CAERNARVON FRESHWATER DIVERSION PROJECT

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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 2004 through September 2005.

2. OPERATIONAL DATA

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

Caernarvon discharge for the reporting period (October 2004-September 2005) averaged 1,752 cfs when the structure was operational and 1,555 cfs including non-operational periods. The 14-year average for discharge is 1,802 cfs when the structure was operational and 1,087 cfs including non-operational periods. Discharge was highest in February and March, averaging in the 3,000-4,000 cfs range, and lowest in the fall months when low river stage precludes operating the structure for significant periods. The structure was closed by Hurricane Katrina and lack of electricity to the structure in September. No significant damage was done to the structure itself by Hurricane Katrina. The new fencing on the inflow wingwalls was damaged by high storm surge in the river allowing large logs to bash against the fencing.

The structure was closed for 32% of the time for a variety of reasons which is slightly lower 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 14-February 28, 2005 and on March 14- March 28, 2005 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 3-February 13, 2005 and March 1-March 13, 2005. As can be seen in figure 2, Caernarvon yearly discharge has been fairly consistent in the past several years; the long-term average discharge 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 69 inches which was 5 inches above the long-term average. Much of the time period rainfall was below the long term-average; a surplus of rainfall occurred during October, February and July. Three tropical systems affected the Louisiana coast in 2004 and five in 2005. The rainfall in September does not reflect rainfall from Hurricanes Katrina and Rita due to gauges being destroyed from these storms.

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 7.2 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 2004 – February 2005 and below the long-term average during the rest of the time period. Unusually low stages occurred in June and July 2005.

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 October and November.

Salinity (Figures 6-7)

Four real-time Data Collection Platforms (DCPs) are located strategically in Breton Sound estuary to monitor salinity levels at the 5 ppt line, the 15 ppt line, and the upper basin. 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 2004 and September 2005. Across the estuary, salinities decreased starting in December 2004 through April 2005, 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.

All gauges in the Caernarvon area were destroyed during Hurricane Katrina so no data is available past the end of August.

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.

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 transects are flown.

Inter-annual variability is high and ranges from 2,000 birds to 30,000 birds observed. Overall, waterfowl increased 83% 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 90%. Waterfowl numbers have been decreasing over the last few years. Likely explanations for low waterfowl numbers during 2000-2005 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 (Crassostrea virginica) is conducted at 27 stations within the Breton Sound estuary to monitor the effects of the Caernarvon freshwater diversion on oyster productivity.

Seed and sack oysters increased 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 1997-2005 and may have had a negative impact on oyster beds through siltation. Hurricane Karina destroyed about 60 % of oyster beds in the Breton Sound area according to LDWF. A dermo (Perkinsus marinus) outbreak occurred in 1996 which also affected spat numbers. Oyster productivity then rebounded in 2000 and decreased in 2001-2005. The recent decrease may by due to environmental conditions that inhibited early spat recruitment, although 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 380 % since the pre-operation period. While inter-annual oyster harvest is variable, it remains high during 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.

Survival of oysters was higher in 2004 than 2005. Survival in 2005 started dropping in April likely due to low salinities from a variety of sources. Hurricane Katrina destroyed all the nestier trays in August and survival, while unknown due to the loss of trays, was probably very low if not zero. Overall survival in 2004 was about 37%. 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 45% post-operation. In 2004, 39% of stations sampled experienced 0% survival by the end of the year. In 2004, 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 yearly average catch per unit effort (CPUE) for stations above and below the 5 ppt line. Due to the volume of data, yearly data is graphed as opposed to monthly data in previous years. Data are presented for Black Bass (<u>Micropterus</u> <u>salmoides</u>), Red Drum (<u>Sciaenops</u> <u>ocellatus</u>), Spotted Seatrout (<u>Cynoscion</u> <u>nebulosus</u>), Blue Crab (<u>Callinectes</u> <u>sapidus</u>), Brown Shrimp (<u>Penaeus</u> <u>aztecus</u>) and White Shrimp (<u>Panaeus</u> <u>setiferus</u>).

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 twice as high 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. CPUE has remained relatively constant throughout the post-operation period with the highest catch in 1998.

RED DRUM (Figures 22-23)
Adult red drum inhabit 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 50% 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 1994 and 2003. Peak catches occurred above the 5 ppt line and catch doubled 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, overall catch doubled in the post-operation period as well as both above and below the 5 ppt line. In the seine data, catch was about equal between the pre/post periods and above and below the 5 ppt line.

BLUE CRAB (Figures 26-27)
In trawls, the mean blue crab catch was about 66% 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 constraints. In seines, mean catch was about the same between the pre/post intervals and more crabs are caught above the 5 ppt line during the post-operation 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 9% 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 above the 5 ppt line is largely consistent except for high catches in 1993 and 2003.

In seines, mean catch was about 65% 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. However, high catches below the 5 ppt line have occurred in several years post-operation.

WHITE SHRIMP (Figures 30-31)
Mean white shrimp catch in trawls has been about 75% 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 similar during the pre and post operation periods as well as above and below the 5 ppt line with the exception of a high 1997 below 5 ppt line catch.

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, 5.2 for 2004 and 2.3 for 2005. It appears that the diversion structure can generally maintain historical salinities in the upper basin.

The values for 2003 and 2005 are low partially due to the recorders being off-line most of the year. In 2005, Hurricane Katrina destroyed all recorders in Breton Sound. Based on field trips to the area, salinities were quite high the remainder of the year due to the after-effects of the storm and high tides and east wind bringing high salinities in the basin.

Salinities in the Breton estuary started declining in December 2004 and remained low until April 2005. 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. The decrease in salinities across the basin from December to April is probably related to several factors. The Mississippi River was at high stage and above average from November to March. Persistent high river stages can depress salinities in the marsh areas of the Caernarvon area. A 10 inch rainfall for the month of February likely contributed to lowered salinities. A single high rainfall event can depress salinities for months. Persistent northerly winds from November to March helped push fresh water from the upper basin down to lower areas of the basin. Caernarvon discharge during February and March also likely contributed to lowered salinities during these months. While Caernarvon discharge probably contributed to this pattern, salinities in Barataria estuary were also low from during this time period indicating a more regional cause for these prolonged low salinities in both 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. Since operations started there has been a dramatic increase in alligator nests counted and a switch to fresh and intermediate habitats for nesting. As a result of increasing intermediate and fresh marsh habitat and food resource, alligators are expected to remain plentiful in the area.

Situated at the southern end of the Mississippi Flyway, Louisiana marshes provide overwintering habitat for 70% of migrating ducks and geese using this route. Waterfowl hunting contributes more than $10 million annually to the local economy and is an important cultural and recreational activity in the region. Waterfowl, particularly dabbling ducks, generally prefer fresh to brackish environments. Manipulation of water levels and salinities is needed to maintain plant species desirable to waterfowl (Chabreck 1988). While waterfowl numbers are dependent on weather and food conditions across the flyway which may keep ducks in more northerly areas, observations from hunters in the Caernarvon area indicate that food in duck ponds is generally good in the upper part of the Breton Sound estuary and the habitat changes sustained by the diversion are generally beneficial to duck populations.

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 patterns: 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 sources 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 the past several years may be related to dermo infestations on seed oyster stock that reduced sack oysters in subsequent years. Low recruitment in recent years may also have contributed to low production on the seed grounds (LDWF personal communication). Survival in 2004 is consistent with previous years. Lower survival in 2005 is probably due to declining salinities from October 2004-

April 2005. Interestingly, despite prolonged low salinities in 2004, oyster survival during this time remained above 50%.

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. Caernarvon diversion is the main reason for the bass population revival. However, LDWF biologists have indicated that lack of consistent discharge from Caernarvon limits bass habitat and productivity. Heavy fishing pressure can also be detrimental. Caernarvon is closed, on average, about 35% of the time for a variety of reasons, usually low flow in the river. These factors may put limits of bass productivity in the Caernarvon outfall. 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 for the benefit of bass populations.

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).

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.

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 4 miles from the structure requires higher water levels associated with set-up from frontal passages. Research by Snedden (2006) indicates that the diversion supplies over 100,000 tons of sediment per year. This amount can be increased to over 500,000 tons per year by diverting river water during high and, especially, rising river stages. While sediment input from the diversion is still much less than an uncontrolled diversion, the upper amount can offset relative sea level rise in the upper part of the basin. 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. Snedden's (2006) analysis indicates that the diversion can affect stages in the outfall out to about 19 miles. 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 than others and account for some of the variation seen in fisheries and land loss data. Pulsing of high discharge during periods of high or rising river stage may be a strategy to maximize benefits.

8. RESEARCH

Dr. John Day and Dr. Jim Cowan supplied a summary of research at Caernarvon from a variety of researchers at LSU and ULL. Sediment loading in the Mississippi River and consequently through the diversion is greatest on a rising and cresting river stage. Sediment distribution within the estuary is primarily down the main channels of Bayou Terre aux Boeufs and Reggio Canal/River aux Chene until the water level reaches marsh level. Sheet flow then contributes about 10-20% of the sediment load to the marsh. Short-term deposition follows expected seasonal and spatial trends with the greatest deposition occurring in spring and during high river stages and closest to the estuary head.

Sediment studies indicate that the upper Breton Sound marshes are sustainable and the long-term deposition is around 2.6-3 mm/year. Of the suspended sediment load in the Caernarvon outfall about 40% stays in Big Mar, 25% travels down Bayou Mandeville toward Lake Lery, about 24% exits to the marshes south of Big Mar, and 11% flows down Delacroix canal toward Reggio and Manual canals. As the water flows over the marsh, it warms up 7-10 degrees C and there is a high reduction in total suspended solids. Water levels in the basin are affected mainly by two factors. Remote atmospheric forcing as winds along the coast influence tide levels with tides dampened and lagged in the upper estuary. The diversion, during high flow or pulses, exerts strong water level impact in the upper estuary.

Nutrient dynamics include a net uptake of nitrate, total nitrogen, total phosphorus and total suspended solids. The N:P ratio decreases and the Si:N ratio increases with increased distance from the diversion. Rainfall and water from the diversion account for most of the water budget in the basin with groundwater an unimportant factor. Nutrient additions from riverine sources accounted for 75% of food web support in the upper basin. Sulfide, a chemical harmful to plant growth, was generally lower in the upper basin nearer the diversion.

While phytoplankton populations are generally low in Breton basin, the mid-basin area around Grand Lake does experience some hypereutropic events due to longer residence times and lower turbidity waters. Some exotic and potentially harmful phytoplankton has been identified in this area. To limit phytoplankton populations, nutrient input should be avoided under high light and temperature conditions whereas spring diversions are more beneficial with regard to phytoplankton development. High levels of turbidity in diverted water and flushing can also inhibit phytoplankton development. An operation regime which allows some salinity rebound may also limit some phytoplankton populations.

Trophic level analysis of fish populations in USA waters has indicated general decreases from piscivorous to planktivorous species which may indicate changes in community structure or environmental degradation. In contrast, since Caernarvon opening, trophic level in Breton Sound has been increasing and could indicate a positive effect of the diversion on fish populations.

9. HURRICANE KATRINA IMPACTS

Hurricane Katrina made landfall on August 29, 2005 around 6AM near Buras, Louisiana as a category 4 storm with 140 mph winds. It had reached category 5 strength with 175 mph winds on August 28 prior to landfall. This hurricane was the costliest on record and one of the deadliest.

The Caernarvon structure experienced minimal damage from the storm. The storm surge in the Mississippi River rose 12 feet and logs in the river smashed against the newly constructed fence on the wingwall of the structure and damaged the fence. Otherwise there was no damage to the structure and the fence has been repaired. The USACE had recently installed stronger fencing on the structure and outfall to keep trespassers from fishing on the structure. The generator used for emergency operations was flooded and has been repaired. The structure was without electricity for about 4 months after the storm.

All salinity, water level, and flow monitoring stations were lost or destroyed by the storm. These stations have been replaced but surveying to a datum is pending. Hurricane Katrina also disrupted the ability of LDWF to conduct the wildlife and fisheries sampling. Personnel, equipment, logistics and access issues made sampling impossible to difficult after the storm. About two months of sampling were lost after the storm.

The effects on the marsh were equally devastating, at least in the short term. Estimates by the USGS indicated that about 41 square miles of marsh were lost in the Breton Sound estuary (Figure 33). The area experienced between 15 and 25 feet of storm surge that went all the way up the estuary. LDNR field crews measured debris in trees 17 feet high near the "crow's foot" near Braithwaite. Surge models indicated similar estimates of over 20 feet (Figure 34). The primary effect seemed to be physical movement of marsh into canals or ponds to form large "shear zones" of denuded marsh. Much of these areas initially were open water or mudflats. Other areas of marsh were uprooted and flipped over. Many ponds or open water such as Big Mar have pieces of marsh or "marsh balls" spread across them (Figures 35-38).

While the images and estimates of marsh damage due to Hurricane Katrina are sobering, it will take several growing seasons to determine how much marsh loss is permanent. Some scar areas are deeper than others and may not re-vegetate without some targeted sediment input to raise the substrate level so marsh can re-grow. Some of the shallower scour areas near the diversion appear to be recovering during the first growing season after the storm (Figures 39-41). An aggressive diversion operational plan and additional methods like targeted sediment input and targeted diversion discharge to needed areas can facilitate natural regeneration of this area devastated by Hurricane Katrina.

10. ADDITIONAL SOURCE OF INFORMATION

Data collected as part of the Caernarvon monitoring program is available at http://dnr.louisiana.gov/crm.

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Table 1. Caernarvon Freshwater Operational Plan January 2005

2005

Month	Flow Range (cfs)[1]
January 1 - 23 January 24 - Febuary 2	3000-6500 [2] 3000-6500 [2]
Pulse Low Flow Feb. 03 - Feb. 13 Pulse High Flow Feb. 14 - Feb. 28	500 6500 [5]
Pulse Low Flow Mar. 01 - Mar. 13 Pulse High Flow Mar.14 - Mar. 28	500 6500 [5]
April	500-6500 [4]
May	500-6500 [3]
June	1000-6500 [3]
July	1000-6500 [4]
August	1000-6500 [4]
September	1000-6500 [4]
October	1000-6500 [4]
November	1000-6500 [4]
December During Duck Season Split	2500 [2] 6500 [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 Reggio Canal near Wills Point reads above 2.4 NAVD-88.

[2] Salinity at Bay Gardene will be monitored to stay above 3 ppt.

[3] For oyster production, the salinities at the Bay Gardene station will be monitored during these months. The structure will be operated at the lower discharge levels. If the Bay Gardene station moves to 9 ppt based on a two-week average, Caernarvon discharge will be increased, but will not exceed 6500 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 6500 cfs.

[5] During the period from the end of duck season through March 28 conduct two two-week 6500 cfs pulse flows with a two-week period of either low flow 500 cfs (experimental request) or existing flow and salinity targets for the month. With the approval of the LSU study group and the DNR Structure Coordinator, maximize the discharge in the period between the high flows (Feb. 28 to Mar. 13).

Caernarvon Operational Summary
2004-2005
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	10/1/2004	8:00	1.4	1.4	1.4	1.4	1.4	4.3	1.3	
Tom Bernard	10/2/2004	8:00	1.4	1.4	1.4	1.4	1.4	4.3	1.3	
Tom Bernard	10/3/2004	8:00	1.4	1.4	1.4	1.4	1.4	4.3	1.3	
Tom Bernard	10/4/2004	8:00	1.4	1.4	1.4	1.4	1.4	4.3	1.3	
Tom Bernard	10/5/2004	8:00	1.4	1.4	1.4	1.4	1.4	4.3	1.3	
Tom Bernard	10/6/2004	8:00	1.4	1.4	1.4	1.4	1.4	4.3	1.3	
Tom Bernard	10/7/2004	8:00	0	0	0	0	0	0	0	Closed due to Tropical Storm Andrew
Tom Bernard	10/8/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/9/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/10/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/11/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/12/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/13/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/14/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/15/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/16/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/17/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	10/18/2004	10:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	Reopened Structure to 1000 cfs
Tom Bernard	10/19/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/20/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/21/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/22/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/23/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/24/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/25/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/26/2004	8:00	2.5	2.5	2.5	2.5	2.5	2.1	1.1	
Tom Bernard	10/27/2004	11:00	6.4	6.4	6.4	6.4	6.4	1.9	1.3	Adjusted Structure to 2000 cfs
Tom Bernard	10/28/2004	8:00	6.4	6.4	6.4	6.4	6.4	2.2	1.5	
Tom Bernard	10/29/2004	8:00	6.4	6.4	6.4	6.4	6.4	2.5	1.7	
Tom Bernard	10/30/2004	8:00	6.4	6.4	6.4	6.4	6.4	2.8	1.9	
Tom Bernard	10/31/2004	8:00	6.4	6.4	6.4	6.4	6.4	3	2.1	
Tom Bernard	11/1/2004	10:30	5.2	5.2	5.2	5.2	5.2	3.2	2.3	Adjusted Structure to keep 2000 cfs
Tom Bernard	11/2/2004	8:00	5.2	5.2	5.2	5.2	5.2	3.4	2.1	
Tom Bernard	11/3/2004	8:00	5.2	5.2	5.2	5.2	5.2	3.6	2	
Tom Bernard	11/4/2004	8:00	5.2	5.2	5.2	5.2	5.2	3.7	1.9	
Tom Bernard	11/5/2004	6:30	2.5	2.5	2.5	2.5	2.5	3.9	1.8	Adjusted Structure to keep 2000 cfs
Tom Bernard	11/6/2004	8:00	2.5	2.5	2.5	2.5	2.5	4.1	1.8	
Tom Bernard	11/7/2004	8:00	2.5	2.5	2.5	2.5	2.5	4.3	1.8	
Tom Bernard	11/8/2004	8:00	2.5	2.5	2.5	2.5	2.5	4.4	1.8	
Tom Bernard	11/9/2004	8:00	2.5	2.5	2.5	2.5	2.5	4.5	1.9	
Tom Bernard	11/10/2004	8:00	2.5	2.5	2.5	2.5	2.5	4.6	1.9	
Tom Bernard	11/11/2004	8:00	2.5	2.5	2.5	2.5	2.5	4.7	1.9	
Tom Bernard	11/12/2004	11:00	1.5	1.5	1.5	1.5	1.5	4.8	1.9	Adjusted Structure to keep 2000 cfs
Tom Bernard	11/13/2004	8:00	1.5	1.5	1.5	1.5	1.5	5.1	2	
Tom Bernard	11/14/2004	8:00	1.5	1.5	1.5	1.5	1.5	5.4	2.1	
Tom Bernard	11/15/2004	12:00	0	0	0	0	0	5.6	2.2	Adjusted Structure down, strong east wilnds produc
Tom Bernard	11/16/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/17/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/18/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/19/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/20/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/21/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/22/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/23/2004	8:00	0	0	0	0	0	0	0	
Tom Bernard	11/24/2004	8:00	0	0	0	0	0	0	0	High Tides
Tom Bernard	11/25/2004	8:00	0	0	0	0	0	0	0	0
Tom Bernard	11/26/2004	8:00	0	0	0	0	0	0	0	0
Tom Bernard	11/27/2004	8:00	0	0	0	0	0	0	0	0
Tom Bernard	11/28/2004	8:00	0	0	0	0	0	0	0	0
Tom Bernard	11/29/2004	10:00	1.2	1.2	1.2	1.2	1.2	5.7	1.2	Open structure to target 1000cfs flow
Tom Bernard	11/30/2004	8:00	1.2	1.2	1.2	1.2	1.2	5.9	1.2	1000
Tom Bernard	12/1/2004	8:00	1.2	1.2	1.2	1.2	1.2	6.1	1.2	1000
Tom Bernard	12/2/2004	8:00	1.2	1.2	1.2	1.2	1.2	6.3	1.2	1000
Tom Bernard	12/3/2004	8:00	1.2	1.2	1.2	1.2	1.2	6.5	1.1	1000
Tom Bernard	12/4/2004	8:00	1.2	1.2	1.2	1.2	1.2	6.7	1.1	1000
Tom Bernard	12/5/2004	8:00	1.2	1.2	1.2	1.2	1.2	6.9	1.1	1000
Tom Bernard	12/6/2004	8:00	1.2	1.2	1.2	1.2	1.2	7.1	1	1000
Tom Bernard	12/7/2004	8:00	1.2	1.2	1.2	1.2	1.2	7.3	1	1000
Tom Bernard	12/8/2004	8:00	1.2	1.2	1.2	1.2	1.2	7.5	1	1000
Tom Bernard	12/9/2004	8:00	1.2	1.2	1.2	1.2	1.2	7.7	1	1000
Tom Bernard	12/10/2004	8:00	1.2	1.2	1.2	1.2	1.2	7.9	0.9	1000
Tom Bernard	12/11/2004	8:00	1.2	1.2	1.2	1.2	1.2	8.1	0.9	1000
Tom Bernard	12/12/2004	8:00	1.2	1.2	1.2	1.2	1.2	8.5	0.9	1000
Barry Richard	12/13/2004	12:30	3.2	3.2	3.2	3.2	3.2	9	0.9	Adjusted Structure To Target flow 4000 cfs
Barry Richard	12/14/2004	8:00	3.2	3.2	3.2	3.2	3.2	9.3	1.2	4000
Barry Richard	12/15/2004	8:00	3.2	3.2	3.2	3.2	3.2	9.6	1.5	4000
Barry Richard	12/16/2004	14:41	2.2	2.2	2.2	2.2	2.2	9.8	1.8	Adjusted Structure To Target flow 2500 cfs
Barry Richard	12/17/2004	8:00	2.2	2.2	2.2	2.2	2.2	9.8	1.7	2500
Barry Richard	12/18/2004	8:00	2.2	2.2	2.2	2.2	2.2	9.8	1.6	2500
Barry Richard	12/19/2004	8:00	2.2	2.2	2.2	2.2	2.2	9.8	1.5	2500
Barry Richard	12/20/2004	8:00	2.2	2.2	2.2	2.2	2.2	9.8	1.4	2500

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Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Barry Richard	12/21/2004	9:50	3.2	3.2	3.2	3.2	3.2	9.8	1.4	Adjusted Structure To Target flow 4000 cfs
Barry Richard	12/22/2004	8:00	3.2	3.2	3.2	3.2	3.2	9.8	1.6	4000
Tom Bernard	12/23/2004	12:00	2.4	2.4	2.4	2.4	2.4	9.9	1.9	Adjusted Structure To Target flow 3000 cfs
Tom Bernard	12/24/2004	8:00	2.4	2.4	2.4	2.4	2.4	9.9	1.8	3000
Tom Bernard	12/25/2004	8:00	2.4	2.4	2.4	2.4	2.4	10	1.7	3000
Tom Bernard	12/26/2004	8:00	2.4	2.4	2.4	2.4	2.4	10.1	1.6	3000
Tom Bernard	12/27/2004	8:00	1.9	1.9	1.9	1.9	1.9	10.2	1.5	3000
Barry Richard	12/28/2004	15:15	1.9	1.9	1.9	1.9	1.9	10.2	1.5	Adjusted Structure To Target flow 2500 cfs
Barry Richard	12/29/2004	8:00	1.9	1.9	1.9	1.9	1.9	10	1.5	2500
Barry Richard	12/30/2004	8:00	1.9	1.9	1.9	1.9	1.9	9.8	1.5	2500
Barry Richard	12/31/2004	8:00	1.9	1.9	1.9	1.9	1.9	9.6	1.5	2500
Barry Richard	1/1/2005	8:00	1.9	1.9	1.9	1.9	1.9	8.3	1.5	2500
Barry Richard	1/2/2005	8:00	1.9	1.9	1.9	1.9	1.9	8.3	1.5	2500
Barry Richard	1/3/2005	10:00	0	0	0	1	0	8.3	1.5	Closed to clear forebay from drift-wood; gate 4 wo
Barry Richard	1/4/2005	8:00	0	0	0	0	0	7.9	1.5	all the way due to drift jam in opening. There was
Tom Bernard	1/5/2005	12:00	4.5	0	4.5	0	4.5	7.5	1.5	spill reported in the Westwego area. Reopen 3-gate
Tom Bernard	1/6/2005	8:00	4.5	0	4.5	0	4.5	7.2	1.6	3000
Tom Bernard	1/7/2005	15:20	4.5	0	4.5	0	4.5	7.3	1.7	4
Tom Bernard	1/8/2005	8:00	3	0	3	0	3	7.3	1.7	Adjusted structure to allow for rising river flow
Tom Bernard	1/9/2005	8:00	3	0	3	0	3	7.5	1.7	3000
Tom Bernard	1/10/2005	8:00	3	0	3	0	3	7.7	1.7	3000
Tom Bernard	1/11/2005	8:00	3	0	3	0	3	7.9	1.7	3000
Tom Bernard	1/12/2005	8:00	3	0	3	0	3	8.1	1.6	3000
Tom Bernard	1/13/2005	8:00	3	0	3	0	3	8.3	1.6	3000
Tom Bernard	1/14/2005	8:00	3	0	3	0	3	8.5	1.6	3000
Tom Bernard	1/15/2005	8:00	3	0	3	0	3	8.7	1.5	3000
Tom Bernard	1/16/2005	8:00	3	0	3	0	3	8.9	1.5	3000
Tom Bernard	1/17/2005	8:00	3	0	3	0	3	9.1	1.5	3000
Tom Bernard	1/18/2005	8:00	3	0	3	0	3	9.3	1.4	3000
Tom Bernard	1/19/2005	8:00	3	0	3	0	3	9.5	1.4	3000
Tom Bernard	1/20/2005	8:00	3	0	3	0	3	9.7	1.4	3000
Tom Bernard	1/21/2005	8:00	3	0	3	0	3	9.9	1.3	3000
Tom Bernard	1/22/2005	8:00	3	0	3	0	3	10.1	1.3	3000
Tom Bernard	1/23/2005	8:00	3	0	3	0	3	10.4	1.2	3000
Tom Bernard	1/24/2005	11:00	3.1	3.1	3.1	3.1	3.1	10.9	1.2	Adjusted stucture to produce a target flow of 3000
Tom Bernard	1/25/2005	8:00	3.1	3.1	3.1	3.1	3.1	11.1	1.5	3000
Tom Bernard	1/26/2005	9:30	4	4	4	4	4	11.3	1.9	Adjusted structure to produce a target flow of 600
Tom Bernard	1/27/2005	8:00	4	4	4	4	4	11.5	2.2	6000
Tom Bernard	1/28/2005	9:00	3.6	3.6	3.6	3.6	3.6	11.8	2.4	Adjusted stucture to produce a target flow of 5000
Tom Bernard	1/29/2005	21:30	0	0	0	0	0	11.8	2.4	Emergency closure, barge accident at mile 88.
Tom Bernard	1/30/2005	8:00	0	0	0	0	0	11.8	2.4	0
Tom Bernard	1/31/2005	8:00	0	0	0	0	0	11.8	2.3	0
Tom Bernard	2/1/2005	8:00	0	0	0	0	0	11.9	2.3	0
Tom Bernard	2/2/2005	8:00	0	0	0	0	0	11.9	2.3	0
Tom Bernard	2/3/2005	12:00	0.7	0	0.7	0	0.7	11.9	2.3	Start of Pulse Study, Low Flow Target flow 500 cfs
Tom Bernard	2/4/2005	8:00	0.7	0	0.7	0	0.7	11.7	2.1	500
Tom Bernard	2/5/2005	8:00	0.7	0	0.7	0	0.7	11.5	1.9	500
Tom Bernard	2/6/2005	8:00	0.7	0	0.7	0	0.7	11.4	1.7	500
Tom Bernard	2/7/2005	11:00	0.6	0	0.6	0	0.6	11.3	1.6	500
Tom Bernard	2/8/2005	8:00	0.6	0	0.6	0	0.6	11.1	1.6	500
Tom Bernard	2/9/2005	8:00	0.6	0	0.6	0	0.6	10.9	1.6	500
Tom Bernard	2/10/2005	8:00	0.6	0	0.6	0	0.6	10.7	1.6	500
Tom Bernard	2/11/2005	8:00	0.6	0	0.6	0	0.6	10.5	1.7	500
Tom Bernard	2/12/2005	8:00	0.6	0	0.6	0	0.6	10.3	1.7	500
Tom Bernard	2/13/2005	8:00	0.6	0	0.6	0	0.6	10	1.7	500
Tom Bernard	2/14/2005	8:30	5.2	5.2	5.2	5.2	5.2	9.8	1.7	Start of Pulse Study, High Flow Target flow 6500 c
Tom Bernard	2/15/2005	14:30	5	5	5	5	5	9.6	2.2	Adjusted gates on 2/14 @ 2:30 pm to get desired cf
Tom Bernard	2/16/2005	8:00	5	5	5	5	5	9.4	2.4	6500
Tom Bernard	2/17/2005	9:00	5.4	5.4	5.4	5.4	5.4	8.8	2.6	Adjusted gates on 2/17 @ 9.00 am to get desired cf
Tom Bernard	2/18/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.8	2.6	6500
Tom Bernard	2/19/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.8	2.6	6500
Tom Bernard	2/20/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.8	2.7	6500
Tom Bernard	2/21/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.8	2.7	6500
Tom Bernard	2/22/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.8	2.8	6500
Tom Bernard	2/23/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.9	2.8	6500
Tom Bernard	2/24/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.9	2.9	6500
Tom Bernard	2/25/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.9	2.9	6500
Tom Bernard	2/26/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.9	2.9	6500
Tom Bernard	2/27/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.9	3	6500
Tom Bernard	2/28/2005	8:00	5.4	5.4	5.4	5.4	5.4	8.9	3	6500
Tom Bernard	3/1/2005	9:30	0.9	0	0.9	0	0.9	8.9	3	500 -- Adjusted gates to pass a flow of 500 cfs.(
Tom Bernard	3/2/2005	9:30	0.8	0	0.8	0	0.8	8.9	1.4	500 -- Adjusted gates to pass a flow of 500 cfs.(
Tom Bernard	3/3/2005	8:00	0.8	0	0.8	0	0.8	8.8	1.2	500
Tom Bernard	3/4/2005	8:00	0.8	0	0.8	0	0.8	8.7	1	500
Tom Bernard	3/5/2005	8:00	0.8	0	0.8	0	0.8	8.6	0.8	500
Tom Bernard	3/6/2005	8:00	0.8	0	0.8	0	0.8	8.5	0.6	500
Tom Bernard	3/7/2005	8:00	0.8	0	0.8	0	0.8	8.4	0.4	500
Tom Bernard	3/8/2005	8:00	0.8	0	0.8	0	0.8	8.3	0.3	500
Tom Bernard	3/9/2005	8:00	0.8	0	0.8	0	0.8	8.2	0.2	500
Tom Bernard	3/10/2005	8:00	0.8	0	0.8	0	0.8	8.1	0.1	500
Tom Bernard	3/11/2005	8:00	0.8	0	0.8	0	0.8	8.1	0	500

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Operator*	Date	Time	Gate 1**	Gate 2**	Gate 3**	Gate 4**	Gate 5**	River Stage	Marsh Stage	Comments
Tom Bernard	3/12/2005	10:00	5	0	5	0	5	8	0	Adjusted gates to pass a flow of 4000 cfs.(3 gate
Tom Bernard	3/13/2005	8:00	5	0	5	0	5	7.9	1	Gate #2 malfunctioned, therefore had to settle for
Tom Bernard	3/14/2005	12:00	5.3	5.3	5.3	5.3	5.3	7.8	1.8	Gate #2 repaired by COE, re-a djusted gates to 650
Tom Bernard	3/15/2005	14:00	5.7	5.7	5.7	5.7	5.7	7.5	2.2	6500 -- River dropping, adjusted gates.
Tom Bernard	3/16/2005	11:00	6.5	6.5	6.5	6.5	6.5	7	2.3	6500 -- River dropping, adjusted gates.
Tom Bernard	3/17/2005	8:00	6.5	6.5	6.5	6.5	6.5	6.6	2.4	6500
Tom Bernard	3/18/2005	8:00	6.5	6.5	6.5	6.5	6.5	6.2	2.4	6500
Tom Bernard	3/19/2005	8:00	6.5	6.5	6.5	6.5	6.5	5.8	2.5	6500
Tom Bernard	3/20/2005	11:45	7.6	7.6	7.6	7.6	7.6	5.5	2.5	6500 -- Adjusted gates to pass 6,500 cfs--river dr
Tom Bernard	3/21/2005	8:00	7.6	7.6	7.6	7.6	7.6	5.4	2.4	6500
Tom Bernard	3/22/2005	8:00	7.6	7.6	7.6	7.6	7.6	5.2	2.3	6500
Tom Bernard	3/23/2005	12:00	8.2	8.2	8.2	8.2	8.2	5	2.2	6500 -- Adjusted gates to pass 6,500 cfs--river dr
Tom Bernard	3/24/2005	8:00	8.2	8.2	8.2	8.2	8.2	4.8	2.3	6500
Tom Bernard	3/25/2005	8:00	8.2	8.2	8.2	8.2	8.2	4.6	2.4	6500
Tom Bernard	3/26/2005	8:00	8.2	8.2	8.2	8.2	8.2	4.5	2.5	6500
Tom Bernard	3/27/2005	8:00	8.2	8.2	8.2	8.2	8.2	4.3	2.6	6500
Barry Richard	3/28/2005	14:30	8.7	8.7	8.7	8.7	8.7	4.2	2.7	6500 -- Adjusted gates to pass 6,500 cfs--river dr
Tom Bernard	3/29/2005	8:00	8.7	8.7	8.7	8.7	8.7	4.2	2.6	6000
Tom Bernard	3/30/2005	8:00	8.7	8.7	8.7	8.7	8.7	4.2	2.5	6000
Tom Bernard	3/31/2005	8:00	8.7	8.7	8.7	8.7	8.7	4.1	2.4	6000
Tom Bernard	4/1/2005	8:00	8.7	8.7	8.7	8.7	8.7	4.1	2.3	6000
Tom Bernard	4/2/2005	8:00	8.7	8.7	8.7	8.7	8.7	4	2.3	6000
Tom Bernard	4/3/2005	8:00	8.7	8.7	8.7	8.7	8.7	4	2.1	6000
Tom Bernard	4/4/2005	10:00	0	1.5	1.5	1.5	0	4	2	700
Tom Bernard	4/5/2005	8:00	0	1.5	1.5	1.5	0	3.7	1.6	700
Tom Bernard	4/6/2005	10:30	0	1	1	1	0	3.5	1.3	700 -- River rising adjusted structure
Tom Bernard	4/7/2005	8:00	0	1	1	1	0	4	1.3	700
Tom Bernard	4/8/2005	8:00	0	1	1	1	0	4.5	1.3	700
Tom Bernard	4/9/2005	8:00	0	1	1	1	0	5	1.3	700
Tom Bernard	4/10/2005	8:00	0	1	1	1	0	5.5	1.2	700
Tom Bernard	4/11/2005	8:00	0	1	1	1	0	6	1.2	700
Tom Bernard	4/12/2005	8:00	0	1	1	1	0	6.5	1.1	700
Tom Bernard	4/13/2005	8:00	0	1	1	1	0	7	1.1	700
Tom Bernard	4/14/2005	8:00	0	1	1	1	0	7.5	1	700
Tom Bernard	4/15/2005	9:00	0	0.7	0.7	0.7	0	8	1	700 -- River rising adjusted structure
Tom Bernard	4/16/2005	8:00	0	0.7	0.7	0.7	0	8.2	1	700
Tom Bernard	4/17/2005	8:00	0	0.7	0.7	0.7	0	8.4	1	700
Tom Bernard	4/18/2005	8:00	0	0.7	0.7	0.7	0	8.6	1.1	700
Tom Bernard	4/19/2005	8:00	0	0.7	0.7	0.7	0	8.8	1.1	700
Tom Bernard	4/20/2005	8:00	0	0.7	0.7	0.7	0	9	1.1	700
Tom Bernard	4/21/2005	8:00	0	0.7	0.7	0.7	0	9.1	1.1	700 Increased flow for 5 hours to 7500 cfs for I-M
Tom Bernard	4/22/2005	7:00	0.7	0	0.7	0	0.7	9	1.1	700 Gate No. 2 malfunctioned. Switched to gates No
Tom Bernard	4/23/2005	8:00	0.7	0	0.7	0	0.7	8.8	1.1	700
Tom Bernard	4/24/2005	8:00	0.7	0	0.7	0	0.7	8.6	1.1	700
Tom Bernard	4/25/2005	8:00	0.7	0	0.7	0	0.7	8.4	1.1	700
Tom Bernard	4/26/2005	8:00	0.7	0	0.7	0	0.7	8.2	1.1	700
Tom Bernard	4/27/2005	8:00	0.7	0	0.7	0	0.7	8	1.1	700
Tom Bernard	4/28/2005	8:00	0.7	0	0.7	0	0.7	7.8	1.1	700
Tom Bernard	4/29/2005	8:00	0.7	0	0.7	0	0.7	7.6	1.1	700
Tom Bernard	4/30/2005	8:00	0.7	0	0.7	0	0.7	7.4	1	700
Tom Bernard	5/1/2005	8:00	0.7	0	0.7	0	0.7	7.2	1	500
Tom Bernard	5/2/2005	8:00	0.7	0	0.7	0	0.7	7	1	500
Tom Bernard	5/3/2005	8:00	0.7	0	0.7	0	0.7	6.8	1	500
Tom Bernard	5/4/2005	8:00	0.7	0	0.7	0	0.7	6.6	1	500
Tom Bernard	5/5/2005	8:00	0.7	0	0.7	0	0.7	6.4	1	500
Tom Bernard	5/6/2005	8:00	0.7	0	0.7	0	0.7	6.2	1	500
Tom Bernard	5/7/2005	8:00	0.7	0	0.7	0	0.7	6	1	500
Tom Bernard	5/8/2005	8:00	0.7	0	0.7	0	0.7	5.8	1	500
Tom Bernard	5/9/2005	8:00	0.7	0	0.7	0	0.7	5.6	1	500
Tom Bernard	5/10/2005	8:00	0.7	0	0.7	0	0.7	5.5	1	500
Tom Bernard	5/11/2005	10:00	0.7	0	0.7	0	0.7	5.3	1	500
Tom Bernard	5/12/2005	8:00	0.7	0	0.7	0	0.7	5	1	500
Tom Bernard	5/13/2005	8:00	0.7	0	0.7	0	0.7	4.7	1	500
Tom Bernard	5/14/2005	8:00	0.7	0	0.7	0	0.7	4	1	500
Tom Bernard	5/15/2005	8:00	0.7	0	0.7	0	0.7	4	1	500
Tom Bernard	5/16/2005	8:00	0.7	0	0.7	0	0.7	4	1	500
Tom Bernard	5/17/2005	8:00	0.7	0	0.7	0	0.7	4.1	1	500
Tom Bernard	5/18/2005	8:00	0.7	0	0.7	0	0.7	3.8	1	500
Tom Bernard	5/19/2005	8:00	0.7	0	0.7	0	0.7	3.5	1	500
Tom Bernard	5/20/2005	9:00	1.3	0	1.3	0	1.3	3.3	1	500 Adjusted gates, river on the fall.
Tom Bernard	5/21/2005	8:00	1.3	0	1.3	0	1.3	3.3	1	500
Tom Bernard	5/22/2005	8:00	1.3	0	1.3	0	1.3	3.4	1	500
Tom Bernard	5/23/2005	8:00	1.3	0	1.3	0	1.3	3.5	1.1	500
Tom Bernard	5/24/2005	8:00	1.3	0	1.3	0	1.3	3.6	1.1	500
Tom Bernard	5/25/2005	8:00	1.3	0	1.3	0	1.3	3.7	1.2	500
Tom Bernard	5/26/2005	8:00	1.3	0	1.3	0	1.3	3.7	1.2	500
Tom Bernard	5/27/2005	8:00	1.3	0	1.3	0	1.3	3.7	1.2	500
Tom Bernard	5/28/2005	8:00	1.3	0	1.3	0	1.3	3.8	1.2	500
Tom Bernard	5/29/2005	8:00	1.3	0	1.3	0	1.3	3.9	1.2	500
Tom Bernard	5/30/2005	8:00	1.3	0	1.3	0	1.3	4	1.3	500
Tom Bernard	5/31/2005	8:00	1.3	0	1.3	0	1.3	4.1	1.3	500

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Tom Bernard	6/1/2005	11:00	0.9	0	0.9	0	0.9	4.1	1.3	500 Adjusted gates, river on the rise.
Tom Bernard	6/2/2005	8:00	0.9	0	0.9	0	0.9	4	1.3	500
Tom Bernard	6/3/2005	8:00	0.9	0	0.9	0	0.9	3.8	1.3	500
Tom Bernard	6/4/2005	8:00	0.9	0	0.9	0	0.9	3.7	1.3	500
Tom Bernard	6/5/2005	8:00	0.9	0	0.9	0	0.9	3.7	1.3	500
Tom Bernard	6/6/2005	8:00	0.9	0	0.9	0	0.9	3.6	1.3	500
Tom Bernard	6/7/2005	8:00	0.9	0	0.9	0	0.9	3.5	1.3	500
Tom Bernard	6/8/2005	8:00	0.9	0	0.9	0	0.9	3.2	1.3	500
Tom Bernard	6/9/2005	13:00	0	0	0	0	0	3	1.3	Closed Structure due to TS Arlene entering Gulf of
Tom Bernard	6/10/2005	8:00	0	0	0	0	0	2.8	1.4	0
Tom Bernard	6/11/2005	8:00	0	0	0	0	0	2.7	1.6	0
Tom Bernard	6/12/2005	8:00	0	0	0	0	0	2.6	1.7	0
Tom Bernard	6/13/2005	10:15	2.5	0	2.5	0	2.5	2.5	1.8	Re-opened to 500 cfs.
Tom Bernard	6/14/2005	8:00	2.5	0	2.5	0	2.5	2.4	1.6	500
Tom Bernard	6/15/2005	8:00	2.5	0	2.5	0	2.5	2.3	1.4	500
Tom Bernard	6/16/2005	9:15	2.5	0	2.5	0	2.5	2.2	1.2	500
Tom Bernard	6/17/2005	8:00	1.5	0	1.5	0	1.5	2.4	1.2	500
Tom Bernard	6/18/2005	8:00	1.5	0	1.5	0	1.5	2.6	1.2	500
Tom Bernard	6/19/2005	8:00	1.5	0	1.5	0	1.5	2.8	1.2	500
Tom Bernard	6/20/2005	8:00	1.5	0	1.5	0	1.5	3	1.2	500
Tom Bernard	6/21/2005	8:00	1.5	0	1.5	0	1.5	3.3	1.2	500
Tom Bernard	6/22/2005	9:15	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/23/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/24/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/25/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/26/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/27/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/28/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/29/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
Tom Bernard	6/30/2005	8:00	0.8	0	0.8	0	0.8	3.5	1.2	500
S & D	7/1/2005	5:00	0	0	0	0	0	3	0.8	
S & D	7/1/2005	16:00	0	0	0	0	0	2.9	1.1	
S & D	7/2/2005	8:30	0	0	0	0	0	3	0.9	
S & D	7/2/2005	17:00	0	0	0	0	0	2.6	0.8	
S & D	7/3/2005	9:00	0	0	0	0	0	3.1	0.8	
S & D	7/3/2005	17:30	0	0	0	0	0	2.5	0.9	
S & D	7/4/2005	9:00	0	0	0	0	0	2.8	0.6	
S & D	7/4/2005	17:00	0	0	0	0	0	2.4	1	
S & D	7/5/2005	5:00	0	0	0	0	0	2.8	0.8	
S & D	7/5/2005	16:00	0	0	0	0	0	2.3	0.9	
S & D	7/6/2005	5:00	0	0	0	0	0	3.2	2	
S & D	7/6/2005	16:00	0	0	0	0	0	3	1.8	
S & D	7/7/2005	5:00	0	0	0	0	0	2.8	1.8	
S & D	7/7/2005	16:00	0	0	0	0	0	2.7	1.7	
R	7/8/2005	8:00	0	0	0	0	0	3.4	1.6	
R	7/9/2005	8:00	0	0	0	0	0	4	1.5	
S & D	7/10/2005	17:00	0	0	0	0	0	4	1.5	
S & D	7/11/2005	5:00	0	0	0	0	0	3.2	1.8	
S & D	7/11/2005	14:30	0	0	0	0	0	3.4	1.6	
S & D	7/12/2005	5:00	0	0	0	0	0	2.8	1.7	
S & D	7/12/2005	16:00	0	0	0	0	0	2.5	1.5	
S & D	7/13/2005	5:00	0	0	0	0	0	2.9	1.8	
S & D	7/13/2005	15:00	0	0	0	0	0	2.5	1.4	
S & D	7/14/2005	5:00	0	0	0	0	0	2.6	1.6	
S & D	7/14/2005	16:00	0	0	0	0	0	2.2	1.2	
S & D	7/15/2005	8:00	0	0	0	0	0	2.6	1.6	
S & D	7/15/2005	17:00	0	0	0	0	0	2	1.3	
S & D	7/16/2005	8:00	0	0	0	0	0	2.6	1.6	
S & D	7/16/2005	17:00	0	0	0	0	0	2	1.2	
S & D	7/17/2005	8:00	0	0	0	0	0	2.6	1.6	
S & D	7/17/2005	18:00	0	0	0	0	0	2	1.3	
S & D	7/18/2005	5:00	0	0	0	0	0	2.6	1.6	
S & D	7/18/2005	17:00	0	0	0	0	0	2.3	1.4	
S & D	7/19/2005	5:00	0	0	0	0	0	2.5	1.5	
S & D	7/19/2005	17:00	0	0	0	0	0	2.7	1.7	
S & D	7/20/2005	5:00	0	0	0	0	0	3	1.8	
S & D	7/20/2005	13:00	9.7	9.7	9.7	9.7	9.7	3.5	1.5	Opened for field trip
S & D	7/21/2005	5:00	0	0	0	0	0	3.2	1.4	
S & D	7/21/2005	17:00	0	0	0	0	0	3	1.3	
S & D	7/22/2005	8:30	11.1	11.1	11.1	11.1	11.1	2.8	1.3	Opened for field trip
S & D	7/22/2005	18:00	0	0	0	0	0	3.2	1.5	
S & D	7/23/2005	9:00	0	0	0	0	0	2.4	1.2	
S & D	7/23/2005	18:00	0	0	0	0	0	2.8	1.2	
S & D	7/24/2005	9:00	0	0	0	0	0	2.4	1	
S & D	7/24/2005	18:00	0	0	0	0	0	2.9	1.4	
S & D	7/25/2005	5:00	0	0	0	0	0	2.5	1	
S & D	7/25/2005	17:00	4.6	4.6	4.6	4.6	4.6	2.5	1.3	
S & D	7/25/2005	19:00	6	6	6	6	6	2.1	1.4	
S & D	7/26/2005	5:00	8	8	8	8	8	1.8	1.4	
S & D	7/26/2005	15:30	12	12	12	12	12	1.8	1.6	
S & D	7/27/2005	5:00	12.5	12.5	12.5	12.5	12.5	1.7	1.5	

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S & D	7/27/2005	17:00	13.5	13.5	13.5	13.5	13.5	1.6	1.5	
S & D	7/28/2005	5:00	13.5	13.5	13.5	13.5	13.5	1.8	1.5	
S & D	7/28/2005	14:00	2.5	2.5	2.5	2.5	2.5	2	1.6	
S & D	7/28/2005	17:00	5.5	5.5	5.5	5.5	5.5	1.5	1.3	
S & D	7/29/2005	5:00	3.5	3.5	3.5	3.5	3.5	1.6	1.4	
S & D	7/29/2005	17:00	3.5	3.5	3.5	3.5	3.5	1.6	1.5	
S & D	7/30/2005	9:00	2	2	2	2	2	2	1.6	
S & D	7/30/2005	18:00	2	2	2	2	2	2.2	1.8	
S & D	7/31/2005	9:00	2.2	2.2	2.2	2.2	2.2	2	1.5	
S & D	7/31/2005	16:00	2.2	2.2	2.2	2.2	2.2	2.1	1.7	
S & D	8/1/2005	5:00	3	3	3	3	3	1.4	1.3	
S & D	8/1/2005	16:00	3	3	3	3	3	1.5	1.4	
S & D	8/2/2005	8:30	3	3	3	3	3	1.4	1	
S & D	8/2/2005	17:00	3.5	3.5	3.5	3.5	3.5	1.3	1.2	
S & D	8/3/2005	9:00	4	4	4	4	4	1.3	1.2	
S & D	8/3/2005	5:00	4	4	4	4	4	1.4	1.3	
S & D	8/3/2005	7:00	3.5	0	0	0	3.5	1.4	1.3	
S & D	8/4/2005	9:00	0	0	0	0	0	1.3	1.2	
S & D	8/4/2005	17:00	0	0	0	0	0	1.4	1	
S & D	8/5/2005	5:00	0	0	0	0	0	1.5	1	
S & D	8/5/2005	16:00	0	0	0	0	0	1.6	1.1	
S & D	8/6/2005	5:00	0	0	0	0	0	2	1	
S & D	8/6/2005	16:00	0	0	0	0	0	1.6	1.2	
S & D	8/7/2005	5:00	0	0	0	0	0	1.5	1	
S & D	8/8/2005	5:00	0	0	0	0	0	1.4	0.9	
S & D	8/8/2005	17:00	0	0	0	0	0	1.2	0.8	
S & D	8/9/2005	5:00	0	0	0	0	0	1.3	0.9	
S & D	8/9/2005	14:30	0	0	0	0	0	1.2	0.7	
S & D	8/10/2005	5:00	0	0	0	0	0	1.3	0.8	
S & D	8/10/2005	16:00	0	0	0	0	0	1.2	0.8	
S & D	8/11/2005	5:00	0	0	0	0	0	1.3	1	
S & D	8/11/2005	15:00	0	0	0	0	0	1.4	1	
S & D	8/12/2005	5:00	0	0	0	0	0	1.2	0.8	
S & D	8/12/2005	16:00	0	0	0	0	0	1.4	0.9	
S & D	8/13/2005	8:00	0	0	0	0	0	1	1	
S & D	8/13/2005	17:00	0	0	0	0	0	1.2	0.8	
S & D	8/14/2005	8:00	0	0	0	0	0	0.8	0.8	
S & D	8/14/2005	17:00	0	0	0	0	0	0.6	0.5	
S & D	8/15/2005	8:00	0	0	0	0	0	0.7	0.5	
S & D	8/15/2005	18:00	0	0	0	0	0	0.6	0.4	
S & D	8/16/2005	5:00	0	0	0	0	0	0.8	0.5	
S & D	8/16/2005	17:00	0	0	0	0	0	0.9	0.7	
S & D	8/17/2005	5:00	0	0	0	0	0	1	0.6	
S & D	8/17/2005	18:00	0	0	0	0	0	1.2	0.8	
S & D	8/18/2005	5:00	0	0	0	0	0	2	0.7	
S & D	8/18/2005	18:00	0	0	0	0	0	2.1	0.8	
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S & D	8/19/2005	17:00	0	0	0	0	0	2.1	0.8	
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S & D	8/21/2005	5:00	0	0	0	0	0	1.5	1	
S & D	8/21/2005	17:00	0	0	0	0	0	1.7	1	
S & D	8/22/2005	8:30	0	0	0	0	0	1.8	0.8	
S & D	8/22/2005	18:00	0	0	0	0	0	1.5	1	
S & D	8/23/2005	9:00	0	0	0	0	0	1.7	1	
S & D	8/23/2005	18:00	0	0	0	0	0	1.3	0.7	
S & D	8/24/2005	9:00	0	0	0	0	0	1.2	1	
S & D	8/24/2005	18:00	0	0	0	0	0	1	0.8	
S & D	8/25/2005	5:00	0	0	0	0	0	0.8	1	
S & D	8/25/2005	17:00	0	0	0	0	0	1	0.7	
S & D	8/26/2005	5:00	0	0	0	0	0	1.3	1	
S & D	8/26/2005	18:00	0	0	0	0	0	1	1.3	
R	8/27/2005	8:00	0	0	0	0	0	1	1.3	Hurricane Katrina - No Readings

* "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.
** Gate setting reflects the predominant position throughout the day.

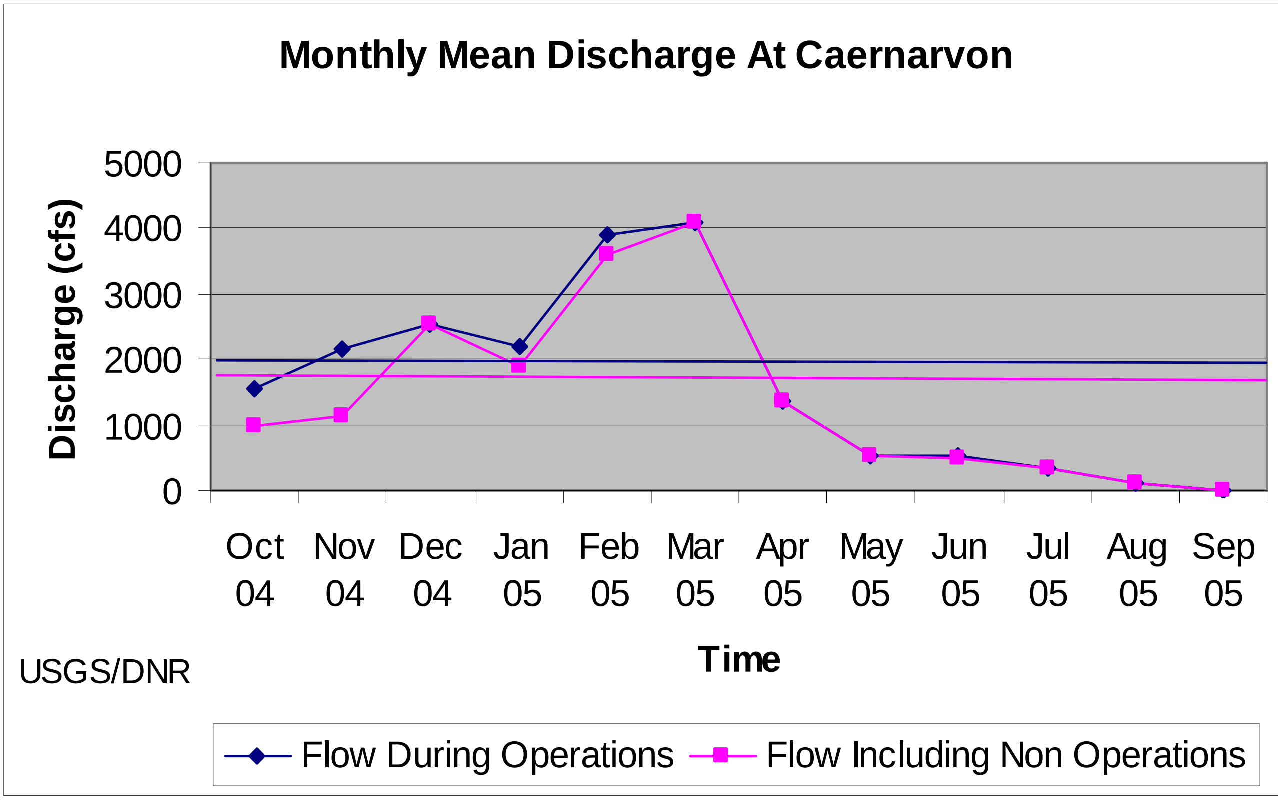

Figure 1. Monthly Mean Discharge at Caernarvon (USGS).

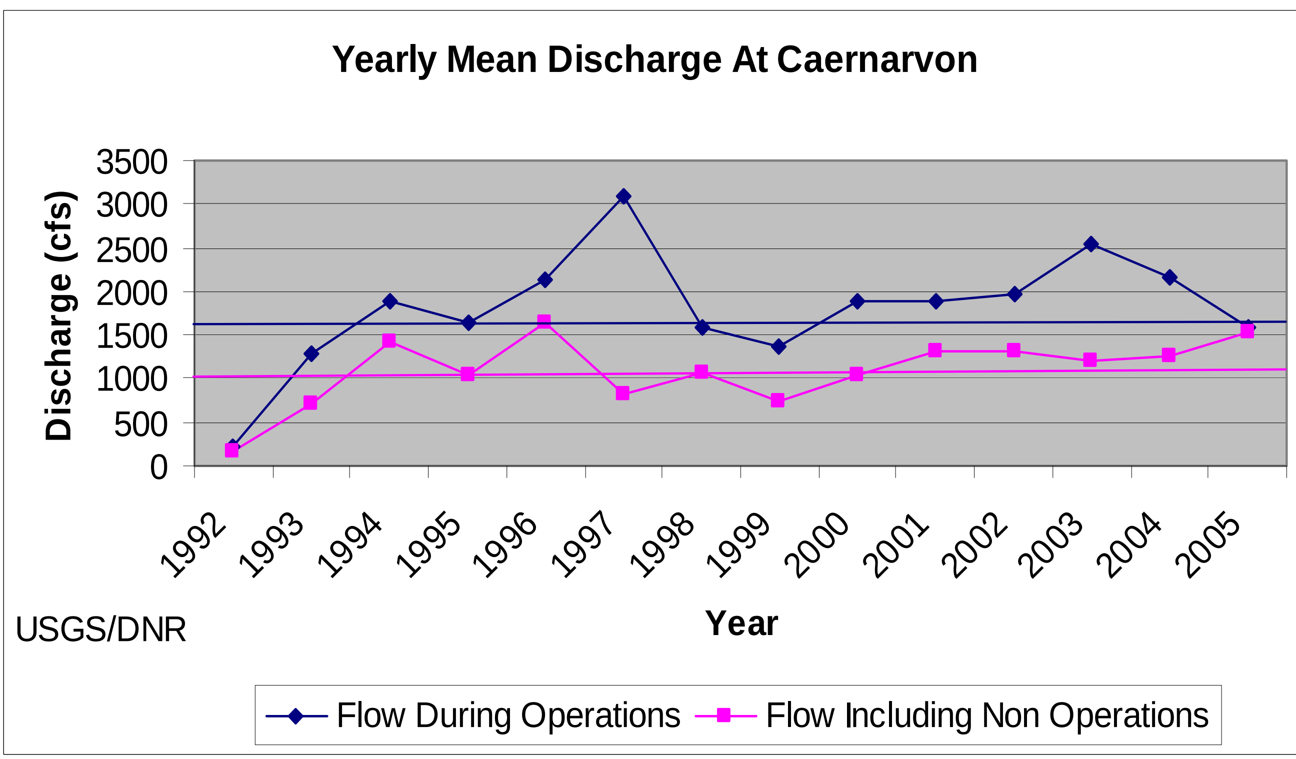

Figure 2. Yearly Mean Discharge at Caernarvon (USGS).

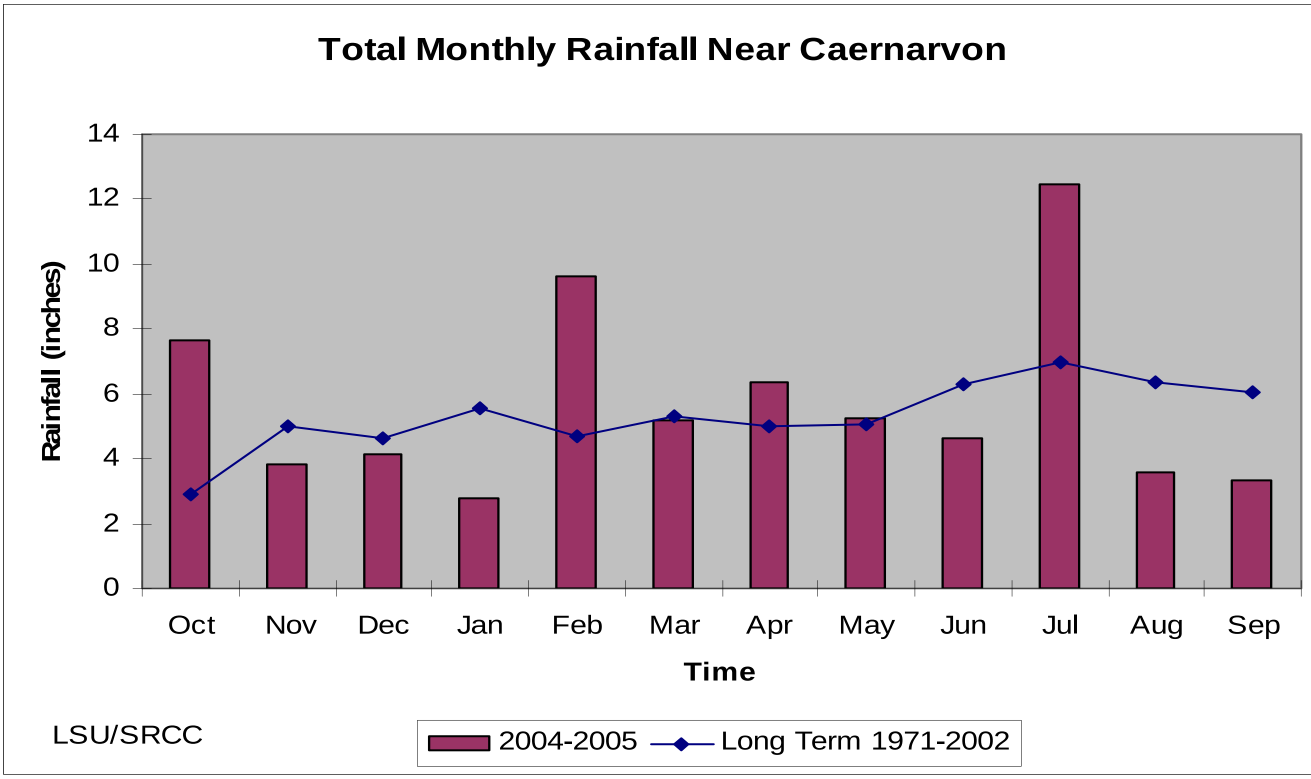

Figure 3. Total Monthly Rainfall Near Caernarvon (LSU Southern Regional Climate Center).

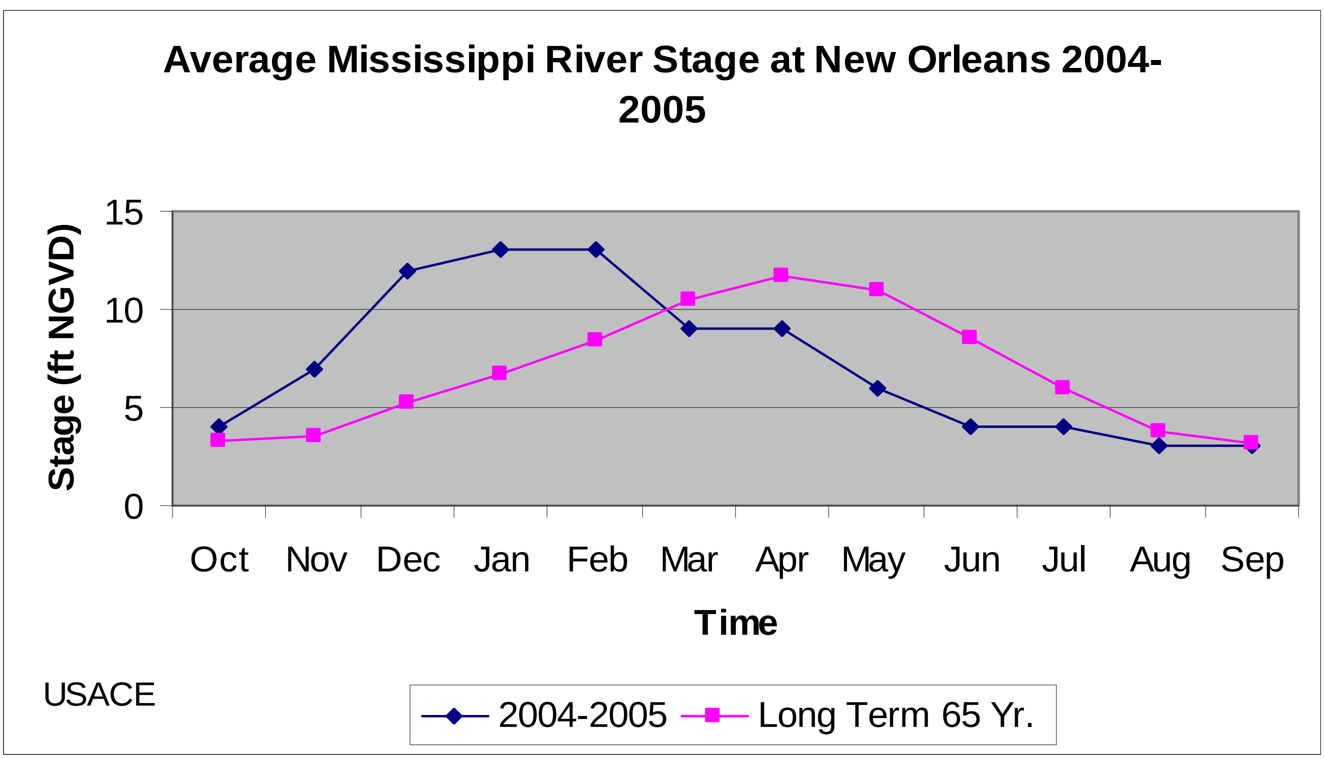

Figure 4. Average Mississippi River Stage at New Orleans (USACE).

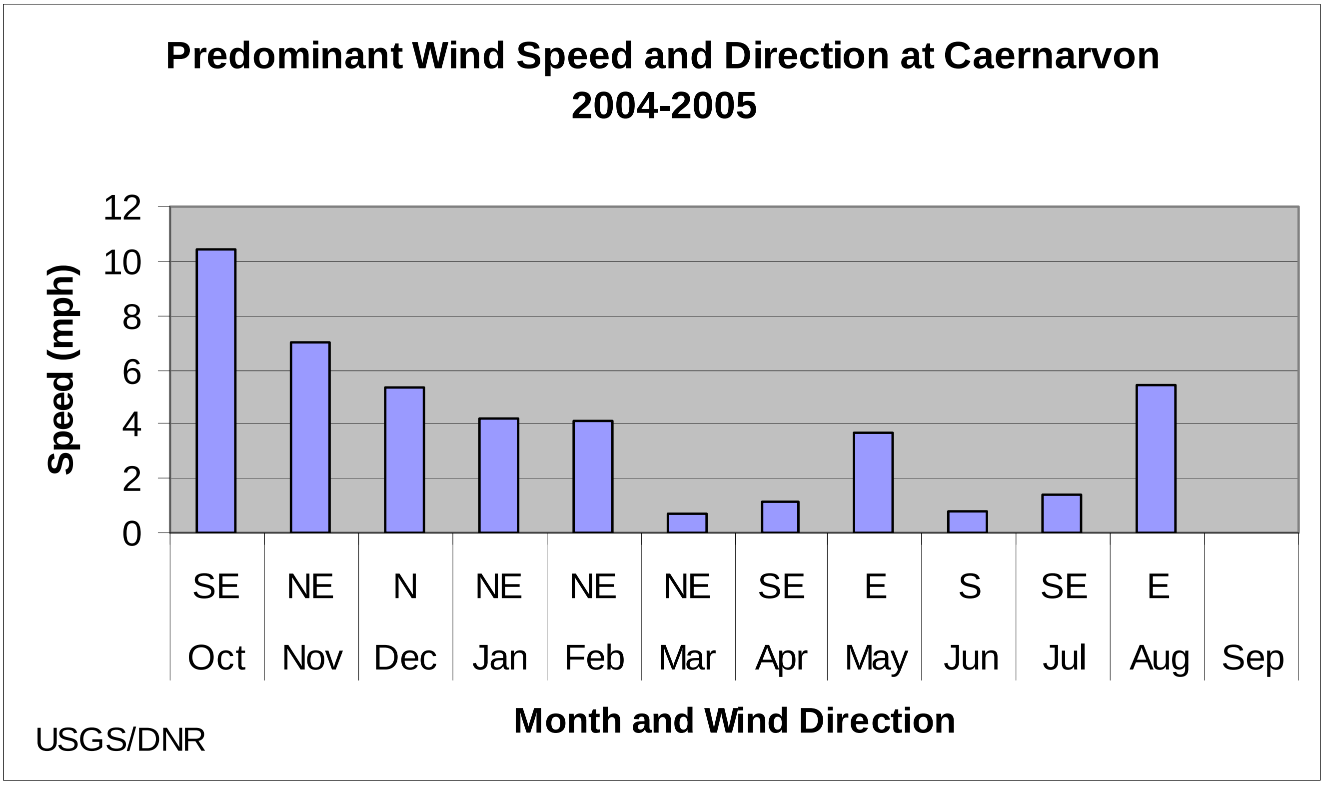

Figure 5. Predominant Wind Speed and Direction at Caernarvon (USGS).

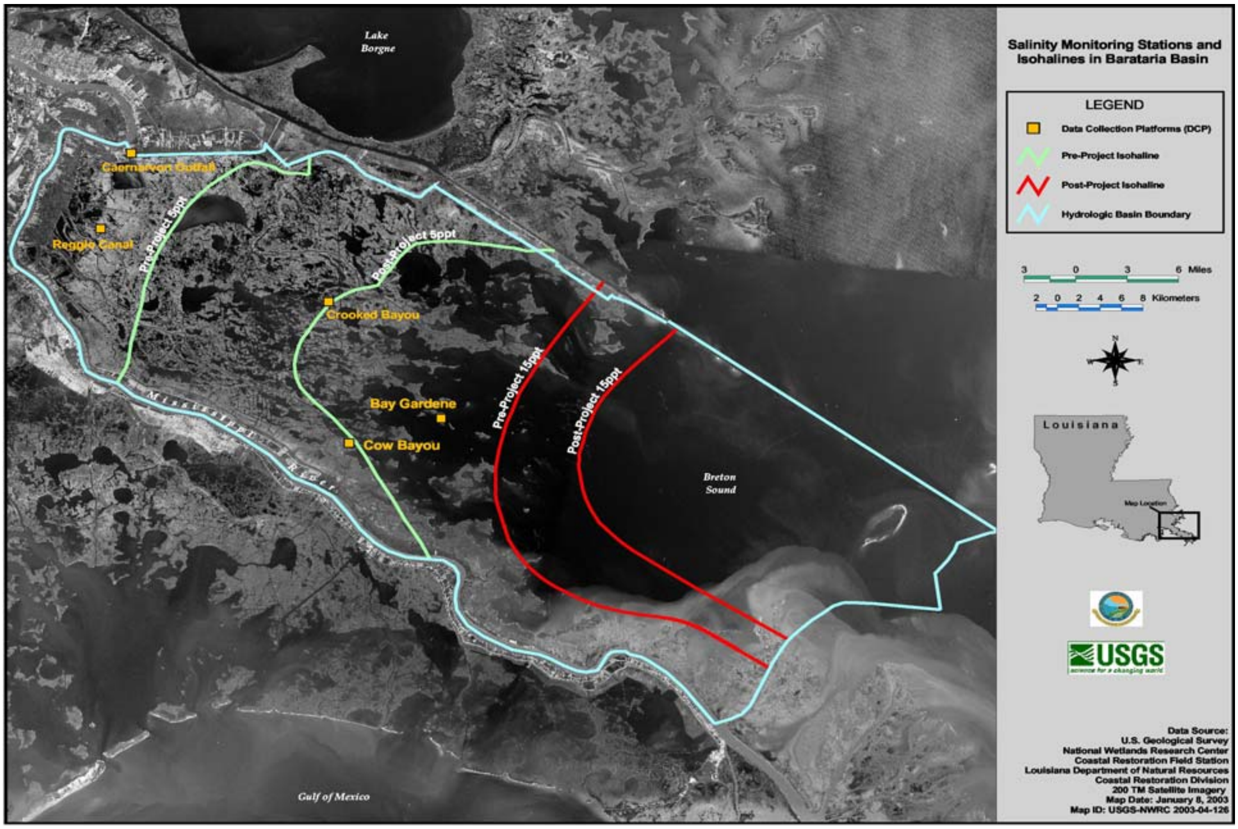

Figure 6. Location of Data Collection Platforms and pre-post construction isohalines for Breton Sound.

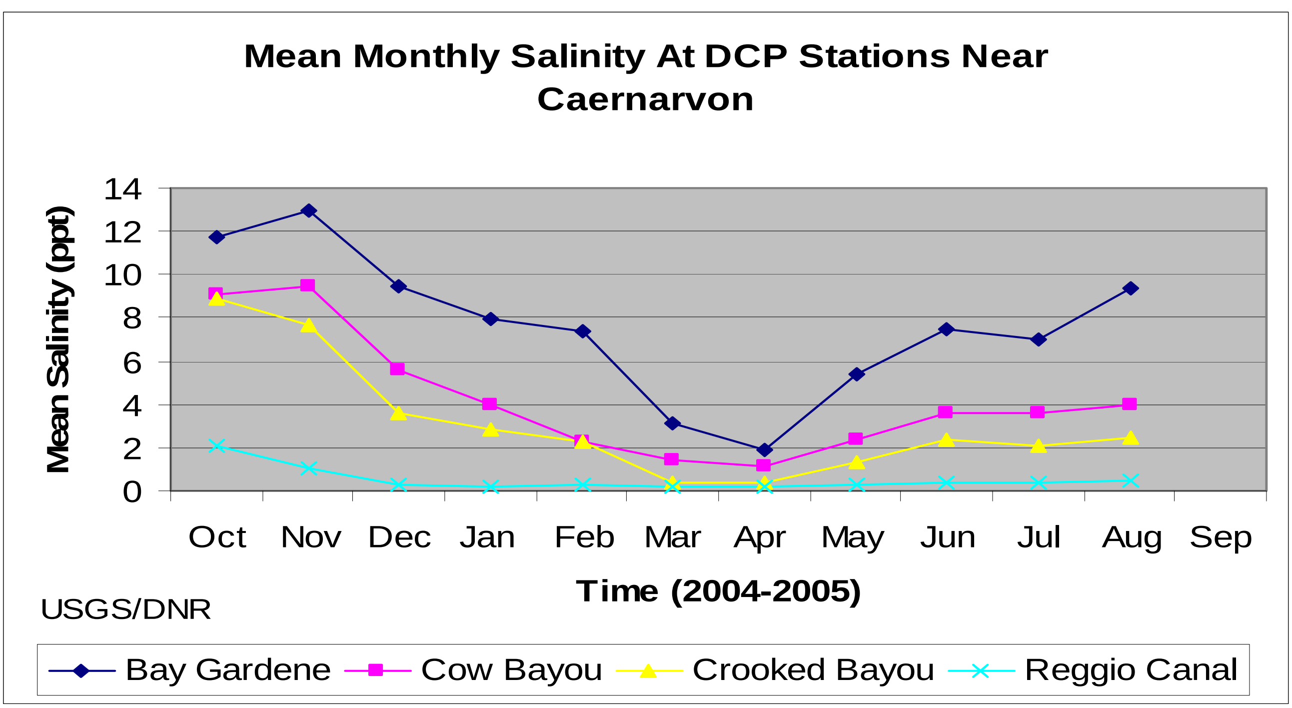

Figure 7. Mean Monthly Salinity at DCP Stations at Caernarvon (USGS).

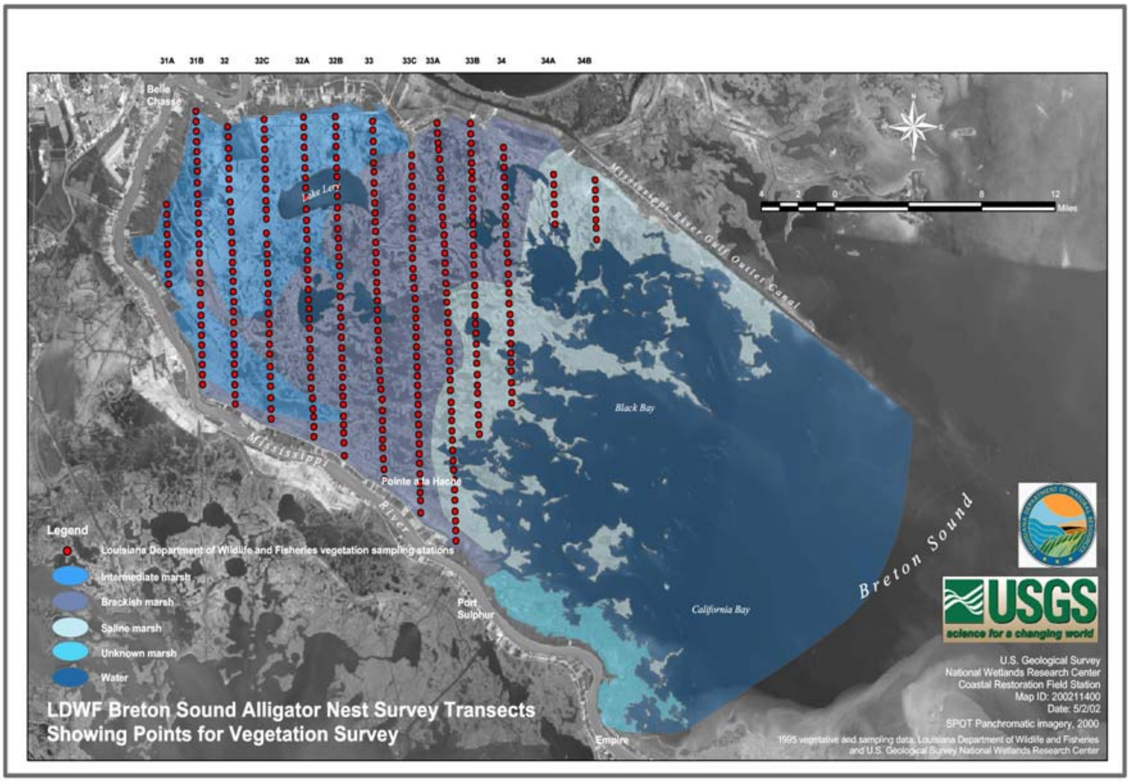

Figure 8. Location of wildlife and vegetation transects at Caernarvon.

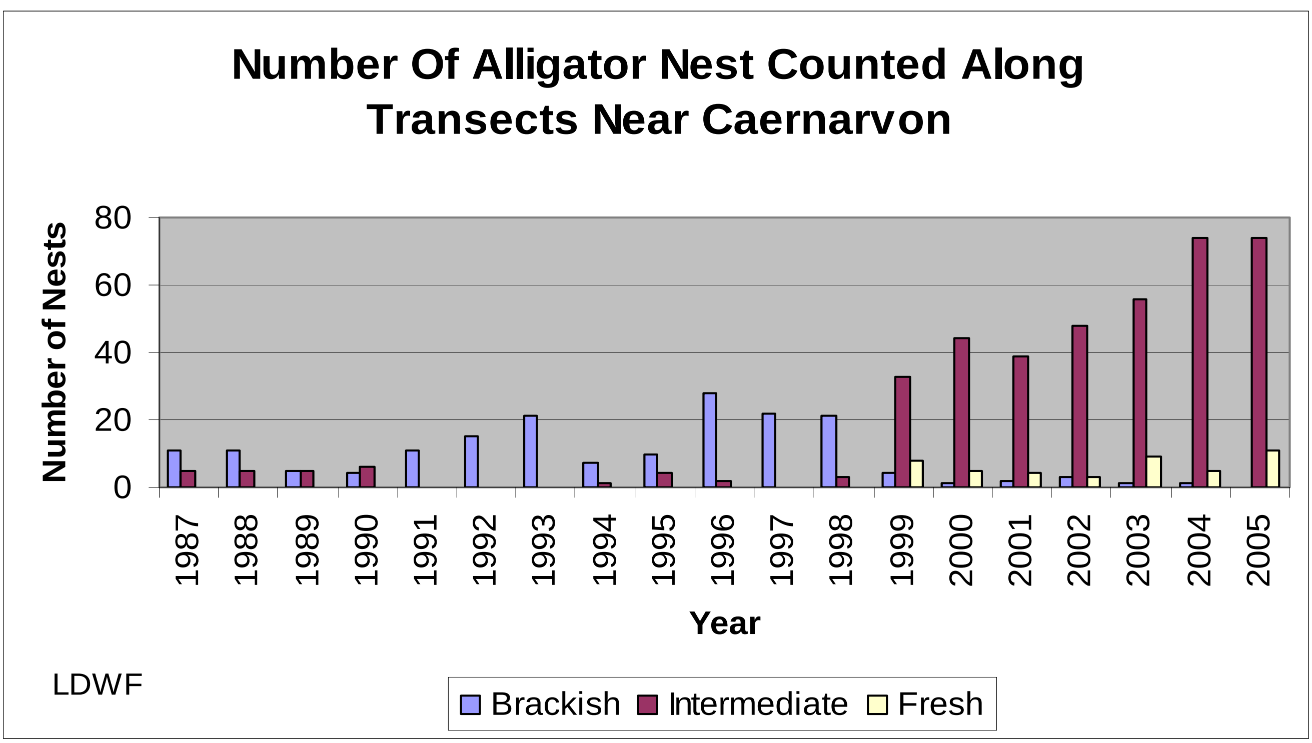

Figure 9. Number of alligator nests counted along transects at Caernarvon (LDWF).

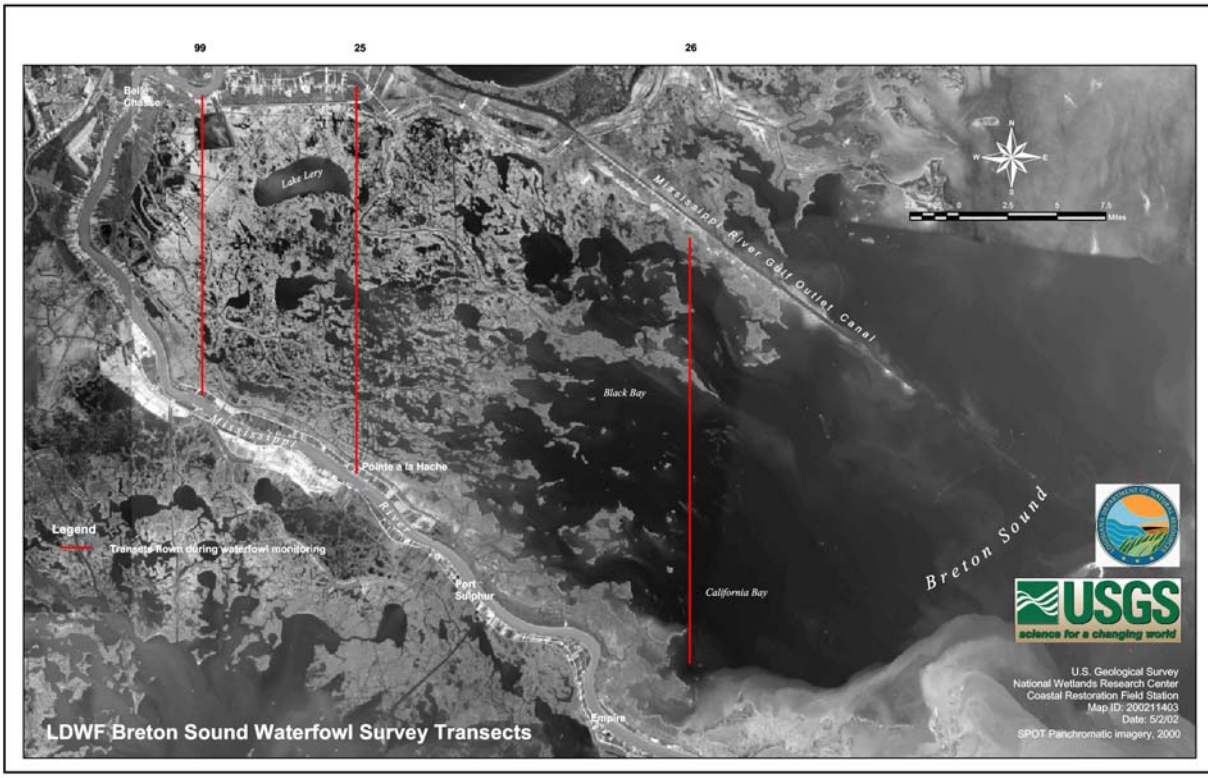

Figure 10. Location of waterfowl transects at Caernarvon.

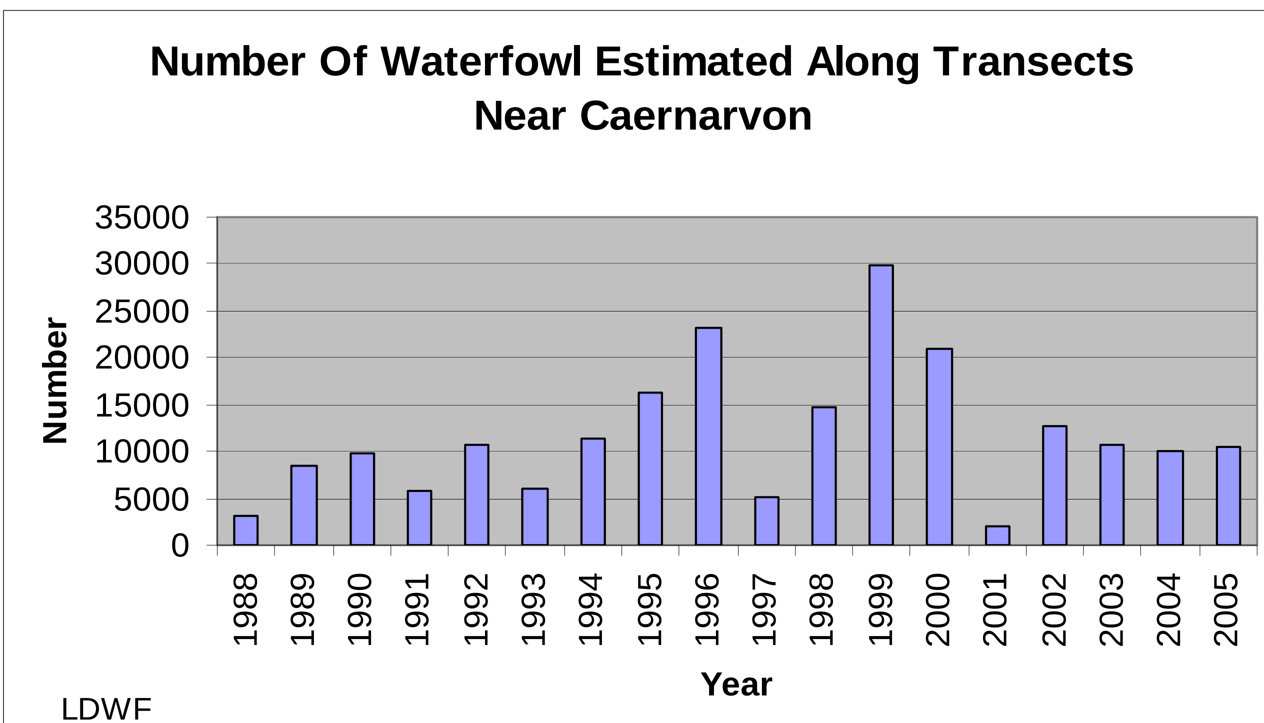

Figure 11. Number of waterfowl estimated along transects at Caernarvon (LDWF).

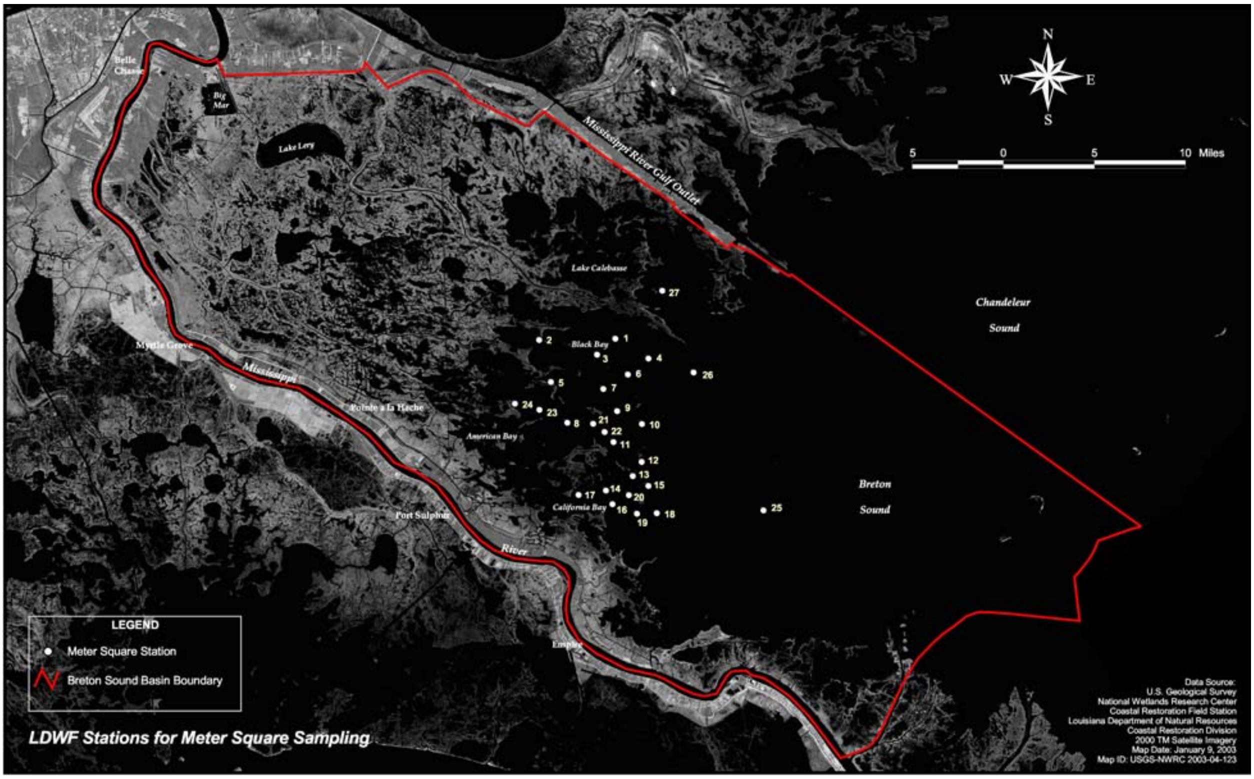

Figure 12. Location of meter square stations at Caernarvon.

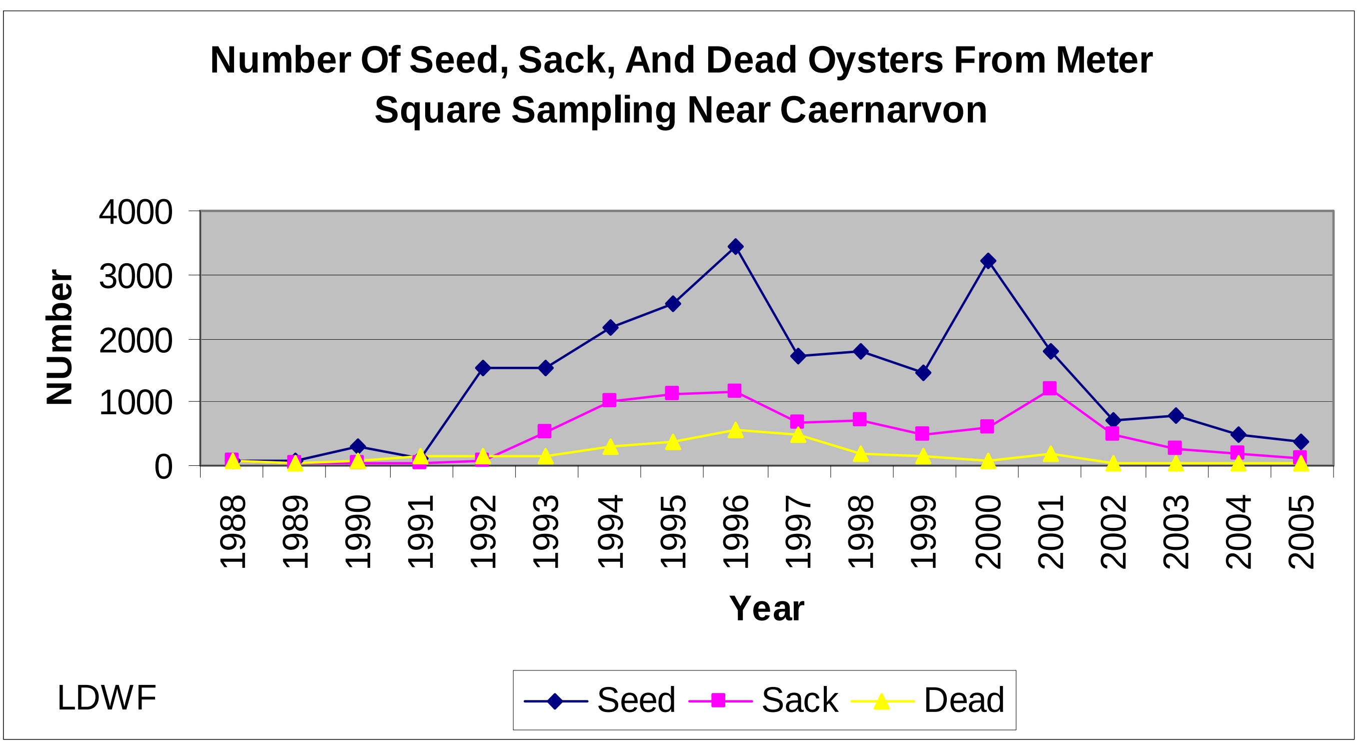

Figure 13. Number of seed, sack and dead oysters from meter square sampling at Caernarvon (LDWF).

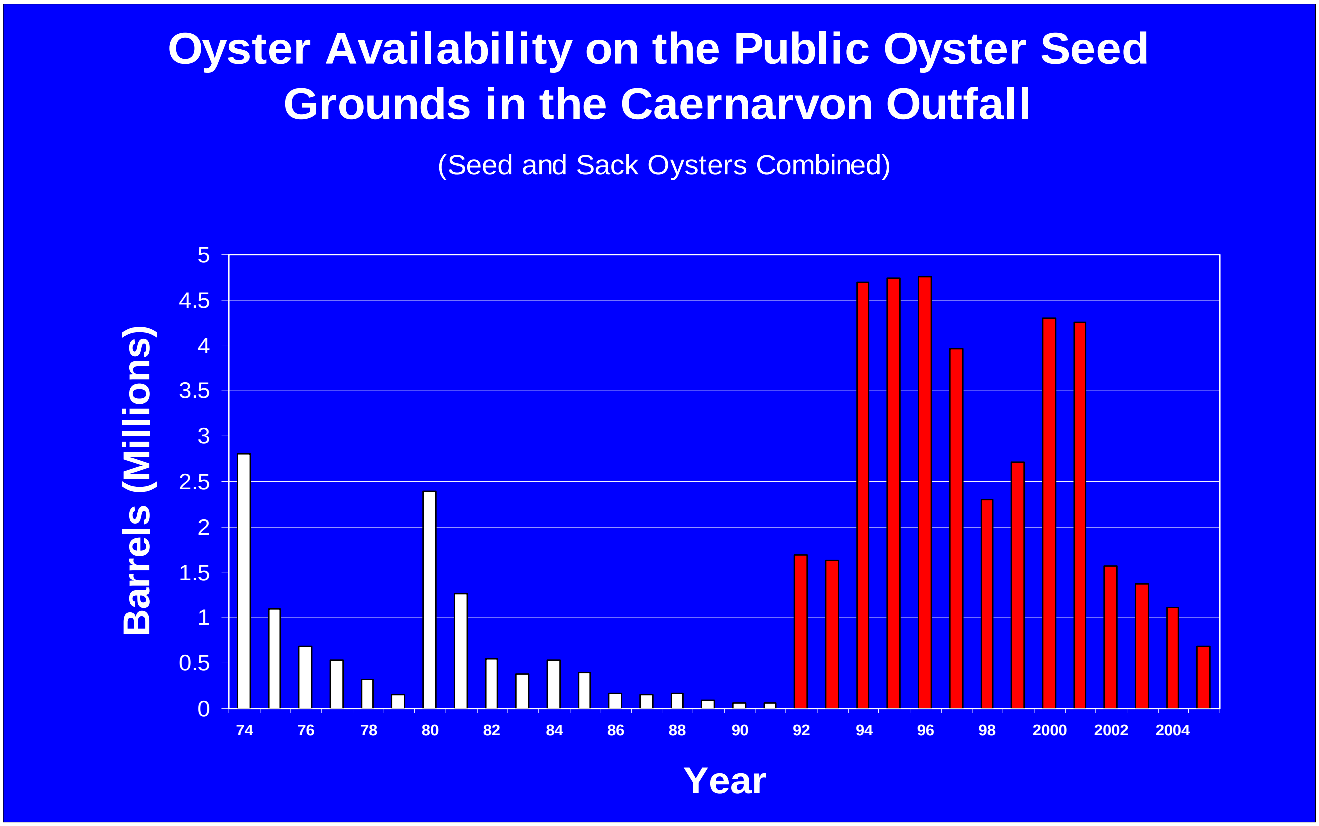

Figure 14. Oyster availability on the public seed grounds at Caernarvon (LDWF).

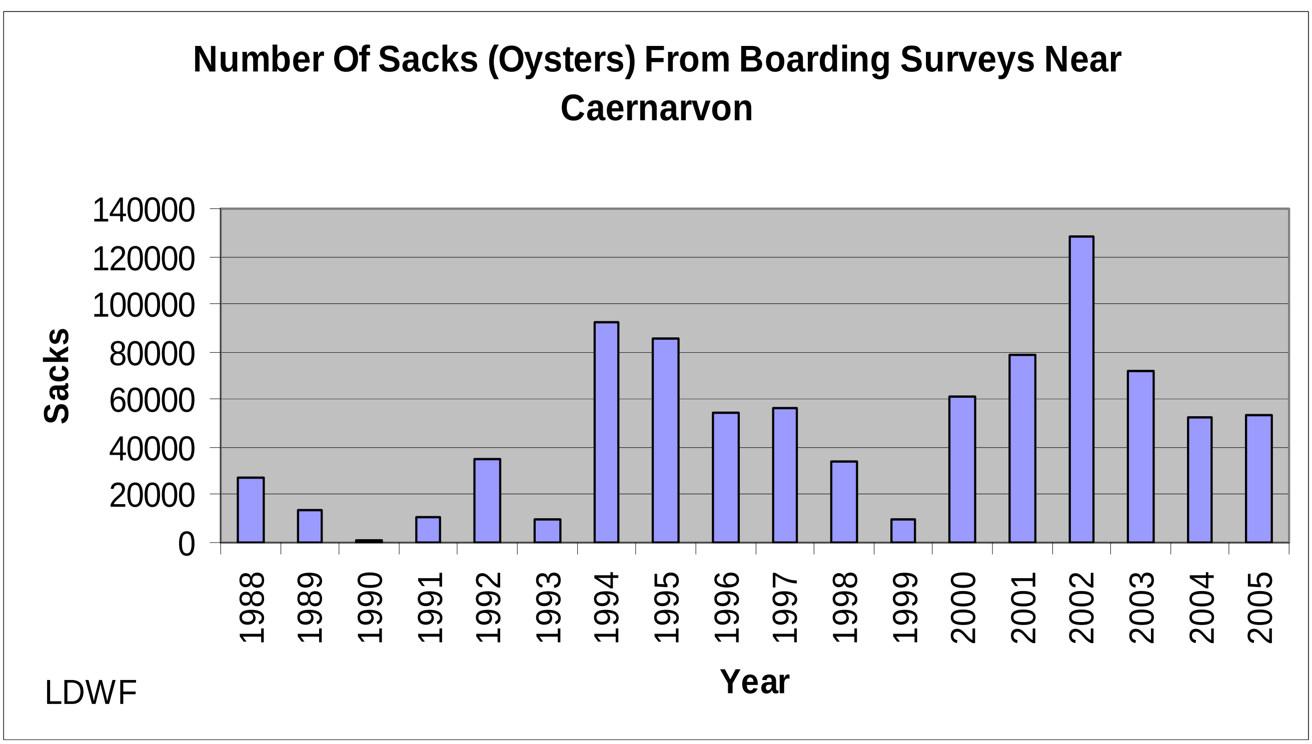

Figure 15. Sack oysters from boarding surveys at Caernarvon (LDWF).

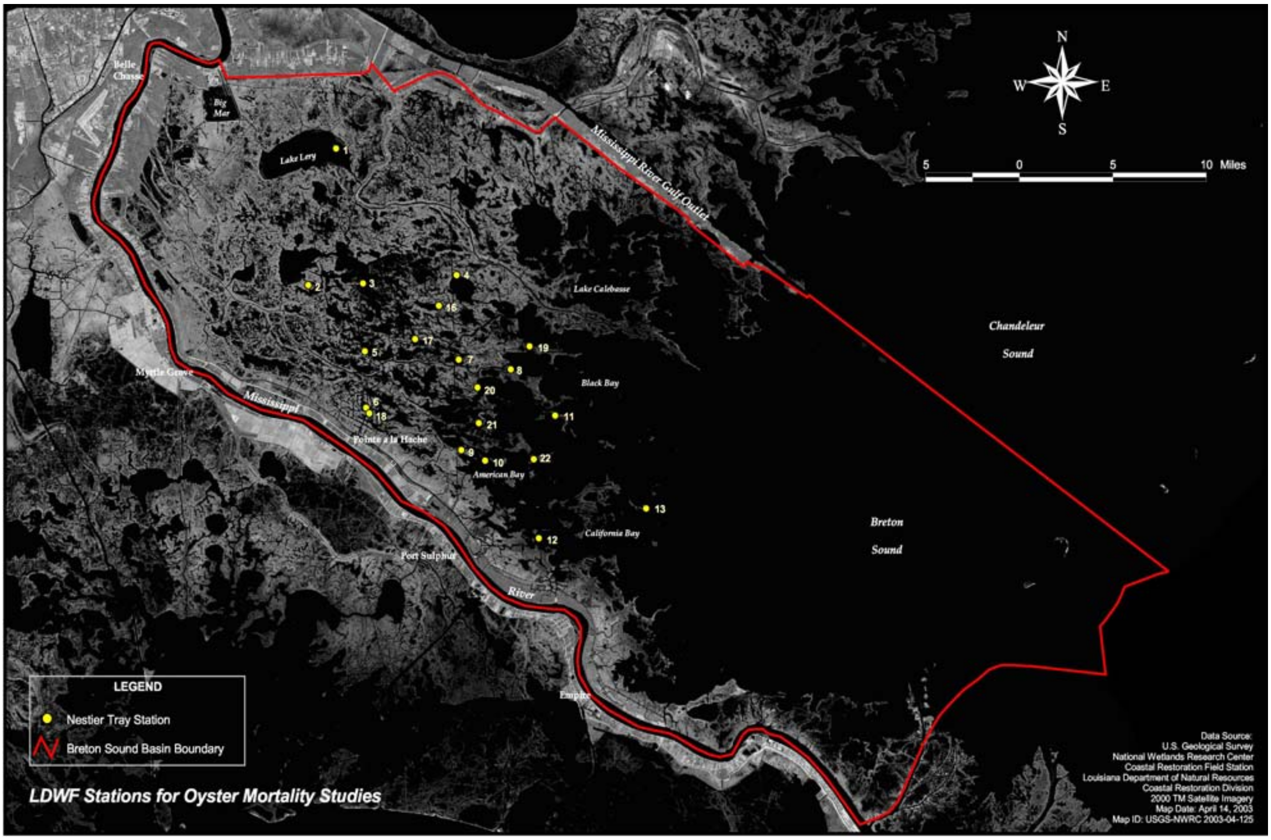

Figure 16. Location of nestier tray stations at Caernarvon.

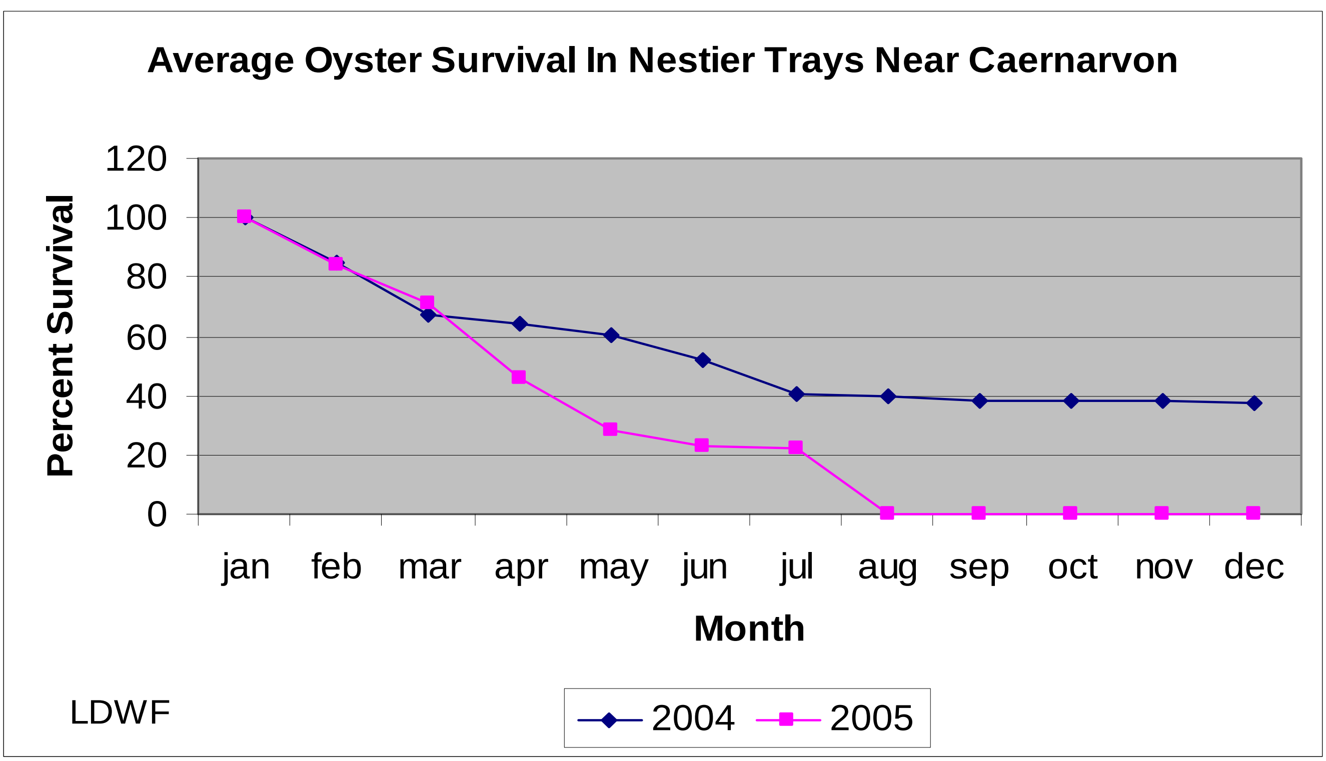

Figure 17. Average oyster survival in nestier trays at Caernarvon (LDWF).

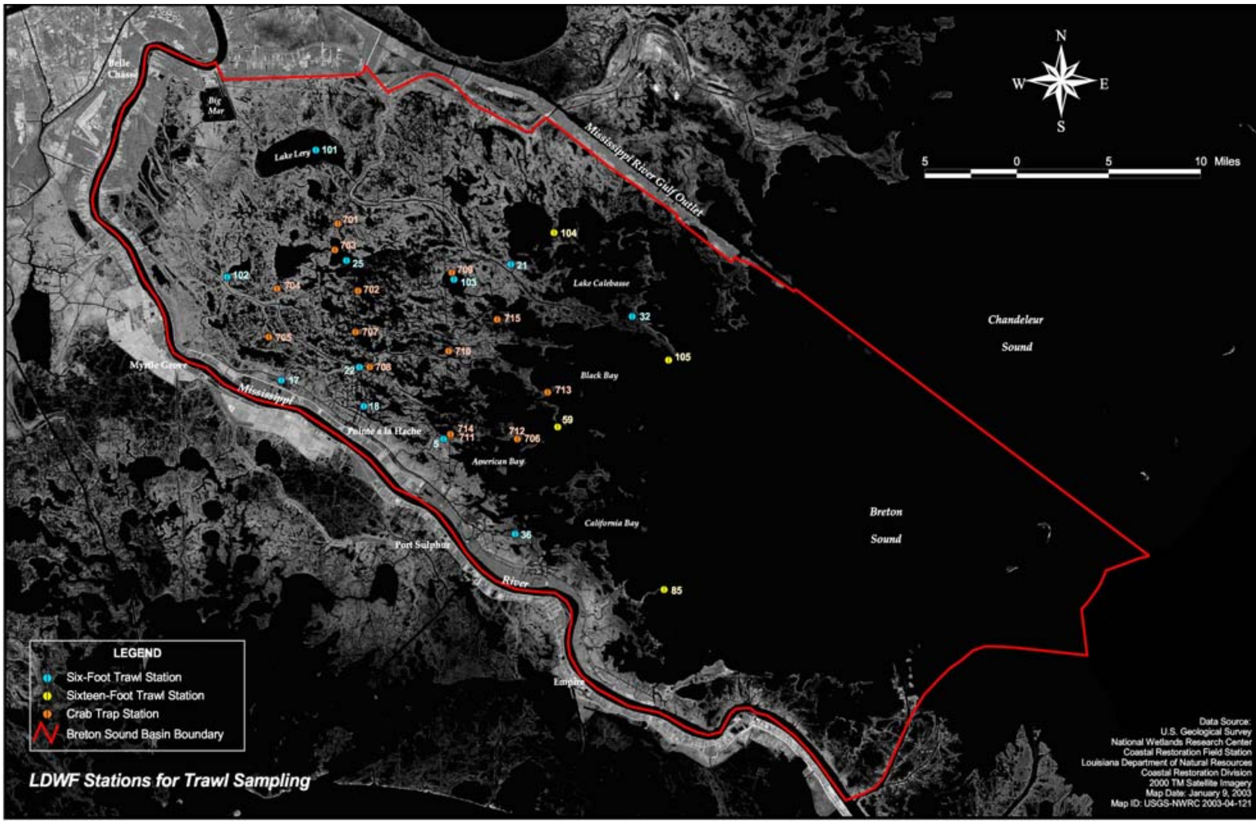

Figure 18. Location of trawl stations at Caernarvon.

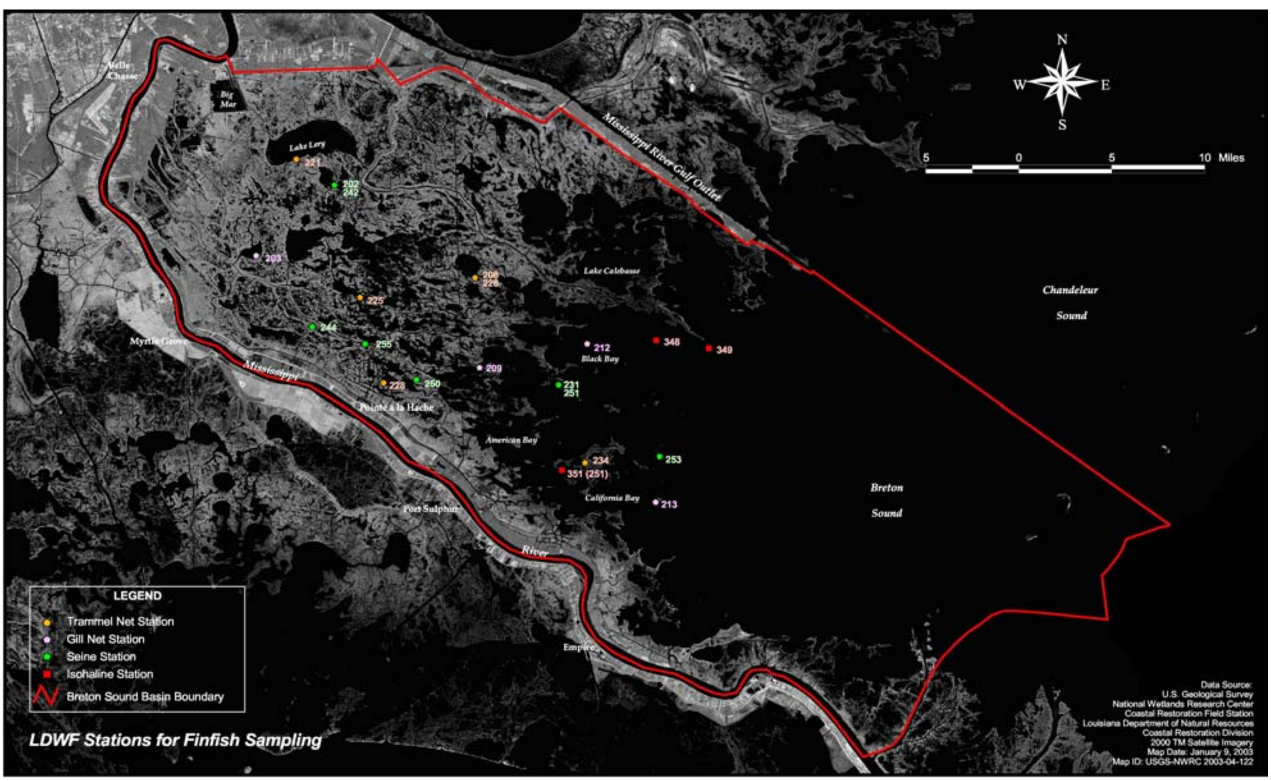

Figure 19. Location of finfish stations at Caernarvon.

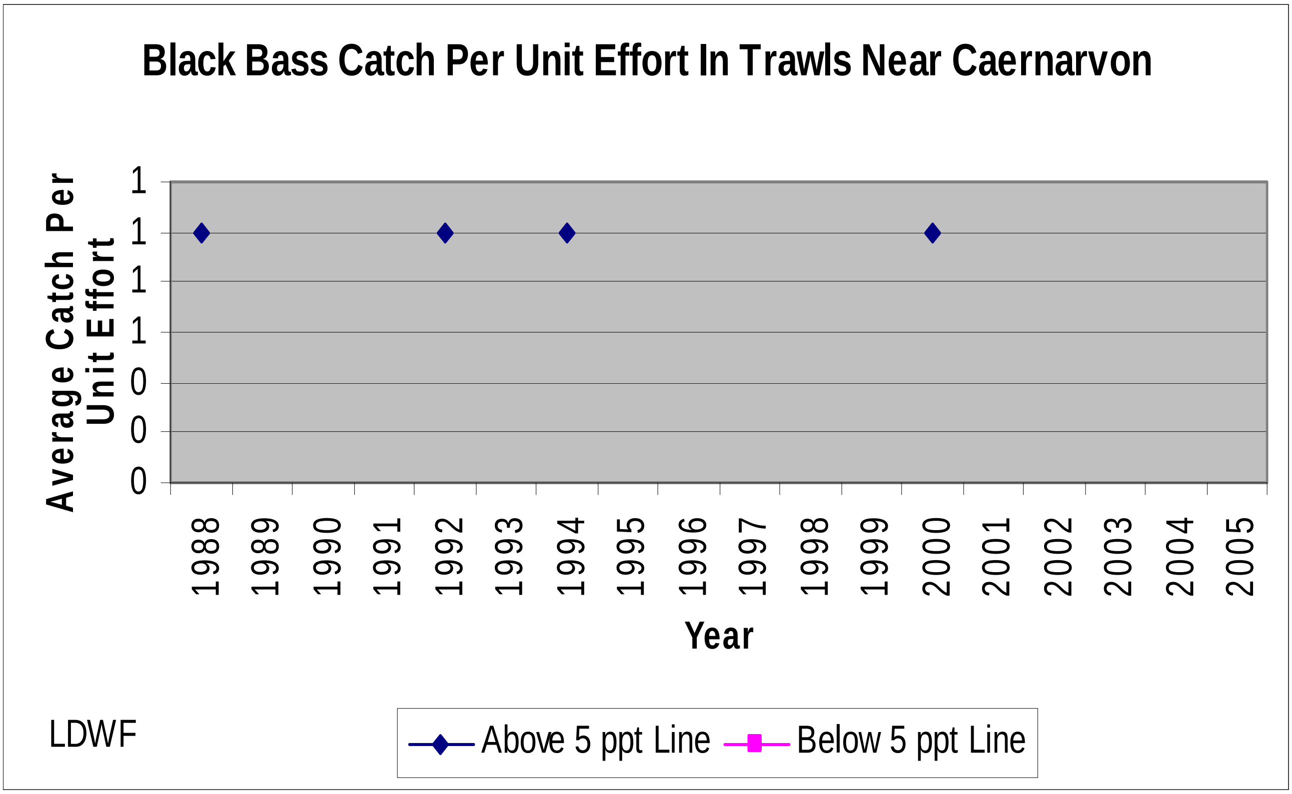

Figure 20. Black bass catch per unit effort in trawls at Caernarvon (LDWF).

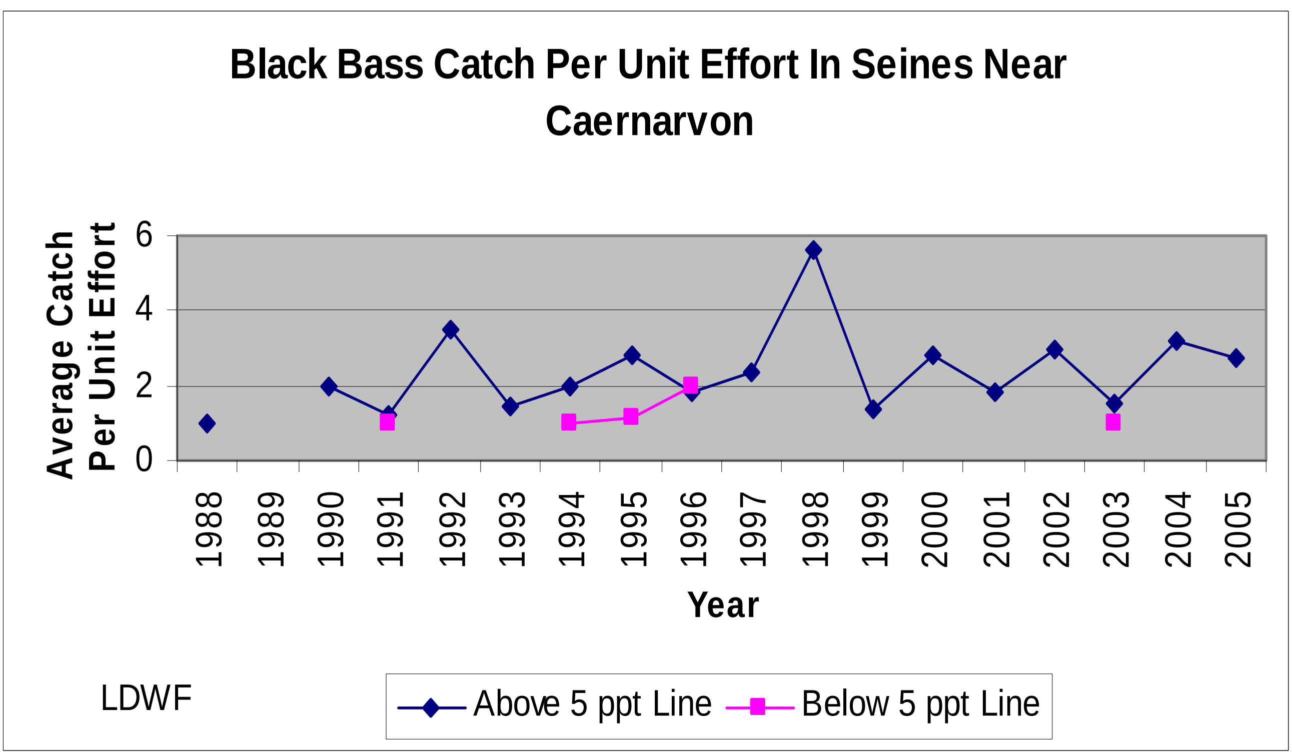

Figure 21. Black bass catch per unit effort in seines at Caernarvon (LDWF).

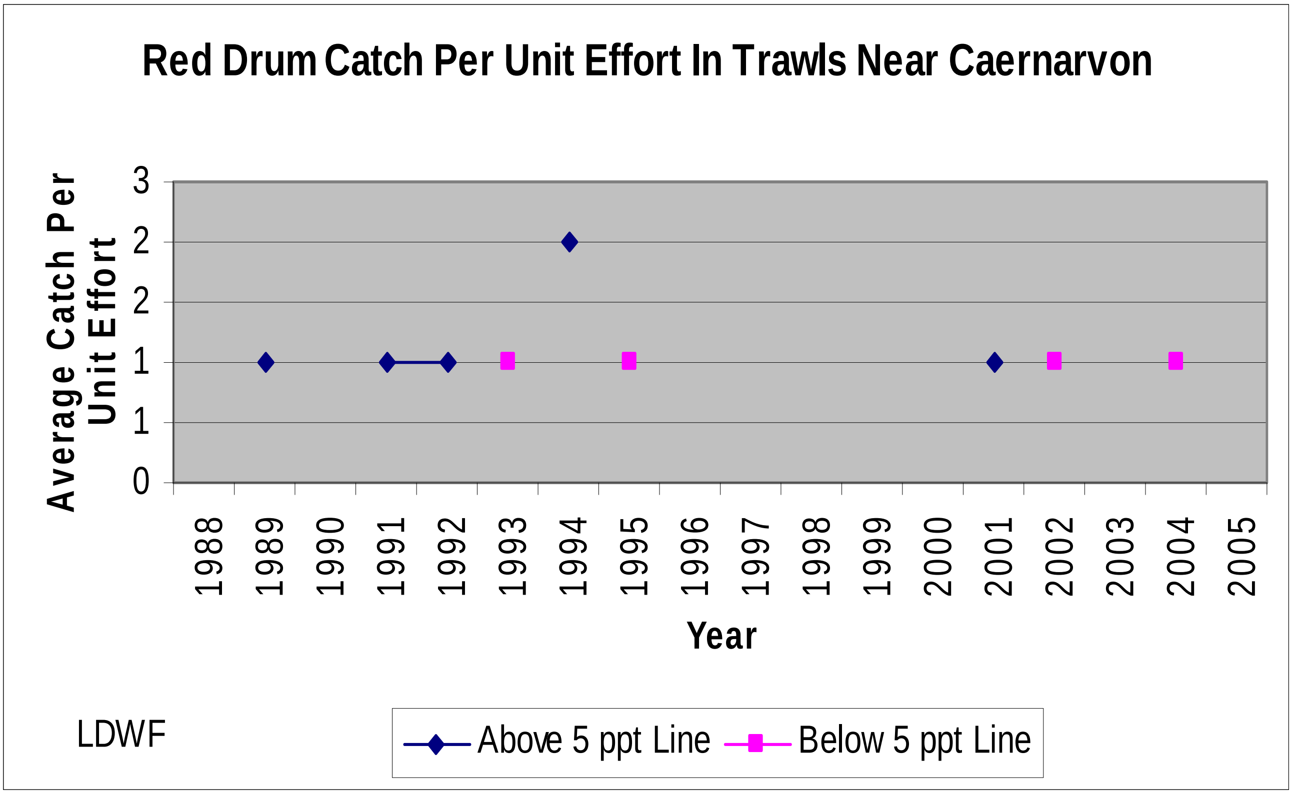

Figure 22. Red drum catch per unit effort in trawls at Caernarvon (LDWF).

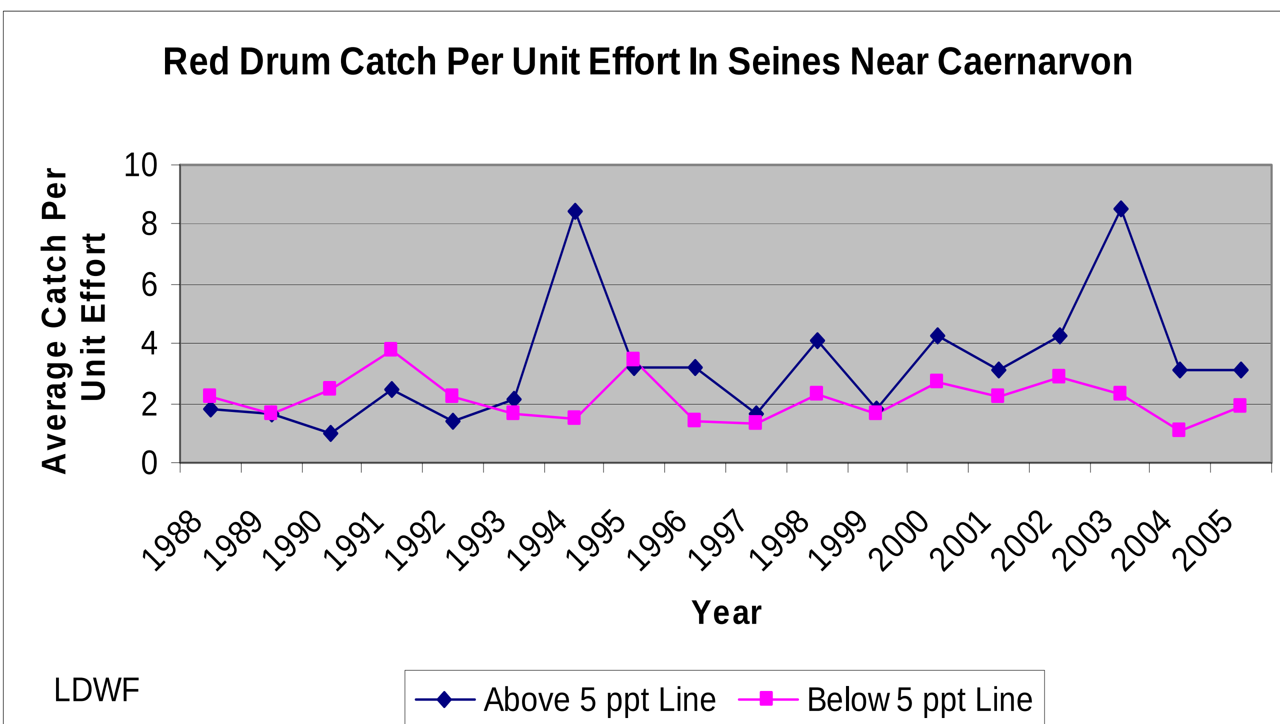

Figure 23. Red drum catch per unit effort in seines at Caernarvon (LDWF).

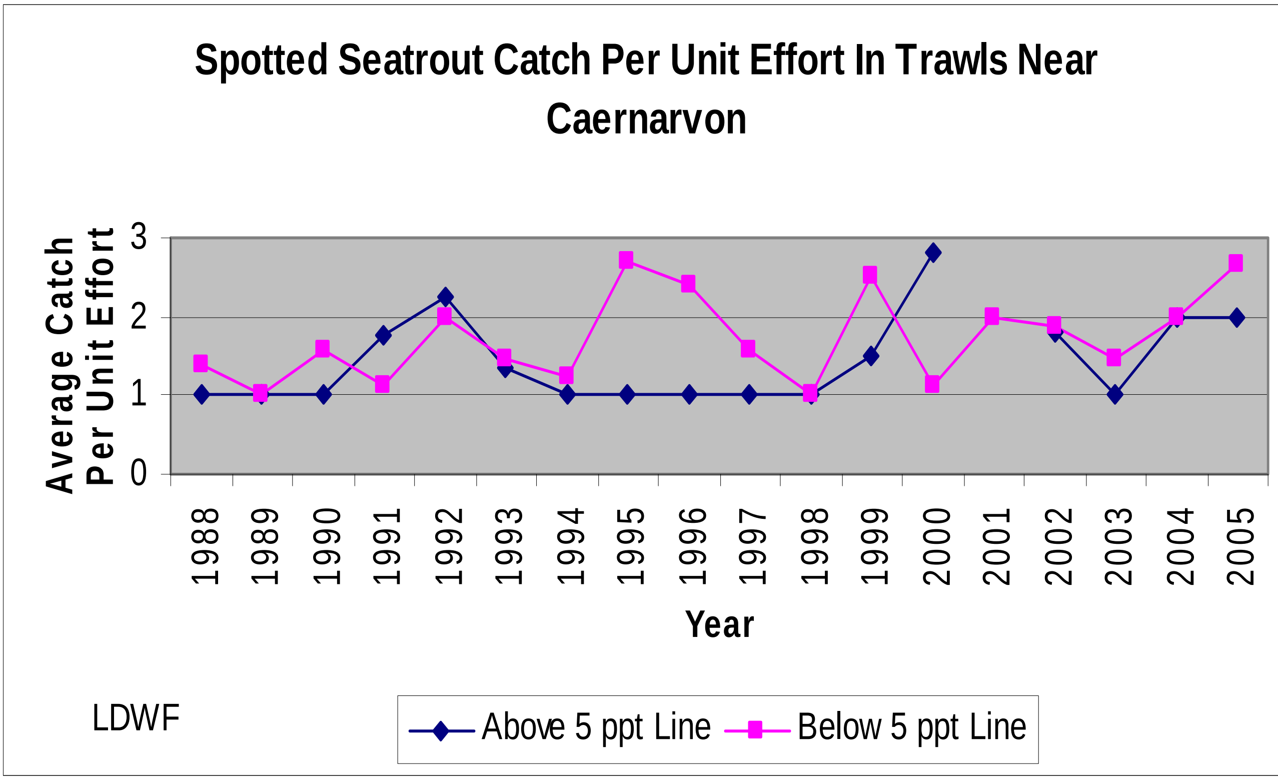

Figure 24. Spotted seatrout catch per unit effort in trawls at Caernarvon (LDWF).

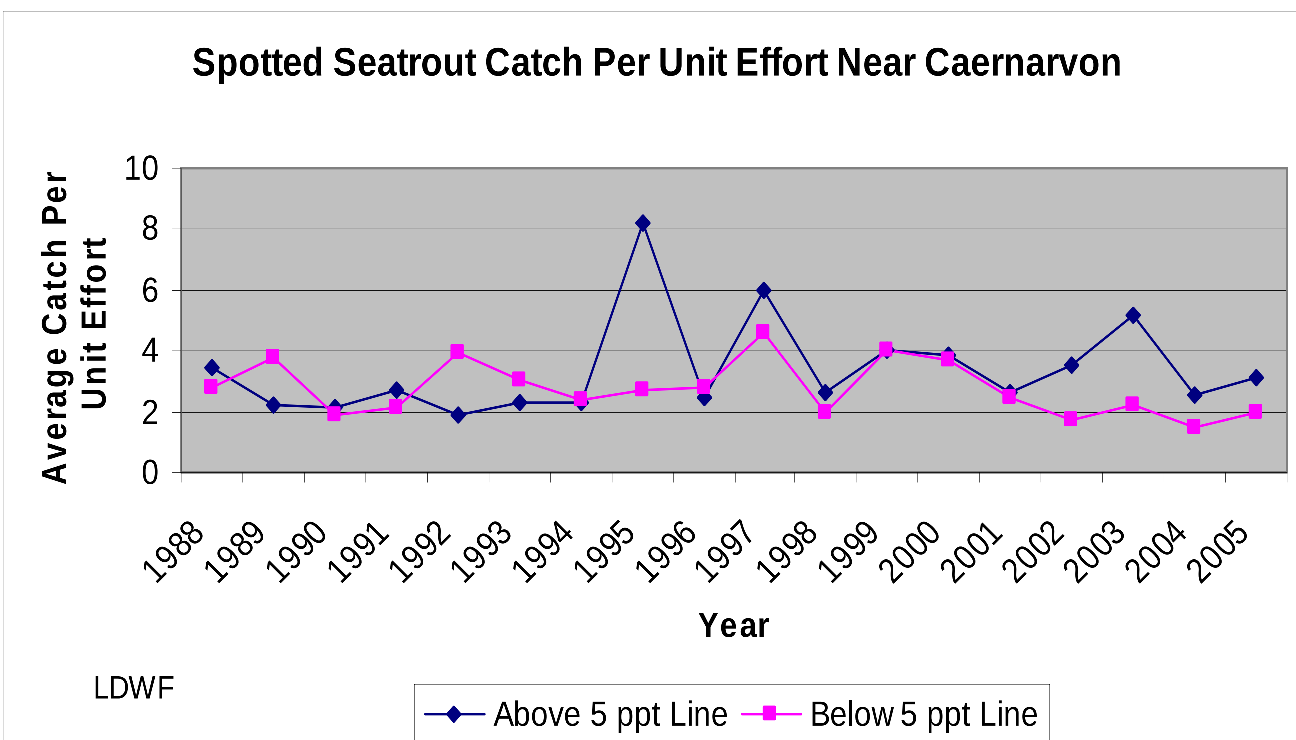

Figure 25. Spotted seatrout catch per unit effort in seines at Caernarvon (LDWF).

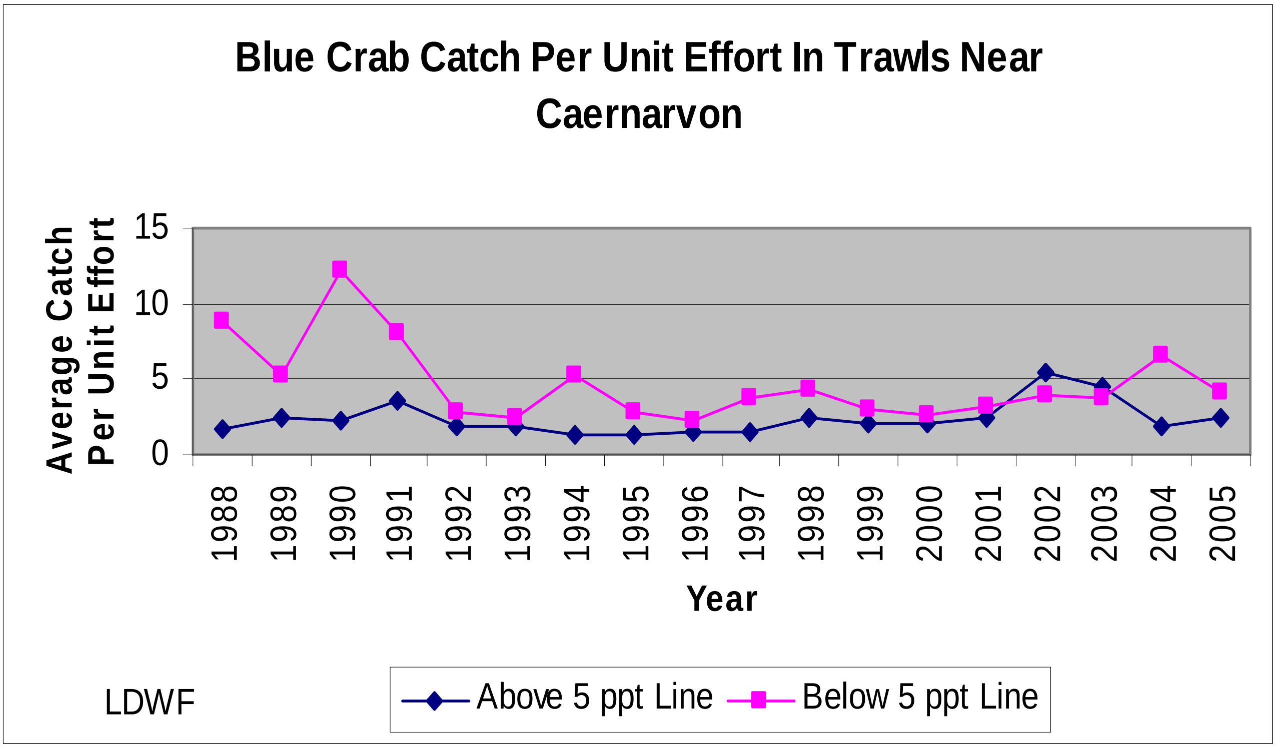

Figure 26. Blue crab catch per unit effort in trawls at Caernarvon (LDWF).

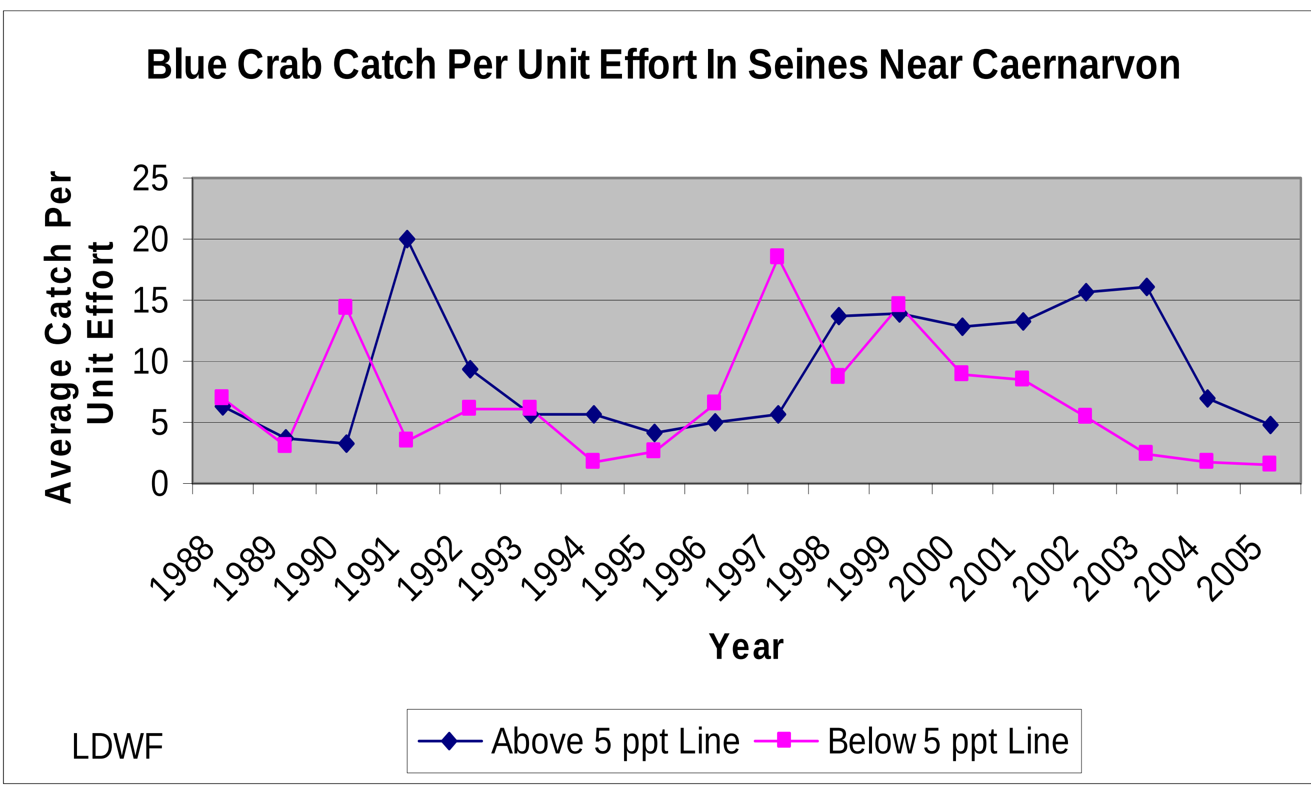

Figure 27. Blue crab catch per unit effort in seines at Caernarvon (LDWF).

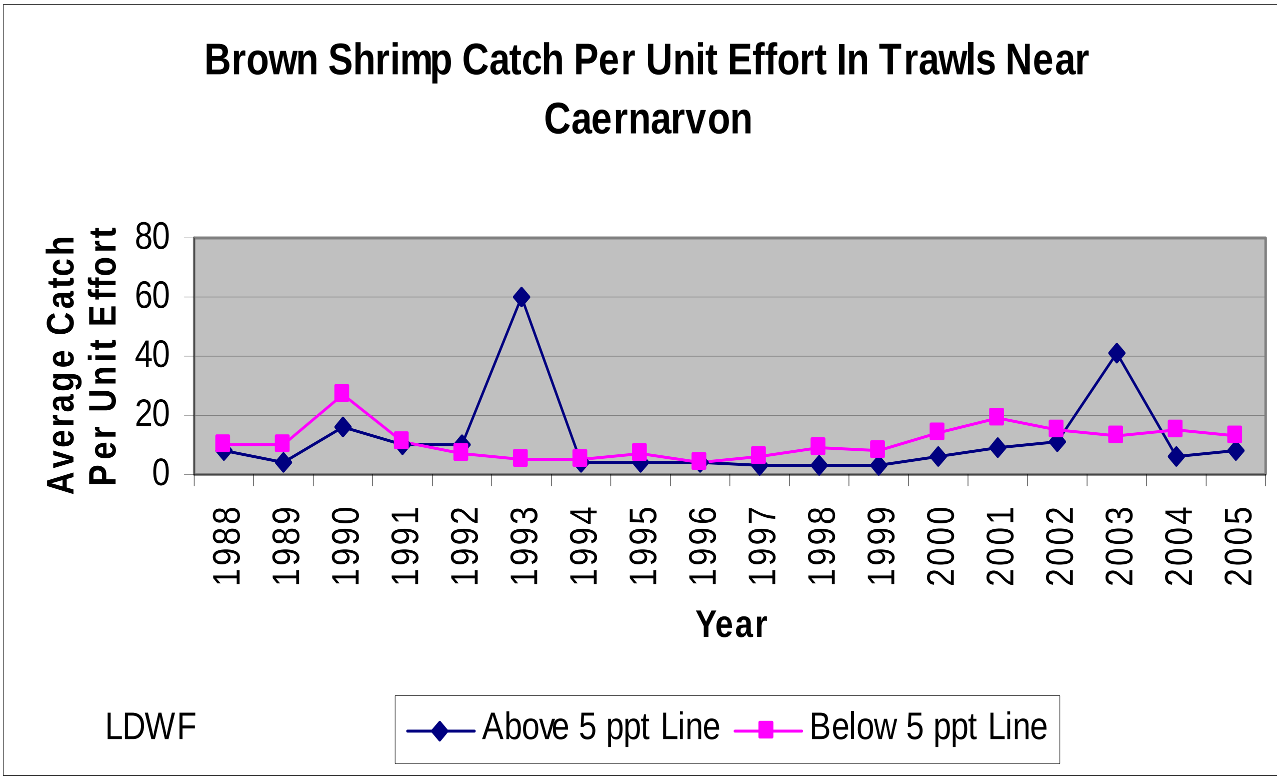

Figure 28. Brown shrimp catch per unit effort in trawls at Caernarvon (LDWF).

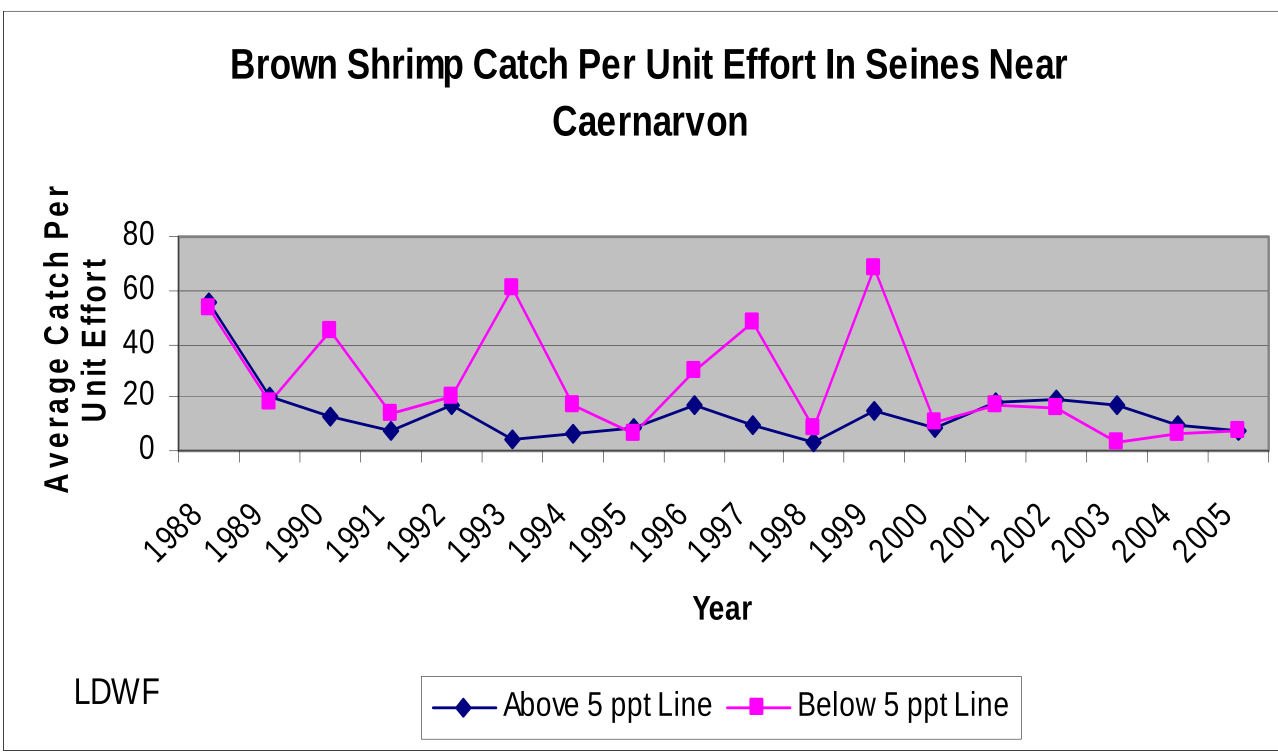

Figure 29. Brown shrimp catch per unit effort in seines at Caernarvon (LDWF).

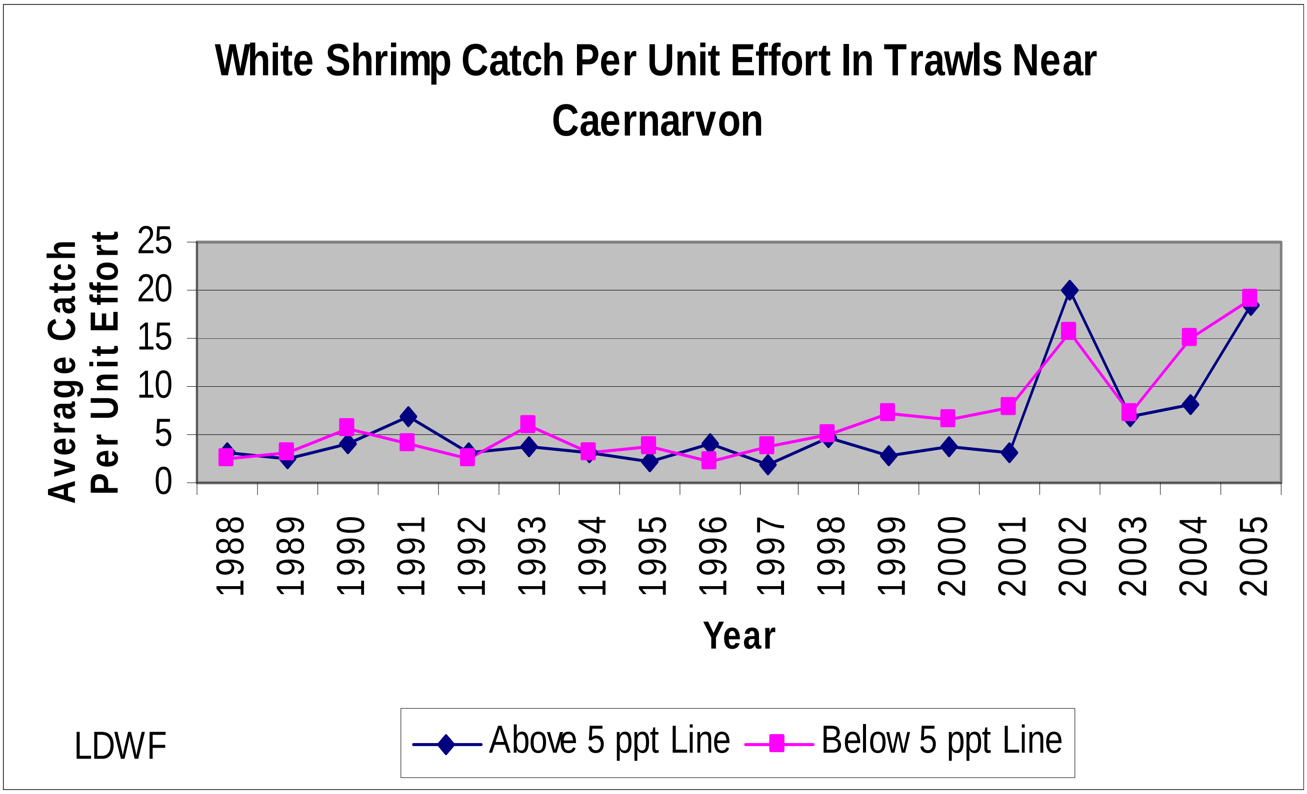

Figure 30. White shrimp catch per unit effort in trawls at Caernarvon (LDWF).

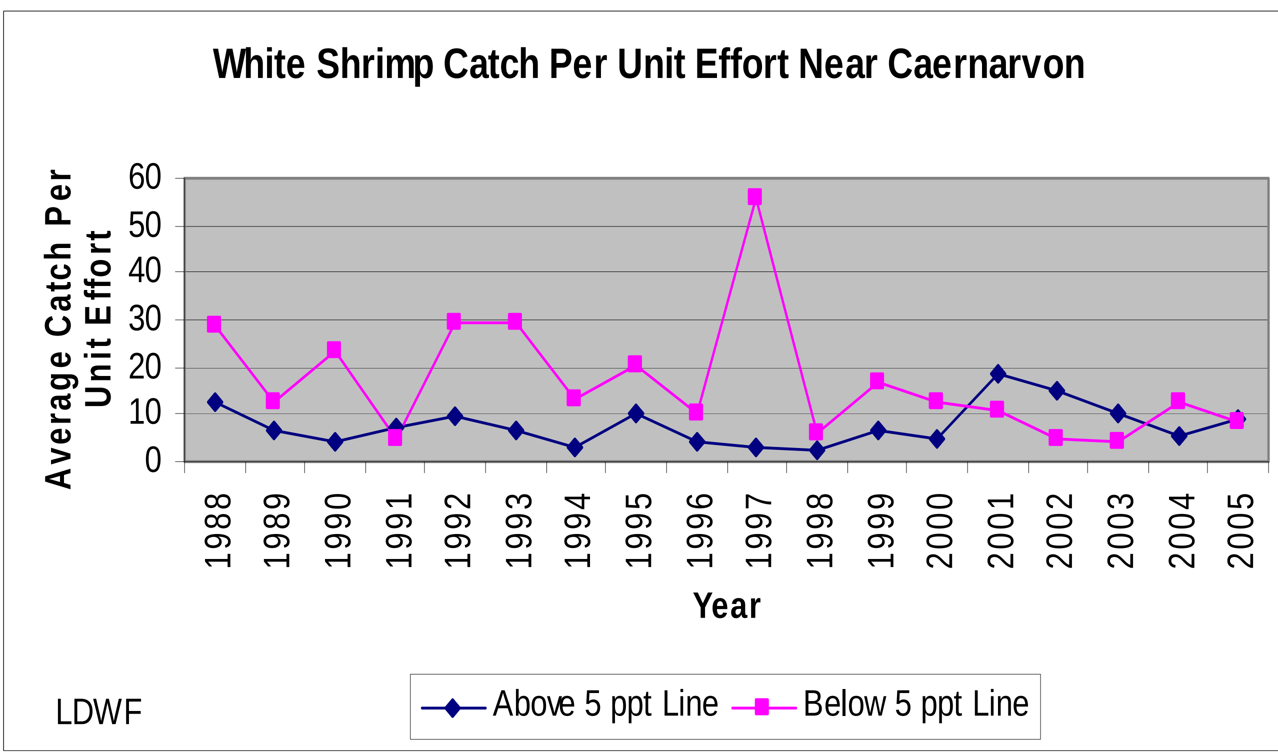

Figure 31. White shrimp catch per unit effort in seines at Caernarvon (LDWF).

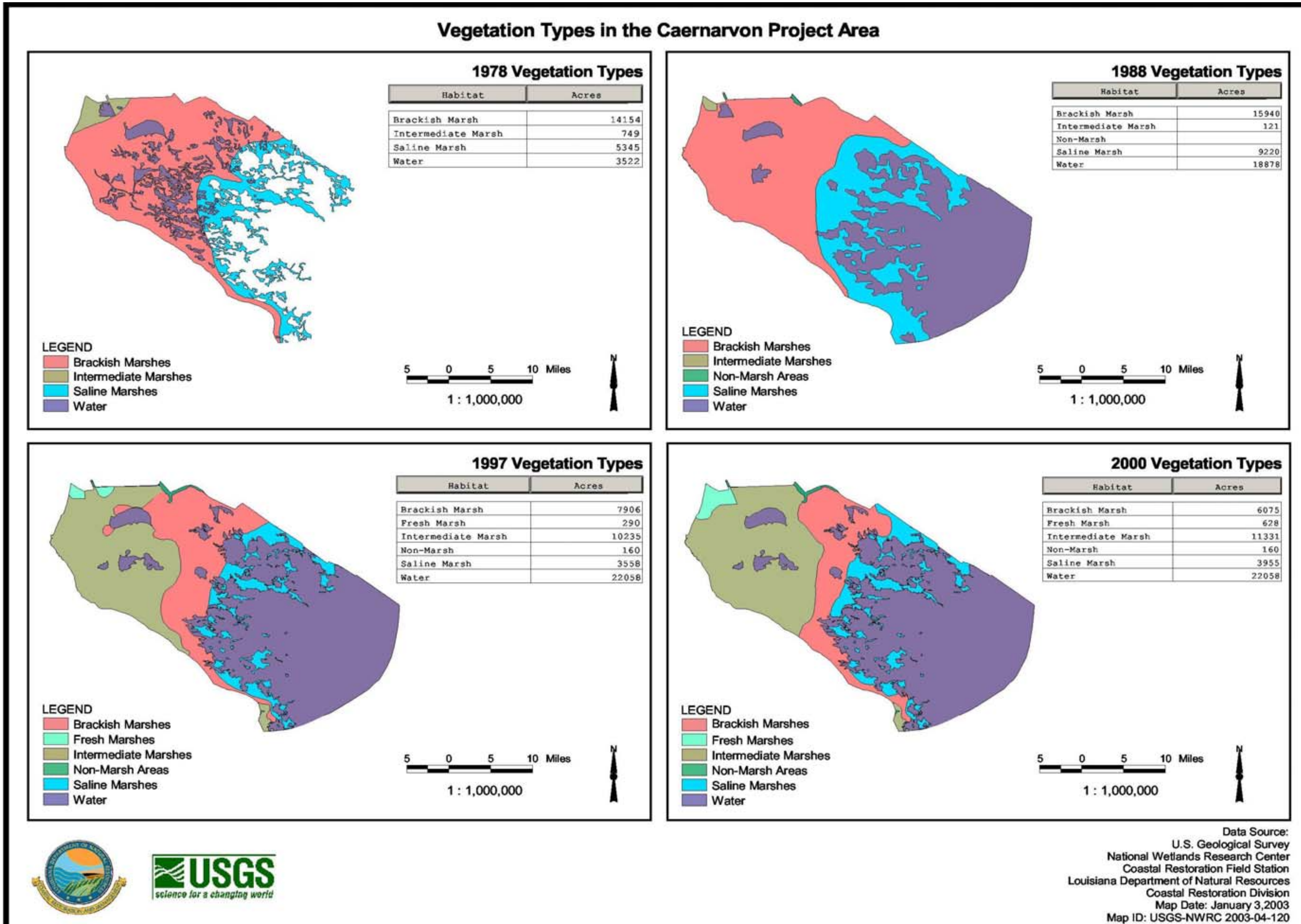

Figure 32. Habitat changes in Breton Sound basin 1978-2000. (USGS)

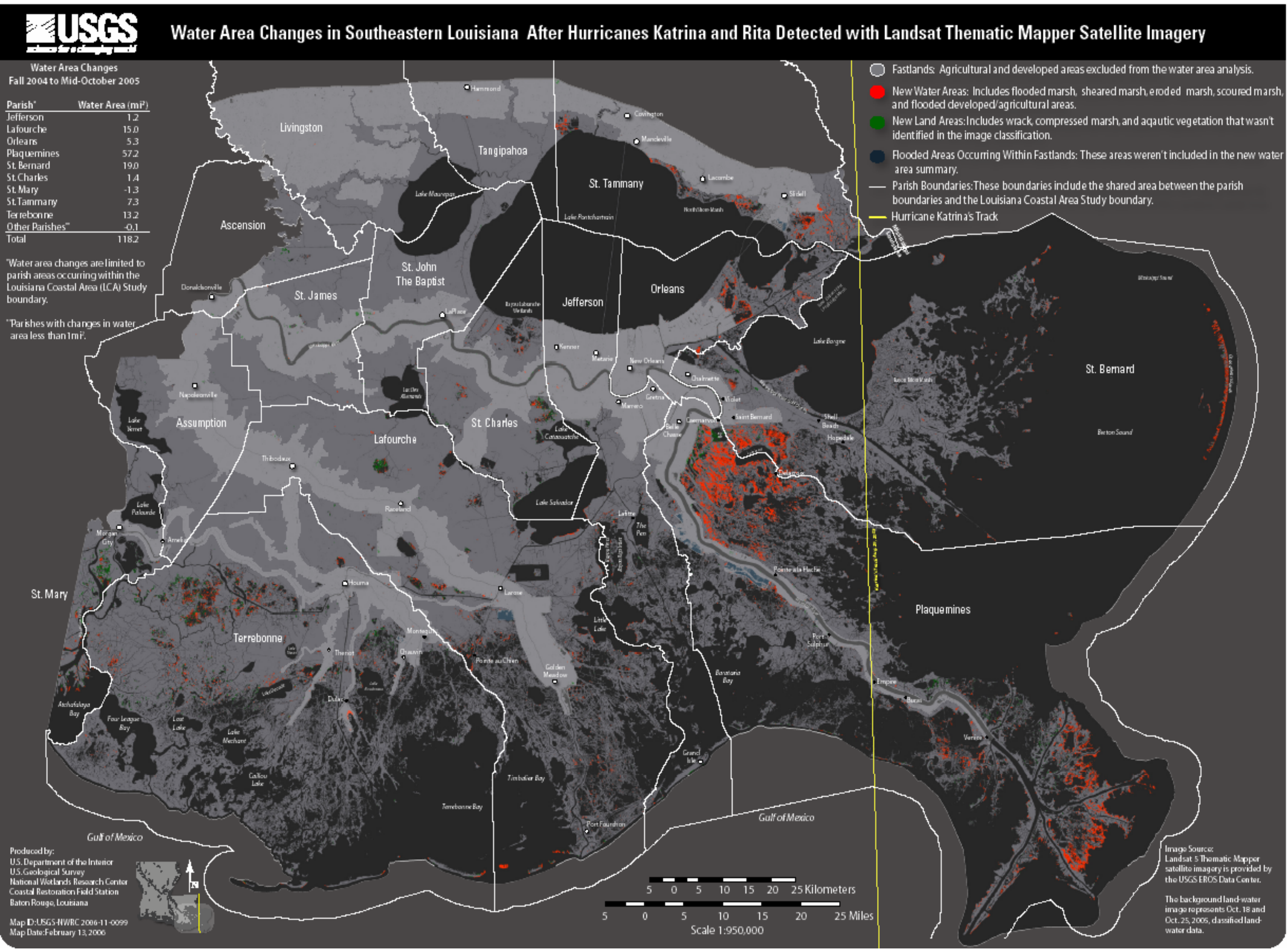

Figure 33. Path of Hurricane Katrina and land loss in Breton Sound Estuary (USGS)

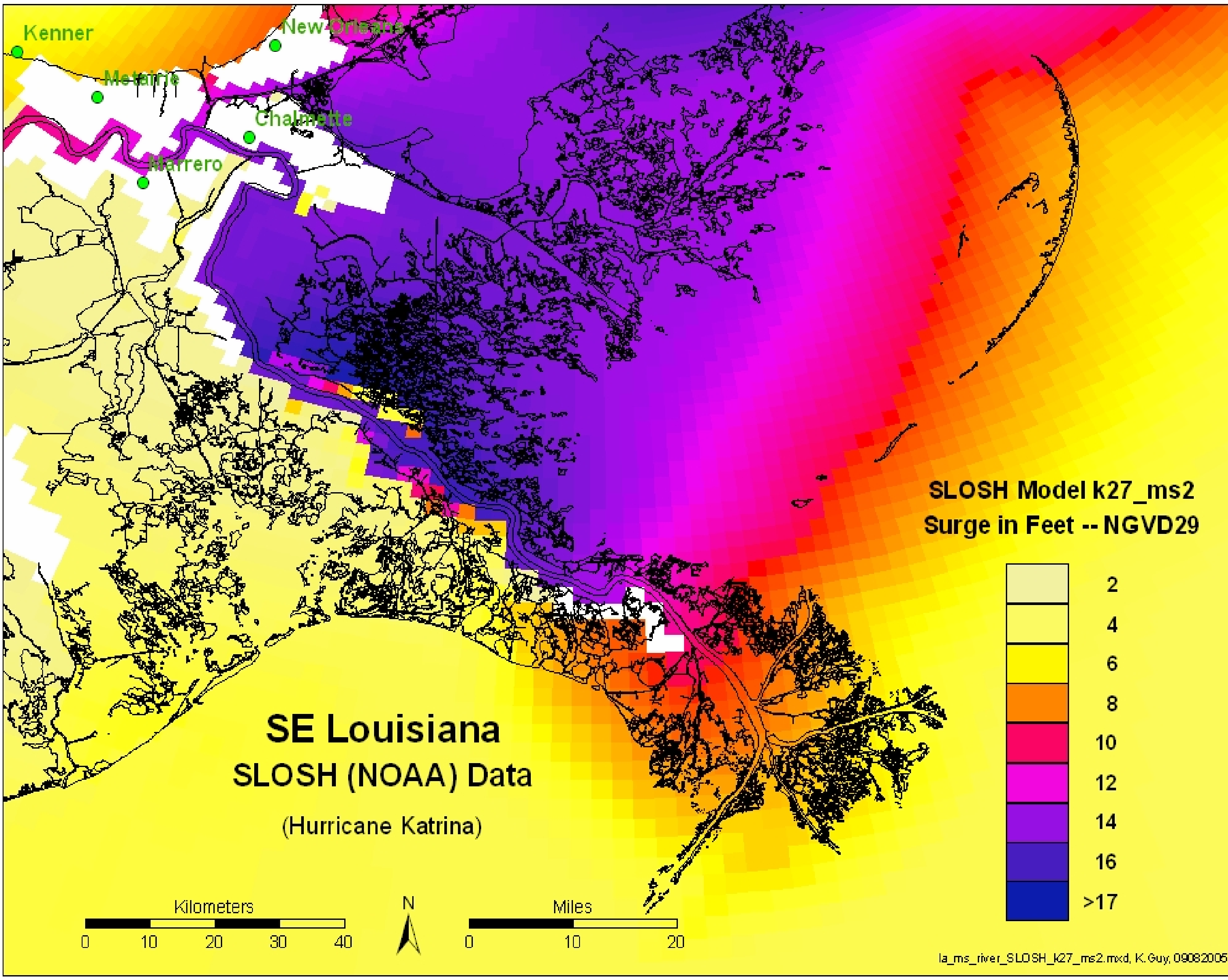

Figure 34. Surge feet in southeast Louisiana (NOAA)

Figure 35. Marsh balls in Big Mar, New Orleans in Background (LDNR).

Figure 36. Marsh turned to mudflat (USGS).

Figure 37. Marsh balls near Reggio Canal (LDNR).

Figure 38. Marsh shear zone and marsh in canals (LDNR)

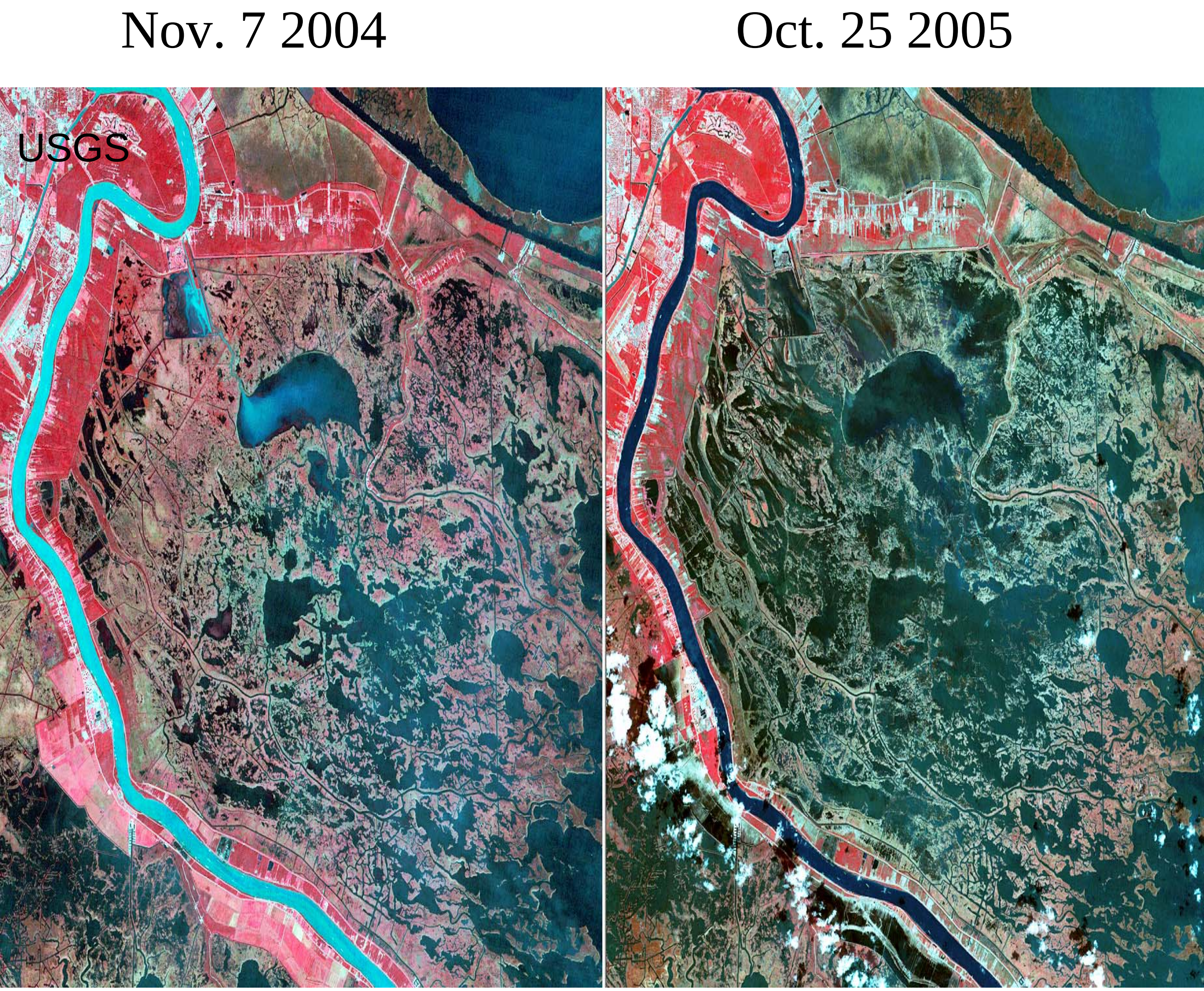

Figure 39. Satellite imagery of Breton estuary before and after Hurricane Katrina (USGS)

Mar. 2 2006

Sep 26 2006

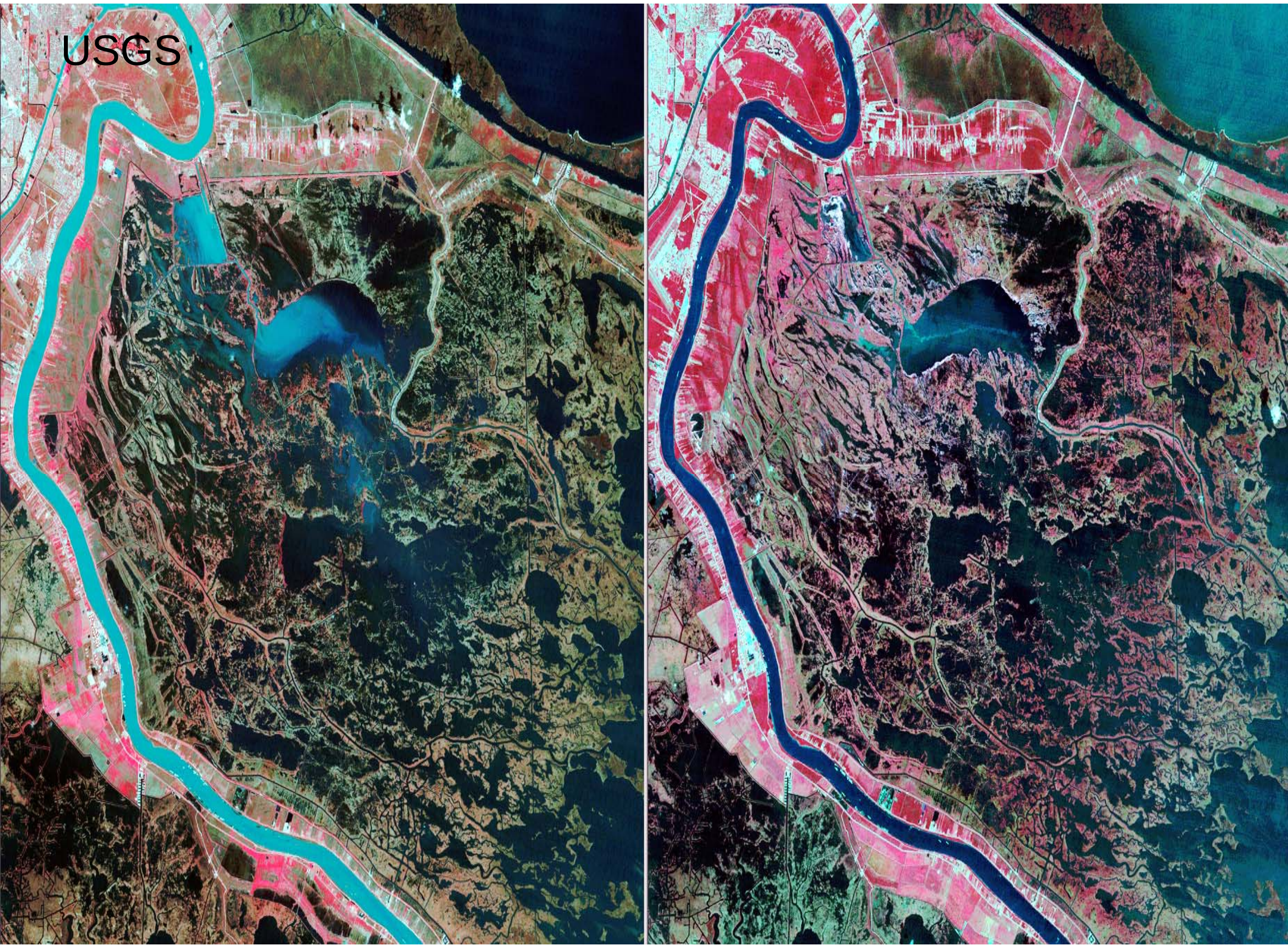

Figure 40. Satellite imagery of Breton estuary during post-hurricane growing season (USGS).

Figure 41. Emerging vegetative growth in mudflats in August 2006 (LDNR).