The Texas Shrimp Fishery

Texas Parks and Wildlife

SEDAR87-RD-16

August 2023

EXECUTIVE SUMMARY

THE TEXAS SHRIMP FISHERY

A report to the Governor and the 77th Legislature of Texas

TEXAS PARKS & WILDLIFE

SEPTEMBER 2002

TEXAS PARKS & WILDLIFE

September 1, 2002

The Honorable Rick Perry
Governor of Texas
P.O. Box 12428
Austin, Texas 78711

The Honorable Members of the
77th Legislature
State Capitol Building
Austin, Texas 78711

Dear Ladies and Gentlemen:

I respectfully submit a report titled "The Texas Shrimp Fishery." This report is submitted pursuant to the provisions of Section 77.005 of the Texas Parks and Wildlife Code.

Your continued support of Texas Parks and Wildlife Department programs is very much appreciated.

Sincerely,

Robert L. Cook
Executive Director

RLC:RKR:klp

cc: Parks and Wildlife Commissioners

To manage and conserve the natural and cultural resources of Texas and to provide hunting, fishing and outdoor recreation opportunities for the use and enjoyment of present and future generations.

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EXECUTIVE SUMMARY

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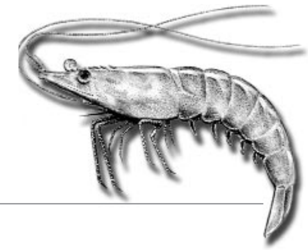


INTRODUCTION

The following Executive Summary is a result of Senate Bill 305, 77th Texas Legislature (2001), which amended Chapter 77 of Texas Parks and Wildlife Law by adding Section 77.005. This section directs the Texas Parks and Wildlife Department (TPWD) to conduct a comprehensive study of the shrimp resources, including the shrimp population and the shrimp industry. The study was mandated to include analysis of: 1) the status of the shrimp population in coastal waters, including the size and projected growth of shrimp grounds; 2) the economic health of the shrimp industry; 3) the status of conservation measures, including TPWD regulations and license buybacks; and 4) the status of marine resources and habitats affected by shrimping.

This report includes information obtained from a survey of resident and non-resident commercial bay, bait and Gulf shrimp boat, bait-shrimp dealer, wholesale fish dealer and wholesale fish truck dealer license holders in Texas. The survey was completed by the Human Dimensions Laboratory, Department of Wildlife and Fisheries Sciences, Texas A&M University. The report also includes a compilation of the monitoring data and special studies conducted by TPWD as well as an extensive literature review. In addition, TPWD solicited and considered input from other scientists, the public, the shrimp industry and the Texas Comptroller of Public Accounts. This Executive Summary represents a synopsis of eight individual appendix documents that are available on request and listed by title in Table 1.

Table 1.
Appendix documents used as source material for the Executive Summary.

Appendix A.	Overview of Coastal and Marine Habitat in Texas
Appendix B.	Estuarine Biodiversity in Texas
Appendix C.	Nearshore Gulf Biodiversity in Texas
Appendix D.	Overview of Bycatch Problems and Solutions in the Shrimp Fishery of Texas and the Southeastern United States
Appendix E.	Sea Turtle Conservation
Appendix F.	Managing for Sustainable Shrimp Stocks
Appendix G.	Status and Trends of Commercial Shrimp in Texas
Appendix H.	A Social and Economic Characterization of the Texas Shrimp Fishery

SHRIMP LIFE HISTORY

Brown shrimp (*Farfantepenaeus aztecus*) range along the North Atlantic and coasts from Massachusetts to Campeche, Mexico. White shrimp (*Litopenaeus setiferus*) range along the North Atlantic and coasts from New York to Campeche, Mexico. Pink shrimp (*Farfantepenaeus duorarum*) occur from the lower Chesapeake Bay south to Isla Mujeres, Mexico with highest densities occurring along the coasts of southwestern Florida and the Gulf of Campeche. Each species is widely distributed around the Gulf of Mexico, with localized centers of abundance but no distinct spawning grounds.

Brown shrimp, white shrimp and pink shrimp are estuarine dependent species and have similar life history stages, but vary seasonally in abundance. In general, adults spawn in the Gulf where fertile eggs hatch into free-swimming larvae. The larvae develop via a series of molts through several larval stages into post-larval shrimp. Movement of eggs and larval stages are by currents, winds and tidal movement. Larvae are also capable of vertical migrations through the water column. Both daily patterns in vertical distribution and variation in vertical distribution among different larval stages have been observed.

After post-larval shrimp enter shallow estuarine bay areas along the Texas coast, they assume a benthic existence. These shrimp usually concentrate in estuarine waters less than 3 feet (ft) deep, where there is attached vegetation and/or abundant detritus. Within the estuary they develop into juvenile shrimp and in time move to deeper bay waters as they continue to mature. At a length of 2.7-4.7 inches (ins) shrimp emigrate to the Gulf as sub-adults where they mature to adults and start the cycle again.

Brown Shrimp

Sexual maturity for brown shrimp is near 4.5 ins for males and 6.5 ins for female. Brown shrimp spawning takes place in Gulf waters ranging from 151 to 299 ft. There is some indication that during the winter, brown shrimp post-larvae may remain offshore in the Gulf for some period before moving into estuaries in early spring. Peak influx of post-larval brown shrimp to estuarine waters is February-April. After entering bays, brown shrimp tend to be found in significantly higher densities in vegetated marsh areas. As brown shrimp grow from juvenile to sub-adults, they begin to feed more on detritus and benthic organisms such as polychaete worms and amphipods. During the juvenile to sub-adult phase, brown shrimp enter deeper bay waters and eventually emigrate from bays to the Gulf. This emigration

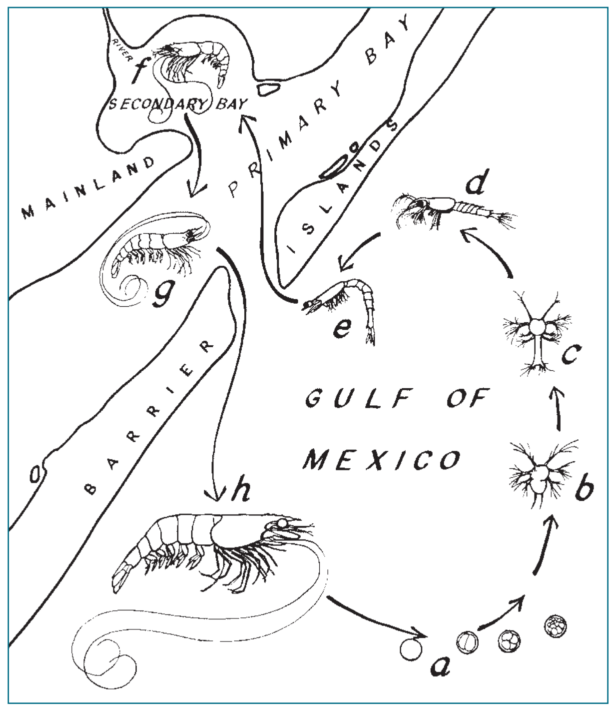
is generally in association with a full moon and strong tidal cycles from May through August with peaks from May to July.

White Shrimp

Size at sexual maturity for white shrimp is 6.0 ins for males and 6.5 ins for females. White shrimp spawning occurs offshore in depths ranging from 23 to 108 ft from March to September. Peak influx of post-larval white shrimp to estuarine bay waters is during summer. As white shrimp grow they begin to move into deeper open bay waters, preferring soft mud or peat bottoms. Decreasing water temperature accelerates emigration of white shrimp to the Gulf. Offshore movements peak from September to December. Along the south-central Texas coast, shrimp move southward during cool months and northward during spring.

Pink Shrimp

Minimum size at sexual maturity for male pink shrimp is 2.9 ins and 3.3 ins for females. Pink shrimp spawning occurs offshore in depths ranging from about 13 to 164 ft. Although spawning occurs all year, activity increases as water temperature rises. Peaks in spawning occur in late spring, summer and early fall. Peaks of immigration of pink shrimp post-larvae into nursery areas occur in the spring and fall. Dense seagrass beds appear to be important to both post-larval and juvenile pink shrimp. Emigration of pink shrimp occurs throughout the spring, summer, and fall and seems to be correlated with full moon ebb tides. Some pink shrimp over-winter in Texas bays, residing in estuaries for up to nine months.

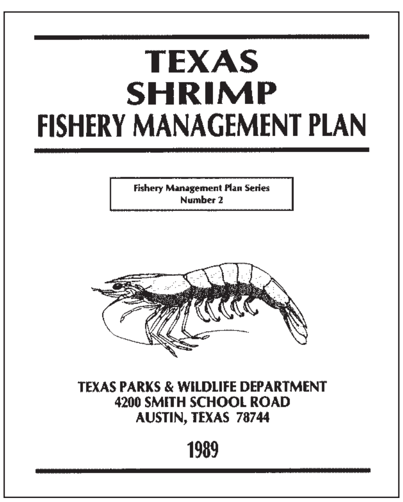


a) shrimp eggs
b) nauplius larva
c) protozoea
d) mysis
e) postmysis
f) juvenile shrimp
g) adolescent shrimp
h) mature adult shrimp

HISTORY OF MANAGEMENT

Commercial shrimping was a minor activity in Texas prior to 1920. In the following years, the shrimp fishery grew rapidly and subsequent management efforts evolved with the growth. Even in the early days of the fishery, there was concern about sustainability, particularly associated with the harvest of small shrimp. The Texas Legislature, which enacted all shrimping rules in the 1930s, established a $5\frac{1}{2}$-in minimum size limit, a shrimping closure during May-July and a maximum trawl width of 10 ft.

A major overhaul of shrimping rules occurred with the Shrimp Conservation Act of 1959 by the Texas Legislature in an effort to better allocate shrimp resources among the increasingly competitive Gulf, bay and bait shrimpers. Previous rules were liberalized to allow more access to shrimp stocks even when the shrimp were at small sizes.



Fishery Management Plan

The Texas Legislature kept the basic framework of the Shrimp Conservation Act of 1959 largely intact until they granted management authority over shrimp to TPWD in 1985. The new authority was contingent upon development of a shrimp fishery management plan (FMP) which was adopted by the TPWD Commission (Commission) in 1989. Based on continued overfishing trends documented in the FMP, the Commission adopted additional fishery restrictions in 1990 and 1994.

Limited Entry and Buyback

Traditional management measures reduce the efficiency of individual shrimpers. More restrictive traditional measures can provide a biological benefit for shrimp stocks but may not maximize social and economic benefits due to the open-access nature of the fishery. To overcome this management handicap, the Texas Legislature in 1995 enacted the first bay and bait shrimp vessel license limited entry program designed to reduce the documented fleet overcapitalization without severe disruptions to the fishing communities.

This license buyback program appears to have been successful in preventing further increases in inshore shrimping effort. However, although fishing effort has been stabilized, it remains at historically high levels. Since the implementation of the buyback program, TPWD has purchased and retired

815 commercial shrimp boat licenses (422 bay and 393 bait) at a cost of approximately $4.3 million. This represents 25% of the original 3231 licenses grandfathered into the fishery in 1995. The purchase price for licenses has increased from the first rounds and leveled off in recent rounds. The average price paid per license was $3,394 in the first round of license buybacks (1996) and $6,607 in the tenth round (2002).

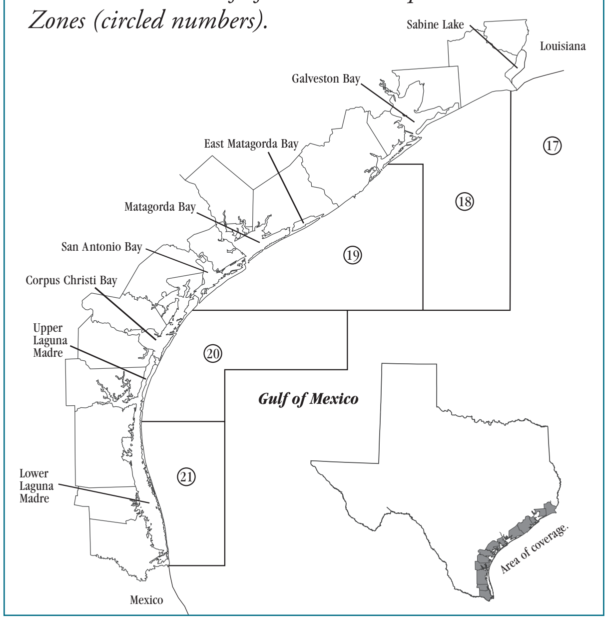
Beginning in 1998, TPWD began a thorough review of all shrimp regulations to evaluate their biological, social and economic effectiveness. Based on the results of that study, the Commission adopted additional conservation measures in 2000 as well as license fee increases for both commercial and recreational fishermen aimed at speeding up the license buyback program. These most recent changes were a refinement of shrimping regulations already in place. They were designed primarily to reduce growth and biological overfishing as defined in the FMP, to increase the economic value of the industry by protecting juvenile shrimp and increasing spawning of adult shrimp, and to reduce the incidental take of sea turtles and other aquatic life in shrimp trawls.

SHRIMP HABITAT

From the broadest perspective, shrimp habitat is the geographic area where shrimp species occur at any time during their life cycle. In the ecological literature, the role of habitat in supporting the productivity of organisms has been thoroughly documented and the linkage between habitat and fishery productivity has been clearly established.

Fishery species use habitat for spawning, breeding, migration, feeding, growth and shelter to increase survival. For purposes of this report, all waters and substrates (mud, sand, shell, rock and associated biological communities) necessary for shrimp to spawn, breed, feed and grow to maturity, including the sub-tidal vegetation (seagrasses and algae) and adjacent tidal vegetation (marshes and mangroves) have been defined as *Essential Shrimp Habitat* (ESH).

Figure 1. *Texas Bay Systems and National Marine Fisheries Service Gulf of Mexico Shrimp Statistical Zones (circled numbers).*



The coastal areas of Texas are highly sought after as places for human habitation. People require places to live as well as related services such as roads, schools, water and sewer facilities, power, etc. These needs often are met at the expense of ESH and may adversely impact the very values that brought people to the coast.

Description of Texas Coastal and Marine Habitat

Estuaries, Bays and Gulf

Estuaries in Texas waters differ in several respects from a typical estuary. First, their connection with the open sea is more restricted, being confined to a few tidal channels that breach the offshore barrier islands. Secondly, Texas estuaries are often divided into at least primary and secondary basins.

Primary bays vary in salinity from marine (30-40 parts per thousand (ppt)) at the tidal inlets to polyhaline (12-30 ppt) or upper mesohaline (3-12 ppt) near their connections with secondary bays. Brackish to freshwater transition is completed within the secondary basins. Some of the best examples of primary-secondary bay systems on the Texas coast occur from Corpus Christi northward and include the Trinity-Galveston, Lavaca-Matagorda, Copano-Aransas and Nueces-Corpus Christi Bay systems. Secondary bay shores are often bounded by extensive low-lying marshlands bisected by numerous narrow drainage channels.

Texas has approximately 365 miles of open Gulf shoreline and contains 2,361 miles of bay-estuary-lagoon shoreline (Figure 1). This is the most biologically rich and ecologically diverse region in the state and supports more than 601,000 acres (ac) of fresh, brackish and salt marshes and 1.5 million ac of open water.

From the Louisiana border to Galveston, the coastline is comprised of marshy plains and low, narrow beach ridges. From Galveston Bay to the Mexican border, the coastline is characterized by long barrier islands and large shallow lagoons. Within this estuarine environment are found the profuse seagrass beds of the Laguna Madre, a rare hypersaline lagoon, and Padre Island, the longest undeveloped barrier island in the world.

Submerged Vegetation

Seagrasses are submerged, grass-like plants that occur mostly in shallow marine and estuarine waters. They may form small patchy or large continuous beds, known as seagrass meadows, which serve as valuable ESH. Seagrass meadows may require decades to form.

Seagrasses are recognized as a dominant, unique habitat in many Texas bays and estuaries. They form some of the most productive communities in the world and are aesthetically and economically valuable to humans. Because seagrasses are sensitive to nutrient enrichment, water quality problems and physical disturbance, the distribution of seagrasses is used as an indicator of the health of the environment where they typically occur.

Seagrasses are dominant on the middle to lower coast where rainfall and inflows to the bays are low, evaporation is high and salinities are >20 ppt. About 79% of seagrass habitat occurs in the upper and lower Laguna Madre, about 19% is found in San Antonio, Aransas and Corpus Christi Bays and less than 2% occurs north of these bays.

Trend data and anecdotal information over the last 40-50 years indicate that considerable change has occurred coastwide, with seagrass beds becoming scarce in some areas and more abundant in others. Change has occurred from both natural and anthropogenic causes. Natural causes include hurricanes, sea level changes and climatic cycles. Anthropogenic causes include direct and indirect destruction and/or degradation of the seagrass caused by more than 770 miles of federally maintained navigation channels and more than 500 dredge spoil disposal sites. In addition, shoreline developments, commercial and recreational boating, and nutrient loading have all led to changes. The cumulative effects of anthropogenic threats are increasing in complexity and severity as human populations continue to increase along the Texas coast.

Salt Marshes

Coastal wetlands serve as nursery grounds for shrimp species and more than 95% of the recreational and commercially important fish species found in the Gulf of Mexico. Coastal marshes in Texas can be divided into two major ecosystems; the Chenier Plain Ecosystem from the Texas-Louisiana border to East Bay (Texas) and the Texas Barrier Island Ecosystem from East Bay to the Texas-Mexico border. Salt marshes are typically dominated by cordgrass (*Spartina alterniflora*), although black mangrove (*Avicennia germinans*) dominates in certain areas.

The broadest distribution of salt marshes is found south of the Galveston Bay area, where they are common on the bayward side of barrier islands and peninsulas and along the mainland shores of narrow bays, such as West Galveston Bay. Although salt marshes occur on bay-head deltas, their biological plant communities change rapidly from brackish to intermediate and fresh marshes.

Brackish, Intermediate and Fresh Marshes

The brackish marsh community is a transitional area between salt marshes and fresh marshes. Brackish marshes are the dominant wetland communities in the Galveston Bay system. They are widely distributed along the lower reaches of the Trinity River delta, in the inland system west of the Brazos River, and along the lower reaches of the Lavaca and Guadalupe River valleys.

Intermediate marsh assemblages occur on the upper coast above Galveston Bay, where average salinities range between those found in the fresh and brackish marsh assemblages.

Fresh marshes occur on the mainland and barrier islands along river or fluvial systems. They are found inland from the Chenier Plain and upstream along the river valleys of the Neches, Trinity, San Jacinto, Colorado, Lavaca, Guadalupe and San Antonio Rivers.

Status and Trends of Texas Coastal Wetlands

Coastwide, recent estimates of wetland loss show that estuarine emergent wetlands decreased by about 10% between the mid-1950s and the early 1990s. There was a net loss of 33,400 ac in the Galveston Bay system or 19% of the wetlands that existed in the 1950s. The most extensive loss of contiguous wetlands on the coast occurred within the Neches River valley. Even with this historical wetland loss, recent federal and state legislation have had a positive influence on wetland conservation and management in Texas.

Gulf of Mexico

The habitat types located in the marine environment in the Gulf of Mexico are varied. Thriving coral reefs, seagrass meadows, non-vegetated bottom, drowned reefs related to ancient shorelines, manmade structures, salt diapirs and large rivers influencing water characteristics on the inner continental shelf all contribute to the diversity of the marine habitat in the Gulf of Mexico. This diversity directly influences the species associated with these varying habitat types.

Runoff from precipitation on almost two-thirds of the land area of the United States (U.S.) eventually drains into the Gulf of Mexico via the Mississippi River. The combined discharge of the Mississippi and Atchafalaya (Louisiana) Rivers alone accounts for more than half the freshwater flow into the Gulf and is a major influence on salinity levels in coastal waters on the Louisiana/Texas continental shelf.

The Gulf of Mexico continental shelf varies in width from about 124 miles off east Texas to 68 miles off southwest Texas. The shelf and shelf edge of the Gulf of Mexico are characterized by a variety of topographic features. Some of these features support hard bottom communities of high biomass, diversity and abundance. These features are unique in that they are small, isolated, highly diverse areas within areas of much lower diversity. They support large numbers of commercially and recreationally important marine species by providing either refuge or food.

The Texas shelf is dominated by mud or sand-laden terrigenous sediments deposited by the Mississippi River. Sediment type is a major factor in determining the associated fish community. Shrimp distribution closely matches sediment distribution. White shrimp and brown shrimp occupy the terrigenous muds, while pink shrimp occur on calcareous sediments.

Water Quantity and Quality

Freshwater inflows into the bays and estuaries are critical to maintaining the health of ESH, but they must be of adequate quantity and delivered during the appropriate season. Ninety percent of all commercially and recreationally important shellfish and finfish depend upon this freshwater inflow. Eleven of Texas' 15 major river systems have historically provided freshwater to the coast. However, increasing demands for freshwater by municipal, industrial and agricultural interests threaten the sensitive coastal ecosystems.

Water quality is also a key environmental factor in maintaining healthy populations of estuarine species such as penaeid shrimp. Major activities affecting Gulf coastal water quality include those associated with the petrochemical industry; hazardous and oil-field waste disposal sites; agricultural and livestock farming; power plants; pulp and paper plants; fish processing; commercial and recreational fisheries; municipal waste water treatment; mosquito control activities; maritime shipping; and land modifications for flood control, river development, harbors, docks, navigation channels and pipelines.

A prevalent example of how human use is curtailed by pollution in Gulf estuaries is the presence of fecal coliform bacteria contamination, which is used as an indicator of shellfish suitability for human consumption. Elevated fecal coliform bacteria counts in estuaries lead to prohibitions on shellfish harvest. Non-point source pollution is a major contributing factor to high bacteria counts.

Another example of curtailed use is in Lavaca Bay where a portion of the bay is designated as a catch and release area only. The possession and consumption of fish or shellfish from this area is prohibited because of mercury contamination. However, the Texas Department of Health has recently reduced the size of the closed area because of reductions of mercury contamination in fish tissue.

Watershed destruction, including non-point source pollution, has been identified as the primary contributor to water pollution nationwide. Gulf of Mexico estuaries and bays are experiencing this phenomenon. A consequence of inadequate estuary water planning is non-optimal productivity and use of fish and shellfish resources.

Impacts on Habitat

Hypoxia

Hypoxia (commonly referred to as "dead zones") or oxygen depletion occurs in some areas of the open Gulf. A zone of hypoxia affecting up to 6,400 square miles of bottom waters on the inner continental shelf from the Mississippi River delta to the upper Texas coast has been identified during mid-summer months. Researchers have expressed concern that this zone may be increasing in frequency and range. Although the causes of this hypoxic zone have yet to be conclusively determined, high summer temperatures combined with freshwater runoff carrying excess nutrients from the Mississippi River have been implicated. Benthic fauna studied within the area exhibited a reduction in species richness, abundance and biomass that was much more severe than has been documented in other hypoxia-affected areas. Motile fishes, cephalopods and crustaceans leave the area. Responses of non-motile benthic organisms range from pronounced stress behavior to death.

Approaches to reduce hypoxia in the Gulf of Mexico are: 1) reduce nitrogen loads to streams and rivers in the Mississippi River watershed, and 2) restore and enhance denitrification and nitrogen retention within the watershed and on the coastal plain of Louisiana. Annual load estimates indicate that a 40% reduction in total nitrogen inflow to the Gulf is necessary to return to average loads comparable to those during 1955-1970. Programs that compensate farmers to restore wetlands, retire sensitive lands, install vegetation buffers along streams and reduce fertilizer use will need to be expanded and funded.

Algal Blooms

Brown tide was first documented in the Texas upper Laguna Madre in early 1990. This chrysophyte has been identified as *Aureoumbra lagunensis* and persisted at high levels for over eight years. Brown tide reduces light available for seagrass photosynthesis and has caused substantial seagrass losses in the upper Laguna Madre.

Red tides are a natural phenomenon in the Gulf, primarily off Florida, Texas and Mexico. Of particular concern are red tides caused by blooms of a dinoflagellate (*Karenia brevis*) that produces potent toxins harmful to marine organisms and humans. They can result in severe economic and public health problems and are associated with fish and invertebrate kills. There are ongoing studies to determine whether human activity that increases nutrient loading contributes to the intensity of red tides.

Fishing

Bottom trawling and other fishing activities that involve direct contact between fishing gear and the bottom environment in the bays, estuaries and Gulf of Mexico can alter the structural character and function of shrimp habitats. When the change is sufficient to preclude or limit use by target species, declines in catch abundance and individual animal size may occur.

In Texas waters, bottom trawling for shrimp is the dominant fishing activity. This method of fishing disrupts the habitat by scraping the substrate to depths of generally up to a few inches. Many studies have documented this effect along with more direct negative impacts on benthic communities. Recovery times can be up to five times the generation time of the biota involved. Depending on the species, this can be less than a month to decades. The more frequently an area is trawled the longer the recovery time could be.

Other

Broad categories of activities which can adversely affect ESH include: dredging (ship channels, waterways and canals); fill; excavation; fossil shell dredging; mining; impoundment; discharge; water diversions; thermal additions; actions that contribute to non-point source pollution and sedimentation; introduction of potentially hazardous materials; introduction of exotic species; and the conversion of aquatic habitat that may eliminate, diminish or disrupt the functions of ESH.

Shrimping Grounds

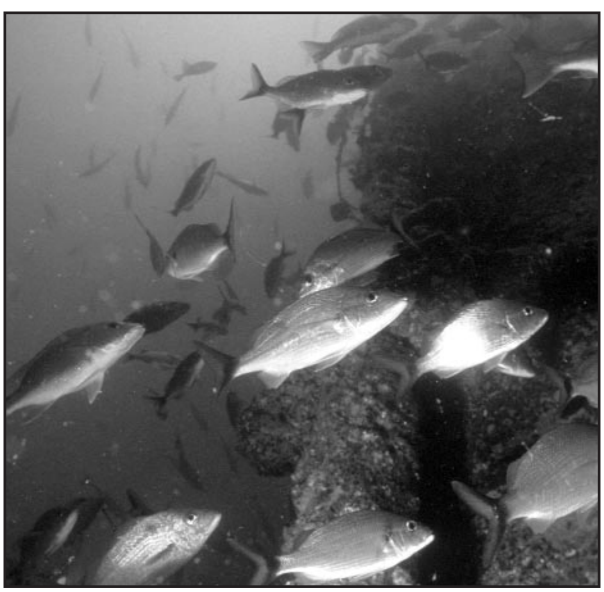
Offshore Texas, the continental shelf encompasses approximately 17.1 million ac with 14.4 million ac being in federal waters and the remaining 2.7 million ac in state waters. The Texas Artificial Reef Program has four reef sites within state waters occupying 520 ac of submerged lands and 36 reef sites in federal waters occupying 2,150 ac. A total of 802 oil and gas structures exist offshore Texas, with 505 of these structures in federal waters and 297 structures in state waters. Assuming the Artificial Reef Program captured all the structures offshore Texas, made a 40 ac reef site around each structure and added the acreage of the program's existing sites, only 0.20% of the continental shelf offshore Texas would be covered by planned artificial reefs. If the continental shelf area offshore Texas was separated between state and federal submerged lands, planned artificial reefs would cover 0.46% and 0.16% respectively.

Another type of unintentional artificial reef is the relatively small but numerous underwater obstructions that litter the Gulf of Mexico, including sunken vessels and assorted oil and gas drilling related debris. All these items can provide habitat for fish and hard substrate for invertebrate colonization. More than 10,000 hangs and obstructions have been documented along the Louisiana and Texas coasts. There is no information on how many of these obstructions have disappeared over time.

BIODIVERSITY

Biodiversity refers to the diversity of species occupying a given area at a particular time. Ecologically, high biodiversity is thought to promote strong, resilient and healthy ecosystems. *Biological integrity* has been defined as "the ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of natural habitats within a region."

Although nearshore oceanic ecosystems make up only a fraction of total oceanic habitats available to marine species, they account for almost a third of all marine biological productivity. Estuarine ecosystems are the most productive, with nearshore oceanic ecosystems second. Important environmental variables that have been shown to influence species assemblages include freshwater inflows, circulation patterns, temperature, salinity, water depth and sediment type.



Most of the species diversity in marine ecosystems consists of invertebrates residing in and on sediments. These invertebrates include animals such as shrimp and crabs, however, most species are relatively small polychaetes, crustaceans, mollusks and nematodes. Small crustaceans also make up a large portion of the zooplankton in the water column. In addition, there are poorly known microbiota which include bacteria and protists.

The sustainability of any complex ecosystem, such as the Gulf of Mexico, depends on the maintenance of adequate conditions as well as the resilience of organisms to adapt to changing conditions. The web of ecosystem processes is not limited to specific depth zones, distances from shore, height in the water column or political boundaries. Biological processes provided by organisms in the nearshore Gulf may affect organisms in adjacent coastal inshore waters, mid and outer continental shelf, open ocean and vice versa.

Many methods have been used to assess the condition of aquatic ecosystems and to evaluate impacts of anthropogenic activity on these resources over time. One recently developed method involves the use of a multimetric index of biotic integrity (IBI). A metric is a characteristic of an ecosystem that changes in some predictable way. Metrics are usually selected from four basic criteria: (1) richness: diversity or variety of ecosystem species; (2) composition: species identity and dominance; (3) tolerance: sensitivity to disturbance; and (4) trophic or habitat: feeding strategies and guilds or groupings of organisms.

TPWD recently initiated statistical analysis of its coastwide monthly routine fishery-independent monitoring data in an effort to detect significant changes in IBIs over time in both estuarine water (1982-2000) and nearshore Gulf waters (Texas Territorial Sea (TTS), ≤9 nautical miles (nm) from shore, 1nm=1.15 statute mile) (1986-2000). Specific categories of sampled fish and crustaceans were selected to calculate IBIs for testing. These baseline analyses can be repeated in future years to aid in evaluating the effects of regulatory changes such as increased shrimp nursery areas and BRD requirements. However, it must be noted that the baselines are established based on the previous conditions in the bays and estuaries. This includes the effects of previous fishing pressure, fishing patterns, freshwater inflows and other environmental influences.

Estuarine Biodiversity

IBIs were developed based on eleven metrics that represented the major aspects of estuarine finfish and macroinvertebrate assemblages. These included: carnivores, omnivores, planktivores, estuarine exclusive, estuarine dependent, total species, major shrimp, percent drum species, Gulf species, juveniles and the Shannon-Weiner score which is a measure of species diversity and evenness.

A total of 75,018 samples (14,061 gill nets, 30,050 bag seines and 30,907 otter trawls) were collected in Texas bays from 1982-2000. A total of 547 finfish and invertebrate species were encountered during the sampling period.

Although there are many similarities among bay systems, each displays their own unique pattern of IBI scores over time. IBI scores were highly seasonal and bimodal, generally with a spring peak, a smaller fall peak and were lowest in January and February. There were statistically significant trends in IBI scores for Sabine Lake where IBI scores have been increasing, and upper and lower Laguna Madre where scores have been decreasing over time. IBI scores in other bay systems showed no significant trend.

Temperature was significantly related to IBI scores in all nine bays, with the IBI score increasing with increasing temperature. Salinity was significantly related to the IBI score in most bays (except San Antonio, Aransas and East Matagorda) with IBI scores decreasing with increasing salinity. Conversely, a positive relationship was detected for Sabine Lake. Salinity, along with IBI scores, has been increasing in Sabine Lake during most of the 1990s because of persistent drought conditions. Sabine Lake is a mesosaline system and experiences only moderate salinities during drought conditions, while other bay systems can become hypersaline which negatively affects biodiversity.

IBI scores were also significantly related to the December 1989 freeze, with some bay systems more impacted than others. Upper and lower Laguna Madre IBI scores increased significantly after the event. This may have been due to the influx of nutrients from freeze-killed organisms or from reduced competition. The Laguna Madre does not receive any significant freshwater inflow and is thought to be nutrient-limited. Other bay systems did not exhibit a significant change in IBI scores after this perturbation.

Quartiles from the distribution of the mean IBI scores by TPWD sampling grid (1-minute latitude by 1-minute longitude area) for all years combined were determined for each bay system. The quartiles were then used to graphically show the distribution of the mean IBI scores by grid within each bay system (Figures 2-10). In general, peripheral habitats (i.e., upper reaches and surrounding marshes) of each bay system had IBI scores by grid in the 3rd and 4th quartile (highest diversity scores).

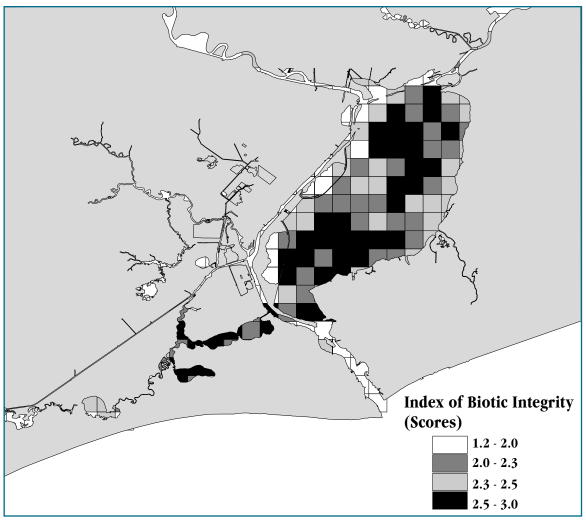


Figure 2. *Distribution of IBI scores for Sabine Lake (1986-2000).*

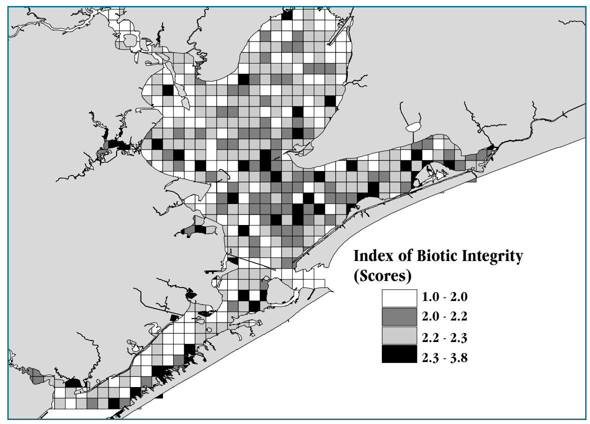


Figure 3. *Distribution of IBI scores for Galveston Bay (1982-2000).*

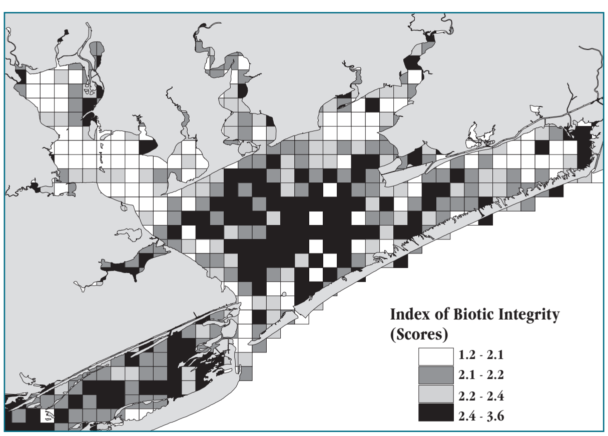


Figure 4. *Distribution of IBI scores for Matagorda Bay (1982-2000).*

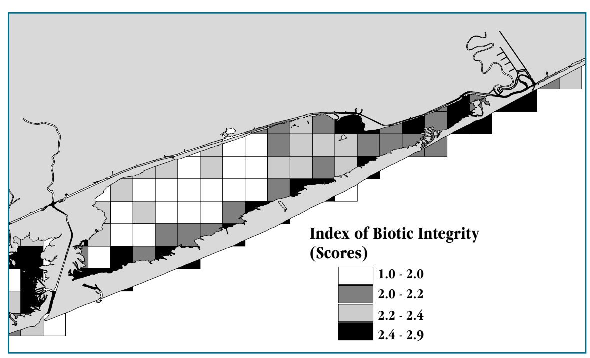


Figure 5. *Distribution of IBI scores for East Matagorda Bay (1982-2000).*

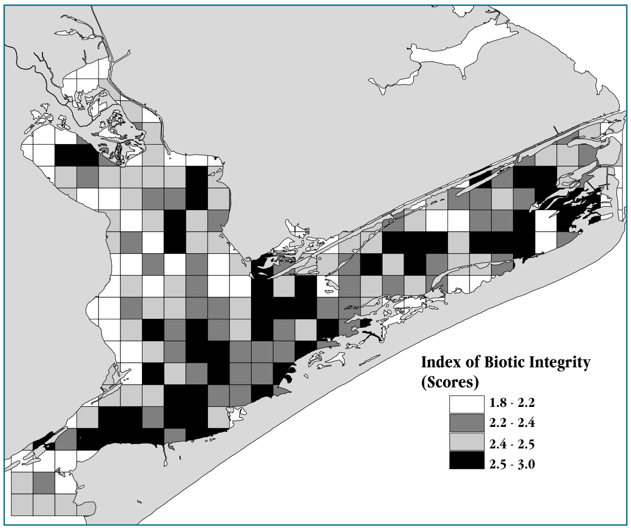


Figure 6. *Distribution of IBI scores for San Antonio Bay (1982-2000).*

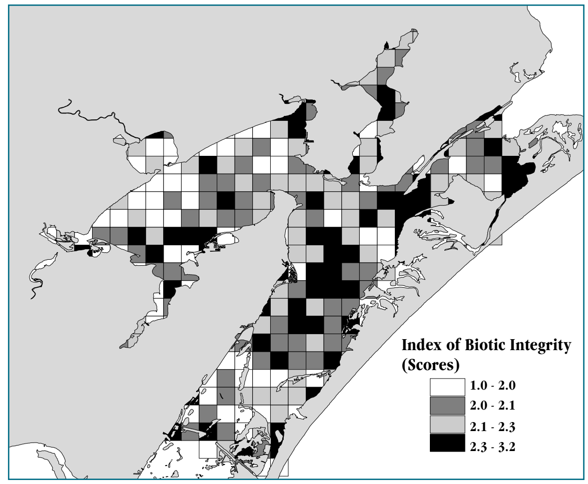


Figure 7. *Distribution of IBI scores for Aransas Bay (1982-2000).*

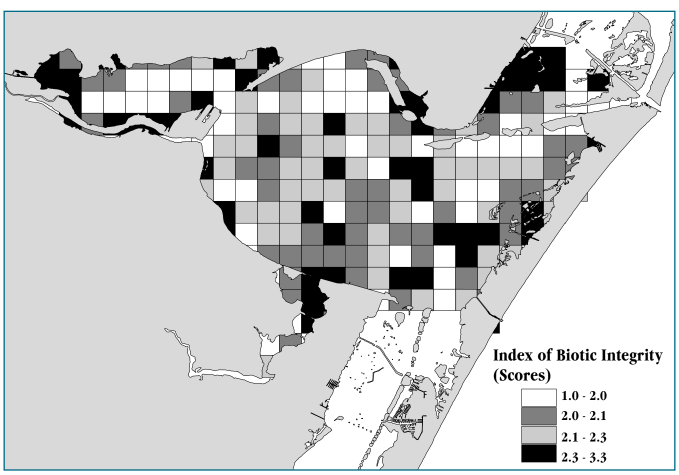


Figure 8. *Distribution of IBI scores for Corpus Christi Bay (1982-2000).*

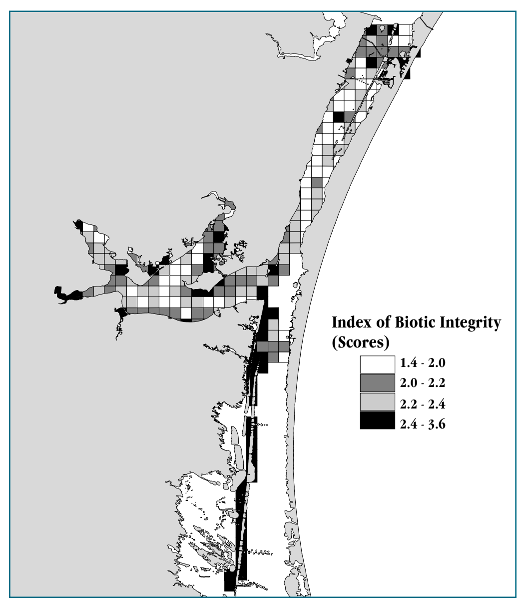


Figure 9. *Distribution of IBI scores for upper Laguna Madre (1982-2000).*

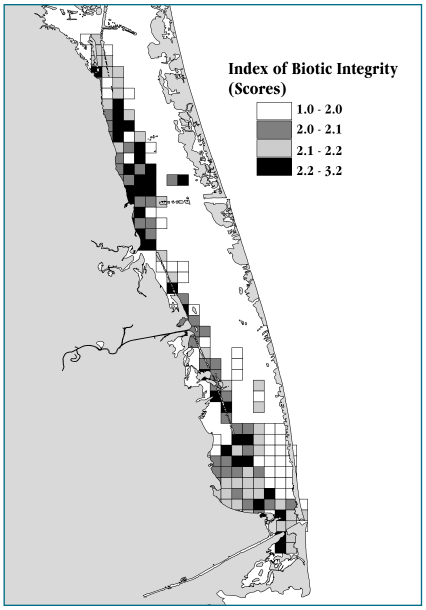


Figure 10. *Distribution of IBI scores for lower Laguna Madre (1982-2000).*

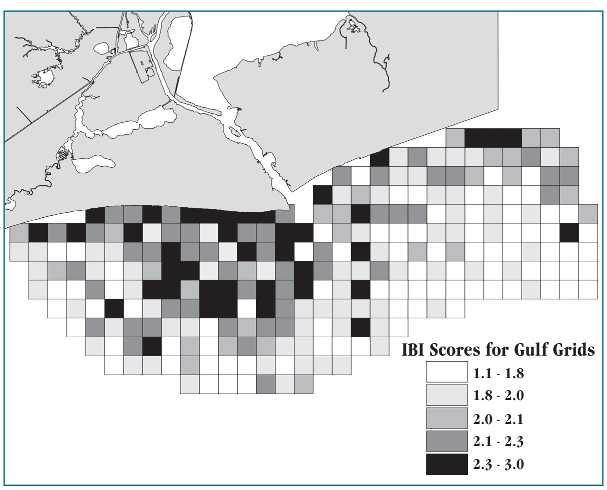


Figure 11. *IBI scores for Gulf grids at Sabine Pass.*

Nearshore Gulf Biodiversity

IBIs were developed based on fifteen metrics: permanent species (encountered at least nine months out of the year), transient species (encountered less than nine months out of the year), nektonic, demersal, sessile, vertebrates, invertebrates, total species, major shrimp, minor shrimp, number of drums, number of snappers, marine species, estuarine species and the Shannon-Weiner species diversity score.

A total of 14,161 trawl samples were collected in the TTS from 1986-2000. A total of 439 finfish and invertebrate species were identified during the sampling period.

Although there were many similarities among Gulf areas, each displayed their own unique pattern of IBI scores over time. Scores were highly seasonal and bimodal, generally with a spring peak, a smaller fall peak and were lowest in January and February. There were statistically significant increasing trends

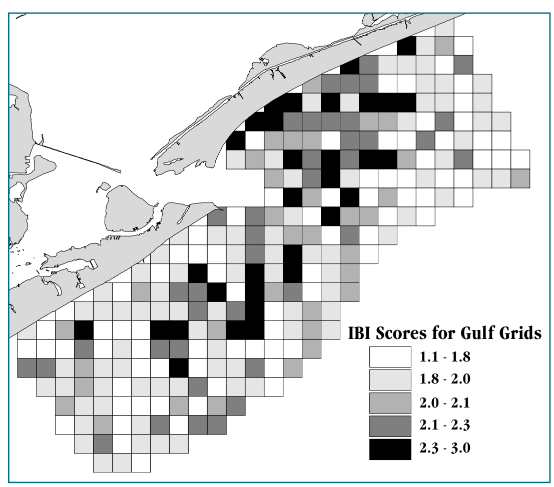


Figure 12. *IBI scores for Gulf grids at Bolivar Roads.*

in IBI scores for Sabine Pass, Matagorda Ship Channel and Brazos Santiago Pass, but no trends were detected in Bolivar Roads and Aransas Pass.

Lagged temperatures were significantly related to IBI scores for all the Gulf areas except Brazos Santiago Pass, with the IBI score negatively related to water temperatures from three months earlier. Lagged salinity was significantly related to IBI scores in Bolivar Roads and Aransas Pass only, with IBI scores positively related to salinity from three previous months.

In the Sabine Pass and Bolivar Roads areas, IBI scores were highest in grids near the passes (Figures 11-15). In the Brazos Santiago Pass area, IBI scores were highest near the mouth of the Rio Grande River, which had higher mud composition than in northern grids. IBI scores were related to sediment texture in Matagorda Ship Channel and Aransas Pass where two sediment type zones exist. Sediment texture explained over 1/4 of the variance in these two areas. For all areas combined, sediment texture explained almost 1/5 of the IBI score variance, with higher IBI scores in finer sediments and lower IBI scores in coarse sediments. Analysis indicated that shrimp are commonly found in areas inhabited by other fish and invertebrates.

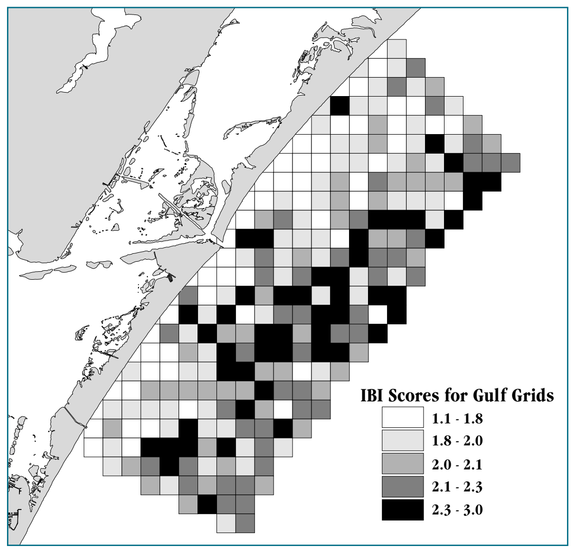


Figure 14. *IBI scores for Gulf grids at Aransas Pass.*

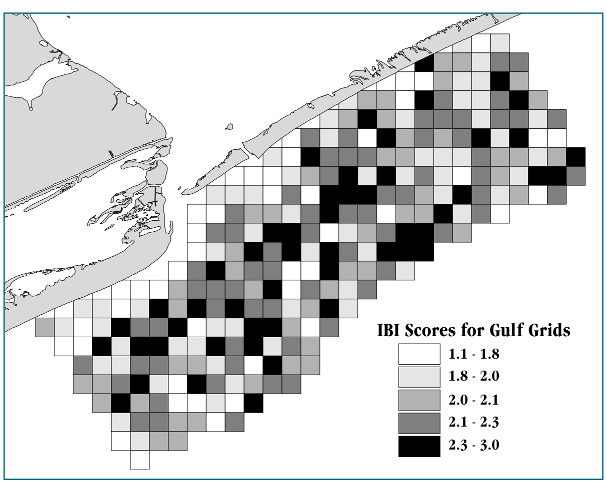


Figure 13. *IBI scores for Gulf grids at Matagorda Ship Channel.*

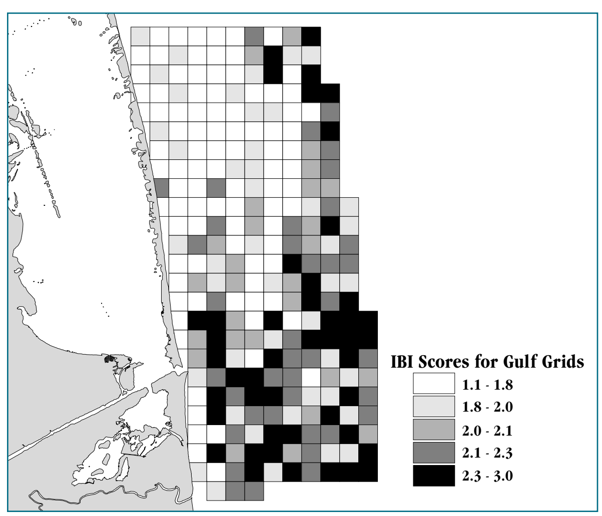


Figure 15. *IBI scores for Gulf grids at Brazos Santiago Pass.*

BYCATCH ISSUES

Bycatch, the catch of non-target species, occurs in all fisheries. In sport fisheries unwanted species generally are released without harm. However, bycatch associated with commercial net-fisheries, such as shrimp fisheries, frequently die. In some instances the commercial bycatch has value and can be sold, but in many cases it is discarded. Unfortunately, bycatch species may be caught in sufficient numbers to cause overfishing and alteration of the marine ecosystem.

In Texas, bycatch associated with the shrimping industry is of concern. Atlantic croaker (*Micropogonias undulatus*) is an example of a Texas inshore fish population affected by its incidental catch in shrimp trawls. These fish are reported to live to about age-8 and begin spawning at about age-1. Atlantic croaker populations began to decline in the 1950s. In the early 1970s it was estimated the drum family of fishes (including Atlantic croaker) made up 70% of the bycatch and Atlantic croaker were a major component of it. By the early 1990s the Atlantic croaker population had declined in both size and number, becoming mostly juveniles and a single year class of spawning individuals.

In the offshore waters of the Gulf of Mexico, trawling has also affected important recreational and commercial species such as red snapper (*Lutjanus campechanus*). Combined catches of the recreational and commercial fishery began a steady decline in 1983, reaching a low in 1990. Implementation of quotas and size limits in 1991 stopped the decline but stock assessments suggested recovery was being slowed because age-0 and age-1 red snapper were being caught in shrimp trawls and discarded at a rate greater than the catch rate of the directed fisheries. To reduce the red snapper bycatch, the National Marine Fisheries Service (NMFS) began requiring the use of bycatch reduction devices (BRD) by the Gulf of Mexico shrimp fleet in 1998.

A search for methods of reducing bycatch in the shrimping industry has been conducted worldwide. Closing areas and times to shrimping can be effective in reducing bycatch. However, management efforts have generally been concentrated in two areas: modification in construction of the trawl or the addition of devices to the trawl. Types of BRDs that have been tested most frequently in the southeastern U.S. are the fisheye and the large mesh extended funnel (Figure 16). Currently BRDs are required in trawls in federal waters of the Gulf of Mexico and South Atlantic. North Carolina, South Carolina, Georgia and Florida also require BRDs to shrimp in their state waters. The Commission mandated the use of BRDs in Texas waters beginning September 2001.

Bycatch in Texas Bays

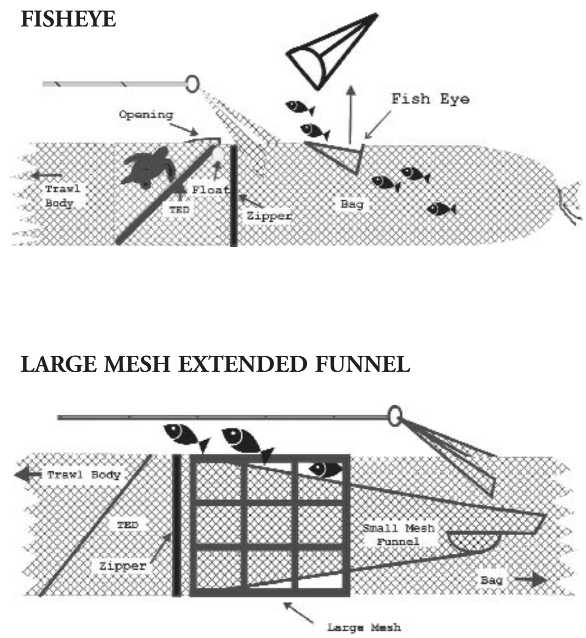
TPWD conducted studies in 1993, 1994 and 1995 in most Texas bays to assess the composition and magnitude of bycatch associated with the spring and fall bay shrimp fisheries. These studies, which were done prior to the mandated use of BRDs, found bycatch:shrimp ratios ranged from 1.5 to 11.8 (median 4.3) (i.e., 1.5 to 11.8 pounds (lbs) of bycatch for each 1 lb of shrimp) depending on the bay and season. The studies indicated that Atlantic croaker, sand seatrout (*Cynoscion arenarius*), Gulf menhaden (*Brevoortia patronus*), bay anchovy (*Anchoa mitchilli*), blue crab (*Callinectes sapidus*) and lesser blue crab (*C. similis*) are some of the most common species caught as bycatch in the spring and fall seasons. In addition, the important recreational and commercial flounder (*Paralichthys* spp.) fisheries are impacted by bycatch.

Evaluation of BRDs in Texas Bays

Several studies have been conducted by TPWD to evaluate the effectiveness of BRD usage in Texas bays. In 1997, a study conducted in Aransas Bay indicated the large mesh extended funnel was the most effective of the three devices tested, significantly reducing weight of total bycatch (13%) and invertebrates (18%), other than shrimp, in the spring season. In the fall season the large mesh extended funnel significantly reduced total bycatch (44% in numbers and weight), finfish (49% in numbers and 54% in weight) and invertebrates (25% in numbers and 22% in weight). However, shrimp catches in the fall season were also significantly reduced (21% in numbers and 15% in weight).

In 1999 three different placements of the fisheye and one placement of the Seaeagle® was tested in West Matagorda Bay. The Seaeagle® is a modified fisheye with a plastic flap that opens while the trawl is being fished but closes to prevent loss of shrimp when trawling ceases. Analysis of the data suggest the Seaeagle® was the most effective device tested,

Figure 16. *Diagram of commonly used fisheye and large mesh extended funnel BRDs in relation to TEDs.*



reducing total bycatch numbers and weight by 15% and 12%, respectively, and finfish numbers and weight by 18% and 10%, respectively, without loss of shrimp.

In 2000 the fisheye and the Seaeagle® were tested in Galveston Bay. The fisheye was the more effective of the two devices. In the spring the fisheye reduced total bycatch by 51% in numbers and 46% in weight. The fisheye reduced finfish numbers and weight by 57% and 62%, respectively. In the fall the fisheye reduced total bycatch numbers and weight by 20% and 19%, respectively, and finfish numbers and weight by 32% and 33%, respectively.

Management Implications

Reducing the catch of unwanted species in shrimp fisheries is a focal point of state, national and international research and management. The annual bycatch in Texas waters is about 80 million lbs from the bays and 200 million lbs from the Gulf off Texas. This unwanted catch affects the quality of the targeted product, reduces efficiency, can adversely affect the population of the bycatch species and can create user conflicts.

Recognizing that the most effective devices for reducing bycatch in Texas marine waters are undergoing research and development, initial definitions of required BRDs are broad. Additional studies with BRDs to further reduce bycatch in shrimp trawls should be continued by TPWD. The shrimp industry should also be encouraged to develop devices, means and methods that are effective in reducing bycatch.

SEA TURTLE CONSERVATION

Turtles were the first commercial fishery in the southeastern U.S. due to their abundance and their ease of capture during nesting. The method of capture for sea turtles included gill nets, seining, harpooning, diving and by hand while nesting on beaches. All of the five most common sea turtles found along the U.S. coast (the Atlantic green, the hawksbill, the leatherback, the loggerhead and the Kemp's ridley) were fished.

In the 1840s, several turtle canning factories opened along the Texas coast. Commercial fishing for turtles increased dramatically during the 1880s and peaked during the mid-1890s with landings totaling over 1.1 million lbs. Since then, commercial fisheries, habitat destruction and pollution have threatened sea turtle populations in both the U.S. and the world. Finally, the U.S. Endangered Species Act of 1973 and subsequent amendments provided legislation to prevent the extinction of these animals.

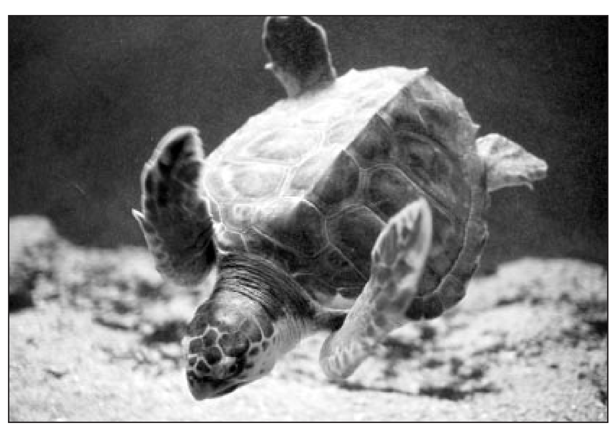
Texas Marine Sea Turtle Life Histories

The Atlantic green sea turtle has a worldwide distribution. They are long-range migrants, traveling between their feeding areas and nesting beaches. As adults they eat primarily a vegetarian diet consisting of algae and seagrasses.

The hawksbill sea turtle favors the relatively clear and shallow water of the Atlantic, Pacific and Indian oceans. Hawksbills are omnivores feeding on algae, seagrasses, sponges, soft corals, crustaceans, mollusks, jellyfish and sea urchins. Sexual maturity in this species is not reached until 20 to 40 years of age. Declines have been noted in hawksbill populations in the Caribbean, although one population nesting on the Yucatan Peninsula has increased significantly due to a diminishing tortoise shell trade and increased law enforcement.

The leatherback is the largest of the sea turtles, weighing up to 1,300 lbs. They are widely distributed and have migrations that cover distances greater than 1,750 miles. Leatherbacks are known to feed on jellyfish and other pelagic, gelatinous animals. They have a life span between 30-50 years and become sexually mature within 8-20 years. Most estimates of population trends of leatherbacks indicate declining abundance.

The loggerhead sea turtle is found in shallow tropical and sub-tropical waters. Adults weigh up to 350 lbs. They are carnivorous, feeding on benthic shellfish such as crabs, oysters, mussels and shrimp. Loggerheads have a life span of 50-100 years and reach sexual maturity at age 20-30 years. Loggerheads are declining in abundance in the northern portion of their range and around the Yucatan Peninsula but appear to be increasing in south Florida.



The Kemp's ridley is the smallest of the world's sea turtles, weighing between 70-100 lbs. Their range includes the Gulf of Mexico and the Atlantic extending north to Newfoundland. Kemp's ridleys inhabit shallow coastal areas where they feed on crabs, clams, mussels, jellyfish, sea urchins, squid, shrimp and small fish. They become sexually mature between 8-13 years of age and live 60-100 years. Kemp's ridley turtles were placed on the endangered species list in 1970.

Sea Turtle Management

Kemp's Ridley Recovery Efforts

The Kemp's ridley is the most seriously endangered sea turtle. The major nesting beach for Kemp's ridleys is at Rancho Nuevo, Mexico. Females come ashore during the day in large aggregations to deposit their eggs. During the late 1940s, it was estimated that over 40,000 females nested on Rancho Nuevo beaches. Over the next two decades, the Kemp's ridley population declined significantly probably due to the exploitation of eggs. The Mexican government took steps to protect nesting beaches beginning in 1966. Since 1985, there has been an increase in the annual number of nests on Mexican beaches (Figure 17), with the current number of nests at well over 5,000.

In 1977, the Mexican and U.S. governments agreed on a conservation program to provide greater protection for the Kemp's ridley. The program is designed to increase the wild population through protection of nesting beaches and establishment of a secondary nesting site on Padre Island, near Corpus Christi, Texas, through "head-starting." The potential benefit of a second nesting area is to create a supplemental breeding site for natural recruitment of the Kemp's ridley and to protect the population

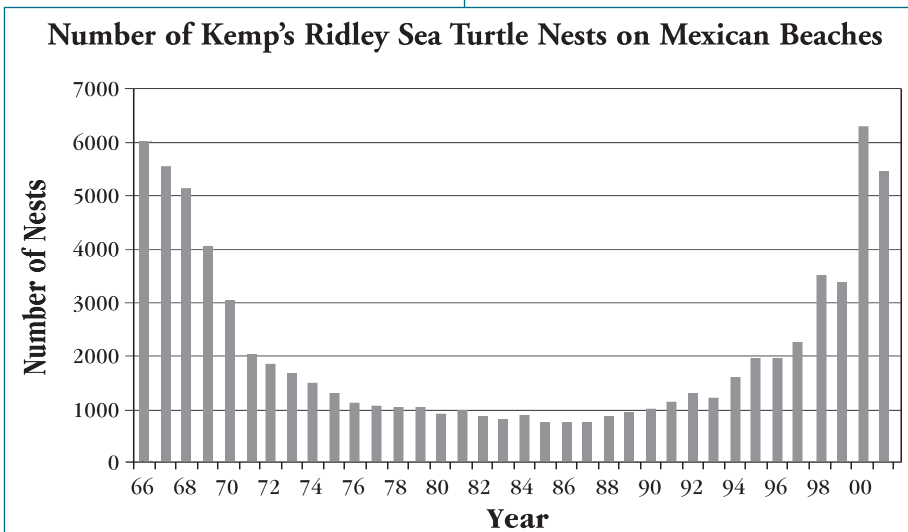


Figure 17. *Kemp's ridley nests per year on Mexican beaches.*

recovery against catastrophic events that could occur at Rancho Nuevo. In this program, from 1978 to 1988, 15,875 Kemp's ridley hatchlings were imprinted on Padre Island sand and taken to the NMFS laboratory in Galveston for one year of protected growth and marking. A total of 13,275 yearlings were then released into the Gulf of Mexico. In 1996, two of the marked hatchlings returned to the Texas coast to nest. Through 2001, ten marked Kemp's ridleys have returned to nest on Padre Island. Head-start programs and hatchling protection efforts have likely contributed to increases in numbers of juveniles and adults in the Gulf.

Protective Measures

The U.S. Endangered Species Act protects sea turtles from being harvested, possessed or even disturbed. This includes the turtles in state and federal waters off Texas. A turtle excluder device (TED) (Figure 16) is required under state and federal law in all shrimp trawls with a few exceptions. Nesting females are also given extra protection during the nesting season.

An increase in mortalities associated with shrimping occurred in 1994, prompting NMFS to enact an emergency plan calling for additional law enforcement and modifications of some TED rules. In 1999, a memorandum of understanding between U.S. and TPWD law enforcement enabled Texas game wardens to enforce federal TED regulations. Then, a Commission regulation requiring the use of an approved TED in the TTS was implemented beginning September 2001.

Mortality

Causes of mortality are similar among all species of sea turtles and increased commercial shrimping effort has often been blamed for the decline in sea turtle populations. Significant correlations have been found between strandings of sea turtles and shrimp-

ing effort in the nearshore waters of Texas and Louisiana. From 1980-1997, the Sea Turtle Stranding and Salvage Network documented 9,489 sea turtle strandings in states bordering the Gulf of Mexico. However, the widespread use of TEDs did not occur until about 1990. Almost half of the strandings (4,657) occurred along the Texas coast and it has been estimated that 70-80% of the turtles stranded during the shrimping season in Texas were caught and killed in shrimp trawls.

Despite current mandatory use of TEDs and reported high compliance with TED regulations, there continues to be a correlation between shrimping effort in Gulf waters off Texas and sea turtle strandings on Texas beaches. Some of the strongest evidence that bottom trawling results in increased sea turtle strandings is the decrease in strandings during periods of a closure (Figure 18). Nearly every year since 1981, shrimp trawling has been prohibited off the Texas coast out to 200 miles in early summer. Recent data for 2001 indicate strandings were reduced by 13% as compared to the previous five year average. This decline coincides with new TTS shrimping restrictions enacted by the Commission in 2000.

Research has shown that Kemp's ridley and loggerhead turtles are attracted to shrimping areas. Analysis of digestive tract contents in Kemp's ridley turtles in Texas has documented consumption of species that are routinely discarded as bycatch by shrimp trawlers. Over the past five years, there have been more loggerhead turtle strandings than any other species of sea turtle. However, more adult Kemp's ridleys are now found stranded in Texas than in any other state in the U.S. or Mexico. There is high shrimping pressure along the entire Texas coast, however, there is a higher incidence of strandings on the southern coast versus the northern coast. This

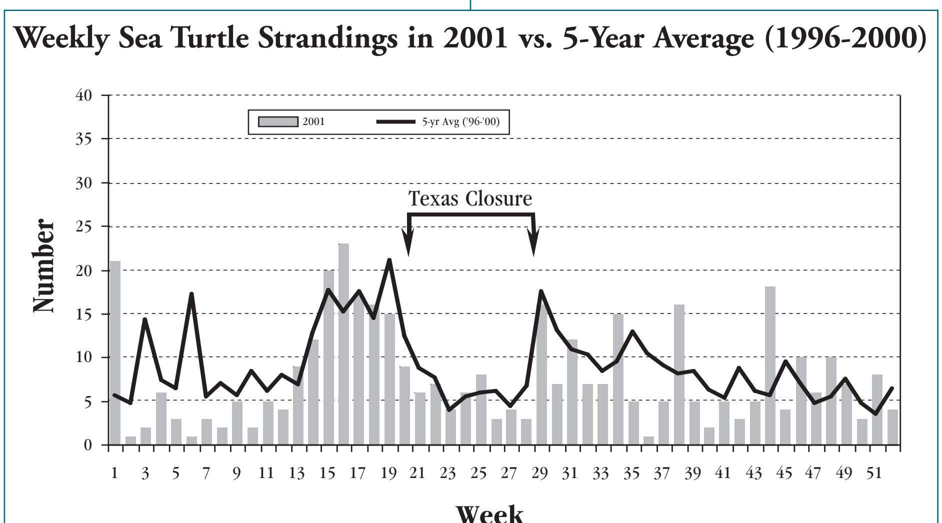


Figure 18. *Sea turtle strandings in 2001 compared to the five-year average (1996-2000).*

correlates with the documented larger concentration of sea turtles in the southern coastal region.

All five species of sea turtles that occur in the Gulf are also found in areas exploited by pelagic longline fishers. The type of encounters with longline gear appears to be determined by feeding behavior and environmental conditions. The most commonly observed longlining problem has been with leatherback turtles from entangling or foul-hooking.

There were 118 Kemp's ridley sea turtles documented as being caught during 1980-92 by recreational fishers. One hundred and one (86%) were unharmed and released alive. In addition to incidental recreational catch, discarded or lost monofilament fishing line can entangle or be ingested by sea turtles. During 1980-92, 182 stranded sea turtles had been entangled in monofilament fishing line and 94 turtles had ingested monofilament line and/or fishing hooks.

Debris and trash on nesting beaches and drifting in coastal waters are also potential threats to all species of marine turtles. Marine debris ingested by sea turtles may ultimately cause their death. Ingested items include plastic, pieces of balloons, monofilament line, fishing hooks, tar and oil.

The vast majority of sea turtle or sea turtle egg poaching occurs in Third World countries where turtles and eggs are supplemental sources of protein. In addition to poaching and illegal harvest of sea turtles, predation by various animals pose additional threats to turtle populations. Highest mortality among first-year young occurs in the first hour after entering the sea, and most of the predators are fish.

Ecotourism

The Marine Turtle Specialist Group of the Species Survival Commission of the World Conservation Union has endorsed ecotourism as a partial solution to the problems facing sea turtle populations in the face of a growing human population. Sea turtle ecotourism is relatively new but has had a few forerunners in both the public and private sectors. Visitors have come to Padre Island National Seashore to attend sea turtle hatchling releases for many years. Hundreds of visitors assemble multiple times each summer to watch the hatchlings crawl to the water's edge and enter the surf. There is strong public interest and support for the sea turtle conservation efforts on Padre Island.

MANAGING FOR SUSTAINABLE SHRIMP STOCKS

Shrimp caught in Texas waters are part of common stocks that range throughout the Gulf of Mexico. Texas regulates the shrimp fishery within its bays and the TTS. NMFS and the Gulf of Mexico Fishery Management Council (GMFMC) regulate the shrimp fishery from the TTS offshore to 200 nm in the Gulf of Mexico.

More than just their food value, shrimp also play a significant ecological role in many tropical and temperate marine ecosystems. They form an important link in the energy flow of food webs by feeding on benthic organisms, detritus and other organic material found in sediments. The sustainability of shrimp stocks, thus, can lead to substantial biological, economic and social benefits. To prevent overfishing and rebuild depleted marine stocks, NMFS has called for a precautionary approach in resource management decisions. This approach is designed to be proactive, using management actions that balance the expected benefits from fishing against the potential risk to the resource.

Theoretical Management Concepts

Natural Populations

Regulation of animal abundance occurs continuously because of environmental factors that promote an increase in biomass through growth and reproduction, and those that promote a decrease through natural mortality. Natural populations tend to preserve a state of stable and self-regulated balance once they achieve equilibrium among these influences. The maximum population abundance will be regulated by the ability of the environment to sustain that species, called the carrying capacity of the habitat.

Effects of Fishing

The introduction of human influences on animal populations alters the equilibrium that is characteristic of a natural state. Fishing effort invariably reduces the stock size but also increases the rate of biological productivity (individual growth and reproduction) as the population tends to rebound to its former carrying capacity. If the harvest each year equals the highest possible annual sustainable biological productivity, then that harvest will be the maximum sustainable yield (MSY) (Figure 19). If the population is again subjected to even more fishing effort, then the stock will produce lower available harvest and reduced equilibrium stock size.

MSY and MEY

Fishery managers have historically attempted to regulate fishing effort to a level corresponding to MSY in weight to assure maximum production from a public resource. However, even greater public benefits are possible by managing for maximum economic yield (MEY) (Figure 19). This advice is based on the decreases in per unit profit (revenue minus cost) that occur with increases in per unit effort as the fishery approaches MSY. At MEY the difference between the cost of harvesting and the value of the harvest is the greatest, producing the largest profit margin for the industry. If fishing effort moves beyond MEY and MSY, the resource is not being managed for either maximum production or profits and is subject to greater risk of overfishing.

Overfishing Definitions

Shrimp stocks can be subjected to several types of overfishing. Growth overfishing occurs when total yield or mean size decreases with increasing effort. Shrimp are caught before they grow to a size large enough to substantially contribute to the biomass. Since larger shrimp are generally more valuable than smaller shrimp, lost economic potential for the industry can result from growth overfishing. In addition, because shrimp are taken earlier in their life cycle, they have less opportunity to mature and spawn. Excessive growth overfishing can also lead to recruitment overfishing.

A second type of overfishing, biological overfishing, occurs when harvest falls below maximum sustainable harvest due to increasing fishing pressure and reduces biological productivity. In Figure 19 any point on the graph to the right of MSY would be considered biological overfishing. Declines in catch per unit effort (CPUE) can be indicative of biological overfishing. If biological overfishing is excessive, it can lead to recruitment overfishing.

Recruitment overfishing occurs when there are too few adults to produce the maximum number of individuals for the next generation. In effect the carrying capacity of the habitat for shrimp would be underutilized. In general shrimp species are considered to be resilient to high fishing mortality because of their high annual fecundity. However, if the number of adult spawners decline, the health of the shrimp population becomes more susceptible to ecological disasters that could suddenly even further reduce the spawning capabilities.

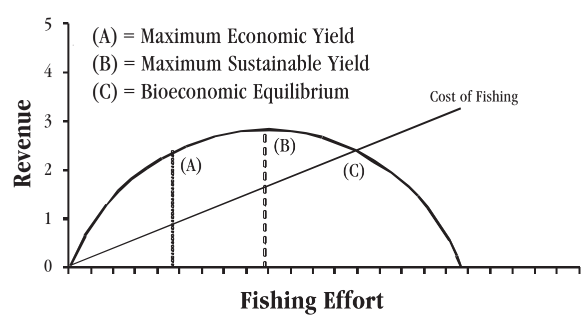


Figure 19. *Relationship of revenues and yield to fishing effort.*

Management Concerns

International

Shrimp fisheries have evolved differently around the world, but many have ultimately reached a common point of full- or over-exploitation. Shrimp recruitment was long considered independent of the adult stock size but that assumption has been effectively challenged. Saudi Arabia, Kuwait, Bahrain, Qatar, the United Arab Emirates, Australia, Indonesia, China, India, Senegal, Brazil and Nicaragua all have suffered severe declines in shrimp production which have largely been attributed to overfishing.

Gulf of Mexico

Mexico: Mexico's commercial shrimp fisheries in the Gulf of Mexico have also been negatively affected. Growth overfishing of white and brown shrimp by artisanal inshore fishing effort has caused serious economic losses to the overall shrimp industry and increased the risk of losing shrimp resource sustainability.

Northern Gulf: For the U.S. shrimp fishery in the northern Gulf of Mexico, scientific research concluded that fishing effort was clearly affecting stock abundance and that harvest of small shrimp was reducing yield. Researchers have emphasized that the minimum size of shrimp fished should be increased to a significant degree to economically take advantage of shrimp's rapid growth. Expansion of fishing pressure on shrimp was also discouraged because of the possibility of stock and recruitment declines.

Texas: For the Texas shrimp fishery specifically, scientists found excessive shrimping effort primarily in the bays and shallow offshore waters during spring and early summer. As a result, both brown and white shrimp experienced growth overfishing. Modeling efforts indicated optimal harvest could occur through a substantial reduction in bay landings and a shift in small shrimp landings in favor of larger sizes. Reduced shrimping effort and improved size distribution provided gains to both producer and consumer group benefits.

Current Status: The current status of Gulf of Mexico shrimp stocks in U.S. federal waters is measured by NMFS using an index based on commercial shrimp fleet landings of mature shrimp. This definition illustrates the difficulty managers have had in collecting relevant data and in adequately measuring overfishing in shrimp stocks. Because of the current uncertainties in fisheries data, scientists have suggested the need for a more risk averse approach, by defining overfishing with a defalut of 75% of MSY in the absence of other information. While no species of shrimp in the Gulf of Mexico has been reported to be recruitment overfished, all stocks are considered to be fully exploited and any increases in shrimping effort would not produce a substantially greater yield.

Trawling Efficiency

Compounding the concern associated with this fully exploited stock is a long-term decline in CPUE and size of shrimp landed from the Gulf of Mexico. The CPUE decline is less steep than it would otherwise be because the effort data from the shrimp fleet are not standardized and do not account for increases in trawling efficiency. For the Texas shrimp fleet, a 25% increase in efficiency from the 1960s to the early 1990s in the harvesting capacity of both bay and Gulf trawlers has been documented. Most of this increase in fishing power came from improvements in vessel size, vessel engines, number and size of trawls and electronic equipment. However, this increase in efficiency has likely been moderated somewhat by additional conservation measures and trawl gear modifications, such as BRDs and TEDs.

Management Strategies

Environmental Influences

Environmental influences such as water temperature, salinity, habitat types and predation are known to play important roles in growth and survival of shrimp. However, analyses have found fishing effort in some cases accounted for 60-70% of the variability in catch. Environmental effects on recruitment, although an acceptable explanation for short term fluctuations in yield, are unlikely to have been the major cause of long term declines in yield. Control of exploitation on species like shrimp, which are susceptible to environmental as well as fishing effects, will be increasingly necessary as fishing efficiency advances and coastal habitat and water quality and quantity are compromised.

Regulatory Tools

Conservation of essential shrimp habitat has been cited as a critical on-going management goal. Fishery managers, however, generally have more control over fishing pressure than over environmental conditions. Useful management tools include: limitation on vessel numbers, license buybacks, permanent closures of nursery habitats, time and area closures, minimum size limits, mesh and gear restrictions, and vessel size and power restrictions. Closure of inshore juvenile shrimp habitat has been noted as having greater benefits for the fishery than offshore closures. To effectively apply these regulatory measures, however, extensive data sets are needed on an on-going basis on both the fishery stocks and the affected stakeholders.

Management Objectives

The Texas legislature has directed the Commission to both prevent overfishing of the resource and achieve optimum yield for the fishery. Optimum yield was defined in the FMP as "the amount of shrimp that the fishery will produce on a continuing basis to achieve the maximum economic benefits to the shrimping industry and the state as modified by any relevant social or ecological factors". This management strategy is similar to those currently recommended for many other marine fisheries.

STATUS AND TRENDS OF COMMERCIAL SHRIMP IN TEXAS

The Texas commercial shrimp fishery is primarily a trawl fishery that harvests from both bay and Gulf waters for food or bait. Principal species landed are brown shrimp, white shrimp and pink shrimp. On average, Texas commercial shrimp landings are comprised of 74% brown shrimp and pink shrimp, 25% white shrimp and 1% “other” species. Other shrimp species landed in Texas include seabobs (*Xiphopenaeus kroyeri*) and rough-back shrimp (*Trachypenaeus* sp.), and from outside the TTS, within federal waters, royal red shrimp (*Hymenopenaeus robustus*) and rock shrimp (*Sicyonia brevirostris*).

Texas commercial shrimp are monitored with both fishery independent and fishery dependent data. Fishery independent data include TPWD bag seine, bay trawl and Gulf trawl sample data, and NMFS trawl data. Fishery dependent data include NMFS bay and Gulf shrimp landings and catch data, TPWD commercial bay and bait landings data and TPWD recreational fishery bait-use data. Additionally, TPWD has monitored shrimp size and abundance since 1959. TPWD also monitors shrimp mariculture facilities, which commercially produce almost exclusively non-indigenous Pacific white shrimp (*Litopenaeus vannamei*).

Fishery Independent Data

Bag seines and trawls were used to collect samples at randomly selected sites in the nine major bay systems and five Gulf areas along the Texas coast. Bag seine data refers to samples collected from 1977-2000, bay trawl data from 1982-2000 and Gulf trawl data from 1986-2000. Bag seines are collected along bay shorelines and sample juvenile organisms. Bay trawls are collected in deeper bay waters (greater than 3 ft) and sample mainly sub-adults. Gulf trawls are collected within the TTS and sample sub-adult and adult organisms. Data are summarized for mean total length (TL) and CPUE; number per acre (No/ac) for bag seines and number per hour (No/h) for trawls. For each gear and species, TL and CPUE were tested by bay system and coastwide for statistically significant trends across years.

Fishery Dependent Data

Commercial Landings Data

Landings of marine species from Texas bays and the Gulf off Texas have been collected from seafood dealers since 1887. These data were collected sporadically until 1936 when the Texas Game, Fish and Oyster Commission initiated annual surveys. Since 1936 TPWD has monitored landings and value of marine finfish, oysters, crabs and shrimp through a

mandatory self-reporting system known as the Monthly Aquatic Products Report which is completed by the seafood dealer. Since 1956 NMFS has collected landings data on shrimp through dealer reports and vessel crew interviews. In 1985 NMFS and TPWD instituted a formal cooperative agreement to collect and exchange fisheries statistics. NMFS currently collects commercial shrimp data (except bait) and TPWD collects all other commercial data.

Bait Shrimp Use Data

TPWD has collected marine sport-boat harvest data with trip-ending interviews along the Texas coast since 1974. For each fishing party, landings were enumerated (identified, counted and measured), fishing effort was determined (number of anglers times trip length) and anglers were queried as to how they were fishing (gear and bait) and where the landings were obtained. Beginning in May 1983, angling parties were queried about the source (bought live, bought dead or caught by anglers) and amount of bait shrimp acquired for each fishing trip.

Fishery Independent Data Trends

Bay Bag Seine Data: 1977-2000

<u>Brown Shrimp</u>: During the period since 1977, average brown shrimp CPUE has been highest April-June, with greatest abundance during May, while average length was greatest during June and July and lowest during January. Annual average CPUE significantly increased coastwide (Figure 20), especially in Sabine Lake, West Matagorda Bay and upper Laguna Madre. However, annual average length significantly decreased in Sabine Lake,

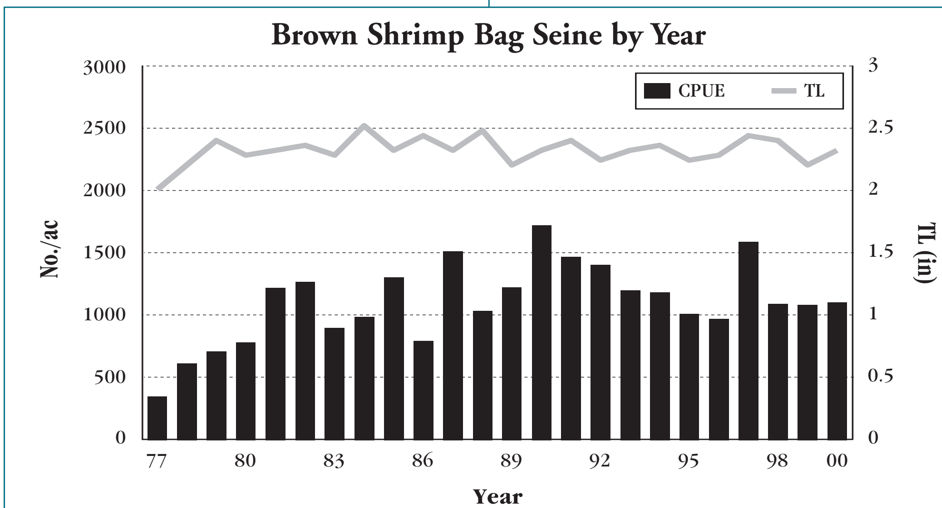


Figure 20. *Coastwide average catch rate (number/acre) and average total length (inches) by year of brown shrimp caught in TPWD bag seines, 1977-2000.*

Galveston Bay, East Matagorda Bay, West Matagorda Bay, San Antonio Bay and lower Laguna Madre during that time but did not decrease coastwide (Figure 20). Conversely, there was a significant increase in brown shrimp lengths in Corpus Christi Bay and lower Laguna Madre.

White Shrimp: White shrimp abundance was highest in October (range July to November) while length was greatest in August and lowest in June. The average annual CPUE coastwide and in Galveston Bay has shown a significant decrease since 1977 (Figure 21). The coastwide trend for annual average length during the same period has also significantly decreased, but trends for individual bays have been mixed. Galveston Bay, East Matagorda Bay, West Matagorda Bay and upper Laguna Madre have also decreased, while Sabine Lake, San Antonio Bay, Aransas Bay and lower Laguna Madre lengths have increased.

Pink Shrimp: Pink shrimp showed the highest average CPUE March-April and August-December, the greatest abundance during November, the greatest average length during May and the lowest average length during January. Both Coastwide and in West Matagorda Bay, East Matagorda Bay, San Antonio Bay and lower Laguna Madre, there has been a significant increase in annual average CPUE (Figure 22). San Antonio Bay and upper and lower Laguna Madre have demonstrated a significant decrease in annual average length. In contrast, lengths have significantly increased in Galveston Bay, West Matagorda Bay, Aransas Bay, and Corpus Christi Bay and coastwide.

Bay Trawl Data: 1982-2000

Brown Shrimp: Average brown shrimp CPUE in bay trawls was highest during May-July; average length was greatest during August and lowest during

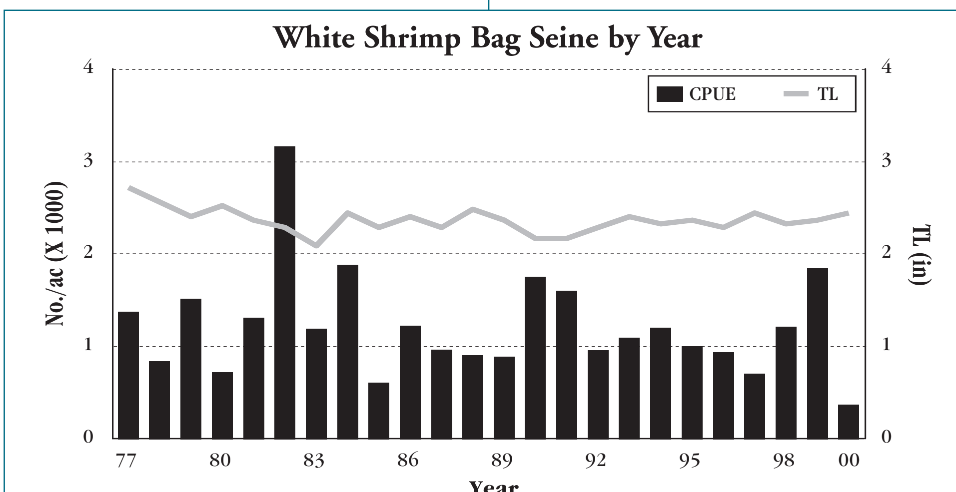


Figure 21. *Coastwide average catch rate (number/acre) and average total length (inches) by year of white shrimp caught in TPWD bag seines, 1977-2000.*

January. Annual average CPUE significantly increased in Sabine lake and Galveston Bay, but not coastwide (Figure 23). In contrast, Aransas and Corpus Christi Bay showed a significant CPUE decrease. Coastwide, average annual length decreased significantly, as did measures in Sabine Lake, East Matagorda Bay, West Matagorda Bay, San Antonio Bay, Aransas Bay, Corpus Christi Bay and upper Laguna Madre.

White Shrimp: July-December displayed the highest average CPUE, with smaller peak abundance during August. A significant decrease in annual average CPUE was found in Corpus Christi Bay and coastwide (Figure 24), while East Matagorda Bay had a significant increase. Average length for white shrimp was greatest during May and lowest during January and December. Sabine Lake, Galveston Bay, East Matagorda Bay, San Antonio Bay, Aransas Bay, Corpus Christi Bay and upper Laguna Madre displayed a significant decrease in annual average length as did coastwide data.

Pink Shrimp: Pink shrimp had their highest CPUE in bay trawls during March-May, with a minor jump in abundance during November-December. Overall, there was a significant increasing trend in annual average CPUE over time in Galveston Bay, West Matagorda Bay, upper and lower Laguna Madre, and coastwide (Figure 25). Average length was greatest during June and lowest during September. East and West Matagorda Bay, San Antonio Bay, Aransas Bay, Corpus Christi Bay, upper and lower Laguna Madre, and coastwide revealed a significant decrease in annual average length, in contrast to the trends for CPUE.

Gulf Trawl Data: 1986-2000

Brown Shrimp: Average CPUE from Gulf trawls was highest during May-July, while average length

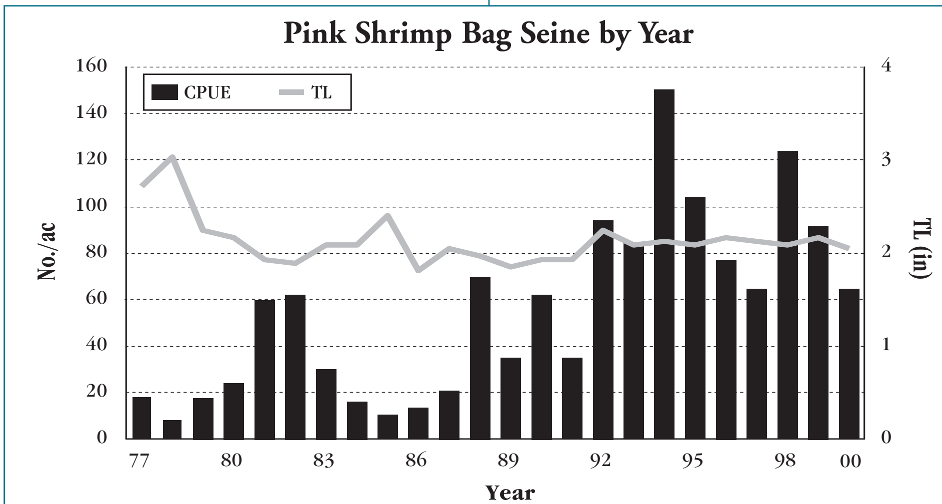


Figure 22. *Coastwide average catch rate (number/acre) and average total length (inches) by year of pink shrimp caught in TPWD bag seines, 1977-2000.*

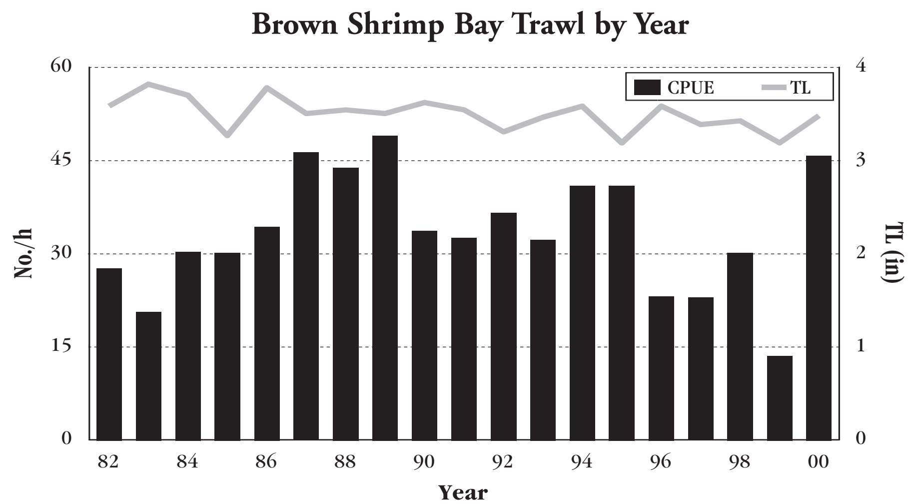


Figure 23. *Coastwide average catch rate (number/hour) and average total length (inches) by year of brown shrimp caught in TPWD bay trawls, 1982-2000.*

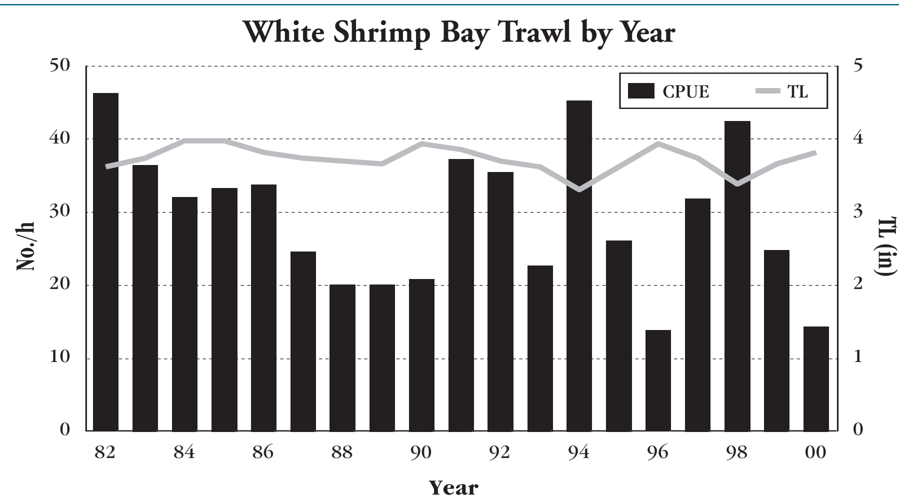


Figure 24. *Coastwide average catch rate (number/hour) and average total length (inches) by year of white shrimp caught in TPWD bay trawls, 1982-2000.*

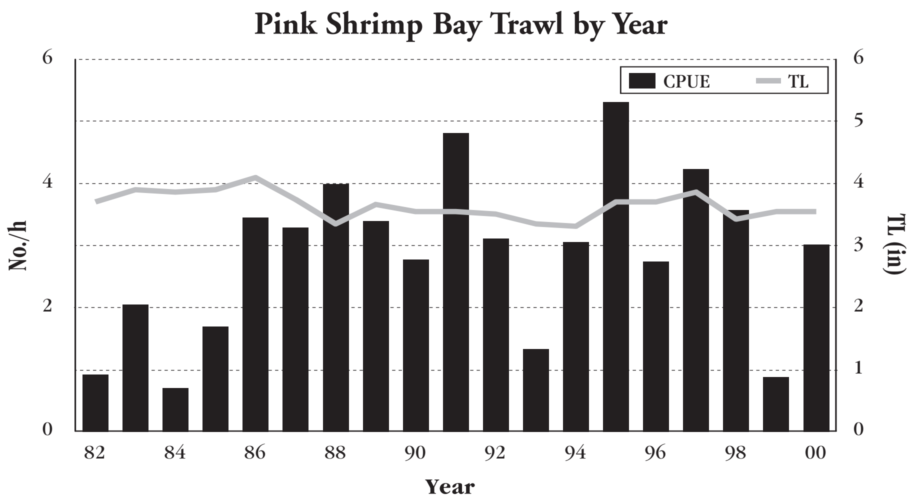


Figure 25. *Coastwide average catch rate (number/hour) and average total length (inches) by year of pink shrimp caught in TPWD bay trawls, 1982-2000.*

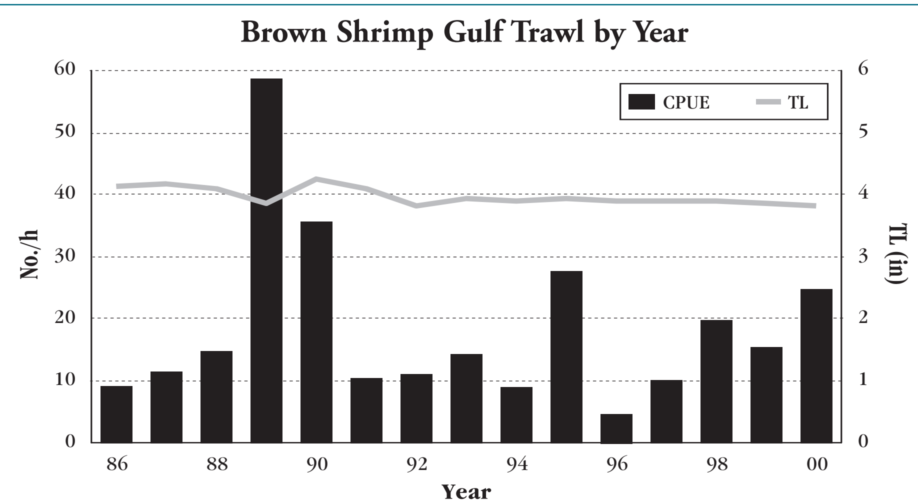


Figure 26. *Coastwide average catch rate (number/hour) and average total length (inches) by year of brown shrimp caught in TPWD Gulf trawls, 1986-2000.*

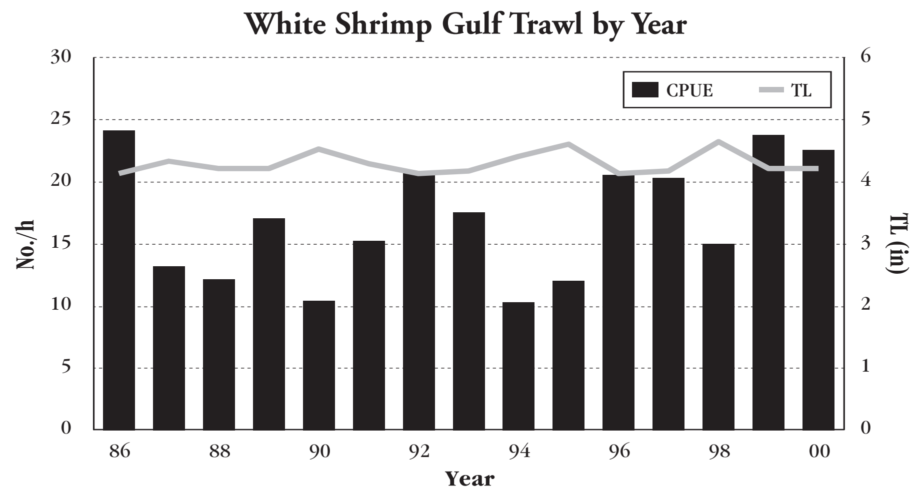


Figure 27. *Coastwide average catch rate (number/hour) and average total length (inches) by year of white shrimp caught in TPWD Gulf trawls, 1986-2000.*

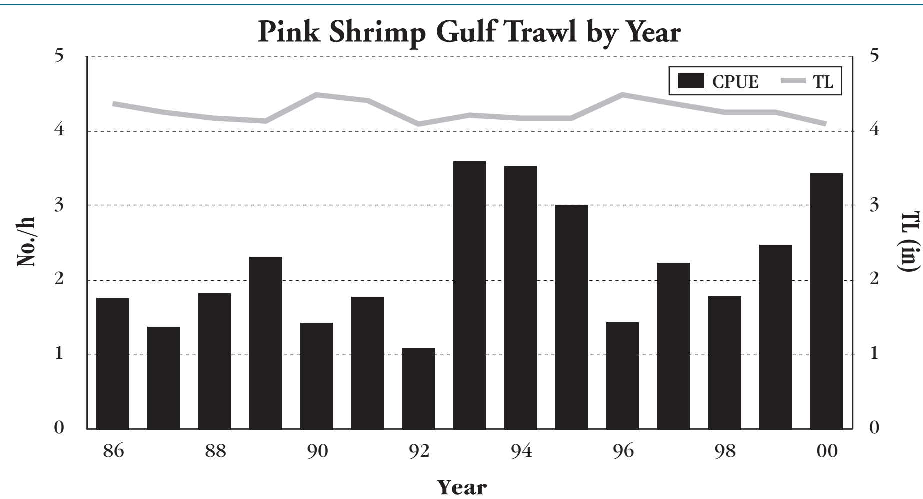


Figure 28. *Coastwide average catch rate (number/hour) and average total length (inches) by year of pink shrimp caught in TPWD Gulf trawls, 1986-2000.*

was greatest during March and lowest during May and October. Coastwide annual average CPUE showed no statistically significant trend (Figure 26), however, significant annual increases were found in Sabine Pass and significant decreases were seen in Bolivar Roads and Aransas Pass. Coastwide, annual average length decreased over time, a trend also found in Gulf waters off Sabine Pass, Bolivar Roads, Matagorda Ship Channel and Aransas Pass.

White Shrimp: Average white shrimp CPUE was highest November-January, with greatest abundance during January. Average length was highest during June and lowest during December. A significant increase in annual average CPUE was found in Sabine Pass, Aransas Pass and Brazos Santiago Pass, and coastwide (Figure 27). There was also a significant increase in annual average length off Matagorda Ship Channel and Aransas Pass but not coastwide.

Pink Shrimp: Average pink shrimp CPUE peaked during April-May, with a smaller peak in November and average length was greatest during August and least during May. Off Brazos Santiago Pass and coastwide, a significant CPUE increase was found (Figure 28), while at the same time a significant decrease in annual average length was seen off Brazos Santiago Pass, but not coastwide.

Fishery Dependent Data Trends

Commercial Effort

NMFS collects fishing effort data using nominal days fished, which is defined as actual hours of shrimping per vessel, summed for all vessels that fished and converted to total days fished. These values do not consider changes in fishing power or efficiency over time.

Annual fishing effort in the bays generally increased since 1966 (Figure 29). Shrimp trawling for brown and pink shrimp in the bays was the most dramatic, with a 10-fold increase from 1966 to the peak effort in 1994. Bay effort since then has declined substantially for all shrimp species, likely due in part to the license buyback program and the economic conditions in the industry.

Annual fishing effort in the Gulf also generally increased since 1966 (Figure 29). Brown and pink shrimp were the dominant species sought with a 72% increase in effort from 1966 to the peak effort in 1987. Gulf effort on brown and pink shrimp has generally declined since then. White shrimp effort has fluctuated widely with a 64% increase from 1966 to 2000.

Commercial Landings

Brown shrimp and pink shrimp: Landings (tails) of brown shrimp and pink shrimp in Texas bays increased substantially from 1962-1987, then fluctuated through 2000 (Figure 30). Annual landings averaged 4 million lbs and ranged from 0.2 million lbs in 1968 to 8.7 million lbs in 1991. Ex-vessel value has also increased through time. Texas bay landings had an average annual value of $5.8 million and ranged from $76,000 in 1968 to $17.7 million in 1994.

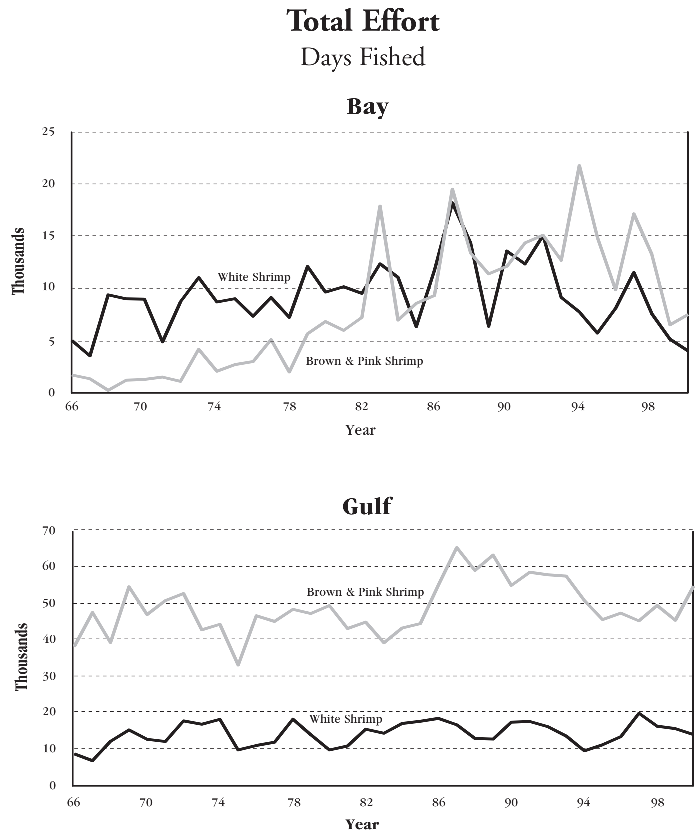


Figure 29. *Total days fished (1 day=24 hours) for brown, pink and white shrimp in the bays and the Gulf of Mexico off Texas during 1966-2000.*

Brown shrimp and pink shrimp landings from the Gulf off Texas increased substantially through 1967 and then fluctuated through 2000, showing a slight decline (Figure 30). Annual landings averaged 32 million lbs and ranged from 17 million lbs in 1997 to 48 million lbs in 1967. Ex-vessel value increased through the 1980s then declined through the 1990s. Average annual ex-vessel value of Gulf landings during 1962-2000 was $87 million and ranged from $19 million in 1964 to $158 million in 1986.

White shrimp: Landings (tails) of white shrimp in Texas bays have fluctuated from 1962-2000. Annual landings averaged 3 million lbs and ranged from 1.4 million lbs in 1967 to 4.7 million lbs in 1986 (Figure 31). Ex-vessel value of white shrimp landed from Texas bays has increased substantially over time. Average annual ex-vessel value during 1962-2000 was $8.6 million and ranged from $1.4 million in 1967 to $19.4 million in 1990.

White shrimp landings from the Gulf off Texas have varied slightly between 1962 and 2000.

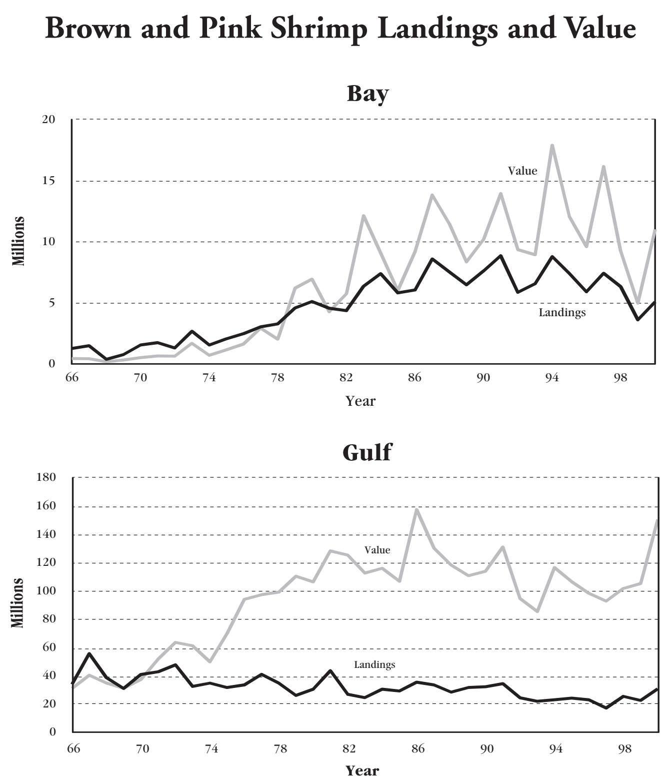


Figure 30. *Total landings (pounds) and ex-vessel value (dollars) of brown and pink shrimp in the bays and the Gulf of Mexico off Texas during 1966-2000.*

Landings averaged 7 million lbs/year and ranged from 3.0 million lbs in 1962 to 13.0 million lbs in 2000 (Figure 31). Ex-vessel value of white shrimp landed from the Gulf has also increased substantially over time. Average annual ex-vessel value of Gulf landings during 1962-2000 was $22 million, ranging from $2 million in 1962 to $66 million in 2000.

Commercial CPUE

Annual CPUE for brown and pink shrimp has fluctuated substantially, but an overall downward trend is noted in both the bay and the Gulf (Figure 32). From the peak CPUE in 1978 to 2000, bay CPUE declined 58%. Seven years between 1966 and 1984 had annual bay CPUE above 1000 lbs/day while no years since then has exceeded 700 lbs/day. Gulf CPUE declined 52% from the peak in 1967 to 2000. Ten years between 1966 and 1981 had annual Gulf CPUE above 800 lbs/day while no years since then has exceeded that value.

Annual CPUE for white shrimp has been relatively stable in both the bay and the Gulf compared to brown and pink shrimp (Figure 32). The year

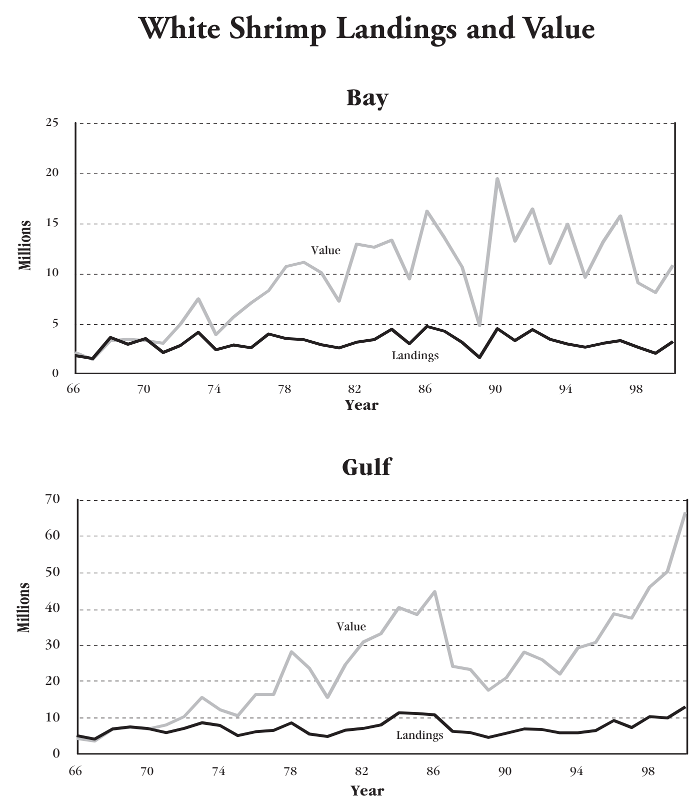


Figure 31. *Total landings (pounds) and ex-vessel value (dollars) of white shrimp in the bays and the Gulf of Mexico of Texas during 1966-2000.*

2000 produced a record CPUE in both the bay and the Gulf, although shrimping effort for white shrimp was down from recent years, particularly in the bays.

Size and Age Composition of Shrimp Landed

Shrimp caught in bays are generally smaller than shrimp caught in the Gulf. The fishery on 0-year class brown shrimp starts in Texas bays in April with shrimp of a count greater than 67 tails/lb. Overall, more than 90% (by weight) of brown shrimp and 50% of white shrimp caught in bays have a count size of greater than 67 tails/lb (Figure 33). The dominant size class in the offshore fishery is 31-40 tails/lb for brown shrimp and 16-20 tails/lb for white shrimp.

From 1959 to 1976 there was a significant trend towards decreasing size of brown shrimp landed from Texas Gulf waters. On a Gulf-wide basis, that trend has continued. The percentage of recruits to the fishery landed from each year-class has increased and average age of capture has decreased since the early 1960s.

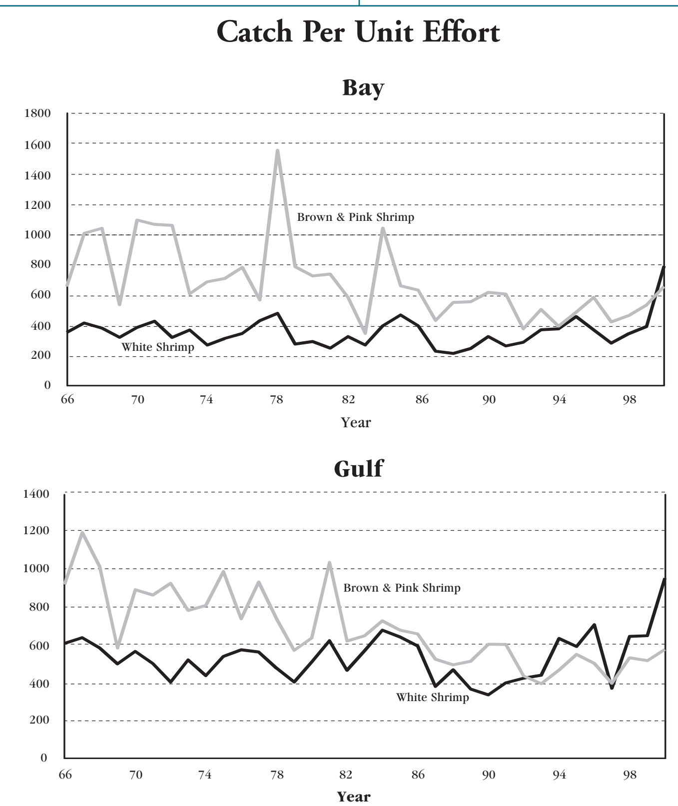
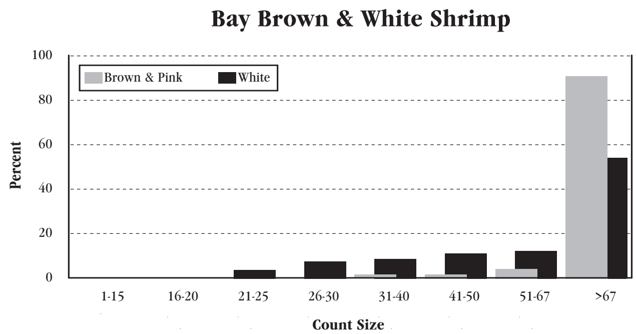


Figure 32. *Catch per unit effort (landings/days fished) for brown, pink and white shrimp in the bays and the Gulf of Mexico off Texas during 1966-2000.*

Catch by Count Size



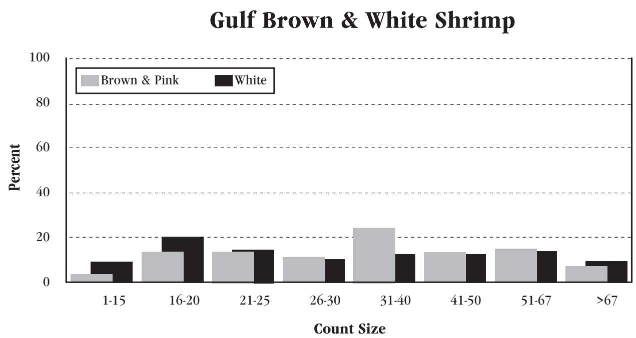


Figure 33. *Catch of brown and white shrimp by count size harvested from the bays and brown and white shrimp by count size harvested from the Gulf of Mexico during 1991-2000 (10 year mean).*

Bait Shrimp

Brown, white and pink shrimp are also landed as bait (live and dead). TPWD bait shrimp data collected since 1994 indicate that bait shrimp landings annually averaged 1.5 million lbs and ranged from 700,000 lbs in 1994 to 2 million lbs in 1997. Fifty percent by weight of live and dead bait shrimp was reported from Galveston Bay during 2000. Bait shrimp ex-vessel value averaged $3.5 million and ranged from $1.8 million in 1994 to $5.5 million in 1997.

Live shrimp was the most often used bait by private-boat anglers in Texas bay systems during 1983-1997. Dead shrimp was the second most often used bait during 1983-1987 and the fourth most often used bait during 1987-1997.

Shrimp Aquaculture Production

World shrimp aquaculture production has increased from 1.3 billion lbs in 1989 to 1.9 billion lbs in 2000. U.S. commercial aquaculture of saltwater shrimp species began in the early 1980s, with production steadily increasing since. However, aquaculture disease episodes have temporally decreased Texas and world production during various years from 1987 to 2000.

Texas is the major shrimp aquaculture production state in the U.S. Hawaii and South Carolina also have a long history of commercial shrimp farming. Arizona, Florida, Alabama, and Georgia have recently started to produce saltwater shrimp. For the last five years, Texas produced over 80% of the U.S. farm raised saltwater shrimp. Texas production has increased from around 1 million lbs in 1987 to near 7 million lbs in 2001 (Figure 34).

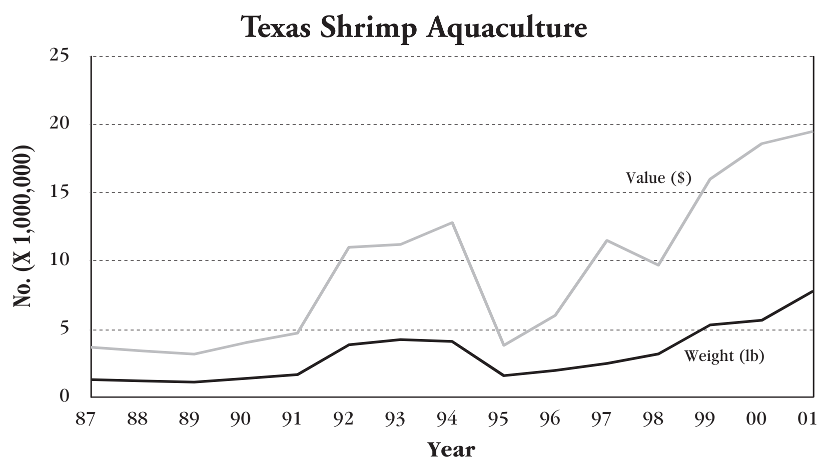


Figure 34. *Texas shrimp aquaculture production and estimated value, 1987-2001.*

SOCIO-ECONOMIC CHARACTERIZATION OF THE TEXAS SHRIMP FISHERY

U.S. commercial landings of shrimp in 2000 ranked number one in total value among all seafood with 332 million lbs, worth $690 million at the dock. The U.S. Gulf of Mexico produces 77% of this harvest worth 84% of the total national value. Texas shrimp landings and value account for about one-third of the U.S. Gulf of Mexico harvest. However, annual imports of foreign raised or caught shrimp into the U.S. are nine times higher than Texas shrimp landings. The U.S. also ranked second in value for world seafood imports, importing 12.5% of the $56.9 billion world total. The U.S. currently imports around 80% of the shrimp consumed. The shrimp fishery is the most important commercial fishery in Texas in terms of both amount landed (Figure 35) and ex-vessel value (Figure 36).

Overview of Texas Shrimp Fishermen

Commercial Shrimp Licenses

Shrimp harvesters must possess at least one of three different boat licenses (bay, bait or Gulf) to commercially harvest shrimp from Texas waters. Individuals may possess any combination of shrimping licenses and may also participate in other Texas marine fisheries.

The total numbers of commercial shrimp boat licenses for all three license types have decreased since the 1980s (Figure 37). The decline may be attributed to increased government regulations, increased operating costs, increased competition from shrimp imports and aquaculture and declining profit margins. The decline is also partly a result of the shrimp license buyback program for commercial bay and bait licenses since 1996. In 2001, TPWD issued 1,237 bait, 1,250 bay and 1,794 Gulf licenses to residents and non-residents combined.

Characterization of Texas Shrimp Fishermen

TPWD license data for fiscal year 1999 showed that commercial shrimp fishermen with Asian surnames held 28% of shrimp boat licenses and a recent characterization study from Texas A&M University confirmed that 28% of the fishermen surveyed considered themselves Vietnamese. In addition, the average Texas commercial shrimp fisherman was male, 51.6 years of age and reported having been in the commercial shrimping industry 22 years. Almost half (48%) the respondents indicated their gross annual household income was $39,999 or less, with 13% indicating it was less than $20,000. Annual expenditures for the shrimper's primary boat were highest for fuel (median = $10,000); followed by crew wages (median = $7,000); engine purchase, repair or replacement (median = $3,000) and gear purchase, repair or replacement (median = $2,500).

Eighty-four percent of respondents that fished either bay or Gulf waters had shrimped "since this

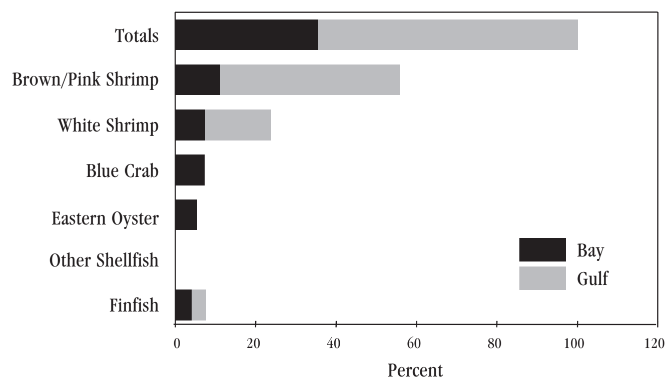


Figure 35. *Percent of total coastwide bay and Gulf landings contributed by major commercial species groups for 1995-1999.*

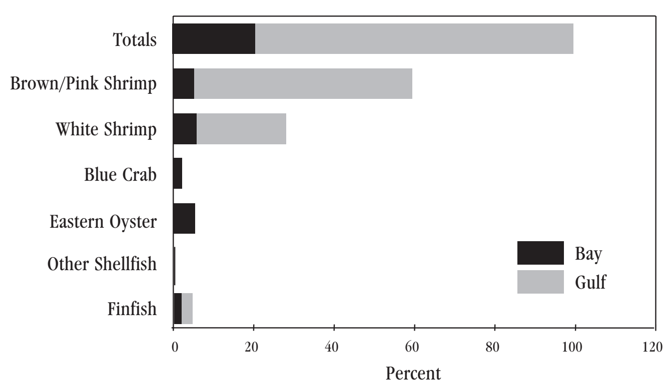


Figure 36. *Percent of total coastwide bay and Gulf ex-vessel value contributed by major commercial species groups for 1995-1999.*

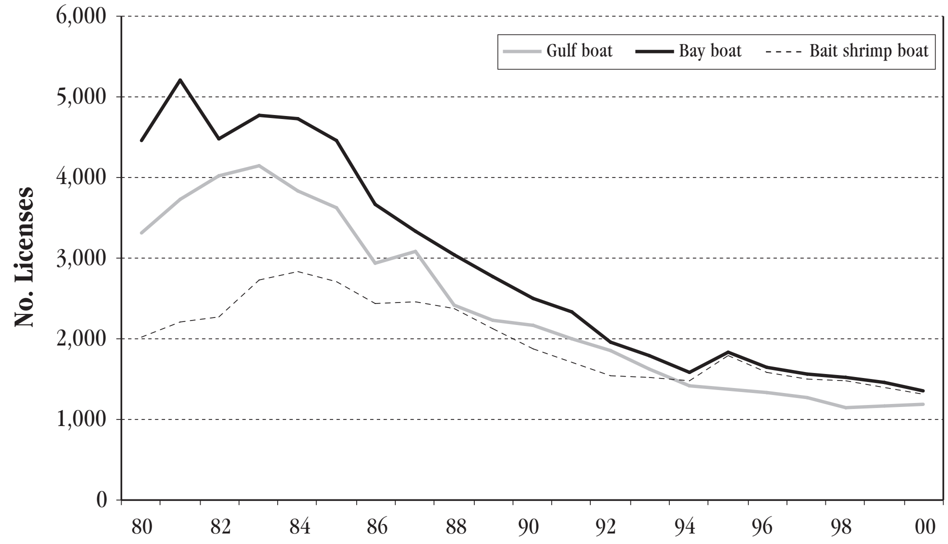
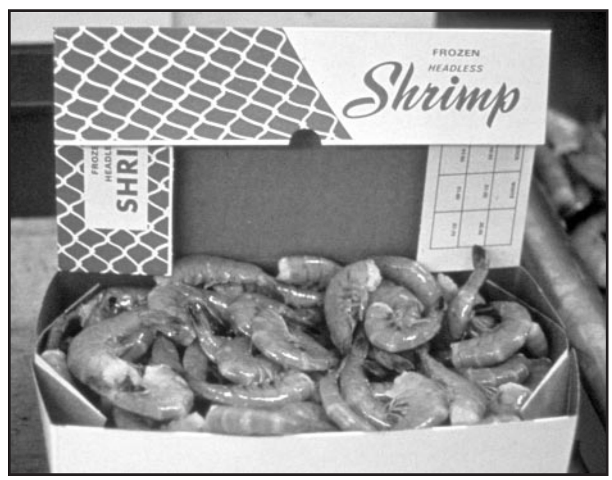


Figure 37. *Total number of commercial shrimp boat licenses for bay, bait and Gulf license types.*



time last year." Most frequently they reported fishing 1-50 days but others who fished very frequently increased the overall average to 131 days. However, if they had shrimped in offshore waters, the most frequent response was 251-300 days, with the average decreased by others who infrequently shrimp to 157 days.

Forty-seven percent of the respondents indicated they had no health insurance and 63% stated they had no insurance on their primary vessel. When asked if their spouse earned income from work outside the shrimping industry, 44% agreed and 43% stated their spouse did not earn extra income. About half of the fishermen said they received all of their household gross annual income from fishing, however, 11% indicated that between 91% and 100% of their household gross annual income did not come from fishing.

Using a scale from strongly disagree to strongly agree, fishermen were asked their opinions regarding shrimp issues. Respondents who strongly agreed with the following statements are shown by percentage: "Pollution in saltwater bays is hurting shrimp populations" (41%); "Imported shrimp cause dock side prices to be lower" (57%); "Not allowing shrimping in nursery areas will allow shrimp to grow to a more valuable size" (40%); "The environment affects shrimp populations more than commercial harvest" (34%); and "Harvesting shrimp at small sizes is hurting industry profits" (30%).

When asked about their level of satisfaction for a number of statements (from not at all to extremely satisfied), a plurality were either very satisfied or extremely satisfied with the following: "shrimping as an occupation" and "shrimping as a way of life", 29% and 32%, respectively. However, the majority of respondents indicated that they would not encourage young people to enter the business (83%).

Overview of Texas Shrimp Industry Dealers

Bait Dealers

For the period 1996-2000, the number of dealers who purchased/harvested and reported bait shrimp declined slightly (Figure 38). On average there were 178 bait dealers per year who reported landings in Texas.

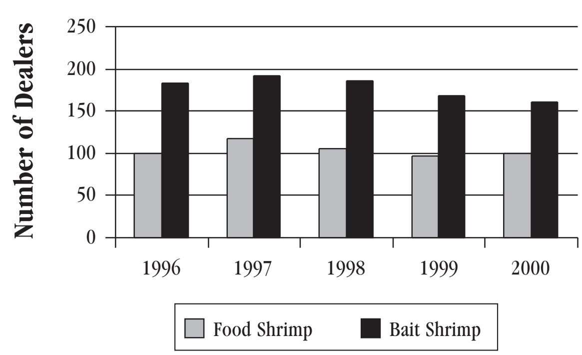


Figure 38. *Number of bait and food shrimp dealers reporting landings in Texas, 1996-2000.*

Bait Dealer Landings

A summary of seafood products handled by bait dealers in Texas showed that as a group, bait dealers dealt predominantly with live and dead bait shrimp (62%). They also handled some table shrimp (12%) and finfish (11%). Other species handled on a small scale were oysters, crabs and squid. These other species each make up less than 10% of the catch, but account for 15%, by weight, of total products handled by dealers. An analysis of bait dealer landings by dealer size class (by weight of product handled) found that the smaller the dealer, the more diverse the product they handled.

Food Shrimp Dealers

Dealers who handled and reported wholesale or retail shrimp, and dealers who reported significantly more wholesale or retail shrimp than bait shrimp, were considered "food shrimp dealers." From 1996 through 2000, the number of food shrimp dealers in Texas remained fairly constant with about 104 dealers who report purchased/harvested shrimp each year (Figure 38).

Food Shrimp Dealer Landings

As observed for bait shrimp dealers, an analysis of food shrimp dealers by size class found that the smaller the dealer, the more diverse the product they handled. Other than in Galveston Bay, where 13% of seafood products were something other than shrimp, shrimp made up at least 95% of seafood products handled by dealers.

Characterization of Texas Shrimp Dealers

Most past research in Texas has been concerned with describing the characteristics of bait shrimp dealers. A recent study from Texas A&M University was conducted to obtain an understanding of the current social and economic status of Texas shrimp dealers. That study documented that 7% of the dealers considered themselves Vietnamese.

Texas shrimp/seafood dealers have been in business an average 14 years. When dealers were asked what percentage of their gross annual household income comes from seafood sales, 42% reported between 91% and 100%, with a median value of 75%. The majority of respondents were male (78%) and between the ages of 41-60 (64%). Twenty-one percent reported gross annual household income between $20,000 and $39,000 with another 17% between $40,000 and $59,000.

Approximately half (51%) operated a place of business under a wholesale fish dealers license, while 39% operated under a bait dealers license, and 27% operated under a retail dealers license. Over three-quarters of the dealers reported that they carry insurance on their place of business. The majority (62%) of dealers indicated they were first generation shrimp/seafood dealers, while 38% reported they were second or third generation dealers or commercial fishermen. Overall, most (64%) dealers reported they employed 1-10 employees (either full-time or seasonal) with a median of four employees. About half (51%) reported employing members of their household.

A majority of dealers (57%) reported selling Texas-caught seafood at their primary place of business, and 74% of it was shrimp. Seventy percent of the dealers reported they had not bought shrimp imported from other countries during the previous twelve months.

On average, bait shrimp dealers responded that they sold 5,297 lbs of dead shrimp per year and 4,958 lbs of live shrimp per year. One-half of those holding commercial bait shrimp dealers license routinely bought from two or more boats.

A majority (59%) of respondents reported they did not earn any income from work other than selling fish or fish-related products in the previous twelve months. Most (57%) dealers reported that their spouse had not earned income from work other than selling fish or fish-related products in the previous 12 months. About one-third (32%) responded as having no health insurance.

On a five-point scale ranging from not-at-all satisfied to extremely satisfied, a plurality of dealers reported they were only moderately satisfied with each of the following statements: "seafood dealing as an occupation" (35%), "seafood dealing as a way of life" (30%), "fisheries management in Texas bays" (38%), "fisheries management in Texas Gulf waters" (33%), "amount of seafood sold in 2001" (33%), and "size of seafood sold in 2001" (40%).

A plurality of dealers agreed with four of the six attitudinal statements presented to them: "imported

shrimp cause dockside prices to be lower" (32%), "my operation is profitable" (43%), "the environment affects shrimp populations more than commercial harvest" (34%), and "harvesting shrimp at small sizes is hurting industry profits" (32%).

Economic Health of the Texas Shrimp Fishery

Total dockside value of all shrimp landed in Texas, whether caught off Texas or elsewhere, increased generally since the 1950s to the mid 1980s and has been somewhat constant since that time. However, when the total dockside value of shrimp landings is adjusted using consumer price indices (CPI), the peak economic value for Texas was reached in 1973 (Figure 39).

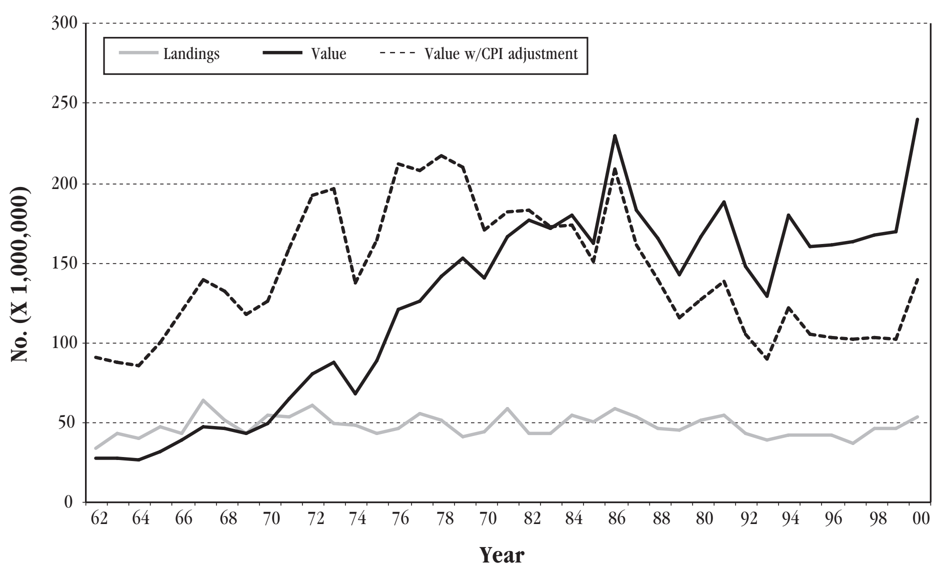


Figure 39. *Texas shrimp landings, ex-vessel values and ex-vessel values adjusted for inflation for 1962-2000 (CPI, base period = 1982-1984 dollars). Landings are expressed as heads off.*

Estimated Number of Jobs

Generating accurate employment estimates and determining economic impact on coastal communities is problematic. By nature, the shrimp industry is seasonal, with employment greatest during periods of heavy fishing activity. Utilizing an average crew size and the number of licensed shrimp vessels, an estimate for employment directly associated with shrimp vessels can be derived (Table 2).

The results show an estimated decline of 37% in shrimp vessel workers between 1990 and 1995 and a further decline of 10% between 1995 and 1999 to less than 4,600 workers. During 1990-1995, total vessels declined by 29% and declined again by 13%

Table 2. *Changes in estimated number of Texas commercial licensed shrimp vessels and associated employment for 1990, 1995 and 1999.*

Industry Groups	1990	1995	% Change 1990-1995	1999	% Change 1995-1999
Shrimp Vessel Employment	8032	5072	-37%	4571	-10%
Number Total Licensed Vessels	4728	3370	-29%	2922	-13%
Number Licensed Gulf Only Vessels	1902	1134	-40%	1273	12%
Number Licensed Bay Only Vessels	811	422	-48%	205	-51%
Number Licensed Bait Only Vessels	352	413	17%	171	-59%
Number Licensed Gulf, Bay and Bait Vessels	571	148	-74%	218	47%
Number Licensed Gulf and Bay Vessels	215	68	-68%	46	-32%
Number Licensed Gulf and Bait Vessels	58	18	-69%	9	-50%
Number Licensed Bay and Bait Vessels	819	1167	42%	1000	-14%

from 1995 to 1999. The decline from 1996 to present can partially be attributed to the license buyback program.

The number of wholesale dealers coastwide who handle shrimp has remained constant through the years, indicating that land-based employment may be consistent. Using the median number of employees (4) reported by dealers in the recent Texas A&M University study and the total of 282 bait and/or food shrimp dealers provides an estimate of less than 1,200 workers.

Ad Valorem Tax Analysis

Ad valorem tax values for shrimp vessels were compared with TPWD licenses for resident commercial shrimp vessel licenses. For 2000-2001, 2,369 resident commercial licensed vessels were obtained from TPWD license files. However, 32% (N=756) of the total resident licensed vessels could not be identified as having ad valorem tax values. Using the known tax values for resident licensed vessels, the average tax value per vessel for the fleet ($37,836) was calculated. That average tax value was used to provide an estimated tax value of the entire resident commercial shrimp fleet of $89,633,484.

Using the data available, the percent tax values paid for vessels versus the total ad valorem tax values assessed to each county were compared (Table 3). Matagorda County had the largest percent of vessel tax values contributing to its total county tax base at 0.81%. Aransas County had the next highest percentage of total ad valorem tax value at 0.43%. The overall county ad valorem tax value of licensed shrimp vessels for all Texas coastal counties combined was less then 0.02% of the total ad valorem taxes per county.

Shrimp Fishery Relative Size

In addition to information concerning jobs and ad valorem taxes, the impact of the shrimp industry to coastal regions of Texas and to the state was also examined. It was estimated for the early 1990s that saltwater recreation-related industries had direct expenditures of $866 million while saltwater commercial fishing (all species) industries had direct expenditures of $174 million. Using economic activity multipliers, saltwater recreation-related sectors were estimated to have a statewide impact of $1.66 billion and 33,529 jobs. Statewide impact for saltwater commercial fishing was $276 million and statewide employment was 6,111 jobs.

For illustrative purposes, the Texas shrimp industry can be compared to other Texas industries such as timber, another renewable natural resource, and several agricultural commodities (Table 4). These commodities allowed a comparison of their cash sales to ex-vessel (dockside) sales reported for the shrimp fishery. Using a three year average from 1998-2000, shrimp ex-vessel value in Texas was $192.7 million. In comparison, farmers' cash sales receipts for corn averaged $442.4 million, peanuts averaged $190 million, and cabbage was $54.3 million. For timber stumpage, foresters received an average of $595.6 million annually.

Table 3. *Ad valorem taxes by coastal county and percent vessel contribution to tax base.*

Coastal Counties	Total Ad valorem Tax by County	Vessel Tax Value/County	% Vessel Contribution to Tax Base	No. Licensed Vessels	No. Missing Values
Aransas	$1,278,157,213	$5,508,782	0.43%	267	56
Brazoria	$12,078,374,723	$1,012,830	0.01%	83	52
Calhoun	$2,923,565,039	$3,425,788	0.12%	235	49
Cameron	$9,682,487,661	$10,583,340	0.11%	353	49
Chambers	$3,864,458,149	$107,740	0.00%	56	47
Galveston	$16,263,134,112	$8,941,080	0.05%	426	86
Harris	$196,355,648,000	$1,769,495	0.00%	173	124
Jackson	$881,412,927		0.00%	1	1
Jefferson	$60,981,458,149	$6,193,950	0.01%	180	42
Kenedy	$297,856,509		0.00%	0	0
Kleberg	$1,000,870,601	$44,047	0.00%	12	8
Matagorda	$2,788,104,359	$22,534,138	0.81%	334	72
Nueces	$11,148,855,267	$896,131	0.01%	108	30
Orange	$3,548,209,080		0.00%	81	81
Refugio	$922,885,712		0.00%	4	4
San Patricio	$2,755,375,343		0.00%	33	33
Victoria	$4,220,159,587	$12,000	0.00%	12	11
Willacy	$523,642,868		0.00%	11	11
Totals	**$331,514,655,299**	**$61,029,321**	**<0.02%**	**2369**	**756**

Table 4. *Value in cash sales of shrimp, various agricultural commodities and stumpage value of timber.*

Commodity Value	1998	1999	2000	Three-Year Average
Shrimp	$168,410,000	$169,819,100	$239,980,100	$192,736,433
Corn	$436,281,000	$415,635,000	$475,328,000	$442,414,667
Peanuts	$225,803,000	$190,921,000	$155,677,000	$190,800,333
Cabbage	$69,360,000	$41,290,000	$52,480,000	$54,376,667
Timber Stumpage	$642,100,000	$606,300,000	$538,500,000	$595,633,333

Source: Texas Agricultural Cash Receipts, by Commodities and Commodity Groups, 1996-2000. 2000 Agricultural Summary. Texas Forest Resource Harvest Trends, 1998, 1999, 2000.

Factors Influencing the Texas Shrimp Fishery

Processing technology: The introduction of "peeler plant" technology had a substantial effect on the shrimp industry. Shrimp peeling machines were first developed in the early 1950s. They reduce labor costs through the automation of peeling and deveining shrimp. As peeler plants gained more widespread application, they allowed a more effective use of smaller shrimp, thus contributing to the increase in growth overfishing.

Territorial issues: Another major action influencing the fishery was the establishment of Mexico's jurisdiction into Gulf of Mexico waters. The U.S. and Mexico signed a treaty in 1976 that established a three year phase-out of commercial shrimp fishing in Mexico's waters by U.S. shrimp fishermen. Prior to this treaty, about 10% of U.S. shrimping efforts occurred in Mexican waters. This had an economic impact of $8.6 million in 1973 dollars, which when adjusted to 2001 dollars, is now equivalent to over $32 million annually.

Endangered species: The shrimp fishery was also influenced by the requirement imposed by NMFS to use TEDs in shrimp trawls in 1989. TEDs are devices sewn into shrimp trawls that are designed to allow turtles to escape from nets while they are being fished. In addition to turtles and other organisms escaping, TEDs can result in some loss of shrimp.

Imports: Shrimp imports impact U.S. and Texas fisheries by contributing significantly to the market competing with domestic products. The quantity of shrimp imported in 2000 into the U.S. was 760.8 million lbs valued at $3.8 billion. A study that looked at the impact of increased imports on domestic prices, showed that in the absence of world shrimp aquaculture, 1988-89 import levels would

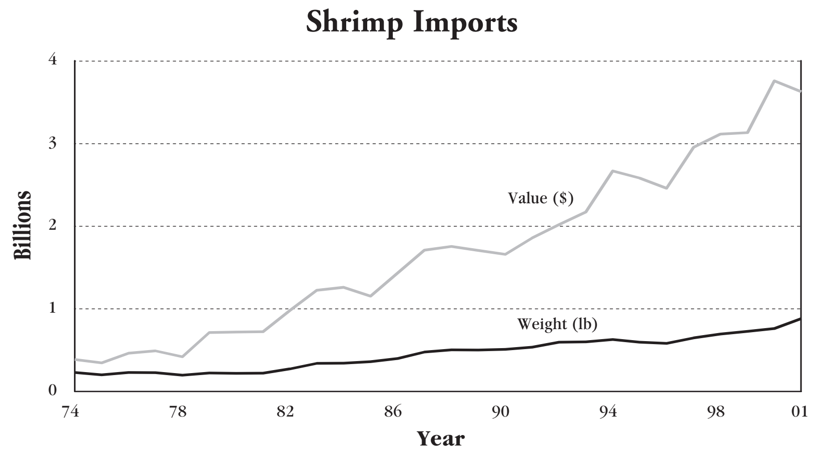
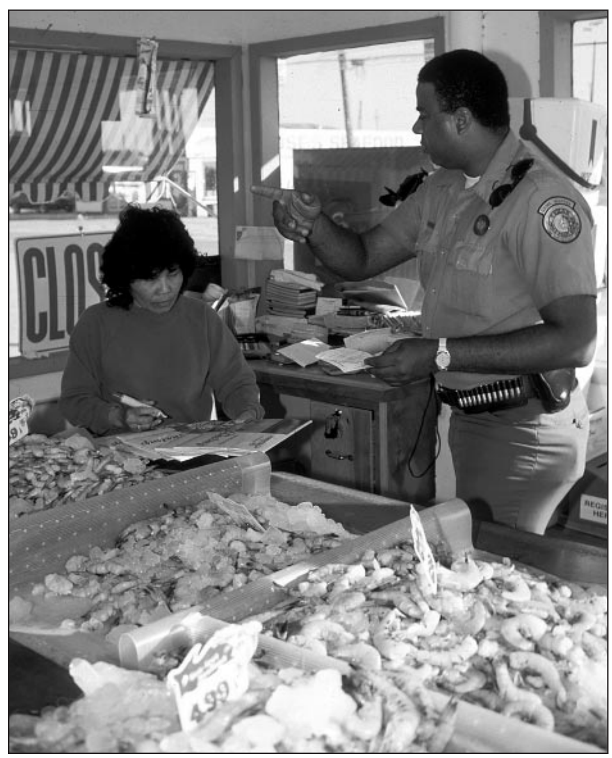


Figure 40. *United States shrimp imports, 1974-2001.*

have been about 175 million lbs less. The U.S. import price would have been 70% higher causing domestic dockside prices to be significantly higher as well. From 1974 to 2001 the poundage of imported shrimp has increased by 300% and the value has risen by 800% (Figure 40).

Law Enforcement Issues

Effective fishery management depends on industry compliance and enforcement of the regulations. Extensive areas of isolated marine waters and fishing under multiple licenses at varying times are especially difficult to monitor. The TPWD Law Enforcement Division has a current staff of 68 game wardens assigned to 14 coastal counties.



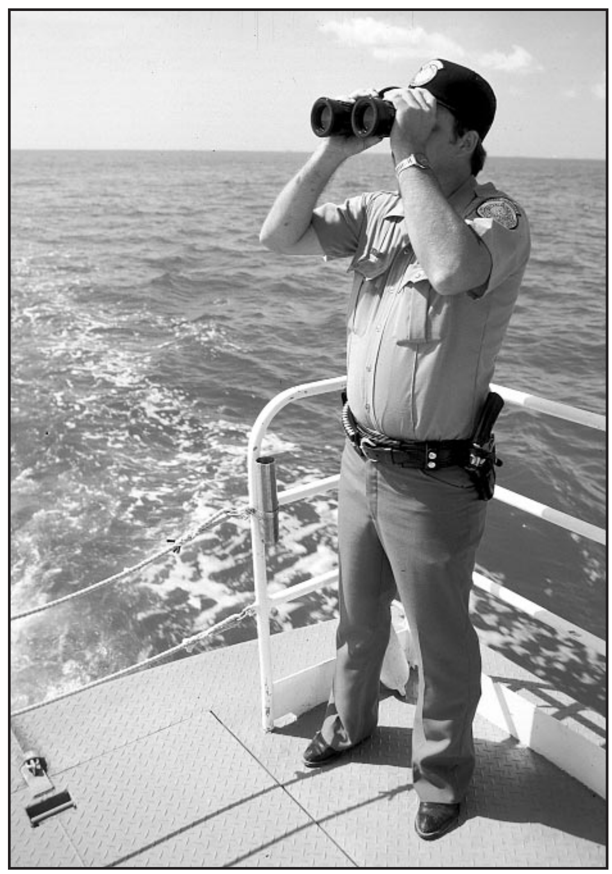
Joint Enforcement Agreement

In July 2001, TPWD Law Enforcement Division entered into a Joint Enforcement Agreement (JEA) with NMFS. The JEA was created to enhance enforcement of shrimp, reef fish, and highly migratory species regulations in the Gulf of Mexico. This program increased law enforcement presence in the Gulf and provided additional equipment to Texas game wardens, allowing them to maintain a higher level of patrol in offshore waters. Since the inception of the agreement, from July 2001 through March 2002, JEA wardens have logged 3572 patrol hours and 719 boardings and inspections. There were 77 citations issued and 13,686 lbs of shrimp confiscated. A proposal for a second JEA has been submitted by TPWD, which would provide additional funding to continue the successful relationship initiated with the first JEA.

Vessel Monitoring Systems

Electronic vessel monitoring systems (VMS) for commercial fisheries are gaining momentum in fisheries throughout the world. Because of the size of restricted areas and their distance from shore, a VMS allows for a more effective means of surveillance. A VMS consists of a transceiver installed on board a fishing vessel that sends data to a satellite system that then transmits the data to a land based monitoring station. The data provide information on the speed and course of the vessel and will show if the vessel is operating in open versus closed fishing areas.

A pilot study in 2000 was conducted by the Gulf and South Atlantic Foundation to test VMS as an electronic log book on Gulf shrimp vessels. The study demonstrated that VMS offers the possibility of an inexpensive means to determine fishing pressure and improve compliance with regulations.



CONCLUSION

The commercial shrimp industry is Texas' most valuable commercial fishery with ex-vessel shrimp landings during 2000 valued in excess of $230 million. The sustained profitability of the industry is affected by a multitude of factors including overfishing, user conflicts, market demand, pricing trends, conservation concerns and operating costs. The complexity of the fishery and diversity of the issues present a tremendous management challenge. TPWD has endeavored to achieve a balance between the biological sustainability of the resource and the social and economic impacts on the commercial shrimp industry. Decreasing trends in relative abundance and length of shrimp in Texas justifies continued management concern and monitoring.

The continued viability of the industry is contingent upon its ability to endure changing global markets, fluctuating operating costs, increased regulatory activities, seasonal stock fluctuations and increased fishing pressure. For example, the negative effects of recent high volumes of imports on prices paid dockside for wild-caught shrimp has made trawling for shrimp less profitable. Texas shrimpers are increasingly subject to global market variations of supply, demand and pricing that have also challenged the viability of other domestic agriculture interests and businesses throughout the state.

The current TPWD management strategy continues to be valid for the Texas shrimp fishery. Shrimp management strategies and conservation measures directed toward sustainability of the resource will lead to a more stable and profitable industry. The license buyback program is showing progress toward reversing the high levels of inshore shrimping effort. A similar limited entry and license buyback program is needed for the Gulf fleet.

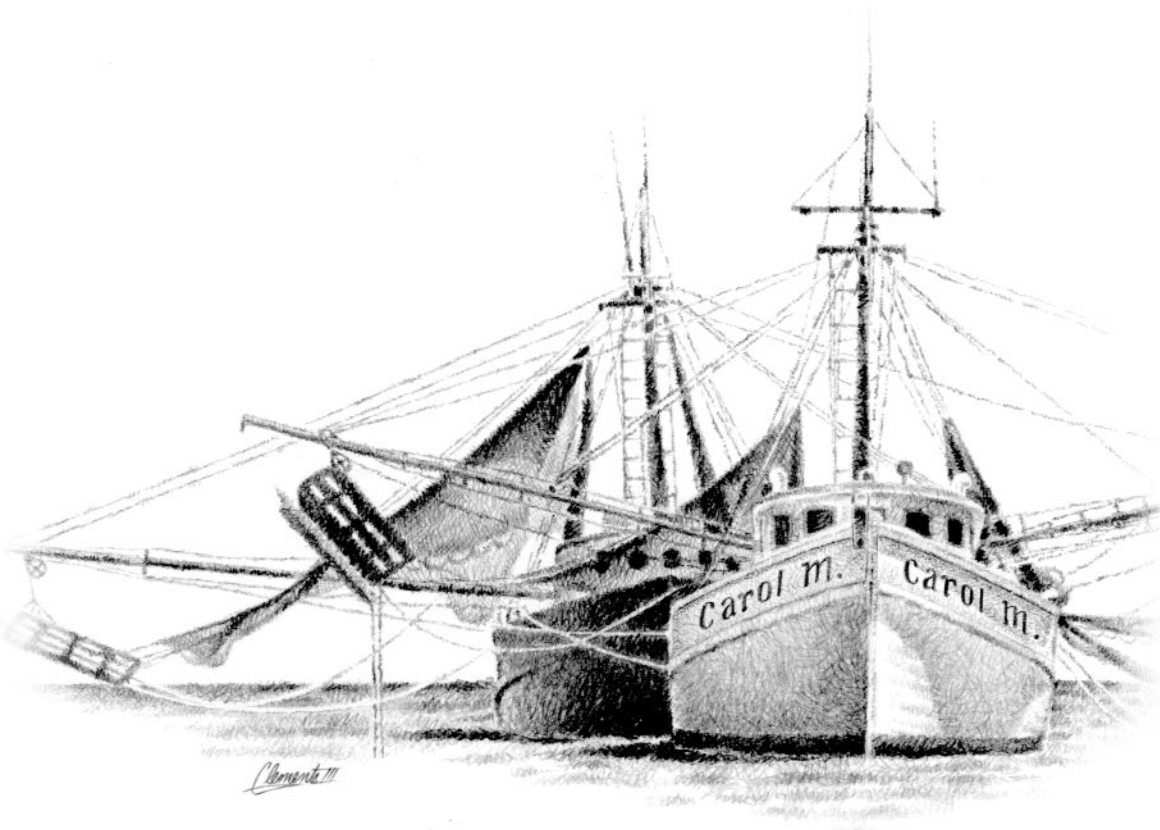
TPWD should continue to work with the fishing community and other management agencies to address the changing conditions in the industry. A recent example of this was the considerable amount of public testimony and a GMFMC vote to not continue in 2002 with the longstanding historical summer Texas closure in federal waters. The vote was based on concerns about high import volumes and low shrimp prices. Ultimately, NMFS overruled that vote and both Texas and federal waters off Texas were closed as usual. However, this highlights a new era where changing price structures and competition in world markets will cause traditional management strategies to be reviewed. A proactive and precautionary approach to control fishing mortality and aggressively protect shrimp habitat should provide the greatest probability for achieving and sustaining a healthy shrimp stock and a profitable shrimp fishery.

ACKNOWLEDGEMENTS

This summary and the appendixes have been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. Reviewers were asked to provide comments to assist in making the published report as sound as possible and to ensure that the report meets standards for objectivity, scientific validity and responsiveness to the legislative charge. None of the reviewers received the entire set of appendixes and any errors in the report are the sole responsibility of TPWD.

A portion of the report was sent to members of TPWD's Shrimp Advisory Committee, including Ms. Pam Baker, Mr. Doug Boyd, Dr. Charles Caillouet, Mr. James Davenport, Mr. Jimmy Evans, Mr. Ivo Goga, Mr. Jack Hemingway, Mr. James Hornbeck, Mr. Buck Lyon III, Mr. Ricky Mai, Mr. Glen Martin, Mr. Richard Moore, Mr. Jeff Noel, Mr. Brian Sybert, Ms. Thuy Thanh Vu, Mr. Richard Wendland, Ms. Mina Williams and Mr. Walter Zimmerman. Other outside reviewers who received a portion of the report include Mr. Tony Amos, Ms. Pam Baker, Mr. David Bernhart, Mr. John O'Connell. Dr. JoJo Estrada, Dr. Benny Gallaway, Ms. Alisa Goldberg, Mr. Michael Haby, Dr. Don Harper, Mr. Scott Holt, Dr. Andre Landre, Jr., Dr. David McKee, Dr. Russ Miget, Dr. Paul Montagna, Dr. Jim Nance, Mr. Ralph Rayburn, Dr. Wes Tunnell and Dr. Roger Zimmerman. Appreciation is expressed to all those who provided comments. Ms. Laure McLaughlin with the Texas Comptroller of Public Accounts is thanked for her contributions.

Sincere gratitude is expressed to Dr. Robert Ditton with Texas A&M University for taking on the challenges of the industry social and economic survey. The many shrimpers and dealers who provided survey information and input throughout the scoping process are thanked. In addition, the hard work and dedication of the staff of the Coastal Fisheries Division is acknowledged as well as the creative talents of the Communication Division staff.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