# CAERNARVON FRESHWATER DIVERSION PROJECT


## ANNUAL REPORT 2004
# DRAFT

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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 2003 through September 2004.

# 2. OPERATIONAL DATA

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

Caernarvon discharge for the reporting period (October 2003-September 2004) averaged 2,082 cfs when the structure was operational and 1,291 cfs including non-operational periods. The 12-year average for discharge is 1,835 cfs when the structure was operational and 1,097 cfs including non-operational periods. Discharge was highest between December and March, averaging in the 2,000-3,500 cfs range and lowest in the fall months when low river stage precludes operating the structure for significant periods. Discharge from the structure was lowered in May in response to low salinities in the basin. Low salinities were also observed in the Barataria estuary from December through September, so Caernarvon discharge was not the only contributing factor to low salinities in the Breton estuary during this time period. The structure was closed for 38% of the time for a variety of reasons which is 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 20-March 4, 2004 and on March 19- April 2, 2004 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 500 cfs on February 9-February 19, 2004 and March 5-March 18, 2004. 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 23% 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 58 inches which was 6 inches below the long-term average. Much of the time period rainfall was below the long term-average; the surplus was made during February and April-June. Three tropical systems affected the Louisiana coast in 2004.

### 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 7.1 ft, NGVD was slightly above the 65-year long-term average of 6.8 ft, NGVD. The mean monthly stage was above the long-term average from October 2003 – February 2004 and again from June 2004-September 2004. In March 2004- May 2004 was below the long-term average. Stage was unusually low in April 2004.

### 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 passages, 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. Persistent north winds from October 2003-February 2004 may have contributed to lower salinities in the basin starting in December 2003.

### 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. Across the estuary, salinities decreased starting in December 2003 through May 2004, then started to increase for the remainder of the time period, with Bay Gardene showing a sharp increase. 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 with a slight increase in September 2004. Cow Bayou was inoperable from October 2003-March 2004 when a new platform was installed for the gauge. This gauge has been repeatedly knocked over by boats.

## 4. WILDLIFE DATA

### Alligator (Figures 8-9)

Alligators (Alligator mississipiensis) 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 from about 10 to around 75. 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 or remain high as more habitat becomes available and food resources favorable to alligators continue to increase with diversion operation.

### 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.

Interannual variability is high and ranges from 2000 birds to 30,000 birds oserved. Overall, waterfowl increased 92% during the post-operation period. In the pre-operation period about 77% of ducks counted occurred in brackish and intermediate marsh whereas in the post-operation period it is 91%. Waterfowl numbers have been decreasing over the last few years. Likely explanations for low waterfowl numbers during 2000-2004 include mild weather conditions shortstopping birds and increased hunter pressure due to more liberal seasons. 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 (<u>Crassostrea</u> <u>virginica</u>) 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 over 1300% during the post-operation period. Although numbers of dead oysters increased also, dead oysters constitute a much higher percentage of the total 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. Hurricane activity increased from 1997-2004 and may have had a negative impact on oyster beds through siltation. Hurricane Andrew destroyed about 25% of central Louisiana's oyster beds according to LDWF. A dermo (<u>Perkinsus marinus</u>) outbreak occurred in 1996 which also affected spat numbers. Oyster productivity then rebounded in 2000 and decreased in 2001-2004. Oyster production on the public seed grounds has remained consistently high since Caernarvon opened.

### 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 266 % since the pre-operation period. Interannual 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 higher in 2004 for all months than in 2003. Overall survival in 2003 and 2004 was about 26%. This compares to an overall survival in the post-operation period of 34%. Overall survival in the pre-operation period was 65%. If stations above the 5 ppt line are excluded, the overall survival is 64% pre-operation and 47% post-operation. In 2003, 61% 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.

### 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 (Penaeus aztecus) and White Shrimp (Panaeus 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 25% 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 2004. Peak catches occurred above the 5 ppt line and catch increased 85% above the 5 ppt line in the post-operation period. Catch in the trawl data was light for both periods. This pattern is 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 31% 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. In the seine data, catch was 27% more prevalent in the post-operation period.

BLUE CRAB (Figures 26-27)
In trawls, the mean blue crab catch was about 49% greater in the pre-operation period than the post-operation. This appears to be due to an exceptionally abundant catch in 1990. Above the 5 ppt line, catch between the pre and post periods is about equal. Below the 5 ppt line, catch of crabs in trawls was much more prevalent in the pre-operation period.

Crab trapping was introduced in the monitoring in 2001 and is reflected in the higher numbers caught in 2001 and 2002 in seines. Crab trapping results are combined in the seine dataset. Crab trapping was discontinued in 2004 due to budgetary reasons. In seines, mean catch was about 17% higher during the post-operation period and more crabs are caught below the 5 ppt line during this period. Much of the increase in crabs appears to be since 1998.

BROWN SHRIMP (Figures 28-29)
Mean brown shrimp catch in trawls was about 8% 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 has increased since 2000. This may be due to drier weather and lower river stage during that time period. However, Caernarvon discharge from March-June since 2000 is 2.5 times greater than for the same months prior to 2000.

In seines, mean catch was about 32% 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 has been about 40% greater during 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 have increased since 1998. Mean catch in seines has been

consistent during the pre and post operation periods as well as above and below the 5 ppt line.

## 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 was nonexistent in 1978; however, 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 7.5 ppt for 1997, 4.7 ppt for 1998, 7.6 for 1999, 8.3 ppt for 2000, 5.6 for 2001, 4.4 for 2002, 3.7 for 2003, and 5.2 for 2004. The value for 2003 is low due to the recorders being off-line most of the year. It appears that the diversion structure can generally maintain historical salinities in the upper basin.

Salinities in the Breton estuary started declining in December 2003 and remained low until June 2004. The pattern at Bay Gardene is similar to Cow and Cooked Bayou indicating that the Mississippi River influenced this pattern. Cow and Crooked Bayou stayed below 5 ppt for about 8 months. While Caernarvon discharge probably contributed to this pattern, salinities in Barataria estuary were also low from December 2003 through August 2004 indicating a more regional cause for these prolonged low salinities in both basins. While rainfall was below normal for the time period, four months of above normal rainfall and generally northern winds during the first several months of the time period probably contributed to lower salinities. Some locally heavy rainfall in the marsh may have also contributed to low salinities; however, the low salinities persisted for months in both the Barataria and Breton basins.

## 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 than 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 and fresh marsh habitat and food resource, alligators have increased and 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 numbers have been decreasing the last several years across the state. Likely explanations for low waterfowl numbers include mild weather conditions shortstopping birds and increased hunter pressure due to more liberal seasons. 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. Despite salinity at the 5 ppt line being below 5 ppt from December 2003-June 2004, oyster survival during this time remained above 50%. 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 (Jae Young  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.

Blue crab productivity appears better post-operation. While trawl data are down, seine and crab trapping 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 may be somewhat misleading 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. However, due to budgetary constraints, crab trapping was discontinued in 2004. 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. However, 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 both above and below 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 recent years, the overall difference for pre-post was reduced from 20% greater in pre-operation to 8% 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). Research indicates that water needs to sheet flow over the marsh to be beneficial. This requires 3,500 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 http://dnr.louisiana.gov/crm.

## 9. FINAL REPORT EXECUTIVE SUMMARY OF PULSES PROJECT

### Final Report Executive Summary (From Dr. John Day et. al.)

**Period Covered by the Report**: February 28, 2000 through August 27, 2004
**Date of Final Report**: December 17, 2004
**EPA Agreement Number**: R828009
**Title**: PULSES-The Importance of Pulsed Physical Events for Watershed Sustainability in Coastal Louisiana
**Investigators**: John Day, Jaye Cable, Dubravko Justic, Brian Fry, Paul Kemp, Enrique Reyes, Paul Templet, Robert Twilley
**Institutions**: Louisiana State University (Baton Rouge, LA), University of Louisiana at Lafayette, LA, and University of New Orleans.
**Research Category**: Water and Watersheds
**Project Period**: February 28, 2000 to August 27, 2004

### Objectives of the Research Project

The overall objective of this project is to evaluate multiple effects of different scales of river inputs in one coastal watershed in the Mississippi delta, the Caernarvon watershed, just south of New Orleans (Fig. 1), where river inputs have been ongoing since the 1991 opening of a gated river diversion structure. Specifically, physical science objectives were 1) to monitor hydrodynamic responses to river inputs and climatic factors, and 2) to evaluate marsh accretion responses to different levels of river inputs. Ecological science objectives were 1) to evaluate marsh plant growth responses to river inputs that bring both sediments and nutrients, 2) to monitor water quality changes at the landscape level at different scales of water diversion, 3) to evaluate the function of wetland soils and benthic sediments as nutrient sinks in response to repeated flooding events with river water, 4) to assay effects of river inputs on fish, shrimp and oysters using stable isotopes, and 5) to monitor phytoplankton responses to pulsed riverine freshwater and nutrient inputs. Subsequently we developed 1) an integrated physical/biological water quality model of the Caernarvon system and 2) a regional-level simulation model to understand freshwater discharge and nutrient dynamic interactions. The objective of the social science subproject were to provide an interface between the natural and human systems of the region within the context of sustainable development through 1) conceptual model building, 2) cost/benefit analysis, 3) energy analysis, and 4) multicriteria/stakeholder analysis.

### Summary of Findings

We studied the multiple effects of different scales of river inputs into the Caernarvon watershed, just south of New Orleans (Fig. 1). River inputs have been ongoing since the 1991 opening of a gated river diversion structure. Discharge levels ranged between 185 $m^3 sec^{-1}$ for high flow, and 15 $m^3 sec^{-1}$ for low flow (Fig. 2).

The estuary stretches SE for about 70-80 km from the diversion structure to the Gulf of Mexico (Fig. 1). The upper 40 km of the estuary, encompassing an area of about 1,100 $km^2$, is composed of extensive marshes, small to medium size water bodies, and channels, while the lower estuary is open water in Breton Sound. Thus, the upper estuary is weakly to moderately coupled to the lower estuary due to shallow, sinuous channels and extensive marshlands. Tidal amplitudes at the Gulf of Mexico end are about 35 cm but are much less in the upper basin due to dampening effects of the marsh dominated area. In this upper estuary, winds and diversions cause much higher water level variations than do tides. Salinity is generally fresh (<1 psu) in the upper basin except during prevailing south winds or very low diversion flow.

Sediment deposition on marshes resulted from a complex set of conditions in which prevailing winds, water velocity, water levels or tides, river flow, and suspended solid loads all contribute to marsh surface delivery. Wind direction was a major controlling factor in providing both TSS and water levels high enough for marsh delivery. The Caernarvon diversion delivered sediment into the northernmost reach of the Breton Sound estuary, but strong or sustained south winds dampened diversion flow and sequestered diverted sediment in the northern estuary, thus preventing deposition in the lower reaches. Statistical analysis revealed that deposition in Breton Sound estuary varied by season, with distance from the diversion ("new" sediment source; see Fig. 3), and with proximity to a major waterway.

Calculations based on results from the sediment pads indicated marsh vertical accretion could reach 2.25 cm $yr^{-1}$, while excess $^{210}Pb$ measurements recorded at the same site showed a much slower rate of 0.11 cm $yr^{-1}$. The $^{137}Cs$ sediment activities showed an annual accretion rate of 0.10 cm $yr^{-1}$, which agreed very well with $^{210}Pb$ measurements. These data illustrate an important point about marsh deposition. Short-term sediment trap measurements do not capture the effects of compaction and decomposition, and thus, represent a more ephemeral mode of deposition.

Discharge from the diversion structure controls salinity through much of the estuary, especially during large 'pulses' when almost the entire estuary freshens. Temperature of incoming Mississippi River water ranged from 6-32 ˚C and generally equilibrated to the rest of the estuary within 10 km, but there were several times when cooler water from the diversion propagated through the entire estuary. During most transects, there were substantial reductions in most nutrient forms, especially nitrate, as water flowed through the estuary. Incoming Mississippi River nitrate concentrations ranged from 41-285 µmol $L^{-1}$, and concentrations at mid-estuary ranged from 1-75 µmol $L^{-1}$. Possible mechanisms for this reduction are dilution with Gulf water, rain, or ground water, and uptake by phytoplankton, bacteria, and marsh plants, denitrification, or burial. In the upper estuary, maximum estimated removal rates of total nitrogen and nitrate during a two-week pulse in May 2001 were 44% and 57% respectively, and phosphate and silicate were reduced by 23% and 38% respectively. During this period, the upper estuary was almost entirely fresh, rainfall was low, and ground water was negligible. On the other hand, overland flow across marshes may have mixed river water with low nutrient marsh water, diluting river nutrient concentrations, and actual removal rates may be lower than the calculated maximum rates to the extent that such dilution occurred. N burial and denitrification are other important sinks for N in these coastal watersheds.

The changes in nutrient concentrations during the May 2001 river pulse also led to downestuary changes in stoichiometric nutrient ratios, with an overall increase in the dissolved DSi:DIN ratio and a decrease in the DIN:DIP ratio (Fig. 4, Table 1, Lane et al. 2004). At this time and during other spring discharge pulses, chlorophyll concentrations near the diversion were low, but increased after suspended sediments decreased below 80 mg $L^{-1}$ several km from the diversion structure. Overall, chlorophyll levels generally peaked at mid-estuary, and gradually decreased to low levels in Breton Sound (Lane et al., in preparation).

Nitrate fluxes in winter/spring 2002 indicated very low uptake or even efflux of nitrate from the sediment. Denitrification rates increased with increasing distance from the diversion and increasing water temperatures in the field, with maximum rates of up to 325 µmol $N_2$-N flux $m^{-2}$ $h^{-1}$ at Grand Lake. In summer 2002 high nitrate fluxes into the sediments of more than 350 µmol $NO_3$ $m^{-2}$ $h^{-1}$ were estimated for cores from Big Mar. Nitrate uptake rates decreased regionally from that maximum down to zero with increasing distance from the diversion. This drop is consistent with a reduction of ambient dissolved inorganic nitrate in the water to non-detectable levels (Fig. 5). Denitrification rates at Big Mar were higher than 300 µmol $N_2$-N flux $m^{-2}$ $h^{-1}$ in summer and even though no nitrate uptake was detected for Grand Lake with our method, denitrification rates of up to 100 $N_2$-N flux $m^{-2}$ $h^{-1}$ were measured.

The $\delta^{15}N$ values for grass shrimp showed a strong gradient throughout the sampling area, with highest values close to the diversion and decreasing values further away from it (Figs. 6, 7). River-derived nitrogen was strongly incorporated into the food web leading to grass shrimp with elevated $\delta^{15}N$ values through much of the estuary. However, at marsh-influenced sites, this effect was much diminished. The simplest interpretation of these results is that there is another nitrogen source present in marsh-influenced sites, with the source having low $\delta^{15}N$ values. Use of marsh nitrogen derived from this fixation, or also possible use of dissolved organic nitrogen that may have low $\delta^{15}N$ values in river water possibly could lead to the lower $\delta^{15}N$ values in food webs at these stations.

The habitat model was used to test the effects of different management scenarios. Modeled riverine inputs had strong effects on watershed dynamics, as detailed by Reyes et al. (2003).

We incorporated information from Caernarvon in an analysis of the relations among natural capital, pollution, and social welfare. Results showed that sustainable functioning of natural systems should contribute substantially to development of societal wealth in Louisiana. Preliminary results of the stakeholder analysis revealed that although there is high level agreement that coastal land loss is a significant problem, diversions are not always viewed as an appropriate solution to this problem. This is due to a combination of factors, especially that 1) local people tend to make judgments based on heuristics (e.g., personal experience for generalization), 2) there are significantly different responses among decision makers, experts, and local people, 3) channels to accommodate public opinions are available, but not actively used, therefore, 4) diverse opinions and conflicts exist and persist.

The results of the study suggest that there are benefits as well as potential detrimental impacts of diversions. The diversion results in nutrient uptake, marsh accretion, lower salinities and incorporation of riverine materials into local food webs. There is concern, however, over the potential of high nutrient levels leading to eutrophication, and that long-duration pulses of one month or more can depress fisheries yields of shrimp and oysters. These costs and benefits need to be carefully considered in the management of diversions.

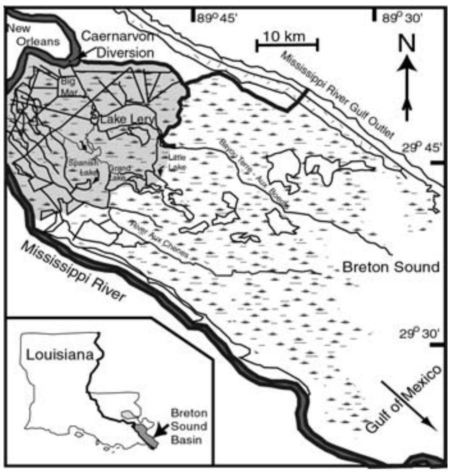


Figure 1. Breton Sound Basin with main region of estuary influenced by diversion highlighted in gray.

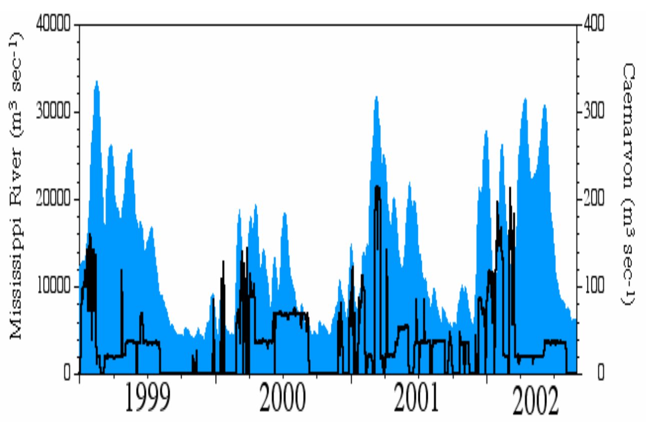


Figure 2. Mean daily Mississippi River (shaded) and Caernarvon structure (line) discharge from 1999 to 2002. Note the large pulses in 2001 and 2002 associated with this project.

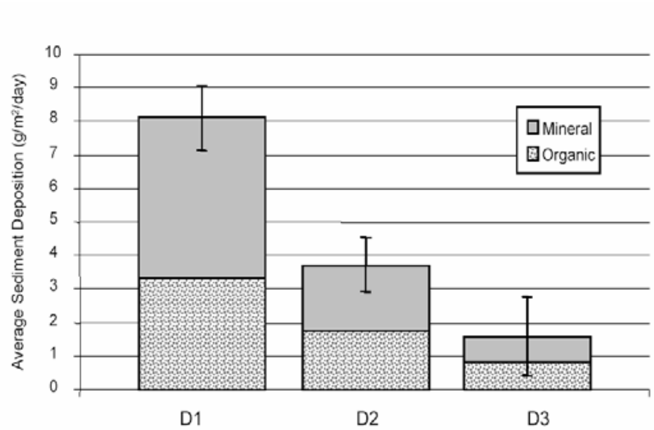


Figure 3: Average sediment deposition by sampling site distance, where D1 = < 6km (n = 5), D2 = 6 to 10 km (n = 6), and D3 = >10 km (n = 3). Background conditions at a reference station gave similar results to the D3 data. Overall deposition was highest within 10 km of the diversion.

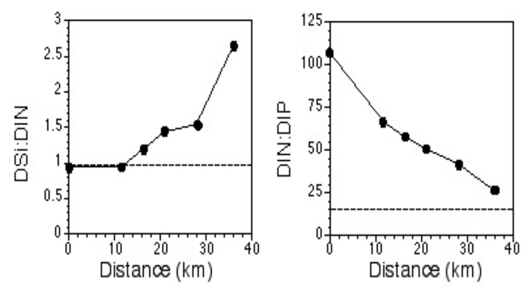


Figure 4. Molar ratios of DSi:DIN, and DIN:DIP with distance from the Caernarvon structure during the spring pulse of 2001. Horizontal dashed lines indicate the Redfield ratio. Distance was determined as a straight-line from the structure to the respective sampling stations.

| Distance (km) | DSi (µM) | TN (µM) | DIN (µM) | TP (µM) | DIP (µM) | Salinity (PSU) |
|---|---|---|---|---|---|---|
| 0 | 117.8 | 138.9 | 128.3 | 5.1 | 1.2 | 0 |
| 11.8 | 108.3 | 108.8 | 112.9 | 3.4 | 1.7 | 0 |
| 16.4 | 96.6 | 99.3 | 86.8 | 2.6 | 1.4 | 0 |
| 21.2 | 76.8 | 72.9 | 50.6 | 2.0 | 1.0 | 0 |
| 28.3 | 62.1 | 60.3 | 35.5 | 2.2 | 0.9 | 1.5 |
| 36.0 | 47.9 | 49.9 | 16.9 | 2.0 | 0.8 | 4.5 |

Table 1. Concentrations of dissolved inorganic silicon (DSi), total nitrogen (TN), dissolved inorganic nitrogen (DIN), total phosphorus (TP), dissolved inorganic phosphorus (DIP) and salinity with distance from the Caernarvon structure during the spring pulse of 2001 (most data are from March 22, 2001).

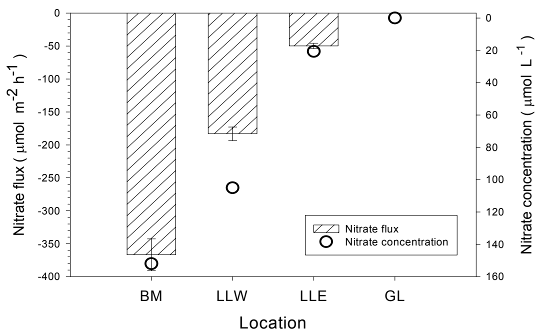


Figure 5. Nitrate Flux averaged from 3 replicate cores per location (summer 2002). Bars show nitrate flux, with flux into the sediment as negative value. Circles give the ambient nitrate concentration in the water column.

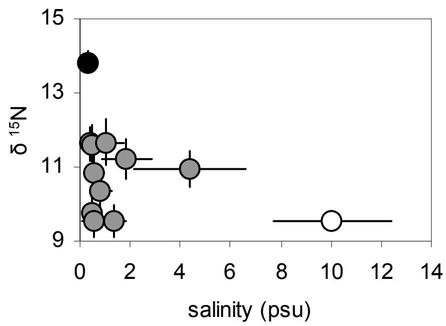


Figure 6. Average $\delta^{15}N$ (‰ ) values of grass shrimp muscle tissue vs. average salinity for the 12 sampling stations. Samples were collected 11 times between Dec. 2000 and July 2002. Error bars represent 95% confidence levels. The black and white symbols stand for the stations closest to the diversion and marine station, respectively.

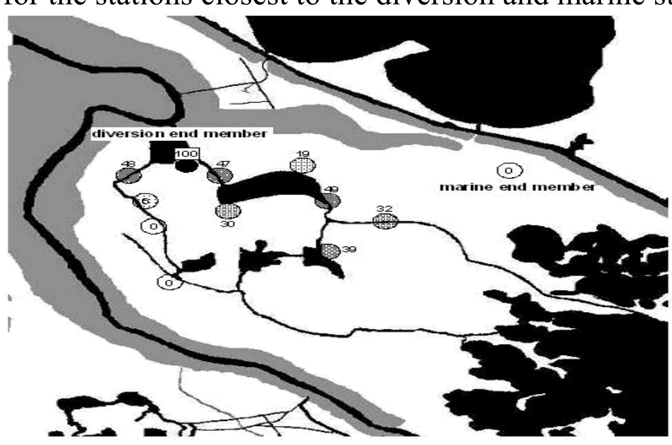


Figure 7. Average contribution (%, black = 100%, and white = 0%) of Mississippi River nitrogen to shrimp muscle tissue for the 12 sampling stations. Calculations area based on figure 3 and the assumption that the $\delta^{15}N$ values at the station closest to the diversion completely derive from Mississippi River nitrogen and that the $\delta^{15}N$ values at the most marine station are not influenced by the Mississippi River nitrogen.

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Hyfield, E., J.W. Day, D. Justic, and J. Cable. Freshwater and nutrient inputs to a Mississippi deltaic estuary with river re-introduction. Anticipated submission to Estuarine, Coastal and Shelf Science.

Lane, R. R., J.W. Day, E. Reyes, D. Justic, J. N. Day, E. Hyfield. The effects pulsed riverine discharge on chlorophyll *a*, suspended sediments, salinity, and temperature in the Breton Sound estuary, Louisiana. Anticipated submission to Journal of Coastal Research.

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Wissel, Bjorn, and Brian Fry. (in preparation) Particulate organic $^{13}$carbon and $^{15}$nitrogen as tracers for hydrology-induced changes in estuaries.

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Fry, B. 2000. Energy flow and the importance of Spartina detritus in a Louisiana salt marsh food web. Presented at the Fourth Gulf of Mexico Symposium. Mobile, Alabama, April 9-12.

Fry, B. 2000. Individuals-their movement and foraging in patchy wetland aquascapes. Presented at 21st Annual Conference of the Society of Wetland Scientists. Montreal, Canada. August 6-12.

Templet, P.H. 2000. Externalities, subsidies and the distribution of wealth. Presented to Ecosummit Quality of Life session, Halifax, Nova Scotia, Canada. June 26-29.

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Day, J.W. and P.H. Templet. 2001. Energetic pulsing: the basis for sustainable management of deltas. Presented at the Mega Deltas Conference in the Hague, Netherlands, Sept. 24-26.

Day, J., J. Cable J., D. Justic, B. Fry, P. Kemp, E. Reyes, P. Templet, and R. Twilley. 2001. PULSES-the importance of pulsed physical events for watershed sustainability in coastal Louisiana. Presented at 2001 Water and Watersheds Progress Review. San Francisco, CA, April 17-19.

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Fry, B. 2001. Stable isotope indicators of ecosystem restoration in coastal Louisiana. Presented at the Western Society of Naturalists' meeting, Ventura, CA. Nov. 10-12.

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Rick, S., R. Twilley, and A. Gowan-Smith. 2001. Benthic nutrient fluxes and sediment oxygen consumption: Preliminary results of the PULES project (poster). Presented at the 16th biennial conference of the Estuarine Research Federation (ERF), St. Pete Beach, FL, Nov.4-8.

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Justic, D. 2002. Coupling between climate variability and coastal marine eutrophication: historical evidence and future outlook. Presented at ICES symposium-Contrasting Approaches to understanding eutrophication effects on phytoplankton. Den Haag, the Netherlands, March 11-13. (Invited presentation).

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Day, J.W. et al. 2003. Pulses: the importance of pulsed physical events for Louisiana floodplains and watershed management. Presented at the First Interagency Conference on Research in the Watersheds. Benson, AZ. October 27-30.

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Ko, J., J.W. Day, and P.H. Templet. 2003. Exploring conflict resolutions among diverse stakeholders over estuarine ecosystem restoration: a case study of the Caernarvon river diversion, Louisiana. Presented at the 17th Estuarine Research Federation Conference, Seattle, Washington. September 14-16. (Poster).

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**Outreach to Stakeholders**

The PULSES team organized annual one-day workshop to show preliminary results of the PULSES project to diverse stakeholders (e.g., state employees, scientists, environmental groups, local people) at Louisiana State University, Baton Rouge, Louisiana. The following presentations were done:

**The first PULSES workshop** was held on May 31, 2001 and the following presentations were made:

Day, J. Introduction: The watersheds programs and the Caernarvon Project

Cable, J. Overview of sediment and hydrology research being conducted in Breton Sound Basin

Snedden, G. Characteristics of an experimental flood event (6,500 cfs) with particular focus on synoptic current measurements

Wheelock, K. Assessment of filter pads as an effective means of evaluating sediment deposition with preliminary results from the spring pulse

Kemp, P. Sedimentation from the 1927 flood

Fry, B. Stable isotope tracers in the Mississippi River

Wissel, B. Particulate organic matter dynamics in the Caernarvon area

Twilley, R. Nutrient sinks in the Caernarvon outfall area

Lane, R. The effect of introduced river water on turbidity, salinity, chlorophyll *a*, and temperature in the Breton Sound estuary, Louisiana, USA.

Reyes, E. Modeling fresh marshes and supporting monitoring data

Mashriqui, H. Hydrodynamic modeling of the Caernarvon watershed

Templet, P. A conceptual model of economy and environment

Ko, J. Multicriteria/Stakeholder analysis

Day. J. Concluding Remarks

**The second workshop** was held on December 2, 2002, and the following presentations were made:

Day, J. W. Introduction of the PULSES study.

Templet, P. Wetlands as natural capital.

Swenson, E., J.Cable, G. Snedden, and C. Swarzenski. Preliminary estimates of flushing induced by tides and the diversion in Breton Sound.

Snedden, G., J. Cable, E. Swenson, and C. Swarzenski. Comparing the effects of diversion timing, magnitude, and meteorological forcing on flow dynamics and sediment discharge in the Caernarvon receiving basin.

Wheelock, K, and J. Cable. Sediment depositional patterns on a freshwater marsh adjacent to the Mississippi River, Southern Louisiana.

Delaune, R. Impact of Mississippi River freshwater reintroduction on marsh accretion.

Hyfield, E., J. W. Day, and J. Cable. Preliminary analysis of water budget and water quality in Breton Sound.

Lane, R., J. W. Day, E. Reyes, D. Justic, J. Day, and E. Hyfield. Changes in stoichiometric nutrient ratios at diverted Mississippi River water passes through coastal wetlands.

Wissel, B., and B. Fry. POM dynamics in upper Breton Sound.

Justic, D., H. Mashriqui, B. Rahman, and P. Kemp. A mass balance model of dissolved inorganic nitrogen and phytoplankton in the Caernravon watershed.

Mashriqui, H., D. Justic, B. Rahman, and P. Kemp. Mississippi River diversion into the Breton Sound estuary: hydrodynamic, salinity, sediment transport and nutrient modeling.

Reyes, Enrique, R. Lane, E. Hyfield, M. Hebert, and C. Stevenson. Spatial modeling of land cover changes in the Caernarvon watershed.

Twilley, R. R., Rick, S: Benthic nutrient fluxes in a coastal Watershed influenced by pulsed river diversions, Caernarvon, Louisiana.

Rick, S., Rick, J.J. Phytoplankton community response to nutrient enrichment in an estuarine coastal region influenced by pulsed water diversions from the Mississippi River, Caernarvon, Louisiana.

Ko, J., J. W. Day, and T. Creel. Preliminary results of stakeholders' opinion on the Caernarvon diversion.

Day, J. Concluding remarks.

**The third workshop** was held on May 7, 2004, and the following presentations were made:

Day, J. Introduction

Templet, P. Restored wetlands as natural capital

Snedden, G., J. Cable, B. Wiseman, E. Swenson, and C. Swarzenski. Hydrologic circulation and dominant physical forcing functions in Breton Sound basin, Louisiana

Cable, J., G. Snedden, K. Wheelock, and E. Swenson. Sediment loading to Breton Sound basin and depositional trends within the Upper estuary marshes

Hyfield, E., J. Day, D. Justic, J. Cable, and R. Lane. Water and nutrient budgets for the Breton Sound estuary

Lane, R., J.W.Day, E. Hyfield, and J.N. Day**.** Suspended sediment, salinity, chlorophyll a and inorganic nutrient ratios in the Breton Sound estuary

Rick, S., J. Rick, and J. Noel. Seasonal and spatial distribution of major algal groups at Caernarvon

Rozas, L. T. Minello, I. Munuera-Fernández, B. Fry, and B. Wissel. acrofaunal distributions and habitat change following pulsed releases of freshwater into the Breton Sound estuary

Wissel, B. and Brian Fry. Tracing the Mississippi River floodprint in estuarine consumers in coastal Louisiana

Baker, J. and R. Twilley. Development of flume technique to measure marsh nutrient fluxes during river-pulse events

Bond, D., and R. Twilley. Development of core technique to measure marsh nutrient fluxes during river-pulse events

Twilley,R., S. Rick, J. Baker, and D. Bond. Patterns of nutrient biogeochemical processes in Breton Sound during river-pulsed events: relative role of channel and marsh subsystems.

Justic, D., H. Mashriqui, S. Srikanth, B. Rahman, and P. Kemp. Modeling the impacts of pulsed riverine diversions on water quality in the Breton Sound estuary, Louisiana

Ko, J., P. Kemp, J. Day, and C. Hall. A comparative evaluation of river diversion vs. dredging in restoring coastal ecosystem in Louisiana using economic and energy analyses

Day, J. Concluding Remarks

**Other presentations** to stakeholders are as follows:

Cable, J. 2002. PULSES: importance of pulsed river flooding to sustainability in coastal Louisiana. National Technical Review Committee Meeting for COAST 2050. New Orleans District Office, US Army Corps of Engineers. New Orleans, LA (Invited).

Cable, J. 2002. Implications of pulsed riverine flood events to coastal Louisiana marshes. Presented at the Environmental Cooperative Seminar Series, Louisiana State University, Baton Rouge, LA. March 12. (Invited).

Ko, J. Caernarvon Pulsing Study. Presented at the Louisiana Association of Conservation Districts, Marsh Conservation Committee. 17th Annual Summer Meeting. Caernarvon, LA. July 19. (Invited).

**K-12 Outreach**

Rebecca Currier, St. Joseph's Academy, Baton Rouge, Louisiana, "Using $^{210}Pb$ to Estimate Sedimentation in Lake Leary, Breton Sound, Louisiana" (Supervisor: Jaye Cable).

*Recipient, Second Place, 2001 Capital District Science Fair, Sr Environmental Science Division*;

*Recipient, Second Place, 2001 Louisiana State Science Fair, Sr Environmental Science Division;*

*Recipient, Women Geoscientists Award, 2001 Louisiana State Science Fair*

*Recipient, ExxonMobil Award ($250), 2001 Louisiana State Science Fair*

Science Saturday at LSU, 4 December 2004:
"Water and Sediment Transport in a Deltaic Estuary,"
Seminar series for high school juniors and seniors, Baton Rouge, LA (Invited)

**Supplemental Keywords**: watershed, estuary, restoration, ecosystem, integrated assessment, decision making, survey, ecology, modeling, monitoring, Gulf coast, sustainable management, EPA region 6.

**Relevant Web Sites:**

http://www.lsu.edu/aeg/pulses/pulses.html

http://www.ucs.louisiana.edu/~rrt4630/pulses.html

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Table 1. Caernarvon Freshwater Operational Plan January 2004

**CAERNARVON FRESHWATER DIVERSION OPERATIONAL PLAN**
**January 2004**

| Month | Flow Range (cfs)[1] |
|---|---|
| January 1 - 18<br>January 19 - February 8 | 3000-4000 [2]<br>3000-5000 [2] |
| Pulse Low Flow Feb. 09 - Feb. 19<br>Pulse High Flow Feb. 20 - Mar. 04 | 500<br>6500 [5] |
| Pulse Low Flow Mar. 05 - Mar. 18<br>Pulse High Flow Mar.19 - Apr. 02 | 500<br>6500 [5] |
| April | 500-4000 [4] |
| May | 500-4000 [3] |
| June | 1000-4000 [3] |
| July | 1000-4000 [4] |
| August | 1000-4000 [4] |
| September | 1000-4000 [4] |
| October | 1000-4000 [4] |
| November | 1000-4000 [4] |
| December<br>During Duck Season Split | 2500 [2]<br>5600 [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 or reduced if the water level measured by the official USGS gauge at the southeast corner of Big Mar reads above 3.1 NAVD-88.
[2] Salinity at Bay Gardene will by 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 4000 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.

**Caernarvon Operational Summary**
**2004**
**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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Donald Rodrigue | 1/1/2004 | 16:05 | 0 | 0 | 0 | 0 | 0 | 4.8 | 1.7 | |
| Donald Rodrigue | 1/2/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 4.9 | 1.1 | |
| Donald Rodrigue | 1/3/2004 | 17:25 | 0 | 0 | 0 | 0 | 0 | 5 | 0.9 | |
| Donald Rodrigue | 1/4/2004 | 17:40 | 0 | 0 | 0 | 0 | 0 | 5 | 0.5 | |
| Donald Rodrigue | 1/5/2004 | 13:55 | 0 | 0 | 0 | 0 | 0 | 5.1 | 0.6 | |
| Donald Rodrigue | 1/6/2004 | 17:30 | 0 | 3.7 | 3.7 | 3.7 | 0 | 5.2 | 1.2 | Opened up to target 2000 cfs |
| Donald Rodrigue | 1/7/2004 | 17:45 | 0 | 4.2 | 4.2 | 4.2 | 0 | 4.9 | 2.2 | Target flow = 2,500 |
| Donald Rodrigue | 1/8/2004 | 16:36 | 0 | 5 | 5 | 5 | 0 | 5 | 2.3 | |
| Donald Rodrigue | 1/9/2004 | 15:35 | 0 | 5 | 5 | 5 | 0 | 5.1 | 2.2 | |
| Donald Rodrigue | 1/10/2004 | 17:40 | 0 | 5 | 5 | 5 | 0 | 5.3 | 1.8 | |
| Donald Rodrigue | 1/11/2004 | 16:05 | 0 | 5.5 | 5.5 | 5.5 | 0 | 5.3 | 1.6 | |
| Donald Rodrigue | 1/12/2004 | 17:40 | 0 | 5.8 | 5.8 | 5.8 | 0 | 5.4 | 1.5 | |
| Donald Rodrigue | 1/13/2004 | 16:00 | 0 | 5.8 | 5.8 | 5.8 | 0 | 5.6 | 1.6 | |
| Donald Rodrigue | 1/14/2004 | 17:15 | 0 | 5.8 | 5.8 | 5.8 | 0 | 5.7 | 1.4 | |
| Donald Rodrigue | 1/15/2004 | 14:25 | 0 | 5.8 | 5.8 | 5.8 | 0 | 5.8 | 1.3 | |
| Donald Rodrigue | 1/16/2004 | 13:55 | 0 | 5.8 | 5.8 | 5.8 | 0 | 5.9 | 1.4 | |
| Donald Rodrigue | 1/17/2004 | 19:50 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.1 | 1.6 | |
| Donald Rodrigue | 1/18/2004 | 17:45 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.2 | 1.8 | |
| Donald Rodrigue | 1/19/2004 | 17:45 | 0 | 5.8 | 5.8 | 5.8 | 0 | 5.8 | 2 | |
| Donald Rodrigue | 1/20/2004 | 16:05 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.3 | 2.2 | |
| Donald Rodrigue | 1/21/2004 | 18:00 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.4 | 2.1 | |
| Donald Rodrigue | 1/22/2004 | 17:45 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.1 | 2.4 | |
| Donald Rodrigue | 1/23/2004 | 17:30 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.4 | 2.3 | |
| Donald Rodrigue | 1/24/2004 | 13:10 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.7 | 2.3 | |
| Donald Rodrigue | 1/25/2004 | 16:30 | 0 | 5.8 | 5.8 | 5.8 | 0 | 6.9 | 2.5 | |
| Donald Rodrigue | 1/26/2004 | 17:30 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 7.2 | 2.2 | |
| Donald Rodrigue | 1/27/2004 | 17:45 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 7.1 | 2 | |
| Donald Rodrigue | 1/28/2004 | 19:09 | 4 | 4 | 4 | 4 | 4 | 7.1 | 1.8 | Target flow = 5,000 cfs |
| Donald Rodrigue | 1/29/2004 | 17:45 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 7 | 1.4 | |
| Donald Rodrigue | 1/30/2004 | 17:45 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 6.8 | 1.6 | |
| Donald Rodrigue | 1/31/2004 | 17:40 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 6.8 | 1.9 | |
| Donald Rodrigue | 2/1/2004 | 17:30 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 6.4 | 2.3 | |
| Donald Rodrigue | 2/2/2004 | 17:25 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 6.6 | 2.6 | |
| Donald Rodrigue | 2/3/2004 | 16:00 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 6.4 | 2.7 | |
| Donald Rodrigue | 2/4/2004 | 20:10 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 6.3 | 2.7 | |
| Donald Rodrigue | 2/5/2004 | 17:30 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 6.1 | 2.4 | |
| Donald Rodrigue | 2/6/2004 | 20:10 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 2.5 | |
| Donald Rodrigue | 2/7/2004 | 17:30 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.4 | 2.2 | |
| Donald Rodrigue | 2/8/2004 | 17:35 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.2 | 2.3 | |
| Donald Rodrigue | 2/9/2004 | 21:40 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.3 | 2.2 | |
| Donald Rodrigue | 2/10/2004 | 17:15 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 1.8 | |
| Donald Rodrigue | 2/11/2004 | 17:25 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 6 | 1.6 | |
| Donald Rodrigue | 2/12/2004 | 17:20 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 6.4 | 1.5 | |
| Donald Rodrigue | 2/13/2004 | 17:50 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 6.7 | 1.1 | |
| Donald Rodrigue | 2/14/2004 | 20:10 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 6.9 | 1.3 | |
| Donald Rodrigue | 2/15/2004 | 17:25 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 7.2 | 1.2 | |
| Donald Rodrigue | 2/16/2004 | 17:20 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 7.7 | 0.9 | |
| Donald Rodrigue | 2/17/2004 | 17:35 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 8.2 | 0.4 | |
| Donald Rodrigue | 2/18/2004 | 18:00 | 0 | 0 | 0 | 0 | 0 | 8.6 | 0.1 | Closed due to debris on the river side. |

**Caernarvon Operational Summary**
**2004**
**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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Donald Rodrigue | 2/19/2004 | 8:00 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 8.8 | 0 | Opened to 6,500 cfs for pulse. |
| Donald Rodrigue | 2/20/2004 | 17:50 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 9 | 0.2 | |
| Donald Rodrigue | 2/21/2004 | 17:45 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 9.2 | 0.4 | |
| Donald Rodrigue | 2/22/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 9.4 | 0.8 | Closed because of oil spill. |
| Donald Rodrigue | 2/23/2004 | 17:25 | 0 | 0 | 0 | 0 | 0 | 9.6 | 0.9 | |
| Donald Rodrigue | 2/24/2004 | 18:30 | 0 | 0 | 0 | 0 | 0 | 9.8 | 1.1 | |
| Donald Rodrigue | 2/25/2004 | 17:15 | 0 | 0 | 0 | 0 | 0 | 10 | 1.4 | |
| Donald Rodrigue | 2/26/2004 | 17:15 | 0 | 0 | 0 | 0 | 0 | 10.2 | 1.3 | |
| Donald Rodrigue | 2/27/2004 | 17:25 | 0 | 0 | 0 | 0 | 0 | 9.7 | 1.5 | |
| Donald Rodrigue | 2/28/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 9.4 | 1.8 | |
| Donald Rodrigue | 2/29/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 9.1 | 2.5 | |
| Donald Rodrigue | 3/1/2004 | 13:10 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 8.8 | 3 | Opened to 6,500 cfs for pulse. |
| Donald Rodrigue | 3/2/2004 | 17:35 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 8.6 | 3 | |
| Donald Rodrigue | 3/3/2004 | 17:15 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 8.4 | 2.8 | |
| Donald Rodrigue | 3/4/2004 | 17:45 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 8.3 | 2.3 | |
| Donald Rodrigue | 3/5/2004 | 17:30 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 8.1 | 1.8 | |
| Donald Rodrigue | 3/6/2004 | 17:25 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 7 | 1.5 | |
| Donald Rodrigue | 3/7/2004 | 17:15 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 7.2 | 1.2 | |
| Donald Rodrigue | 3/8/2004 | 21:40 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 6.7 | 1.1 | Lowered to 500 cfs |
| Donald Rodrigue | 3/9/2004 | 17:00 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.8 | 1.1 | |
| Donald Rodrigue | 3/10/2004 | 17:45 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 6.2 | 1 | |
| Donald Rodrigue | 3/11/2004 | 17:20 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 6.4 | 1.2 | |
| Donald Rodrigue | 3/12/2004 | 17:30 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 6.8 | 1.1 | |
| Donald Rodrigue | 3/13/2004 | 17:15 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 7.2 | 1.3 | |
| Donald Rodrigue | 3/14/2004 | 17:45 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 7.5 | 1.4 | |
| Donald Rodrigue | 3/15/2004 | 8:20 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 7.8 | 1.4 | |
| Donald Rodrigue | 3/16/2004 | 17:25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 8.2 | 1.2 | |
| Donald Rodrigue | 3/17/2004 | 17:45 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 8.6 | 1 | |
| Donald Rodrigue | 3/18/2004 | 17:35 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 8.8 | 0.8 | Pulsed to 6,500 cfs. |
| Donald Rodrigue | 3/19/2004 | 18:23 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 9 | 2.8 | |
| Donald Rodrigue | 3/20/2004 | 17:15 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 9.2 | 2.7 | |
| Donald Rodrigue | 3/21/2004 | 17:45 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 8.7 | 2.6 | |
| Donald Rodrigue | 3/22/2004 | 17:35 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 7.9 | 2.5 | |
| Donald Rodrigue | 3/23/2004 | 17:25 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 7.5 | 2.3 | |
| Donald Rodrigue | 3/24/2004 | 17:24 | 4 | 4 | 4 | 4 | 4 | 6.9 | 2.1 | |
| Donald Rodrigue | 3/25/2004 | 18:45 | 4.4 | 4.4 | 4.4 | 4.4 | 4.4 | 7 | 2.2 | |
| Donald Rodrigue | 3/26/2004 | 19:15 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 7.2 | 2.4 | |
| Donald Rodrigue | 3/27/2004 | 17:55 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 7.5 | 2.8 | |
| Donald Rodrigue | 3/28/2004 | 17:30 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 7.7 | 2.9 | |
| Donald Rodrigue | 3/29/2004 | 9:20 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 7.8 | 3 | |
| Donald Rodrigue | 3/29/2004 | 17:09 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 7.9 | 3.2 | Lowered to 3,000 cfs due to high water. |
| Donald Rodrigue | 3/30/2004 | 17:30 | 5.3 | 5.3 | 5.3 | 5.3 | 5.3 | 7.6 | 2.2 | Pulsed to 6,500 cfs. |
| Donald Rodrigue | 3/31/2004 | 17:00 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 7.2 | 2.4 | |
| Donald Rodrigue | 4/1/2004 | 20:10 | 6 | 6 | 6 | 6 | 6 | 6.1 | 2.6 | |
| Donald Rodrigue | 4/2/2004 | 9:00 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 5.6 | 2.8 | Lowered to 500 cfs (end of pulse) |
| Donald Rodrigue | 4/3/2004 | 22:00 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.7 | 2.6 | |
| Donald Rodrigue | 4/4/2004 | 17:20 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.8 | 2 | |
| Donald Rodrigue | 4/5/2004 | 17:30 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.9 | 1.3 | |
| Donald Rodrigue | 4/6/2004 | 17:00 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.7 | 1.2 | |

**Caernarvon Operational Summary**
**2004**
**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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Donald Rodrigue | 4/7/2004 | 18:15 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 6 | 1.4 | |
| Donald Rodrigue | 4/8/2004 | 17:30 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.8 | 1.1 | |
| Donald Rodrigue | 4/9/2004 | 17:55 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.7 | 1.2 | |
| Donald Rodrigue | 4/10/2004 | 18:25 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.6 | 1.4 | |
| Donald Rodrigue | 4/11/2004 | 17:00 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.7 | 1.8 | |
| Donald Rodrigue | 4/12/2004 | 17:20 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 5.5 | 1.3 | |
| Donald Rodrigue | 4/13/2004 | 15:00 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.6 | 0.6 | |
| Donald Rodrigue | 4/14/2004 | 17:55 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.5 | 0.8 | |
| Donald Rodrigue | 4/15/2004 | 17:30 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.4 | 0.7 | |
| Donald Rodrigue | 4/16/2004 | 17:00 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.1 | 0.9 | |
| Donald Rodrigue | 4/17/2004 | 17:55 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.3 | 1.2 | |
| Donald Rodrigue | 4/18/2004 | 18:00 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.2 | 1.4 | |
| Donald Rodrigue | 4/19/2004 | 17:00 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.3 | 1.6 | |
| Donald Rodrigue | 4/20/2004 | 17:45 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.2 | 1.3 | |
| Donald Rodrigue | 4/21/2004 | 17:55 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 5.1 | 1.2 | |
| Donald Rodrigue | 4/22/2004 | 17:20 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5 | 1.1 | |
| Donald Rodrigue | 4/23/2004 | 17:00 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5.1 | 1.5 | |
| Donald Rodrigue | 4/24/2004 | 17:45 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5 | 1.3 | |
| Donald Rodrigue | 4/25/2004 | 17:30 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5.4 | 1.4 | |
| Donald Rodrigue | 4/26/2004 | 17:00 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5.3 | 1.6 | |
| Donald Rodrigue | 4/27/2004 | 20:10 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5 | 1.8 | |
| Donald Rodrigue | 4/28/2004 | 18:45 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 5.8 | 1.7 | |
| Donald Rodrigue | 4/29/2004 | 17:25 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 6.5 | 1.6 | |
| Donald Rodrigue | 4/30/2004 | 17:55 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 7.8 | 2 | |
| Donald Rodrigue | 5/1/2004 | 17:45 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 8.2 | 2.2 | |
| Donald Rodrigue | 5/2/2004 | 17:20 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 8.5 | 2.3 | |
| Donald Rodrigue | 5/3/2004 | 9:00 | 0 | 0 | 0 | 0 | 0 | 8.6 | 2.1 | Closed structure |
| Donald Rodrigue | 5/4/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 8.5 | 1.4 | |
| Donald Rodrigue | 5/5/2004 | 17:00 | 0 | 0 | 0 | 0 | 0 | 8.4 | 1.2 | |
| Donald Rodrigue | 5/6/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 8.2 | 1 | |
| Donald Rodrigue | 5/7/2004 | 17:55 | 0 | 0 | 0 | 0 | 0 | 8.3 | 1.2 | |
| Donald Rodrigue | 5/8/2004 | 17:00 | 0 | 0 | 0 | 0 | 0 | 8.2 | 1.2 | |
| Donald Rodrigue | 5/9/2004 | 17:55 | 0 | 0 | 0 | 0 | 0 | 8 | 1 | |
| Donald Rodrigue | 5/10/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 7.9 | 1.1 | |
| Donald Rodrigue | 5/11/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 7.6 | 1.2 | |
| Donald Rodrigue | 5/12/2004 | 18:15 | 0 | 0 | 0 | 0 | 0 | 7.9 | 1.7 | |
| Donald Rodrigue | 5/13/2004 | 18:25 | 0 | 0 | 0 | 0 | 0 | 8.2 | 2.4 | |
| Donald Rodrigue | 5/14/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 8.6 | 2.5 | |
| Donald Rodrigue | 5/15/2004 | 17:50 | 0 | 0 | 0 | 0 | 0 | 8.4 | 2.4 | |
| Donald Rodrigue | 5/16/2004 | 17:30 | 0 | 0 | 0 | 0 | 0 | 8.5 | 2.3 | |
| Donald Rodrigue | 5/17/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 8.7 | 2.1 | |
| Donald Rodrigue | 5/18/2004 | 17:55 | 0 | 0 | 0 | 0 | 0 | 8.8 | 2 | |
| Donald Rodrigue | 5/19/2004 | 17:40 | 0 | 0 | 0 | 0 | 0 | 8.4 | 2.1 | |
| Donald Rodrigue | 5/20/2004 | 21:40 | 0 | 0 | 0 | 0 | 0 | 7.3 | 2 | |
| Donald Rodrigue | 5/21/2004 | 17:30 | 0 | 0 | 0 | 0 | 0 | 7.1 | 1.6 | |
| Donald Rodrigue | 5/22/2004 | 18:30 | 0 | 0 | 0 | 0 | 0 | 6.6 | 1.5 | |
| Donald Rodrigue | 5/23/2004 | 17:40 | 0 | 0 | 0 | 0 | 0 | 6.2 | 1.4 | |
| Donald Rodrigue | 5/24/2004 | 18:50 | 0 | 0 | 0 | 0 | 0 | 5.8 | 1.3 | |
| Donald Rodrigue | 5/25/2004 | 18:15 | 0 | 0 | 0 | 0 | 0 | 5.5 | 1.7 | |

**Caernarvon Operational Summary**
**2004**
**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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Donald Rodrigue | 5/26/2004 | 17:40 | 0 | 0 | 0 | 0 | 0 | 5.2 | 1.7 | |
| Donald Rodrigue | 5/27/2004 | 17:30 | 0 | 0 | 0 | 0 | 0 | 5 | 1.3 | |
| Donald Rodrigue | 5/28/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 4.7 | 1.3 | |
| Donald Rodrigue | 5/29/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 4.6 | 1.3 | |
| Donald Rodrigue | 5/30/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 4.2 | 1.1 | |
| Donald Rodrigue | 5/31/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 4.7 | 1.3 | |
| Donald Rodrigue | 6/1/2004 | 18:30 | 0 | 0 | 0 | 0 | 0 | 4.7 | 1.4 | |
| Donald Rodrigue | 6/2/2004 | 17:40 | 0 | 0 | 0 | 0 | 0 | 5 | 1.2 | |
| Donald Rodrigue | 6/3/2004 | 17:30 | 0 | 0 | 0 | 0 | 0 | 5 | 1.9 | |
| Donald Rodrigue | 6/4/2004 | 17:50 | 0 | 0 | 0 | 0 | 0 | 5.4 | 2.2 | |
| Donald Rodrigue | 6/5/2004 | 17:30 | 0 | 0 | 0 | 0 | 0 | 6.2 | 2.1 | |
| Donald Rodrigue | 6/6/2004 | 17:55 | 0 | 0 | 0 | 0 | 0 | 7 | 1.4 | |
| Donald Rodrigue | 6/7/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 7.2 | 1.7 | |
| Donald Rodrigue | 6/8/2004 | 18:25 | 0 | 0 | 0 | 0 | 0 | 7.4 | 2.1 | |
| Donald Rodrigue | 6/9/2004 | 17:50 | 0 | 0 | 0 | 0 | 0 | 8.1 | 2 | |
| Donald Rodrigue | 6/10/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 9.1 | 1.8 | |
| Donald Rodrigue | 6/11/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 9.3 | 1.4 | |
| Donald Rodrigue | 6/12/2004 | 18:15 | 0 | 0 | 0 | 0 | 0 | 9.6 | 1.6 | |
| Donald Rodrigue | 6/13/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 9.7 | 1.5 | |
| Donald Rodrigue | 6/14/2004 | 17:30 | 0 | 0 | 0 | 0 | 0 | 10.2 | 2 | |
| Donald Rodrigue | 6/15/2004 | 17:55 | 0 | 0 | 0 | 0 | 0 | 10.3 | 2.1 | |
| Donald Rodrigue | 6/16/2004 | 17:30 | 0 | 0 | 0 | 0 | 0 | 10.2 | 1.4 | |
| Donald Rodrigue | 6/17/2004 | 17:45 | 0 | 0 | 0 | 0 | 0 | 10.1 | 1.3 | |
| Donald Rodrigue | 6/18/2004 | 17:35 | 0 | 0 | 0 | 0 | 0 | 10.2 | 1.4 | |
| Donald Rodrigue | 6/19/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Structure remained closed |
| Donald Rodrigue | 6/20/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/21/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/22/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/23/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/24/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/25/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/26/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/27/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/28/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/29/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 6/30/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/1/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/2/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/3/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/4/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/5/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/6/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/7/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/8/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/9/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/10/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/11/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/12/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/13/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

**Caernarvon Operational Summary**
**2004**
**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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Donald Rodrigue | 7/14/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/15/2004 | 17:45 | 0 | 1.3 | 0 | 1.3 | 0 | 8 | 0.6 | Opened up to target 1000 cfs; gate #1 lever broken. |
| Donald Rodrigue | 7/16/2004 | 19:10 | 0 | 1.2 | 1.2 | 1.2 | 0 | 7.1 | 0.6 | |
| Donald Rodrigue | 7/17/2004 | 8:00 | 0 | 1.2 | 1.2 | 1.2 | 0 | 6.9 | 0.7 | |
| Donald Rodrigue | 7/18/2004 | 8:00 | 0 | 1.2 | 1.2 | 1.2 | 0 | 6.6 | 0.7 | |
| Donald Rodrigue | 7/19/2004 | 8:00 | 0 | 1.2 | 1.2 | 1.2 | 0 | 6.3 | 0.7 | |
| Donald Rodrigue | 7/20/2004 | 8:00 | 0 | 1.2 | 1.2 | 1.2 | 0 | 6 | 0.6 | |
| Donald Rodrigue | 7/21/2004 | 8:00 | 0 | 1.2 | 1.2 | 1.2 | 0 | 5.7 | 0.6 | |
| Donald Rodrigue | 7/22/2004 | 19:20 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 5.4 | 0.8 | Gate #1 fixed. Opened them all. |
| Donald Rodrigue | 7/23/2004 | 8:00 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 5.4 | 0.8 | |
| Donald Rodrigue | 7/24/2004 | 8:00 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 5.4 | 0.8 | |
| Donald Rodrigue | 7/25/2004 | 8:00 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 5.4 | 0.8 | |
| Donald Rodrigue | 7/26/2004 | 8:00 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 5.4 | 0.8 | |
| Donald Rodrigue | 7/27/2004 | 8:00 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 5.4 | 0.8 | |
| Donald Rodrigue | 7/28/2004 | 8:00 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 5.4 | 0.8 | |
| Donald Rodrigue | 7/29/2004 | 16:30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Oil spill in river. Emergency closure. |
| Donald Rodrigue | 7/30/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 7/31/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 8/1/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 8/2/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Donald Rodrigue | 8/3/2004 | 18:45 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | Reopened structure to 1000 cfs |
| Tom Bernard | 8/4/2004 | 8:00 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | |
| Tom Bernard | 8/4/2004 | 8:00 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | |
| Tom Bernard | 8/5/2004 | 8:00 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | |
| Tom Bernard | 8/6/2004 | 8:00 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | |
| Tom Bernard | 8/7/2004 | 8:00 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | |
| Tom Bernard | 8/8/2004 | 8:00 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | |
| Tom Bernard | 8/9/2004 | 8:00 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 3.5 | 0.7 | |
| Tom Bernard | 8/10/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Closed due to Tropical Storm Bonnie |
| Tom Bernard | 8/11/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 8/12/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 8/13/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 8/14/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 8/15/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 8/16/2004 | 12:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | Reopened structure to 1000 cfs |
| Tom Bernard | 8/17/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/18/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/19/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/20/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/21/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/22/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/23/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/24/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/25/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/26/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/27/2004 | 8:00 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 3.7 | 1.2 | |
| Tom Bernard | 8/28/2004 | 18:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Closed due to reported Oil Spill in the Miss. River |
| Tom Bernard | 8/29/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Will remained closed for conclusion of USACOE maintenance. |
| Tom Bernard | 8/30/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

**Caernarvon Operational Summary**
**2004**
**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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Tom Bernard | 8/31/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/1/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/2/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/3/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/4/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/5/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/6/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/7/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/8/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/9/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/10/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/11/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/12/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/13/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/14/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/15/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/16/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/17/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/18/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/19/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/20/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/21/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/22/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/23/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/24/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/25/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/26/2004 | 8:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Tom Bernard | 9/27/2004 | 12:00 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 4.3 | 1.3 | Reopened Structure to 1000 cfs |
| Tom Bernard | 9/28/2004 | 8:00 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 4.3 | 1.3 | |
| Tom Bernard | 9/29/2004 | 8:00 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 4.3 | 1.3 | |
| Tom Bernard | 9/30/2004 | 8:00 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 4.3 | 1.3 | |

* "R" in the operator column indicates that no physical measurements for marsh or river stage were taken on that day
by 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.

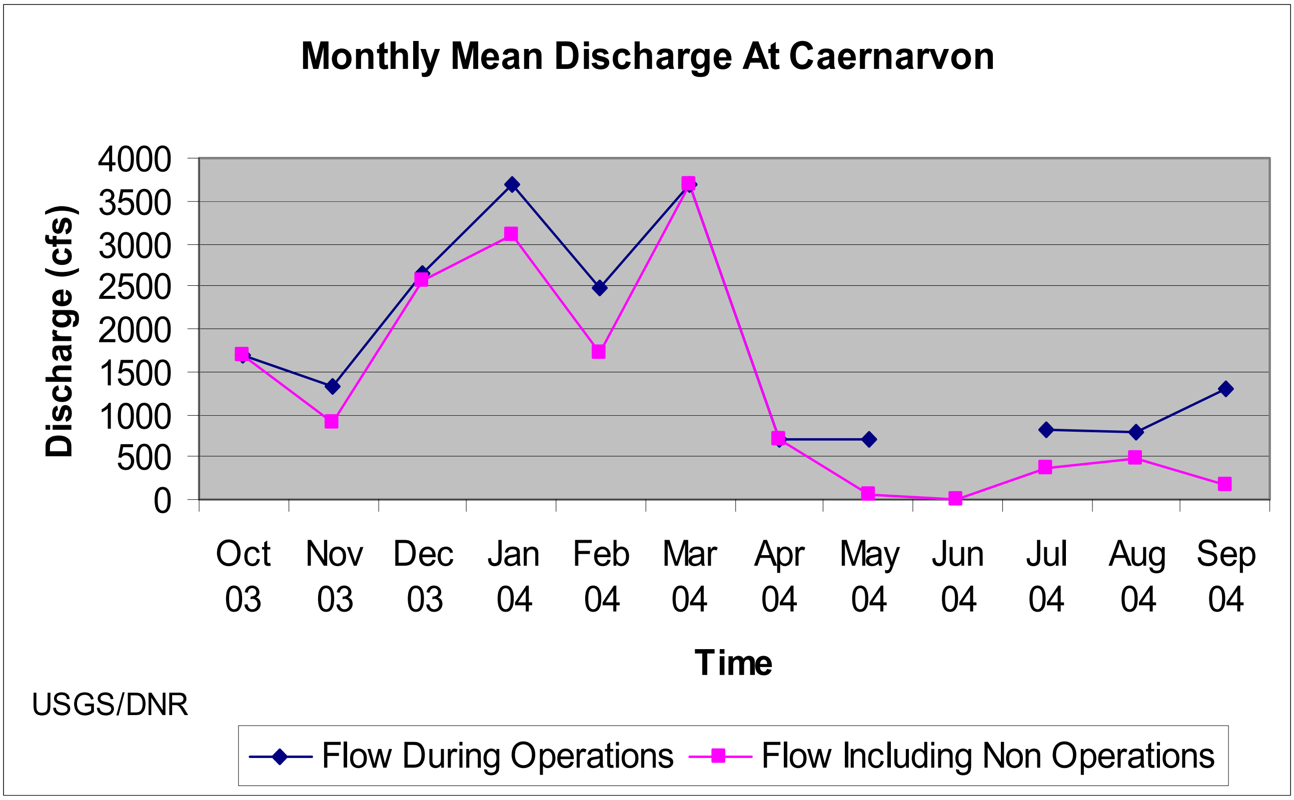


Figure 1. Monthly Mean Discharge at Caernarvon (USGS).

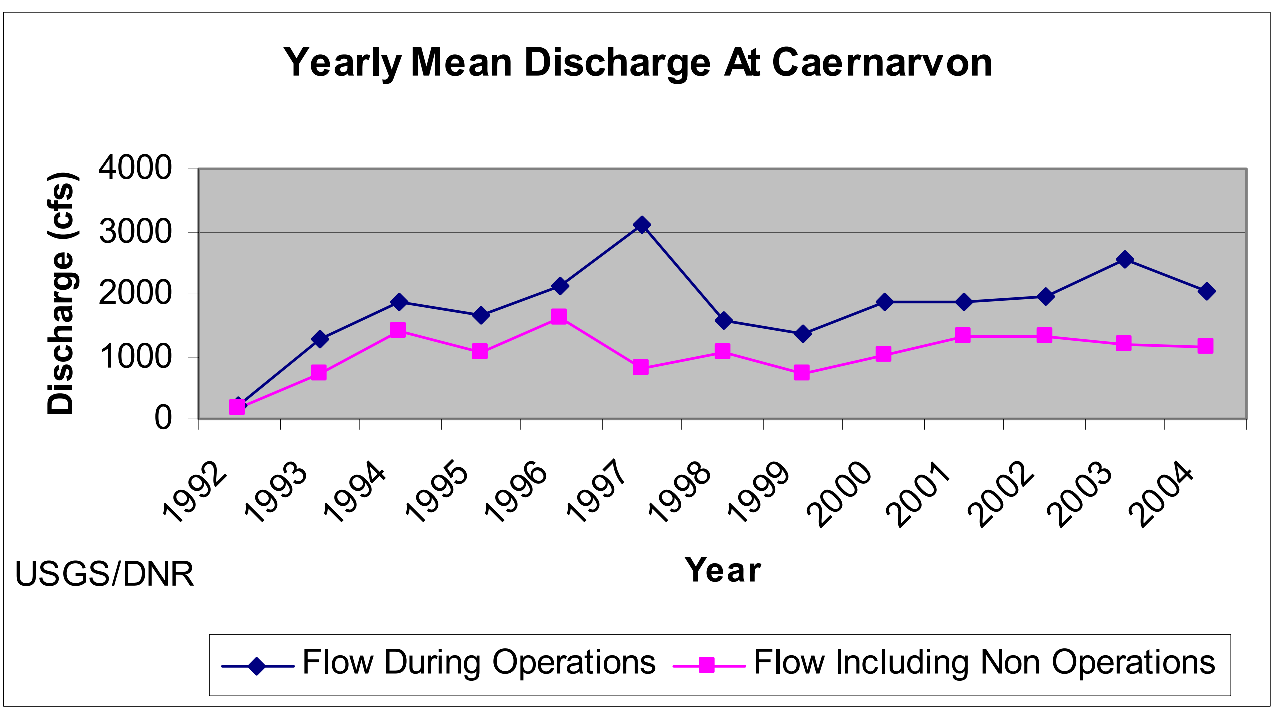


Figure 2. Yearly Mean Discharge at Caernarvon (USGS).

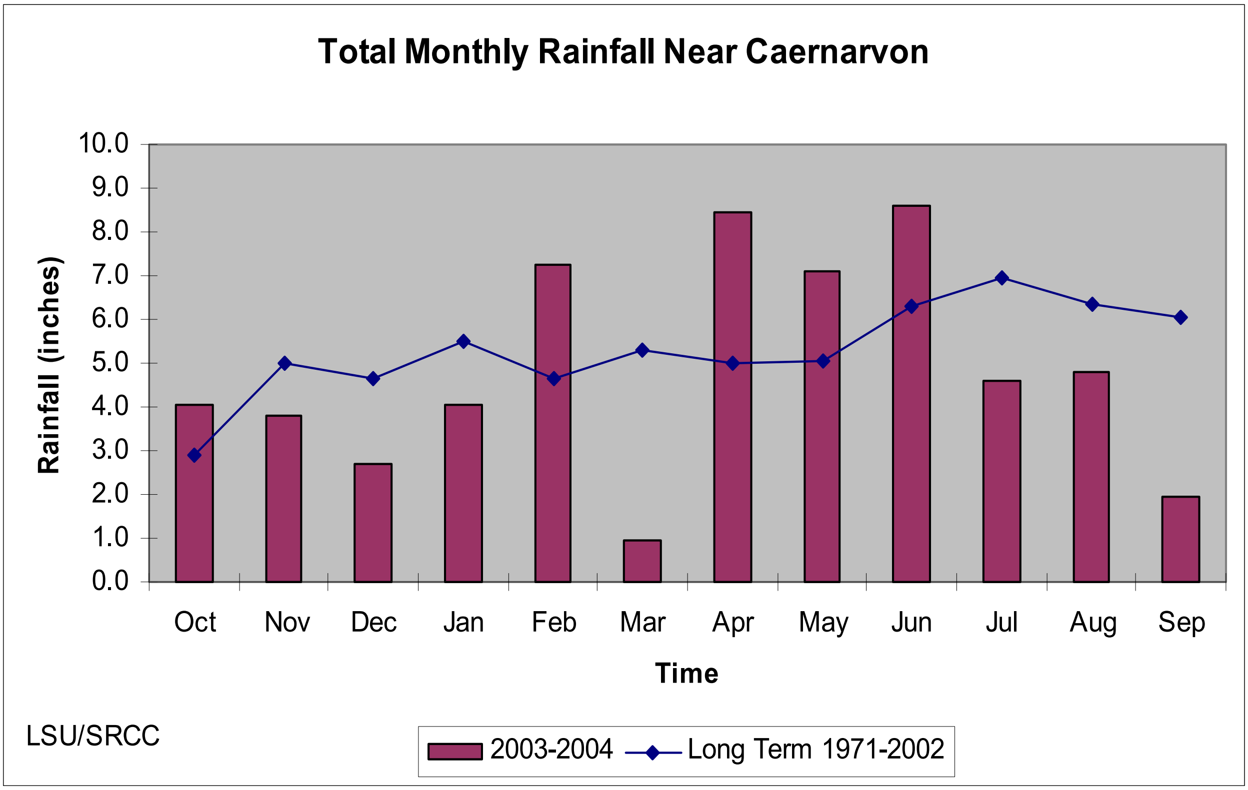


Figure 3. Total Monthly Rainfall Near Caernarvon (LSU Southern Regional Climate Center).

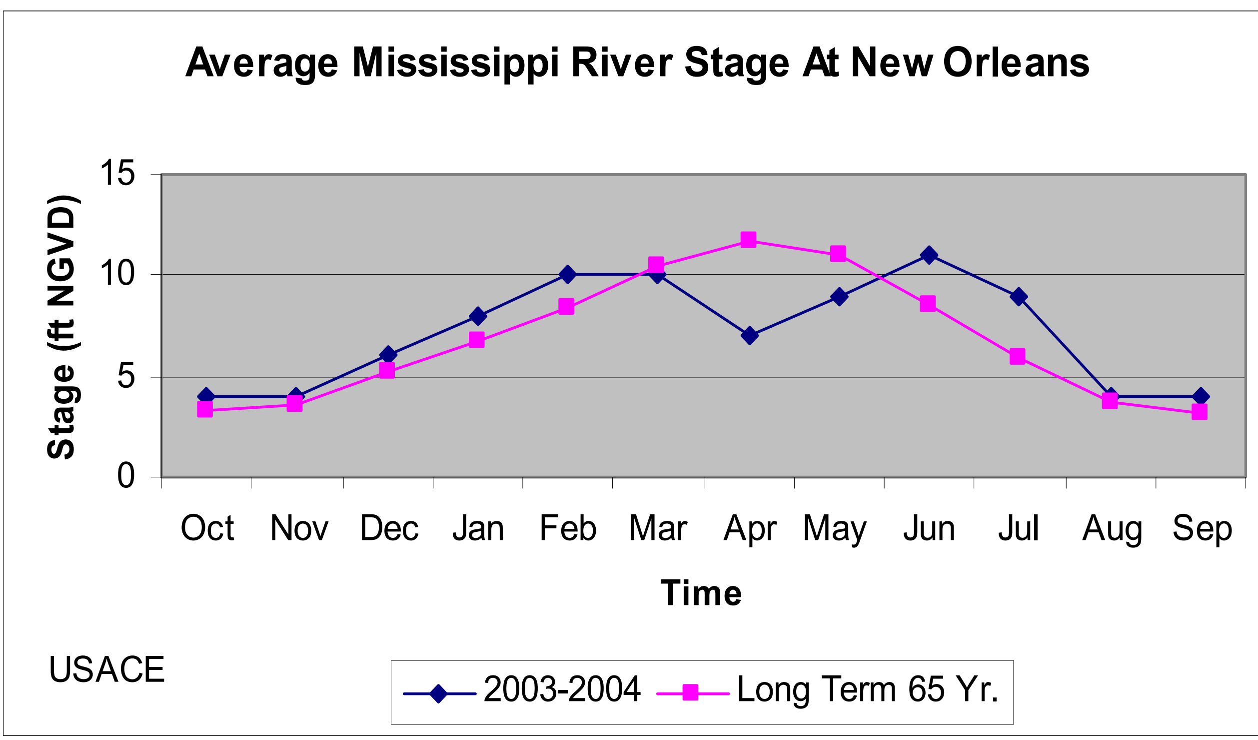


Figure 4. Average Mississippi River Stage at New Orleans (USACE).

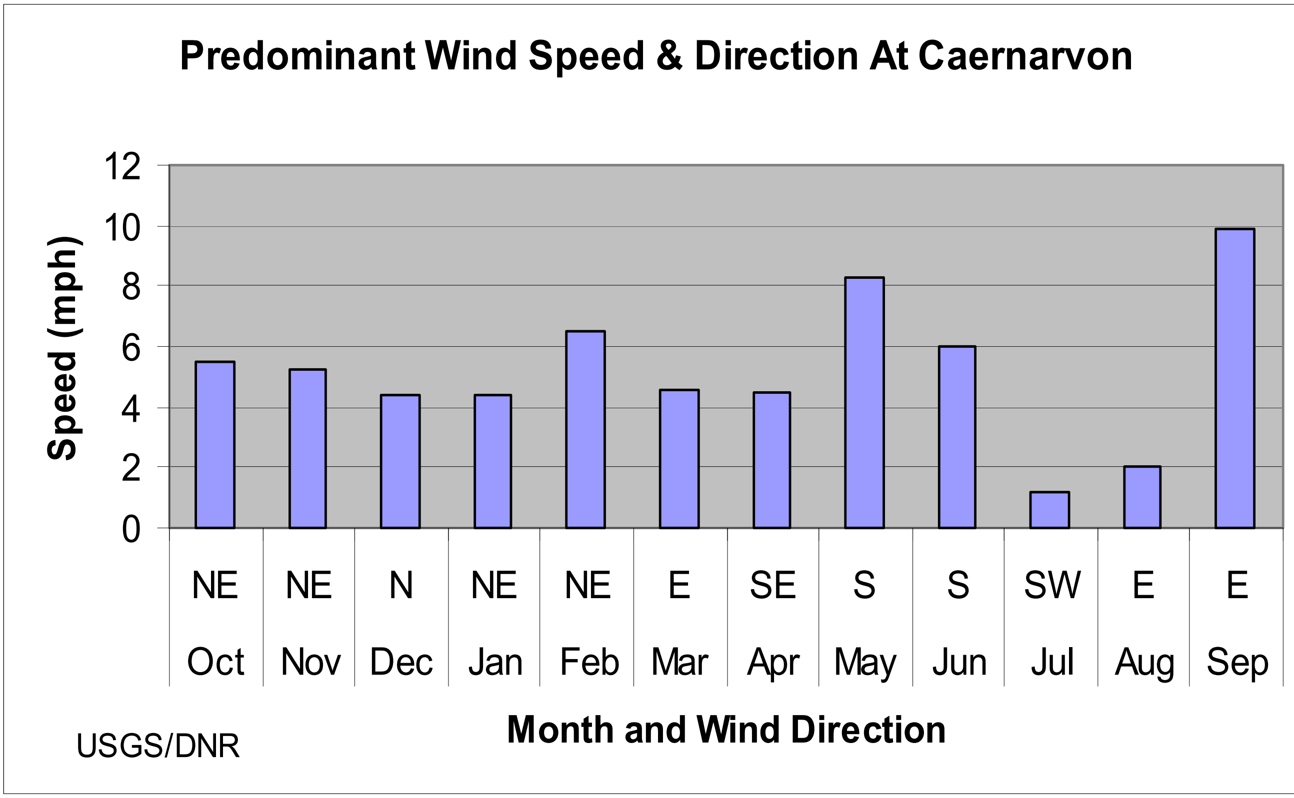


Figure 5. Predominant Wind Speed and Direction at Caernarvon (USGS).

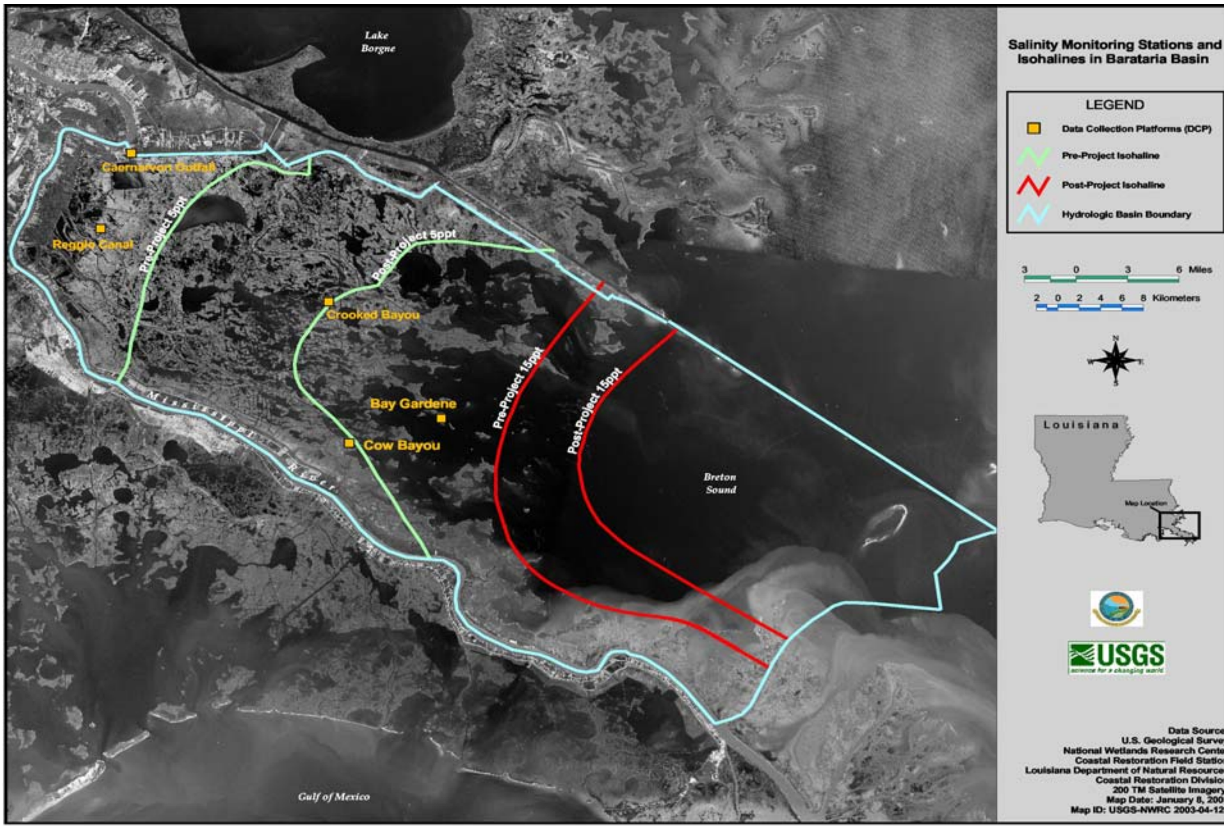


Figure 6. Location of Data Collection Platforms and pre-post construction isohalines for Breton Sound.

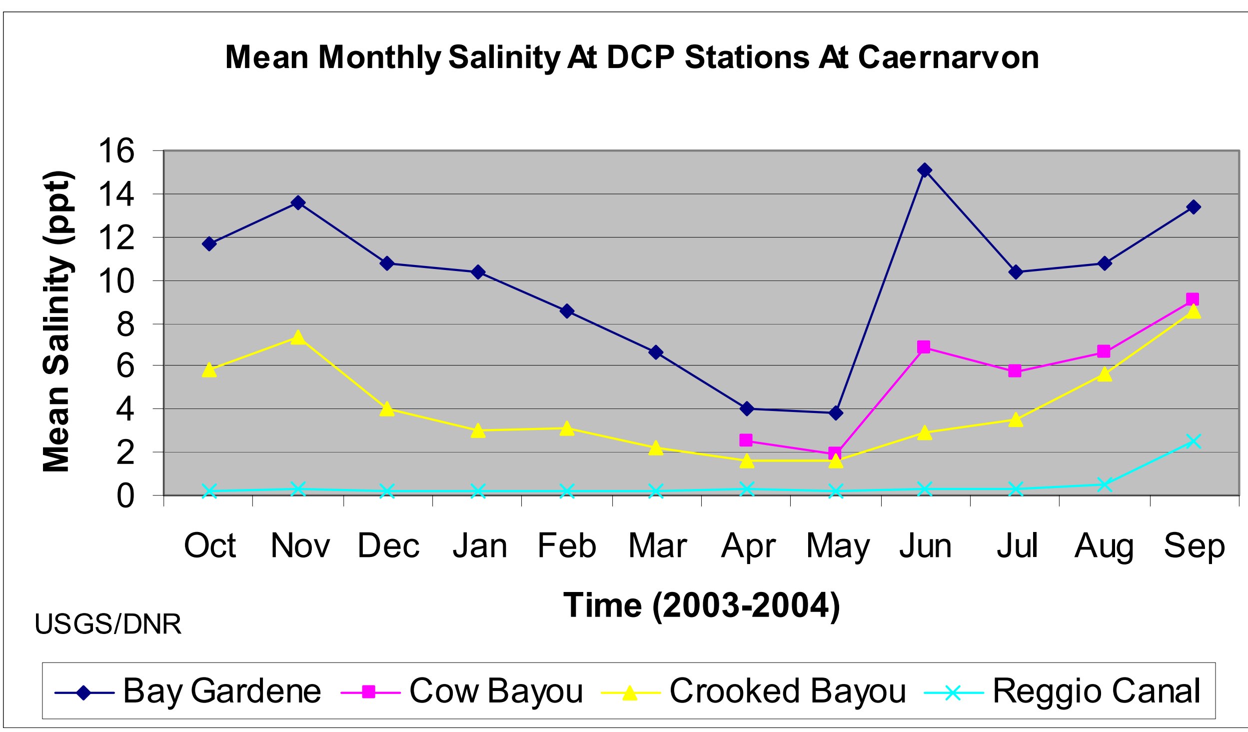


Figure 7. Mean Monthly Salinity at DCP Stations at Caernarvon (USGS).

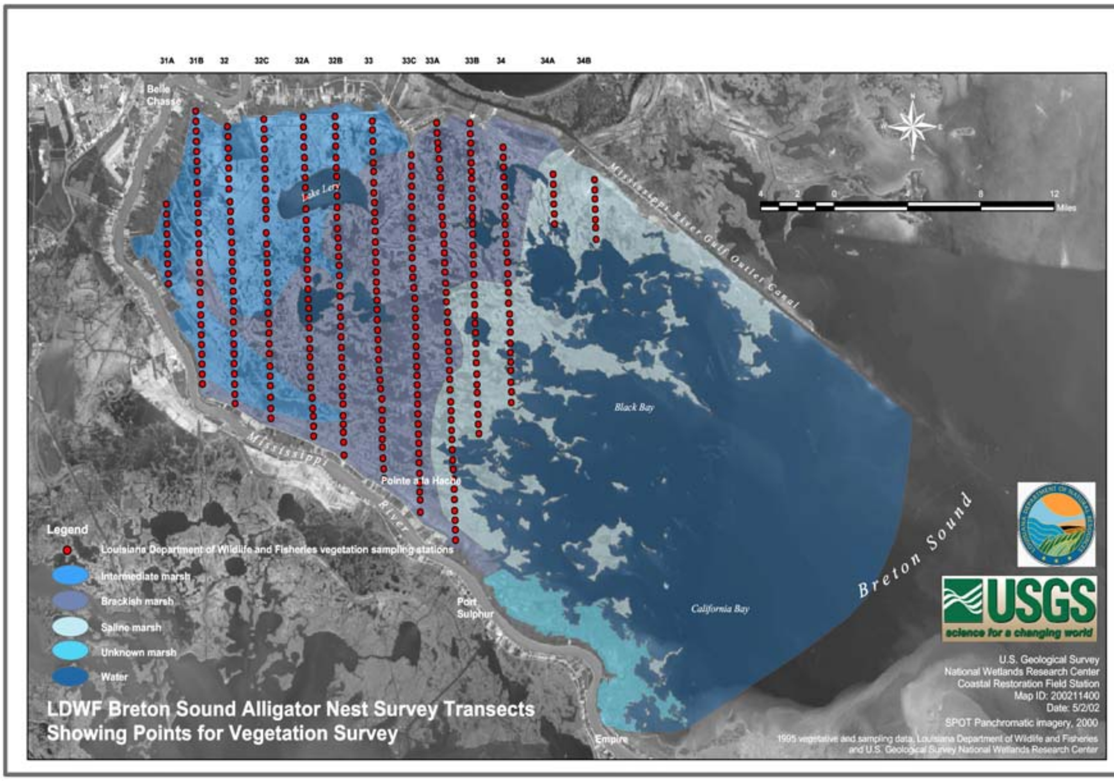


Figure 8. Location of wildlife and vegetation transects at Caernarvon.

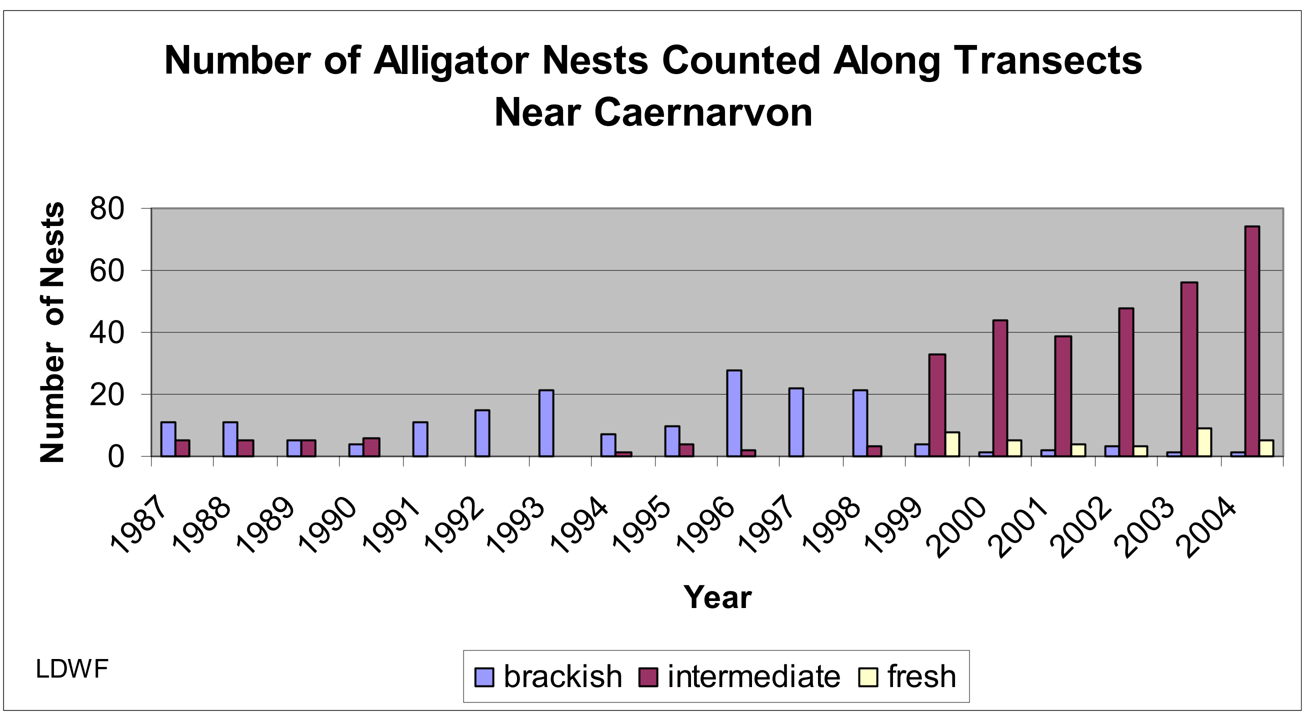


Figure 9. Number of alligator nests counted along transects at Caernarvon (LDWF).

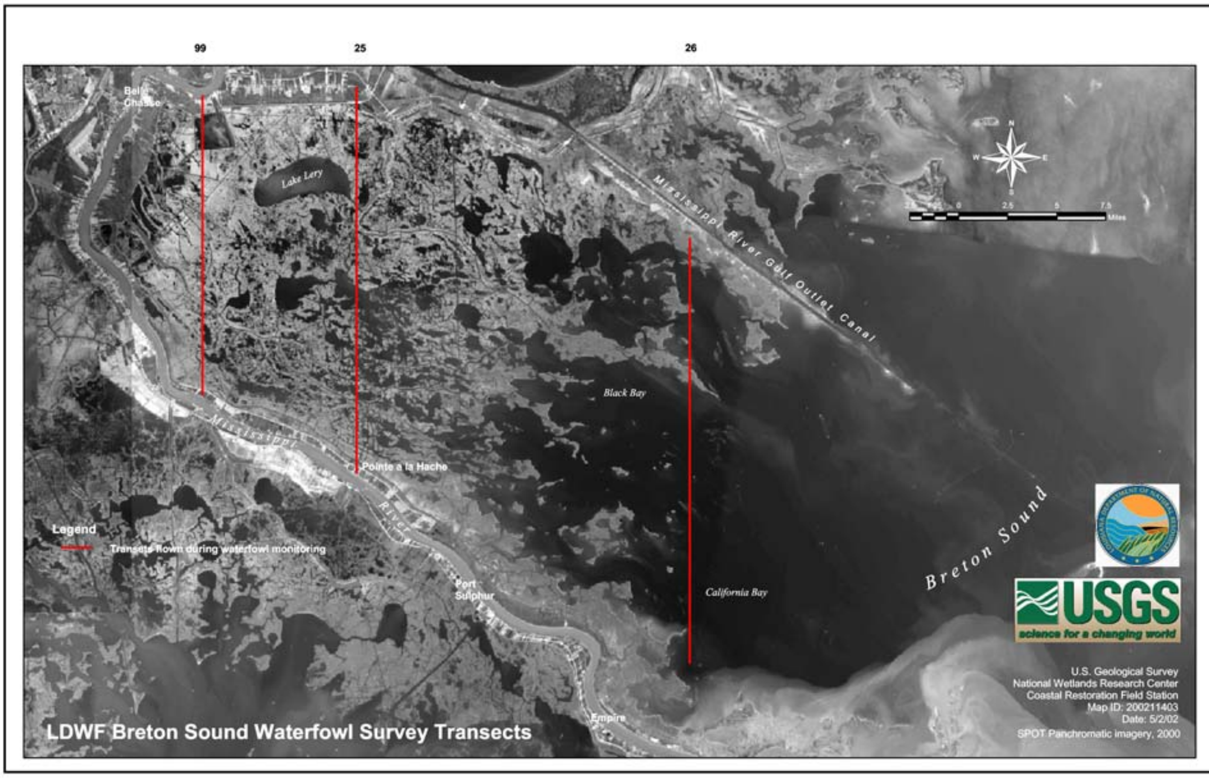


Figure 10. Location of waterfowl transects at Caernarvon.

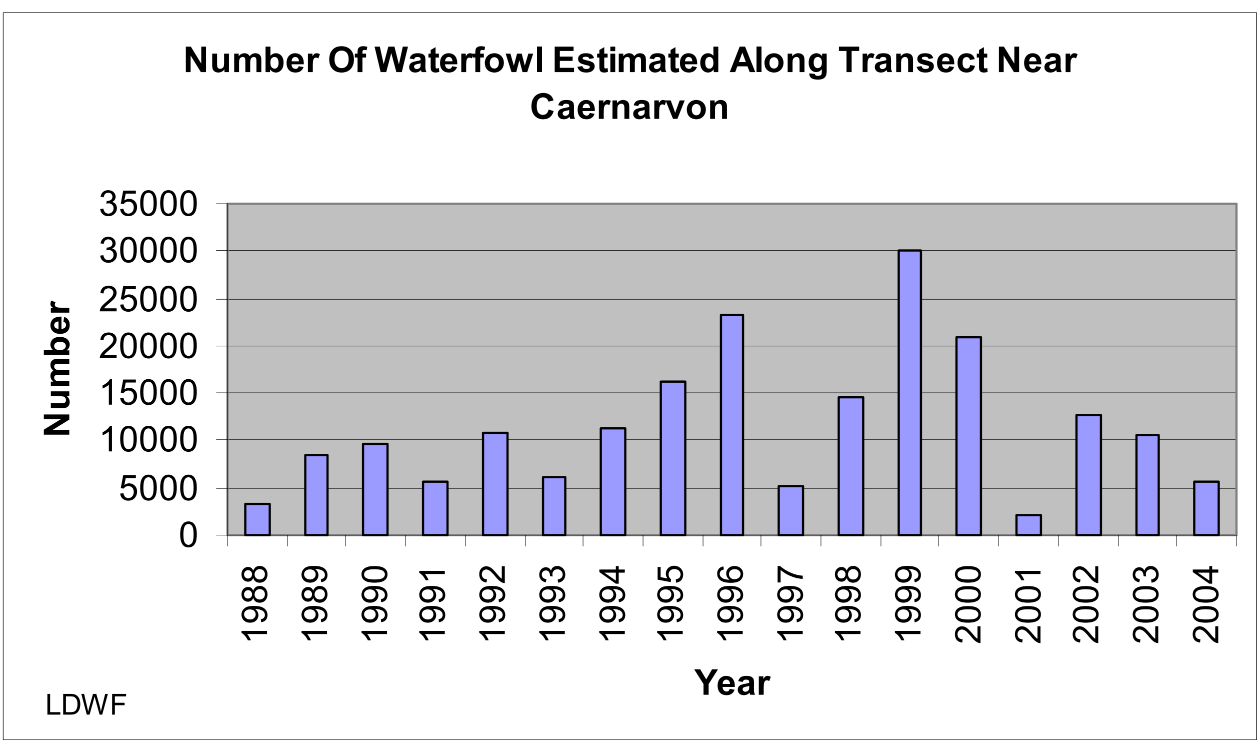


Figure 11. Number of waterfowl estimated along transects at Caernarvon (LDWF).

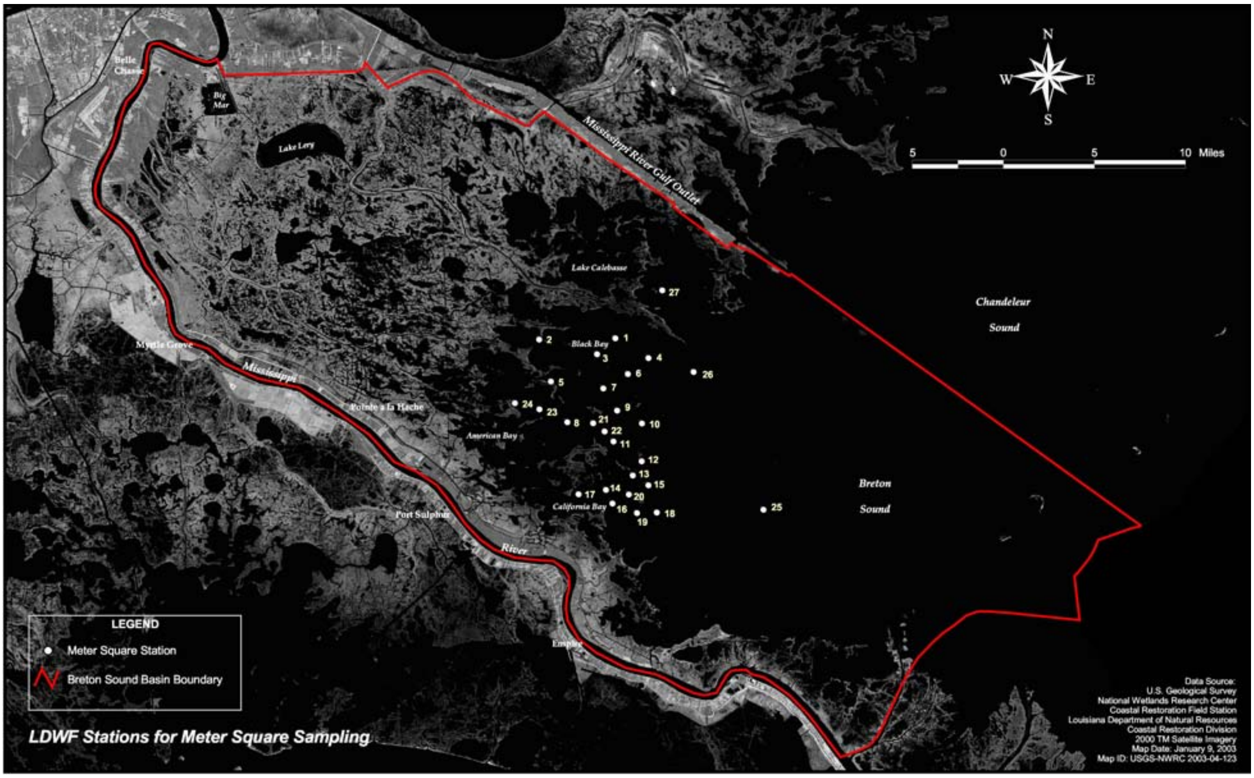


Figure 12. Location of meter square stations at Caernarvon.

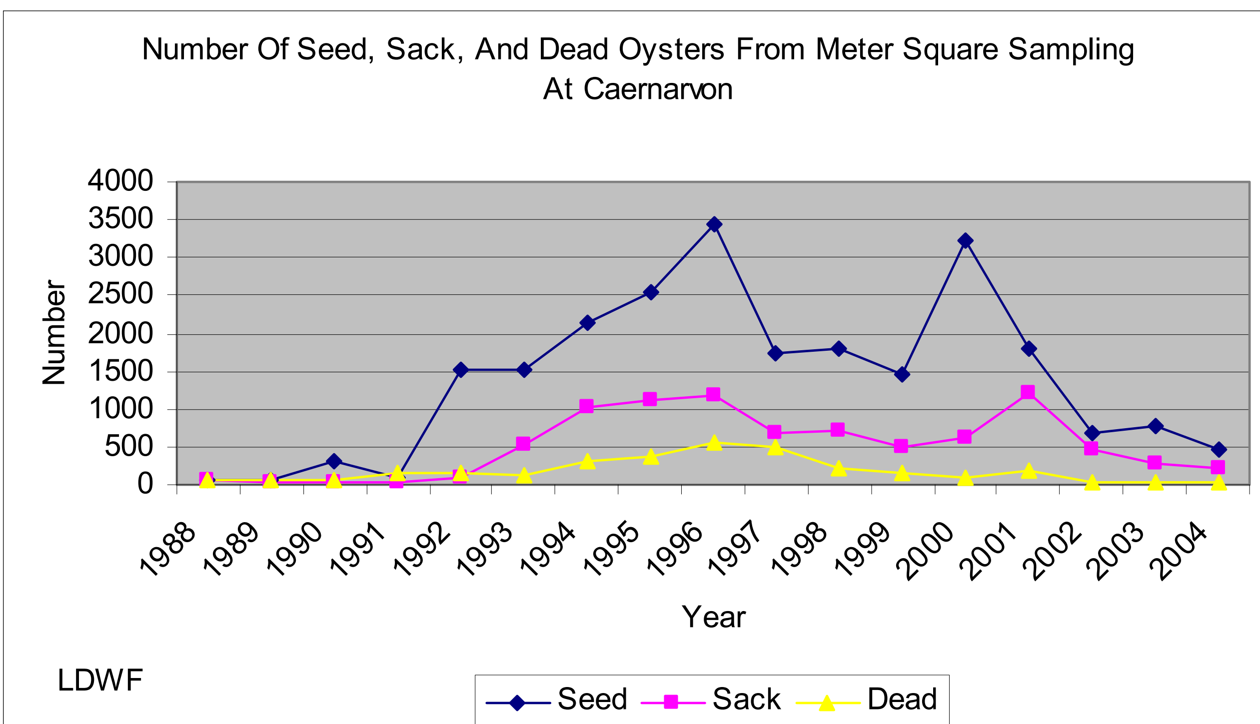


Figure 13. Number of seed, sack and dead oysters from meter square sampling at Caernarvon (LDWF).

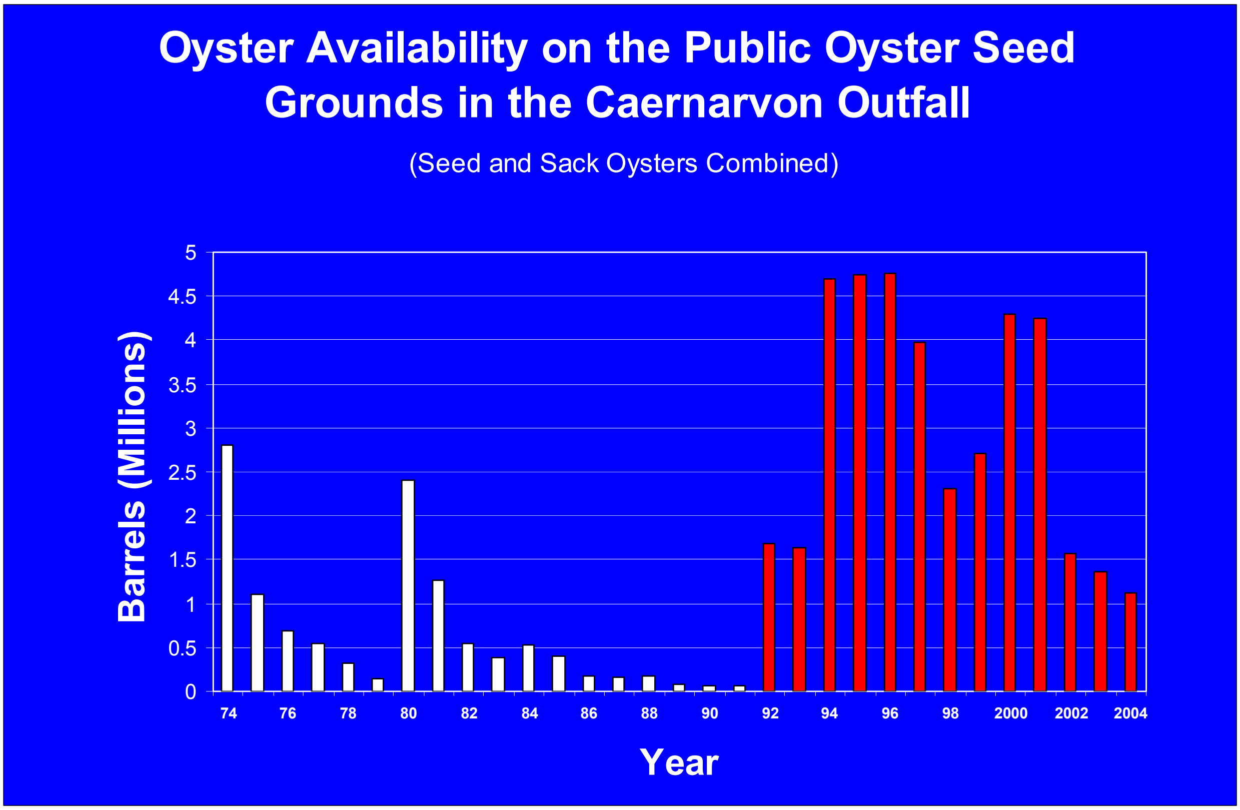


Figure 14. Oyster availability on the public seed grounds at Caernarvon (LDWF).

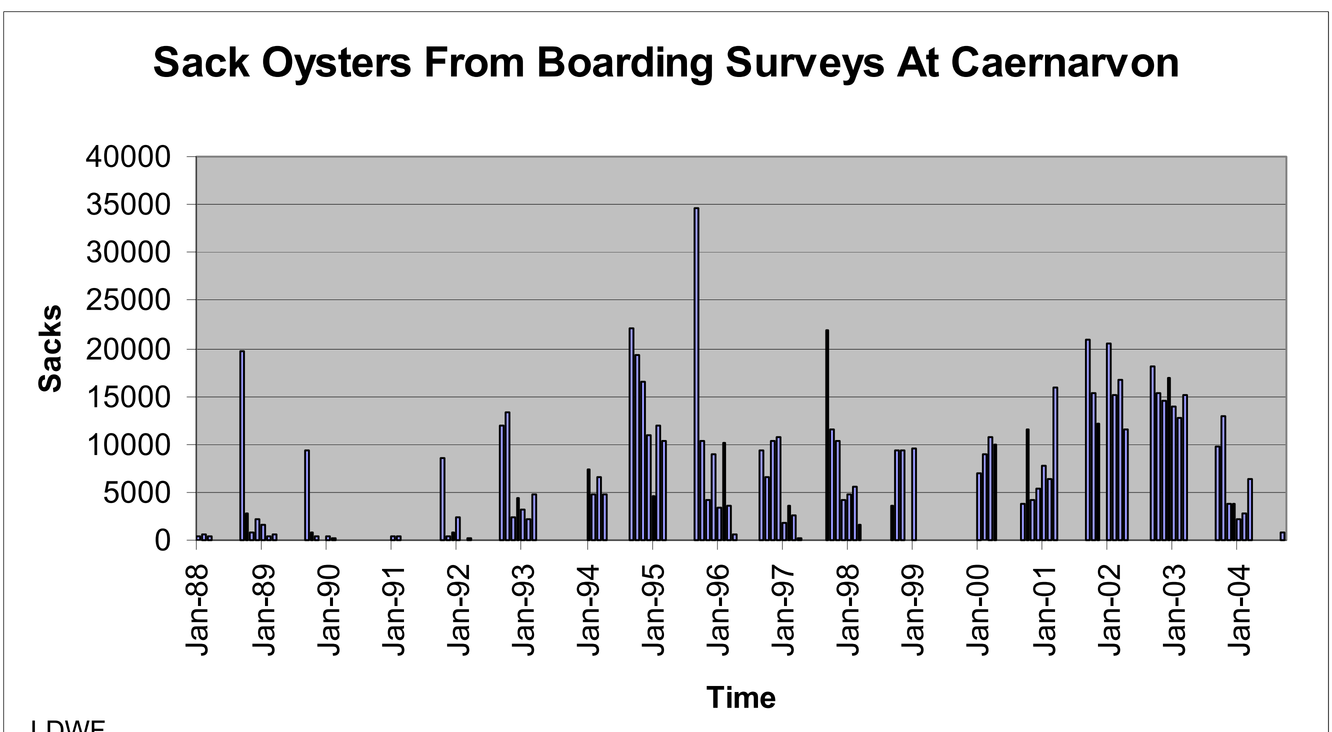


Figure 15. Sack oysters from boarding surveys at Caernarvon (LDWF).

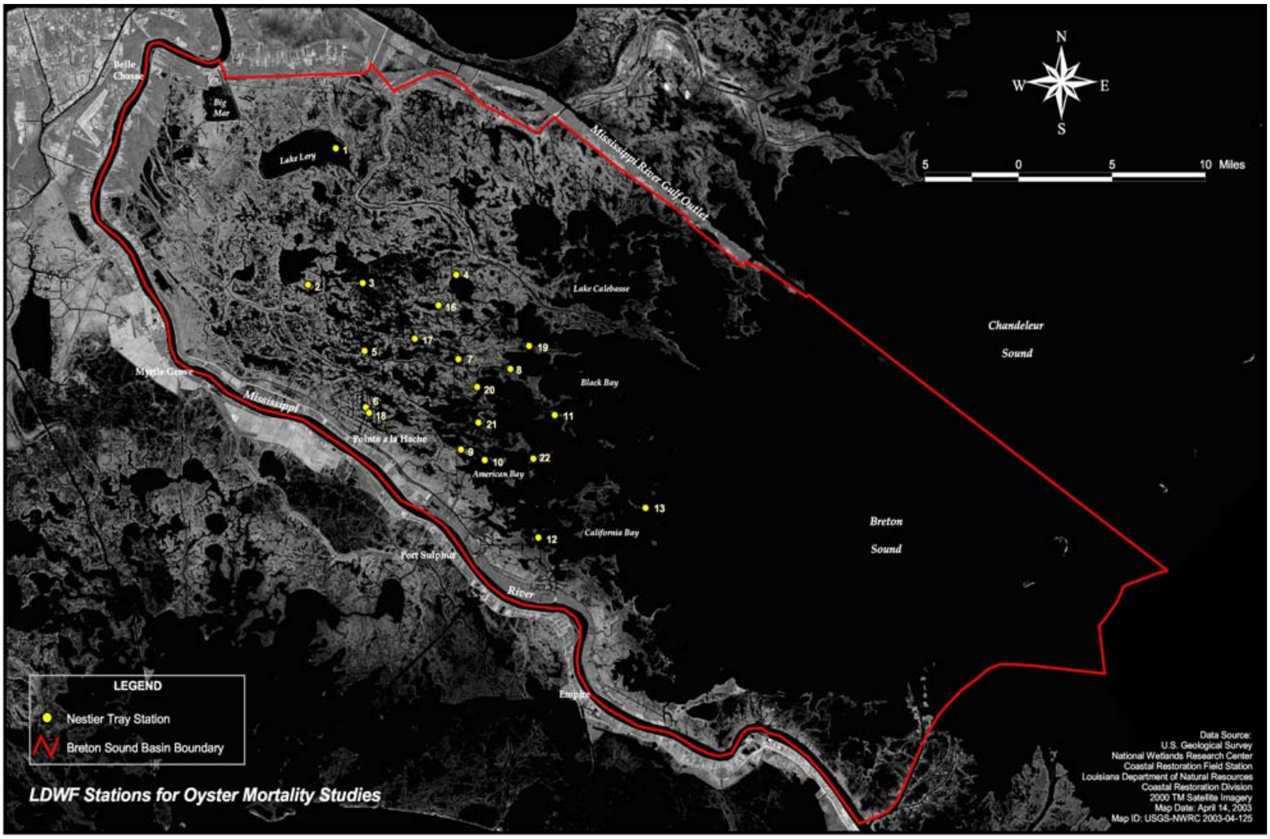


Figure 16. Location of nestier tray stations at Caernarvon.

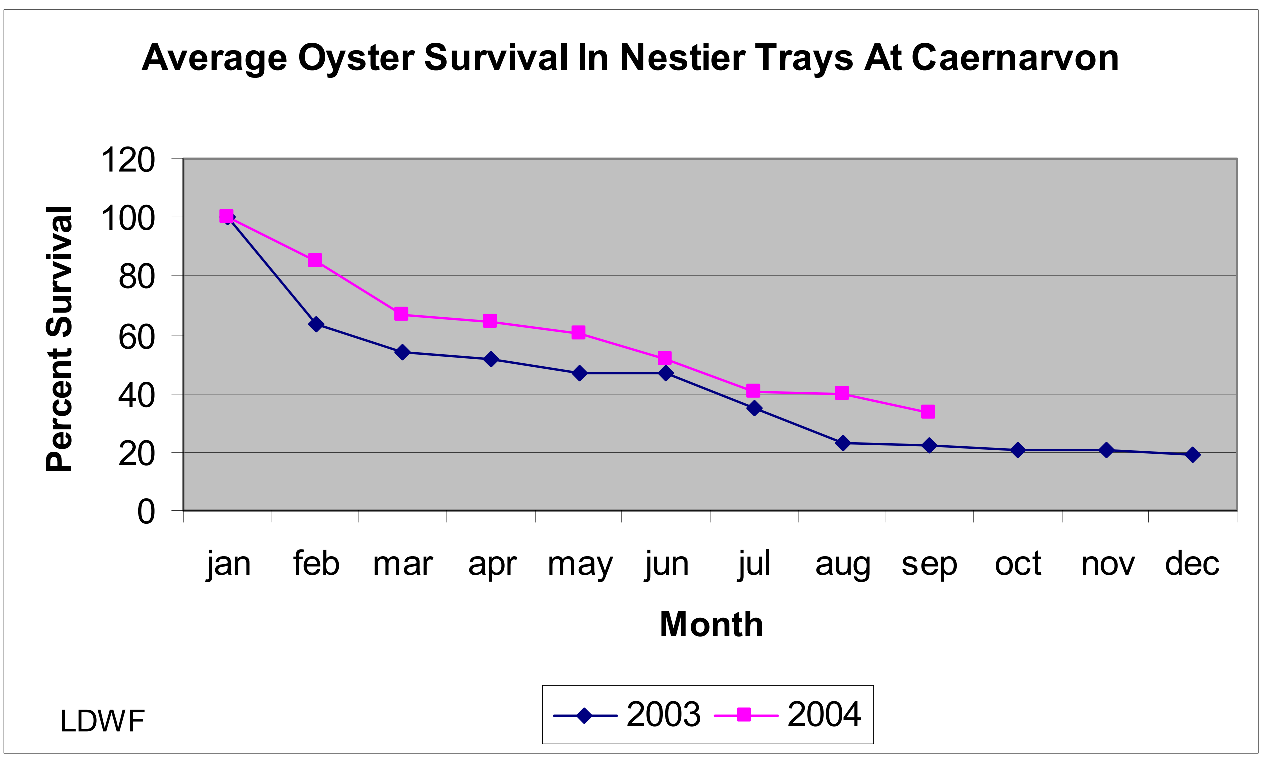


Figure 17. Average oyster survival in nestier trays at Caernarvon (LDWF).

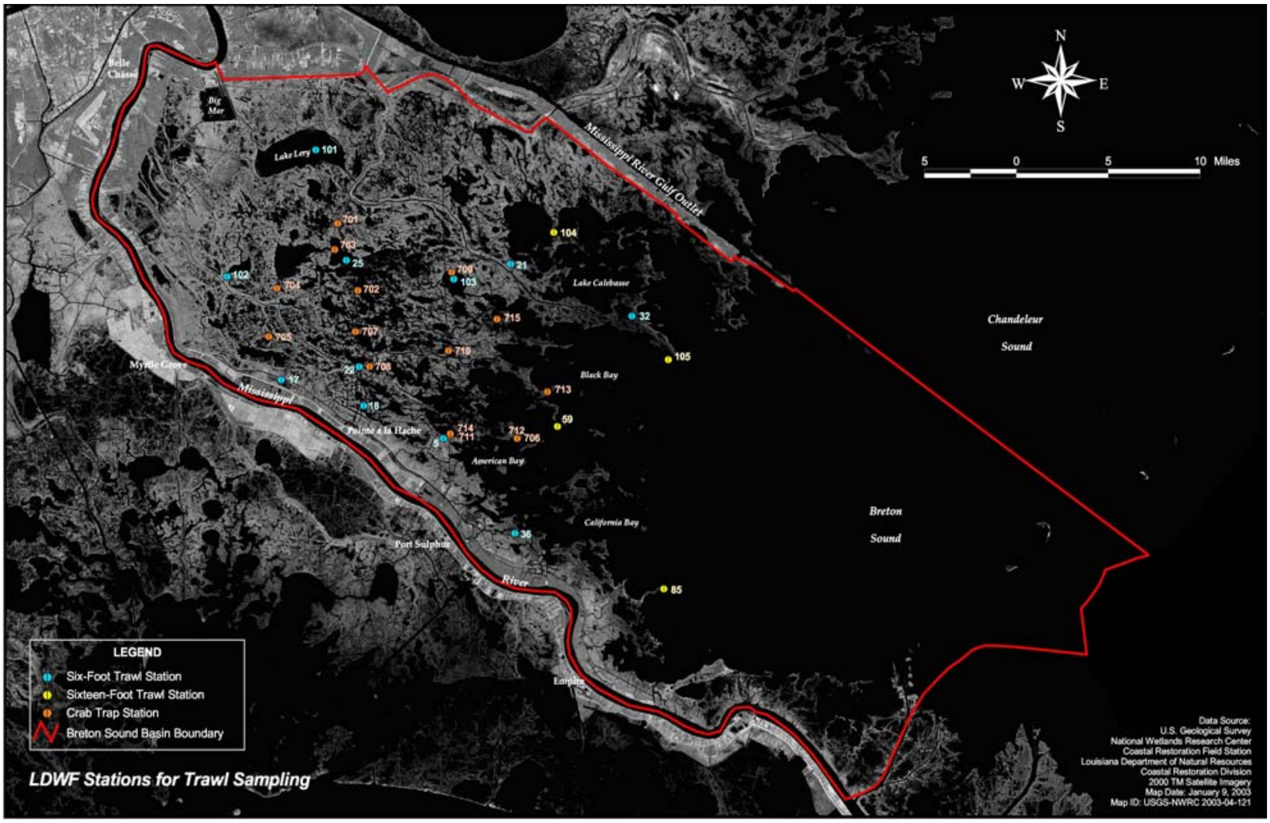


Figure 18. Location of trawl stations at Caernarvon.

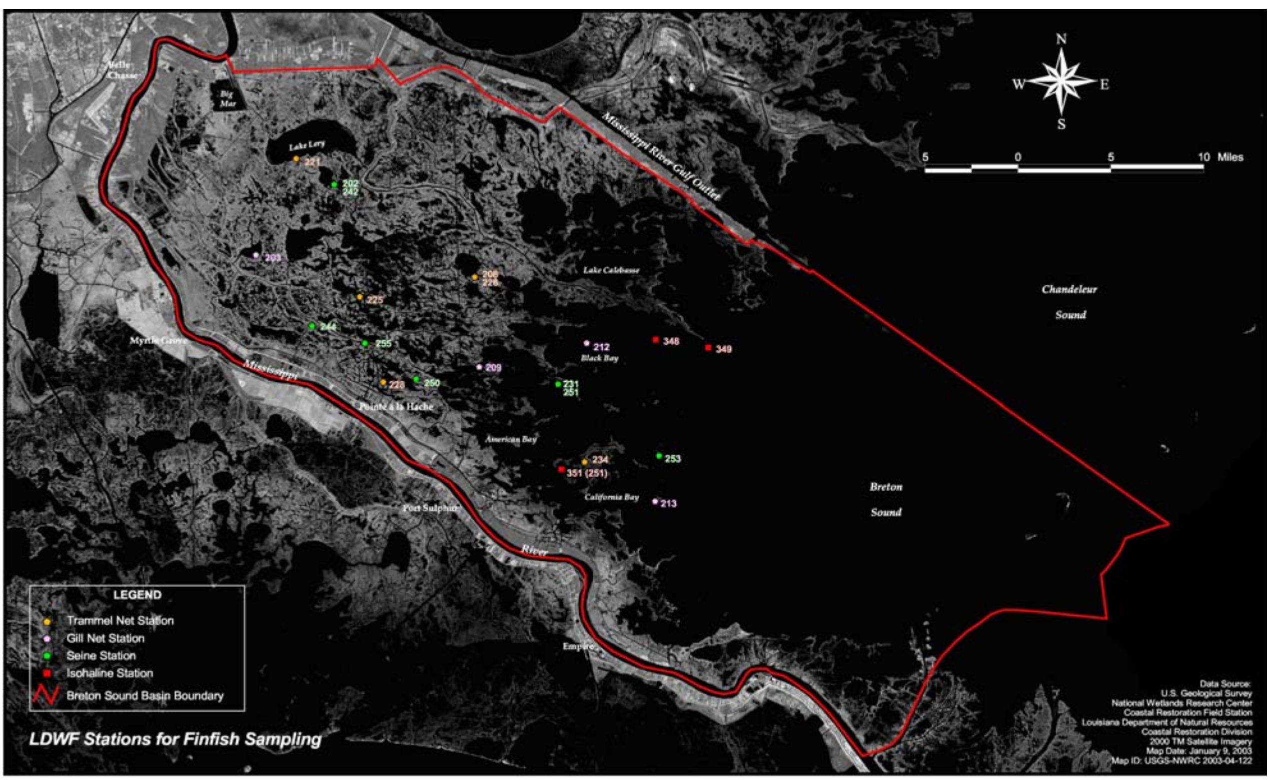


Figure 19. Location of finfish stations at Caernarvon.

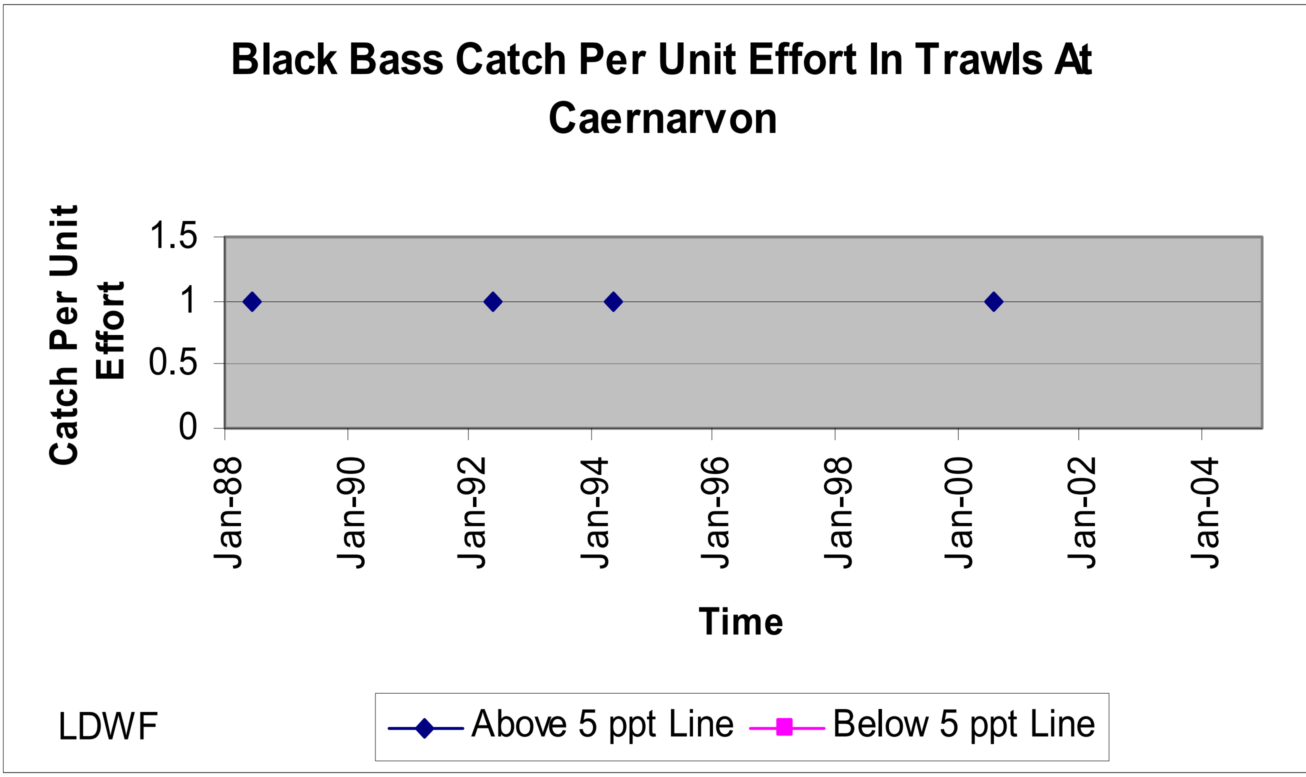


Figure 20. Black bass catch per unit effort in trawls at Caernarvon (LDWF).

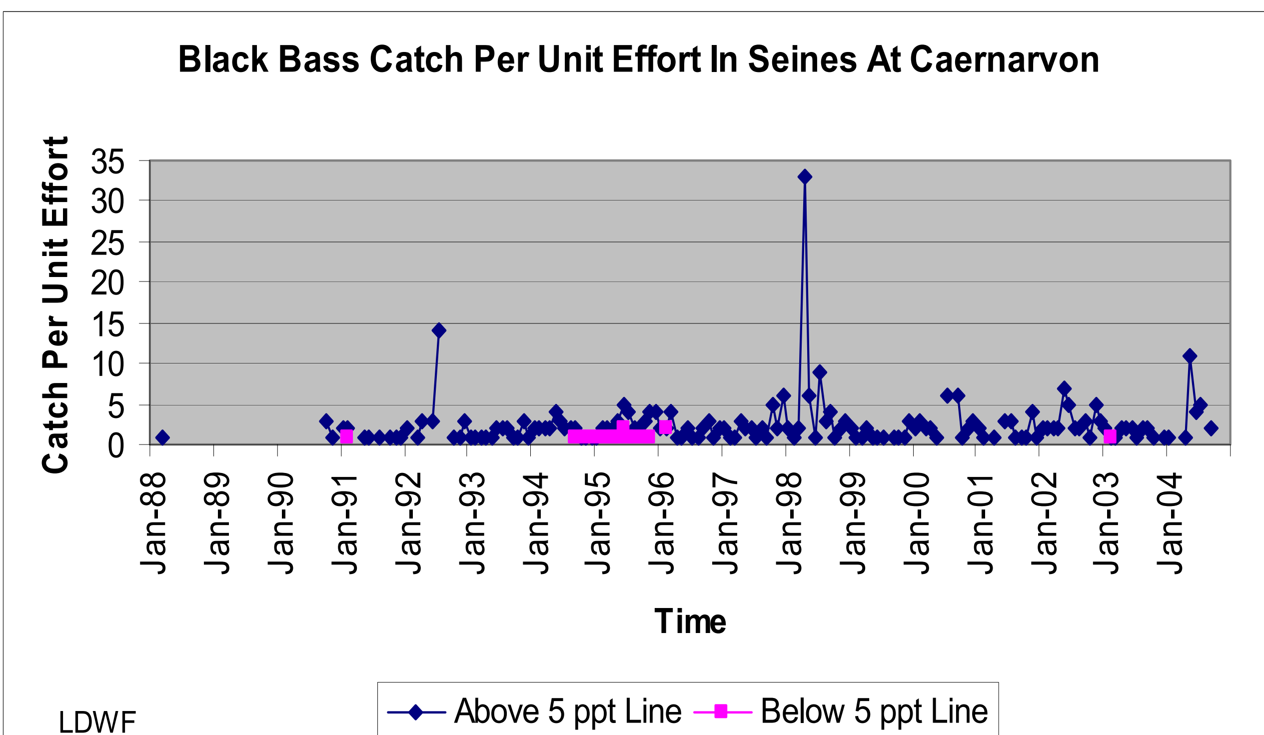


Figure 21. Black bass catch per unit effort in seines at Caernarvon (LDWF).

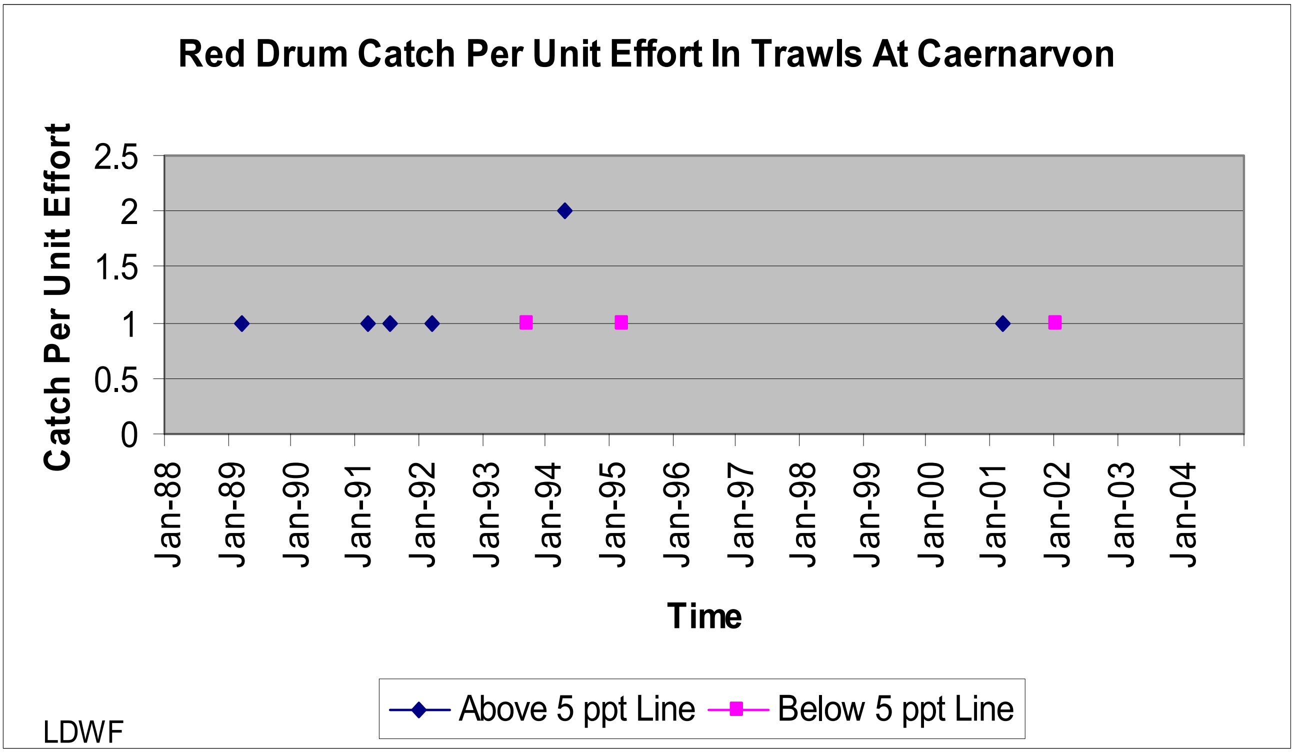


Figure 22. Red drum catch per unit effort in trawls at Caernarvon (LDWF).

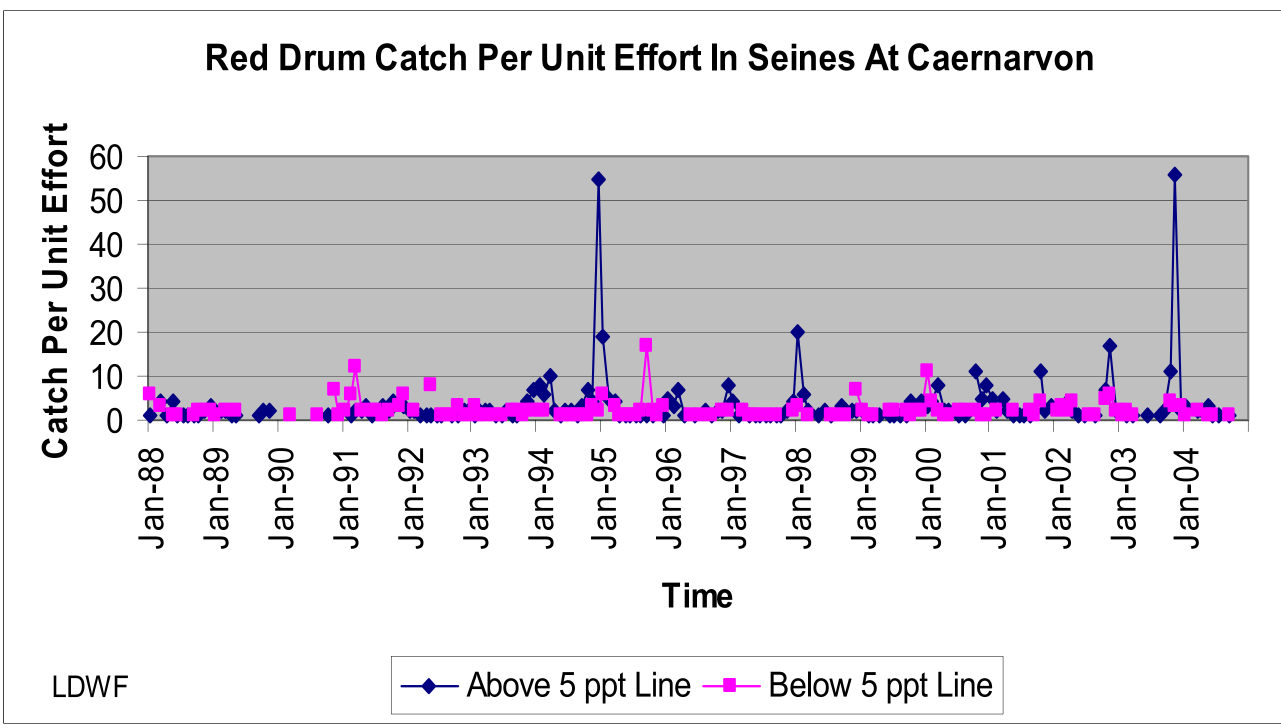


Figure 23. Red drum catch per unit effort in seines at Caernarvon (LDWF).

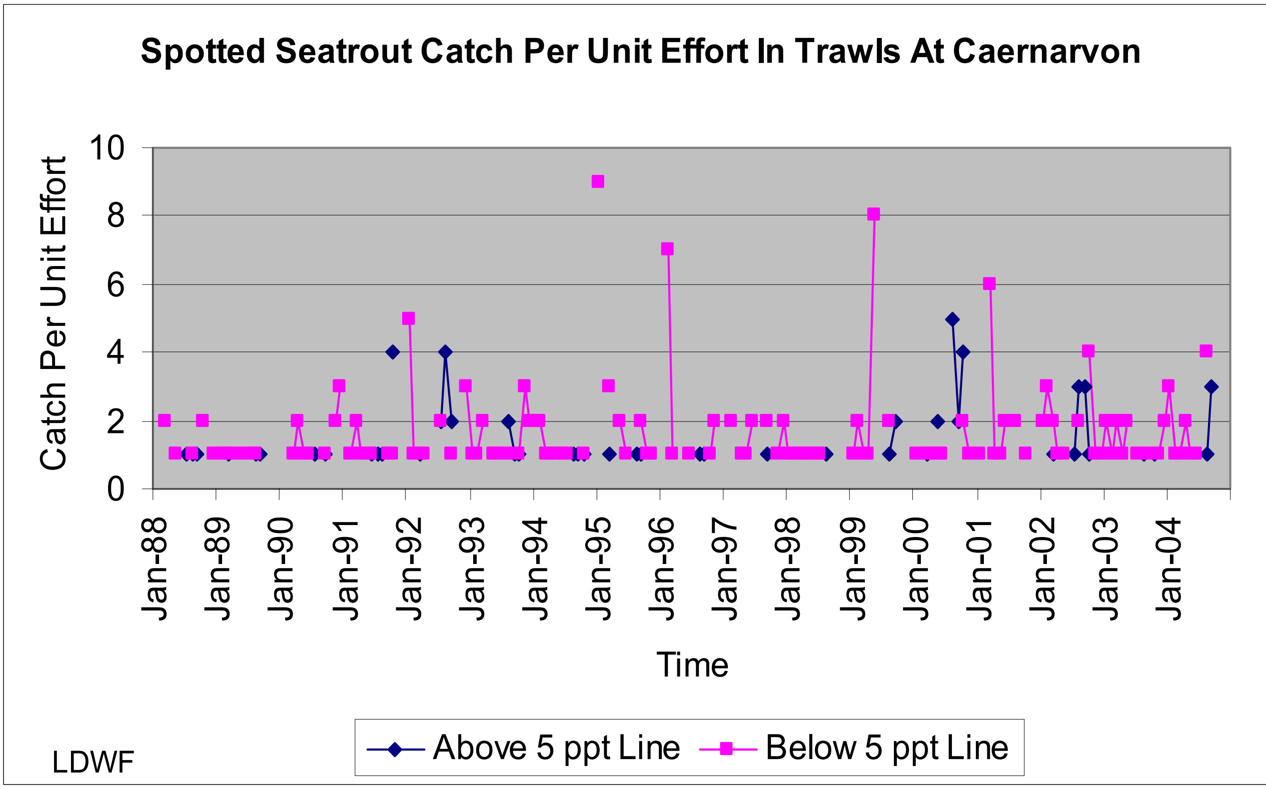


Figure 24. Spotted seatrout catch per unit effort in trawls at Caernarvon (LDWF).

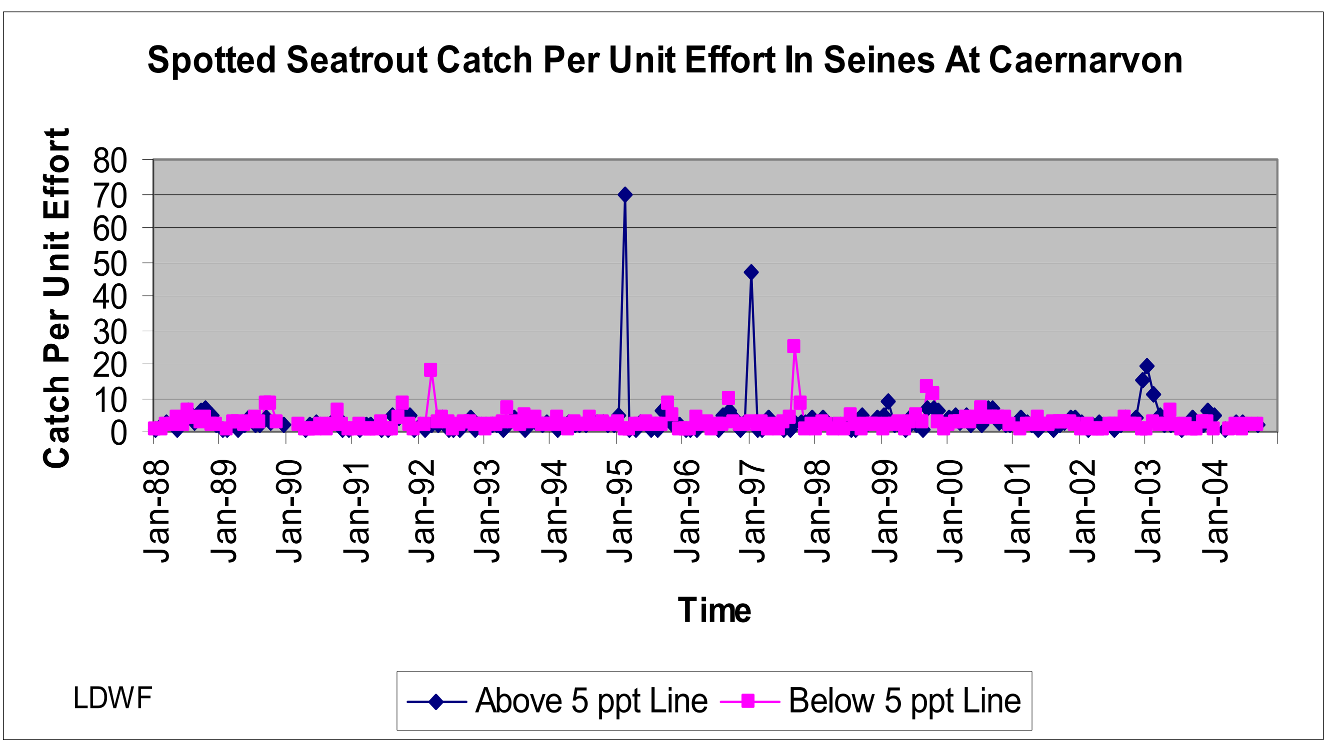


Figure 25. Spotted seatrout catch per unit effort in seines at Caernarvon (LDWF).

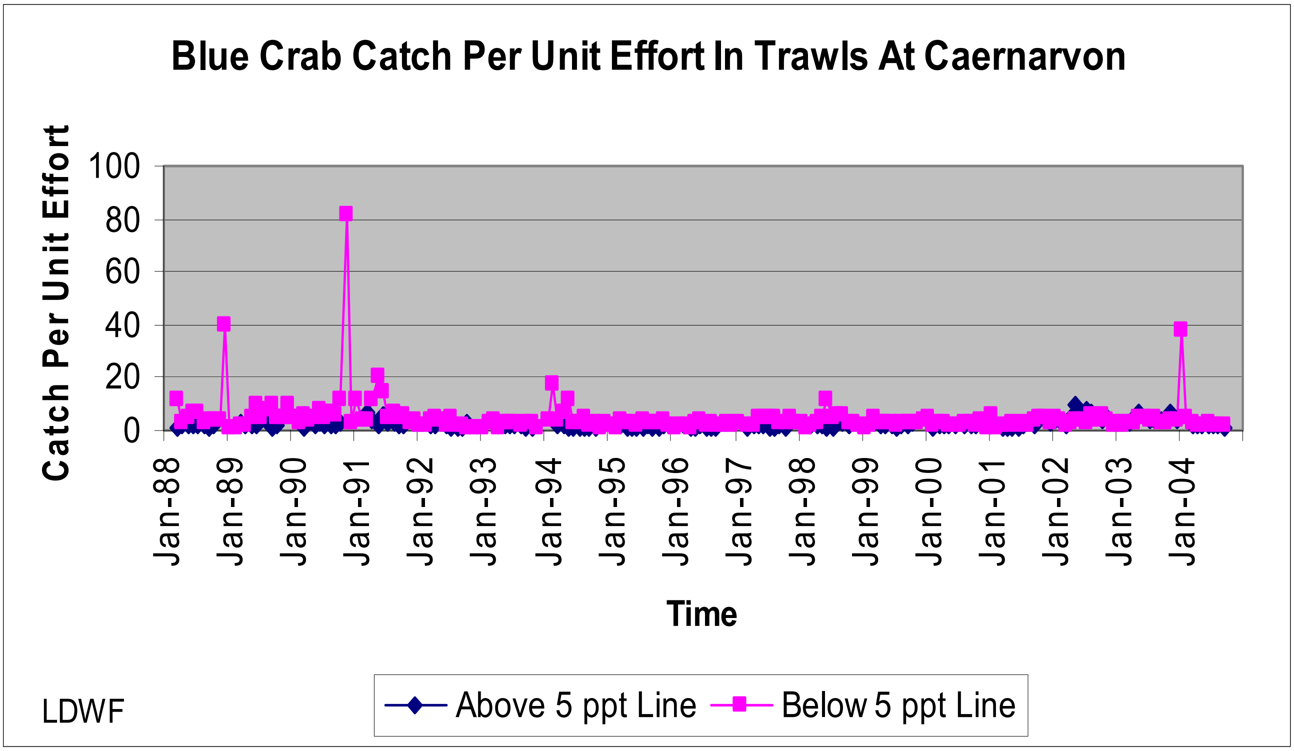


Figure 26. Blue crab catch per unit effort in trawls at Caernarvon (LDWF).

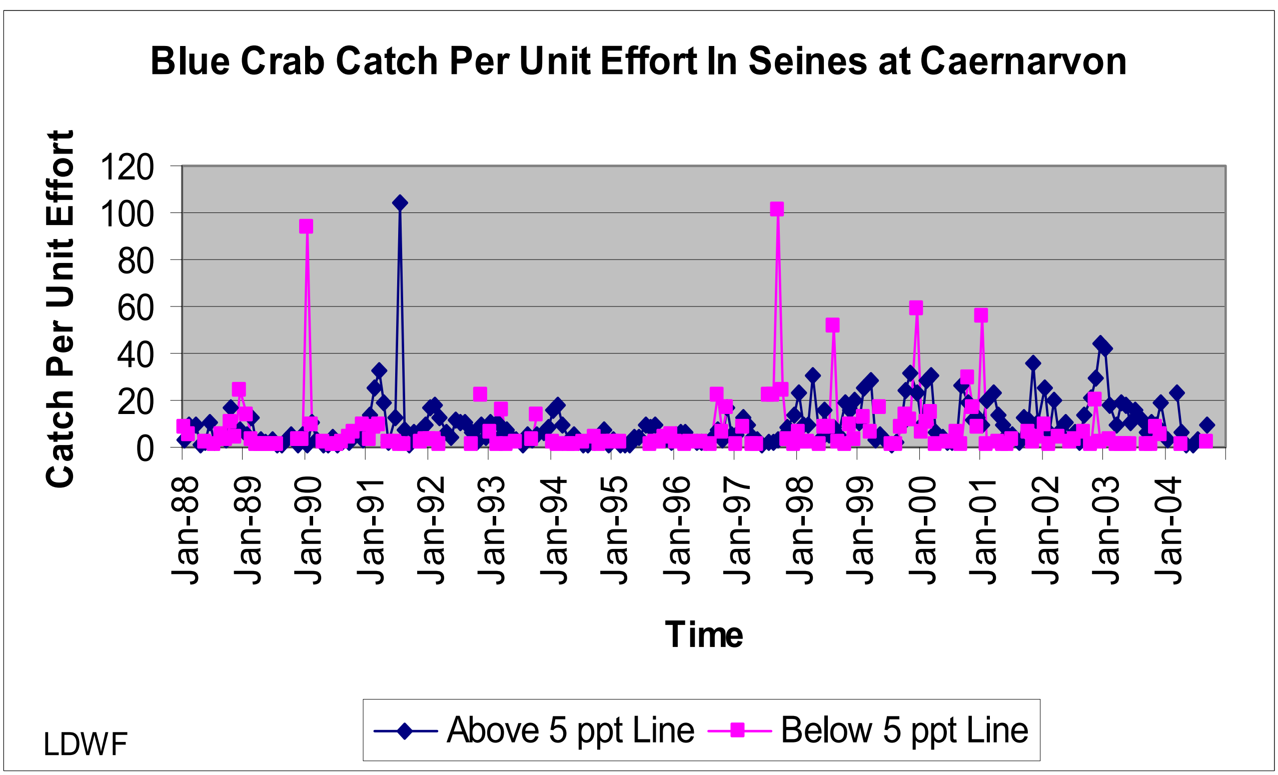


Figure 27. Blue crab catch per unit effort in seines at Caernarvon (LDWF).

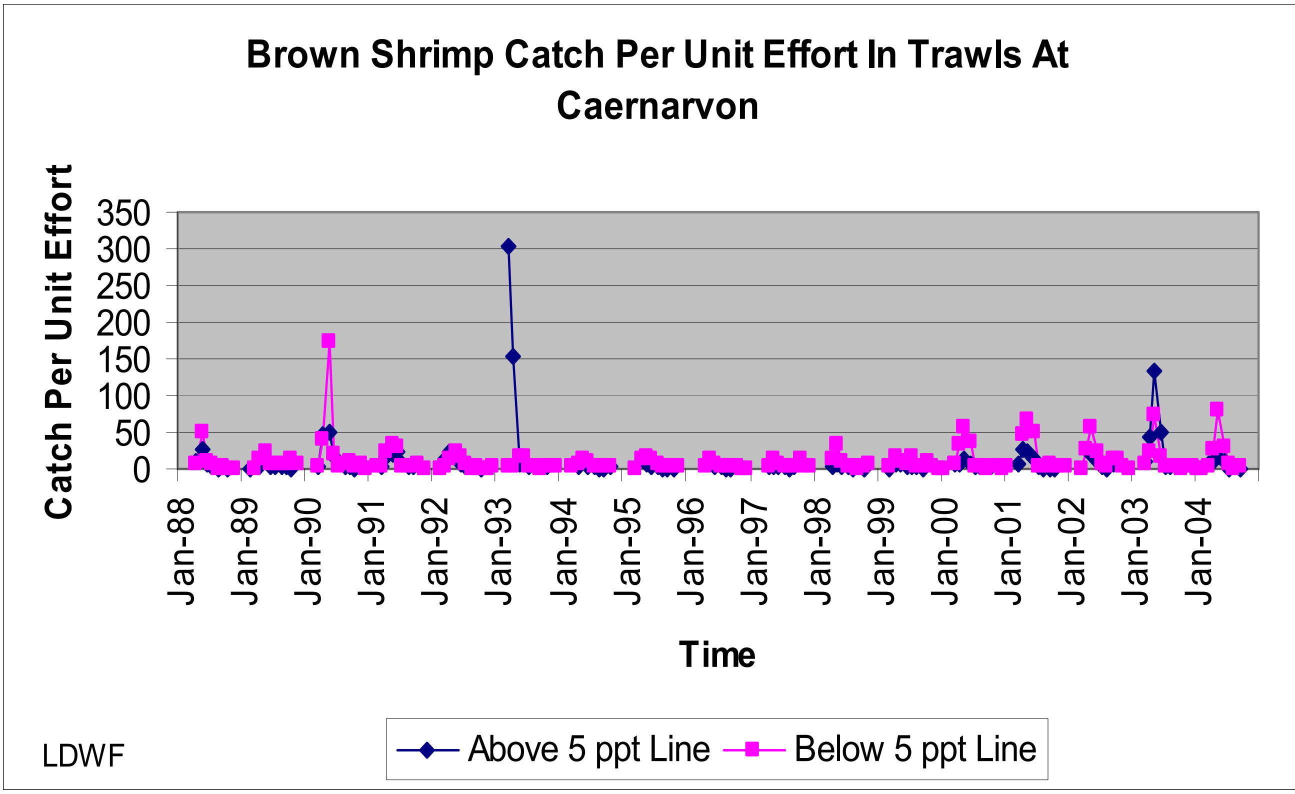


Figure 28. Brown shrimp catch per unit effort in trawls at Caernarvon (LDWF).

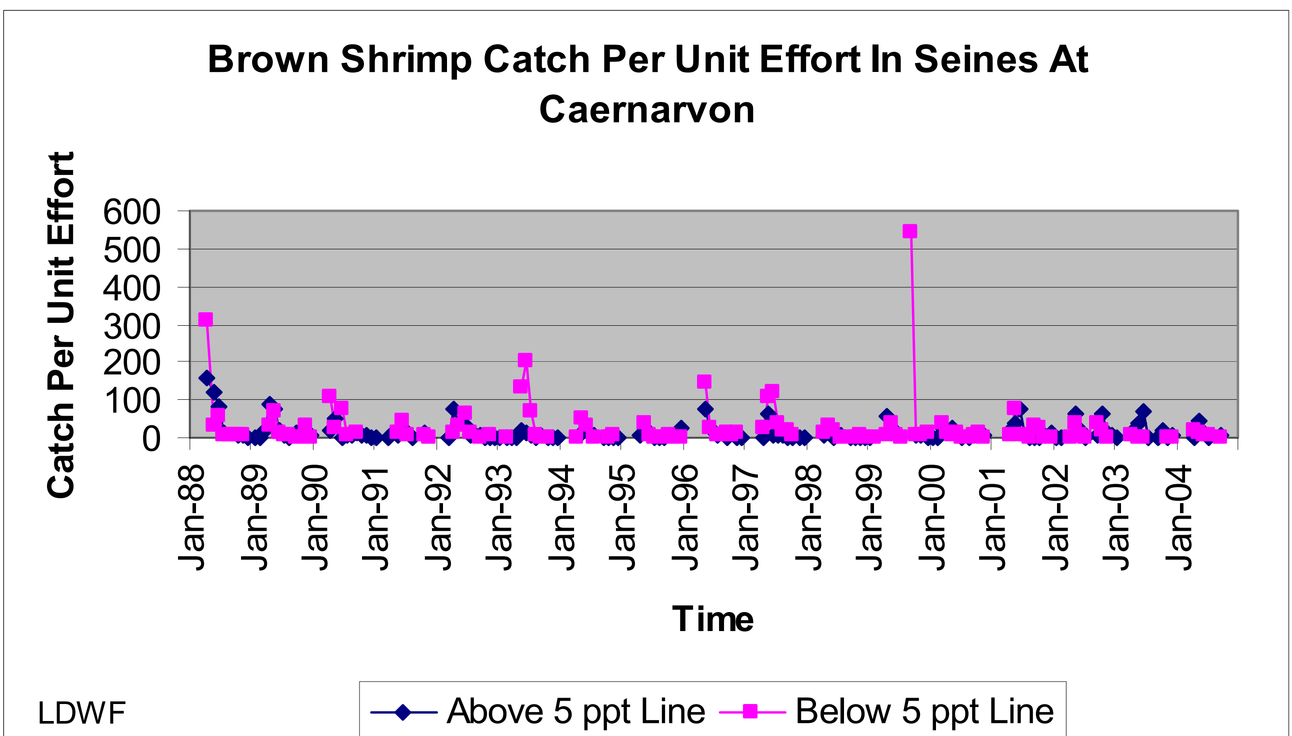


Figure 29. Brown shrimp catch per unit effort in seines at Caernarvon (LDWF).

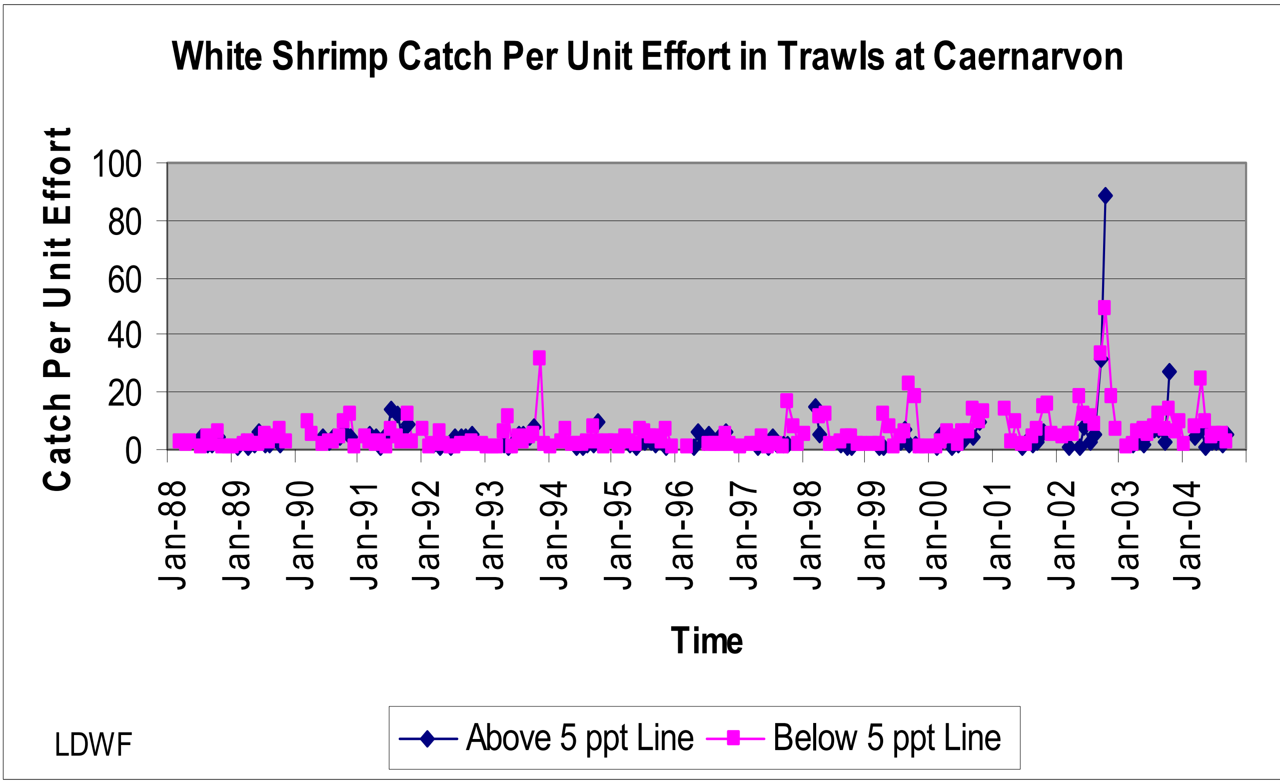


Figure 30. White shrimp catch per unit effort in trawls at Caernarvon (LDWF).

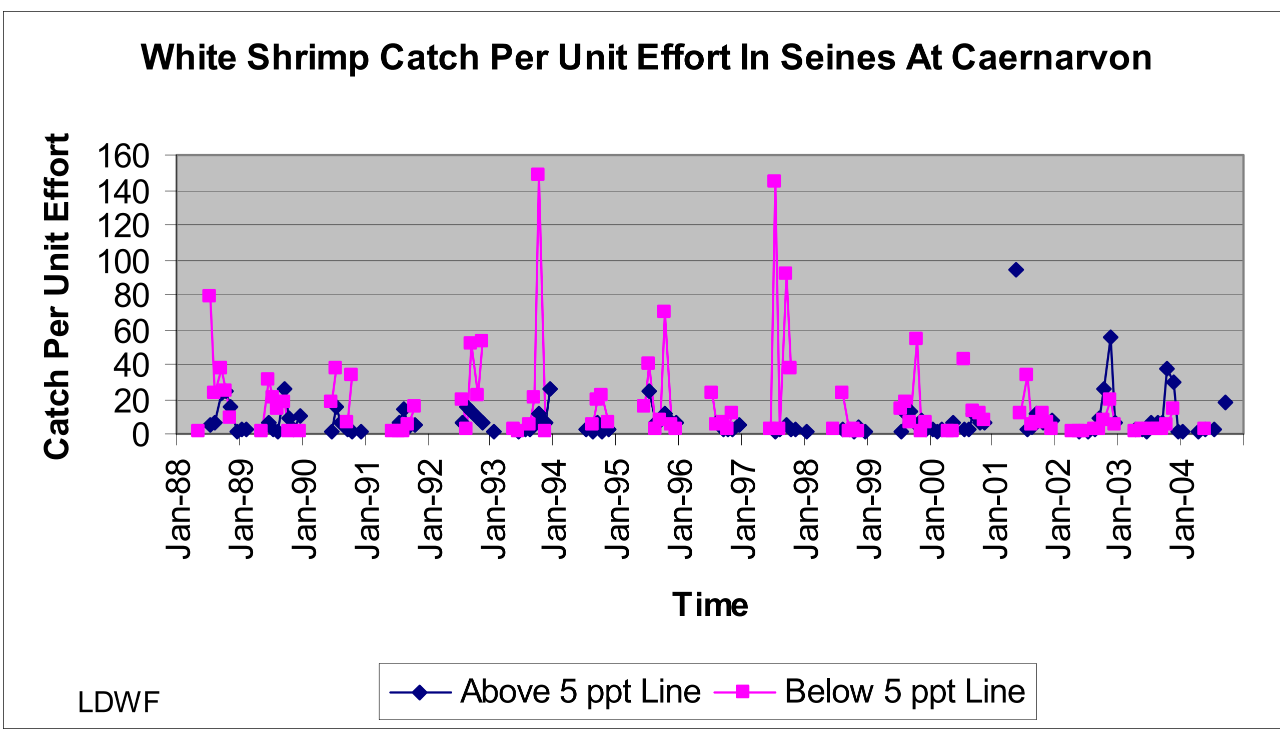


Figure 31. White shrimp catch per unit effort in seines at Caernarvon (LDWF).

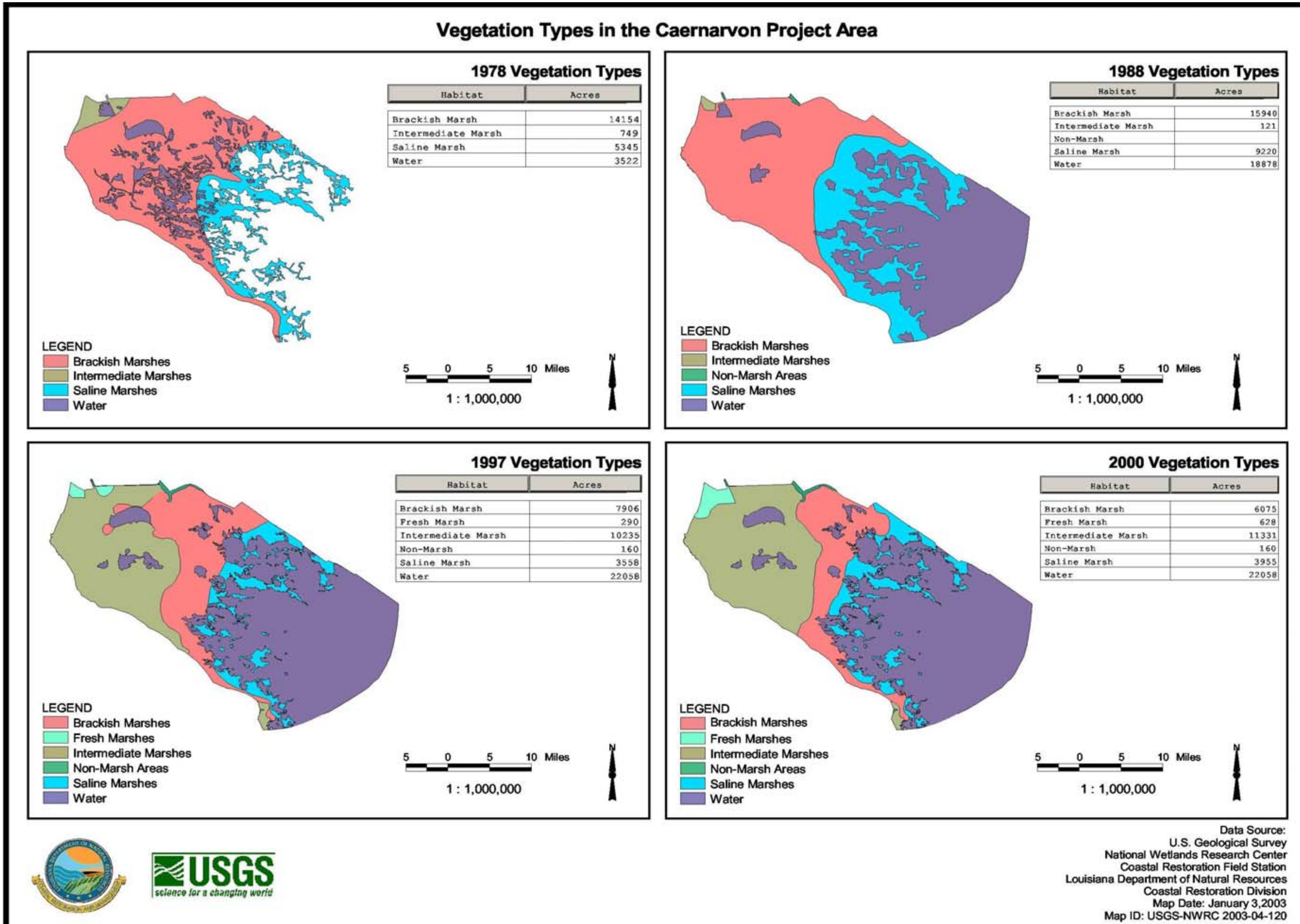


Figure 32. Habitat changes in Breton Sound basin 1978-2000. (USGS)

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)

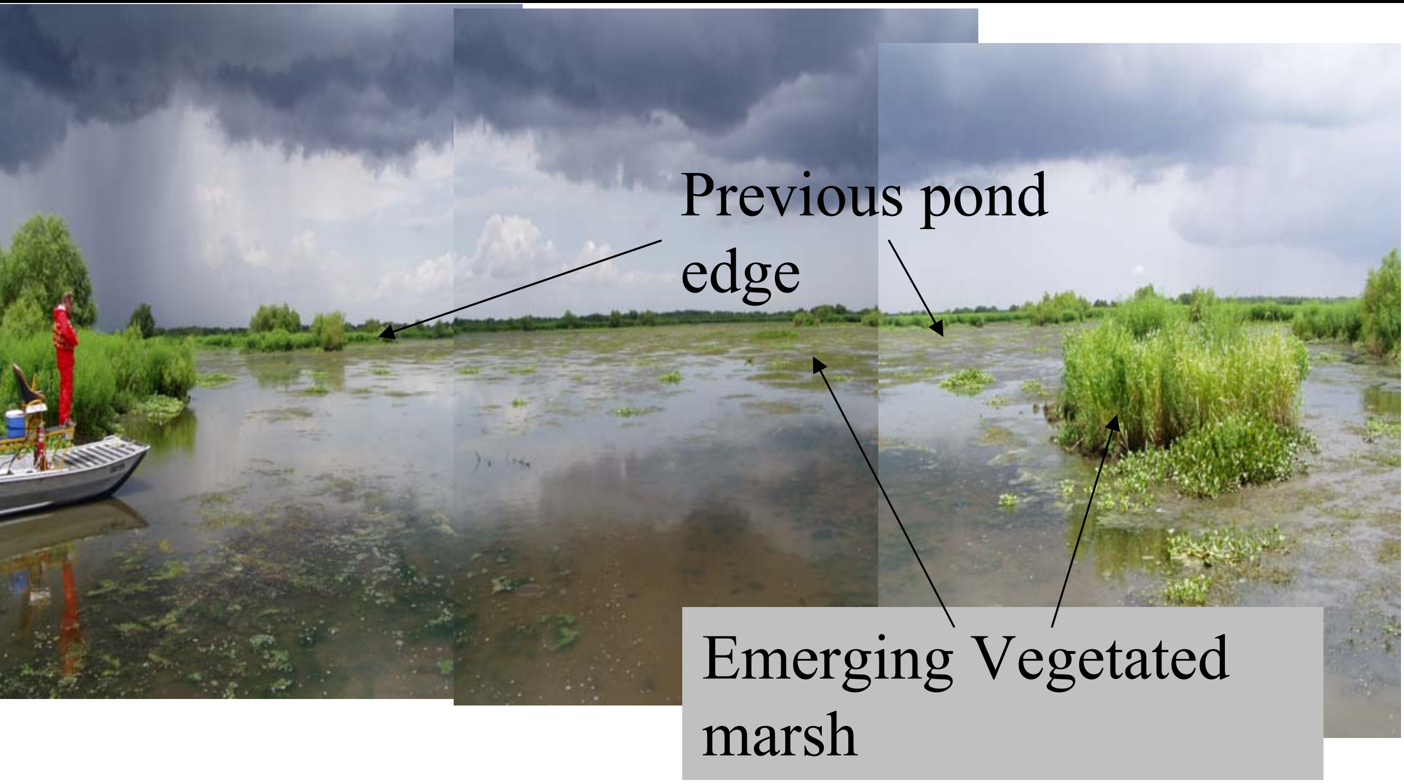


Figure 34. Open water pond converting to vegetated fresh marsh (DNR).

Figure 35. Mud flats and emergent vegetation  in Big Mar