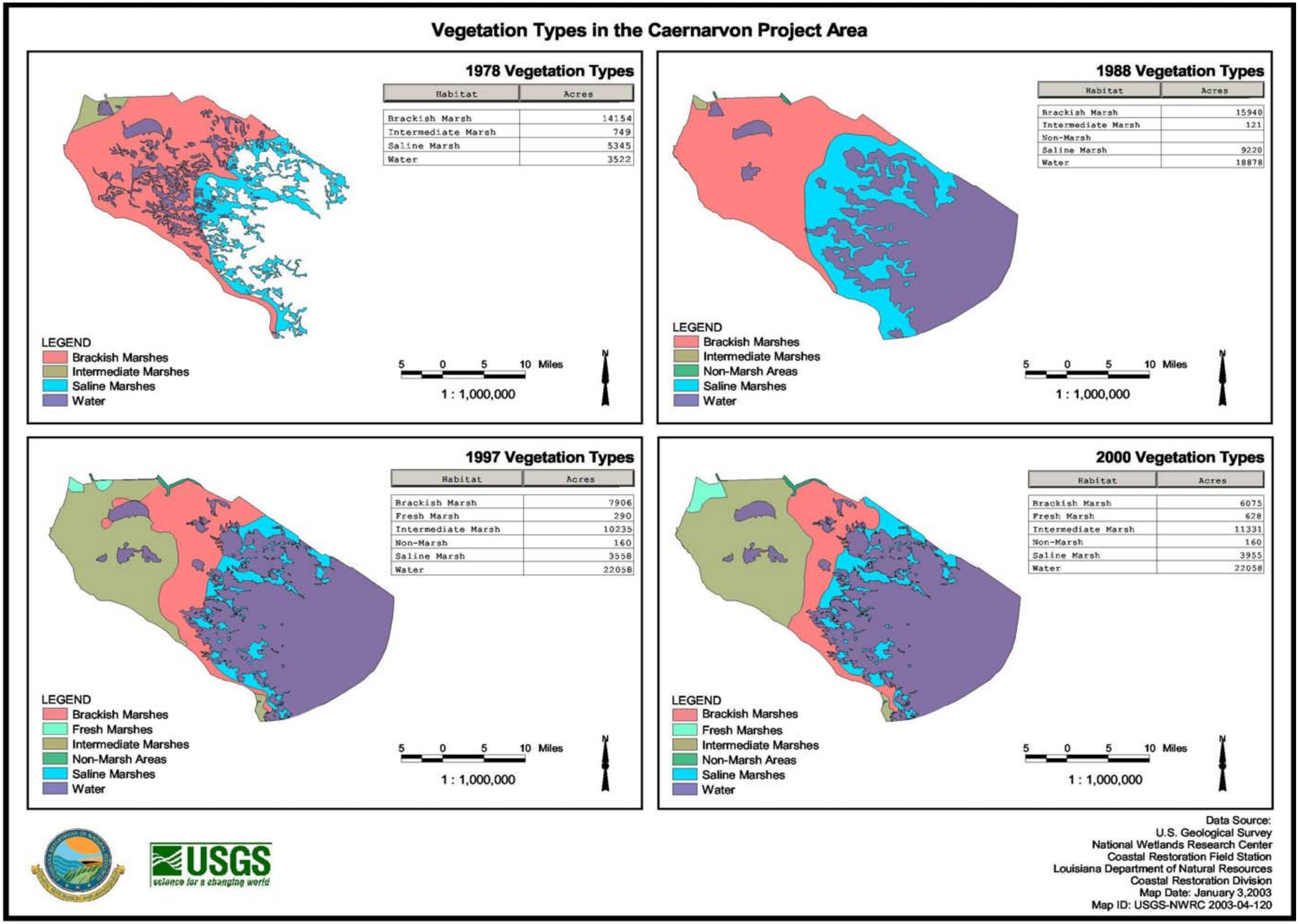

Figure 32. Habitat changes in Breton Sound basin 1978-2000. (USGS)

Figure 33. Shallow pond filling with emergent and submerged vegetation (DNR).

Open-water pond converting to vegetated fresh marsh 3.2 miles south of Caernarvon Freshwater Diversion Structure at a location of an SAV station for monitoring of BS-3a. Emergent vegetation first appeared in the summer of 2003. Three years previously pond was ~1 foot deep. Emergent vegetation includes arrowhead (*Sagittaria latifolia*) and bulltongue (*Sagittaria lancifolia*). SAV (*Heteranthera dubia*) was identified for the first time east of the Mississippi River. (documented by Michael Sealy – DNR)

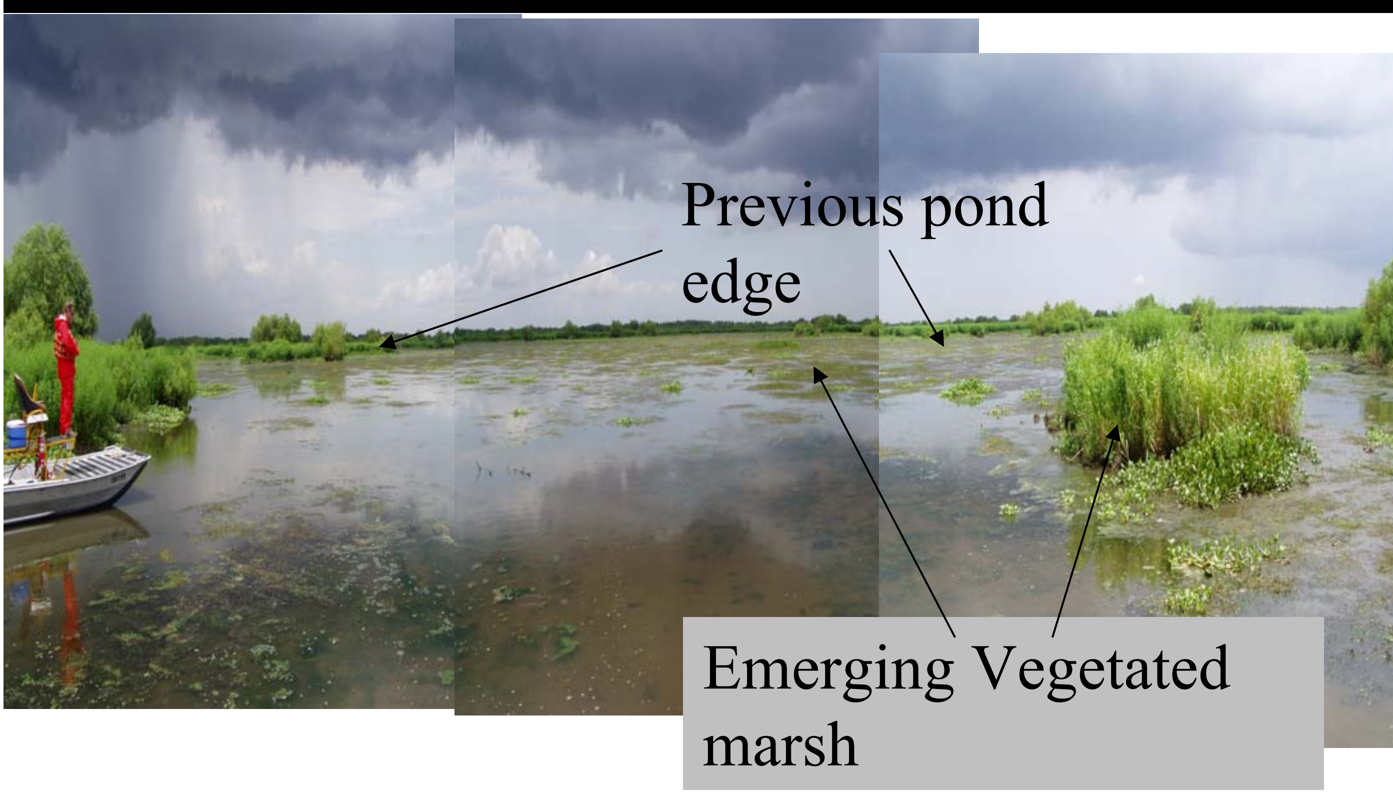

Figure 34. Open water pond converting to vegetated fresh marsh (DNR).