TEXAS SHRIMP FISHERY MANAGEMENT PLAN

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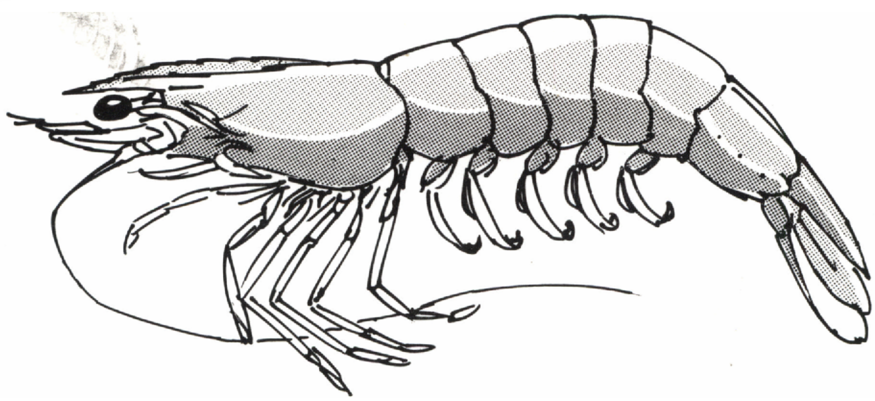

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TEXAS SHRIMP FISHERY
MANAGEMENT PLAN

Source Document

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1.0 INTRODUCTION

The Texas Legislature has managed the shrimp fishery in Texas primarily to maximize ex-vessel value (dockside) of shrimp landed in Texas. Since the 1950's, Texas has led all other gulf states in ex-vessel value of shrimp landed commercially for food. Average annual Texas landings were 39 million kg (whole weight, heads-on) with an ex-vessel value of $186 million from 1983 through 1987. The impact on the Texas economy is about $580 million annually, based on an economic multiplier of 3.12 (Texas Department of Water Resources 1982). The fishery employs about 20,000 fishermen, although most jobs are not full-time equivalents (Texas Water Development Board 1987), uses 7,000 vessels and boats, and depends primarily on three species: brown shrimp (Penaeus aztecus), white shrimp (P. setiferus), and pink shrimp (P. duorarum).

Shrimp have one of the highest ex-vessel values of seafood product in the United States (United States Department of Commerce 1988). Average annual ex-vessel value of the United States shrimp fishery was $541 million during 1983-1987. The Gulf of Mexico is the most important shrimp producing area of the United States with average annual landings worth $458 million.

1.1 Historical Perspective

The complex nature of the Texas shrimp fishery makes management difficult. Shrimp are both estuarine- and gulf-dependent; several harvesting fleets have evolved with diverse economic goals and objectives. These fleets include the commercial food and bait fisheries in the bays, a food fishery in the Gulf of Mexico and a recreational fishery for food and bait. Each fleet exploits different stages of the shrimp life cycle. A further management complication is the fishery's direct impact on finfish, endangered species (i.e. sea turtles), and other animals that are part of the by-catch.

Adding to the complexity of the shrimp fishery is the fact that the three shrimp species important to the Texas fishery occur in waters under the jurisdiction of 5 gulf states (only Louisiana shrimp significantly intermix with Texas shrimp), and the governments of the United States and Mexico. Overlap of federal and state jurisdiction led to joint management of the fishery by Texas and the United States Department of Commerce through the Gulf of Mexico Fishery Management Council's Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico. There are no formal shrimp management programs between the United States and Mexico.

1.2 Goal and Objectives for Management Plan

In 1985, the 69th Texas Legislature delegated to the Texas Parks and Wildlife Commission authority to regulate the shrimp fishery in Texas bays and the Texas territorial sea (Figure 1.1). However, the Legislature mandated that before existing regulations are changed, the Texas Parks and Wildlife Department prepare a Shrimp Fishery Management Plan and economic impact analysis in accordance with Chapter 77 of the Parks and Wildlife Code.

This is the Source Document for the Texas Shrimp Fishery Management Plan. It was prepared by the Texas Parks and Wildlife Department staff. However, the Plan is the culmination of a process designed to maximize public participation. In particular, the Shrimp Fishery Management Plan was prepared based on information from the Texas Coastal and Marine Council and its Shrimp Advisory Committee, the Joint Interim Committee on the Texas Shrimp and Oyster Industry, the Interim Report on Shrimp Management by the Texas House of Representatives Committee on Environmental Affairs, bills introduced to the Legislature but not enacted, and meetings with representatives from Professional Involvement of Seafood Concerned Enterprises, United Shrimpers Association, Texas Shrimp Association, Center for Environmental Education, and the Marine Advisory Service of the Texas A & M University Sea Grant Program. Comments were also incorporated from those who attended seven public hearings held in July-August 1986 (over 10,000 personal invitations were mailed to individuals, county judges, state representatives, commercial and recreational organizations, marine extension agents and other parties with a special interest in the Texas shrimp industry), those who attended 25 additional public hearings held across the State in 1989 (over 600 copies of the Plan were mailed to interested parties prior to the hearings) and finally, all those who wrote, called or otherwise contacted the Texas Parks and Wildlife Department to offer their comments.

The goal of the Shrimp Fishery Management Plan is to provide a management strategy for the shrimp fishery in Texas. The Plan will allow the Texas Parks and Wildlife Commission to regulate, by proclamation, the catching, possession, purchase, and sale of shrimp as described in Section 77.007 of the Parks and Wildlife Code. In determining the need for a proclamation, the Commission shall consider:

(1) measures to prevent overfishing while achieving, on a continuing basis, the optimum yield for the fishery;

(2) measures based on the best scientific information available;

(3) measures to manage shrimp throughout their range;

(4) measures, where practicable, that will promote efficiency in utilizing shrimp resources, except that economic allocation may not be the sole purpose of the measures;

(5) measures, where practicable, that will minimize cost and avoid unnecessary duplication in their administration; and

(6) measures which will enhance enforcement.

A proclamation issued by the Commission may limit the quantity and size of shrimp that may be caught, possessed, sold, or purchased and may prescribe the times, places, conditions, and means and manner of catching shrimp. However, measures dealing with sale and purchase may only be implemented at first sale or exchange transaction.

Through the six measures identified in Section 77.007 and listed above, the Legislature provided policy for the Texas Parks and Wildlife Department to follow in managing shrimp. Economic considerations are an integral part of the measures listed, but are not the only factors to be considered. In particular, the Department is instructed to manage shrimp scientifically to achieve optimum yield and promote efficiency while minimizing costs of administration and ensuring adequate enforcement. It is clear that the statute directs the Department to recognize that shrimp are to be treated similarly to other publicly-owned natural resources managed by the state and country, like oil, gas, or timber.

The Legislature has directed the Department to manage the fishery to achieve optimum yield for the shrimping industry. For purposes of this Plan, optimum yield is defined 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. Stated simply, this fishery needs to be managed by the State in a way that does not differ significantly from the way it would be managed by a privately-owned firm. This approach is consistent with that taken by the State in its management of other natural resources and the United States government in managing its natural resources, including fisheries.

The Legislature clearly indicated that management measures beyond those concerned with economics be considered. Not only was optimum yield to be achieved but overfishing was also to be prevented. Overfishing, environmental factors, and other events can cause depletion. Depletion is defined as the process, regardless of cause, that reduces the population abundance and composition to a depleted state. For purposes of this Plan, shrimp are considered depleted when the population abundance and composition are not sufficient to maintain a harvest equal to the optimum yield. In other words, if shrimp are in a state that prevents the achievement of management goals, they are by definition depleted. The prevention of overfishing will ensure that depletion caused by controllable factors will not occur.

Available and applicable biological, economic, legal and sociologic information essential to the management of shrimp in Texas upon which the Plan is based is contained in this document. Weights are whole weights (heads-on) unless otherwise noted. Descriptions of the biology, life history, fishery and past and future management practices are presented.

2.0 PENAEID SHRIMP BIOLOGY

2.1 Identity and Morphology

Penaeid shrimp are members of the Phylum Arthropoda, Class Crustacea, Order Decapoda, Suborder Natantia (Barnes 1968). In Natantia the body is generally adapted for swimming (natant - "swimming"), and tends to be laterally compressed with a well-developed abdomen. The cephalothorax bears a keel-shaped serrated rostrum and slender legs. The first three pairs of legs are similar, chelate and slender, increasing in length posteriorly. The abdominal pleura of the second segment do not overlap those of the first. The pleopods are well-developed and adapted for swimming.

Three Penaeus, one Xiphopenaeus and two Trachypenaeus species (Family Penaeidae) occur in Texas waters and comprise the major portion of the fishery: P. aztecus (brown shrimp), P. setiferus (white shrimp), P. duorarum (pink shrimp), X. kroyeri (seabob) and Trachypenaeus sp. (roughneck shrimp).

Royal red shrimp (Hymenopenaeus robustus) and rock shrimp (Sicyonia brevirostris) are also exploited off Texas. These non-estuarine dependent shrimp apparently complete their life cycles within open waters of the gulf beyond the Texas territorial sea. Because they are harvested almost exclusively in the Exclusive Economic Zone, they will not be discussed in this Plan.

The following sections document the identity and morphology of brown shrimp gametes, larvae, and postlarvae (Cook and Murphy 1971, Lassuy 1983). A comparison with pink shrimp and white shrimp follows.

Brown Shrimp

2.1.1 Gametes

Viable eggs are round, golden-brown and translucent, and average 0.26 mm in diameter. Semi-bouyant eggs are externally fertilized and hatch within 24 hr to the first naupliar stage. Brown shrimp pass through 5 naupliar, 3 protozoeal, and 3 mysis stages over a 10-25 day period before transforming into postlarvae.

2.1.2 Larvae

Naupliar Stages (I-V): The naupliar stages are distinguished by an unsegmented pyriform body (average lengths 0.35-0.50 mm), the posterior of which is rounded in the first stage, but becomes progressively more elongate through the fifth stage. Three pairs of appendages and two pairs of antennae are present. In the first stage all setae are smooth but become more plumose in subsequent stages. At stage 3, small frontal organs are present at the anterior end of the body. During stage 5, the outline of a developing carapace can be seen on the dorsal surface of the body.

<u>Protozoeal Stages (I-III)</u>: The larvae change radically from the fifth naupliar stage to the first protozoeal stage. A loose-fitting carapace covers the anterior portion of the body. The abdomen is unsegmented; the thorax is divided into six segments. The maxillae and maxillipeds become large and functional. The body is colorless with the exception of two red spots.

The second protozoeal stage is characterized by the appearance of stalked compound eyes, a ventrally projecting rostrum, and a segmented abdomen. Frontal organs are absent in this and later stages.

The third protozoeal stage is characterized by the presence of biramous uropods and spines on the abdominal segments.

<u>Mysis Stages (I-III)</u>: The larvae assume a more shrimp-like appearance during the molt from the third protozoeal stage to the first mysis stage. Functional pereiopods develop with long brushlike exopods. The carapace fits the body much more closely and the rostrum protrudes forward on a horizontal plane. The five pairs of pereiopods become enlarged, and their exopods serve as the principle swimming organs.

The second mysis stage is characterized by the presence of unsegmented pleopods and a spine on the antennal blade. The third mysis stage is distinguished by the pleopods and endopod of the second antennae being composed of two segments.

2.1.3 Postlarvae

Morphology does not change greatly during the molt from the third mysis to the first postlarval stage. The pleopods become the principal swimming organ. Mean 28 day growth rates (mm/day) for postlarval brown shrimp were 0.90, 0.82, 0.24 and 0.02 mm/day at temperatures of 32, 25, 15, and 11 C, respectively (Zein-Eldin and Aldrich 1965). However, salinity appears to have little effect on either survival or growth. Average length of postlarvae raised at 32 C was 37.4 mm at 28 days, average weight was 413 mg.

White Shrimp and Pink Shrimp

Examination of newly hatched nauplii through first postlarval stage of both white shrimp and pink shrimp revealed no major differences in setation or other major morphological characters from those described for brown shrimp.

2.1.4 Sub-adults and Adults

Juvenile and adult brown shrimp and pink shrimp are distinguished from white shrimp primarily by the presence of a lateral rostral groove on the carapace posterior to the last rostral spine (Figure 2.1). This groove is absent posterior to the last rostral spine in white shrimp (Williams 1984).

Pink shrimp usually have a conspicuous lateral spot located at the juncture of the third and fourth abdominal segment. Chromatophores are uniformly distributed over the uropods. Brown shrimp do not have the conspicuous spot and uropod chromatophores are concentrated distally (Williams 1984).

Seabobs are easily distinguished by their long, upturned rostrum and last two pairs of slender, greatly elongated walking legs. Trachypenaeids have a rostrum with no ventral teeth that is much shorter than the carapace and not upturned. Dorsal region of carapace has fine, short setae; branchial region of carapace and last two abdominal segments are variably pubescent.

2.2 Stock Identification

Brown shrimp range along the north Atlantic and gulf coasts from Martha's Vinyard, Massachusetts to Campeche, Mexico (Williams 1965). White shrimp range along the north Atlantic and gulf coasts from Fire Island, New York to Campeche, Mexico (Perez- Farfante 1969). Pink shrimp occur from the lower Chesapeake Bay south to Isla Mujeres, Mexico. Seabobs range between Cape Hatteras and Cape Lookout, North Carolina, through the Gulf of Mexico and Caribbean Sea to near Santos, Sao Paulo, Brazil. T. constrictus ranges from Tangier Sound, Chesapeake Bay to Veracruz, Mexico, Bermuda, Puerto Rico and Sombrero Island, Surinam and off Ceara, Sao Paulo and Santa Catarina, Brazil (Williams 1984).

Brown shrimp, white shrimp and pink shrimp are all treated and managed as unit stocks in the Gulf of Mexico. No genetic differences have been detected within any species throughout its distribution (Klima and Nance in press). Each species is widely distributed around the Gulf of Mexico, with localized centers of abundance but no distinct spawning grounds (Osburn et al. 1969). Each species is capable of moving several hundred kilometers (Klima 1964, 1974; Gitschlag 1986; Sheridan et al. 1987).

2.3 Life History

Fishery managers must have a thorough understanding of the life history of an organism to manage it effectively. Information regarding biological and ecological processes that impact shrimp throughout their lives is needed to evaluate consequences of alternative management practices. Because life history information on Texas shrimp is limited, information developed from the study of penaeid shrimp stocks in other areas is used, where applicable.

2.3.1 Spawning

Brown shrimp: Spawning takes place at >14 m (Table 2.1). At 27 m, spawning occurs from spring until early winter. At 46 m, spawning occurs throughout the year but peak activity is in October-December with a smaller peak in March-May. At 64, 82 and 110 m, spawning occurs throughout the year with only slight increases in intensity (Cook and Lindner 1970).

White shrimp: Spawning occurs offshore (Pearson 1939, Lindner and Anderson 1956) in depths ranging from 7 to 33 m (Heegaard 1953) from March to September (Weymouth et al. 1933). Lindner and Anderson (1956) speculated a single shrimp could spawn as many as four times in a season, but this has not been verified.

Pink shrimp: Spawning occurs offshore in depths ranging from 15 to 50 m. Spawning occurs year around with peaks in late spring, summer and early fall (Williams 1965). The spawning season may be shorter in the more northern portions of its range (Joyce 1965).

Seabobs: Information on spawning of seabobs in Texas waters is sparse. Gunter (1950) found two ripe females 3.2 km SSE of Aransas Pass in June. Renfro and Cook (1963) captured seabobs near Galveston from April through October. Trawl data in the early 1930's from Georgia and South Carolina indicate seabobs spawn in the south Atlantic between April and November (Anderson 1970, Juneau 1977).

Trachypenaeid shrimp: Information on spawning in Texas waters is sparse. Gunter (1950) found ripe females in September off Texas. Brusher et al. (1972) reported gravid females were most numerous between March and October, with peaks in April and August. Subrahmanyam (1971) reported spawning from April through November in Mississippi with peaks in spring-early summer and in October-November. Maximum numbers of larvae were found in depths 18-36 m.

2.3.2 Recruitment and Nurseries

Egg and larval transport: Young of the three species of Penaeus hatch within a few hours of spawning and pass through eleven larval stages in 12-20 days. By the time they reach postlarval stages, shrimp have been transported into the estuaries where they assume a benthic existence (Figure 2.3). There is some indication, however, that brown shrimp postlarvae may remain offshore for some period before moving into the estuaries (Jackson 1975).

The actual distribution mechanisms are unknown, but shrimp larvae are probably transported into estuaries by gulf currents (Jackson 1975). In Texas, these currents may be largely wind-driven. King (1971) indicated a positive correlation between wind direction and abundance of postlarval shrimp in Cedar Bayou, a natural Texas pass.

Seabobs and trachypenaeids are not as estuarine dependent as the other penaeids. Recruitment and larval transport is unknown.

Nurseries: All three Penaeus species utilize estuarine waters as nursery grounds. Postlarvae usually concentrate in water <0.9 m deep, where there is attached vegetation and/or abundant detritus. Shrimp stay in these areas 2-4 weeks before moving to deeper water (St. Amant et al. 1966, Parker 1966). Seabobs are found in some nursery areas but do not appear to require estuarine conditions for survival.

2.3.3 Distribution and Movement

As Penaeus species grow, they move to deeper portions of bays where they continue to feed (Perez-Farfante 1969). Movements within bays are imprecisely known, but freshwater inflow and decreases in water temperature have caused movement of shrimp to deeper water (Jackson 1975). Stimuli causing emigration from the bays to the gulf varies by species.

<u>Brown shrimp</u>: Brown shrimp generally emigrate from Texas bays in association with a full moon and strong tidal cycles from May through August with peaks from May to July (Copeland 1965, Moffett 1967, Trent 1967, Parker 1970, King 1971, Moffett 1972, Benefield and Baker 1980, Johnson 1982, Benefield et al. 1983, Bryan 1985). Once brown shrimp enter the gulf they rapidly move to 18 m and thereafter gradually move to spawning depths of 46 to 91 m (St. Amant et al. 1966).

In Louisiana, Gaidry and White (1973) observed that emigration of brown shrimp occurs in two stages. The first movement normally begins at 60 to 70 mm when juveniles leave shallow marsh areas for open bays. These bays serve as a "staging area" where shrimp continue to feed and grow until they begin a second migration to offshore waters at 90 to 100 mm.

Tagging studies in the northern gulf indicate a slightly westward overall movement in offshore waters (Klima 1964, St. Amant et al. 1966, Gaidry and White 1973, Barrett and Ralph 1976). Tagging during 1978-1980 at the Texas-Mexico border indicates the net population movement was southward and may be related to food, substrate or currents (Sheridan et al. 1987).

Temperature also affects movement of shrimp. Postlarval penaeids are only recruited to estuaries when temperatures are >12 C (Christmas 1966). Aldrich et al. (1967) reported postlarval brown shrimp burrow into available substrate as temperatures declined to 12 C and emerged as temperatures increased. Abundance of juvenile brown shrimp in bays increased when temperatures were ≥15 C (Ford and St. Amant 1971).

<u>White shrimp</u>: Emigration of white shrimp to the gulf generally occurs when shrimp are 70-125 mm and is accelerated by decreasing water temperatures (Jackson 1975, Muncy 1984). Offshore movements peak from September to December. Movements within the northwestern gulf occur in a generally eastward direction. Along the south-central Texas coast, shrimp move southward during cool months and northward during spring (Jackson 1975).

White shrimp move from shallow to deeper water during cold periods and smaller shrimp return to shallower water during periodic temperature increases (Lindner and Anderson 1956).

<u>Pink shrimp</u>: Emigration of pink shrimp is not clearly understood. Some pink shrimp overwinter in Texas bays, residing in estuaries up to 9 months (Jackson 1975). Movements of pink shrimp are similar to those for brown shrimp (Cody and Fuls 1981). Pink shrimp tagging at the Texas-Mexico border indicated a more variable movement pattern than brown shrimp, resulting in no overall movement north or south of their release location (Sheridan et al. 1987).

Pink shrimp burrow into sediments during cold winter temperatures (Williams 1955). They also migrate from shallow to deeper waters during cold periods (Lindner and Anderson 1956).

Seabobs: Little is known about movements of seabobs. In Louisiana, seabobs move toward shore after passage of a cold front (Juneau 1977, Gulf of Mexico Fishery Management Council 1981).

Trachypenaeid shrimp: Little is known about distribution and movement of trachypenaeid shrimp. Preferred habitat is sand or mud and shell bottom in high salinity water; preferred depths are $\leq$ 84 m (Brusher et al. 1972). Gunter (1950) reported them rare in coastal bays, largely confined to waters >30 o/oo. Burkenroad (1939) reported T. constrictus might be restricted to sandy bottom. Hildebrand (1955) suggested a distribution correlated with bottom type, but did not give the preferred type. No information is available on movements.

2.3.4 Feeding Behavior and Diet

Penaeid shrimp generally feed indiscriminately on plants, animals and decaying organic matter. The diet varies with shrimp size, location and food availability.

Larval stages: Planktonic larval stages feed on algae, zooplankton and phytoplankton in the water column (Pearson 1939, Ewald 1965, Van Lopik et al. 1980, Muncy 1984).

Postlarval stages: After moving into nursery areas, postlarvae become demersal and feed at the vegetation-water interface (marsh grass, mangrove, or seagrass) ingesting the top layer of sediment containing detritus, algae and microorganisms (Pearson 1959, Jones 1973, Lassuy 1983). Planktonic diatoms and epiphytes are potential sources of nutrition for postlarval brown shrimp (Gleason and Zimmerman 1984). Zein-Eldin and Griffith (1969) fed post larval shrimp algae, Artemia salina nauplii, and ground fish or shrimp in the laboratory.

Juveniles and adults: Juvenile and adult brown, white, and pink shrimps ingest whatever is available, including decaying organic matter, animals, and plants (Viosca 1920, Weymouth et al. 1933, Flint 1956, Darnell 1958, Broad 1965, Perez-Farfante 1969, Odum 1971, Jones 1973). Condrey et al. (1972) reported high and comparable assimilation efficiencies (80-85%) on a variety of plant and animal diets by juvenile brown and white shrimps. Proteins and liquids were assimilated more efficiently than carbohydrates and rates varied on different material depending on how rapidly the diet could be ground and filtered for assimilation.

Jones (1973) intensively studied food habitats and absorption efficiency of brown shrimp 25-104 mm long in a Louisiana marsh. He observed a shift in diet and habitat as shrimp grew. Juveniles 25-44 mm long were concentrated in the nearshore environment. Here they indiscriminately ingest the top layer of sediment containing detritus and microorganisms. Jones classified this stage as "omnivores" or "encounter-feeders". At 45-64 mm long, they selected the organic fraction of the sediment and were classified as "opportunistic omnivores". At 65-104 mm long, shrimp moved from the nearshore environment to deeper waters of the marsh and were active predators feeding intensively on polychaetes, amphipods, nematodes, chironomid larvae, and ostracods. However, they continued to ingest detritus and algae and were classified as "omnivore predators".

Darnell (1958) found the foreguts of white shrimp (91-142 mm) contained sand, detritus and ground organic matter, along with fragments of mollusks, ostracods, copepods, insect larvae, and foraminifera. Christmas and Etzold (1977) added chitin, parts of annelids and gastropods, fish parts, bryozoans, sponges, corals, and filaments of algae and vascular plant stems and roots as major food items. Cannibalism is common among juveniles and adults (Perez-Farfante 1969).

Eldred et al. (1961) found pink shrimp in Tampa Bay contained both animal and plant remains. These included aquatic macrophytes, red and blue-green algae, diatoms, dinoflagellates, polychaetes, nematodes, shrimp, mysids, copepods, isopods, amphipods, mollusks, foraminfera, and fish.

Seabobs and trachypenaeid shrimp: Specific food habits of seabobs and trachypenaeid shrimp are unknown.

2.3.5 Parasites and Diseases

The extent parasites and diseases impact shrimp stocks in Texas is unknown. Literature on penaeid shrimp parasites and diseases deals primarily with identification.

Penaeus shrimp suffer from a number of diseases, some being caused by parasites which infest them: fungi, microsporidians, gregarines, protozoans, trematodes, cestodes, nematodes, barnacles, and others (Sprague 1950, 1954; Kruse 1959; Hutton et al. 1959a, 1959b; Hutton et al. 1962; Hutton 1964; Johnson 1978; Overstreet 1978). Aldrich (1965) reported brown shrimp and white shrimp serve as intermediate hosts for Prochristianella penaei: a trypan orhynchan cestode, which as an adult lives in the Atlantic stingray (Dasyatis sabina). Dawson (1957b) and Joyce (1965) reported Balanus on white shrimp. Overstreet (1978) and Johnson (1978) provide detailed descriptions of common parasites and commensals of penaeid shrimp.

The microsporidian Thelohania duorara causes a condition known as "milk" or "cotton" shrimp, because of the whitish discoloration of infected specimens (Perez-Farfante 1969). Whereas one viral disease, Braculovirus penaei, involves the digestive gland of shrimp, most are chitinoclastic organisms, including bacteria, causing shell diseases like black spot or black gill (Overstreet 1978). One fungi (Fusarium solani), has been investigated (Overstreet 1978). Parasitic and commensal relationships with some new world penaeid shrimp is provided in Johnson (1978); other parasites and diseases are discussed in Hutton et al. (1959b) and Sinderman (1970). Castille and Lawrence (1979) documented benefits of bacteria as intermediates in uptake and assimilation of dissolved organic material by early postlarval penaeid shrimp. Helminth and cestode parasites are discussed in Sinderman and Rosenfield (1967).

2.3.6 Predators

Man is a predator of penaeid shrimps, but predation by fishes may be the most important cause of natural mortality. In general, Penaeus constitute part of the diet of many teleost and elasmobranch fishes (Gunter 1945; Kemp 1950; Miles 1950; Darnell 1958, 1961; Divita et al. 1983; Sheridan and Trimm 1983; Minnello and Zimmerman 1984) and crustaceans (Hunt et al. 1980). Cannibalism is common among Penaeus as soon as they reach the postlarval stage of development (Perez-Farfante 1969). Aquatic birds, estuarine mammals and reptiles are probable predators.

Fishes that prey upon shrimp under natural conditions include: red drum (Sciaenops ocellatus) (Yokel 1966), snook (Centropomus undecimalis) (Marshall 1958), spotted seatrout (Cynoscion nebulosus) (Moody 1950, Tabb 1961, Stewart 1961), red snapper (Lutjanus campechanus) (Bradley and Bryan 1974), mangrove or gray snapper (Lutjanus griseus) (Croker 1962), toadfish (Opsanus beta) (Woodburn et al. 1957), blue croaker (Bairdiella batabana) (Robins and Tabb 1965) and hake (Urophycis sp.) (Sikora et al. 1972). Researchers have found shrimp in stomachs of king mackerel (Scomberomorus cavalla), and mutton snapper (Lutjanus analis) (unpublished observations). Costello and Allen (1962), in tank experiments, found mangrove snapper, red grouper (Epinephelus morio), and black grouper (Mycteroperca bonaci) predaceous on shrimp. Undoubtedly, many fish not documented also prey upon penaeid shrimp.

Sheridan et al. summarized qualitative and quantitative studies of fish predation on penaeid shrimps (Tables 2.2 and 2.3) and also reported a study of offshore fishes by Rogers (1977) that indicated shrimps of the genera Sicyonia, Solenocera, Parapenaeus and Trachypenaeus were found in the diets of the 26 species examined, but no Penaeus (Table 2.4). Man may be the major predator of penaeid shrimps (Sheridan et al. 1984).

2.3.7 Habitat Requirements

Various environmental factors affect shrimp survival and abundance. Although penaeid shrimp can grow and survive throughout a wide range of environmental conditions, the combination of salinity, temperature, dissolved oxygen, substrate, and vegetation are probably the most important environmental factors affecting growth, movement and survival. Optimum conditions include vegetated areas with temperatures of 18-25 C, salinities of 20-30 o/oo (except < 10 o/oo for juvenile white shrimp), dissolved oxygen levels >3 mg/l and soft mud or peat bottoms.

Temperature: Penaeid shrimp can survive water temperatures ranging from 3 to 35 C (Kutkuhn 1966). Tolerance to low temperature varies by species with pink shrimp being most tolerant and white shrimp being least tolerant (Williams 1960). Temperature tolerance of seabobs and trachypenaeids is unknown.

Temperature directly influences growth rates of shrimp. Molting frequency and growth apparently stop below 11 C and generally increase as temperature increases. Optimum growth occurs between 18 and 25 C (Zein-Eldin and Aldrich 1965).

Salinity: Penaeid shrimp can withstand salinities ranging from 0-40 o/oo. However, tolerances vary among species. Brown shrimp have been reported from salinities of 0 o/oo (Gunter et al. 1964) to 69 o/oo (Simmons 1957). Optimum salinity appears to be 20-30 o/oo (Gunter et al. 1964).

Zein-Eldin and Aldrich (1965) indicated survival and growth rates of brown shrimp may be dependent on combined effects of salinity and water temperature. They found brown shrimp postlarvae do not tolerate salinities $\leq$10 o/oo at temperatures $\leq$15 C.

Juvenile white shrimp prefer low salinities ($\leq$10 o/oo). Abundance is generally higher in these areas (Gunter 1950, 1961; Gunter and Shell 1958; Gunter et al. 1964). However, white shrimp have been found in salinities as high as 48 o/oo (Hildebrand 1958).

Pink shrimp occur in salinities from 0-47 o/oo (Tabb et al. 1962), but appear to prefer $\geq$18 o/oo (Gunter et al. 1964). Salinity requirements of seabobs and trachypenaeids are unknown, but presumably they prefer higher salinities than other species since they are generally non-estuarine.

Freshwater inflow needs: Gunter and Hildebrand (1954) observed a lag effect in the commercial shrimp landings-rainfall correlation in which landings of white shrimp correlated with rainfall of the two previous years. Gunter and Edwards (1969) observed a positive correlation between annual successes (1922-1964) of white shrimp in Texas with rainfall for that year and the two previous years. They suggested the lag effect of rainfall was a result of arid conditions. Gunter and Edwards suggested that high rainfall is necessary in Texas to dilute the estuaries for optimum white shrimp production.

Browder (1983), Barrett and Gillespie (1975) and Venkataramiah et al. (1974) suggested the possibility of increasing production of shrimp by controlling river discharge. Williamson (1977) found no detectable relationship between brown shrimp abundance and changes in freshwater inflow. White shrimp, however, was found to have a significant positive correlation with May-June inflow and with the previous year's September-October inflow.

Two factors that determine the effect freshwater inflow has on shrimp habitat are: 1) volume of freshwater entering estuaries, and 2) seasonal variability of the hydrology. Occasional heavy rains can have a substantial short term effect on estuaries and may affect shrimp yields if resulting flood waters occur during critical growth periods.

Tagging studies by White and Boudreaux (1977) indicated that heavy freshwater inflow into nursery areas in Louisiana may cause juveniles to migrate to deeper water or to move laterally towards offshore shallows (i.e. to higher salinity habitats) earlier than under normal hydrographic conditions.

Dissolved oxygen: Trent et al. (1976) attributed decreased brown shrimp abundance at altered marsh sites in West Bay, Texas, to low dissolved oxygen conditions (below 3 mg/l from 20 May to 12 August). Detailed studies of oxygen consumption by brown shrimp and interaction of oxygen consumption with temperature, salinity, and body size are presented in Bishop et al. (1980). At each salinity (10, 20 and 30 o/oo), oxygen consumption increased linearly as temperature increased, except at 30 o/oo, where oxygen consumption peaked at 28 C and decreased significantly at 30 C. This study indicated decreasing metabolic rate (per unit mass) with increasing size, although extreme variability exists. Small shrimp (3.7 g) may be capable of tolerating relatively variable hemolymph osmolalities implying that varying salinities would be more expensive energetically for larger shrimp and may be partially responsible for their offshore movement prior to maturity.

Renaud (1985) found brown shrimp and white shrimp were only sparsely distributed through hypoxic bottom water (<2.0 mg/l D.O.) in Louisiana coastal waters during 1983. Brown shrimp and white shrimp were found to avoid oxygen deficient sea water (<3.0 mg/l D.O.) under laboratory conditions (Renaud 1986).

Turbidity: The following quote from Kutkuhn (1966) addresses turbidity: "No successful studies have been conducted to relate turbidity with shrimp occurrence and density, but gross observation suggests that those bays which are consistently the most roily generally harbor per unit area and, in season, the largest concentrations of young shrimp. Whether this reflects more the nutritive potential of the detrital material in suspension, or protection of transient shrimp from predation by fishes, birds, and other animals remains a moot question".

Substrate: Substrate preferences of shrimp appear to be important to their distribution patterns along the gulf coast. Pink shrimp prefer calcareous sediments and are found mainly off the lower Texas coast. Brown shrimp, white shrimp, and seabobs prefer soft mud or peat bottoms and are found all along the coast. Trachypenaeids prefer sand, or mud and shell bottoms and are found all along the coast.

Juvenile brown shrimp and white shrimp prefer a soft mud or peat bottom with large quantities of decaying organic matter or vegetation (Williams 1955, 1959; Christmas et al. 1966; Mock 1967; Jones 1973). Sand or clay substrates are sometimes satisfactory for young brown shrimp, unless these substrates are bare clay, sand, or shell (Williams 1959). Adult brown shrimp are found on mud or silt and also on sand and shell (Perez-Farfante 1969). In the gulf, white shrimp are also found on muddy or silty bottoms and on clay or sand with fragments of shell (Springer and Bullis 1954; Hildebrand 1954, 1955).

Pink shrimp prefer firm mud or silt bottoms with coral sand containing a mixture of mollusk shells (Springer and Bullis 1954; Hildebrand 1954, 1955; Williams 1958) and firm sand bottoms (Perez-Farfante 1969).

Zimmerman et al. (1983) found overall mean density of brown shrimp in vegetated areas was significantly greater than mean density in nonvegetated areas. Minello and Zimmerman (1983) indicate artificial *Spartina* sp. structure reduced predation rates of some, but not all, fish on brown shrimp.

Zimmerman and Minello (1984) found brown shrimp and pink shrimp were significantly more dense in vegetated habitat, but white shrimp were not consistently more abundant in either vegetated or nonvegetated habitats. Minello and Zimmerman (1985) monitored distributions of juvenile brown shrimp and white shrimp in laboratory enclosures. They found brown shrimp selected simulated Spartina sp. (green strand) during the day but not at night, and white shrimp never showed a strong selective preference for structure.

Other environmental conditions: Couch (1978) reviewed the literature on effects of various pollutants (petroleum and non-petroleum organic chemicals, heavy metals), biological agents, the interactions among them and their interactions with environmental conditions for several penaeid shrimps.

The effects of brine disposal in Texas have been recognized as a problem since the 1930's (Wiebe et al. 1934). Many oilfield operators in the 1930's discharged the salt water into any body of water that was conveniently located, resulting in increased osmotic pressure and direct toxic effects on fish and other organisms in the rivers. $MgCl_2$ and $CaCl_2$ (often found in brine) have a greater lethal effect on fish than NaCl. Disposal in the marine environment has been discussed by Edwards and Heffernan (1970), Heffernan (1970), Spears (1970), Parker and Blanton (1970), Mackin (1971, 1973), and Pincince and List (1973). Recent studies have focused on effects of brine disposal in offshore areas such as the Bryan Mound brine disposal site off Freeport, Texas (Hann and Randall 1980, Howe 1981, Owens and Neff 1981). Howe (1981) presented lethal and sublethal effects of salt brine effluent on adult and subadults of brown and white shrimp. These studies indicate 50% of any group of exposed shrimp can be expected to die when held 48 hours in saltwater 18-22 o/oo above normal. Data for brown shrimp suggests that yearly maximum bottom temperature of 30 C would be associated with 10% mortality at 48 hours, providing the increase in salinity reached 12 o/oo, nearly twice the worst case prediction and six times the maximum 24 hour exposure predicted in the National Oceanic and Atmospheric Administration model of brine plume behavior.

2.4 Estimates Of Life History Parameters

2.4.1 Fecundity

Female penaeid shrimp produce approximately 200,000-3,000,000 eggs/spawn. Chamberlain and Lawrence (1983) observed that fecundity and hatching rate averaged 297,600 and 55%, respectively, for white shrimp and 194,200 and 77.6%, respectively, for brown shrimp along the Texas coast. Bray and Lawrence (1984) reported 197,000-309,000 eggs/spawn for white shrimp collected off Port Aransas, Texas during 1981-1983. Information on the number of eggs/spawn is sparse and current information suggests early estimates may have been too high. Earlier estimates ranged from 500,000 to 1,000,000 eggs/spawn for white shrimp (Burkenroad 1934, Anderson et al. 1949a) and 500,000/spawn for pink shrimp (Matosubrato 1974). There is evidence that females of each species may spawn more than once during their life span (Burkenroad 1939, King 1948, Cummings 1961, Perez-Farfante 1969) and that smaller females are less fecund. Fecundity of seabobs and trachypenaeids is unknown.

2.4.2 Sexual Maturity and Sex Ratio

Estimated minimum size at sexual maturity for Texas populations of male brown shrimp is 110-120 mm, and is 160-170 mm for females (Chamberlain and Lawrence 1983). Size at sexual maturity for Texas populations of white shrimp is 150-160 mm for males and 160-170 mm for females. However, estimates of minimum sizes at sexual maturity for other populations in the Gulf of Mexico vary (Table 2.5). Males apparently mature at a smaller size than females (Parrack 1979). Estimates are based on a few shrimp, definitions of maturity stages are often not clear, and few supporting details are given.

The sex ratio (male:female) for the three Penaeus species is generally considered to be 1:1 (Cook and Lindner 1970, Lindner and Cook 1970, Costello and Allen 1970, Nichols 1984). However, Perez-Farfante (1969) indicates some segregation by sex may occur offshore because samples for white shrimp and pink shrimp sometimes contain only one sex. Bryan and Cody (1975) reported a sex ratio of 1:1.1 for white shrimp collected off Texas (from Gilchrist to Yarborough Pass) during 1973-1975. The male to female ratio for brown shrimp, white shrimp and pink shrimp was 1:1, 1:1.3 and 1.9:1, respectively, in 11-79 m of water off Port Aransas, Texas during 1981-1982 (Texas Parks and Wildlife Department unpublished data).

2.4.3 Age Determination

No reliable method has been developed to determine the age of penaeid shrimp (Lindner and Cook 1970, Parrack 1979). Crustaceans are difficult to age because all hard parts are lost with each molt (Calder et al. 1974). Age composition can be inferred from large volume size frequency data (Chavez 1973) but varies directly with recruitment and movement of maturing shrimp to offshore waters (Kutkuhn 1962). Mark-recapture experiments using individually numbered tags estimate age by adding the time free to the estimated age at release.

2.4.4 Growth

Growth of "large" shrimp (>70 mm) has normally been estimated from mark and recapture experiments. A simple linear relationship of length (or weight) to time is not applicable, since penaeid shrimp enter a self-limiting period of growth where the rate of increase in size is much lower at an age of 3-4 months and becomes very low at approximately 10-12 months (Parrack 1979, Gulf of Mexico Fishery Management Council 1981). Christmas and Etzold (1977) summarized estimates of growth parameters for brown shrimp, white shrimp and pink shrimp for several studies in the Gulf of Mexico and South Atlantic (Table 2.6).

Brown shrimp: The best estimates for growth of Texas brown shrimp are those of Parrack (1979) who estimated growth rate of brown shrimp from mark and recapture experiments conducted in the northern gulf in 1967, 1968, and 1969 (Table 2.7). He reported the size-age relation appears linear in young individuals, the rate of increase in size decreases with age, and a nonlinear function is therefore required to model brown shrimp growth. The von

Bertalanffy equation fits the data best for both sexes in the modeling of both length and weight. Parrack (1979) observed that females grow more rapidly, weigh more, and attain a larger final length and weight (see Section 2.4.5) than males of the same age. He also reported differences in growth between northwest Atlantic, northern gulf and southern gulf brown shrimp populations, and concluded they were likely correlated with gross water temperature.

Growth of brown shrimp is slow during January and February (0.5 mm/day), increases in March, and reaches a maximum (0.5-3.3 mm/day) during April and June (Gulf of Mexico Fishery Management Council 1981, which summarized, Loesch 1965, Ringo 1965, St. Amant et al. 1966, Broom 1968, Ford and St. Amant 1971, Jacob 1971, Swingle 1971, Johnson 1976). This seasonal variation in growth rate has been associated with spring warming (St. Amant et al. 1963, Ford and St. Amant 1971).

Growth is related to temperature and salinity (Cook and Lindner 1970, Lassuy 1983). Zein-Eldin and Griffith (1966) reported growth rates for laboratory-reared postlarval brown shrimp increased with temperatures up to 32.5 C, with optimal growth and production at 22.5-30 C. In Barataria Bay, Louisiana St. Amant et al. (1966) found growth limited to <1.5 mm/day when water temperatures were <25 C, <1 mm/day when water temperatures were <20 C,and little or no growth when water temperatures were <16 C. White (1975) and White and Boudreaux (1977) reported unusually cool water temperature and low salinity resulted in an estimated mean growth rate of only 0.7 mm/day during April and May in western Louisiana. Venkataramiah et al. (1972) observed highest growth and survival at temperature-salinity combinations of 26 C and 17 o/oo.

<u>White shrimp</u>: The best estimate of growth for Texas white shrimp were determined using a seasonally-varying growth model developed from mark/recapture experiments (Nichols 1982). Growth rate is predicted from water temperature and shrimp size. The simplest function for instantaneous growth rate (G) is:

$$G = b_o + b_1L + b_2L^2 + b_3T + b_4T^2 + b_5LT$$

where:

L = length;
T = temperature; and
b = regression coefficients.

The coefficients for males and females are :

Variable	Males	Females
Intercept	-2.24324	-3.18010
L	0.0303993	0.0367000
L^2	-0.0000932129	-0.000107964
T	0.0863683	0.143113
T^2	-0.000383294	-0.00135301
LT	-0.000587585	-0.000723210

Growth is rapid from April through October and slower from November through March (Lindner and Anderson 1956), whereas, Klima (1964, 1974) observed faster growth in August to October than in September to November. These observations suggest the differences in seasonal growth are due to differences in water temperature, as Lindner and Anderson (1956) found growth to be slower when water temperatures were below 20 C.

Rate of increase in weight is relatively low in small shrimp, reaches a maximum in the middle size range, then decreases progressively with further increases in size (Kutkuhn 1962). Etzold and Christmas (1977) state that female white shrimp grow more rapidly and reach larger sizes than males.

Klima (1964) calculated von Bertalanffy growth parameters from mark-recapture experiments. Lindner and Cook reported Klima's parameters for 7-day periods were:

Parameter	Test 1	Test 2
t_o	-0.6	-0.2
L_{oo}	224 mm	214 mm
W_{oo}	87 g	75.1 g
K	0.06	0.09

Pink shrimp: Estimates of juvenile (<100 mm) growth rate range from 7-52 mm TL/month (Williams 1955, Costello and Allen 1959, Eldred et al. 1961, Tabb et al. 1962), whereas monthly increments of subadult and adult shrimp range from 0-22 mm (Costello and Allen 1960, Iverson et al. 1960, Iversen and Jones 1961, Costello 1963, Kutkuhn 1966, Knight 1966, McCoy and Brown 1967).

Higman et al. (1972) determined growth of postlarval and juvenile pink shrimp held in enclosures in the estuarine area of Everglades National Park. Multivariate regression analysis was used to determine significant relationships between weekly growth rate estimates and weekly estimates of bottom salinity, temperature, and dissolved oxygen. Salinity appeared to be the most significant factor. Since the salinity regime of the area is dependent upon drainage through southern Florida into the Everglades, Higman concluded pink shrimp success in the Dry Tortugas may be related to local rainfall in the Everglades drainage basin as well as to man-made alterations which block the normal waterflow patterns.

Rates of pink shrimp growth (in length) vary with size and sex (Iversen and Jones 1961) and water temperature (Williams 1955, Teinsongrusmee 1965). Larval pink shrimp increase their total length from about 0.38 mm (nauplii) to 4.1 mm (postlarvae) in 2 to 3 weeks (Dobkin 1961, Ewald 1965).

Pond-raised shrimp: Growth of Penaeus shrimp has also been determined in culture ponds along the gulf coast. However, these results must be interpreted with caution: intensive culture ponds are stocked at much higher densities than probably found in nursery areas. Water quality, feeding rates, and other problems attributed to crowded conditions can also influence growth rates. In culture ponds, survival and growth generally are inversely related.

High survival in a pond (for whatever reason) often leads to low individual growth rates.

Growth rates of brown shrimp and white shrimp stocked at 98,800/ha and fed at 3% body weight were determined at 7, 15, and 21 o/oo in 0.2 ha ponds in Texas (Hysmith and Colura 1976). Growth of both species was highest at 15 o/oo, averaging 0.19 g/day and 0.14 g/day for brown and white shrimps, respectively. At 21 o/oo, growth rates of 0.15 g/day and 0.10 g/day were observed. At 7 o/oo, no survival was evident in brown shrimp; however, white shrimp grew at 0.14 g/day.

A subsequent Texas study resulted in white shrimp growth rates of 0.94-0.98 mm/day at a stocking rate of 20,000/ha, 0.85-1.02 mm/day at 35,000/ha, and 0.73-0.89 mm/day at 50,000/ha when shrimp were fed at 7.5% body weight (Elam and Green 1974). At salinities ranging from 25-100% of seawater (36 o/oo), growth of brown shrimp in Mississippi culture ponds was highest at 25-50% seawater, and ranged up to 0.95 mm/day and 31.45 mg/day (Venkataramaiah et al. 1972). Growth in 75-100% of seawater ranged from 0.83-0.86 mm/day and 27.11-27.95 mg/day.

Seabobs: Growth rates for seabobs are virtually unknown. In laboratory studies, Renfro and Cook (1963) found early larval development of seabobs from spawning to first protozoeal stage took 58 hours at 23-24 C and 27 o/oo. Growth rates for later life stages have not been reported, but maximum length is less than other penaeids (Gulf of Mexico Fishery Management Council 1981).

2.4.5 Maximum Age and Length

Few penaeid shrimp live more than 1 year (Anderson 1966). The maximum age penaeid shrimp reach in Texas is about 18 months, with some females living slightly longer (Kutkuhn 1962). Some pink shrimp have been reported to live more than 2 years (Eldred et al. 1961).

Maximum length attained by Penaeus shrimp varies with species and sex. Females grow larger than males (Tables 2.6 and 2.8). Parrack (1979) reported brown shrimp females are much larger than males of the same age. Estimates of the asymptotic length differ between sexes: about 169 mm for males and 194 mm for females (Tables 2.6 and 2.8).

2.4.6 Weight-Length Relationships

Many weight-length relationships and conversion tables have been published for penaeid shrimp (Tables 2.9 and 2.10). However, most are not specific to Texas waters.

Conversion tables for penaeid shrimp reveal pink shrimp weigh more than brown shrimp and brown shrimp weigh more than white shrimp at the same total length (Table 2.9). There are significant differences in weight-length relationships between sexes for brown shrimp and pink shrimp (Table 2.10) (Fontaine and Neal 1971, Parrack 1981). Differences are not as large for white shrimp. Weight-length relationships for other species are not available.

2.4.7 Mortality

Death of penaeid shrimp is either due to natural causes or to harvest by man. Coefficients of fishing mortality (F), natural mortality (M), and total mortality (Z) are defined as instantaneous death rates for a cohort of N individuals over a short time. Rate of decline in population numbers through time is presented as a function of these observed values (Gulf of Mexico Fishery Management Council 1981).

Values of the weekly total mortality (Z) coefficient range from 0.07 to 1.51 (Table 2.11) or a loss of 7 to 78% of the population during one week. Weekly instantaneous total mortality rate for Texas and Louisiana brown shrimp is 0.27 (Christmas and Etzold 1977, Gulf of Mexico Fishery Management Council 1981). Mortality rates for Texas white shrimp range from 0.14 to 0.46. Pink shrimp mortality rates range from 0.07 to 1.51 in Florida and North Carolina; rates are not available for Texas.

Natural Mortality: Natural mortality is defined as death of organisms from all causes except man's fishing (Ricker 1975). Best estimates for natural mortality are 0.275 (24%) per month for brown and white shrimps and 0.30 (26%) per month for pink shrimp (Nance 1989).

Reported weekly estimates of M for brown shrimp range from 0.025-0.364 in Gulf of Mexico and mid-Atlantic waters (Table 2.11). Estimates for white shrimp in Texas range from 0.04 to 0.12; estimates in other gulf areas range from 0.04 to 0.56. Studies in Louisiana have reported estimates as high as 0.556 (Phares 1980a). Specific estimates for pink shrimp in Texas have not been made; they range from 0.01 to 0.55 in Florida and North Carolina.

Natural mortality by predation on penaeid shrimps has been examined by Gunter (1945), Darnell (1958), Creel and Divita (1982) and Sheridan et al. (1984a, 1984b). These data are discussed in Section 2.3.6.

Fishing mortality: Fishing mortality is defined as instantaneous rate of F and is equal to instantaneous Z multiplied by the ratio of fishing deaths to all deaths when fishing and natural mortality act concurrently (Ricker 1975). Reported estimates of F have been derived from shrimp marking studies and shrimp landings data.

Weekly estimates of F for brown shrimp within Texas bays and adjacent gulf water range from 0.02-0.32 (Table 2.11). White shrimp estimates for Texas range from 0.06-0.19. No estimates of fishing mortality have been made for pink shrimp in Texas; however, estimates for Florida and North Carolina range from 0.02 to 0.34.

Discarding of small shrimp back into the gulf by the commercial fishery is a source of fishing mortality discussed by Berry and Benton (1969), Baxter (1973), and Bryan et al. (1982). They estimate shrimp discarding ranged from 0-29% of the total shrimp catch (by weight) from Texas gulf waters during June-August 1964-1966; 23-43% during June 1972, and 11-38% during June-August of both 1973 and 1974. Berry and Benton (1969) reported that of shrimp discarded, at least 50% die from exposure to air before they are returned to gulf waters.

Recent changes in Texas laws (elimination of minimum sizes in the gulf), combined with new harvesting strategies and increased markets for smaller shrimp have reduced the amount of shrimp discarded by the commercial fleet in recent years (Klima et al. 1982, 1986, 1987).

There are no estimates of sport shrimping mortality for Texas. King (1974) stated that about 1.1% (408,606 kg) of the total Texas shrimp harvest by weight was taken by recreational or sport shrimp fishermen during 1973. Totals comprised 5.7% of the shrimp harvested from Texas bays and 0.5% of the shrimp harvested from gulf waters.

2.4.8 Size and Age Composition

Trends in age and size compositions may reflect changes in the status of fish stocks (Ricker 1975, 1977). As a fishery develops, stocks exhibit gradual juvenescence that leads to decreased standing stocks and average size of the individual. These changes are normal as fishing mortality increases; they eventually lead to a maximum sustainable yield as the population is reduced but culminate in growth overfishing if fishing mortality becomes too high.

Larvae: In general, brown shrimp, white shrimp and pink shrimp are less than 5-7 mm in length through their various larval stages. Growth and size of organisms are dependent upon environmental parameters such as salinity and temperature.

Postlarvae: Most authors consider postlarval penaeid shrimp to be <25 mm (Renfro 1964, Zamora and Trent 1968). Postlarval brown shrimp entering coastal bays from the gulf range from 8-18 mm whereas white shrimp and pink shrimp range from 6-10 mm (Compton 1965a, Kutkuhn 1966, Copeland and Truitt 1966, Baxter and Renfro 1967, Zamora and Trent 1968, King 1971, Duronslet et al. 1972). There is no information on larvae and postlarvae of seabobs and trachypenaeids for Texas.

Juveniles and subadults: Penaeid shrimp are considered to be juveniles from 25-100 mm TL, at which time they emigrate out of coastal bays into the Gulf of Mexico as subadults. Juvenile and subadult shrimp have been monitored by Texas Parks and Wildlife Department in Texas coastal bays with marsh nets, bar seines, bag seines, and otter trawls since 1959 (Leary and Compton 1960; Compton 1962; Pullen 1963; Moffett 1964, 1965, 1966, 1967a, 1967b, 1968, 1969, 1971a, 1971b, 1972a, 1972b, 1973; Moffett and McEachron 1974, 1975; Johnson 1976, 1977; Benefield and Baker 1980; Benefield 1982; Hammerschmidt et al. 1988).

Mean lengths of brown shrimp caught in Texas Parks and Wildlife Department bag seines range from 51-64 mm, white shrimp range from 53-68 mm, and pink shrimp range from 48-77 mm (Hammerschmidt et al. 1988). Trends in annual mean length of each shrimp species caught in Texas Parks and Wildlife Department bag seines during 1978-1986 indicate a slight increase for brown shrimp and downward trends for white shrimp and pink shrimp; these data have not been tested statistically (Figure 2.4)

Mean lengths of brown shrimp caught in bay trawls range from 83-97 mm, white shrimp range from 92-101 mm, and pink shrimp range from 93-104 mm (Hammerschmidt et al. 1988). Trends in annual mean length of each shrimp species caught in Texas Parks and Wildlife Department bay trawls during 1982-1986 indicate fluctuations around 90 mm for brown shrimp and upward trends for white shrimp and pink shrimp; these data have not been tested statistically (Figure 2.5).

Bag seine catches reveal each species is found during slightly different seasons within bays. Mean lengths for brown shrimp are smallest during December-April and largest during May-November (Figure 2.6). White shrimp mean lengths are smallest during June-February and largest during March-May. For pink shrimp, mean lengths are smallest during June-February and largest during March-May.

Seasonal mean lengths from bay trawls differ for each species. Mean lengths for brown shrimp are smallest during April and largest from June-August (Figure 2.7). White shrimp lengths are smallest from November-February and largest during March-October. For pink shrimp, mean lengths are smallest during August-September and largest during February-June.

Adults: Adults are usually defined as the mean size at which shrimp become sexually mature. Chamberlain and Lawrence (1983) estimate minimum sizes for sexually mature shrimp in Texas are 110-120 mm for brown shrimp males, 160-170 mm for brown shrimp females, 150-160 mm for white shrimp males and 160-170 mm for white shrimp females. Eldred et al. (1961) report estimates of 74 and 92 mm for male and female pink shrimp.

The Texas Parks and Wildlife Department has monitored shrimp size and abundance in the gulf since 1960 (Compton 1961, 1962, 1965b; Compton and Bradley 1963, 1964; Bradley and Bryan 1971, 1972; Bryan and Cody 1974; Cody et al. 1978, 1979; Cody and Avent 1980; Bryan et al. 1982; Cody and Fuls 1984, 1986b; Hammerschmidt et al. 1985; Benefield et al. 1986).

Coastwide annual mean length of brown shrimp collected by the Texas Parks and Wildlife Department within the Texas Territorial Sea range from 105-109 mm (Figure 2.8). Mean length of brown shrimp is largest in nearshore waters from March to April and decreases in May as juvenile shrimp begin to emigrate from Texas coastal bays. Mean length increases from May through August then decreases through February (Figure 2.8).

In general, smallest shrimp are found in shallow gulf waters. Mean length increases as depth increases and as distance from shore increases (Figure 2.9) (Cody and Crowe in preparation). Matthews (1981) found a difference in size of brown shrimp between areas along Texas. Fuls and Cody (1988) reported brown shrimp were significantly larger off Aransas Pass than off Mansfield Pass during May-July 1980-1981.

Coastwide annual mean lengths of white shrimp collected by the Texas Parks and Wildlife Department within the Texas territorial sea range from 105-115 mm (Figure 2.10). Mean length of white shrimp in the gulf is largest from April-June, then decreases from August through January as juvenile and subadult shrimp begin to emigrate from Texas coastal bays (Figure 2.10). Except during June, when large "spawning" white shrimp are found in shallow gulf waters, smaller white shrimp are generally found in waters <9 m whereas larger whites are found in waters >9 m.

Coastwide annual mean length of pink shrimp within the Texas territorial sea ranged from 111-116 mm (Figure 2.11). Mean length of pink shrimp generally increases with depth (Cody and Crowe in preparation). Mean length of pink shrimp is smallest during November-April and largest from July-October (Figure 2.11).

2.4.9 Fluctuations in Abundance

Abundance of Penaeus in bag seines has fluctuated with no consistent trends since the current Texas Parks and Wildlife Department sampling program began in 1978. However, in the deeper portions of the bays there appears to be a downward trend in the catch rate of white shrimp since Texas Parks and Wildlife Department routine monitoring started in 1982.

Plankton-larvae: Fluctuations in abundance of plankton and larvae may depend on many factors, including: (1) number and size composition of spawners, (2) environmental conditions such as temperature and salinity, (3) food availability, (4) predators, and (5) transporting currents. A systematic study in gulf waters was conducted during 1961 (Temple and Fischer 1968). Peak abundance of larvae was at 14 m in gulf waters during May-August and at 46 m and 92 m during September-November (Figure 2.12). Relative abundance and distribution of planktonic stages off Galveston are presented in Figures 2.13-2.15.

Postlarvae: Peak abundance of postlarval brown shrimp migration into bays along the Texas coast occurs mainly from February through April with sporadic peaks through September (Baxter and Furr 1964; Compton and Bradley 1964a; Compton 1965a; Baxter 1966, 1967, 1968b; Copeland and Truitt 1966; Baxter and Renfro 1967; King 1971; and Duronslet et al. 1972). Benefield (1982) and Benefield and Baker (1980) found peak abundance of postlarval brown shrimp in Galveston and Aransas Bays during March 1979 and 1980. Year to year variation appears to be the result of environmental conditions.

Peak abundance of postlarval white shrimp migration into Texas bays occurs mainly from May-June and August-October (Compton 1965a, Copeland and Truitt 1966, Baxter and Renfro 1967, King 1971, and Duronslet et al. 1972). Benefield (1982) reported postlarval white shrimp were found in greatest abundance in Galveston, Matagorda, San Antonio, and Aransas Bays during August-November 1978-1980 with sporadic peaks in Matagorda and Aransas Bays during June and July. As with brown shrimp, yearly variation appears to be the result of environmental conditions.

Because of difficulty in identifying pink shrimp postlarvae from brown shrimp postlarvae and low abundance in relation to brown shrimp and white shrimp postlarvae, little effort has been spent detailing their abundance. Some studies group brown shrimp and pink shrimp postlarvae together (King 1971). Copeland and Truitt (1966) found peak occurrence of pink shrimp postlarvae in Aransas Channel during August and September, with minor abundances in June and July. Compton (1965a) reported pink shrimp postlarvae were caught in Aransas Channel as early as June.

Juveniles: Abundance data for juvenile shrimp populations has been collected by the Texas Parks and Wildlife Department since at least the early 1950's and in a routine coastwide monitoring program using bag seines since 1978. No consistent trends are apparent in these data.

Abundance of juvenile brown shrimp in bag seines is highest during April-July with major peaks in May and June (Figure 2.16). Annual catch rates ranged from 247/ha in 1978 to 611/ha in 1987 (Figure 2.17).

Abundance of juvenile white shrimp in bag seines is highest during July-November with major peaks fluctuating from year to year within this period (Figure 2.16). Annual catch rates ranged from 242/ha in 1985 to 1277/ha in 1982 (Figure 2.17).

Abundance of juvenile pink shrimp in bag seines is highest during March-April and August-November (Figure 2.16). Annual catch rates ranged from 3/ha in 1978 to 26/ha in 1982 (Figure 2.17).

Subadults: The abundance of subadult shrimp in Texas bays has been sampled with trawls by the Texas Parks and Wildlife Department since the 1950's and is currently being monitored with a coastwide random sampling program started in 1982. Since 1982 brown shrimp and pink shrimp abundance has fluctuated. White shrimp abundance has steadily declined.

Abundance of subadult brown shrimp in bay trawls is highest during May-July (Figure 2.18). Annual catch rates since 1982 ranged from 21/h in 1983 to 32/h in 1987 (Figure 2.19).

Abundance of subadult white shrimp is highest from August to December within Texas bays, with occasional increases during March-May and July (Figure 2.18). Annual abundance ranged from 47/h in 1982 to 17/h in 1987 indicating a decreasing trend (Figure 2.19).

Abundance of subadult pink shrimp in trawls is highest during March-May and October-December (Figure 2.18). Catch rates (<2.3/h) were much lower than other species; there has been a small increase in catch rate during the last three years (Figure 2.19).

Adults: Adult abundance within the Texas Territorial Sea has been monitored by the Texas Parks and Wildlife Department since 1960. White shrimp abundance has steadily declined in gulf trawls since 1985 when the current program based on randomly selected stations began. Brown shrimp and white shrimp catch rates are higher than for pink shrimp (Figure 2.20).

Abundance of brown shrimp in gulf trawls is highest from May-July as small brown shrimp emigrate into gulf waters from Texas bays (Figure 2.21). Abundance decreases from September through February.

Brown shrimp data from Southeast Area Monitoring and Assessment Program samples indicates decreasing abundance during 1982-1987 (Figure 2.22). Fuls and Cody (1988) reported a significant difference between annual May-August 1980 and 1981 catch rates of brown shrimp on the central and lower coast. But Cody and Fuls (1986) found no significant difference in catch rate off Aransas Pass during 1981 compared to the previous 5 year average (1976-1980). Matthews (1982c) used Texas Parks and Wildlife Department and National Marine Fisheries Service data for May-July 1981 and reported significant differences in abundance among sub-areas 18-21 (Sabine Lake to Brownsville) and among 18-m depth zones (0-18, 19-37, and 38-55 m). Fuls and Cody (1988) reported no significant difference in abundance when smaller depth zones (9 m) off the south Texas coast were analyzed (Table 2.12).

Abundance of white shrimp is highest in gulf waters from November-February as white shrimp emigrate from coastal bays (Figure 2.21). There is no difference in abundance among the first three adjacent 9-m depth zones in Texas offshore waters. White shrimp were not found beyond 37 m during Southeast Area Monitoring and Assessment Program cruises in June and July 1982-1987 (Table 2.13).

Fuls and Cody (1988) found abundance of white shrimp was significantly greater off Aransas Pass than Mansfield Pass during May-August 1980 and 1981. Catch rates fluctuated during the period May-July 1970-1982, however, no significant trend was found. Cody and Fuls (1986) found no significant difference in catch rate between 1981 and the previous 6-year November-February average.

Pink shrimp are most abundant during February-May within the Texas territorial sea (Figure 2.21). Pink shrimp were not found beyond 55 m during Southeast Area Monitoring and Assessment Program cruises in June and July 1982-1987 (Table 2.13). Fuls and Cody (1988) found pink shrimp catch rates were significantly greater off Mansfield Pass than off Aransas Pass during May-August 1980 and 1981.

The best available monthly data for seabobs off Texas comes from Texas Parks and Wildlife Department gulf samples; catch rates fluctuate widely throughout the year (Figure 2.23). During a white shrimp discard study along the central Texas coast, Cody et al. (1978) reported seabobs in 3-4% of their samples with annual catch rates of 0.2-0.5/h. Thompson and Bane (1986a, 1986b) and Thompson et al. (1988) reported seabobs in 0.5-3.8% of the gulfwide samples taken during the June-July Southeast Area Monitoring and Assessment Program studies in 1983-1985. In Louisiana, Juneau (1977) reported greatest abundance from July-November.

Thompson and Bane (1986a, 1986b) and Thompson et al. (1988) reported trachypenaeids in 51.7-61.8% of the gulfwide samples taken during June-July Southeast Area Monitoring and Assessment Program studies in 1983-1985. Bryan et al. (1982) reported 88-93% of their nighttime samples on the brown shrimp grounds contained trachypenaeids; they accounted for 23% (by number) of the "other" invertebrates captured. Cody et al. (1978) reported trachypenaeids in 28-38% of the daytime samples on the white shrimp grounds.

2.4.10 Estimates of Spawner-Recruit Relationships

A spawner-recruit relationship is the quantifiable relationship between number of reproducing adults and resulting number of young recruited to the fishery. Spawner-recruit relationships within the fishery have been proposed by Nichols (1984) and Nance and Nichols (1987) for white shrimp. Klima and Nance (in press) verified an apparent stock-recruitment relationship for white shrimp, but cautioned that factors unrelated to fishing could be affecting the relationship. Rothschild and Brunenmeister (1984) and Nance et al. (1988) have discussed the spawner-recruit relationship for brown shrimp. Klima and Nance (in press) could not demonstrate a significant relationship for brown shrimp or pink shrimp with the data currently available.

2.5 Biological Status Of Penaeid Shrimp In Texas

Average number of brown shrimp caught in Texas Parks and Wildlife Department bag seines and bay trawls fluctuates yearly and indicates no significant upward or downward trend. Average number of white shrimp caught in Texas Parks and Wildlife Department bag seines has fluctuated yearly since 1978; however, since 1982 average number of white shrimp caught in bay trawls has declined.

The best explanation of maximum sustainable yield for penaeid shrimp is contained in the Gulf Council's Fishery Management Plan for the Shrimp Fishery (Gulf of Mexico Fishery Management Council 1981). Estimates of maximum sustainable yield presented in the Federal Plan apply to the whole Gulf of Mexico region and do not specifically target one state. Estimates of maximum sustainable yield for the entire gulf range from 53 to 64 million kg (whole weight) for brown shrimp, 27 to 32 million kg for white shrimp and 11 to 15 million kg for pink shrimp (Nichols 1982). Since Texas historically accounts for 46% of the gulfwide brown shrimp catch, 16% of the white shrimp and 0.05% of the pink shrimp, these ratios were used to estimate maximum sustainable harvest for Texas.

Estimates of maximum sustainable harvest for Texas range from 24 million kg to 30 million kg for brown shrimp, 4 to 5 million kg for white shrimp and 0.5 to 0.7 million kg for pink shrimp (using the ratio of Texas landings to gulfwide landings). Texas landings during the last 10 years averaged 109% of the minimum estimated maximum sustainable harvest for brown shrimp, 233% of the minimum estimated maximum sustainable harvest for white shrimp and 250% of the minimum estimated maximum sustainable harvest for pink shrimp.

Caution concerning harvest level of shrimp is in order since Nichols (1984) demonstrated a spawner-recruit relationship for white shrimp in the northern gulf. Caution regarding future harvest has been advised by Rothschild and Gulland (1982) and Nance et al. (1988) for the brown shrimp fishery.

2.5.1 Harvest

Harvest of a fishery is defined as the quantity of resource landed by weight, during a specified period of time (Ricker 1975). It is dependent upon usable stock size and amount of fishing effort applied to the resource. Usable stock is the number or weight of all animals in a stock that are within the range of sizes customarily considered harvestable (or designated so by law) and fishing effort is the amount of fishing gear involved in harvest during a specific time period (Ricker 1975).

Usable stock for the Texas shrimp fishery is weight of all harvestable shrimp. During the harvest season usable stocks are replenished through the growth of previously recruited shrimp (increase in weight), and the recruitment of young shrimp. Recruitment is the entry of young individuals into the usable stock through growth (attainment of useful size).

Fishing effort in the Texas shrimp fishery is defined as the number of active fishing vessels multiplied by the amount of time each is engaged in fishing.

Harvest is generally expressed as short-term harvest (e.g. one year or one harvest season) or long-term harvest (e.g. average of many consecutive harvest seasons). During the short-term, effort and harvest can be assumed to be linearly related (Figure 2.24); every unit increase in effort produces a unit increase in harvest. Short-term harvest is not a good indicator of the condition of a resource since a fishery will generally harvest more over the short-term, if enough effort is applied, than can be sustained for the long-term.

Unlike short-term harvest, long-term harvest and effort are not linearly related but can be represented by a curve with a steadily decreasing slope (Figure 2.24). During the long-term, each successive unit of effort will increase harvest less than the previous unit of effort. If increased level of fishing effort is sustained during the long-term, resource condition will determine whether elevated harvest levels can be sustained. As a result, long-term harvest equilibria are more useful in evaluations of resource condition; they are more meaningful than short-term harvest to the development of a long-range fishery management plan. Harvest, as it is used in the following discussion, refers to long-term harvest only.

Population size and biological potential of a resource determine the relationship between fishing effort and harvest of that resource. If a fishery resource is not harvested, growth and recruitment can increase population size to a point where environmental limitations prevent further growth. Growth and recruitment will eventually be balanced by natural mortality and an equilibrium between biological potential and environmental limitations will be established. This maximum biomass is termed environmental carrying capacity for the resource (Cunningham et al. 1985). In the absence of fishing, maximum population size or biomass is the environmental carrying capacity.

When fishermen begin to harvest the resource, population size is reduced by the amount of resource harvested in addition to that amount lost through natural mortality. Initially, harvest exceeds biological production (increase in weight by growth or numbers) and population size is reduced. As population size decreases, biological production increases, providing more resource for harvest and reducing net population size reductions. As more fishermen enter the fishery (effort increases) more resource will be harvested and population size will be reduced proportionately. Increases in fishing effort will result in increased biological production until the population has been reduced to 1/2 environmental carrying capacity. This occurs because animal growth rates increase, population recruitment rates increase, and natural mortality decreases as population density decreases to 1/2 environmental carrying capacity (Ricker 1975). Increases in population growth rate are reflected by increases in biological production as population size decreases from environmental carrying capacity to 1/2 environmental carrying capacity. If fishing effort continues to increase, population size could be reduced to less than 1/2 environmental carrying capacity. Below 1/2 environmental carrying capacity, population growth rate and biological production begin to decrease while fishing effort continues to increase. As population size is reduced, biological productivity is decreased also, providing less resource for harvest.

When fishing occurs, the part of the population that is landed is referred to as harvest. Fishermen may harvest an amount less than, equal to, or greater than the biological production of a population. If fishermen remove less than the net biological production, population size will increase and over the long-term population size will grow. If fishermen consistently harvest an amount equal to the biological production, the population size will not change. When fishermen harvest an amount greater than net biological production, population size will be reduced.

One of the primary factors determining harvest (amount of resource removed) is amount of fishing effort applied. For each population size and level of biological production there is a level of effort that will remove only net production and will not reduce population size. Likewise, for each level of sustained fishing effort there is a population size and level of biological production that can be maintained. During the long-term, it is fishing effort that determines not only the harvest but the population size of a resource. If the resource is in good biological condition and is underutilized (near environmental carrying capacity), a unit increase of sustained effort will produce a sustained increase in harvest (Figure 2.25). As sustained fishing effort increases, population size decreases, while biological production and harvest increase. As population size approaches 1/2 environmental carrying capacity, it's point of maximum biological potential, maximum harvest will be obtained (Figure 2.25). When population size has been reduced to less than 1/2 environmental carrying capacity, it's biological production and harvest will begin to decrease. Beyond the point of maximum harvest, increases in fishing effort may initially produce a harvest increase, but if the new elevated level of harvest cannot be off-set by biological production, harvest and population size will decrease until a new equilibrium is achieved. Reduced biological production will translate to a lower long-term harvest equilibrium. Since short-term population losses can no longer be off-set by biological production, a lower long-term harvest equilibrium will result. The new equilibrium will be less than the maximum harvest and if sustained effort continues to increase, harvest will steadily decline (Figure 2.25). When population size is near zero, net biological production is near zero and harvest is also near zero. For every level of effort there is a level of harvest that can be sustained over the long-term called the sustainable harvest.

2.5.2 Sustainable Harvest

Sustainable harvest is the quantity of shrimp that can be taken annually, during the long-term with a constant level of fishing effort, without affecting shrimp stocks. A classic harvest-effort curve (Figure 2.26) illustrates that during the long-term an increase in effort will produce an increase in sustainable harvest until harvest equals maximum biological production of the resource. This point is called maximum sustainable harvest. Maximum sustainable harvest is often the objective of fisheries managers. If effort continues to increase beyond the level where maximum sustainable harvest is achieved, sustainable harvest will begin to decrease. Biological overfishing occurs whenever sustainable harvest falls below maximum sustainable harvest due to increasing fishing pressure. If sustained effort is sufficiently high the resource will be driven to extinction and harvest will eventually fall to zero.

The best information available indicates the Texas fishery is operating at a point where the shrimp population is being overfished. This is occurring because Texas fishery resources have traditionally been regarded as common property where access is unlimited. In an open-access system, fisheries tend to become overcapitalized (more boats than are needed to harvest the available resource) and eventually overfished, thus creating a fishery problem. When fishing effort is allowed to increase, the cost of fishing eventually equals the total revenue for the fishery. If effort continues to increase, the fishery problem only gets worse. The cost of fishing will increase, but sustainable harvest will decrease and the resulting revenues will not be sufficient to cover all fishing costs. Inadequate revenues would tend to force some participants from the fishery and could lead to economic failure for the industry.

This "problem" has often been cited as justifying the active role of government in fisheries management. It is argued that government action is necessary to prevent the potential problems related to overfishing. However, the main goal of government has often been to simply conserve the resource without concern for the economic costs to the fishery. Various techniques have been and are being utilized as conservation measures in fisheries management: bag and possession limits, landings quotas, time and seasonal fishing restrictions, area closures, and gear restrictions. Regardless of the methods employed to conserve, the problem of open access remains. The traditional conservation techniques do not reduce the incentive for fishermen to take as much of the resource as they can, and often as quickly as they can, which further increases costs. Many conservation techniques tend to make fishermen even more economically inefficient by increasing fishing costs.

In the last 10 years the number of boats working Texas waters has reached all time highs. Landings since 1980 have been sold for record amounts, but Texas

Parks and Wildlife Department resource monitoring data indicate that brown shrimp abundance has been stable and white shrimp abundance has been declining. It is important, then, to change the economic situation of the fishermen so that it is advantageous for them to harvest in an economically efficient manner throughout the long term. In other words, the fishery should be managed to achieve optimum yield.

3.0 SHRIMP UTILIZATION

3.1 Commercial Fishery

The Texas shrimp fishery depends primarily on brown shrimp, white shrimp, and pink shrimp. The management area includes the nine major bay systems (Sabine Lake, Galveston, East Matagorda, Matagorda, San Antonio, Aransas, Corpus Christi, upper Laguna Madre, lower Laguna Madre), all of their associated inlets and wetlands, the Texas Territorial Sea out to 16.7 km (9 nautical miles) and the Exclusive Economic Zone through Texas Parks and Wildlife Department staff participation in the Gulf of Mexico Fishery Management Council (Figure 1.1). The Texas shrimp fishery is diverse and complex. It is primarily a trawl fishery, and is divided into commercial and recreational (non-commercial) segments (Figure 3.1). Each segment harvests shrimp from both the bays and gulf to sell, use for food, or use for bait.

Brown shrimp has the highest ex-vessel value of all shrimp species in the gulf fishery. Although landings of brown shrimp are not reported separately from those of pink shrimp, Christmas and Etzold (1977) estimated brown shrimp constitute about 95% of the landings of these two species combined. The value of the bay fishery relies primarily on white shrimp followed by brown shrimp and pink shrimp.

Brown shrimp are caught in Texas bays primarily from May through July coinciding with the annual migration from the bay to the gulf. They return to the gulf in early summer and are caught out to at least 91 m, though most are caught within 55 m (Gulf of Mexico Fishery Management Council 1981). White shrimp are a comparatively shallow-water shrimp, with most of the catch coming from <27 m. Those white shrimp caught in the bays are typically taken in late summer-early fall.

Landings of marine species from Texas bays and the gulf off Texas have been collected from seafood dealers since 1887 (Perret et al. 1980). These data were collected sporadically until 1936 when annual surveys were initiated (Texas Game, Fish and Oyster Commission 1937). Since 1936 the Texas Parks and Wildlife Department has monitored landings and value of marine finfishes, oysters, crabs and shrimps through a mandatory self reporting system known as the Monthly Marine Products Report which is completed by the seafood dealer (Osburn et al. 1985). Since 1956 the National Marine Fisheries Service has collected landings data on shrimp through dealer reports and vessel crew interviews (Prytherch 1980).

Types of gear used to harvest shrimp have changed with improvements in technology. Prior to 1917 shrimp were harvested commercially in shallow inshore areas with haul seines (Anderson et al. 1949, Anderson 1966). Introduction of the trawl completely revolutionized the shrimp industry. The shrimp trawl was adaptable for use in deeper waters, operated with fewer men, and was a much more efficient type of gear. From 1917 to the 1940's, shrimp were caught from vessels with single "otter" trawls usually within 10 km of shore. Vessels in the offshore fishery ranged from 15 to 20 m in length, with a few from 21 to 26 m. This larger vessel, because of its seaworthiness, was introduced into Louisiana from Florida about 1938 to engage in the offshore fishery. From Louisiana, its use spread rapidly throughout the fishery from Alabama to Texas. White shrimp were the primary species caught and marketed until the early 1950's. The fishery was predominantly a daytime fishery.

In the early 1950's, markets for brown shrimp and pink shrimp increased as discovery of new fishing grounds off Texas stimulated harvest of these species (Rothschild and Brunenmeister 1981). This fishery was predominantly a night fishery (Anderson 1966).

In the late 1950's and early 1960's double-rig trawling evolved. Two smaller nets were towed by each vessel instead of a single large net (Anderson 1966; Rothschild and Brunenmeister 1981). The double-rigged vessels were more efficient and were used mostly on the brown shrimp and pink shrimp grounds. A more recent development in the offshore gulf fleet has been the twin-trawl rig where four 9-17 m trawls are pulled instead of two (Rothschild and Brunenmeister 1981; Appendix A-public comments).

The bay fishery in Texas typically consists of small boats <17 m which return daily to the docks (Warren and Bryan 1981; Crowe and Bryan 1986, 1987). Shrimp are unloaded freshly dead (heads-on) or alive. Seasons vary for species; restrictions on fishing seasons and areas are set by the Legislature and the Texas Parks and Wildlife Commission (see Section 4.1).

The gulf fishery typically consists of larger more powerful boats which are capable of staying out of port for days or weeks. The main gulf season is July through October, but fishing occurs year around. Shrimp are usually unloaded heads-off, packed in ice or frozen.

The bait fishery in Texas is generally limited to shallow bay waters and is dependent on white shrimp and brown shrimp. Mortality is minimized by short tows in the cooler early morning hours. Due to the limited capacity of live-holding facilities on board and the perishability of live shrimp, bait operations are restricted to areas close to bait dealers. It appears that more boats are purchasing the bait shrimp boat license as well as the bay boat license, presumably to be able to fish year around for food (Crowe and Bryan 1986, 1987).

3.1.1 Historical Trends in Commercial Landings

Landings: Reported landings (shrimp brought to the dock and sold in Texas) of shrimp were less than 300,000 kg from 1880 through 1918 (Anderson et al. 1949b). Shrimp landings remained less than 8 million kg per year through the mid 1940's then increased dramatically from 10 million kg in the late 1940's to nearly 40 million kg during the late 1950's (Figure 3.2). Total landings of shrimp sold as food increased in the early 1960's and have remained stable at about 36 million kg. Annual landings have varied since 1962; they ranged from 25 million kg in 1962 to 47 million kg in 1967 (Figure 3.3). Landings of brown shrimp and pink shrimp (bay and gulf) averaged 28 million kg from 1962-1987 and ranged from 20 million kg in 1962 to 42 million kg in 1967. Landings of white shrimp (bay and gulf) averaged 8 million kg during 1962-1987 and ranged from 4.5 million kg in 1967 to 13 million kg in 1984.

The distinction between catch and landings is an important concept for analysis. Catch data indicate where the shrimp are actually caught whereas landings data reflect the shore location where shrimp are sold, regardless of where they were caught. Because the shrimp fleet is highly mobile, shrimp caught in one location (e.g. bay system or state) can be landed in another location. Landings data are often used incorrectly to describe and quantify the shrimp catch within an area near where shrimp are landed. Landings data, however, do provide some management information since it may provide a proxy for total shrimp being harvested in Texas bay and gulf waters (Texas Coastal and Marine Council 1983).

Shrimp landings in this section are shrimp that are landed from the gulf and bays and sold as food. Shrimp that are landed as bait are discussed under the bait section (next page).

Brown shrimp and pink shrimp

Brown shrimp and pink shrimp landings from the Texas gulf increased substantially through the 1960's and then gradually decreased through 1987. Landings averaged 26 million kg annually; they ranged from 19 million kg in 1983 to 41 million kg in 1967 (Figure 3.4). An estimated 951 million brown shrimp were landed each year from Texas gulf waters during 1966-1986. Yearly estimates ranged from 653 million in 1983 to 1.5 billion in 1967.

Landings of brown shrimp and pink shrimp in Texas bays have increased substantially during 1962-1987. Annual landings averaged 2.2 million kg and ranged from 0.2 million kg in 1968 to 6.2 million kg 1987 (Figure 3.5). The total number of brown shrimp harvested each year from Texas bays has increased from the late 1960's through the 1980's. An estimated 283 million brown shrimp were harvested from Texas bays by commercial shrimpers (food) each year during 1966-1986. Yearly estimates ranged from 26 million in 1968 to 672 million in 1984. These may be underestimates since the smallest category reported by the NMFS was >150 shrimp tails/kg.

White shrimp

White shrimp landings from the Texas gulf have increased slightly between 1962 and 1987. Landings averaged 4.5 million kg/year and ranged from 2.3 million kg in 1962 to 7.7 million kg in 1984 (Figure 3.6). An estimated 178 million white shrimp were harvested each year from gulf waters during 1966-1986. Yearly estimates ranged from 86 million in 1967 to 300 million in 1984.

Landings of white shrimp in Texas bays have fluctuated but have generally increased during 1962-1987. Annual landings averaged 3.4 million kg and ranged from 1.6 million kg in 1967 to 5.1 million kg in 1986 (Figure 3.7). The number of white shrimp harvested from the bays exceeds the number harvested from the gulf and has increased during the last 20 years. Average number landed each year was 303 million during 1966-1986. Yearly estimates ranged from 107 million in 1967 to 542 million in 1986.

Seabobs

Seabobs represent <1% of the total gulf landings in Texas. Annual average seabob landings during 1977-1986 were 140,000 kg and ranged from 10,205 kg in 1978 to 429,098 kg in 1986. Seabobs are harvested mainly from the Texas territorial sea along the upper coast from December-February.

Bait shrimp

Brown shrimp, white shrimp and pink shrimp are also landed as bait (live and dead). McKee (1986) reported Texas bait shrimp landings (live and dead) averaging 0.72 million kg per year during 1977-1984. However, estimates for the Galveston Bay system have ranged from 150,000 kg per year in the late 1950's (Chin 1960) to over 1 million kg per year in the early 1980's (Lamkin 1984). Baxter et al. (1988) estimated the bait shrimp fishery in Galveston Bay landed more than 356,000 kg in 1984 and bait shrimp landings declined from 38% of the total bay landings in 1961 to 11% in 1984. Brown shrimp were predominant in the catch during May-August and white shrimp comprised the majority of the catch during September-December. Both species were generally 60 to 110 mm TL.

Live shrimp are retailed by number or by volume. One liter of live shrimp is about equivalent to 0.72 kg of heads-on shrimp, or 106 shrimp. Stokes (1974) studied the live bait fishery in the lower Laguna Madre from November 1970 through October 1972. During the first year 25,948 liters were sold and during the second year 24,378 liters were sold. In the Laguna Madre system, Port Isabel produced 67% of the live bait shrimp, the Arroyo Colorado produced 17% and Port Mansfield the rest.

Sport-boat fishermen used over 200,000 kg of shrimp for bait during 1983-1985 (Osborn and Spiller, in preparation). Total amount of bait shrimp used for all saltwater sport fishing is at least two times greater. Private sport-boat fishing accounted for over 90% by weight of the bait shrimp used. Live shrimp accounted for over 60% of the bait used by private sport-boat fishermen and 99% of the shrimp used by party-boat fishermen. Shrimp was used for bait on 60-70% of all private sportfishing trips, 38-69% of all party-boat trips and 87-89% of all bay headboat trips. Brown shrimp was the predominant species in May-July and white shrimp predominated in all other months. Galveston Bay fishermen used the most bait shrimp each year, followed by Corpus Christi, Matagorda and Aransas Bay fishermen.

Seasonal Distribution of Landings: Penaeid shrimp are landed throughout the year, but landings for each species vary among seasons (months). Typically, the bay fishery on 0-year class (148 tails/kg) brown shrimp starts in April. The catch peaks in June, and then declines exponentially through March (Figure 3.8). The gulf fishery for brown shrimp follows a similar pattern except that catches peak in July. Catch becomes restricted to deeper waters in October to December.

Like brown shrimp, white shrimp catches reflect the annual nature of their life cycle. The bay fishery on the 0-year class, spawned in spring and summer, begins in August; high catches continue through November (Figure 3.9). In gulf water, highest catches occur from September to November then decline from December through April.

<u>Size and Age Composition of Shrimp Landed</u>: 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 149 tails/kg. Overall, >90% (by weight) of brown shrimp caught in bays have a count size of >149/kg (Figure 3.10). The dominant size class reported in the offshore fishery is 68-89 tails/kg. Average size caught may be smaller since undersized shrimp may be discarded (Baxter 1973). The July-August brown shrimp catch is predominately 68-89 tails/kg and the September catch is 51-66 tails/kg. From January to April offshore catches of shrimp are a count less than 46 tails/kg. Overall, <25% (by weight) of brown shrimp caught in gulf waters have a count >89/kg.

Caillouet et al. (1980) state from 1959 to 1976 there was a significant trend towards decreasing size of brown shrimp landed from Texas gulf waters. On a gulfwide basis, that trend has continued through 1986. The percentage of recruits to the fishery that are landed from each year-class has increased and average age of capture has decreased since the early 1960's (Nance and Nichols 1987).

White shrimp from the gulf are generally larger than white shrimp or brown shrimp landed from the bays. (Figure 3.11). The 0-class white shrimp fishery begins in August and September. The legal count during this fall season is 110 heads-on/kg (about 170 tails/kg). From 1 November-15 December no minimum count is required. Overall, >88% (by weight) of white shrimp caught in bays have a count size >67/kg. Generally <20% (by weight) of white shrimp caught in gulf waters have a count of >89/kg.

Caillouet et al. (1980) found decreasing sizes in commercial landings. One explanation was that more small shrimp were being landed instead of being discarded. Fuls et al. (in preparation) found there is a significant trend towards decreasing size of white shrimp within Texas gulf waters.

<u>Geographic Distribution of Landings</u>:

Shrimp that are harvested as food from the bays are landed in all major bay systems except the lower Laguna Madre. Approximately 52% of the brown shrimp and pink shrimp and 62% of the white shrimp are harvested from the Galveston and Matagorda Bay systems (Figure 3.12). The Aransas Bay system is also a large producer of brown shrimp and pink shrimp.

3.1.2 Historical Trends in Commercial Effort

Fishing effort has generally increased since 1966. The number of trips in the bays has increased substantially while the number of gulf trips has decreased slightly (Figure 3.13). No direct measure of total effort has been obtained, but several estimates of fishing effort are available to help explain changes in landings and to predict future landings (Blomo et al. 1978). Reliability of effort data is unknown because collection and estimating procedures have not been thoroughly documented (Matlock 1984).

The National Marine Fisheries Service has collected fishing effort data (trips and days, by area and depth) since 1956 (Caillouet and Baxter 1973). Nominal days fished is one measure of fishing effort. Most researchers agree total number of nominal days fished is a "crude" measure of effort because it fails to account for changes in efficiency of vessels in the fleet through time (Blomo et al. 1978).

Number of Licenses Issued: The number of commercial shrimp boat licenses, an indicator of potential coastwide fishing effort, generally increased through the early 1980's (Figure 3.14). Each segment of the fishery requires a different license.

Although the size of the Texas gulf shrimp fleet fluctuates yearly, the total number of licenses in the fishery increased from about 1,600 in 1962 to over 4,600 in 1984, then declined to about 3,000 in 1987. Non-resident vessels influence the annual variation in the size of the shrimp fleet operating off Texas.

Size of the shrimping fleet in the bays fluctuates yearly, and the total number of bay boat licenses increased from about 1,800 in 1964 to about 5,000 in 1981 then declined to about 3,500 in 1987. The number of bait licenses decreased from about 1,900 in 1964 to about 600 in 1968 then increased to about 3,000 in 1984 with a slight decline in the following years.

Number of Fishermen: The number of fishermen participating in the shrimp fishery has increased. TPWD license sales indicate the fishery currently employs about 20,000 fishermen. Estimates provided by the National Marine Fisheries Service for 1979-1984 indicate 6,400-15,000 fishermen were employed in the fishery.

Number and Geographic Distribution of Boats: Numbers of boats licensed in Texas to fish for shrimp have increased. Based on Texas Parks and Wildlife Department boat license sales (1979-1985), numbers of shrimp boats and vessels ranged from 6,598 to 7,733 (Crowe and Bryan 1987) (Figure 3.15). Estimates provided by the National Marine Fisheries Service for the period 1960-1983 (2,000-3,000 boats and vessels) appear to be low. Based on the number of licensed boats and vessels, the Texas Parks and Wildlife Department data appear to provide the best estimate.

License classes are bay, gulf and bait with fishermen possessing combinations of bay, gulf and bait licenses (Figure 3.16). Number of boats licensed to shrimp in the gulf increased from 1980 to 1983, then declined. Although the number of boats licensed to shrimp in bays has decreased since 1981, the number of boats with combination licenses increased. Since the season on the bait fishery is almost unrestricted, the increase in number of boats with a combination of licenses (Figure 3.17) and/or bait licenses reflects an increase in the number of boats fishing year around.

From 83-89% of the licensed vessels were registered in the 18 coastal counties (Warren and Bryan 1981; Crowe and Bryan 1986, 1987). The percentage dropped from 89% in 1979 to 83% in 1983 as the proportion of out-of-state vessels increased from 4% to 10% during the same period. The Fulton to Corpus Christi area, Galveston/Freeport and Brownsville/Port Isabel areas contain the highest concentration of shrimp boats.

Landings/Effort: Landings data (see section 3.1.1) and number of licenses issued reveal landings/license have decreased (Figure 3.18). Brown shrimp landings/license declined in the gulf and increased in the bays (Figure 3.19). White shrimp landings/license fluctuated in the gulf and generally decreased in the bays (Figure 3.20). Based on Texas landings, overall landings/trip in Texas ranged from 830 kg/trip in 1967 to 330 kg/trip in 1986 (Figure 3.21). Gulf catch/trip fluctuated from year to year whereas bay catch/trip has declined since the late 1970's.

3.1.3 Economic Impacts of Commercial Fishing

Direct Economic Impacts: Shrimp is the most valuable seafood product in the United States; Texas leads all other states in value of shrimp landed. The Brownsville-Port Isabel and Aransas Pass-Rockport areas were consistently in the top five ports in value of product landed in the United States during 1984-1986 (Figure 3.22). Preliminary data for 1987 indicate the Brownsville-Port Isabel and Aransas Pass-Rockport areas ranked 7th and 12th, respectively, in value of product landed. United States landings in 1986 were worth $662.7 million, an increase of 40% in value over 1985 (Figure 3.23). The gulf region produced 85% of the value of the United States shrimp crop in 1986. Texas contributed about 33% of the total value.

Ex-vessel value of gulf shrimp landings increased ten-fold between the late 1950's and mid-1980's (Figure 3.24). Value increased steadily during the 1960's, then increased dramatically after 1974. Most of the increase in value was due to increases in ex-vessel prices.

From 1958 to 1977 Texas averaged 46% of the value of all gulf shrimp landings and consistently had highest ex-vessel value of all gulf states (Gulf of Mexico Fishery Management Council 1981). Approximately 57% of the annual value of the brown shrimp catch and 30% of the white shrimp catch is from Texas.

The value of shrimp landed in Texas ranged from $26 million in 1962 to $229 million in 1986 (Figure 3.25). Ex-vessel value of brown shrimp and pink shrimp (bay and gulf) averaged $79 million from 1962-1987 and ranged from $19 during 1964 to $167 million in 1986. Value for white shrimp averaged $24 million from 1962-1987 and ranged from $5 million during 1963 to $61 million dollars in 1986. Shrimp landed in Texas accounted for over 93% of the value of all seafood landed in Texas from 1977 through 1986 (Osburn et al. 1987). Gulf landings were 85% of the total ex-vessel value, a result of gulf landings being 2.5 times more valuable per kilogram than bay landings.

A study by Chui (1980) indicates the existence of separate markets by size for gulf shrimp: large (<66 tails/kg), medium (66-110 tails/kg), and small (>110 tails/kg). Ex-vessel demand for shrimp varies significantly by size of shrimp. Demand is higher for larger sizes of shrimp and, with the exception of small shrimp, the larger the size the greater the price response to changes in supply. Price responsiveness was, however, small within the eastern, northern and western regions of the Gulf of Mexico.

Generally, Texas regulations result in much greater landings of larger-sized shrimp than do those of other gulf states. Caillouet and Koi (1980) reported average annual ex-vessel value/kg for shrimp in Texas was greater than that for other gulf states from 1959 to 1975. They attributed the difference in ex-vessel value to differences in size composition of the shrimp catches among the states. Texas has continued to be above the average gulfwide ex-vessel price since 1977 (Figure 3.26).

Brown shrimp and pink shrimp

From 1977 to 1980, brown shrimp and pink shrimp comprised 73% of the ex-vessel value of shrimp landed in Texas. Although there have been variations in relative importance of ex-vessel value of brown shrimp, white shrimp and pink shrimp on a gulfwide basis, brown shrimp was the most valuable, accounting for 52-56% of the total value of all species from 1958 to 1977. The percentage of total value of gulf shrimp catch attributable to pink shrimp has fallen from 21% during 1958-1967 to 13% during 1968-1977.

Average value of brown shrimp and pink shrimp landed from the gulf and bays has increased substantially. Average ex-vessel value of gulf landings during 1962-1987 was $75 million; the range was $19 million in 1964 to $158 million in 1986 (Figure 3.27). Texas bay landings had an average value of $3.3 million; they ranged from $76,000 in 1968 to $13.7 million in 1987.

White shrimp

During 1977-1980, white shrimp accounted for 26% of the ex-vessel value of all shrimp landed in Texas. White shrimp is the second most valuable species. White shrimp increased from 25% of total value during 1958-1967 to 30% of total value during 1968-1977.

Average value of white shrimp landed from the gulf and bays has increased substantially. Average ex-vessel value of gulf landings during 1962-1987 was $17 million, ranging from $2 million in 1962 to $45 million in 1986 (Figure 3.28). Texas bay landings had an annual average value of $7.0 million; they ranged from $1.4 million in 1967 to $16.2 million in 1986.

Seabobs

Average seabob landings during 1977-1986 were valued at $135,000. Landings were valued from $5,600 in 1978 to $611,000 in 1986.

Bait shrimp

McKee (1986) reported Texas bait shrimp landings (live and dead) averaged $5.94 million per year during 1977-1984. Chin (1960) estimated a total retail value of $653,520 for live bait and $112,761 for dead bait during June 1957 through May 1959 in Galveston Bay. By 1964 the bait fishery in Galveston Bay landed shrimp with a retail value of almost $1 million (Inglis and Chin 1966). Baxter et al. (1988) estimated the market yield for bait shrimp in Galveston Bay was $4.3 million in 1984.

Inglis and Chin (1966) reported that during summer, when shrimp are plentiful, the retail price of live shrimp averaged $2.11/liter or 2¢/shrimp on the upper Texas coast and $3.17/liter or 3¢/shrimp in the Port Isabel area. During winter, when shrimp were scarce, the price on the upper coast rose to $3.17/liter and in the Port Isabel area was as high as $7.40/liter. Dead bait was sold at $1.10 to $1.65/kg throughout the year. Stokes (1974) studied the live bait fishery in the lower Laguna Madre from November 1970 through October 1972. Shrimp were sold at an average cost of $5.54/liter. During the first year of study the retail value totaled $137,000; the second year was $128,805. McKee (1986) reported dead bait increased from <$1.00/kg during 1956-1966 to $6.60/kg in 1985 and live bait increaded from $2.93/kg during 1956-1966 to $14.67-17.60/kg in 1985.

<u>Indirect and Induced Economic Impacts</u>: Average annual economic impact of the shrimp industry for the past 5 years is $575 million. Total economic impact is composed of direct, indirect, and induced economic impacts (Hushak 1987, Probst and Gavrilis 1987). Amount of money received by shrimp fishermen for shrimp landed is the direct impact. Indirect impacts represent additional spending by businesses as a result of receiving some of the money injected into the economy by the initial transactions (direct impact). Induced impacts are a result of employees of the impacted businesses respending the money at other businesses in the area. Economic impact can be estimated using output multipliers which measure the total change in local, regional, and state economic activity generated by each dollar of initial output. An estimate of the statewide economic impact of the shrimp industry can be obtained by multiplying initial output (ex-vessel value) by the appropriate economic multiplier. An estimation of the industry's impact can be made by using multiplier analysis. A multiplier reveals the relationship between a primary, readily observable economic event and the total economic activity stimulated by the primary event.

Output multipliers specific for the Texas shrimp industry (Jones et al. 1974) are available and for fisheries in general have been developed (Hawkin 1972, Murrell et al. 1972, Stern 1972, Grubb 1973, Texas Department of Water Resources 1982). Using an economic multiplier of 3.12 (Texas Department of Water Resources 1982) yields a gulfwide impact of approximately $1.76 billion. The impact on the Texas economy peaked at $712 million in 1986. Included in the $712 million is $228 million in landings (Osburn et al. 1987) and $484 million of indirect and induced output by support industries. Direct and indirect income payments to workers in shrimp related businesses is estimated at $201 million for 1986 (value of landings X 0.37 X 2.37 after Jones et al. 1974).

Coastwide landings (kg-whole weight), ex-vessel value($) and economic input ($) during 1983-1987.

Year	Landings	Value	Economic Input
1983	32,239,894	171,113,200	533,873,180
1984	40,825,037	179,331,800	559,515,220
1985	37,028,741	161,217,800	502,999,540
1986	43,332,042	228,184,400	711,935,330
1987	40,088,176	182,303,200	568,785,980
Average	38,702,778	184,430,080	575,421,850

Employment in the Texas Shrimp Fishery: Employment in the Texas shrimp fishery can only be estimated. Total employment in the fishery includes number of fishermen on vessels and boats and all seafood wholesaling and processing employees associated with processing and marketing of shrimp products. Direct employment includes only those on vessels and boats. Using the Texas results of 0.78 people employed directly in the shrimp industry/$10,000 of landings (Jones et al. 1974), the number of individuals employed in 1986 would be approximately 22,911. When the multiplier effect (1.22) of total employment is included, the estimate becomes 27,951 individuals.

Direct and Aggregate Impact of the Texas Shrimp Industry: The direct impact of the shrimp industry on the Texas economy is demonstrated by the value of its estimated purchases from other major economic sectors. The largest component is payment for labor and managerial services. Using percentages developed by Jones et al. (1974), it is estimated from a total value of $229.1 million in 1986, the industry paid $85.9 million (>37%) in wages, salaries and profits. Other direct purchases by the shrimp industry include food processing, petroleum products, ships and boats, wholesale marketing, insurance, property payments, depreciation and imports of goods and services (Table 3.1).

Direct purchases are only part of the total impact of the industry on the Texas economy. Direct purchase by the shrimp industry from input-supplying industries stimulates output and subsequent purchases by those industries (Jones et al. 1974). In turn, these output changes give rise to more secondary and tertiary output responses in related industries. These indirect impacts, as well as output increases induced by expenditures made by employees who receive income from the shrimp industry, are included in estimates of the aggregate (direct, indirect and induced) economic impact.

The aggregate economic impact of the shrimp industry can be estimated on both a per dollar and total dollar of shrimp output basis. The more significant supporting industries in terms of indirect and induced output are food processing, petroleum products, ship building, wholesale trade, retail trade, finance payments and services (Table 3.2). One dollar of output by the shrimp industry has a total economic impact on the Texas economy of $3.09. In total dollars, estimated direct, indirect and induced impact on the Texas economy was $707 million from $229 million of shrimp production during 1986. About 80% of this aggregate statewide economic impact is concentrated in the three gulf regions. Estimated aggregate impact by region for one dollar of output by the shrimp industry was $2.46, $2.37 and $3.11 total economic output in the Brownsville-Aransas, Port Lavaca-Galveston and Beaumont-Port Arthur regions, respectively.

Within the Brownsville-Aransas region during 1986, $135 million of landings by the commercial shrimp industry stimulated total economic output of $331 million. Within the Port Lavaca-Galveston region, 1986 landings valued at $85 million stimulated total economic output of $201 million. Total economic output of $31 million was stimulated by the $10 million of landings by the commercial shrimp industry in the Beaumont-Port Arthur region.

3.1.4 Impacts on Other Species

Discard of incidental finfish caught during commercial shrimping operations in the gulf is a matter of concern to fishery managers (Gulf of Mexico Fishery Management Council 1981). In most cases, weight of shrimp caught is a fraction of the total catch. At least 300 million kg of organisms are discarded annually by the shrimp fleet in the gulf. In shrimping operations, the trawl is dragged along the bottom for up to several hours and many finfish and invertebrates other than shrimp are captured and packed into the bag of the trawl. Most of the incidental catch is dead upon delivery to the vessel deck (Blomo and Nichols 1974); others die as a result of handling and exposure before they are discarded (Gulf of Mexico Fishery Management Council 1981). Bycatch includes shrimp heads, crabs, non-commercial shrimps, jellyfish, starfish, squids, mollusks, turtles, and various fishes. Blue crabs and some fishes in the catches are marketable, but the largest portion of the catch is usually discarded (Moffett 1970).

Shrimp: The gulf off Texas is generally closed 1 June to 15 July to protect small brown shrimp. However, shrimping for white shrimp within a water depth of 7.3 m is still allowed during daylight hours (see section 4.2, Figure 4.2). Small brown shrimp occur in the bycatch during the Texas Closure, which results in illegal landing of brown shrimp and/or waste of the resource through discarding. The practice may interfere with satisfying the Texas objective of maximizing ex-vessel value of gulf brown shrimp landings (Bryan et al. 1982, Fuls and Bryan 1986). At least 50% of shrimp discarded during normal gulf shrimping operations die from effects of exposure to air when temperatures are greater than 20 C (Berry and Benton 1969). Long-term mortality is unknown.

A similar situation occurs during the winter closed season in the gulf (16 December-1 February). An exception to the closed area within a water depth of 12.8 m allows the catch of seabobs with one 7.6 m trawl as long as seabobs comprise at least 90% of the catch. The amount of white shrimp and brown shrimp illegally landed or wasted during this "seabob season" is unknown.

Crabs: The most common crab in the bycatch is the lesser blue crab (C. similis). On the Texas brown shrimp grounds, Bryan et al. (1982) caught lesser blue crab in ≥98% of the samples during 1973 and 1974, whereas blue crabs were captured in 27%-41% of the samples. The lesser blue crab constituted 22% of total weight and 16% of total number during June-December 1973 and 1974. During the same period the blue crab comprised 1% by weight and <1% by number of the total organisms caught. Watts and Pellegrin (1982) reported higher catch rates for blue crab. In waters >18.2 m, it comprised 18.05% of the total Texas bycatch biomass during 1981, 6.80% during 1980, and 1.78% during 1973-1978. For waters <18 m, the blue crab comprised 3.22% of the total Texas bycatch biomass during 1981, 0.67% during 1980, and 0.53% during 1973-1978.

Finfish: A gulf trawler will normally catch >4.1 kg of finfish for every 0.4 kg of shrimp (Martin 1986). Blomo and Nichols (1974) estimated between 52 and 368 million finfish are discarded annually from shrimper's bycatch in the western gulf. Bryan et al. (1982) reported average annual discard of finfish from the Texas brown shrimp grounds was 43.7 million kg. Seidel (1975) estimated that 1.8-5.4 kg of finfish are taken for each 0.4 kg of shrimp harvested. The annual finfish discard for 1977-1987 was estimated by multiplying Seidel's low and high estimates by the total yearly shrimp catch in the gulf; estimates ranged from 126.5 million kg to 173.3 million kg (using 4:1 ratio) and from 364.1 million kg to 519.8 million kg (using 12:1 ratio) (Table 3.3).

The actual amount and species of finfish caught varies by location, season, time of day, water temperature, and other environmental and physical parameters. Species currently marketed as foodfish comprise between 0.5 and 5.0% of the total bycatch (Blomo and Nichols 1974). Most finfish caught are less than 454 g live weight and comprise no more than 2.5% of an average trawl catch (Blomo and Nichols 1974). Bryan et al. (1982) stated the largest average weight recorded for one species (C. arenarius) in their shrimp trawls was 67 g; most dominant species averaged <25 g.

Bryan et al. (1982) reported shrimping operations on the Texas brown shrimp grounds have had little detectable effect on the dominant finfish species. Chittenden and McEachran (1976) attribute the resiliency of the fish species to their short life spans (1 or 2 years). Short-lived species, which mature early and have high fecundity rates, are apparently able to withstand intensive fishing pressure as long as environmental conditions remain favorable.

Controversy exists concerning the need to utilize finfish from the shrimp fishery bycatch. The Gulf of Mexico Fishery Management Council (1981) stated that discarding shrimp bycatch represented a conversion of natural resources into food for scavengers, whereas many of these resources could be used by other national interests. Moffett (1970) believed use of incidental bycatch would provide supplemental income to shrimpers. During the 1960's there was an attempt to establish a plant in Aransas Pass, Texas to utilize bycatch of the shrimp fleet, but the venture was unsuccessful (Bryan et al. 1982).

Bryan et al. (1982) noted that discarding of bycatch may produce benefits beyond the market potentials from direct human utilization. The return of organic material for utilization in the food chain may enhance populations affected by shrimping operations.

Under present economic and technological conditions there appears to be no monetary incentive to market incidental invertebrates and fish species captured on the Texas brown shrimp grounds because of their relatively low volume and small size (Bryan et al. 1982). Gulfwide income from sale of incidental catch in shrimp trawls is low. Information reported to the National Marine Fisheries Service in 1974 revealed (by states) the following percentages of income were from sale of incidental catch: Florida, 1.7%; Alabama, 13.0%; Mississippi, 7.0%; Louisiana, 0.8%; and Texas, 0.5%. Sixty percent of fishermen selling some of the incidental catch responded they were not able to sell all the food fish harvested. Therefore, shrimp vessels are dependent almost entirely on income from shrimp (Gulf of Mexico Fishery Management Council 1981).

Bycatch in the bay fishery is not well quantified but Texas Parks and Wildlife Department trawls averaged 2.25 finfish for each shrimp caught during 1982-1987. Annual coastwide ratios ranged from 2.08 to 2.67 finfish per shrimp. Six-year averages varied by bay system (Table 3.4).

Matlock (1982) estimated 9,740,800 southern flounder (Paralichthys lethostigma) and 195,686 gulf flounder (P. albigutta) were caught by commercial shrimp trawlers in Texas bays during April through November 1978.

Lamkin (1984) reported on bycatch in the Galveston Bay bait fishery (mainly West Bay). He estimated a total of 348,585 kg of fish and 94,831 kg of invertebrates were harvested as bycatch from July 1981-June 1982. The most abundant species (by number) were Atlantic croaker, (Micropogonias undulatus) 31.2%, sand seatrout (C. arenarius) 16.2% and blue crab (C. sapidus) 9.7%. Lamkin's annual fish:shrimp ratio was 1:3.2.

Bait shrimpers operate primarily in early morning hours. Mortality of the incidental catch is probably minimized by: (1) short duration of the tows; (2) speed at which catch is sorted; and (3) cooler, humid conditions. Sorting techniques that use salt boxes undoubtedly increase mortality of finfish, although total numbers and long-term effects are unknown.

Sea Turtles: All sea turtles occurring in United States waters are either endangered or threatened and are protected by Texas Parks and Wildlife Commission regulations and the United States Endangered Species Act. Anyone taking, killing, injuring, or harassing a sea turtle is subject to arrest, and penalties could result in 5-year imprisonment and/or a $20,000 fine (Martin 1986).

Reported sea turtle nesting areas and recaptures in relation to shrimping effort for the gulf are displayed in Figure 3.29. Accidental capture of sea turtles by shrimpers along the gulf coast is a major problem (Ogren 1977) as sea turtle populations continue to decline.

A portion of sea turtles captured in shrimp nets die (Owens 1986). These air-breathing reptiles can hold their breath and remain under water for extended periods under minimal metabolic demand conditions, but the stress of being dragged in a shrimp trawl results in a death rate of about 4% after 1 hour; 10% die after 1.5 hours (Martin 1986, Owens 1986). In the gulf, trawl durations average more than 3 hours (Martin 1986). Table 3.5 provides estimates of total effort, catch and mortality of sea turtles captured in four gulf states during 1976 and 1977.

The Turtle Excluder Device (TED) was developed by the National Marine Fisheries Service to selectively eliminate capture of sea turtles (Christmas and Etzold 1977, Owens 1986). Although this gear was initially developed to exclude sea turtles from the shrimper's catch, some versions include a removable finfish reduction feature that eliminates 75% or more of the finfish during daytime shrimping and 50% or more at night (Martin 1986). The difference in behavioral responses between shrimp and finfish are utilized by this device to guide shrimp into the trawl and finfish out of the trawl (Taylor et al. 1985). Approximately 90% of the shrimp passing through this device are retained (Christmas and Etzold 1977); the Turtle Excluder Device can improve efficiency of shrimp trawls by allowing longer towing times with reduced labor in sorting shrimp from the bycatch (Taylor et al. 1985).

3.2 Recreational Fishery

3.2.1 Historical Trends in Recreational Landings

<u>Landings</u>: Recreational shrimpers probably land about 1 million kg of shrimp annually. In 1973, about 408,000 kg (1.1%) of the total shrimp harvest was taken by sport fishermen (King 1974). The recreational harvest increased to 619,000 kg in 1980 (Brown 1981).

In 1979, 43,000 kg of brown shrimp, 376,000 kg of white shrimp and 25,000 kg of mixed catch were harvested (Brown et al. 1980a). In 1980, 305,000 kg of brown shrimp, 204,000 kg of white shrimp and 109,000 kg of mixed catch were harvested (Brown 1981).

<u>Seasonal Distribution of Landings</u>: During the 1973 spring season 72,000 kg were harvested; average catch/successful fisherman was 23.1 kg. During the fall season 293,000 kg were harvested; average catch/successful fisherman was 43.5 kg. About 43,000 kg were harvested for the year as bait shrimp (King 1974).

<u>Size and Age Composition of Shrimp Landed</u>: Shrimp caught in bays are generally smaller than shrimp caught in the gulf. The fishery on 0-year class of brown shrimp and white shrimp parallels the commercial fishery, beginning in April for brown shrimp and August-September for white shrimp. Brown (1981) reported on the size of shrimp landed in the recreational shrimp fishery along the Texas coast. In 1979 and 1980 mean count of brown shrimp was 71/kg and 120/kg, respectively. The count for white shrimp was 70/kg in 1979 and 80/kg in 1980, whereas, the mixed shrimp count was 81/kg in 1979 and 110/kg in 1980.

<u>Geographic Distribution of Landings</u>: Trends in current Texas Parks and Wildlife Department data indicate there may have been a shift in landings since 1973. King (1974) found Galveston Bay fishermen landed more shrimp than all other bays combined. Data collected during 1983-1984 by the Texas Parks and Wildlife Department revealed 99% of the major harvest by recreational shrimpers is in the Galveston and Matagorda Bay systems.

3.2.2 Historical Trends in Recreational Effort

Recreational effort for shrimp has decreased since 1979. No direct measure of total effort is available. However, recreational shrimp fishermen are required to have a sport fishing license and a saltwater stamp in Texas and each trawl must have an individual bait shrimp trawl license. The number of trawls licensed can be used as an indicator of potential fishing effort. In 1979, the daily limit for recreational fishermen was reduced from 45.5 kg to 6.8 kg. Since that time the number of these licenses issued has decreased dramatically.

Number of Licenses Issued: The number of licensed sport trawls decreased from about 10,500 in 1979 to about 3,000 in 1988 (Figure 3.14). The decline has been steady since the daily limit for recreational fishermen was reduced. Since the legal catch limits for personal licenses are less than those for commercial licenses, many recreational shrimpers may purchase the relatively inexpensive commercial bay shrimp license (Christmas and Etzold 1977, Krauthamer et al. 1984, Crowe and Bryan 1986).

Number of Fishermen: The number of recreational shrimpers has decreased since 1979. Based on ratios from Brown (1981) there were about 12,000 participants in 1988. During 1983 and 1984 mean party size for sport shrimping trips was 2.3 and 2.2 persons, respectively (Texas Parks and Wildlife Department unpublished data). Brown (1981) estimated nearly 50,000 shrimp fishermen in the Texas fishery in 1980 using 5.5 participants for each license sold.

Geographic Residence and Distribution of Fishermen: Most recreational shrimp fishermen reside in coastal counties or immediately adjacent counties (Gulf of Mexico Fishery Management Council 1981). There is no reported recreational shrimping by residents of other states. Data collected by the Texas Parks and Wildlife Department during 1983 and 1984 support these findings. Fifty-five percent were residents of the coastal counties adjacent to the fishing area, 20% were from coastal non-adjacent counties, and 25% were non-coastal residents.

Seasonal Distribution of Trips: Sport boat fishermen interviews by the Texas Parks and Wildlife Department reveal that recreational shrimpers constitute from 0% (December through March) to 3.8% (September) of the total interviews (Texas Parks and Wildlife Department unpublished data). Brown (1981) estimated 95,315 trips were made by recreational shrimpers in Texas during 1979. During 1980, over 121,000 recreational trawling trips were made.

Type of Gear Used: Most recreational or part-time fishermen in Texas use small boats (<7.6 m), and harvest shrimp with a trawl <6.1 m in width (King 1974, Warren and Bryan 1981, Krauthamer et al. 1984). Because other types of gear are not licensed, the extent of use is unknown. Seines, cast nets, dip nets, and bait traps may be used in localized areas.

Effort: The average recreational shrimping trip lasts 3-4 hours (Brown et al. 1980a, Brown 1981). Data collected during 1983-1984 by the Texas Parks and Wildlife Department reveals major effort was exerted by recreational shrimpers in the Matagorda and Galveston Bay systems. Together they accounted for 91% of the total coastwide man-hours (Figure 3.30).

Bait: Ferguson and Spiller (1988) reported <5% of the 200,000 kg of bait shrimp used by sport boat fishermen in 1983-1985 (worth $2.2 million) was caught by the fishermen. King (1974) reported 10.6% of total recreational harvest was used for bait during 1973.

3.2.3 Economic Impacts of Recreational Fishery

Direct Impacts: The direct revenue to the Texas Parks and Wildlife Department through sale of Individual Bait Shrimp Trawl Tags has fallen with the decrease in number of tags sold. This revenue decrease was reversed in fiscal year 1985-1986 with an increase in cost of the tag from $10.00 to $15.00. A fishing license and saltwater stamp is also required for recreational shrimp fishermen. Assuming 12,000 participants and all bought licenses and saltwater stamps, total estimated revenues to Texas Parks and Wildlife Department including trawl tags was $201,000 in 1988.

King (1974) estimated 1.1% of total landings (by weight) were by recreational fishermen in 1973. If average value/kg was equal to that harvested by the commercial sector ($2.51), then direct impact may have been nearly $1.6 million dollars. Total expenditures by recreational shrimp fishermen to harvest these shrimp is unknown, but is likely higher than actual value of shrimp landed.

Indirect and Induced Impacts: In Texas, sale of shrimp caught by a recreational shrimp fisherman is illegal, but some shrimp undoubtedly are sold for cash or bartered for other goods or services. Extent of this is unknown, but Brown et al. (1980b) and Brown (1981) reported 3.4% of the recreational shrimpers in 1979 indicated they were going to sell an average of 38.9 kg of recreational shrimp to commercial processors.

King (1974) reported average catch/successful fisherman for all purposes (human consumption and bait) ranged from 2.7 kg/year in upper Laguna Madre to 49 kg in Galveston Bay. Total landings of 408,000 kg in 1973 to 636,000 kg in 1980 must reduce local sales for food and bait by commercial fishermen to some extent. Brown et al. (1980b) reported an average count of 70/kg. At that size an estimated 28-45 million shrimp were harvested by recreational fishermen.

3.2.4 Impacts on Other Species

No studies are currently available on the magnitude of incidental catch discarded by recreational shrimpers. Based on Texas Parks and Wildlife Department finfish to shrimp ratios (Table 3.4, section 3.1.4), recreational shrimpers catch 60-100 million finfish per year.

3.3 Shrimp Consumption

3.3.1 Domestic Markets

Wholesale Market: Shrimp accounted for 60% of the production of processed fishery products in the gulf and south Atlantic region in 1983 (United States International Trade Commission 1985) and was valued at $933 million. This was 83% of total United States processed shrimp production. Total value of processed shrimp products more than doubled between 1971 and 1977, increasing from $253.7 million to $528.9 million.

Wholesale values (millions of dollars) of processed shrimp for gulf states. Numbers do not add due to rounding.

State	1971	1972	1973	1974	1975	1976	1977
Florida[a]	70.2	70.9	80.0	69.5	83.3	133.2	150.9
Alabama	11.6	23.2	30.7	20.3	28.9	59.0	68.3
Mississippi	12.7	13.7	15.7	16.9	15.7	26.9	40.0
Louisiana	65.7	64.8	76.9	72.4	64.1	95.6	125.4
Texas	93.6	110.2	120.6	80.7	67.7	141.4	144.2
Gulf Total	253.7	282.6	330.0	259.9	259.8	456.1	528.9

[a]West coast

Source: National Marine Fisheries Service, Processed Fishery Products Annual Summary (Washington, District of Columbia: Department of Commerce, various years) (from Gulf of Mexico Fishery Management Council 1981).

Although large foreign markets exist, United States exports historically have been minor compared with domestic production. This is caused by factors such as a readily accessible United States market that is capable of absorbing all domestic supplies, market preferences in foreign markets, relative world prices, and exchange rate differences (United States International Trade Commission 1985). Annual United States exports of domestic shrimp remained relatively stable during 1980-1983 at 80.6-100 million kg; the value ranged from $59 million to $79 million (United States International Trade Commission 1985). In 1984, exports fell to 7.3 million kg worth $52 million. The portion of United States shrimp production exported (heads-off basis) declined from 15% in 1980 to 11% in 1984. Exports to Canada, the major (54-56%) export market for United States shrimp, declined from 5.4 million kg ($36 million) in 1980 to 4 million kg ($33 million) in 1984.

Food Products: Major products produced by the gulf and south Atlantic shrimp processing sector in decreasing order of commercial importance are: raw, heads-off, shell-on shrimp, breaded shrimp, peeled shrimp and canned shrimp (United States International Trade Commission 1985). Breaded raw and cooked shrimp and raw headless and heads-on shrimp account for about 35% and 33% of total production, respectively. Raw peeled shrimp rank third in terms of market importance. Other shrimp products individually account for <10% of average annual production.

United States production of processed shrimp products as a % of total production by product groups, 1971-1981 (thousands of pounds). (from Shrimp Notes Inc. 1983)

Year	Breaded raw & cooked	Raw heads on & headless	Raw peeled	Cooked peeled	Canned	Speci-alties[a]	Other[b]
1971	34.5	31.0	11.3	6.8	7.4	8.3	0.7
1972	36.1	30.6	10.1	7.7	8.0	6.0	0.7
1973	38.1	29.7	8.3	8.7	8.6	6.0	0.6
1974	36.5	32.4	9.0	6.8	8.8	5.8	0.7
1975	41.8	29.9	9.5	6.1	5.3	5.0	2.0
1976	33.6	36.0	11.6	6.6	7.0	3.6	1.6
1977	31.7	36.5	11.6	7.6	8.0	3.5	1.1
1978	33.0	33.7	11.9	12.5	5.1	3.0	0.8
1979	34.8	32.3	16.6	8.6	3.5	3.3	0.9
1980	33.6	32.2	13.9	9.5	6.6	2.9	1.3
1981	30.6	35.6	13.5	12.2	4.5	2.2	1.4
Mean	34.8	32.8	11.6	8.5	4.6	6.6	1.1

[a]Specialities include cocktail, creole and gumbo, cakes and patties, stuffed, other cooked, and other breaded.
[b]Other includes sun-dried, meal and scrap, and rock shrimp.

Food Markets: Shrimp is mainly consumed in restaurants and retail outlets. It is estimated about 80% of United States shrimp supplies are marketed through institutional trade (restaurants, hotels, cafeterias, schools, military and hospitals), and the remainder are marketed through retail outlets. (retail fish markets, supermarkets, grocery stores, and convenience food stores)(United States International Trade Commission 1985). The retail sector of the food industry currently utilizes shrimp products which have lower value.

Size is the principal factor influencing market channels and use. Larger size shrimp usually go to restaurants, those in the 66-143/kg range go principally to breaders, fresh seafood retailers, canners and other processors. Smaller shrimp are used by canners, driers and specialty producers. In recent years, there is a growing trend to use the full range of shrimp sizes for breaded, peeled and stove-ready products (Gulf of Mexico Fishery Management Council 1981).

Variation in use of marketing channels depends on many factors: shrimp size, processed form, location of processor, degree of industry concentration, source of raw shrimp, amount of imported shrimp used and amount of foreign labor involved in processing. A telephone survey of shrimp processors and middlemen conducted by the Gulf of Mexico Fishery Management Council's Fishery Management Plan for the Shrimp Fishery in each of the gulf states revealed a general pattern of marketing channels (Figure 3.31).

Roadside marketing of fresh shrimp represents a substantial, but incalculable, portion of the shrimp market in the United States The major problem in estimating the percentage is much of these roadside sales are made by fishermen whose catch does not go through normal channels where catch data are collected (Shrimp Notes Inc. 1983). In Texas, roadside dealers must have a Retail Fish Truck license. Sales of these licenses increased from about 100 in 1972 to 1,287 in 1982, then declined to 907 in 1987 (Quast et al. 1988).

Bait Markets: Bait shrimp comprise a large portion of the landings and value of the commercial fishery in Texas bays yet the percent of the total has not been routinely estimated (Osborn and Spiller In Preparation). McKee (1986) reported bait shrimp landings (live and dead) ranged from 0.54 (1979) to 0.96 million kg (1981) during 1977-1984. He reported estimates of 1.04 million kg for 1985 from the Texas Parks and Wildlife Department. Brown shrimp generally represent 50-60% of the catch and as much as one-half may be sold as live shrimp. Value of bait shrimp during 1977-1984 ranged between $3.45 million and $8.64 million per year (McKee 1986). Osborn and Spiller (In Preparation), using on-site interviews with sportboat angers, estimated over 0.8 million kg of bait shrimp ($6.5 million) were used by sport anglers during 1983-1984 and almost 0.6 million kg ($4.4 million) were used in 1984-1985.

During 1987, 495 bait shrimp dealers were licensed. The number of licensed dealers has remained between 400 and 700 since 1960 while the number of bait shrimp boat licenses has more than doubled since 1964 (Quast et al. 1988). Lack of increase in total bait shrimp sales since the 1970's indicates either reduced incomes to individual commercial bait shrimpers or diversion of shrimp caught with the increased bait shrimping effort into the food market (Osborn and Spiller In Preparation).

Trends in Consumer Demands: The United States is the world's leading consumer of shrimp. Annual per capita consumption increased from 0.54 kg in 1965 to 0.86 kg in 1984 (Chamberlain 1985). Experts predict that United States consumption will continue to rise until 1990. United States annual consumption of shrimp (all forms, converted to a heads-off, shell-on basis) increased from 192 million kg in 1980 to 285 million kg in 1987 (LMR Fisheries Research, Inc. 1988).

Demand for shrimp in the United States market is affected by a variety of factors. Principal factors are number of consumers, level of their disposable income (Shrimp Notes Inc. 1983), price of shrimp and competing goods, and consumer preferences. Number of potential United States shrimp consumers can be determined by utilizing the population of the United States The United States population was 241 million in 1987, up from 203 million in 1970. The population is projected to increase to 249 million by 1990.

Seasonal shrimp consumption patterns are clearly evident in the market. Shrimp consumption is highest during the third quarter followed by a decline in the fourth quarter. Shrimp consumption on a quarterly basis is lowest in the January to March quarter (Shrimp Notes Inc. 1983).

World stocks of shrimp are considered fully exploited and have yielded a stable harvest of 1.72 to 1.82 million mt (live weight) since 1977 (Figure 3.32). Production from the domestic fleet has provided 35-40% of annual market needs in recent years (Branstellar and Beckbam 1986). It is expected that increases in world consumption will have to be met by expanded production from aquaculture (Chamberlain 1985). World output of aquaculture raised shrimp is projected to increase from 78 million kg in 1982 to 239 million kg in 1990.

3.3.2 Imports

Source of Imports: The United States has imported more shrimp than it has produced since 1960. Historically, imports have supplied a major share of the United States shrimp demand. During 1980-1983, the share of the total United States shrimp consumption supplied by imports increased from 61% in 1980 to 82% in 1983 (all forms, converted to heads-off weight). This share dropped to 70% in 1984 as domestic landings increased (United States International Trade Commission 1985).

United States shrimp imports increased from 99 million kg ($719 million) in 1980 to 163 million kg ($1.1 billion) in 1985 (all forms, product weight). Projections for 1987 go as high as 213 million kg (LMR Fisheries Research, Inc. 1988). In 1987 the top suppliers of United States shrimp imports were, in decreasing order of value: Mexico (21%), Ecuador (16%), China (9%), Taiwan (8%), and India (6%)(LMR Fisheries Research, Inc. 1988).

A significant development affecting the United States shrimp market during 1980-1984 was the emerging importance of shrimp produced by aquaculture. This development was, mainly, the result of increased aquaculture production in Ecuador and, to a lesser extent, in other Latin American and some Asian countries. The number of countries producing aquaculture shrimp is expected to increase from 17 in 1982 to 44 in 1990. Countries expected to yield largest production in 1990 are India (50,000 metric tons), Ecuador (40,000 mt), Indonesia (40,000 mt), Taiwan (30,000 mt), Thailand (25,000 mt) and the Philippines (20,000 mt) (Chamberlain 1985).

Importance of Imports to the Domestic Fishery: The supply of shrimp available to the domestic harvesting sector is limited by ecological factors; thus, imports have gained a significant share of the market as the demand for shrimp has increased. Imports have limited price increases caused by increasing market demand (United States International Trade Commission 1985). During 1980-1984, below-average levels of United States shrimp landings and a strengthening United States shrimp market contributed to record-high United States shrimp imports (United States International Trade Commission 1985).

United States producers have little economic advantage over foreign producers in marketing shrimp in the United States because imports enter duty free. Cost of transporting shrimp from a foreign source to a United States market (3-12% of value of shrimp) is higher than cost of transporting domestic shrimp to a United States market (1-5% of value). However, transportation costs are not considered a major economic barrier to importation of shrimp because these costs are offset by lower foreign production costs and exchange rate differentials. Only in the case of fresh (not frozen) shrimp, do United States producers have a substantial transportation advantage over imports. However, this market is small compared to the frozen shrimp market (Chamberlain 1985, United States International Trade Commission 1985).

As a result of an increase in United States imports of aquaculture shrimp, certain structural changes occurred in the United States shrimp market during 1980-84. First, shrimp supplies became less seasonal because aquaculture provided a relatively steady annual flow of shrimp. Also, price relationships changed as supplies within certain size categories were increased by a more consistent supply of imported aquaculture shrimp. In addition, inventories (which are also affected by interest rates) became less of a factor in the United States shrimp market owing, in part, to a lessening of the seasonality of supplies (United States International Trade Commission 1985).

Expected increases in world supplies of shrimp due to aquaculture could eventually meet or exceed world demand. The effect of these predicted increases on prices was estimated for several different scenarios by John Vondruska (Industry Economist, Fisheries Development Analysis Branch, National Marine Fisheries Service, St. Petersburg, Florida). In the most likely scenario (United States importation of 1/3 of expected future aquaculture production), real prices for shrimp (excluding inflation) would increase by about 10% from 1983 to 1990 (as compared to nearly 30% without aquaculture supply increases). Shrimp Notes, Inc. (1983) has projected that 1990 prices for shell-on 26/30 count shrimp will range from a slight increase to a decline relative to current prices unless additional marketing and promotional efforts are undertaken by the industry (Chamberlain 1985).

Aquaculture shrimp have a price advantage over ocean-caught shrimp due to differences in handling after shrimp are harvested (Chamberlain 1985). It is possible that increase in world supplies of shrimp from aquaculture by 1990 could depress real prices sufficiently to prevent a rise from their present levels (Vondruska 1984).

Members of the United States gulf and south Atlantic region shrimp industry have expressed concerns about their competitive position in the United States market, largely in terms of competition from shrimp imports. The principal claims of the United States gulf and south Atlantic region shrimp industry are:

1. Shrimp harvesters in the gulf and south Atlantic region are being injured as a result of imports;

2. Shrimp industries in foreign countries benefit from government assistance, which makes their products more competitive in the United States market; and

3. Access has been restricted to traditionally open foreign shrimping grounds, particularly off the coast of Mexico, thus limiting United States gulf and south Atlantic region harvesters to United States waters and increasing the pressure on shrimping activities.

Foreign shrimp producers maintain that:

1. Imports have historically provided a large and necessary share of United States shrimp supplies since domestic supplies cannot fully meet demand in the United States market;

2. In many cases, imported shrimp commands a higher price than domestic shrimp in the United States market;

3. Tariffs or quotas on United States imports of shrimp would increase domestic shrimp prices to a point where the quantity of shrimp demanded and shrimp consumption would drop; and

4. There is a significant amount of United States investment in foreign shrimp operations, particularly in aquaculture, which export shrimp to the United States.

At the wholesale level of distribution, real or perceived quality differences between domestic and imported shrimp, or between shrimp of different foreign sources, sometimes lead to price premiums or discounts being applied. Depending on size category and species, which in most markets are important distinctions, imported shrimp may sell at substantial premiums or discounts from domestic-shrimp prices. At the final-consumer level, however, the distinction between imported and domestic shrimp disappears. Processors are sometimes able to play one source against another when dealing with various sources of supply (United States International Trade Commission 1985).

Government assistance in foreign countries is likely to result in increased production of shrimp with resulting increases in exports to the United States (United States International Trade Commission 1985). Public support of the United States shrimp industry, on the other hand, is unable to alter the basic constraint underlying domestic production, the fixed resource base.

The overall determination of the United States International Trade Commission 1976 report was that shrimp were being imported into the United States in such increased quantities as to be a substantial cause of serious injury to the domestic shrimp catching industry. Adjustment assistance to the industry was recommended (Gulf of Mexico Fishery Management Council 1981).

3.3.3 Analog Seafood Products

<u>Sources</u>: Presently, nine Japanese companies market their own brand of analog shellfish products in the United States, either through subsidiaries or through United States import distributors (Vondruska 1984).

<u>Importance of Analog Seafood Products to the Domestic Fishery</u>: Whereas, low cost production of quality shrimp from foreign mariculture represents the primary new supply source impacting the traditional domestic shrimp harvesting industry, the advent and recent growth of analog seafood products threatens to put further downward pressure on shrimp prices. Imitation or substitute shrimp products, manufactured from less expensive fish flesh, are both technically and economically viable. Although product fabrication technology is still evolving, cost-effective shrimp analogs are already competitive at the lower end of the shrimp price spectrum. Imitation or substitute products for peeled and deveined shrimp, breaded shrimp, breaded butterfly shrimp and flaked shrimp pieces are already on the market. Although manufactured products will probably never fully imitate natural shrimp, adequate simulation technology exists to allow these products to compete in the less discriminating shrimp markets. Moreover, labeling and nomenclature problems

in this distribution channel are far less limiting than in retail food distribution (Vondruska 1984).

Whereas, definitive cost information is not available for analog shrimp products, it is clear that an acceptable breaded shrimp product can be produced with current fabrication technology and marketed at the wholesale level in the $3.85 to $5.50/kg price range. The price range for comparable natural shrimp products would be $9.24 to $12.54/kg (Vondruska 1984).

3.4 Maximum Economic Yield

The best information available indicates the shrimp fishery in Texas is not providing maximum economic benefit to the state and is therefore not achieving maximum economic yield.

An understanding of the relationship between yield and effort in a fishery is essential for an evaluation of the economics of that fishery (Anderson 1980). Total revenue is the total economic benefit received by the fishery at the initial exchange of the resource. The amount of revenue realized by a fishery for the product it supplies is directly related to the amount of a product or resource landed (yield). The shape of a curve representing the total revenue of the fishery, with respect to effort, is generally the same as the shape of the yield versus effort curve for that fishery (Crutchfield 1975, Anderson 1980)(Figure 3.33 top). If a curve representing the total cost of fishing with respect to effort, is plotted along with the total revenue curve the relationship between total cost of fishing and total revenue for each level of effort can be demonstrated (Figure 3.33 bottom).

The maximum economic yield of a resource is that yield that produces the greatest difference between cost of fishing and total revenue (A)(Figure 3.33 bottom). At maximum economic yield the ratio of total revenue to cost of fishing is greater than the same ratio at any other level of effort. Therefore, maximum economic yield is associated with that level of effort which produces the greatest amount of economic benefit for each unit of effort or increment of fishing cost (Crutchfield 1975). It can be similar to the yield produced by a greater amount of effort and greater fishing costs (B)(Figure 3.33 bottom), but it can be achieved with less effort and at a lower cost. It is a biologically conservative management goal.

Texas fishery resources have traditionally been regarded as common property where access is unlimited. In an open access system, fisheries tend to become overcapitalized, and eventually overexploited (Bainton et al. 1987). As fishing effort increases without restriction an equilibrium will be achieved between cost of fishing and total revenue (B) (Figure 3.33 bottom). At this point the total cost of fishing equals total revenue for the fishery. This point, referred to as the open access bioeconomic equilibrium, represents the least economically efficient relationship between effort or cost and yield or total revenue. The cost of fishing is assumed to increase in proportion to increases in the amount of effort invested. If effort continues to increase, the cost of fishing will increase but sustainable yield will decrease and the resulting revenues will not be sufficient to cover all fishing costs.

Access to a fishery or the ability to enter a fishery such as the Texas shrimp fishery may be regulated indirectly through harvest quotas and user fees (licenses) or directly through limited entry. Texas currently has no total landings quota system, nor is there any method of directly regulating the number of participants in the fishery. Access to the Texas fishery is regulated exclusively through license fees levied on fishing boats, gear and participants.

To enter the Texas shrimp fishery a Texas resident must secure a General Commercial Fisherman's License ($15.00) and a Commercial (Bay, Bait or Gulf) Shrimp Boat License ($80-Bay or Bait; $100-Gulf). Fees for comparable non-resident licenses are $100, $160, and $200, respectively. Therefore, for $95-115 (resident) or $260-$300 (non-resident) in payments to the state per year, a fisherman may enter the Texas shrimp fishery. The nominal annual fees levied by Texas do not effectively limit fishery participation. For all practical purposes Texas has an "open access" fishery. The low cost of fishery participation encourages overcrowding in the industry and inevitably leads to overfishing. As participants compete for "their" portion of the diminishing resource, overcrowding tends to lead to marginal success for many if not most participants.

4.0 SHRIMP MANAGEMENT

4.1 Management Structure

4.1.1 Historical

The Texas Legislature has managed the shrimp fishery primarily through the Shrimp Conservation Act of 1959 (Chapter 77, Parks and Wildlife Code) and has enacted laws at 2-year intervals to maintain this resource. Texas legislators have delegated some authority to the Texas Parks and Wildlife Commission, which is appointed by the Governor and approved by the Senate. The Texas Parks and Wildlife Commission establishes policy for the Texas Parks and Wildlife Department and adopts regulations. The Texas Parks and Wildlife Department administers the Texas Parks and Wildlife Commission management programs, enforces statutes and regulations, conducts research and provides information and recommendations to the Texas Parks and Wildlife Commission, Legislature and Governor. The Texas Parks and Wildlife Department was granted regulatory authority in a number of counties via the Wildlife Conservation Act of 1983 (Chapter 61, Parks and Wildlife Code), and has additional authority in certain other counties via Title 7 (Local and Special Laws) of the Parks and Wildlife Code. In addition, through Chapter 79 (Parks and Wildlife Code, Extended Fishery Jurisdiction), the Texas Parks and Wildlife Department is authorized to cooperate with the Gulf of Mexico Fishery Management Council for management of shrimp in waters of the Gulf of Mexico beyond state waters.

4.1.2 Current

The present management structure exists as stated in the previous paragraph (Figure 4.1). In addition, the Texas Parks and Wildlife Department was mandated to develop a Shrimp Fishery Management Plan in accordance with Chapter 77, Parks and Wildlife Code. The Shrimp Fishery Management Plan developed by Texas Parks and Wildlife Department will be reviewed by an Interim Shrimp Committee and will contain comments received during public hearings, industry group meetings, written and oral testimonies (Appendix A) and reports by the Subcommittee on Shrimp Management (68th Legislature) and the Texas Coastal and Marine Council.

4.2 Management Regulations

4.2.1 Historical

The 1959 Shrimp Conservation Act established licenses (privilege tax) for each of the user groups including dealers (bait and food); set seasons, size limits, bag limits, possession limits, time limits and gear limits; established areas for fishing (major bays, bait bays, nursery areas, gulf waters); established regulations concerning handling, loading, unloading, buying, selling, and processing of shrimp; and established penalties for violations.

Seasonal restrictions in the shrimp fishery are complicated (Figure 4.2) and do not effectively stop shrimping any time during the year except in parts of the Gulf of Mexico during the gulf closed season. Bait shrimping occurs year around during the day and night except during 15 August through 15 December, when only day shrimping is allowed in all areas except the Laguna Madre (where night shrimping continues). Shrimp caught as bait during this season cannot legally be sold as food but once they reach the dock, final disposition cannot be controlled.

Under the 1959 Act, the Texas Parks and Wildlife Department is required to:

(1) enforce shrimping regulations;

(2) administer the sale of all licenses;

(3) conduct continuous research and study of:

  (a) the supply, economic value, environment and breeding habits of the various species of shrimp;

  (b) factors affecting the increase or decrease in shrimp abundance;

  (c) the use of trawls, nets and other devices for the taking of shrimp;

  (d) industrial and other pollution of the water naturally frequented by shrimp; and

  (e) statistical information gathered by the Department on the marketing, harvesting, processing and catching of shrimp landed at points in the state;

(4) publish a report on findings of fact for presentation to the Governor and Legislature before each regular session of the Legislature; and since 1979

(5) permit vessels for fishing in nursery areas.

The Texas Parks and Wildlife Commission may:

(1) based on sound biological data, change the 1 June through 15 July gulf closed season to provide for an earlier, later or longer season not to exceed 60 days;

(2) negotiate reciprocal agreements with another state with respect to the application of one state's shrimping regulations in its contiguous zone to citizens of the other state. (Note: This was an attempt to regulate shrimping beyond state waters and is now moot due to the passage of the Magnuson Fishery Conservation and Management Act of 1976).

Under Chapter 79 (Parks and Wildlife Code, Extended Fishery Jurisdiction) the Texas Parks and Wildlife Department is authorized to:

(1) cooperate with the Gulf of Mexico Fishery Management Council in developing state management programs that are consistent with plans proposed by the Council and approved by the Secretary of Commerce, and

(2) provide regulatory authority for shrimp if federal regulation in state waters is proposed and under no other circumstances.

Subchapter C of Chapter 61, Parks and Wildlife Code, defines the regulatory duties of the Texas Parks and Wildlife Commission and the Texas Parks and Wildlife Department. The Department shall conduct scientific studies and investigations of all species of wildlife resources. These studies and investigations may be made periodically or continuously and the Commission shall make findings of fact based on the studies and investigations of the Department.

The Commission shall regulate by proclamation the periods of time, means, methods, manners, and places in which it is lawful to take or possess wildlife resources from the areas covered by this chapter (Title 7, Parks and Wildlife Code). If the Commission finds there is a danger of depletion or waste it shall amend or revoke its proclamations to prevent the depletion or waste. The Commission may amend or revoke its proclamations at any time it finds the facts warrant a change.

The Texas Parks and Wildlife Commission has regulatory authority for shrimp in Brazoria, Jackson and Willacy Counties and the inside waters of Cameron County. The Texas Parks and Wildlife Commission does not have Chapter 61 regulatory authority in Jefferson and Orange Counties, but special laws provide broad authority.

In Brazoria County, the Texas Parks and Wildlife Commission has essentially adopted rules similar to Chapter 77, Parks and Wildlife Code, with the exception that bait shrimp may be taken in nursery areas (daytime only) with cast nets, dip nets and 6.1-m minnow seines. There is a 1.9 liter daily limit.

In Jackson County, shrimping is restricted to bait shrimp only, except during 15 August through 15 December, when 45.4 kg/day may be taken for personal use. These restrictions do not apply to the waters of Carancahua Bay below Highway 35. These regulations were in the enabling legislation when Jackson County came under regulatory authority and have not been changed.

In Jefferson County, the use of trawls is prohibited south of the Intracoastal Waterway and west of the Port Arthur Causeway (Keith Lake area). Cast nets and 6.1-m minnow seines may be used to take 1.9 liter of bait shrimp/day. Fishing restrictions are consistent in all counties in the Laguna Madre.

4.2.2 Current

Current regulations are comprised of the statutes and regulatory mandates detailed in the previous section. The United States government also regulates the shrimp fishery in Texas. During the gulf closed season for brown shrimp in state waters, a concurrent season in the Exclusive Economic Zone results in the suspension of the minimum size restriction for brown shrimp throughout the year. Through the Endangered Species Act the federal government has the authority to promulgate rules and has to date exercised this authority to protect sea turtles in both federal and state waters. Senate Bill 609 (69th Texas Legislature) provided the Texas Parks and Wildlife Department authority to regulate catching, possession, purchase and first sale of shrimp in Texas once a Shrimp Management Plan and Economic Impact Analysis was adopted by the Texas Parks and Wildlife Department.

5.0 MANAGEMENT WITHIN THE CONCEPT OF OPTIMUM YIELD

5.1 Management Actions

5.1.1 Historical Actions

Through the Legislature, Texas has generally managed its shrimp fishery to harvest larger, more valuable shrimp, to maintain different uses for shrimp and to prevent depletion. Laws have been implemented to meet these objectives, including the setting of size limits, seasonal and area closures, regulation of means and methods of harvesting shrimp, habitat protection, setting of bag and possession limits, requiring licenses of user groups and imposing penalties for noncompliance with regulations (Table 5.1). Each of these objectives is further addressed through the Texas Parks and Wildlife Department's fishery-independent and fishery-dependent monitoring programs, assessment and evaluation of monitoring data and through communication of findings to user groups and related agencies.

5.1.2 Current Actions and Recommendations

1. Statutory Authority: Regulation of the shrimp fishery in Texas is complicated. Primarily, the Legislature has managed the shrimp fishery to prevent depletion and to maximize ex-vessel value of shrimp landed. The result is a management system based on bag and possession limits, size limits, area and time closures and regulations governing the means and methods of taking shrimp. By transforming these statutes into proclamation form, the Texas Parks and Wildlife Commission could initiate a simplification and clarification process that would lead to an orderly transition from management by statute to management by regulation.

   Chapter 12, Parks and Wildlife Code gives the Department authority to administer laws relating to game, fish, oysters and other marine life in Texas waters. The Wildlife Conservation Act of 1983 (Chapter 61, Parks and Wildlife Code) gives regulatory authority to the Texas Parks and Wildlife Commission to provide a flexible mechanism to deal effectively with changing conditions to prevent depletion and waste of wildlife resources.

   In 1985, Chapter 77, Parks and Wildlife Code, directed the Department to conduct continuous research and study of:

   1. the supply, economic value, environment, and reproductive characteristics of the various economically important species of shrimp;

   2. factors affecting the increase or decrease in shrimp stocks in both an annual and long-term cycle;

   3. the use and effectiveness of trawls, nets, and other devices for the taking of shrimp;

4. industrial and other pollution of the water naturally frequented by shrimp;

5. statistical information gathered by the department on the marketing, harvesting, processing, and catching of shrimp landed at points in the state;

6. environmental parameters in the bay and estuary areas that may serve as limiting factors of shrimp population abundance;

7. other factors that, based on the best scientific information available, may affect the health and well-being of the economically important shrimp resources; and

8. alternative management measures for shrimp that may be considered for implementation in the management regime.

Section 77.007, Parks and Wildlife Code expanded the authority of the Department to regulate the catching, possession, purchase and sale of shrimp.

A proclamation of the Texas Parks and Wildlife Commission under this section prevails over:

1. any conflicting provision of this chapter to the extent of the conflict; and

2. a proclamation of the Commission issued under the Wildlife Conservation Act of 1983.

RECOMMENDATIONS: Implementation of Chapter 77, Parks and Wildlife Code may lead to fundamental changes in shrimp management by incorporating socioeconomic factors into the decision-making process. However, change should take place at a rate that minimizes disruption in the shrimp fishery and provides for an orderly transition from statutory authority to management by the Texas Parks and Wildlife Department. A process of clarifying and simplifying existing regulations should be a high priority under the proposed Shrimp Fishery Management Plan.

2. Joint Management: Shrimp that occur in Texas are part of a common stock that ranges throughout the Gulf of Mexico. As such, they fall under the jurisdiction of several states, federal agencies and the government of Mexico. Joint jurisdiction complicates the issue of managing shrimp resources throughout their range. The shrimp resources of Texas are managed by the Texas Parks and Wildlife Department (state waters out to nine nautical miles) and the United States Department of Commerce (gulf waters from 9 to 200 nautical miles). The Texas Parks and Wildlife Commission has direct authority over state waters but Commission members and Department staff also serve as voting or advisory members on various committees of the Gulf of Mexico Fishery Management Council, Gulf States Marine Fisheries Commission, MEXUS-Gulf work groups and other marine advisory councils.

RECOMMENDATIONS: The Texas Parks and Wildlife Department will continue to work with other groups to coordinate shrimp management. Upon adoption of this Shrimp Fishery Management Plan the Texas Parks and Wildlife Department staff will work to incorporate management actions and recommendations based upon the Shrimp Fishery Management Plan into Gulf of Mexico Fishery Management Council, MEXUS-Gulf and Gulf States Marine Fisheries Commission actions. This coordinated effort can provide for more effective management of the shrimp resources of Texas and the gulf.

As the specifics of this Shrimp Fishery Management Plan are to be developed by the adoption of rules and regulations by the Texas Parks and Wildlife Commission, and because it is vital to have the continued input of all individuals and groups interested in the shrimp resources of Texas, an advisory committee consisting of persons from the shrimp industry and individuals and groups interested in the shrimp resources of Texas shall be selected by the Chairman of the Texas Parks and Wildlife Commission for the purpose of advising, with the Texas Parks and Wildlife Department staff, on the preparation and formulation of each and every rule and regulation necessary to carry out the Shrimp Fishery Management Plan prior to the presentation of said rules and regulations to the Texas Parks and Wildlife Commission for its action.

3. Bag and Possession Limits: There are no possession limits in the shrimp fishery. Current statutes impose catch limits on bay, bait and noncommercial shrimp fishermen. Bay fishermen are limited to 136.1 kg/boat/day from 15 May through 15 July. Bait shrimpers are restricted to 90.7 kg/boat/day all year, and 50% of all bait shrimp must be kept alive from 15 November through 15 August. There are no bag limits for gulf commercial shrimp fishermen. Noncommercial shrimpers are limited to 6.8 kg/person/day from 15 August through 15 December (except in Jackson County north of Highway 35 where the limit is 45.4 kg/person/day) and from 15 May through 15 July in the bays. The daily limit for noncommercial shrimpers in the gulf is 45.4 kg/boat/day during the open season. Noncommercial shrimpers shrimping outside the above seasons are limited to 1.9 liter/person/day or 3.8 liter/boat/day for bait.

RECOMMENDATIONS: If other management tools that reduce waste, enhance law enforcement and meet the goal of controlling harvest and allocating catch can be successfully implemented in the shrimp fishery, the use of bag limits should be reduced or eliminated. Management tools other than bag limits, that reduce waste of the resource and enhance law enforcement should be the primary management tools.

There is evidence that the bait shrimp license is being abused. The 50% live shrimp requirement for bait shrimp and the live box requirement were initially successful in reducing number of bait licenses sold but the bait shrimp license is not solely used to provide bait. A means other than the 50% live and live-box requirements needs to be developed to provide for the legitimate needs for bait.

Restrictions on heading shrimp in inside waters should be eliminated in the absence of a bag or count limit. Heading in bays would allow more flexibility for fishermen to react to market situations. It could provide a higher quality product because headed shrimp deteriorate less than whole shrimp.

4. Size (Count) Limits: The only size restriction in effect occurs in major bays from 15 August through 31 October when the legal shrimp count is 110 whole shrimp/kg. Minimum shrimp size restrictions from outside waters have been exempted as long as the Gulf of Mexico Fishery Management Council's management plan is in effect and the taking of shrimp in at least part of the Exclusive Economic Zone is restricted during the Texas gulf closed season. No size limits are imposed on bait or noncommercial shrimping.

RECOMMENDATION: If other management tools that reduce waste or enhance law enforcement can be successfully implemented, the use of size limits should be eliminated because they generally lead to waste of the resource.

5. Time Periods: The Legislature has regulated the time period within which the taking of shrimp is allowed by setting seasons and day/night restrictions. This has resulted in a complicated network of seasons.

Bait shrimp may be taken at any time of the day or night except during the fall open season when bait shrimping is permitted only during the day. An exception in the Laguna Madre allows bait shrimping any time of the day or night year around.

Major bays are open during the day for food shrimp from 15 May through 15 July and from 15 August through 15 December.

Outside waters beyond the 12.8 m depth contour are open year around, day and night, except during the flexible summer closed season from 1 June through 15 July. The closing and opening dates of the summer closed season may be changed by the Texas Parks and Wildlife Commission or Executive Director to provide for an earlier, later or longer season not to exceed 60 days. During this season, there is also an exception that allows the catch of white shrimp in outside waters less than 7.3 m deep during the day.

Outside waters within the 12.8 m depth contour are closed at night year around. Except for the summer closed season and the winter closed season (16 December through 1 February), waters within the 12.8 m depth contour are open during the day. An exception during the winter closed season allows shrimping for seabobs in daylight hours as long as restrictions on gear and composition of catch are met.

Noncommercial shrimpers in both inside and outside waters have the same season restrictions as commercial shrimpers.

RECOMMENDATIONS: Restricting the harvest of shrimp to specific time periods [including, but not limited to, certain times during the day, or certain months (periods) during the year], along with area closures (where an area can be a portion of a bay system or the Gulf of Mexico, a bay system, the Gulf of Mexico, or the entire state including gulf waters) are the primary means for managing the Texas shrimp fishery, especially if bag limits are removed.

Exceptions to closed time periods should be eliminated unless it can be demonstrated that the value of the target species exceeds the loss in value of non-target species.

Time of day when seasons open and close should be standardized. Current inconsistencies cause confusion and are difficult to enforce.

6. Closed Areas: The Legislature regulates the shrimp fishery by designating areas where shrimp may be caught. No person may catch shrimp within natural or man-made passes leading from inside water to outside water. Commercial and noncommercial shrimping in inside waters, except bait shrimping, are restricted to major bays. Bait shrimping is restricted to bait bays and major bays but certain bait shrimp dealers have been authorized to fish in designated nursery areas under a "grandfather clause" that will expire in 1991. The Texas territorial sea is closed during the gulf closed season except in water less than 7.3 m deep where white shrimp may be taken. Outside waters up to 12.8 m deep are closed at night year around and during the day from 16 December through 1 February.

   RECOMMENDATIONS: Area closures, as well as specific time period restrictions, should be the primary management tools for managing the Texas shrimp fishery if they can successfully be used to reduce waste and enhance law enforcement. Areas closed to shrimping should continue to be based on the life history of shrimp, especially as it relates to growth. Boundaries of closed areas should be clearly identified to assist fishermen in recognizing closed areas, and to enhance law enforcement.

7. Means and Methods: The Legislature has regulated taking of shrimp by imposing limits on the dimensions, mesh size, configuration and number of gear units allowed within each fishery.

   The bait shrimp fishery is limited to one main trawl 9.8 to 10.4 m along headrope, and one try net <3.7 m along the headrope from the leading tip of each door. Beam trawls <7.6 m along the beam and try nets not exceeding 1.5 m are also legal. Minimum mesh size is 16.5 cm over 5 stretched meshes.

   For the spring open season, one main net (otter trawl or beam trawl with the same restrictions as above) and one try net less than 6.4 m or beam trawl less than 3.0 m may be used. Minimum mesh size is 16.5 cm over 5 stretched meshes.

During the fall open season, only one otter trawl and one try net may be used. The total width of the otter trawl and doors may not exceed 29 m. The try net may not exceed 6.4 m. A beam trawl used as a try net may not exceed 3.0 m. Minimum mesh size is 22.2 cm over 5 stretched meshes from 15 August through 31 October and 16.5 cm over 5 stretched meshes from 1 November through 15 December.

There are no restrictions on the number or size of trawls in outside waters except when fishing for white shrimp within the 7.3 m depth contour during the gulf closed season (one main trawl, 9.8 to 10.4 m, and one try net may be used; if a beam trawl is used it may not exceed 7.6 m), or when fishing for seabobs during the closed winter season inside the 12.8 m depth contour (one trawl not exceeding 7.6 m in width with 5 stretched meshes no smaller than 16.5 cm). Electro-trawls may have an applied voltage of no more than 3 volts.

A person may catch shrimp for personal use with an individual bait shrimp trawl (minimum mesh size 22.2 cm over 5 stretched meshes; not exceeding 6.1 m in width), cast net, dip net, bait trap or minnow seine not larger than 6.1 m in length.

During the open season in outside waters a seine not exceeding 122 m in length with certain mesh restrictions may also be used.

RECOMMENDATIONS: If regulation of means and methods can successfully regulate the catch of individual fishermen, they should be used instead of bag limits and size limits. Regulations on means and methods should be standardized where practical and designed to reduce waste and enhance law enforcement.

8. Licenses: The Texas Parks and Wildlife Department has the responsibility of issuing licenses, established by the Legislature, for the privilege of catching, buying, selling, unloading, transporting or handling shrimp within the jurisdiction of the state. License documentation provides the Texas Parks and Wildlife Department with a universe of fishery participants. The fees for non-resident fishermen are usually higher than those for resident fishermen. The Texas Parks and Wildlife Commission may increase fees from the minimum set by law.

A General Commercial Fisherman's License is required for residents or nonresidents who harvest edible aquatic products from the waters of the state. For boats having a Commercial Shrimp Boat License, one license may be bought in the name of the boat to cover captain and crew.

A Bait Shrimp Dealer License is required of any person selling shrimp for fish bait in coastal counties.

Business licenses include (1) Wholesale Fish Dealer, (2) Wholesale Fish Truck Dealer, (3) Retail Fish Dealer, (4) Retail Fish Truck Dealer, (5) Shrimp House Operator, and (6) Shellfish Culture License.

Boat licenses include (1) Bait Shrimp Boat, (2) Bay Shrimp Boat and (3) Gulf Shrimp Boat.

For noncommercial shrimping, a person must have a General Fishing License, a Saltwater Stamp and, if a trawl is used, an Individual Bait-Shrimp Trawl Tag.

RECOMMENDATIONS: The licensing and fee system should be as simple as possible. It should be designed to produce revenue to pay for management and recover economic rent associated with the removal of the State's resources.

9. Penalties and Compliance: The Legislature sets penalties and fines for violations of fish and game laws. The Texas Parks and Wildlife Department has the authority to establish guidelines for recovering the value of illegally harvested or killed shrimp (Sections 12.302-12.307, Parks and Wildlife Code) and has the authority to revoke or suspend any license (Section 12.501, Parks and Wildlife Code).

   RECOMMENDATIONS: Penalties for violating regulations should be increased, especially for violations of the recommended primary management tools of area closures, time periods, and means and methods. Higher penalties could include increased fines, higher classification of violations, reduction in the number of violations required for license revocation or suspension, and more consistent penalties for violations. The civil restitution and license revocation and suspension provisions of current law should be continued.

10. Allocation: Allocation is that element of fisheries management that is implemented after protection of spawning stock has been accomplished. Resource allocation can be accomplished directly (by quotas, limited entry, etc.) or indirectly through regulation of fishing means, methods, times, seasons, gear, etc. Historically, the Texas Legislature has allocated shrimp resources through indirect methods.

    RECOMMENDATION: The necessary data should be obtained to assess the feasibility of implementing a limited entry program into the Texas shrimp fishery to achieve optimum yield.

11. Stocking: Shrimp hatchery technology exists but stocking of hatchery produced shrimp into public waters has not been done by the Texas Parks and Wildlife Department. Current law allows the raising of shrimp in the private waters of the state by holders of a Shellfish Culture License. Recent legislation provides that stocking of shrimp is not permitted in Texas public waters without prior notification and approval of the Texas Parks and Wildlife Department. Additionally, it is not legal to transplant shrimp, native or non-native, into Texas for culture or stocking without notification and approval of the Texas Parks and Wildlife Department.

RECOMMENDATIONS: Stocking in public waters to enhance natural populations should be used when necessary to supplement natural recruitment when sufficient research has demonstrated its efficacy.

12. Mariculture Development: Current state law allows the culture of shrimp in private waters of the state by holders of a Shellfish Culture License. Current statutes and Texas Parks and Wildlife Commission rules allow the take of limited quantities of wild brood stock and the importation of live shellfish (that are certified free of disease) by permit for culture purposes (Sections 51.009 and 51.010, Parks and Wildlife Code).

    RECOMMENDATION: The Texas Parks and Wildlife Department should continue to monitor the development of mariculture techniques and the commercial production of penaeid shrimp.

13. Habitat Maintenance, Restoration, and Enhancement: Under Section 77.004, Parks and Wildlife Code, the Texas Parks and Wildlife Department is required to conduct continuous research and study of environmental parameters and other factors that affect shrimp population abundance. The Department is also required to study industrial and other pollution of the water naturally frequented by shrimp.

    RECOMMENDATIONS: The long-term viability of the Texas shrimp fishery depends on maintenance and enhancement of shrimp habitat. The Texas Parks and Wildlife Department should continue to aggressively protect and enhance shrimp habitat and water quality via all available resource protection agencies and programs.

14. Fishery Independent Monitoring: The objectives are to develop long-term trend information on shrimp population abundance and stability in Texas bays and the Gulf of Mexico, and to monitor environmental factors which may influence shrimp availability. A comprehensive monitoring program provides information about most life history stages of the resource and is capable of detecting changes in population structure. To accomplish these objectives, long-term trend information will be collected with 18.3 m bag seines and 6.1 m otter trawls in the bays and Gulf of Mexico.

    RECOMMENDATIONS: The present monitoring program should be maintained or enhanced to meet Legislative mandates and to continue to determine trends in population abundance and stability, movement, growth, mortality and the impacts of environmental influences.

15. Fishery Dependent Monitoring: The objectives are to determine size, catch per unit effort, and value of shrimp landed by commercial and recreational fishermen from Texas bays and the Gulf of Mexico, and to determine monthly and annual purchases of edible seafood products by commercial dealers through Monthly Marine Products Reports. Daylight commercial landings and fishing activities are estimated from on-site surveys of seafood and bait dealers, boat access sites and commercial vessel docking structures. The landings and fishing activities of sport fishermen are monitored through on-site surveys of recreational boat access sites. The Texas Parks and Wildlife Department also has an

agreement with the National Marine Fisheries Service to exchange landings and effort data on the shrimp fishery.

RECOMMENDATIONS: The present monitoring program should be enhanced to meet Legislative mandates and to continue to determine fishery harvest trends, economics and impacts of sociological influences.

16. Assessment and Evaluation: The Texas Parks and Wildlife Department is mandated by Sections 12.001, 61.051 and 77.006, Parks and Wildlife Code to assess annually and publish the status of shrimp populations and associated environmental variables. The Texas Parks and Wildlife Department is responsible for making management recommendations regarding the State's shrimp fishery within the bays, estuaries and gulf waters out to nine nautical miles.

RECOMMENDATIONS: Continued assessment and evaluation are necessary to meet Legislative mandates and to address data needs reviewed in this plan.

17. Communication and Education: The Texas Parks and Wildlife Department is required to report on findings of fishery research, assessments and evaluations and to make recommendations for further actions when studies indicate they are appropriate to accomplish the objectives of this plan (Sections 12.0011, 12.002 and 77.004-77.006, Parks and Wildlife Code).

RECOMMENDATIONS: The Texas Parks and Wildlife Department should continue to maintain a high level of interdepartmental, industrial and interagency communication to more fully benefit from the free flow of information concerning penaeid shrimp research, adverse environmental conditions and changes in economic and societal goals.

6.0 SUMMARY OF RESEARCH NEEDS

1. More precise estimates of natural and fishing mortality and other parameters required for yield assessments are needed.

2. Spawner-recruit relationships need to be analyzed.

3. More precise estimates of yield relationships including maximum sustainable yield are needed.

4. Causes of fluctuations in landings need to be clearly identified.

5. Economic and sociologic factors influencing fishing effort need to be determined.

6. Sociological and economic information needed for equitable allocation and maximum economic yield estimation are incomplete.

7. Impacts of regulations and other management actions on shrimp populations need to be assessed.

7.0 REVIEW AND MONITORING OF THE MANAGEMENT PLAN

The Texas Parks and Wildlife Department will, after approval and implementation of the Shrimp Fishery Management Plan by the Executive Director and Texas Parks and Wildlife Commission, continue to manage the shrimp resources within the guidelines of the goals and objectives set forth by the Shrimp Fishery Management Plan.

The Texas Parks and Wildlife Department will continue to conduct continuous research and study of:

1. the supply, economic value, environment and reproductive characteristics of the various economically important species of shrimp;

2. factors affecting the increase or decrease of shrimp stocks in both an annual and long-term cycle;

3. the use and effectiveness of trawls, nets, and other devices for the taking of shrimp;

4. industrial and other pollution of the water naturally frequented by shrimp;

5. statistical information gathered by the department on the marketing, harvesting, processing and catching of shrimp landed at points in the state;

6. environmental parameters in the bay and estuary areas that may serve as limiting factors of shrimp population abundance;

7. other factors that, based on the best scientific information available, may affect the health and well-being of the economically important shrimp resources; and

8. alternative management measures for shrimp that may be considered for implementation in the management regime.

The Texas Parks and Wildlife Department will periodically update data and information contained within the Shrimp Fishery Management Plan, by incorporating the results of future research and evaluations.

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Table 2.1. Summary of life history parameters for penaeid shrimps along the Texas coast.

Species	Size at sexual maturity (mm)	Gulf area of spawning (m)	Principal Spawning period	Fecundity (no. eggs/spawn)	Principal postlarval recruitment period	Size at emigration (mm)	Emigration period	Growth rate (mm/day)
Brown shrimp	140 both sexes	15-110	Aug-Nov	0.1-0.3 million	Mar-Apr Jun-Sep	75-100	May-Aug	0.5-3.3
White shrimp	155 males 135 females	7-33	May-Jul	0.2-0.4 million	May-Oct	75-125	Aug-Nov	0.5-2.0
Pink shrimp	65 males 90 females	15-50	May-Sep	0.5 million	Aug-Sep	75-100	Sep-Nov	Unknown
Seabob shrimp	60 both sexes	0-7	Jul-Dec	Unknown	Unknown	Not estuarine	Not estuarine	Unknown
Trachypenaeids	Unknown	18-36	Apr-Nov	Unknown	Unknown	Not estuarine	Not estuarine	Unknown

Table 2.2. Qualitative analyses of fish predation on penaeid shrimps based on inshore (I) and offshore (O) studies. (From: Sheridan et al. 1984).

Fish predators	Percent frequency of occurrence				
	0	1-20	21-40	41-60	61-100
Anchoa hepsetus	I				
Anchoa mitchilli	I				
Harengula jaguana	I				
Caulolatilus chrysops	I				
Menticirrhus littoralis	I				
Katsuwonus pelamis	O				
Larimus fasciatus	I				
Thunnus thynnus	O				
Trichiurus lepturus	I				
Raja sp.	O				
Paralichthys albigutta	I	I			
Synodus foetens	I	I			
Leiostomus xanthurus	I	I			
Stellifer lanceolatus	I	I			
Thunnus albacares	O	O			
Caranx hippos		I			
Caulolatilus microps		I			
Euthynnus alletteratus		O			
Porichthys porosissimus		I			
Prionotus tribulus		I			
Stenotomus caprinus		O			
Thunnus alalunga		O			
Cynoscion arenarius		I	I		
Bairdiella chrysoura		I	I		
Urophycis floridanus		I	I		
Micropogonias undulatus	I	I.O	I		
Menticirrhus americanus	I	I	I		
Paralichthys lethostigma		I	I	I	
Lutjanus campechanus			I		
Prionotus scitulus			I		
Scomberomorus maculatus			I		
Carcharhinus sp.			I		
Rachycentron canadum				I	
Menticirrhus sp.				I	
Scomberomorus cavalla		I		I	
Arius felis	I	I		I	I
Bagre marinus		I		I	
Centropristis melana				I	
Cynoscion nebulosus					I
Pomatomus saltatrix					I
Oligoplites saurus					I
Diplectrum formosum					I

Table 2.3. Quantitative analyses of fish predation on penaeid shrimps based on inshore (I) and offshore (O) studies. ? = Penaeids not differentiated from other shrimps. (From: Sheridan et al. 1984).

	Percent by volume, weight or number				
Fish predators	0	1-20	21-40	41-60	61-100
Anchoa mitchilli	I				
Harengula jaguana	I				
Opisthonema oglinum	I				
Leiostomus xanthurus	I				
Rhomboplites aurorubens	I				
Trachinotus carolinus	I				
Bellator militaris	O				
Prionotus salmonicolor	O				
Saurida brasiliensis	O				
Paralichthys lethostigma	I	I			
Cynoscion arenarius	I	I			
Micropogonias undulatus	I	I			
Bairdiella chrysoura	I	I			
Arius felis	I	I			
Anchoa hepsetus	O	I?			
Synodus foetens		I?			
Prionotus roseus		O			
Prionotus scitulus		I.O			
Prionotus tribulus		O			
Prionotus alatus		O			
Lutjanus campechanus		I	I		
Ancyclopsetta quadrocellata	I	I		I	
Citharichthys spilopterus		I			I
Oligoplites saurus		I?			I?
Trachinotus falcatus		I?		I?	
Haemulon plumieri		I?		I?	
Orthopristis chrysoptera			I?	I?	I?
Prionotus ophryas					O
Caranx hippos					I

Table 2.4. Results of a quantitative study of fish feeding on the Gulf of Mexico continental shelf (Rogers 1977). Size = size of fishes. % Vol = percentage of volume of fish stomach contents attributed to shrimp. A total of 4,550 stomachs were examined. (From: Sheridan et al. 1984).

Species	Size (mm:SL)	% volume	Dominant shrimps
Anchoa hepsetus	26-125	0	
Saurida brasiliensis	51-125	0	
Halieutichthys aculeatus	26-75	0	
Ogcocephalus parvus	51-125	0	
Chloroscombrus chrysurus	101-150	0	
Stenotomus caprinus	26-125	0	
Micropogonias undulatus	51-125	0	
Bollmannia communis	26-75	0	
Peprilus burti	26-75	0	
Prionotus stearnsi	26-100	0	
Etropus crossotus	26-125	0	
Symphurus civittatus	51-15	0	
Symphurus plagiusa	101-125	0	
Synodus foetens	50-200	3	Sicyonia
Porichthys porosissimus	26-100	8	Sicyonia, Parapenaeus
Cynoscion arenarius	26-100	15	Trachypenaeus
Trichopsetta ventralis	76-125	18	Trachypenaeus, Parapenaeus
Cynoscion nothus	26-175	19	Sergestids, Trachypenaeus
Centropristis philadelphica	26-225	23	Sicyonia, Sergestids
Syacium gunteri	51-150	29	Trachypenaeus, Carideans
Prionotus rubio	26-175	29-50	Trachypenaeus, Sicyonia
Diplectrum bivittatum	26-125	48	Trachypenaeus, Solenocera
Serranus atrobranchus	26-125	49	Trachypenaeus, Sicyonia
Lepophidium graellsi	101-225	54	Carideans
Cynoscion nebulosus	26-75	57	Trachypenaeus, Sergestids
Citharichthys spilopterus	51-125	62	Trachypenaeus

Table 2.5. Estimates of minimum sizes at which shrimp reach sexual maturity (Fully developed spermatophores for males and ripe ovaries for females).

Species/sex	Total length (mm)	Source
Brown shrimp		
Males	110-120[a]	Chamberlain and Lawrence (1983)
	140 (assumed)	Renfro (1964)
Females	160-170[a]	Chamberlain and Lawrence (1983)
	140	Renfro (1964)
White shrimp		
Males	150-160[a]	Chamberlain and Lawrence (1983)
	155	(Perez-Farfante's [1969] conversion of Burkenroad's [1934] estimate)
Females	160-170[a]	Chamberlain and Lawrence (1983)
	135	(Perez-Farfante's [1969] conversion of Burkenroad's [1934] estimate)
Pink shrimp		
Males	65	Perez-Farfante (1969)
	74	Eldred et al. (1961)
Females	92	Eldred et al. (1961)
Seabob		
Males	60	
Females	60	Anderson (1970)

Revised from: Gulf of Mexico Fishery Management Council. 1981.
[a]Estimates for Texas are listed first.

Table 2.6. Estimates of growth parameters[a] for three commercially important shrimp species. (From: Christmas and Etzold 1977).

Species/sex	K_l	L_{oo} (mm)	K_c	C_{oo} (mm)	W_{oo} (g)	b	t_o Weeks	t_p Weeks	Total length range (mm)	Carapace length range (mm)	Weight range (mm)	Source
Brown												
Combined	0.073	177.7					0.0[d]	12	115.0-135.0			McCoy (1968)
Male			0.317	30.0			0.98			23.5-29.5		McCoy (1972)
Female			0.171	36.6			-7.20			25.0-34.5		McCoy (1972)
White												
Male	0.064	170.0										Lindner and Anderson (1956)
Female	0.047	190.0										Lindner and Anderson (1956)
Combined	0.12				87.0	3.0	-0.57					Klima (1964)
Combined	0.09											Klima and Benigno (1965)
Combined	0.09	214.0										
	0.06	224.0					0.2					Klima (1974)
Pink												
Male			0.016	46.38								Iverson and Jones (1961)
Female			0.022	46.05								Iverson and Jones (1961)
Combined	0.068	185.0			57.8							Lindner (1965)
Combined[b]	0.071				42.0	3.14	0.68	15	88.8-130.4		5.9-19.5	Kutkuhn (1966)
Combined[c]	0.085				35.6	3.14	3.20	15	75.3-157.5		3.5-35.2	Kutkuhn (1966)
Male	0.046	168.0			42.3	3.134	0.68	11	95.3-148.0			Berry (1967)
Female	0.055	199.0			73.3	3.115	0.06	11	95.7-170.0			Berry (1967)
Male			0.217	27.0			-9.82			23.5-26.5		McCoy (1972)
Female			0.188	34.5			-6.93			25.0-32.5		McCoy (1972)

[a]Parameters apply to Von Bertalanffy equations describing growth: (1) in total length, $L_t = L_{oo}\ (L - e^{-k_l(t-t_o)})$ (2) in carapace length, $C_t = C_{oo}(1 - e^{-k_c(t-t_o)})^b$, and (3) in weight $W_t = W_{oo}\ (1 - e^{-k_w(t-t_o)})^b$, in which L_{oo}, C_{oo} and W_{oo} are asymptotic sizes of the average individual in terms of total length, carapace length, and total weight, respectively. K_l and K_c are coefficients proportional to rates of catabolism based on total length and carapace length, respectively. t_o is a hypothetical age at which length is zero. t_p is age at recruitment based on a recruitment size of 70 shrimp per pound (= g). b is the exponent in the relationship between weight, W, and total length, L; viz., $W = aL^b$.

[b]Values represent the Tortugas fishery off south Florida.

[c]Values represent the Sanibel fishery off southwest Florida.

[d]Authors assumed $t_o = 0$.

Table 2.7 Growth models for brown shrimp. Lengths (L) in millimeters, weights (W) in grams, and ages (a) in months. (From: Parrack 1979).

Model	Males	Females
Logistic	$L = 162.8/(1 + 464.1429e^{-0.5664a})$	$L = 187.5/(1 + 534.7143e^{-0.6116a})$
von Bertalanffy	$L = 168.7(1 - 0.9979e^{-0.3357a})$	$L = 193.6(1 - 0.9982e^{-0.3363a})$
Linear	$L = 0.35 + 4.2181a$	$L = 0.35 + 7.8209a$
Gompertz	$W = 5.07(\exp[1.9996(1 - \exp[-0.3735(a - 4.6688)])])$	$W = 3.55(\exp[2.8359(2 - \exp[-0.4410(a - 3.2549)])])$
Monomolecular	$W = 43.51(1 - 0.9999e^{-0.1546a})$	$W = 74.32(1 - 0.9999e^{-0.1416a})$
Linear	$W = 0.0004045 + 1.8018a$	$W = 0.0004054 + 3.901a$

Table 2.8. Observed maximum sizes attained by penaeid shrimp. (From: Perez-Farfante 1969).

Species/sex	Size total length (mm)	Geographic Area
Brown shrimp		
Male	195	Galveston, Texas
Female	236	Morgan City, Louisiana
White shrimp		
Male	175	Sabine River, Texas
Female	200	Bayou Scolfield, Louisiana
Pink shrimp		
Male	269	
Female	280	Campeche, Mexico

Table 2.9. Weight-length conversion table for brown shrimp, white shrimp and pink shrimp (sexes combined). (From: Gulf of Mexico Fishery Management Council 1981).

	Count					
	Brown shrimp[1]		White shrimp[2]		Pink shrimp[1]	
Total length (mm)	Shrimp per kg	Tails per kg	Shrimp per kg	Tails per kg	Shrimp per kg	Tails per kg
50	968	1,558	1,142*	1,758*	924*	1,481*
60	568	913	662	1,021	532	851
70	361	581	499	768	334	535
80	244	392	323	499	222	356
90	172	277	220	341	156	249
100	125	202	158	242	114	180
110	95	154	114	178	86	136
120	75	119	88	134	66	103
130	57	95	68	103	51	81
140	46	75	53	81	40	66
150	37	62	42	66	33	53
160	31	51	35	53	26	44
170	26	42	29	44	22	35
180	22	35	24	35	20*	31*
190	20	31	20	31	*	*
200	15	26	18	26	*	*
210	13	22	13	22	*	*

[1]From Fontaine and Neal (1971).
[2]50-60 mm estimates from Perret (1966) and 70-210 mm estimates from Fontaine and Neal (1971).
*Outside of data range.

Table 2.10. Weight-length and length-length relationships[1] for the three commercially important shrimp species. (From: Christmas and Etzold 1977).

Species/Sex	Total length to total weight: $W = a\,l^b$ — a	b	Size range (mm)	No. measured	Carapace length to total weight: $W = a'\,c^b$ — a'	b	Size range (mm)	No. measured	Carapace length to total length: $l = a''\,c^b$ — a"	b	Size range (mm)	No. measured	Source
Brown													
Combined	12.3×10^{-6}	3.02[3]	65-165[2]	2,104									McCoy (1968)
Male	11.61×10^{-6}	2.911	45-204	1,396									Fontaine and Neal (1971)
Female	9.53×10^{-6}	2.966	55-240	2,016									Fontaine and Neal (1971)
Combined	10.52×10^{-6}	2.938	45-240	3,412									Fontaine and Neal (1971)
Male					0.000819	2.94	10-42[2]	259	[4]				McCoy (1972)
Female					0.00113	2.84	10-42[2]	243	[4]				McCoy (1972)
White													
Combined	7.69×10^{-6}	2.976	55-160	100									Perret (1966)
Male	2.02×10^{-6}	3.261	70-200	970									Fontaine and Neal (1971)
Female	2.32×10^{-6}	3.234	70-214	1,120									Fontaine and Neal (1971)
Combined	2.16×10^{-6}	3.247	70-214	2,090									Fontaine and Neal (1971)
Pink													
Male	4.49×10^{-6}	3.13	35-175[2]	729	0.001	3.04	8-40[2]	729	5.27	0.96	35-175	729	Kutkuhn (1966)
Female	5.06×10^{-6}	3.12	35-215[2]	888	0.002	2.79	85[2]	888	6.14	0.90	35-215	888	Kutkuhn (1966)
Combined	9.79×10^{-6}	2.98[3]	65-165[2]	2,641									McCoy (1968)
Male	10.02×10^{-6}	2.967	70-175	1,173									Fontaine and Neal (1971)
Female	5.93×10^{-6}	3.92	60-214	2,125									Fontaine and Neal (1971)
Combined	7.71×10^{-6}	3.029	60-214	3,298									Fontaine and Neal (1971)
Combined					0.0062	3.03443	6-22[2]						Tabb, et al. (1962a)
Male					0.00148	2.77	10-42[2]	297	[4]				McCoy (1972)
Female					0.00209	2.66	10-42[2]	503	[4]				McCoy (1972)

[1]Additional data on length-weight relationship was published by Anderson and Lindner (1958), pink, and by Iversen and Idyll (1960), white.
[2]Size range was estimated from published graph.
[3]Reported value of b is not significantly different at 95% confidence level from theoretical value, i.e. b = 3.
[4]McCoy (1972) gives linear equations for conversion of carapace length to total length.

Pink	Male L = 12.37 + 3.81C	Brown	Male L = 3.50 + 4.16C
	Female L = 21.90 + 3.40C		Female L = 10.50 + 3.83C

Table 2.11. Comparison of weekly instantaneous mortality rates for three commercially important shrimp species in the Gulf of Mexico. (From: Christmas and Etzold 1977; Gulf of Mexico Fishery Management Council 1981; Berry 1970).

Shrimp species	Fishing mortality (F)	Natural mortality (M)	Total mortality (Z)	Source	Area	Comments
Brown	.06	.21	.27	Klima (1964)	Texas and Louisiana	
	-	.275[a]	-	Nance (1989)	Gulf of Mexico	
	.020-.315	-	-	Neal (1968b)		Calculated from reported maximum exploitation rates
Offshore	-	.025-.075	-	Fox (1981) pers. comm.		
	-	-	.993-1.243	McCoy (1968)	North Carolina	
	.206	.364	.571	McCoy (1972)	North Carolina	
White	-	-	.46	Klima (1963)		
	.06 - .19	.08	.14 - .27	Klima and Benigno (1965)	Texas	
	.104-.131	.041-.121	.164-.226	Klima (1974)	Texas	Values were reported by author as
	-	.275[a]		Nance (1989)	Gulf of Mexico	questionable
Lake	.027-.020	.214-.556	.241-.576	Phares (1980)		
Inshore	.03-.09	-	-	Klima and Parrack (1980)	Louisiana	
Offshore	.01	-	-	Klima and Parrack (1980)	Louisiana	
Pink	.09	.27	.36[b]	Iversen (1962)	Florida	Corrected values
	.96	.55	.76 -1.51	Kutkuhn (1966)	Florida	
	.12-.18	.08-.12	.25	Lindner (1966)		
	.160-.227	.024-.061	.22-.27	Berry (1967)	Florida	
	.03-.07	.08-.11	.11-.18	Costello and Allen (1968)	Florida	
	.02-.16	.01-.03	.07-.16	Berry (1970)	Florida	
	.337	.280	.612	McCoy (1972)	North Carolina	
	-	-	.317-.350[c]	McCoy (1972)	North Carolina	
	-	.30	-	Nance (1989)	Gulf of Mexico	

[a]Monthly mortality rates.
[b]Obtained during the partially exploited phase of the mark-recapture experiment.
[c]$Z = 0.317$ and $Z = 0.350$ were fall and spring values, respectively.

Table 2.12. Mean catch rate (no./h ± 1SE) and weighted mean TL (± 1SE) for brown shrimp, white shrimp and pink shrimp collected in four depth zones within gulf waters off Aransas Pass and Mansfield Pass, Texas during May-August 1980-1981.

Species	Aransas Pass				Mansfield Pass			
	1980		1981		1980		1981	
Depth zone	no./h	TL	no./h	TL	no./h	TL	no./h	TL
Brown shrimp								
9-18 m	2,161 ± 115	102 ± 0.1	1,572 ± 420	97 ± 0.2	1,501 ± 746	93 ± 0.2	885 ± 730	77 ± 0.1
19-27 m	388 ± 133	117 ± 0.2	1,688 ± 825	112 ± 0.1	944 ± 119	103 ± 0.3	3,288 ± 349	101 ± 0.1
28-37 m	508 ± 286	114 ± 0.2	1,108 ± 342	120 ± 0.1	851 ± 489	114 ± 0.2	1,760 ± 700	114 ± 0.1
38-49 m	322 ± 194	126 ± 0.3	793 ± 341	119 ± 0.1	208 ± 104	130 ± 0.5	1,370 ± 582	110 ± 0.2
Overall mean	845 ± 334	108 ± 0.1	1,290 ± 251	110 ± 0.1	876 ± 235	103 ± 0.2	1,826 ± 358	103 ± 0.1
White shrimp								
9-18 m	19 ± 3	160 ± 1.3	62 ± 59	163 ± 0.2	2 ± 1	185 ± 5.9	1 ± 1	82 ± 0.1
19-27 m	2 ± 2	165 ± 0.0	1 ± 1	169 ± 0.0	0		0	
28-37 m	0		0		1 ± 1	170 ± 0.0	0	
38-49 m	0		0		0		0	
Overall mean								
Pink shrimp								
9-18 m	22 ± 14	112 ± 1.1	24 ± 13	117 ± 1.5	92 ± 43	110 ± 0.6	310 ± 135	125 ± 0.2
19-27 m	4 ± 2	110 ± 3.8	2 ± 2	114 ± 0.0	96 ± 50	118 ± 0.6	62 ± 60	99 ± 0.3
28-37 m	4 ± 4	129 ± 3.6	0		4 ± 4	126 ± 0.0	0	
38-49 m	1 ± 1	136 ± 0.0	0		0		0	
9-27 m	13 ± 7	112 ± 1.1	13 ± 7	117 ± 1.4	94 ± 31	114 ± 0.4	186 ± 83	121 ± 0.3
Overall mean	8 ± 4	115 ± 1.2	6 ± 4	117 ± 1.4	48 ± 19	114 ± 0.4	94 ± 47	121 ± 0.3

Table 2.13. Mean catch **rates (no./h)** and mean size (mm) of select shellfishes caught during SEAMAP[a] sampling off the Texas coast during June-July 1982-1987. Blanks = **No measurement** taken. (From: Meador et al. 1988).

Year	Depth (m)	Samples (no.)	Brown shrimp No./h	Brown shrimp Length	White shrimp No./h	White shrimp Length	Pink shrimp No./h	Pink shrimp Length
1982	0-18	22	1,222	108	15	173	161	136
	19-37	50	1,427	115	0		20	138
	38-55	29	138	145	0		<1	126
	56-73	5	117	179	0		0	
	74-91	3	79	182	0		0	
1983	0-18	28	254	99	20	153	195	127
	19-37	47	1,445	119	1	167	87	121
	38-55	24	304	132	0		1	118
	56-73	8	66	156	0		0	
	74-91	2	71	168	0		0	
1984	0-18	16	733	116	30	174	4	151
	19-37	40	1,594	116	1	168	3	150
	38-55	16	544	131	0		0	
	56-73	12	194	138	0		0	
	74-91	5	86	151	0		0	
1985	0-18	30	450	98	41	168	15	135
	19-37	40	1,362	112	2	167	10	131
	38-55	14	150	127	0		<1	127
	56-73	5	154	144	0		0	
	74-91	1	36	179	0		0	
1986	0-18	35	250	98	33	165	18	116
	19-37	43	809	108	0		42	130
	38-55	10	311	124	0		0	
	56-73	5	176	136	0		0	
	74-91	3	49	147	0		111	
1987	0-18	74	189	103	15	159	24	115
	19-37	56	606	107	3	162	19	108
	38-55	17	26	142	0		<1	180
	56-73	8	16	177	0		0	
	74-91	7	11	177	0		0	

[a]**Data presented here were collected by** R/V OREGON II (National Marine Fisheries Service) in conjunction with TPWD research vessels. The data were made available by the Southeast Area Monitoring and Assessment Program (SEAMAP). Samples collected with 12.2-m trawl, except 6.1-m trawl by TPWD vessels during 1987. Data normalized to 12.2-m trawl by National Marine Fisheries Service.

Table 3.1. Direct purchases by the shrimp industry from major economic sectors of Texas during 1986. (After: Jones et al. 1974).

Industry	$ (X 1,000)
Agriculture	32
and profits	
Banking	3,595
Communications	452
Depreciation	20,219
Fisheries	2,111
Food processing	7,427
Imports	18,416
Insurance	6,828
Natural gas	204
Other manufacturing	538
Paints and cleaners	272
Paper and wood	29
Petro products	10,204
Property payments	25,961
Retail	3,749
Services	1,986
Ships and boats	20,111
Taxes	5,272
Textiles	2,251
Transportation	5,699
Utilities	473
Wages, salaries	85,883
Wholesale	7,394
Total	229,106

Table 3.2. Economic impact of the shrimp industry's $229.1 million of output on the economy of Texas during 1986. (After: Jones et al. 1974).

Industry	Impact/dollar of shrimp output ($)	Aggregate impact by the shrimp industry (million $)
Agriculture and forestry	0.0477	10.93
Communications	0.0214	4.90
Construction	0.0094	2.15
Crude oil and natural gas	0.0433	9.92
Finance	0.1334	30.56
Food processing	0.1016	23.28
Households	0.8896	203.82
Other manufacturing	0.0540	12.37
Paints and cleaners	0.0025	0.57
Petroleum products	0.0753	17.25
Retail trade	0.1898	43.49
Services	0.1762	40.37
Ship building	0.0891	20.41
Shrimp	1.0000	229.11
Textiles	0.0163	3.73
Transportation	0.0618	14.16
Utilities	0.0433	9.92
Wholesale trade	0.1045	23.94
Wood and paper	0.0260	5.96
Total	3.0852	706.84

Table 3.3. Annual Gulf of Mexico shrimp catch and estimated finfish discards using fish to shrimp ratios of 4:1 and 12:1 for 1977-1987.

Year	Shrimp catch (heads-on) (million kg)	Estimated discard 4:1 ratio (million kg)	Estimated discard 12:1 ratio (million kg)
1977	41.4	165.7	497.0
1978	38.0	152.0	456.1
1979	30.3	121.4	364.1
1980	32.9	131.7	395.2
1981	42.9	171.6	514.9
1982	31.6	126.5	379.4
1983	32.3	129.0	387.0
1984	40.8	163.3	489.9
1985	37.0	148.1	444.2
1986	43.3	173.3	519.8
1987	40.1	160.4	481.2

Table 3.4. Annual coastwide and 6-year average finfish to shrimp ratios (by number) for Texas Parks and Wildlife Department trawls during 1982-1987.
(Data from Meador et al. 1988).

Year/Bay	Finfish:shrimp ratio
Coastwide	
1982	2.23
1983	2.27
1984	2.08
1985	2.14
1986	2.12
1987	2.67
6-year averages	
Coastwide	2.25
Sabine[a]	1.86
Galveston	0.98
Matagorda	3.12
San Antonio	1.76
Aransas	2.56
Corpus Christi	6.45
Upper Laguna Madre	6.50
Lower Laguna Madre	12.50

[a]1986-1987 only

Table 3.5. Estimated total effort, catch and mortality of sea turtles captured incidentally in shrimp trawls in Florida and Texas during 1976 and Alabama and Louisiana during 1977. (From: Van Lopik et al. 1980).

State	Number of vessels	Total no. of fishing days	Average no. of fishing days	Total no. turtles caught	Number dead	% dead	Turtles caught per boat in one season	No. fishing days for each turtle caught
Florida	26	4,440-4,540	170-175	166-168	35-41	21-25	6.38-6.46	26.32-27.09
Alabama	21	2,218-2,228	116-117	34	7	21	1.62	71.60-72.41
Louisiana	26	5,345	206	102	24	24	3.92	52.55
Texas[1]	66	14,200	215	230	38	16	3.48	62.5

[1]Data for Texas from Cox and Mauermann. 1976.

Figure 1.1. Texas bay systems and adjacent Gulf of Mexico. Boundaries for the Texas Territorial Sea and Exclusive Economic Zone are not to scale.

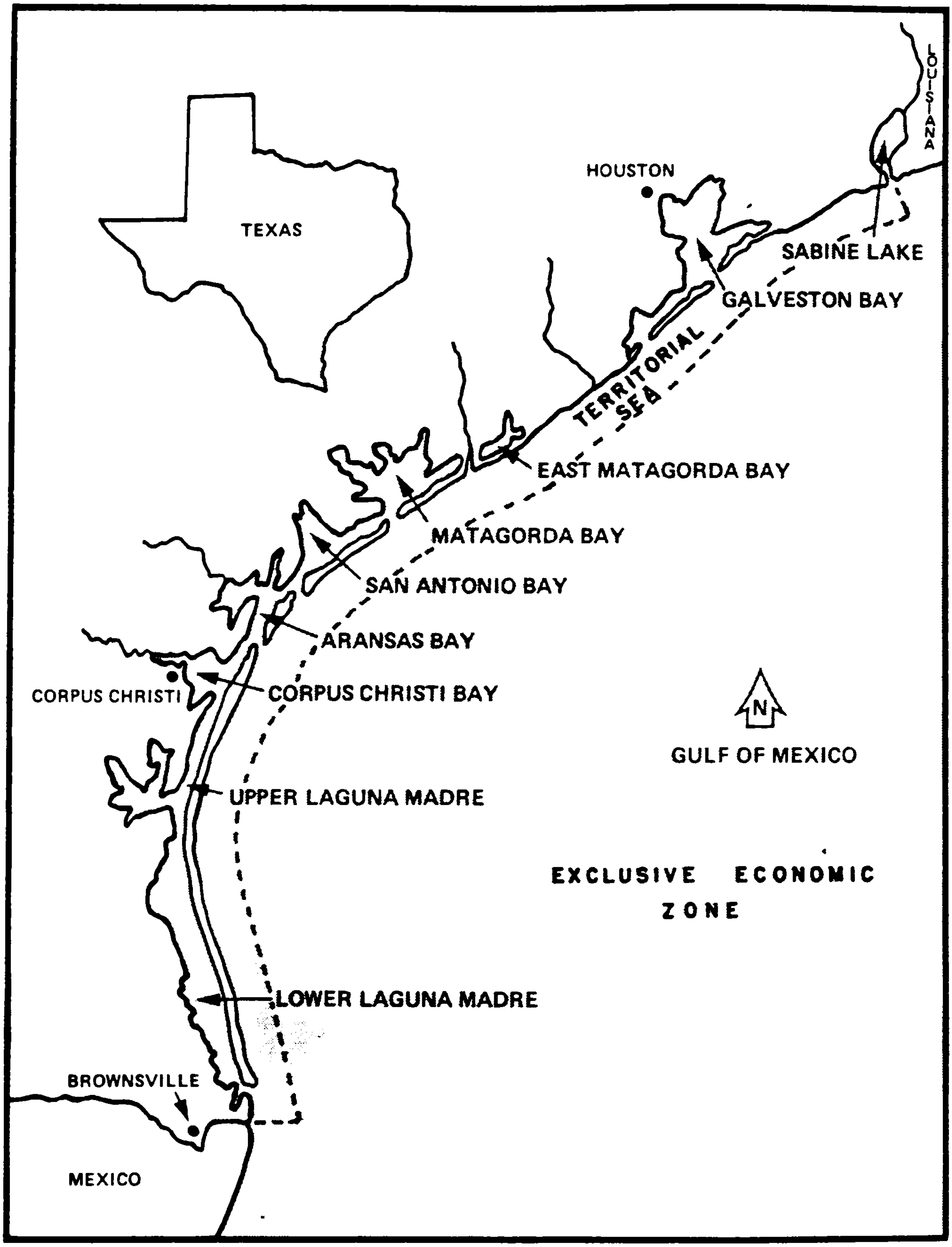
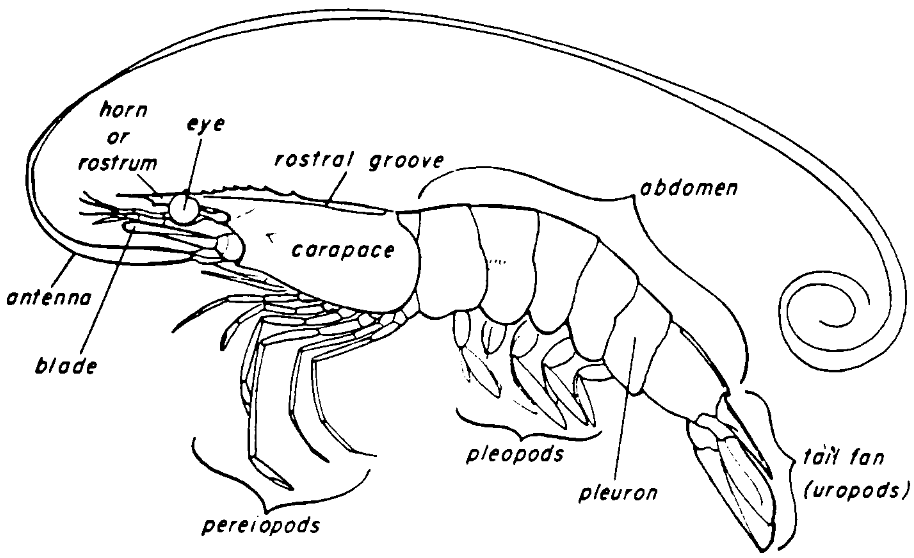
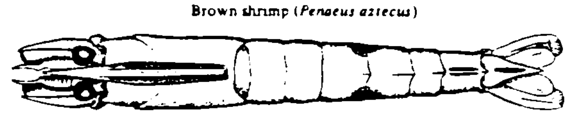

LOUISIANA
HOUSTON
TEXAS
SABINE LAKE
GALVESTON BAY
TERRITORIAL SEA
EAST MATAGORDA BAY
MATAGORDA BAY
SAN ANTONIO BAY
ARANSAS BAY
CORPUS CHRISTI
CORPUS CHRISTI BAY
N
GULF OF MEXICO
UPPER LAGUNA MADRE
EXCLUSIVE ECONOMIC ZONE
LOWER LAGUNA MADRE
BROWNSVILLE
MEXICO

Figure 2.1. Diagram of a penaeid shrimp and distinguishing characteristics of the commercial species. (From: Moffett 1970).

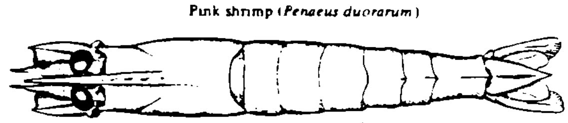


Distinguishing characteristics of commercial shrimp

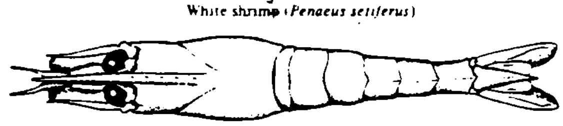
Brown shrimp (*Penaeus aztecus*)



Pink shrimp (*Penaeus duorarum*)

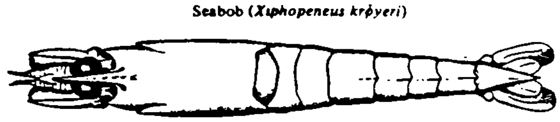


White shrimp (*Penaeus setiferus*)



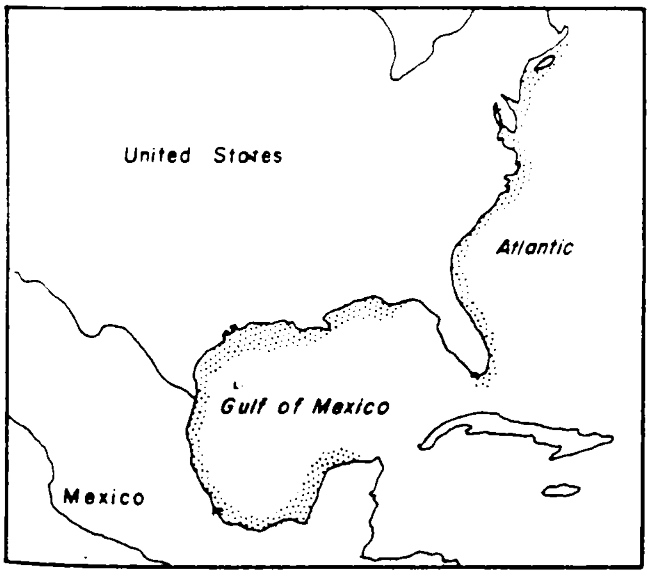
Royal red shrimp (*Hymenopenaeus robustus*)

Seabob (*Xiphopeneus kröyeri*)

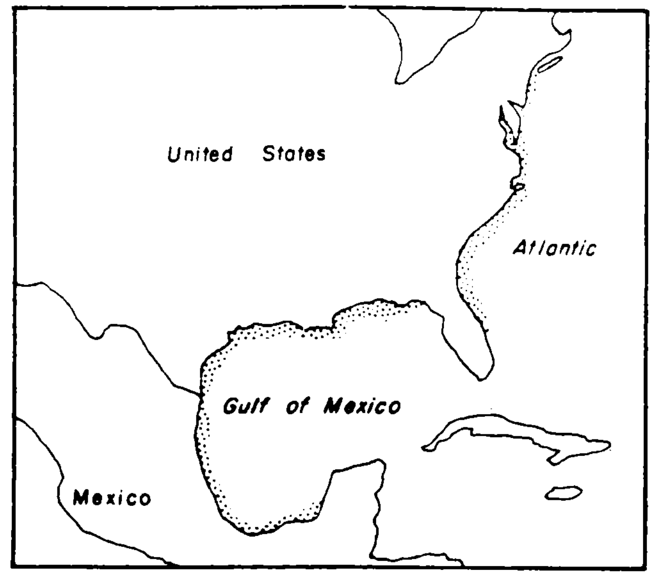


Broken-necked shrimp (*Trachypeneus sp.*)

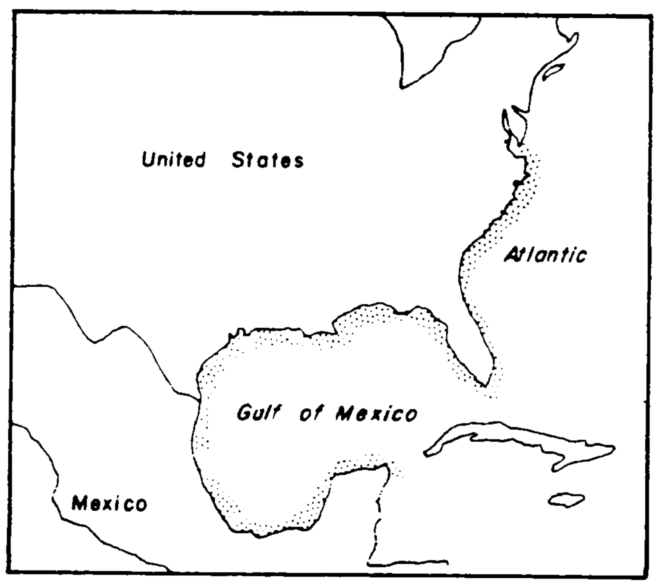
Figure 2.2. Distribution of penaeid species along the United States coast. (From: Christmas and Etzold 1977).



Geographic range of the brown shrimp.



Geographic range of the white shrimp.



Geographic range of the pink shrimp.

Figure 2.3. Generalized life cycle of a penaeid shrimp. (From: Etzold and Christmas 1977).

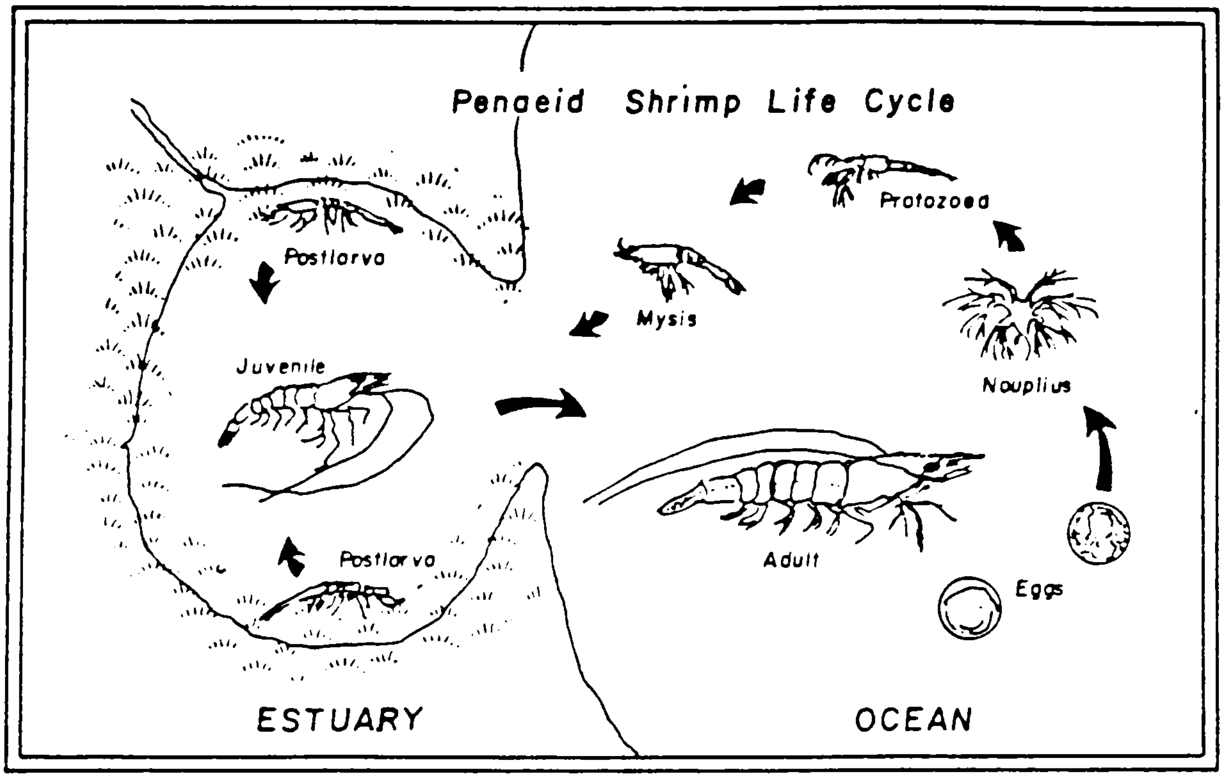
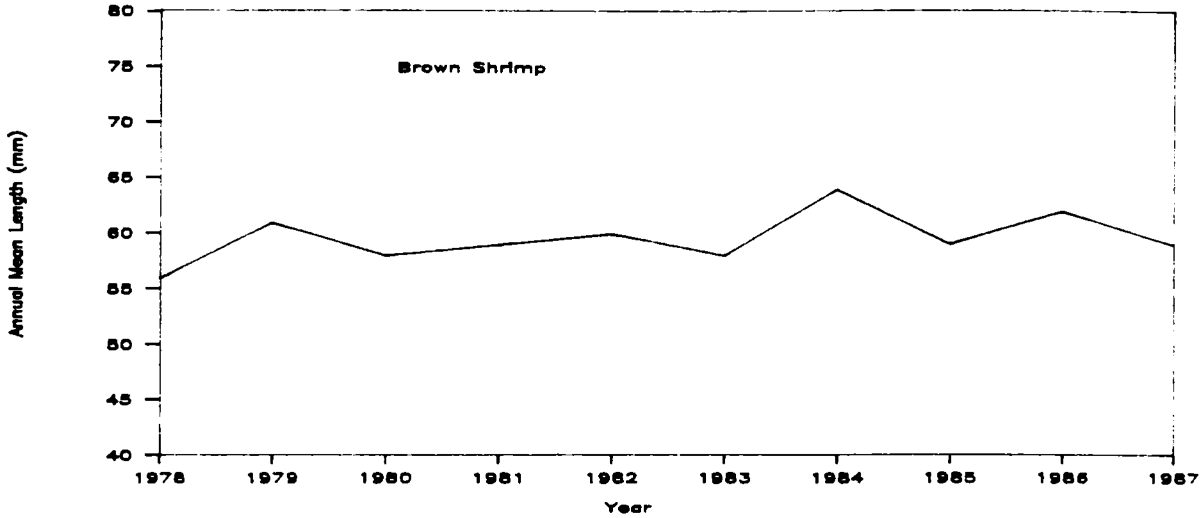
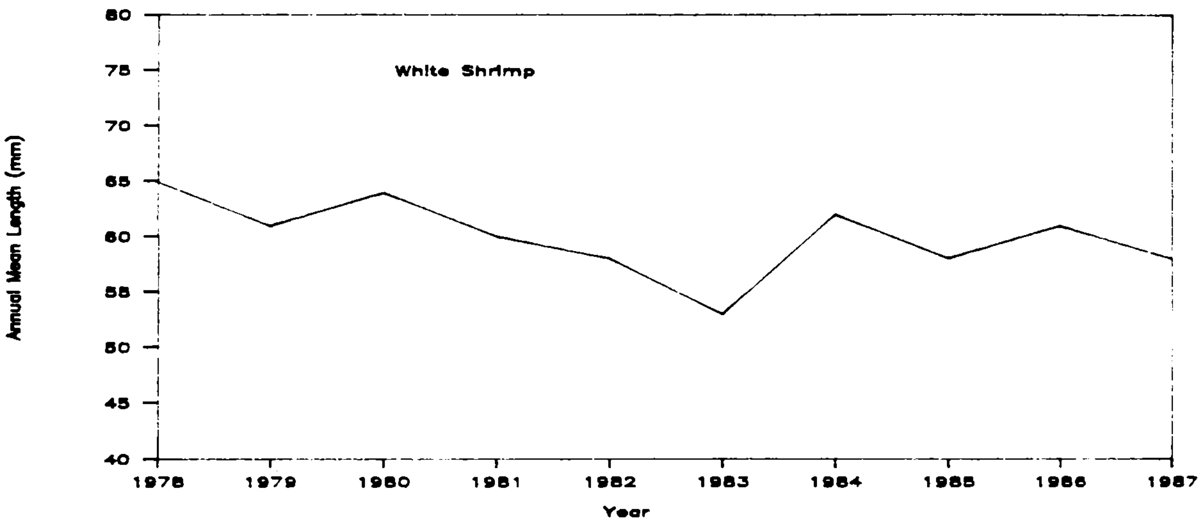

Penaeid Shrimp Life Cycle
Protozoea
Postlarva
Mysis
Nauplius
Juvenile
Adult
Postlarva
Eggs
ESTUARY
OCEAN

Figure 2.4. Annual mean length for penaeid shrimp caught in Texas Parks and Wildlife Department bag seines (1978-1987).


Brown Shrimp
Annual Mean Length (mm)
80
75
70
65
60
55
50
45
40
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
Year


White Shrimp
Annual Mean Length (mm)
80
75
70
65
60
55
50
45
40
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
Year

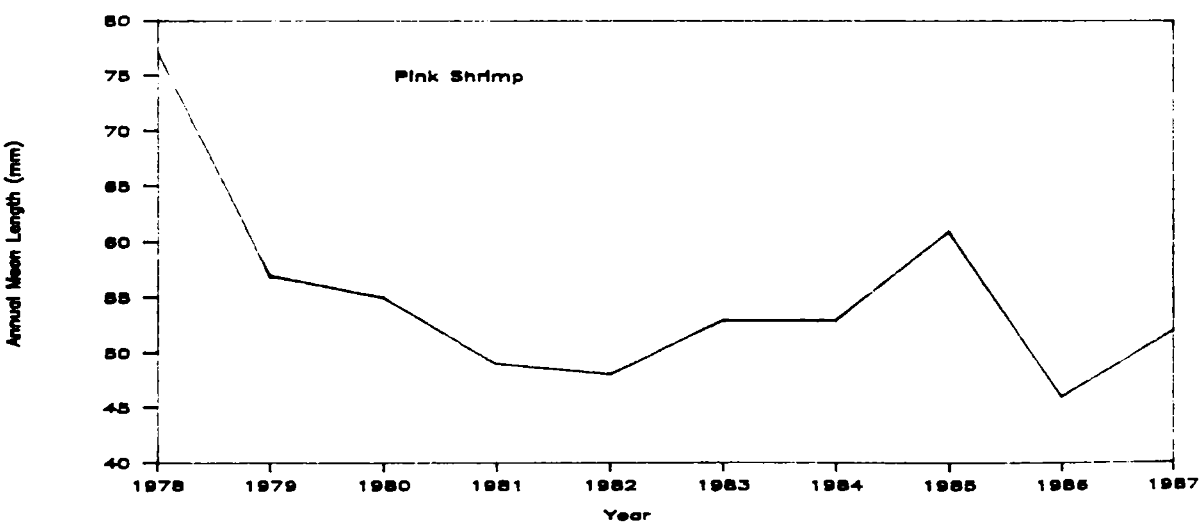
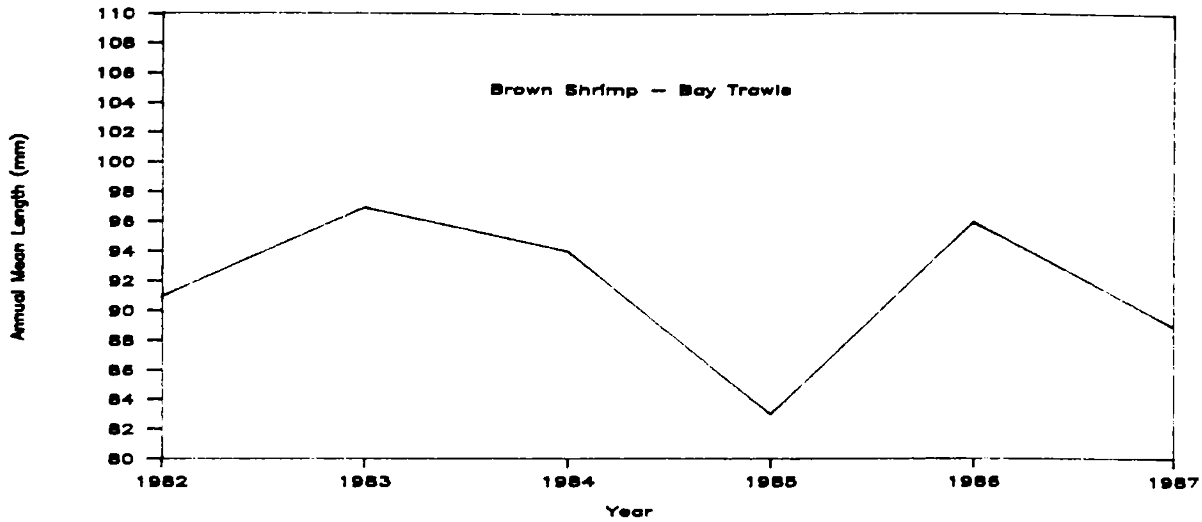
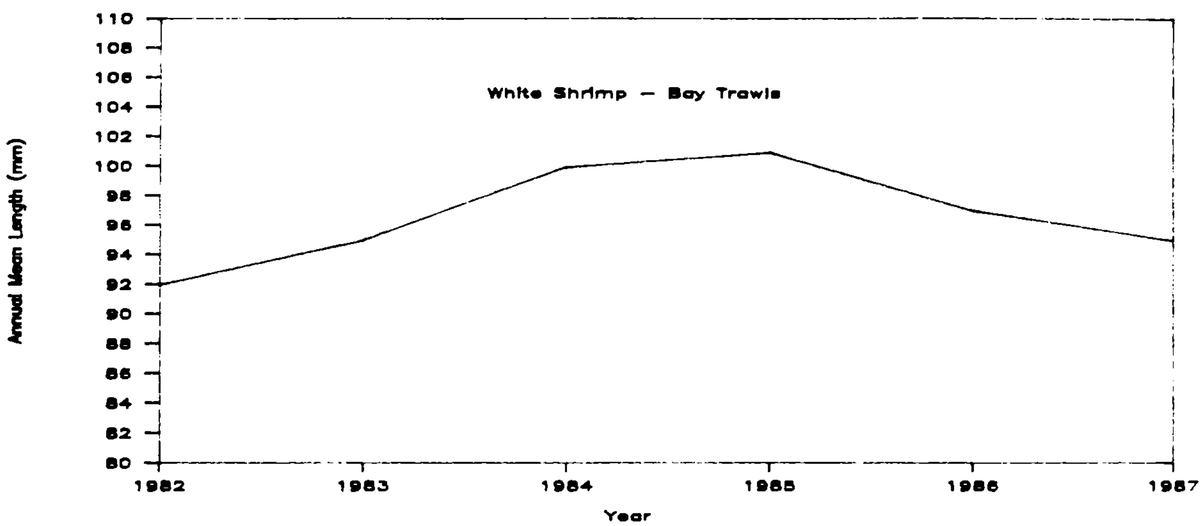

Pink Shrimp
Annual Mean Length (mm)
80
75
70
65
60
55
50
45
40
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
Year

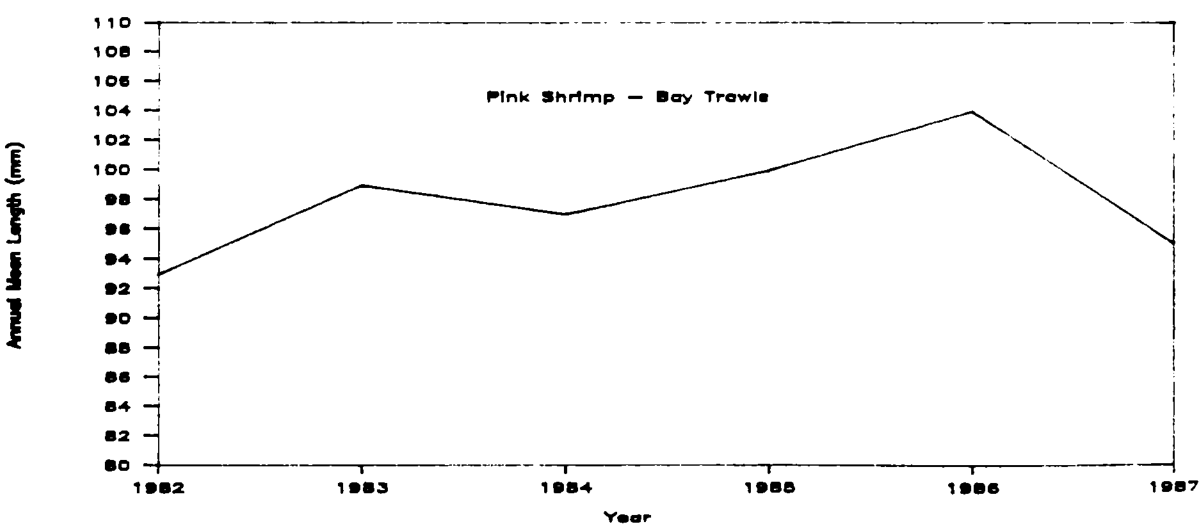
Figure 2.5. Coastwide annual mean length of penaeid shrimp caught in Texas Parks and Wildlife Department bay trawls (1978-1987).



Brown Shrimp — Bay Trawls
Annual Mean Length (mm)
110
108
106
104
102
100
98
96
94
92
90
88
86
84
82
80
1982
1983
1984
1985
1986
1987
Year

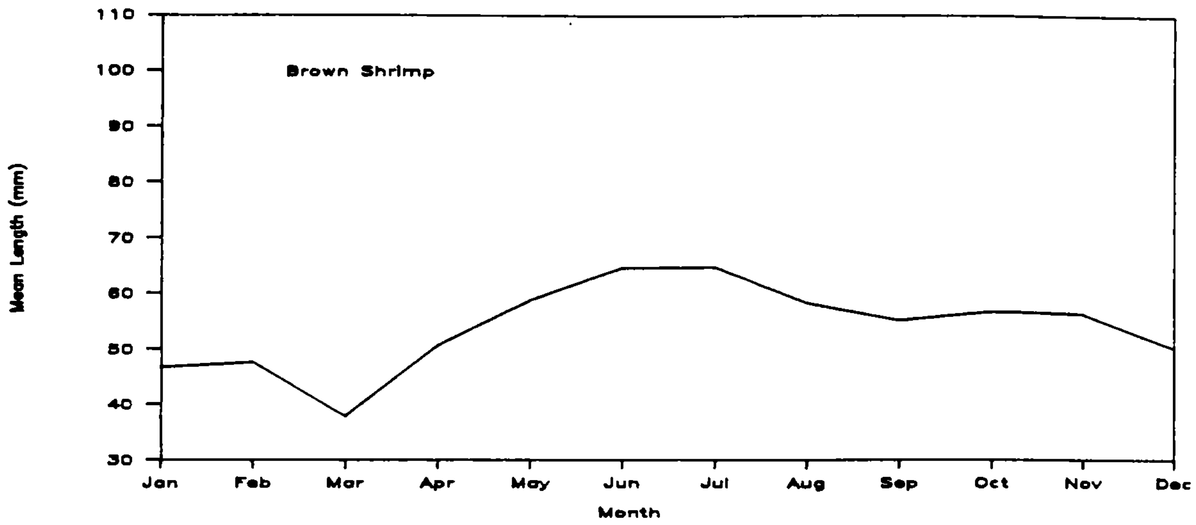


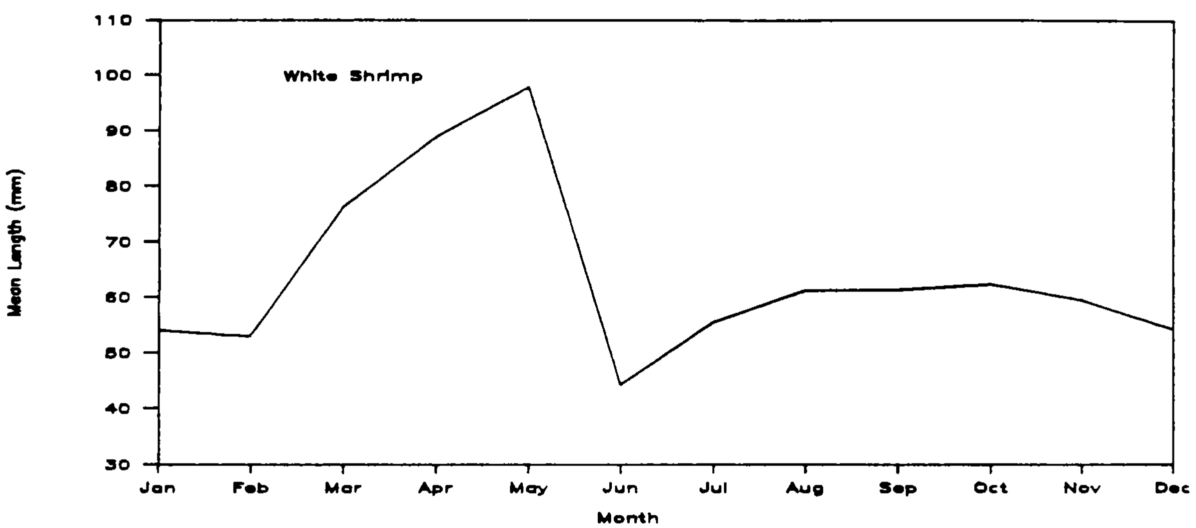
White Shrimp — Bay Trawls
Annual Mean Length (mm)
110
108
106
104
102
100
98
96
94
92
90
88
86
84
82
80
1982
1983
1984
1985
1986
1987
Year



Pink Shrimp — Bay Trawls
Annual Mean Length (mm)
110
108
106
104
102
100
98
96
94
92
90
88
86
84
82
80
1982
1983
1984
1985
1986
1987
Year

Figure 2.6. Coastwide monthly mean length of penaeid shrimp caught in Texas Parks and Wildlife Department bag seines (1978-1987).


Brown Shrimp
Mean Length (mm)
110
100
90
80
70
60
50
40
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


White Shrimp
Mean Length (mm)
110
100
90
80
70
60
50
40
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

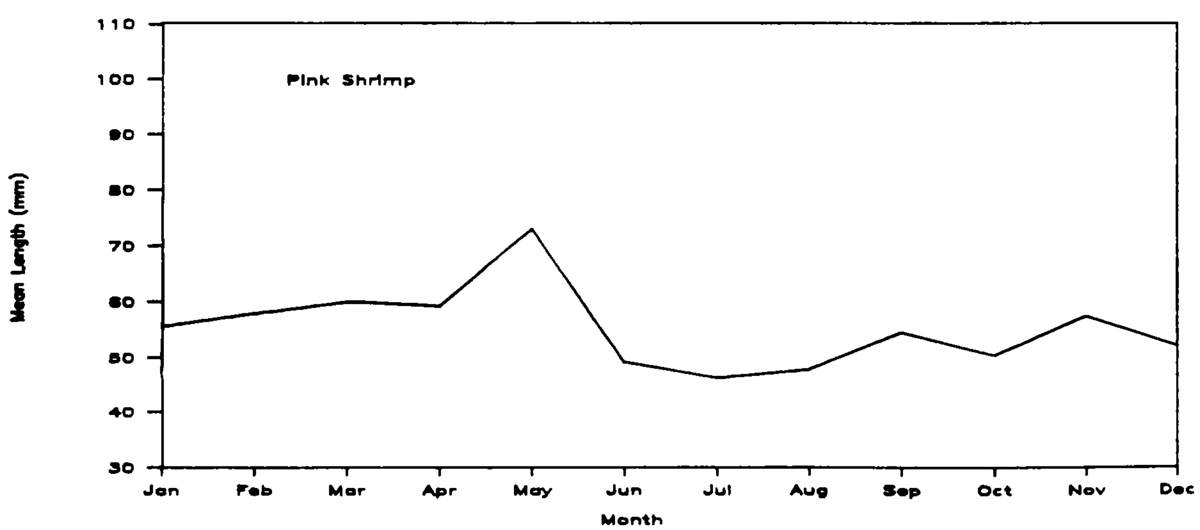
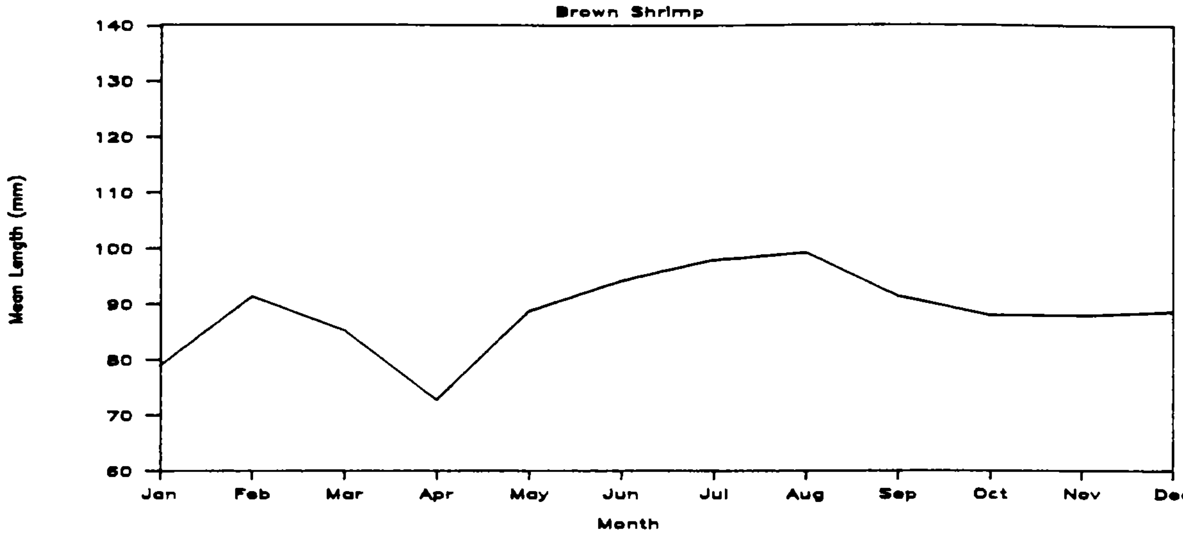
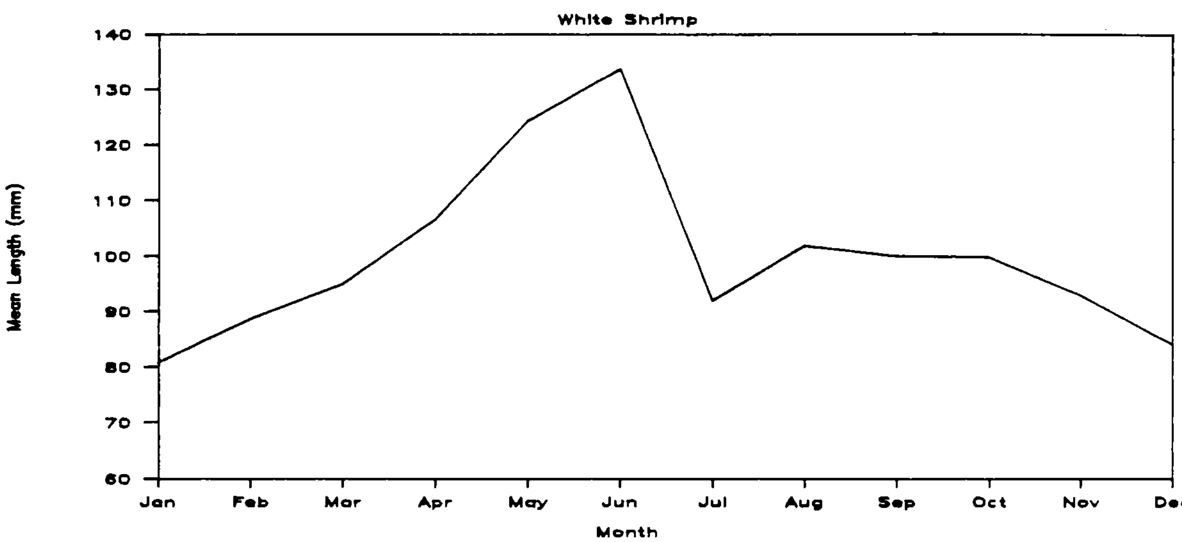

Pink Shrimp
Mean Length (mm)
110
100
90
80
70
60
50
40
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 2.7. Coastwide monthly mean length of penaeid shrimp caught in Texas Parks and Wildlife Department bay trawls (1982-1987).


Brown Shrimp
140
130
120
110
100
90
80
70
60
Mean Length (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


White Shrimp
140
130
120
110
100
90
80
70
60
Mean Length (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

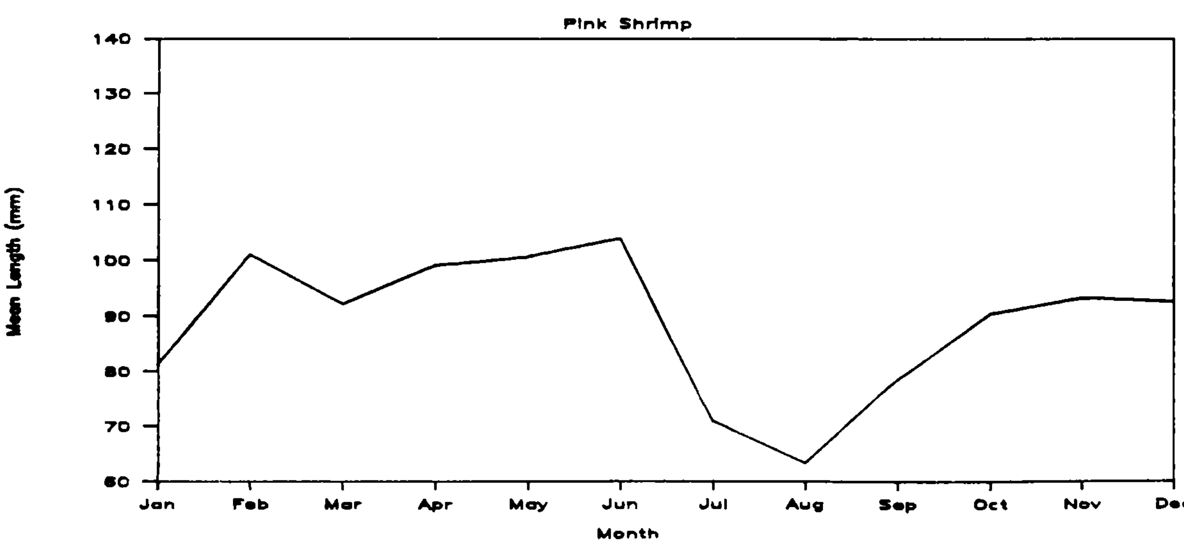
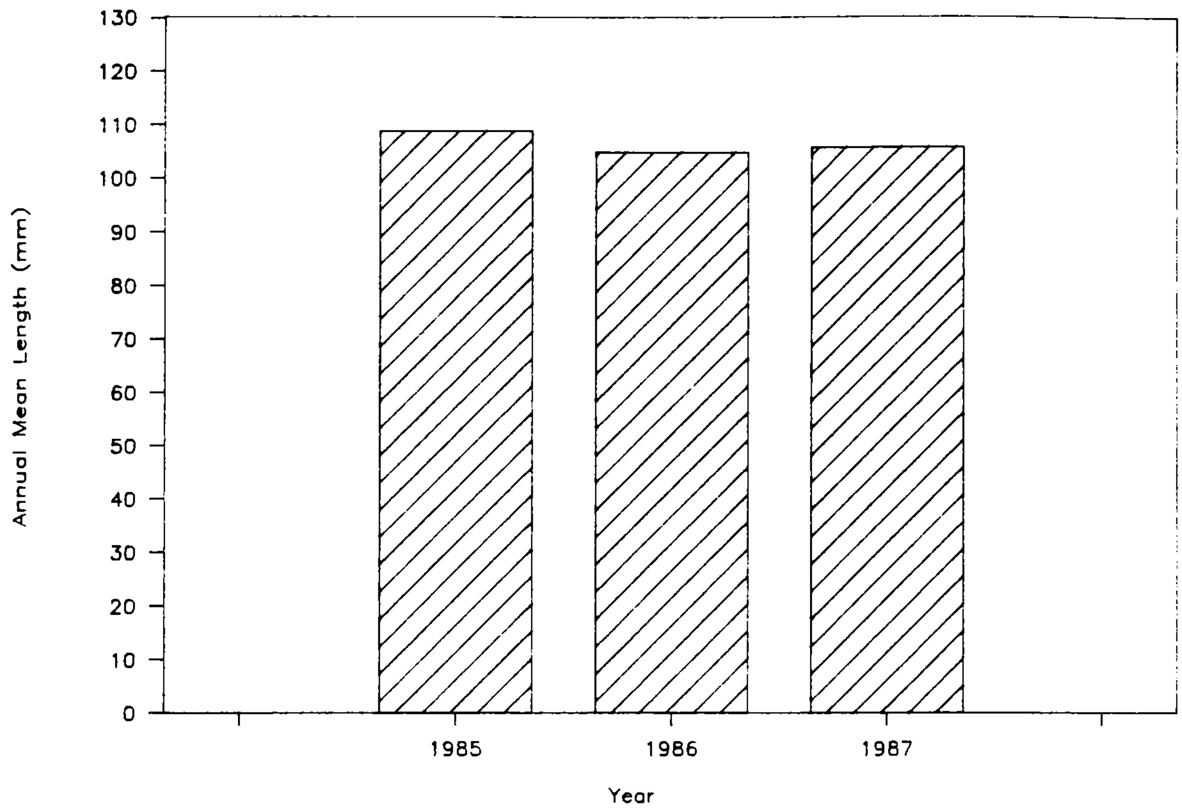

Pink Shrimp
140
130
120
110
100
90
80
70
60
Mean Length (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 2.8. Coastwide annual and monthly mean length of brown shrimp in Texas Parks and Wildlife Department gulf trawls by year (1985-1987).


Annual Mean Length (mm)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1985
1986
1987
Year

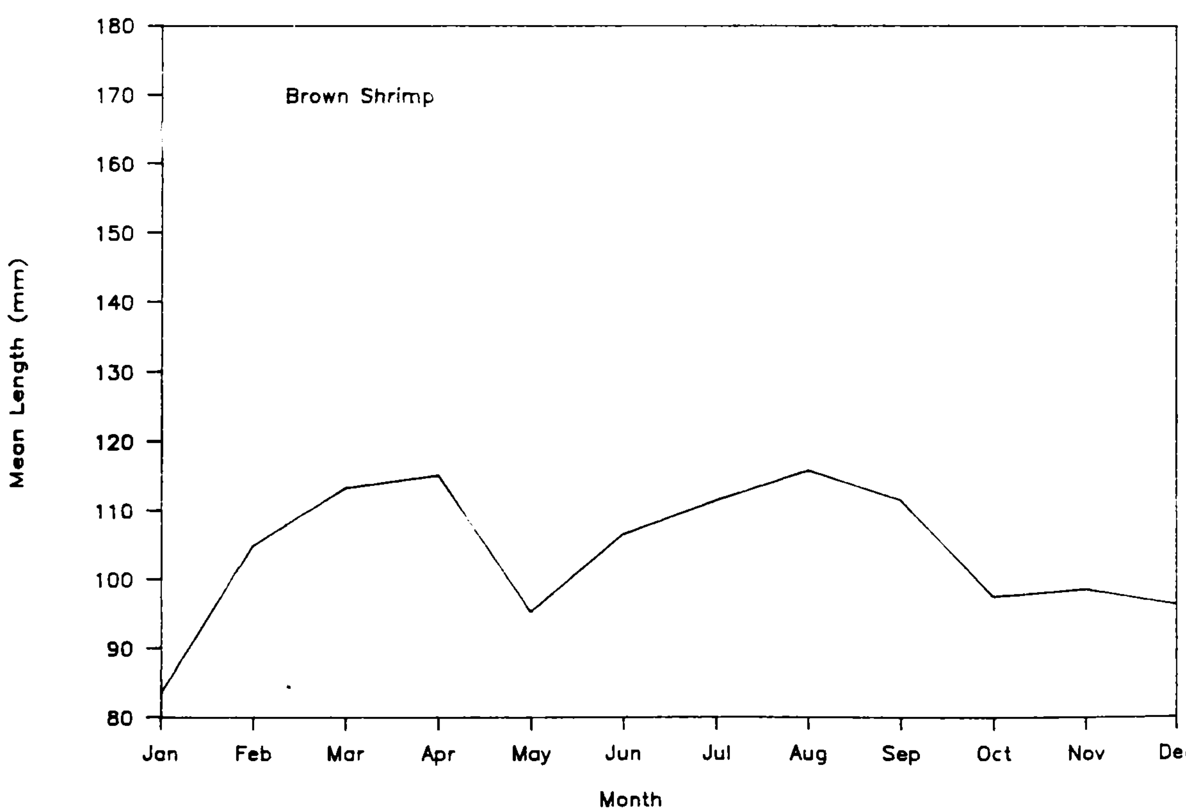
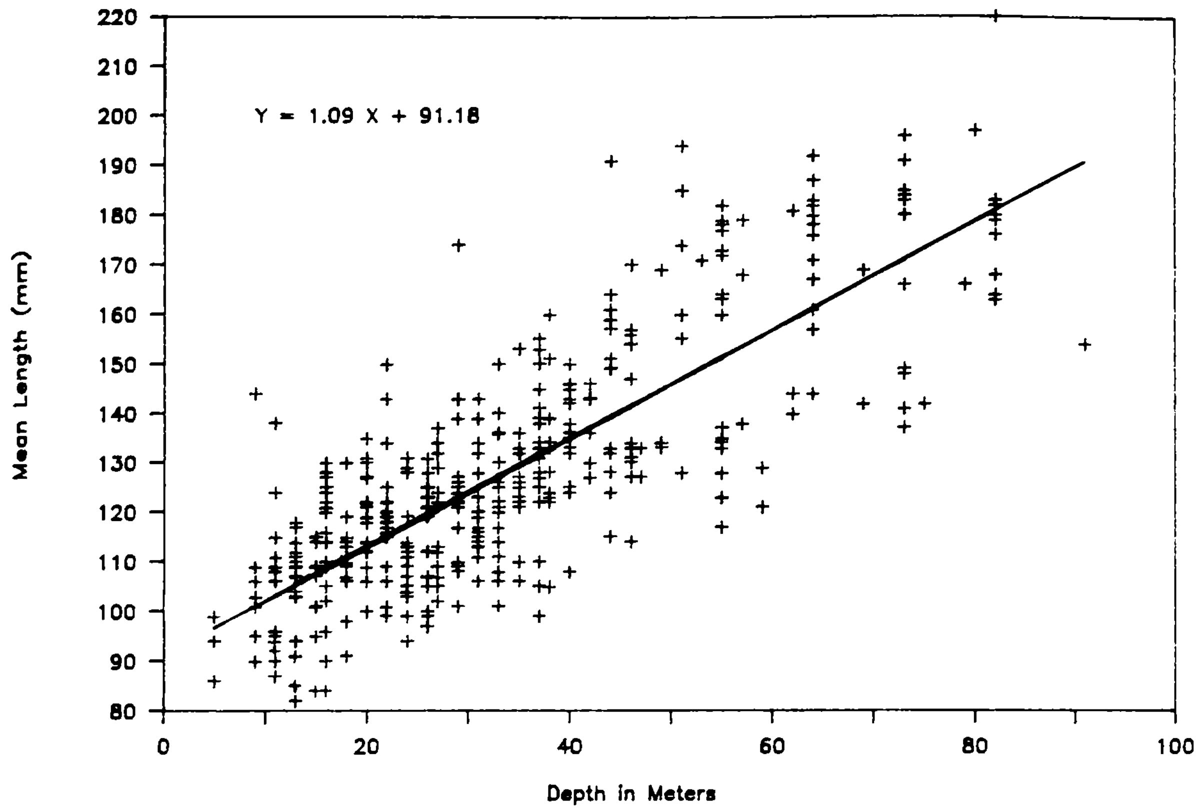

Mean Length (mm)
Brown Shrimp
180
170
160
150
140
130
120
110
100
90
80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 2.9. Mean length versus depth (m) and distance from shore (km) for brown shrimp caught in gulf waters during Southeast Area Monitoring and Assessment Program sampling (1982-1986).

(A)


Y = 1.09 X + 91.18
Mean Length (mm)
Depth in Meters
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
0
20
40
60
80
100

(B)

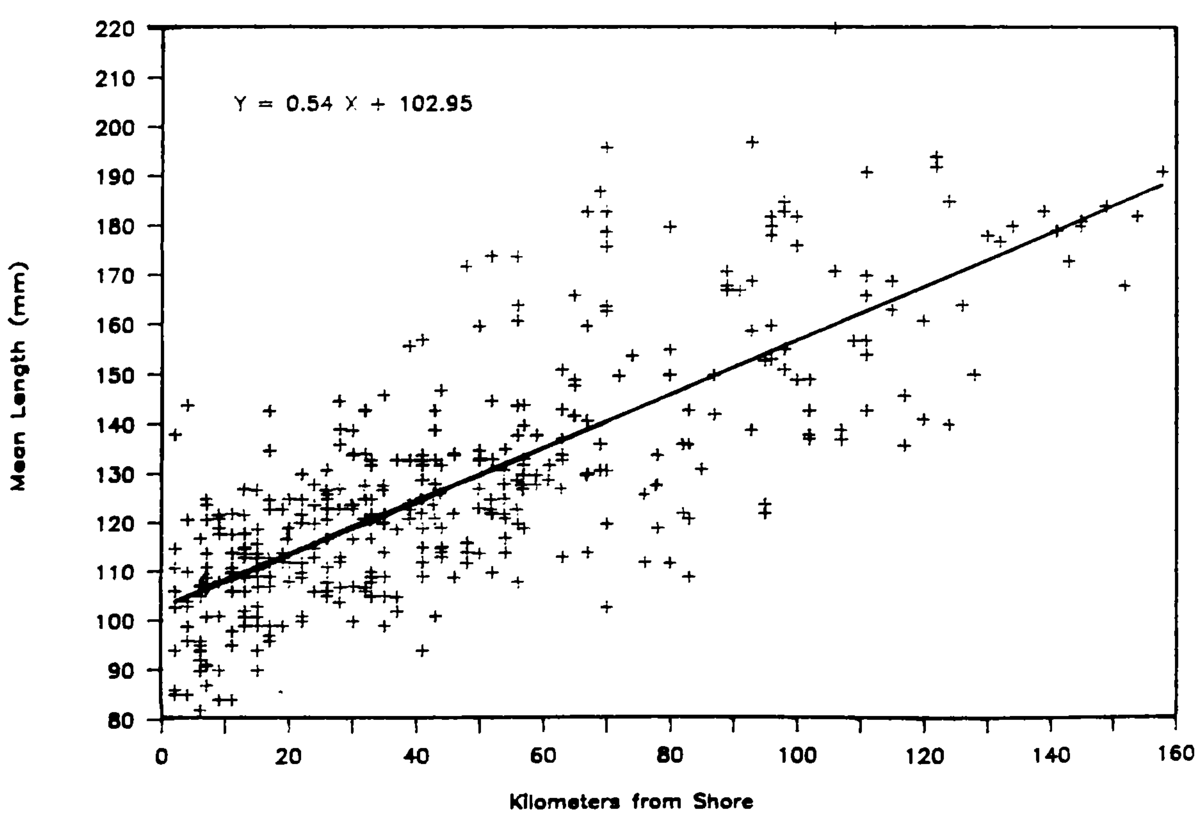

Y = 0.54 X + 102.95
Mean Length (mm)
Kilometers from Shore
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
0
20
40
60
80
100
120
140
160

Figure 2.10. Coastwide annual and monthly mean length of white shrimp in Texas Parks and Wildlife Department gulf trawls by year (1985-1987).


Annual Mean Length (mm)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1985
1986
1987
Year

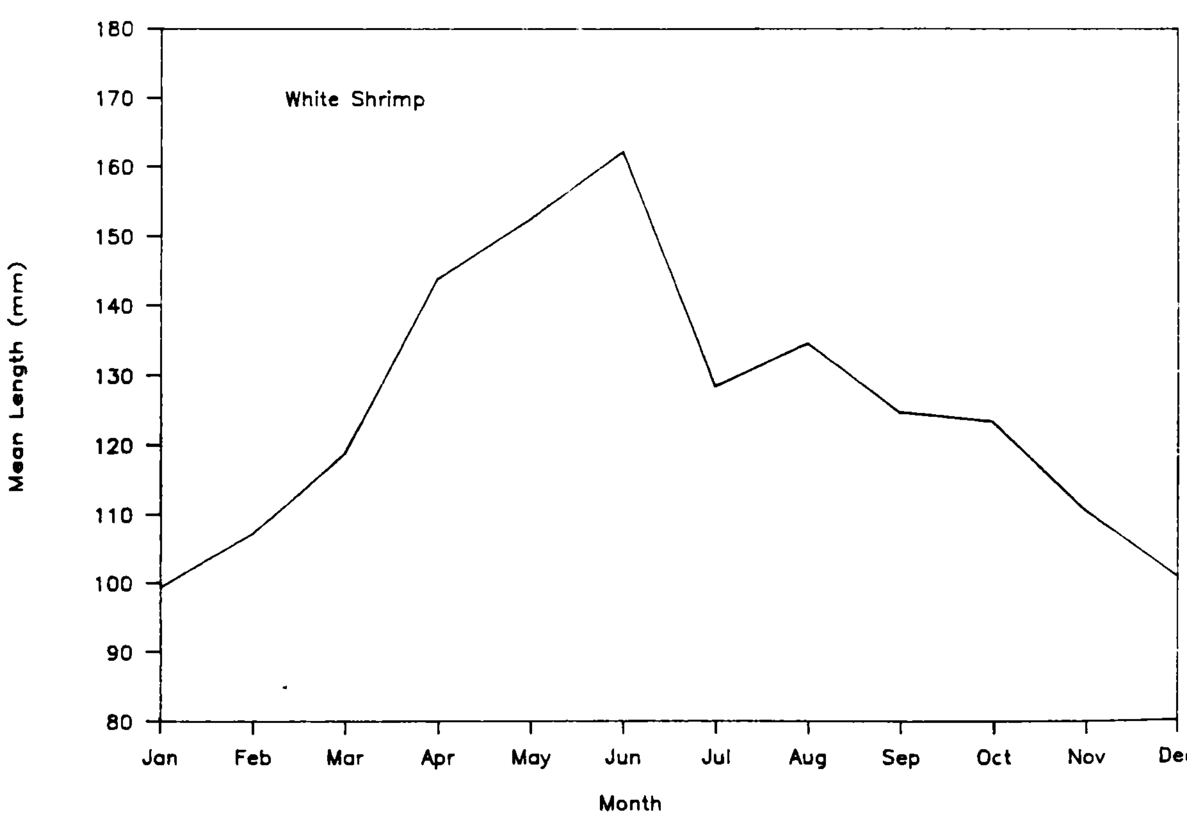
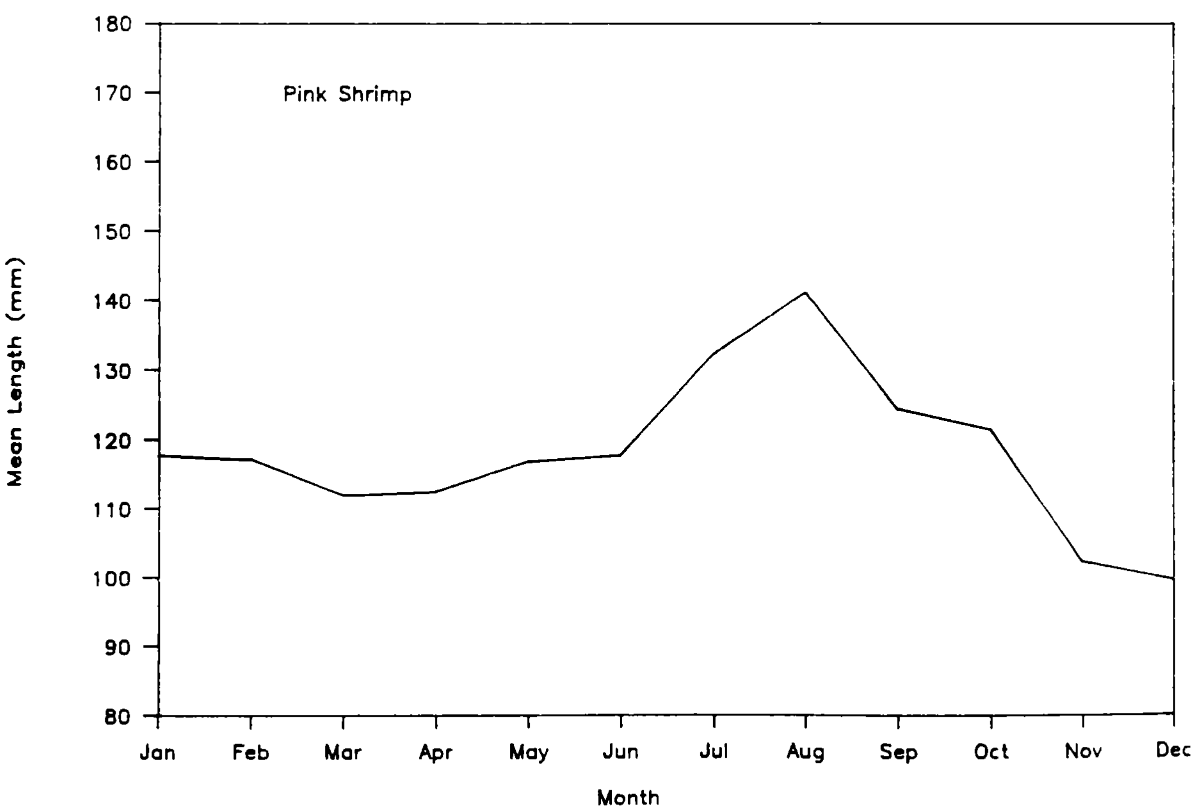

Mean Length (mm)
180
170
160
150
140
130
120
110
100
90
80
White Shrimp
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 2.11. Coastwide annual and monthly mean length of pink shrimp in Texas Parks and Wildlife Department gulf trawls by year (1985-1987).

Annual Mean Length (mm)
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1985
1986
1987
Year



Pink Shrimp
Mean Length (mm)
180
170
160
150
140
130
120
110
100
90
80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 2.12. Seasonal abundance of planktonic <u>Penaeus</u> sp. and average bottom temperature by station depths in 1961.
(From: Temple and Fischer 1968).

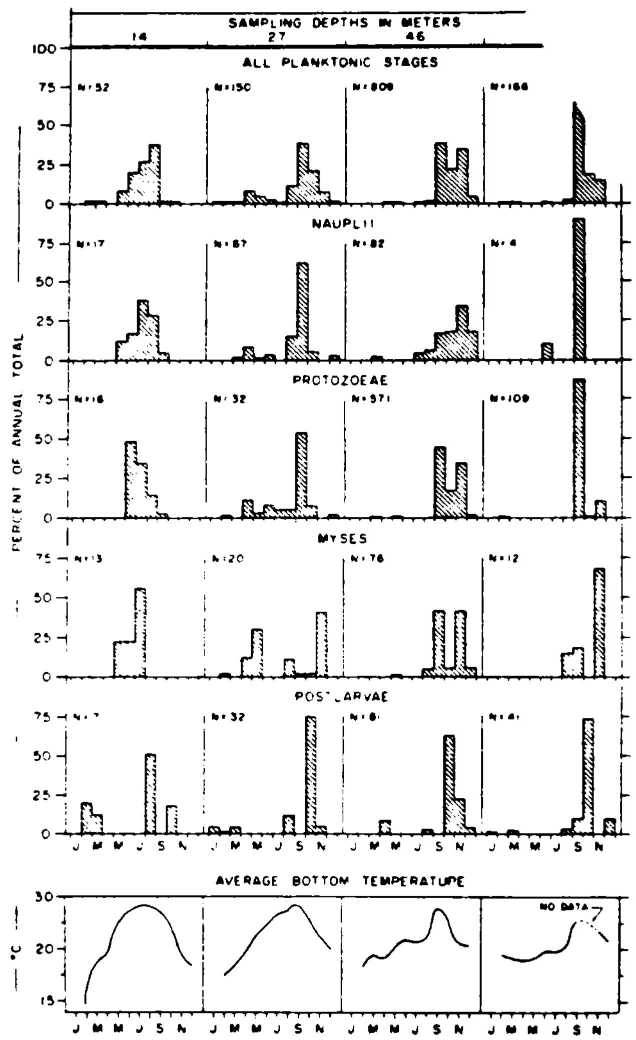

SAMPLING DEPTHS IN METERS
14
27
46
ALL PLANKTONIC STAGES
NAUPLII
PROTOZOEAE
MYSES
POSTLARVAE
PERCENT OF ANNUAL TOTAL
AVERAGE BOTTOM TEMPERATURE
°C
NO DATA
J M M J S N

Figure 2.13. Relative abundance and distribution of planktonic Penaeus sp.--January to March 1961. (From: Temple and Fischer 1968).

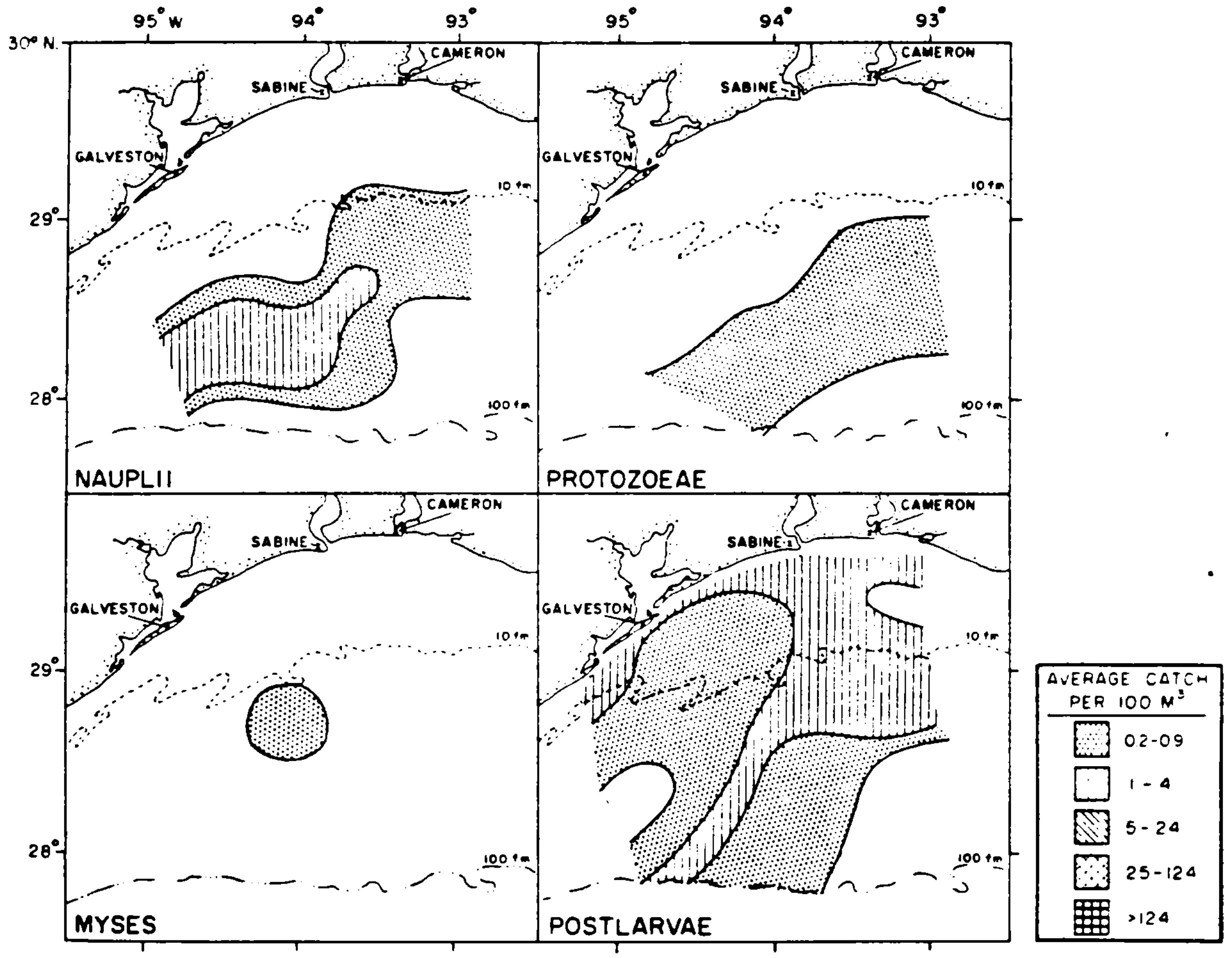

95° W
94°
93°
30° N.
29°
28°
CAMERON
SABINE
GALVESTON
10 fm
100 fm
NAUPLII
PROTOZOEAE
MYSES
POSTLARVAE
AVERAGE CATCH PER 100 M³
02-09
1 - 4
5 - 24
25-124
>124

Figure 2.14. Relative abundance and distribution of planktonic Penaeus sp.--April to August 1961. (From: Temple and Fischer 1968).

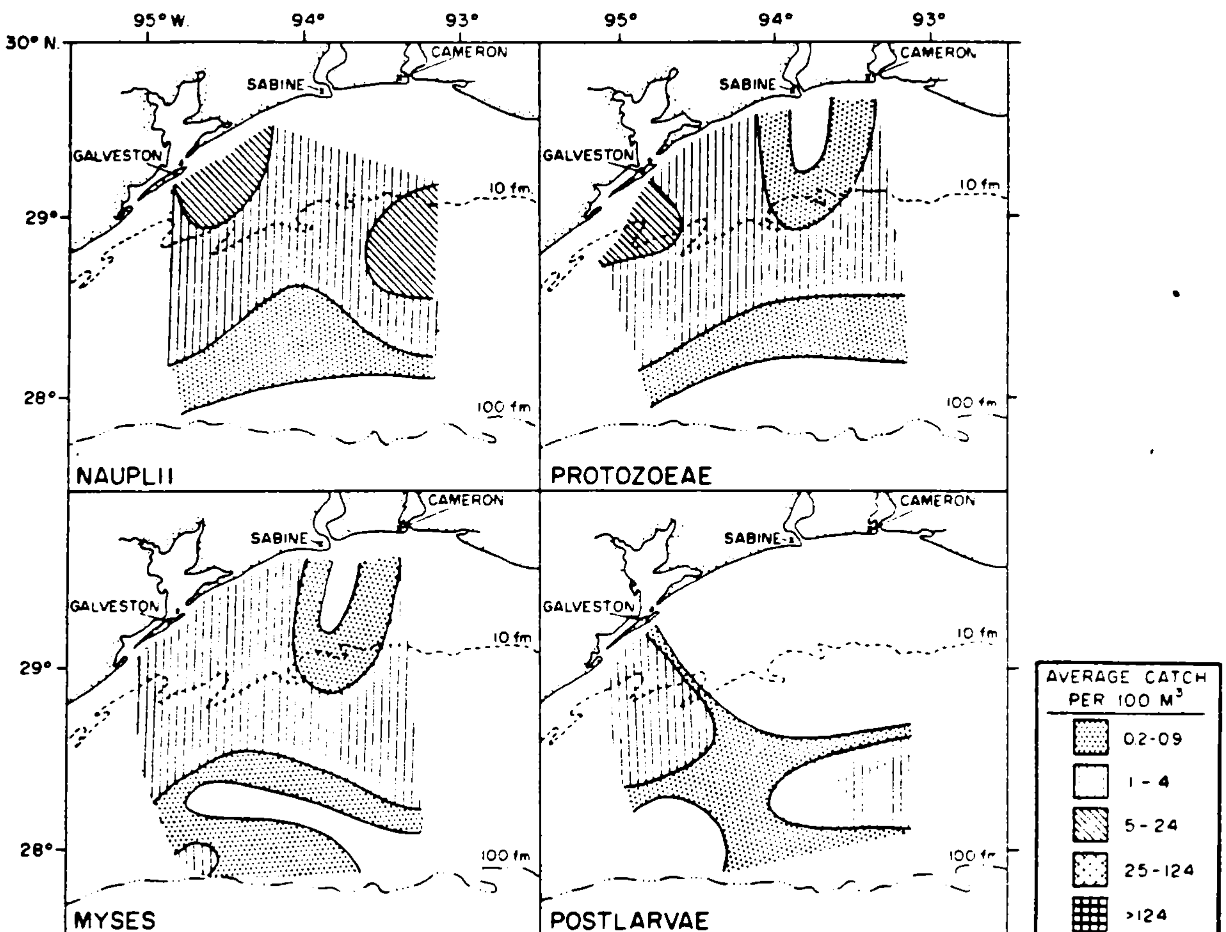

95° W.
94°
93°
95°
94°
93°
30° N.
29°
28°
CAMERON
SABINE
GALVESTON
10 fm
100 fm
NAUPLII
PROTOZOEAE
MYSES
POSTLARVAE
AVERAGE CATCH PER 100 M³
0.2-0.9
1 - 4
5 - 24
25 - 124
>124

Figure 2.15. Relative abundance and distribution of planktonic Penaeus sp.--September to December 1961. (From: Temple and Fischer 1968).

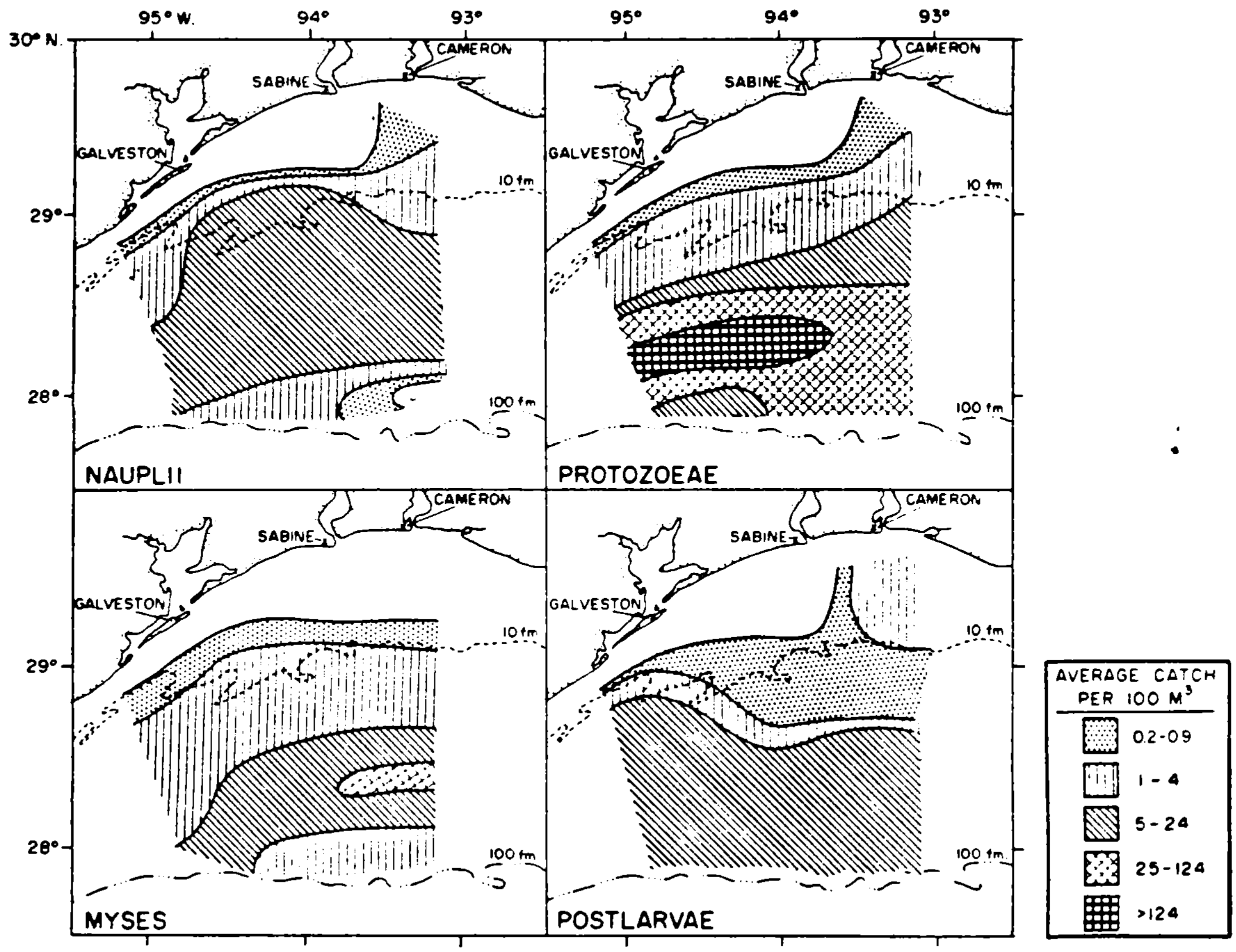
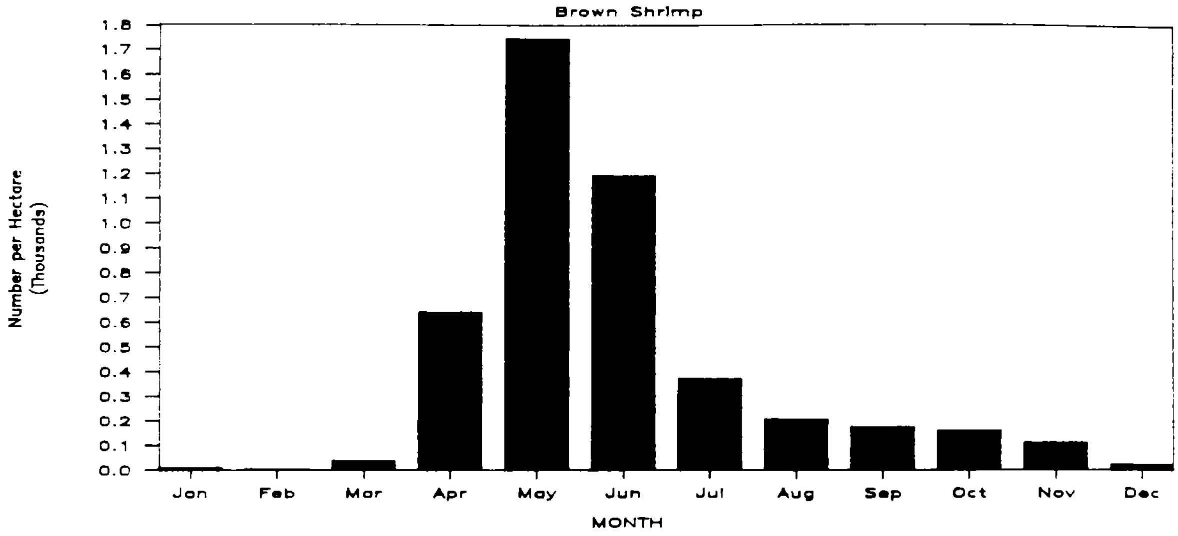
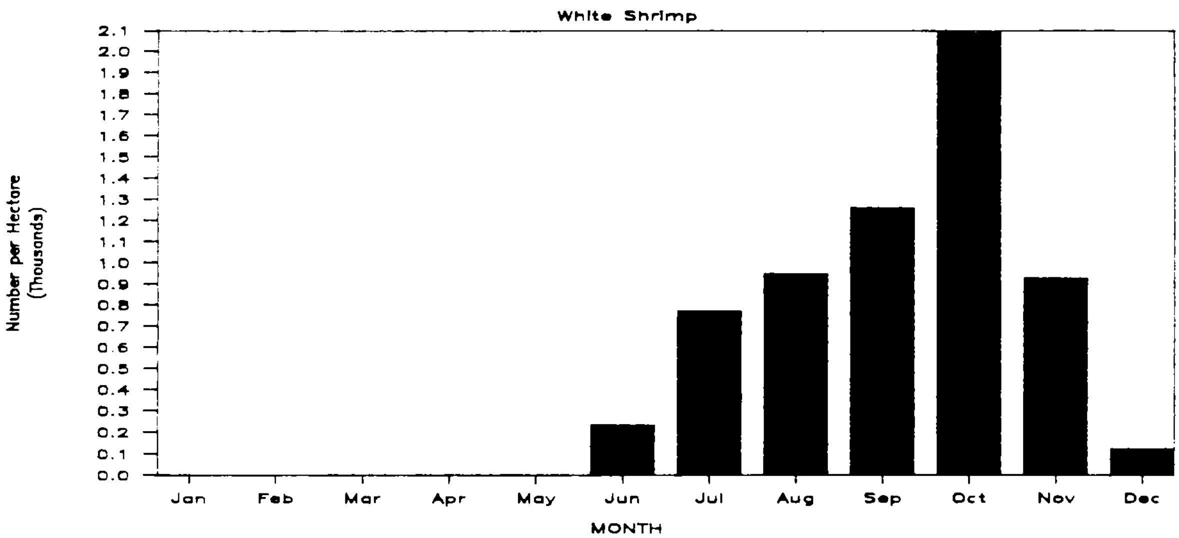

95° W.
94°
93°
95°
94°
93°
30° N.
29°
28°
CAMERON
SABINE
GALVESTON
10 fm
100 fm
NAUPLII
PROTOZOEAE
MYSES
POSTLARVAE
AVERAGE CATCH PER 100 M³
0.2-09
1 - 4
5 - 24
25 - 124
>124

Figure 2.16. Monthly coastwide catch rates of penaeid shrimp in Texas Parks and Wildlife Department bag seines (1978-1986).


Brown Shrimp
Number per Hectare (Thousands)
1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
MONTH


White Shrimp
Number per Hectare (Thousands)
2.1 2.0 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
MONTH

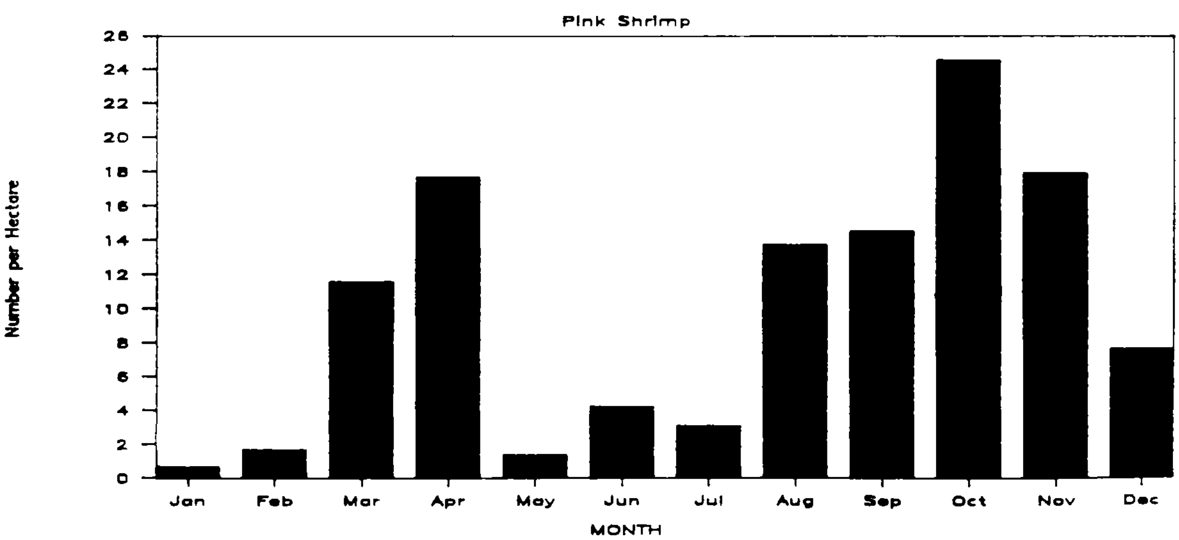

Pink Shrimp
Number per Hectare
26 24 22 20 18 16 14 12 10 8 6 4 2 0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
MONTH

Figure 2.17. Annual coastwide catch rates of penaeid shrimp in Texas Parks and Wildlife Department bag seines (1978-1987).

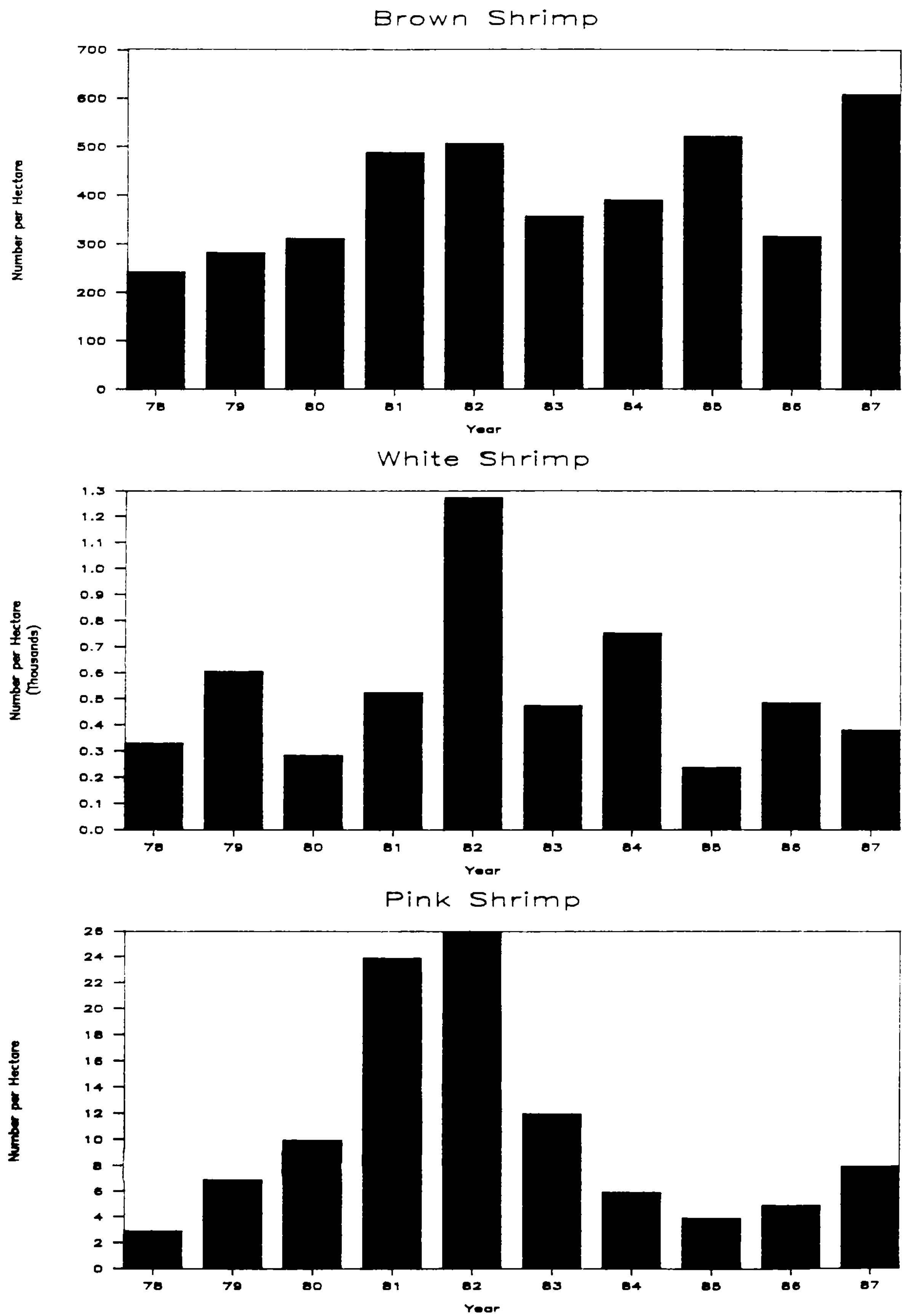
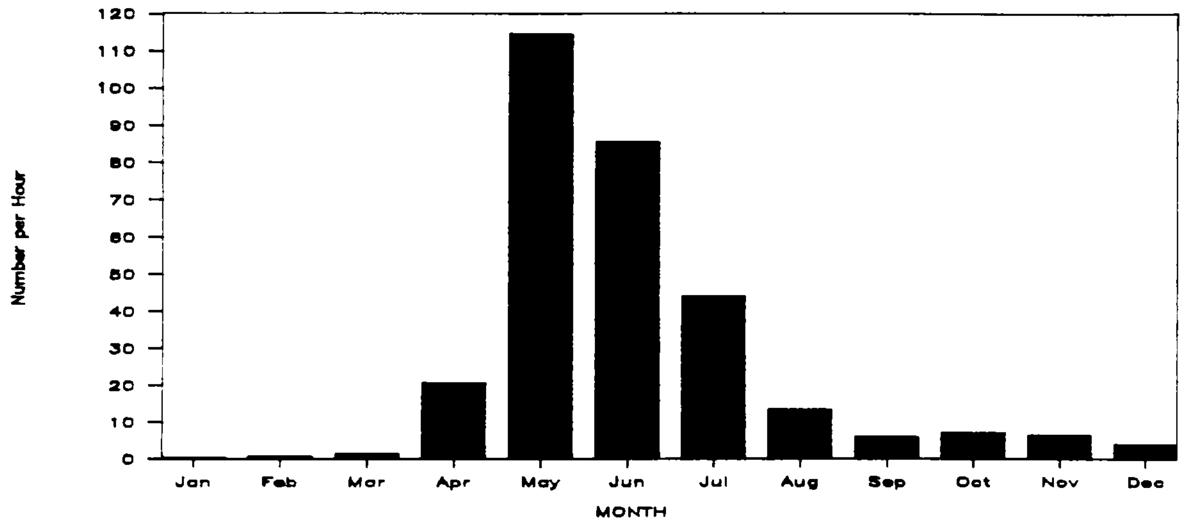
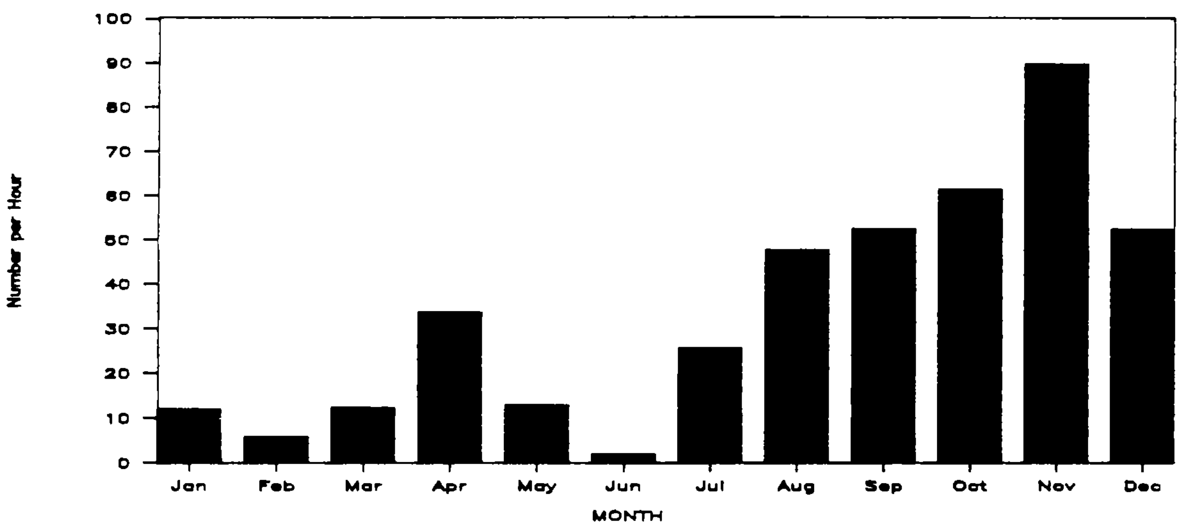

Brown Shrimp
Number per Hectare
700
600
500
400
300
200
100
0
78 79 80 81 82 83 84 85 86 87
Year
White Shrimp
Number per Hectare (Thousands)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
78 79 80 81 82 83 84 85 86 87
Year
Pink Shrimp
Number per Hectare
26
24
22
20
18
16
14
12
10
8
6
4
2
0
78 79 80 81 82 83 84 85 86 87
Year

Figure 2.18. Monthly coastwide catch rates of penaeid shrimp in Texas Parks and Wildlife Department bay trawls (1982-1986).

Brown Shrimp



White Shrimp



Pink Shrimp

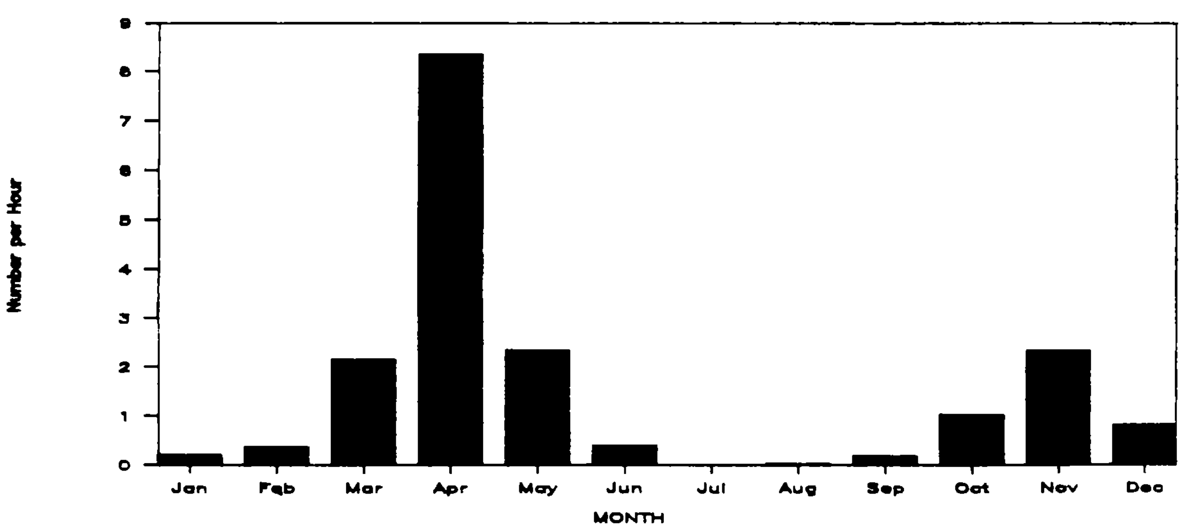
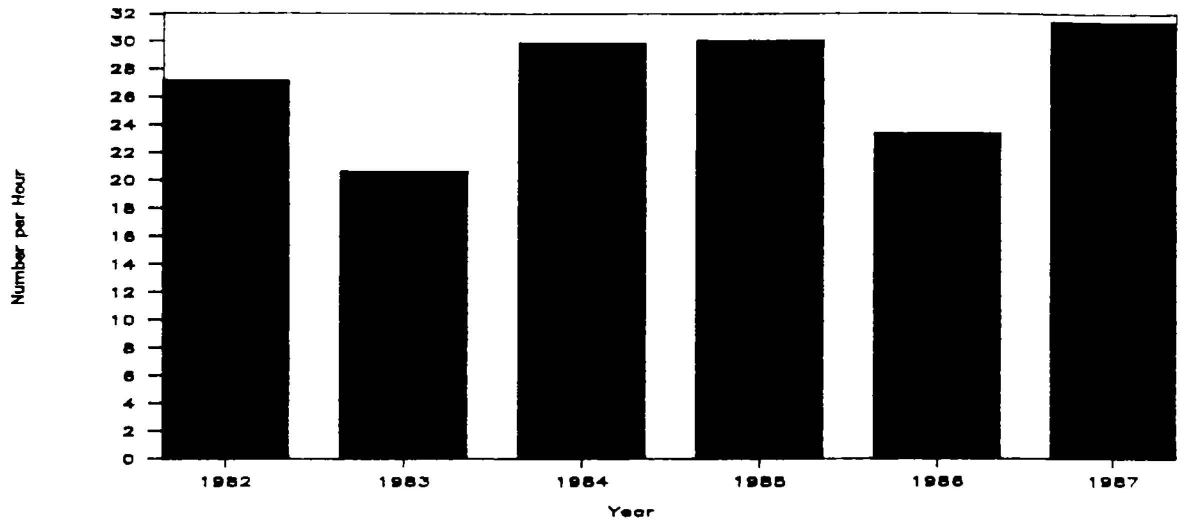
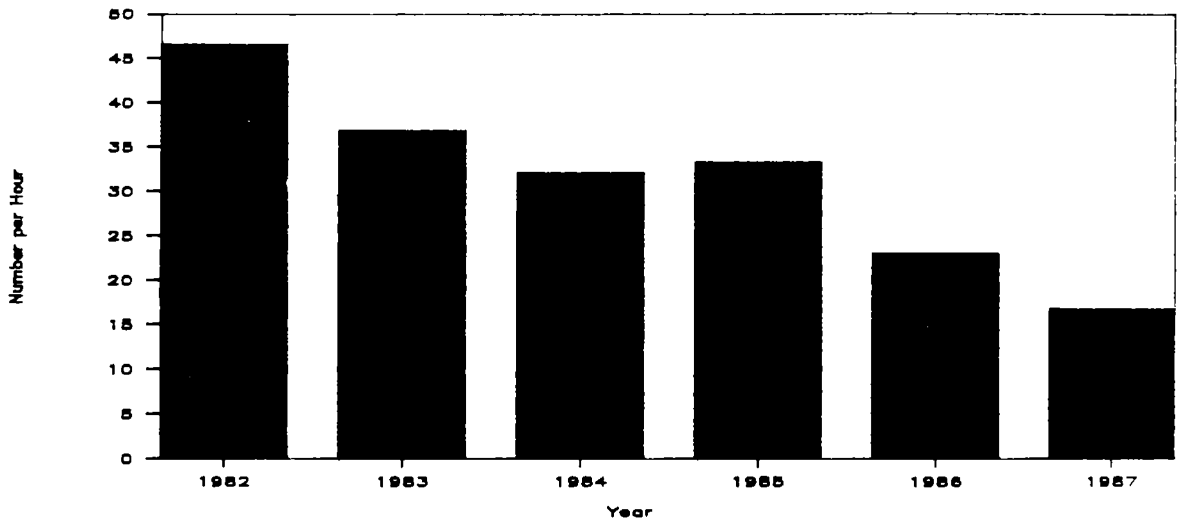


Figure 2.19. Annual coastwide catch rates of penaeid shrimp in Texas Parks and Wildlife Department bay trawls (1982-1987).

Brown Shrimp



White Shrimp



Pink Shrimp

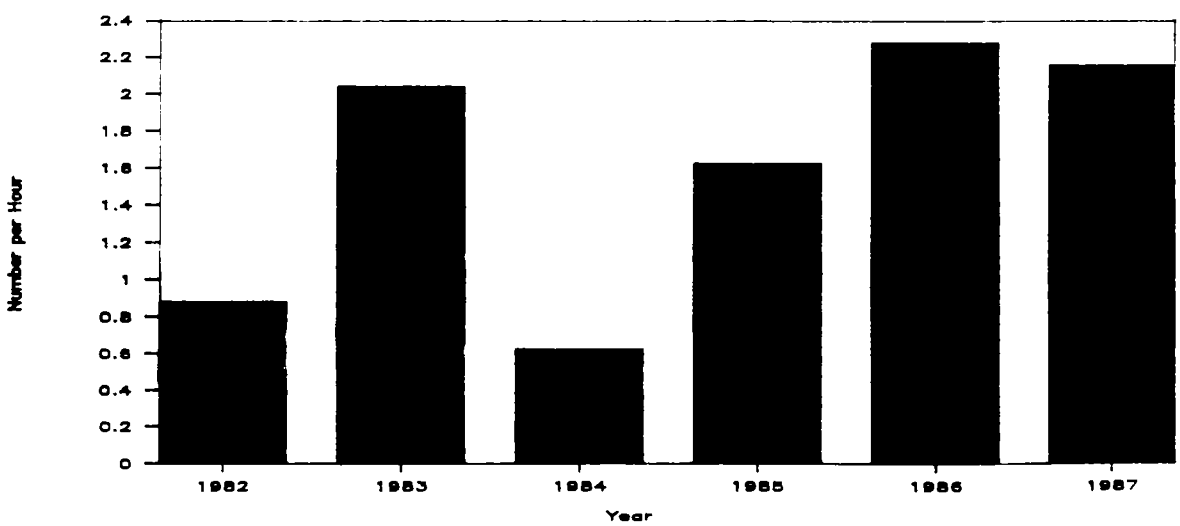
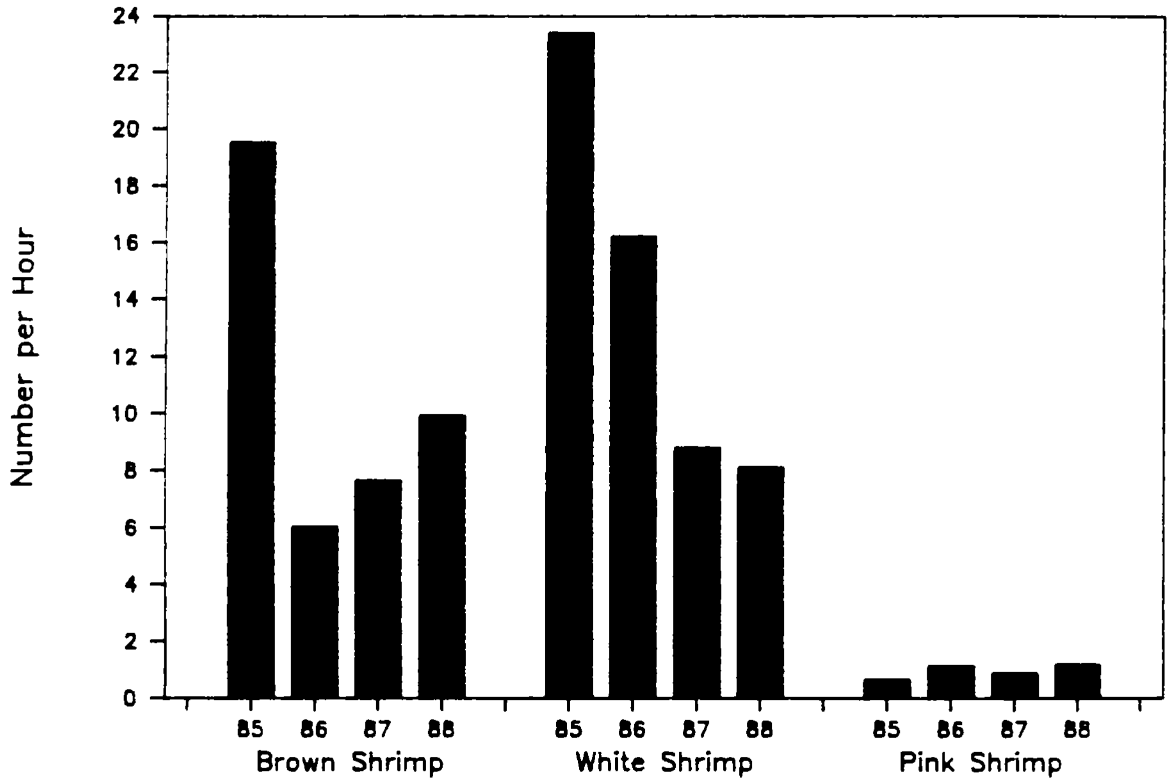
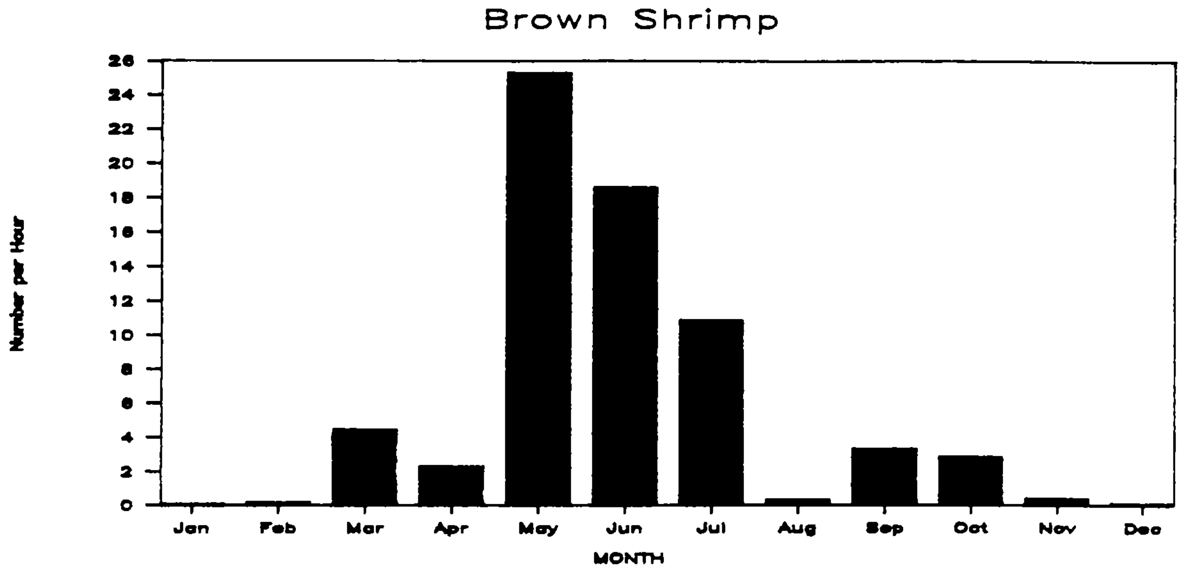


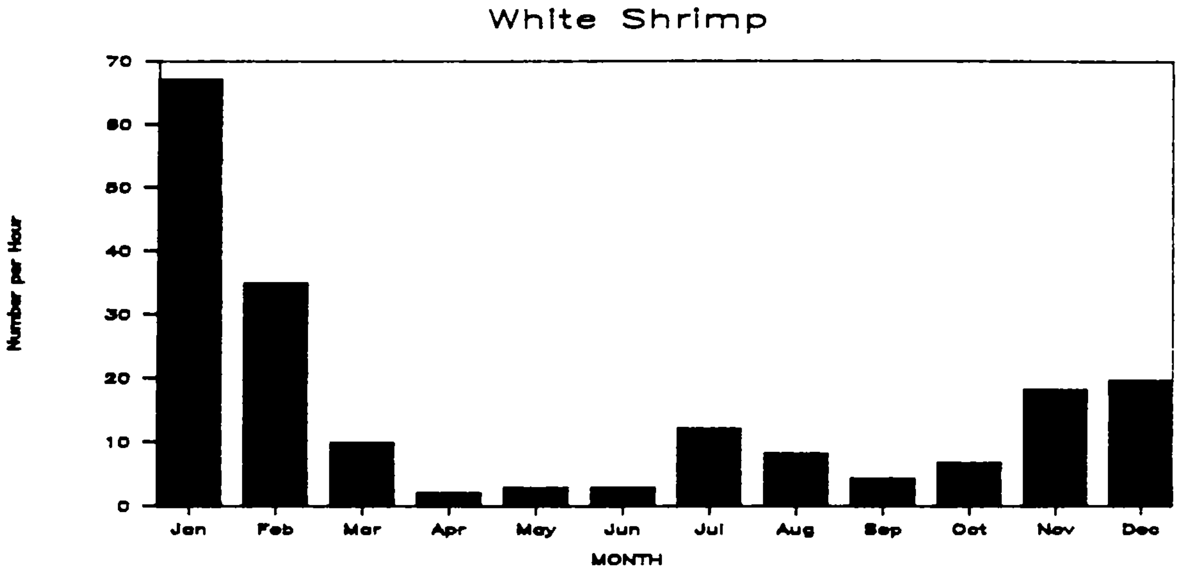
Figure 2.20. Annual coastwide catch rates of penaeid shrimp in Texas Parks and Wildlife Department gulf trawls (1985-1988).



Number per Hour
24
22
20
18
16
14
12
10
8
6
4
2
0
85
86
87
88
Brown Shrimp
85
86
87
88
White Shrimp
85
86
87
88
Pink Shrimp

Figure 2.21. Monthly coastwide catch rates of penaeid shrimp in Texas Parks and Wildlife Department gulf trawls (1986).


Brown Shrimp
Number per Hour
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
MONTH


White Shrimp
Number per Hour
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
MONTH

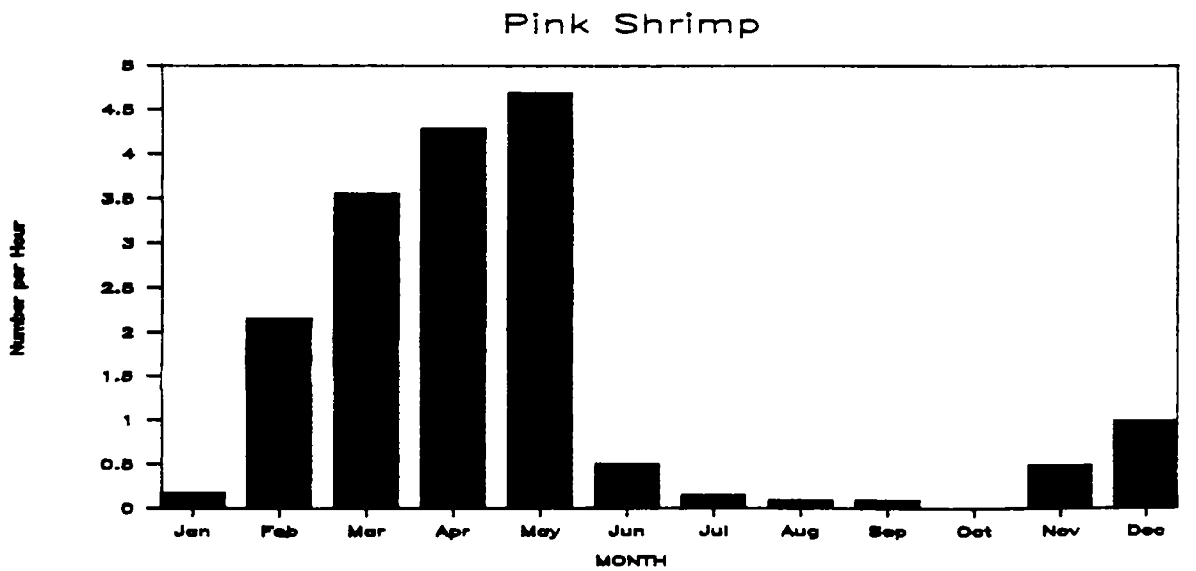

Pink Shrimp
Number per Hour
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
MONTH

Figure 2.22. Annual coastwide catch rates of brown shrimp in Southeast Area Monitoring and Assessment Program gulf trawls (1982-1987).

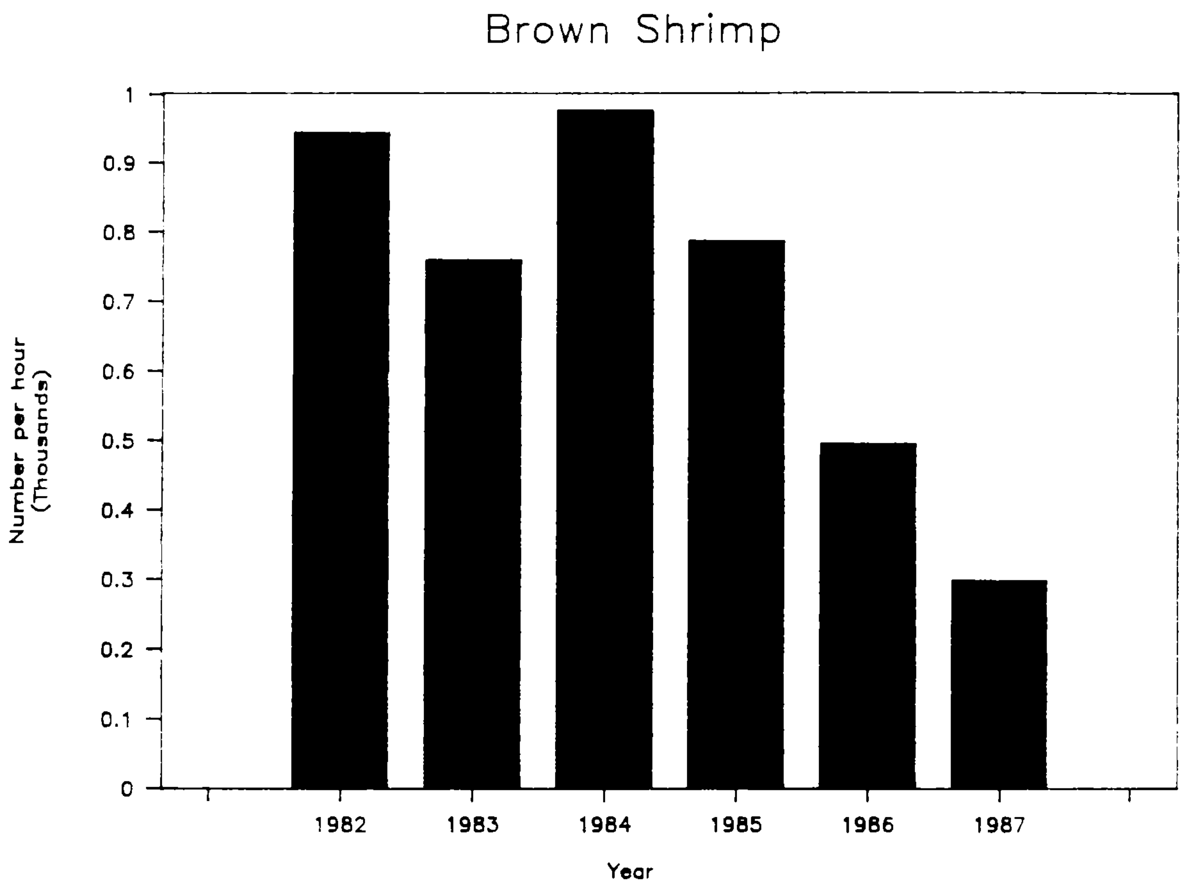
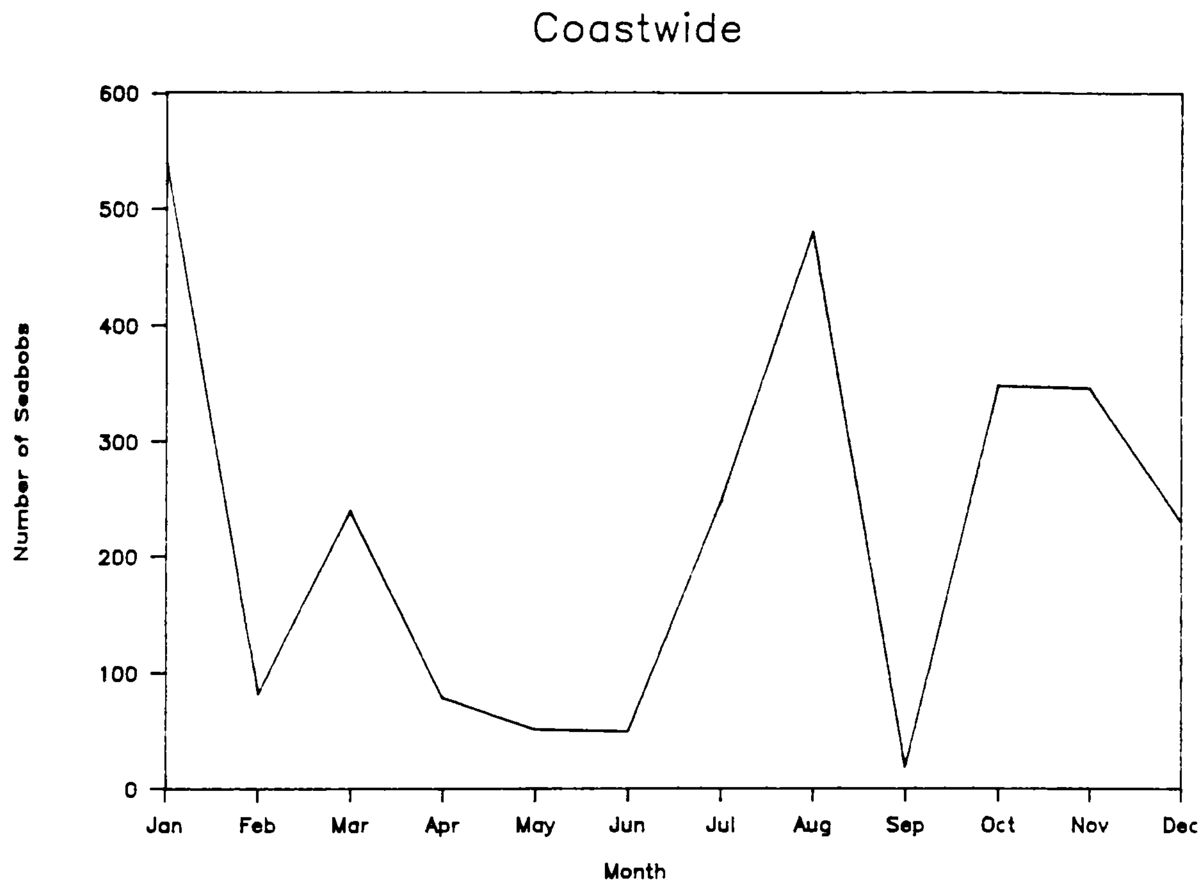

Brown Shrimp
Number per hour
(Thousands)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1982
1983
1984
1985
1986
1987
Year

Figure 2.23. Monthly catch of seabobs in Texas during gulf sampling.


Coastwide
600
500
400
300
200
100
0
Number of Seabobs
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

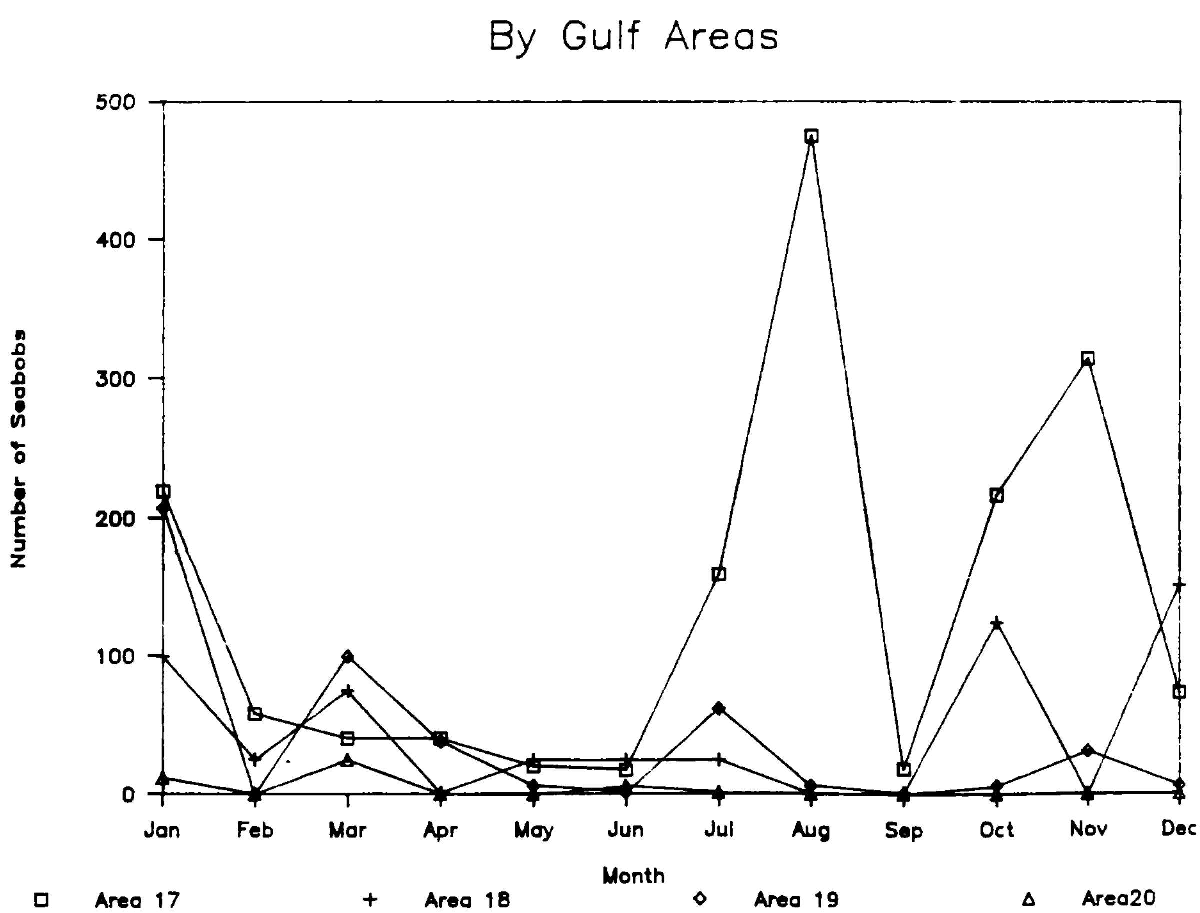

By Gulf Areas
500
400
300
200
100
0
Number of Seabobs
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Area 17
Area 18
Area 19
Area20

Figure 2.24. Short-term and long-term harvest equilibria expressed as functions of harvest and effort.

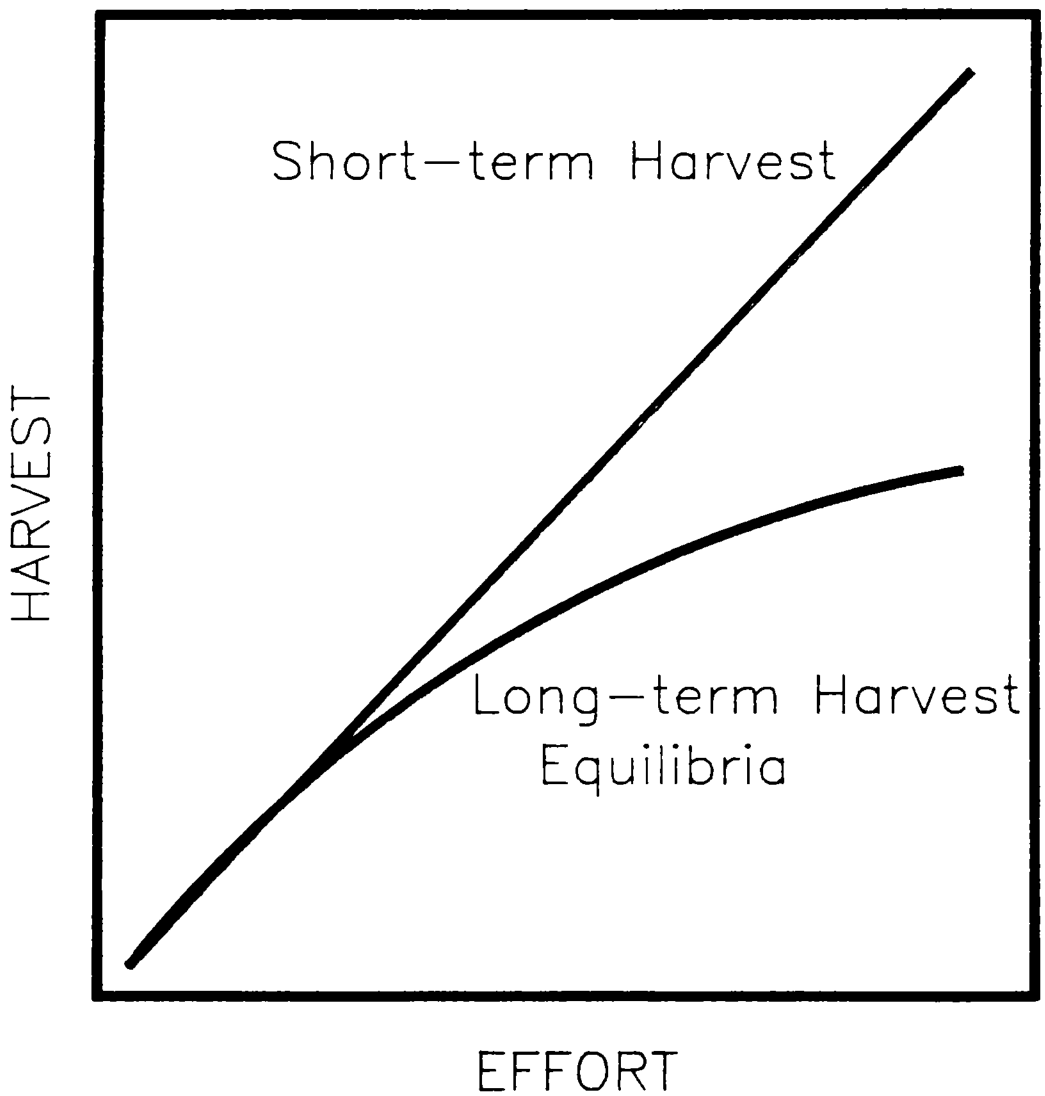

Short–term Harvest
Long–term Harvest
Equilibria
HARVEST
EFFORT

Figure 2.25. Change in biomass, biological production and harvest as a function of effort.

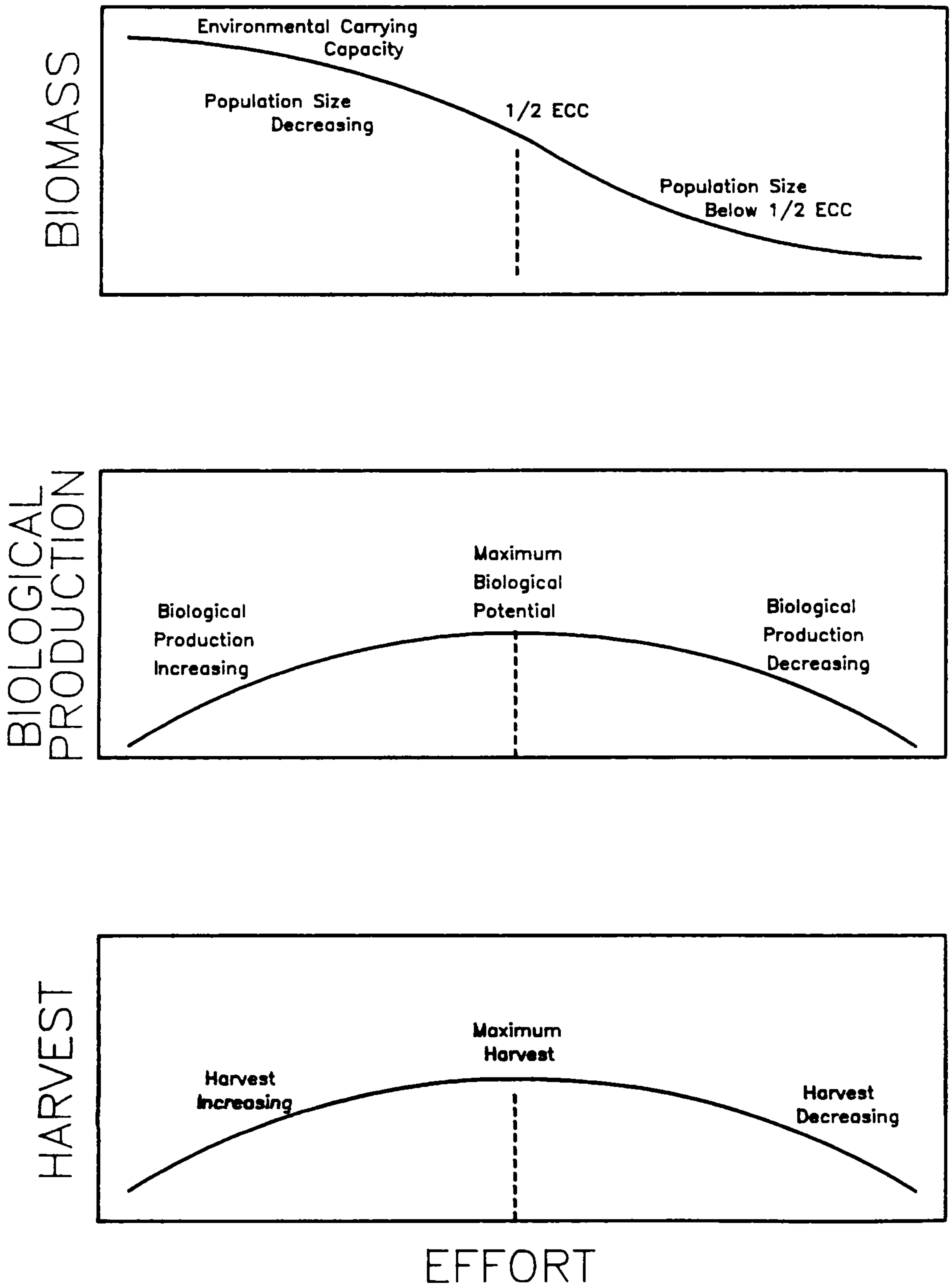
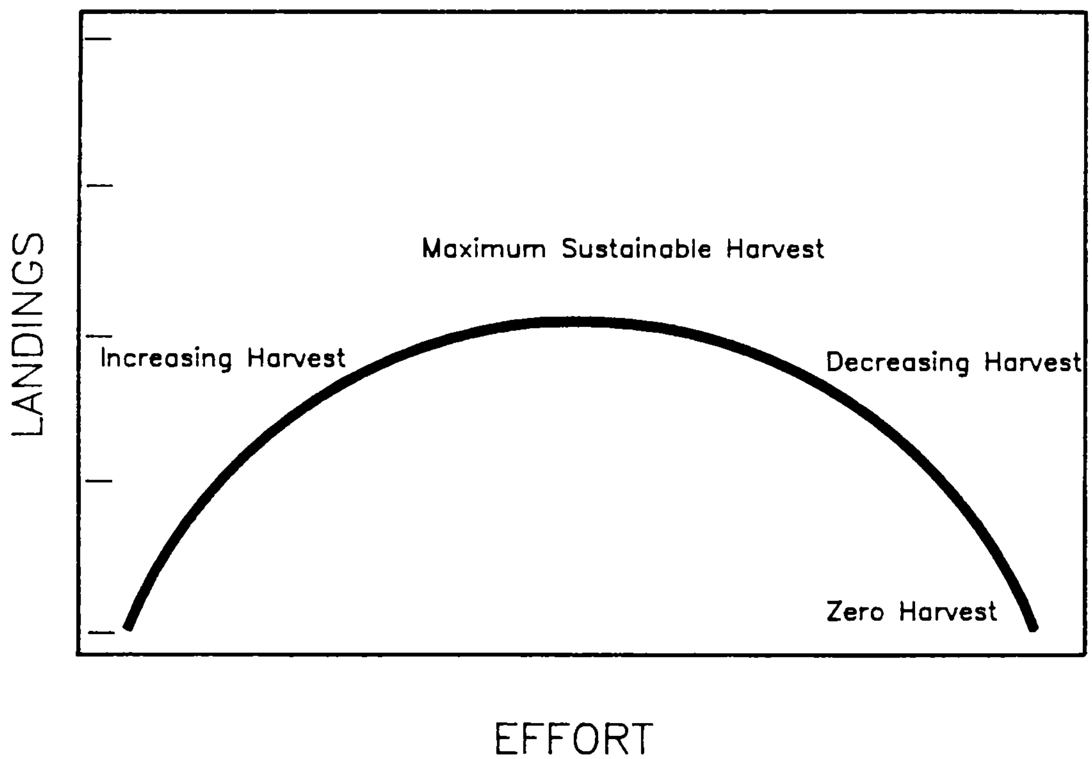

BIOMASS
Environmental Carrying Capacity
Population Size Decreasing
1/2 ECC
Population Size Below 1/2 ECC
BIOLOGICAL PRODUCTION
Maximum Biological Potential
Biological Production Increasing
Biological Production Decreasing
HARVEST
Maximum Harvest
Harvest Increasing
Harvest Decreasing
EFFORT

Figure 2.26. A typical sustainable harvest-effort curve, showing maximum sustainable harvest.



Maximum Sustainable Harvest
Increasing Harvest
Decreasing Harvest
Zero Harvest
LANDINGS
EFFORT

Figure 3.1. Flowchart of the Texas shrimp fishery.

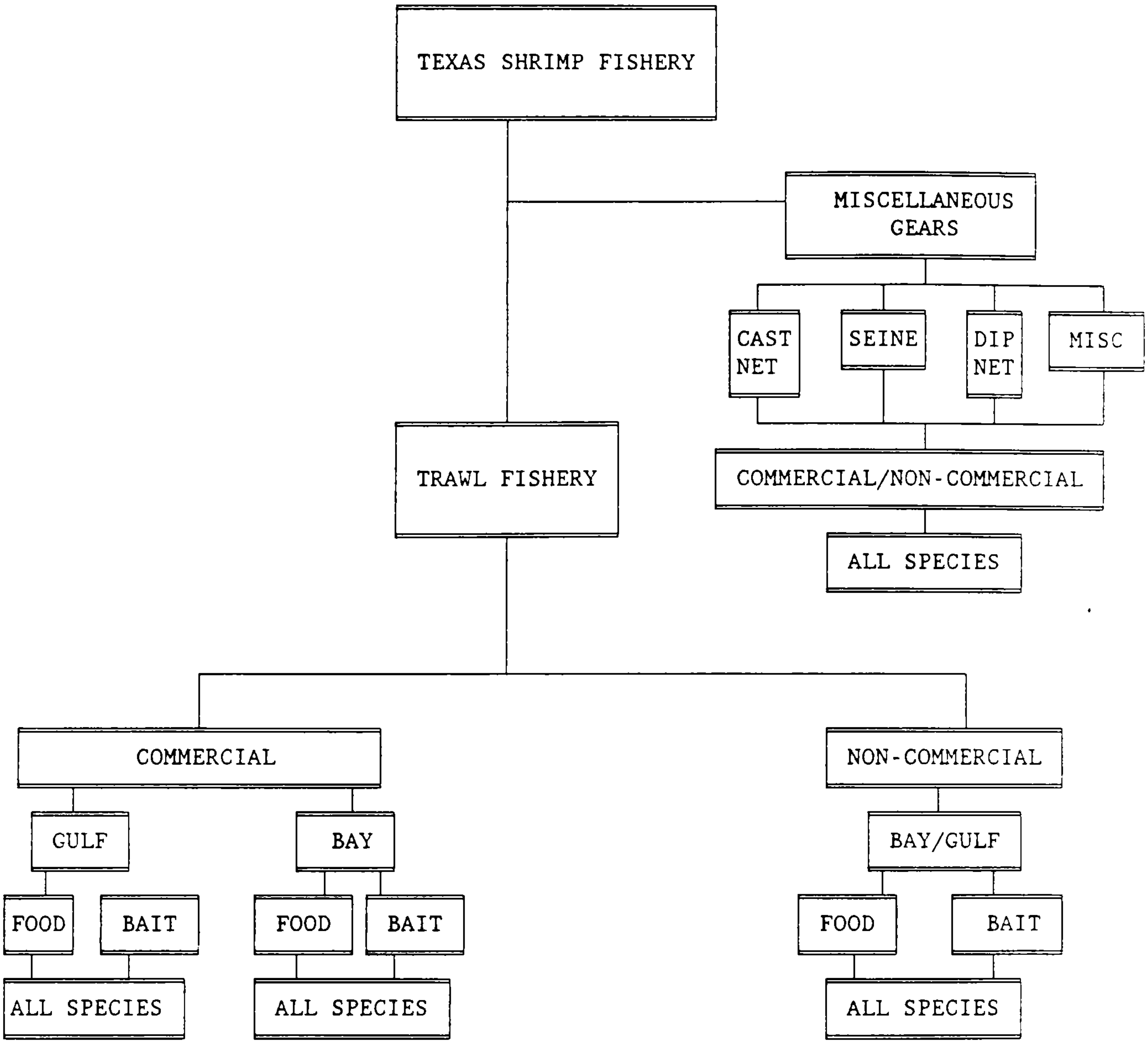

TEXAS SHRIMP FISHERY
MISCELLANEOUS GEARS
CAST NET
SEINE
DIP NET
MISC
COMMERCIAL/NON-COMMERCIAL
ALL SPECIES
TRAWL FISHERY
COMMERCIAL
NON-COMMERCIAL
GULF
BAY
BAY/GULF
FOOD
BAIT
FOOD
BAIT
FOOD
BAIT
ALL SPECIES
ALL SPECIES
ALL SPECIES

Figure 3.2. Total shrimp landings from Texas for the period 1880-1987. Landings data for 1880-1945 from Anderson et al. (1949b). Landings data for 1946-1962 from "Shrimp Landings" and "Texas Landings" (National Marine Fisheries Service--various years). Landings data for 1977-1987 from Quast et al. (1988).

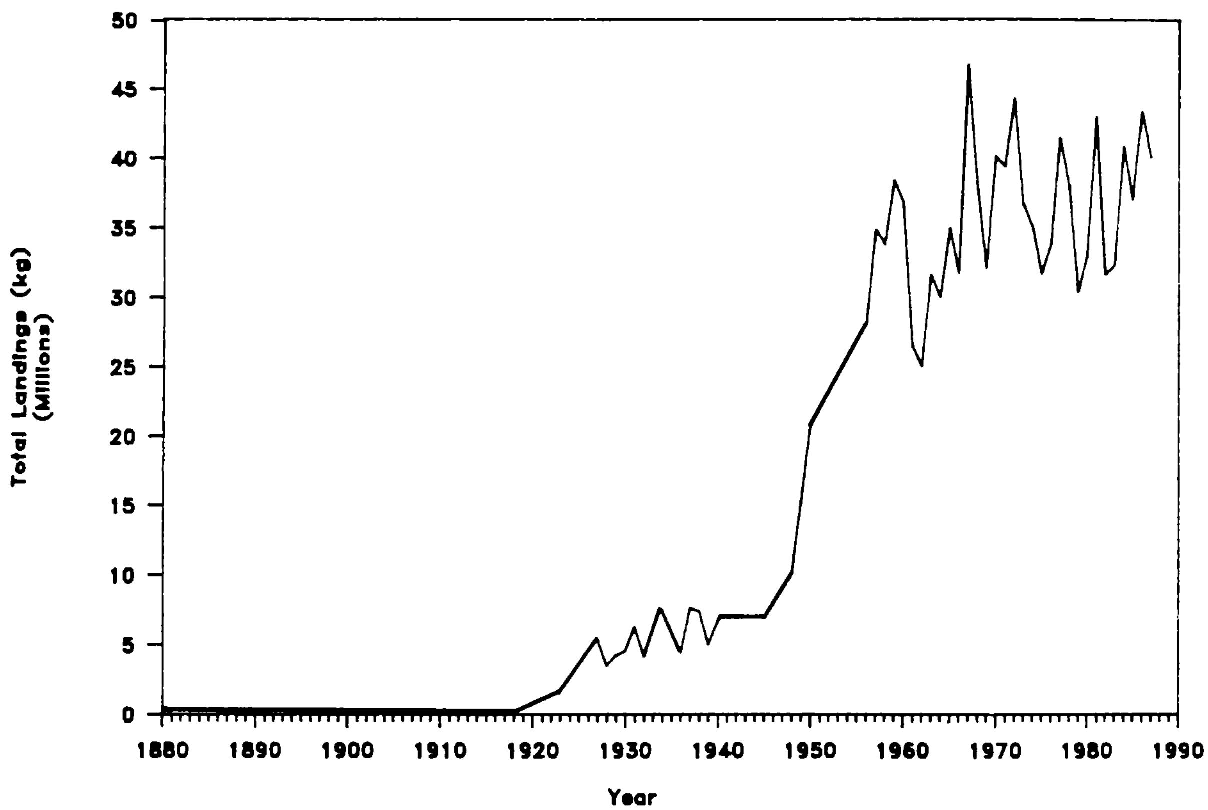
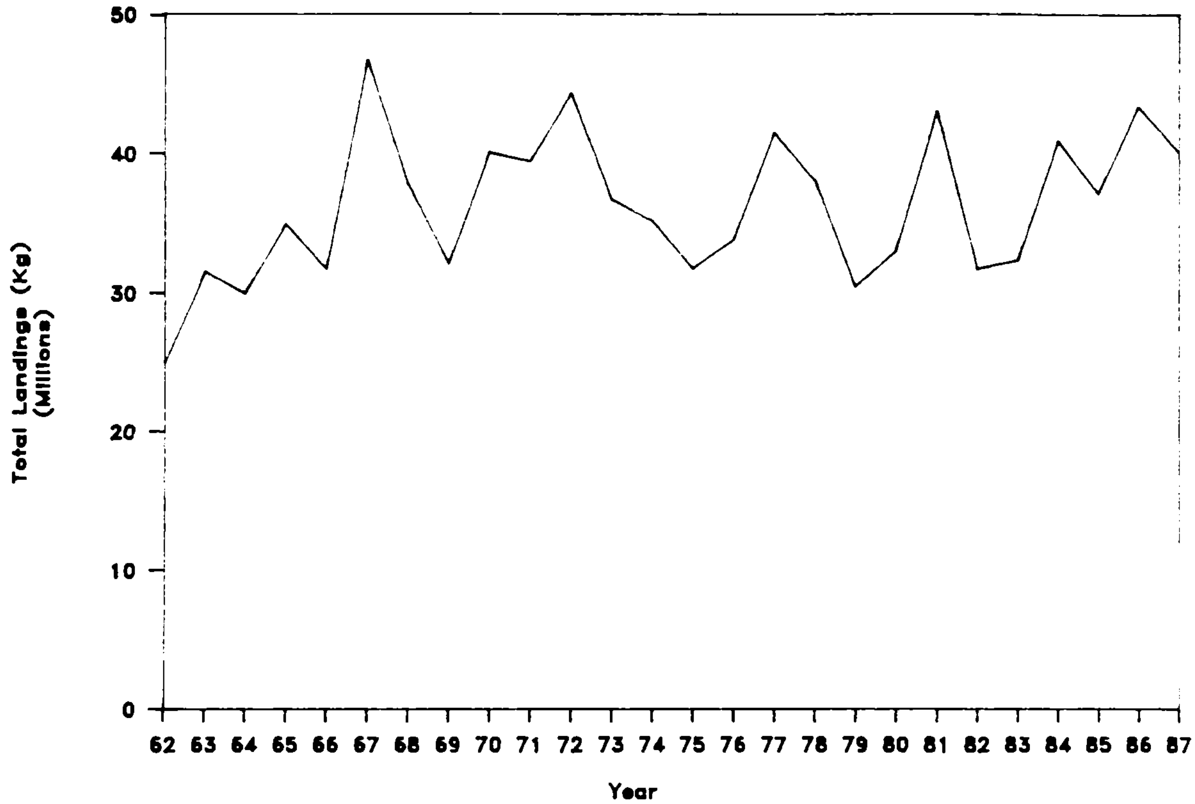

Total Landings (kg)
(Millions)
50
45
40
35
30
25
20
15
10
5
0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
Year

Figure 3.3. Annual Texas landings (kg) of penaeid shrimp and landings by species (1962-1987).


50
40
30
20
10
0
Total Landings (Kg)
(Millions)
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

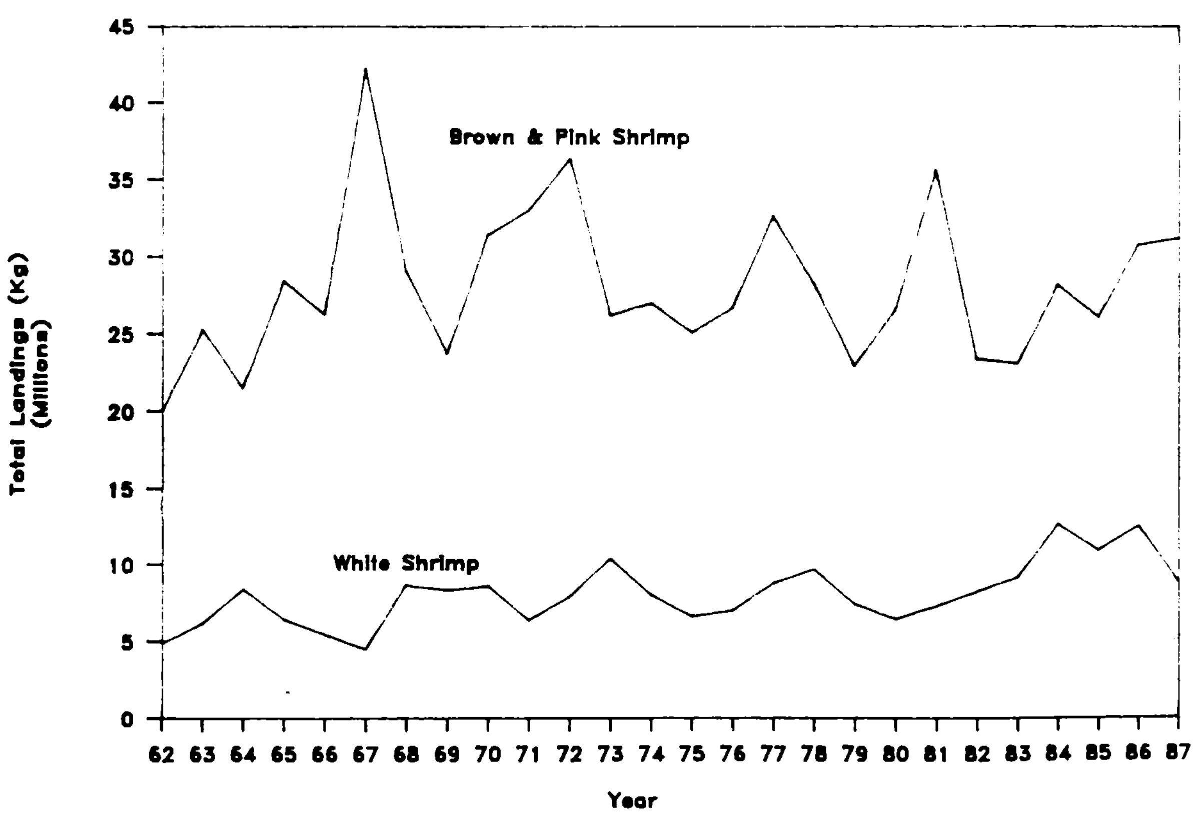
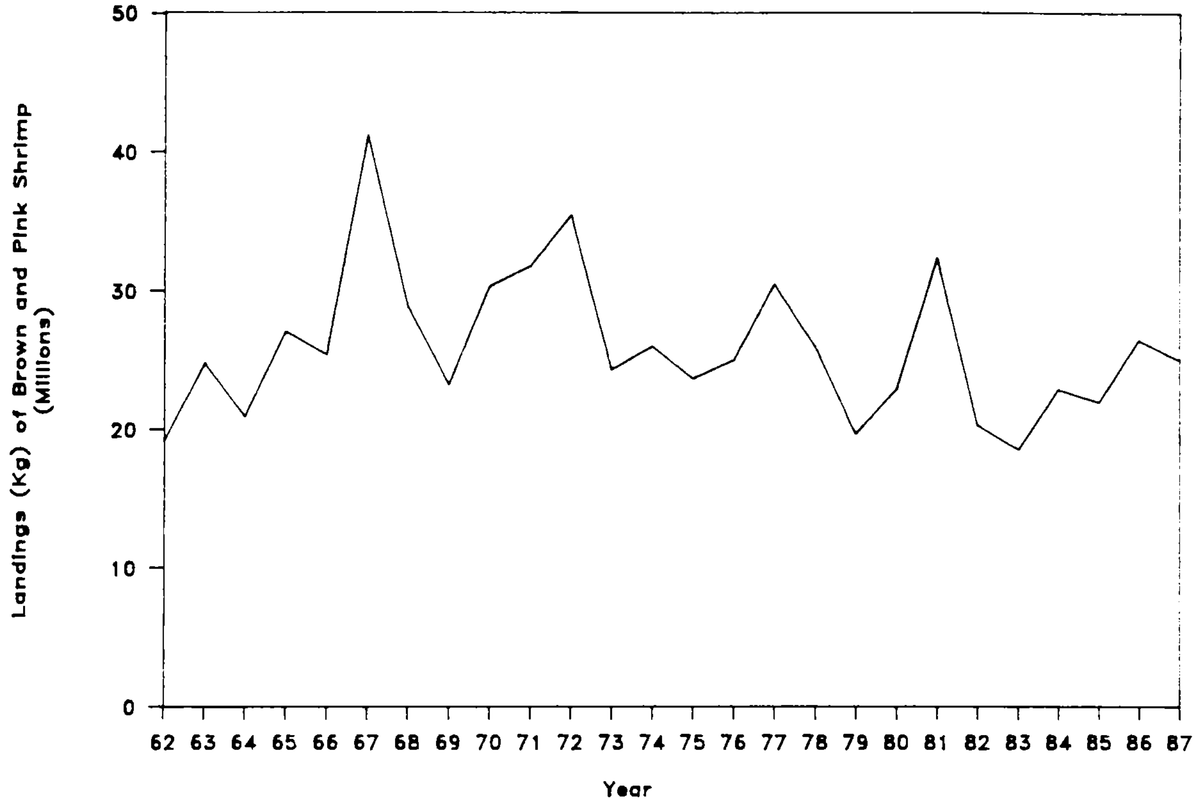

45
40
35
30
25
20
15
10
5
0
Brown & Pink Shrimp
White Shrimp
Total Landings (Kg)
(Millions)
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.4. Annual landings (kg) (1962-1987) and estimated number (1966-1986) of brown shrimp and pink shrimp from Texas gulf waters.


Landings (Kg) of Brown and Pink Shrimp (Millions)
50
40
30
20
10
0
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

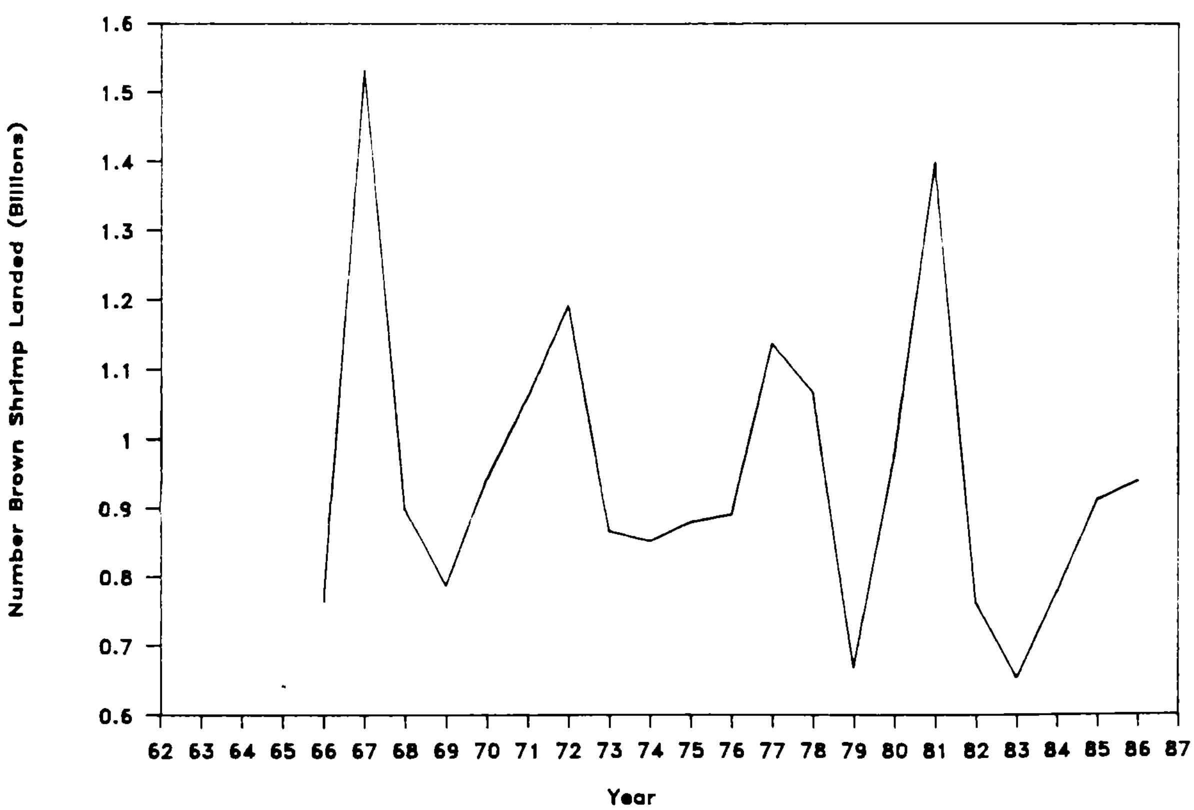
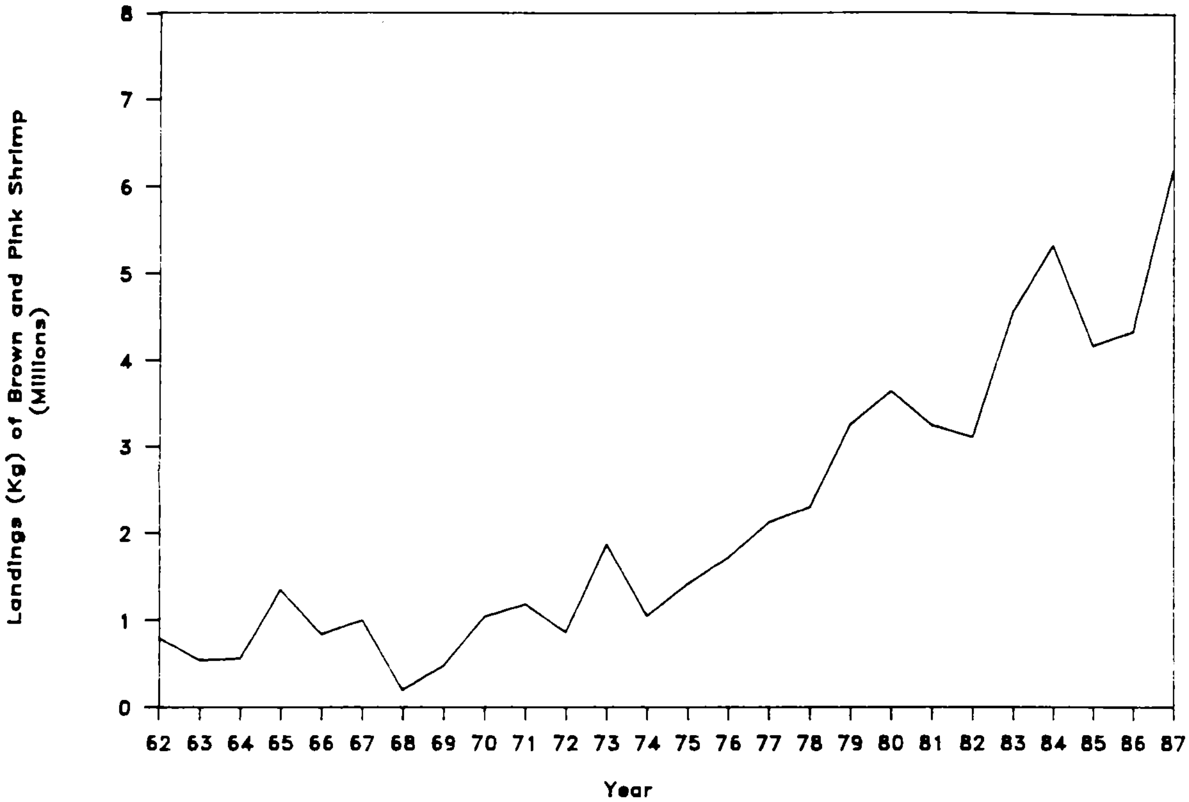

Number Brown Shrimp Landed (Billions)
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.5. Annual landings (kg) (1962-1987) and estimated number (1966-1986) of brown shrimp and pink shrimp from Texas bay waters.


Landings (Kg) of Brown and Pink Shrimp (Millions)
0
1
2
3
4
5
6
7
8
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

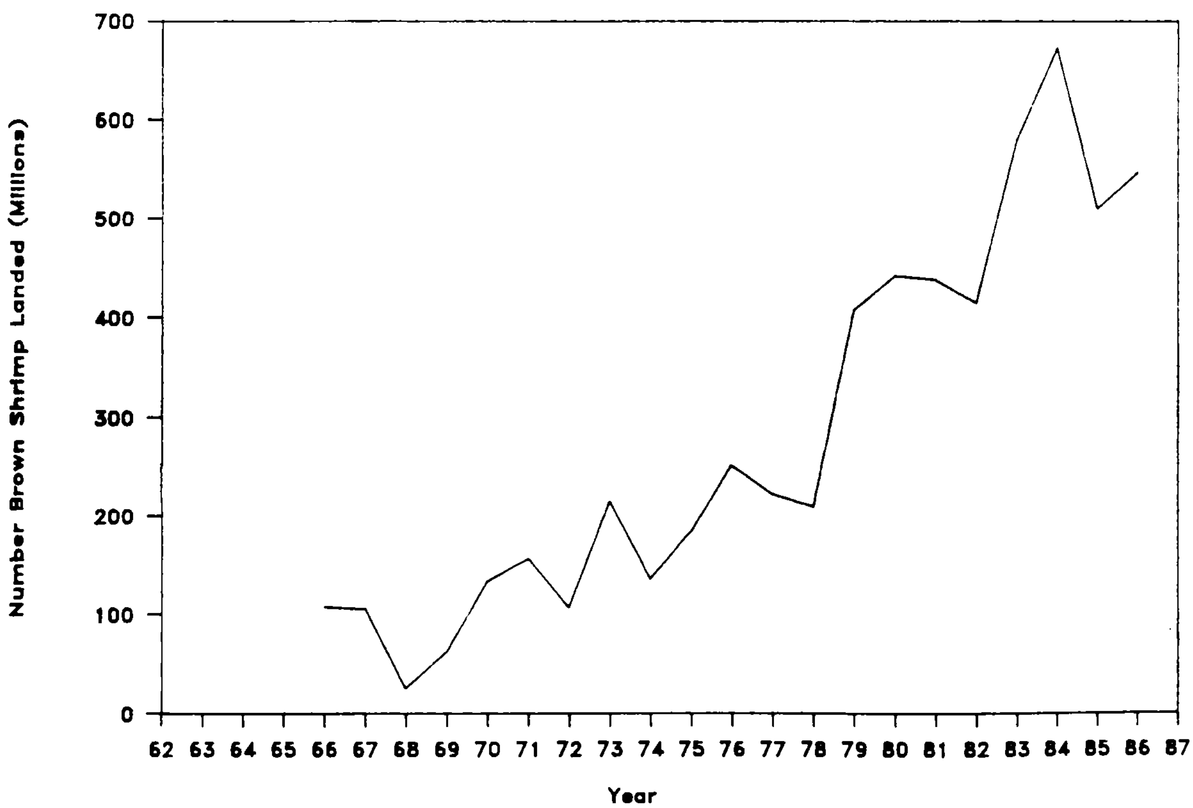
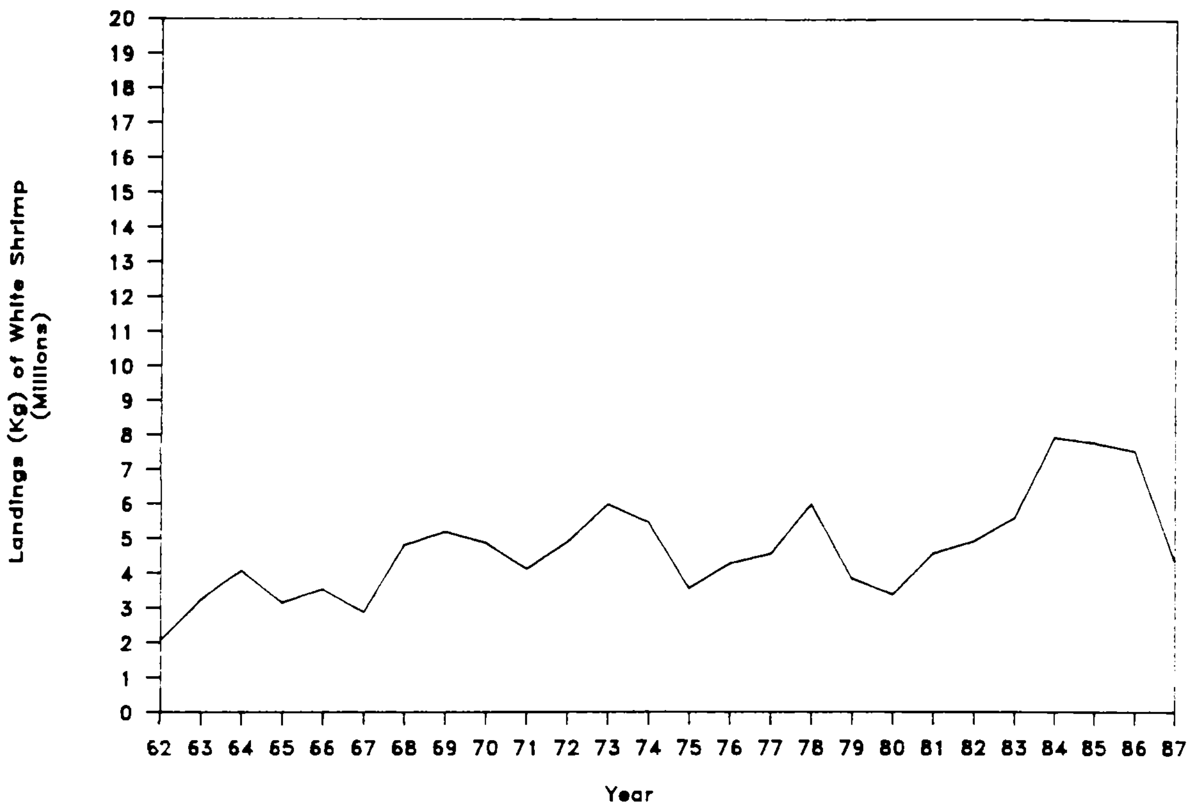

Number Brown Shrimp Landed (Millions)
0
100
200
300
400
500
600
700
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.6. Annual landings (kg) (1962-1987) and estimated number (1966-1986) of white shrimp from Texas gulf waters.


Landings (Kg) of White Shrimp (Millions)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

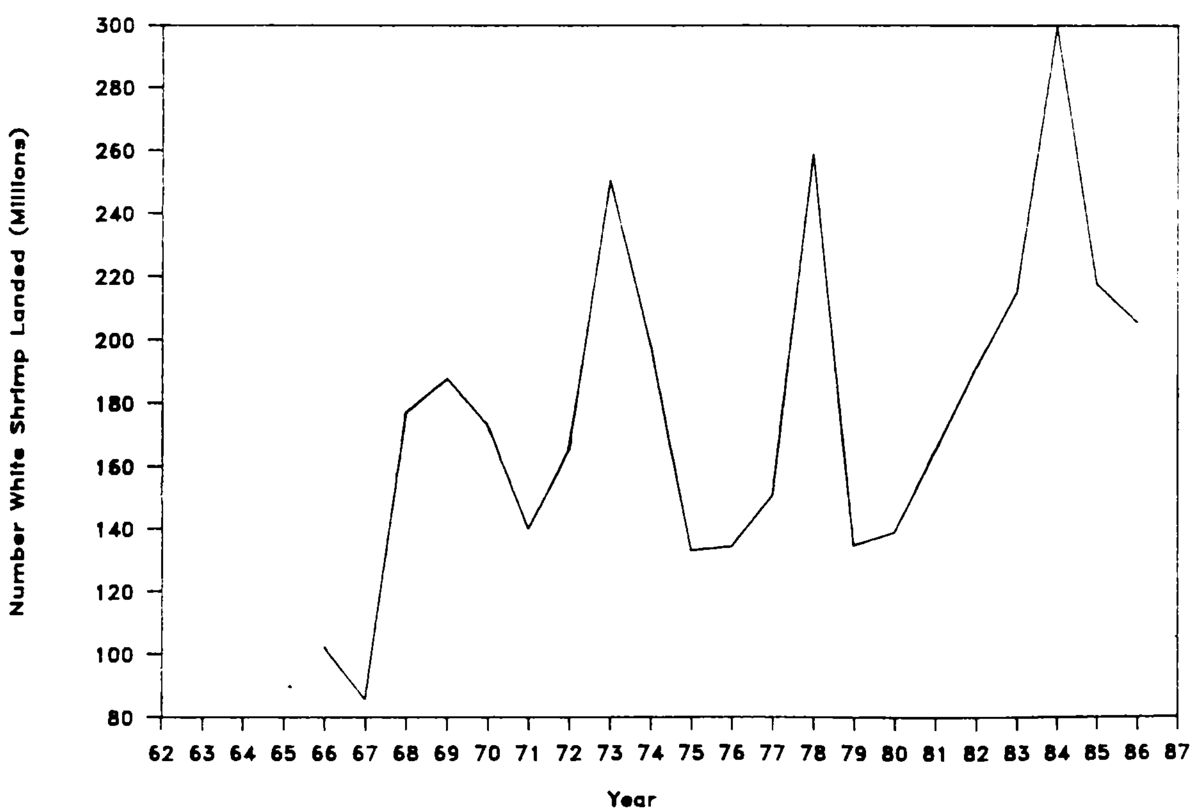
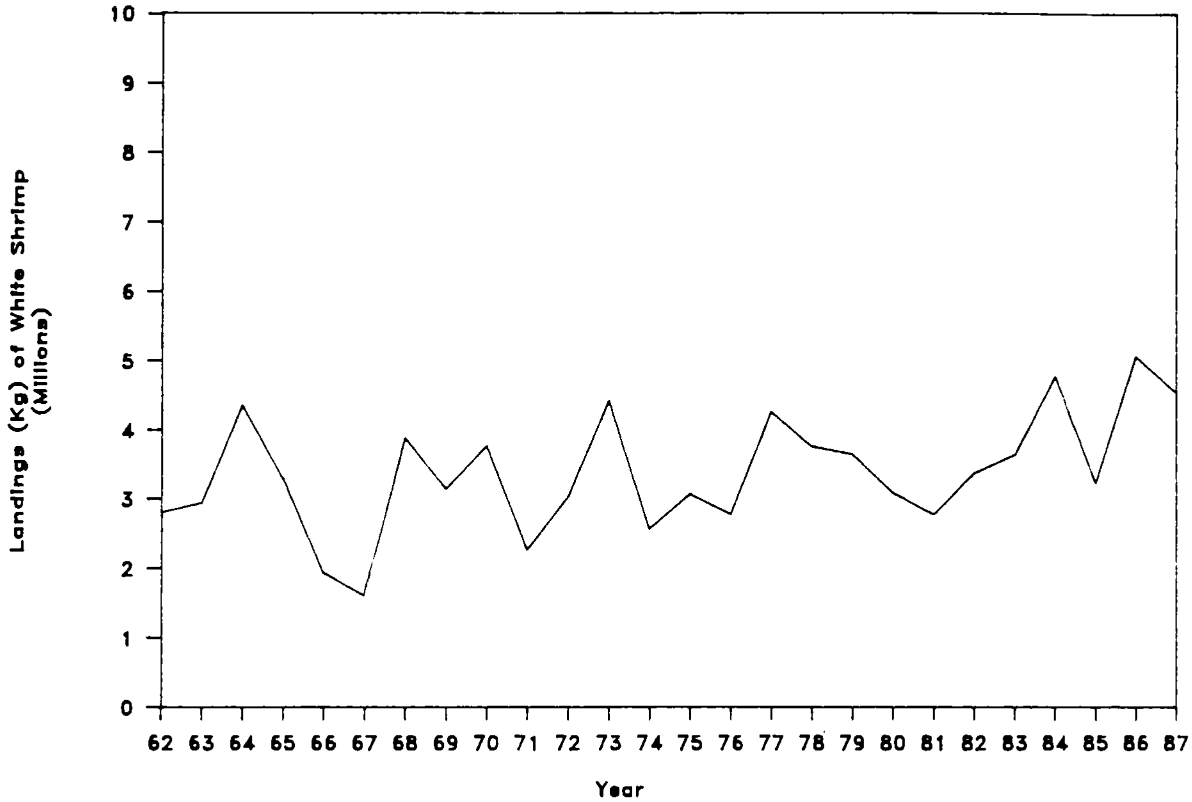
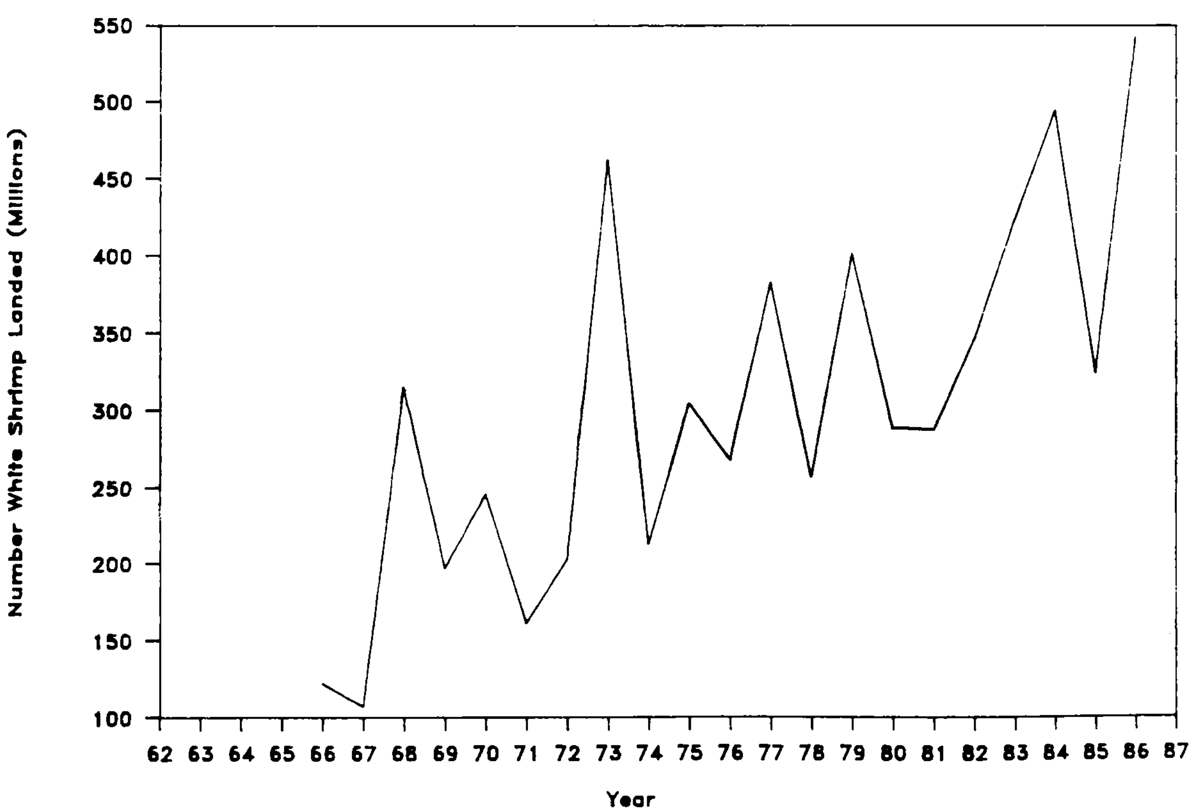

Number White Shrimp Landed (Millions)
300
280
260
240
220
200
180
160
140
120
100
80
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.7. Annual landings (kg) (1962-1987) and estimated number (1966-1986) of white shrimp from Texas bay waters.

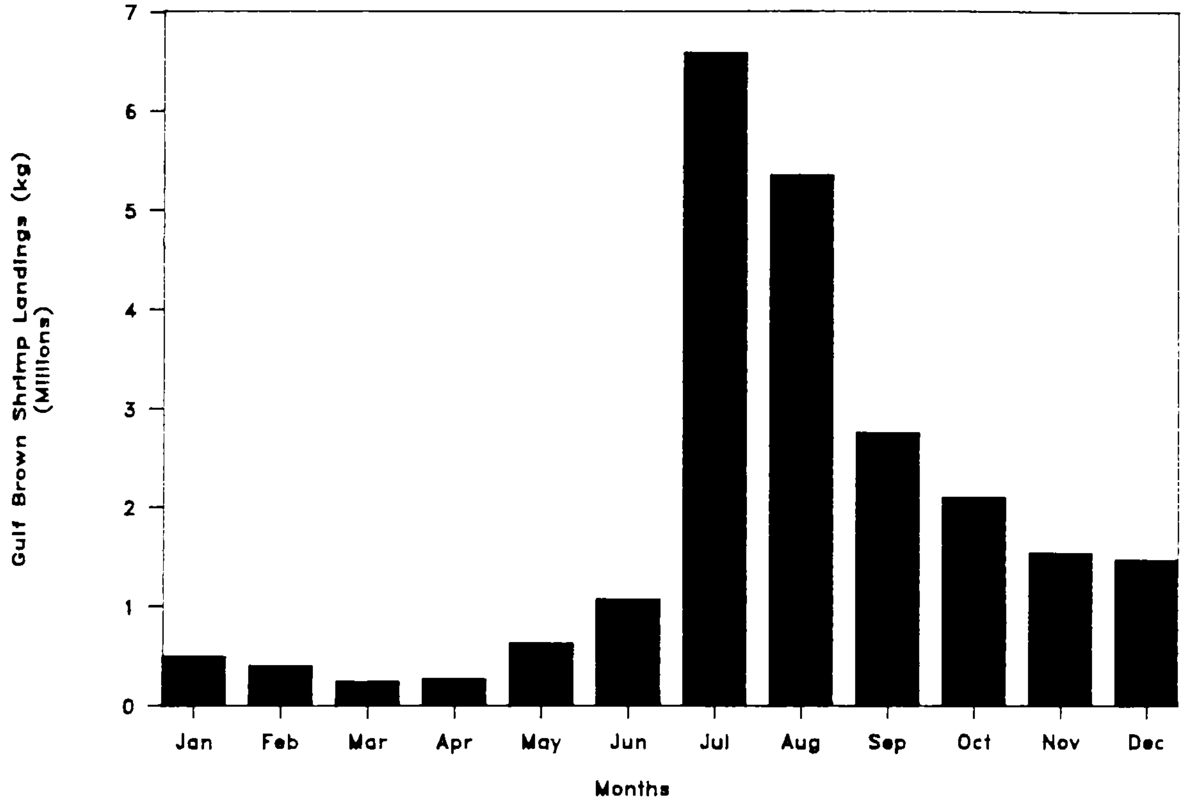


Landings (Kg) of White Shrimp (Millions)
10
9
8
7
6
5
4
3
2
1
0
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year



Number White Shrimp Landed (Millions)
550
500
450
400
350
300
250
200
150
100
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.8. Average monthly gulf and bay brown shrimp landings (1981-1985).


Gulf Brown Shrimp Landings (kg)
(Millions)
0
1
2
3
4
5
6
7
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

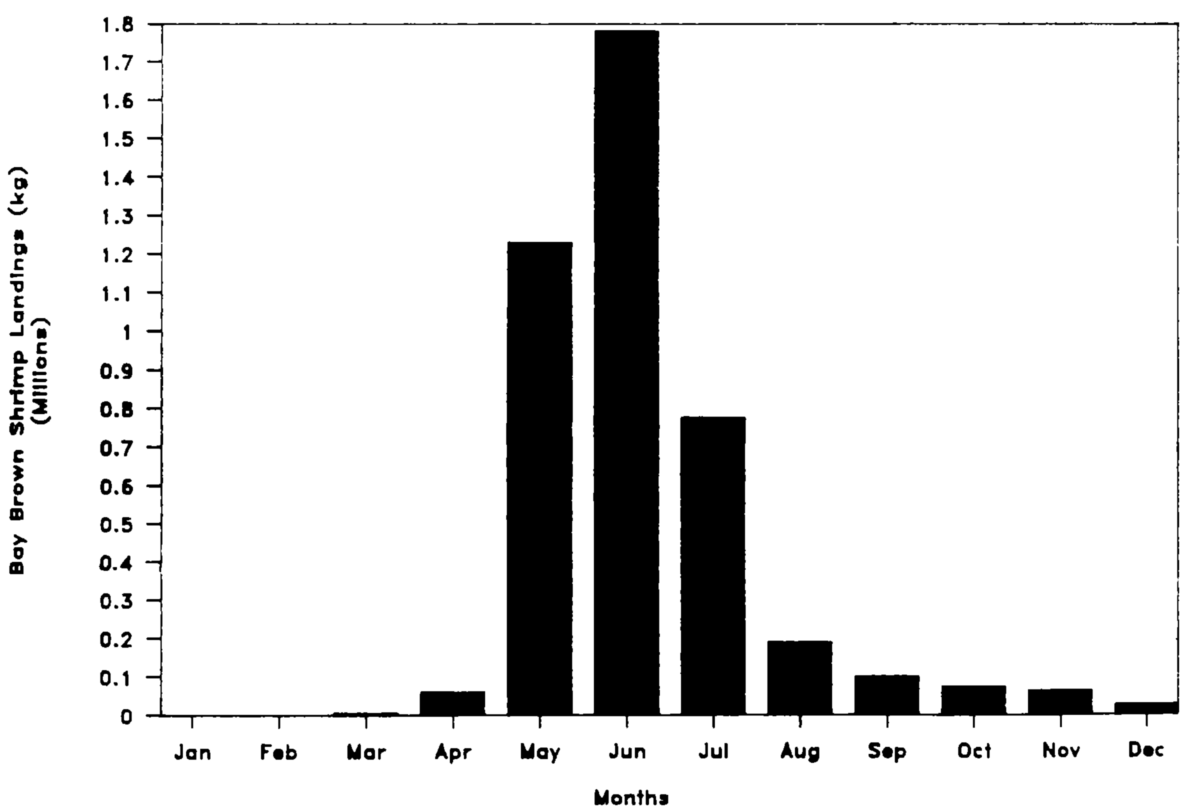
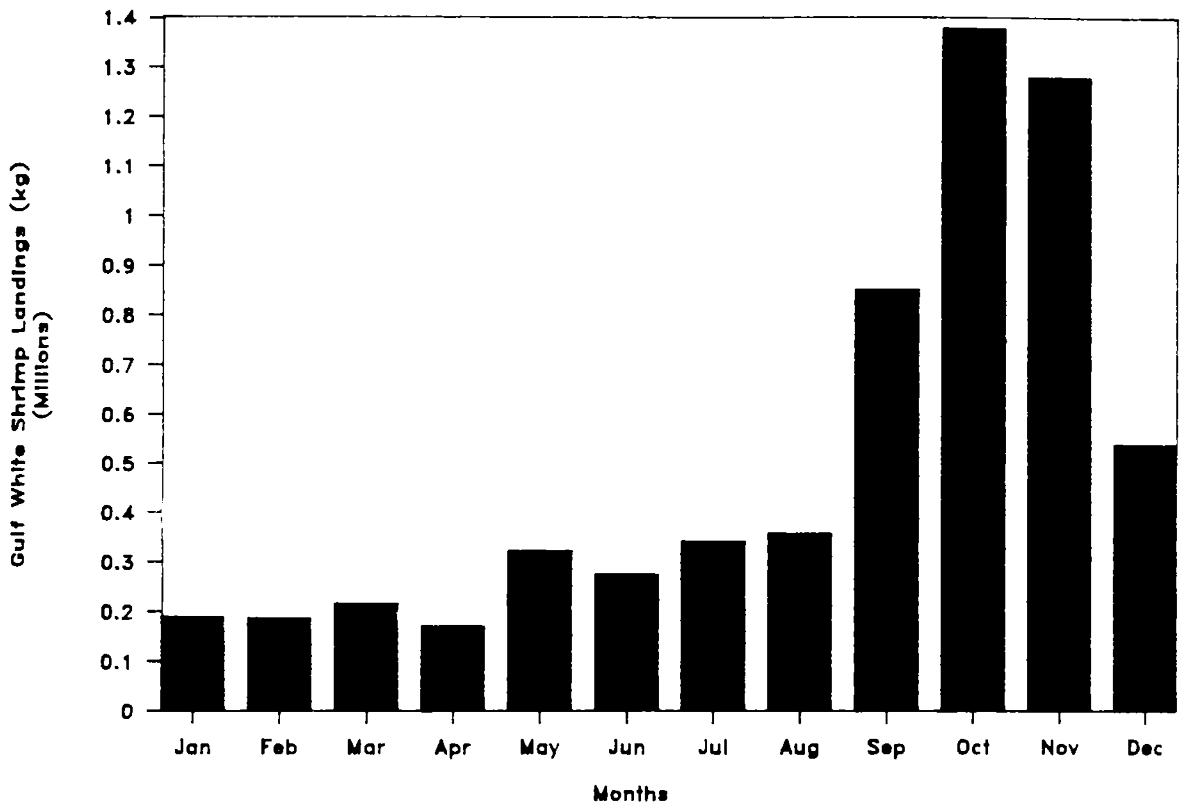
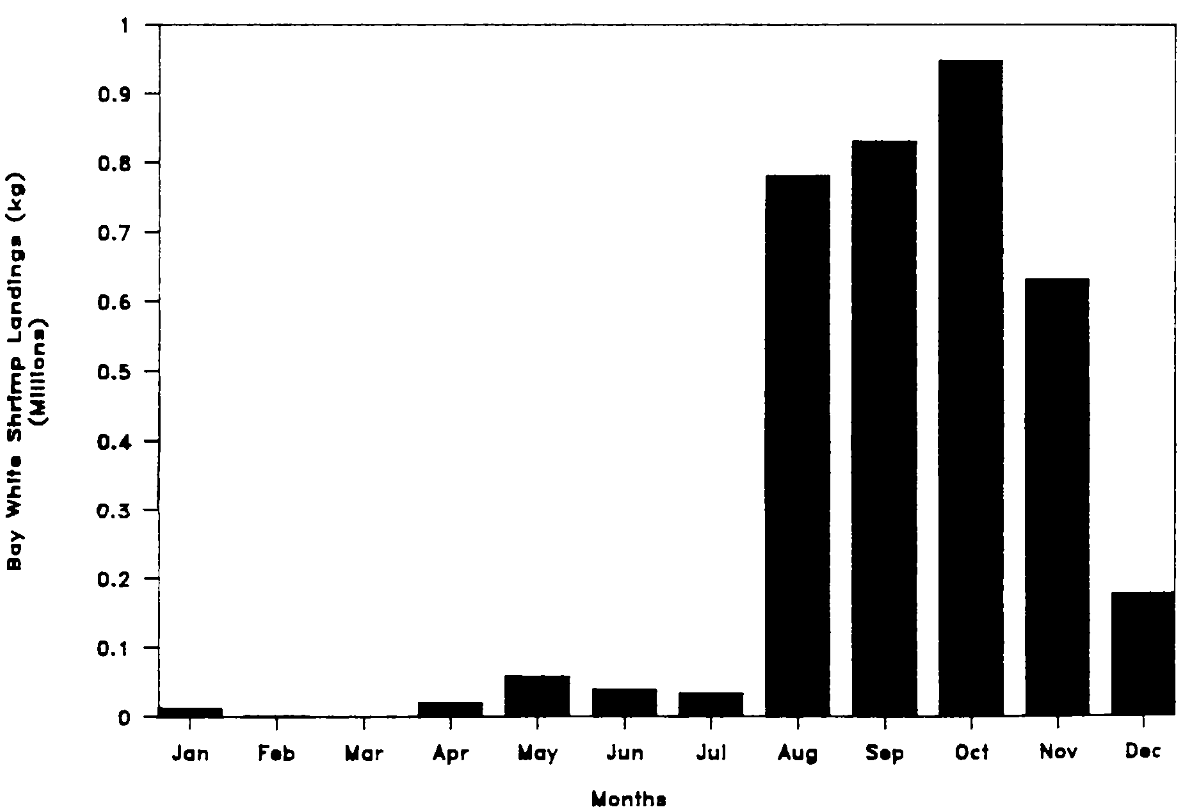

Bay Brown Shrimp Landings (kg)
(Millions)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 3.9. Average monthly gulf and bay white shrimp landings (1981-1985).

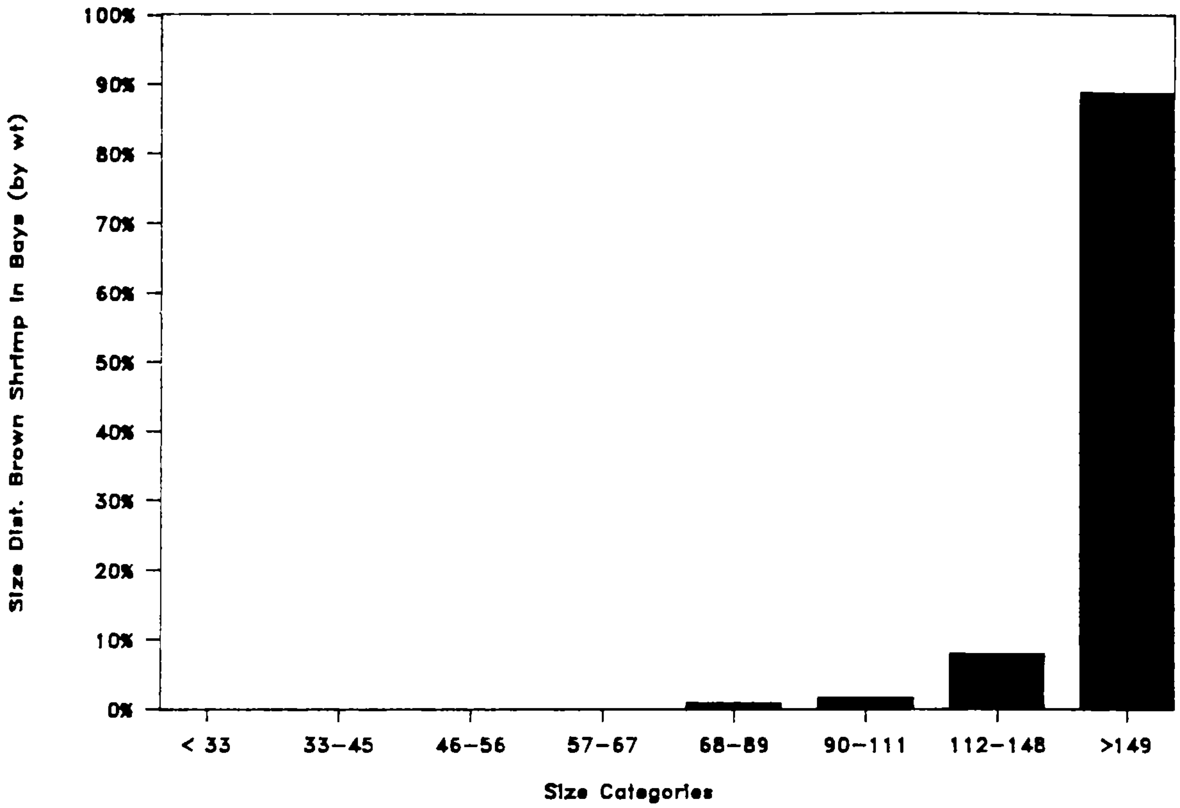


Gulf White Shrimp Landings (kg)
(Millions)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months



Bay White Shrimp Landings (kg)
(Millions)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

Figure 3.10. Average size distribution in tails/kg of brown shrimp caught in Texas bays and offshore gulf (1966-1986).


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Size Dist. Brown Shrimp In Bays (by wt)
< 33
33-45
46-56
57-67
68-89
90-111
112-148
>149
Size Categories

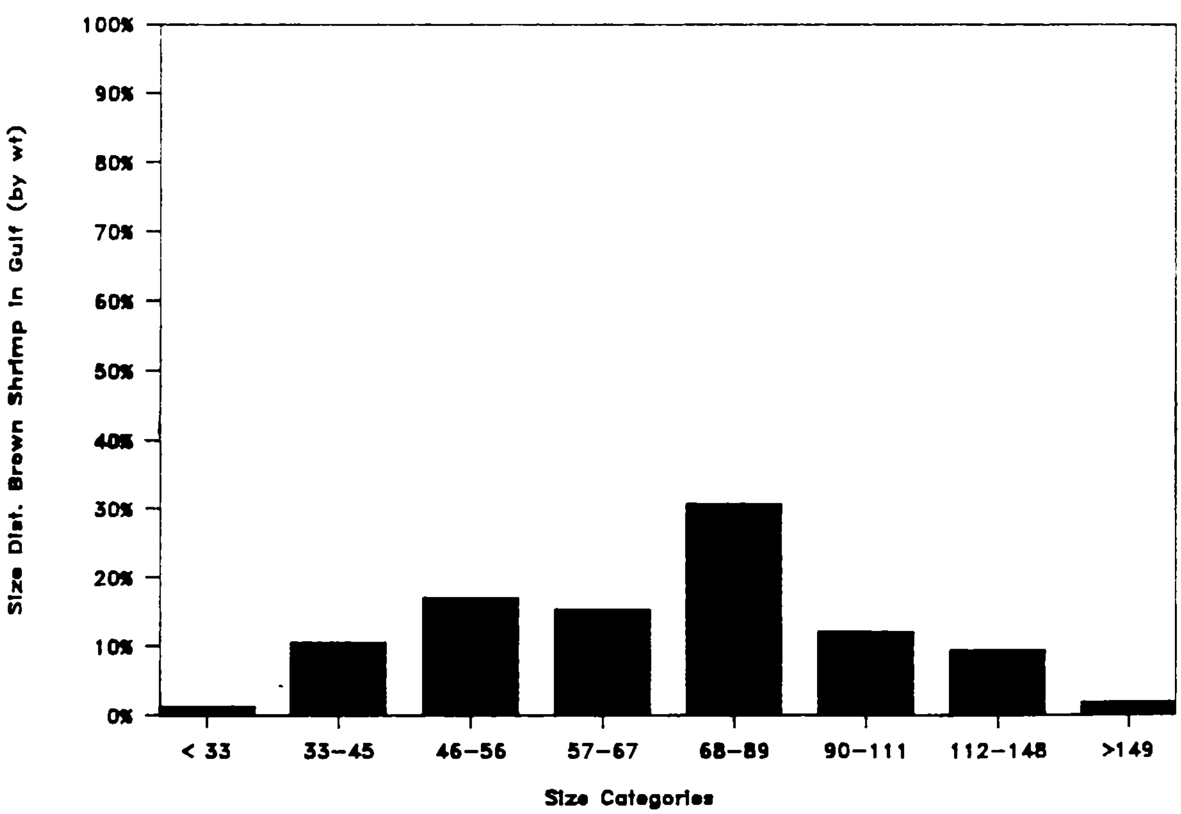
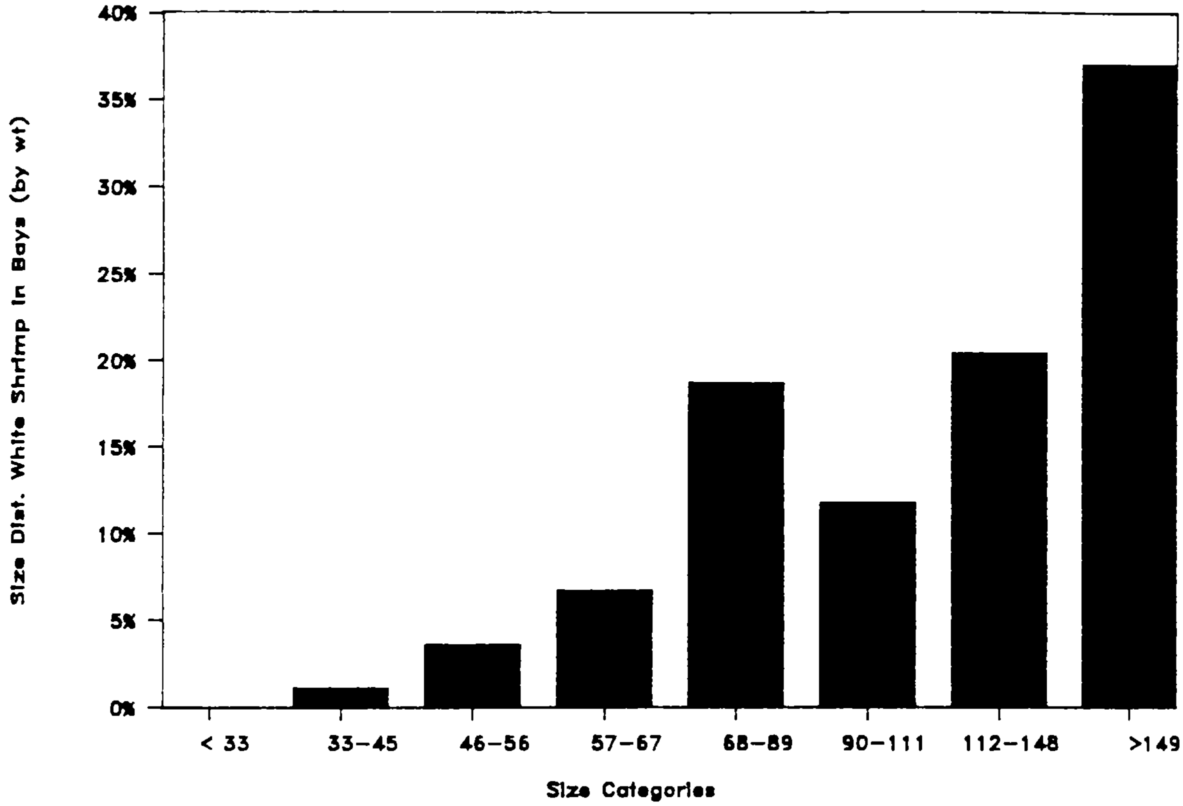

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Size Dist. Brown Shrimp In Gulf (by wt)
< 33
33-45
46-56
57-67
68-89
90-111
112-148
>149
Size Categories

Figure 3.11. Average size distribution in tails/kg of white shrimp caught in Texas bays and offshore gulf (1966-1986).


Size Dist. White Shrimp In Bays (by wt)
40%
35%
30%
25%
20%
15%
10%
5%
0%
< 33
33-45
46-56
57-67
68-89
90-111
112-148
>149
Size Categories

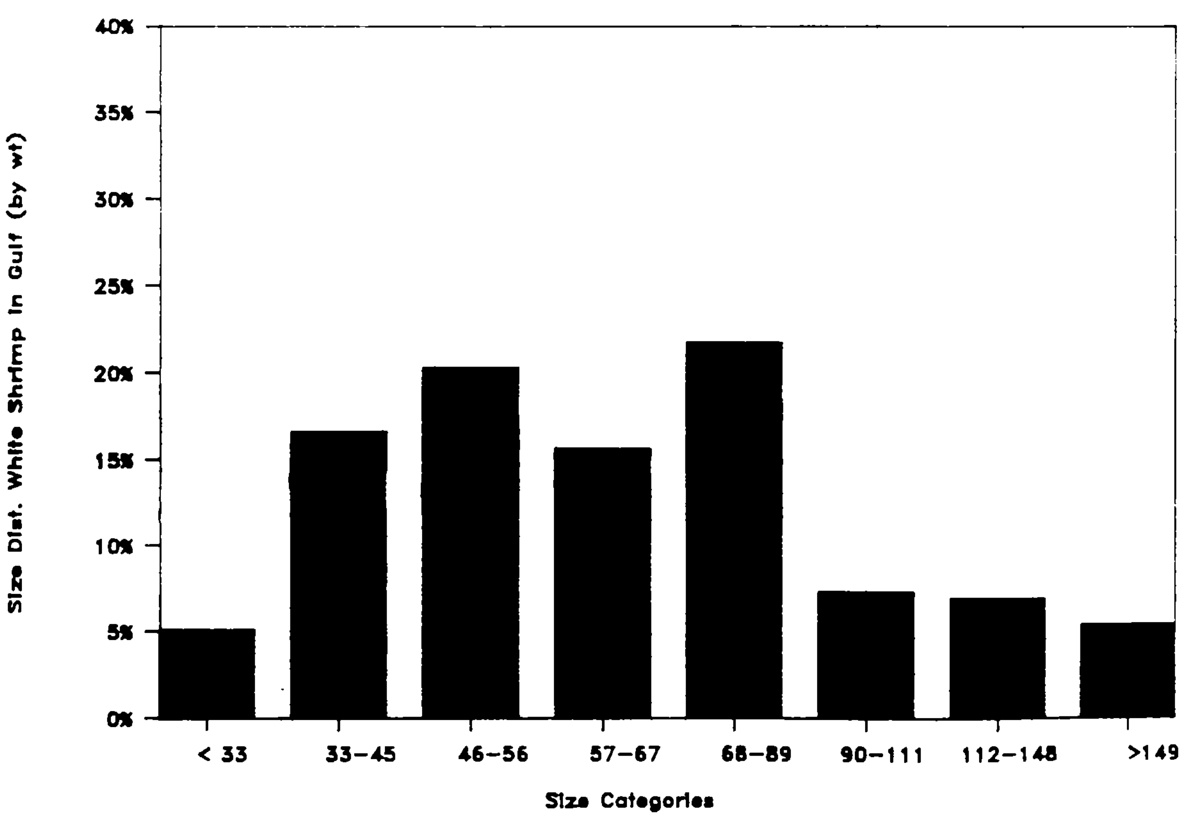
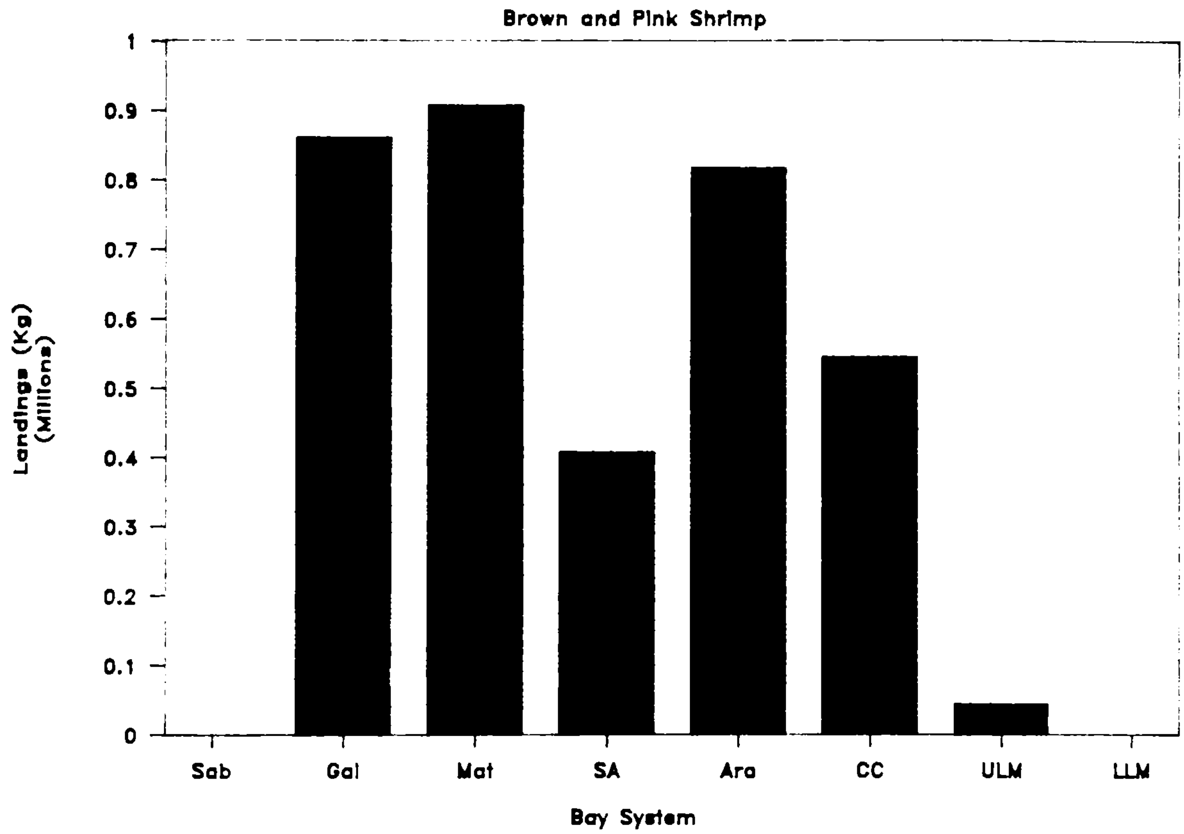

Size Dist. White Shrimp In Gulf (by wt)
40%
35%
30%
25%
20%
15%
10%
5%
0%
< 33
33-45
46-56
57-67
68-89
90-111
112-148
>149
Size Categories

Figure 3.12. Average reported landings (1977-1986) of penaeid shrimp by bay system.


Brown and Pink Shrimp
Landings (Kg)
(Millions)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Sab
Gal
Mat
SA
Ara
CC
ULM
LLM
Bay System

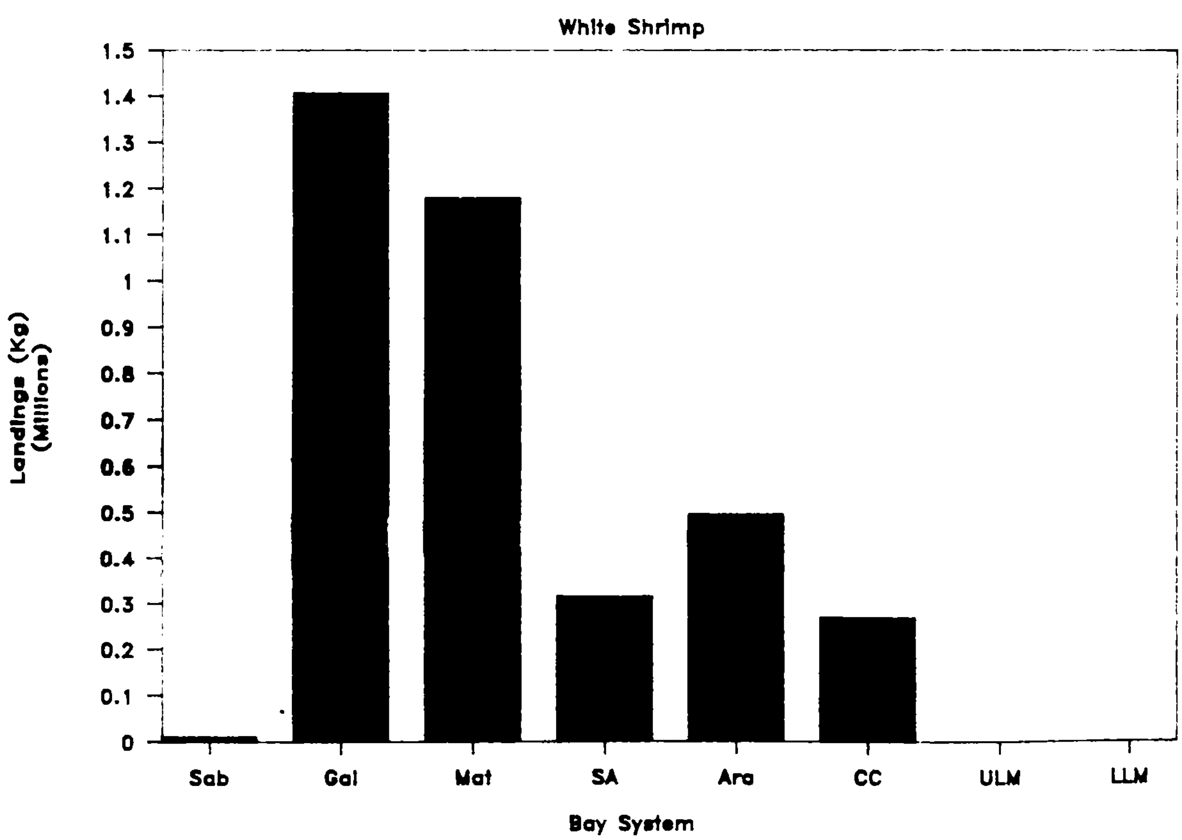
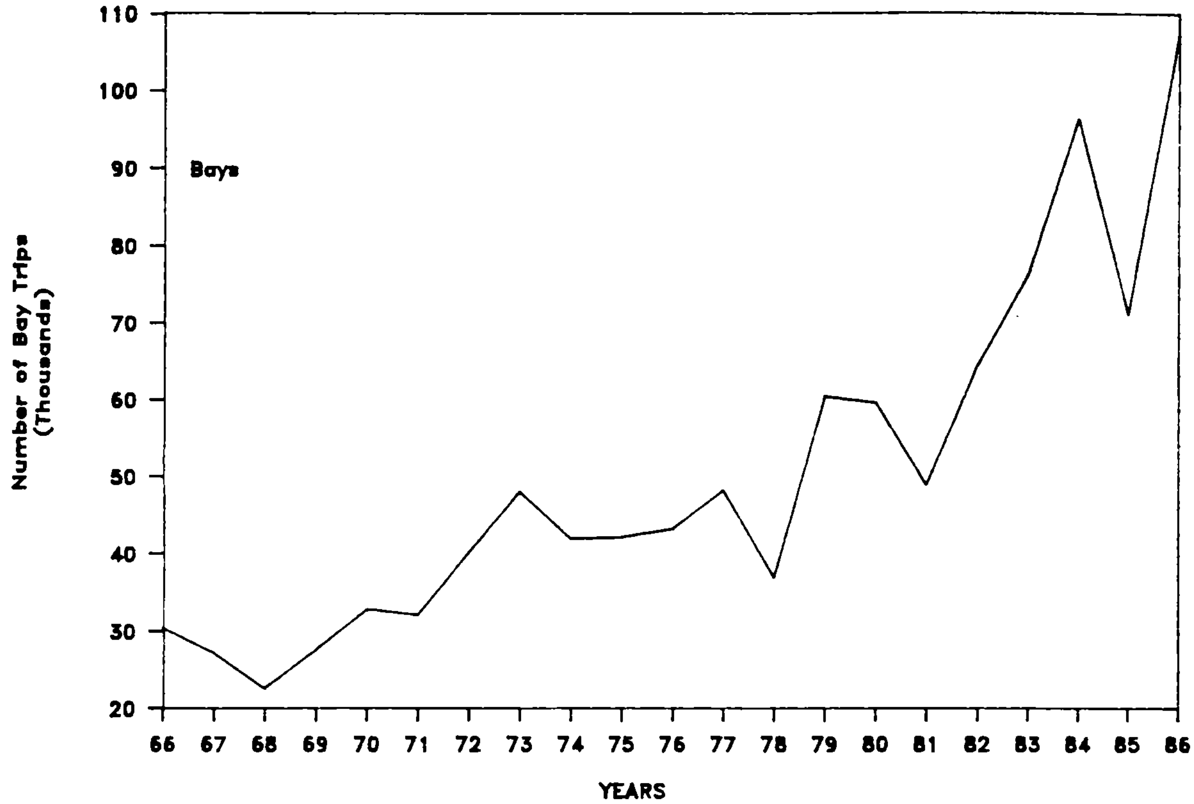

White Shrimp
Landings (Kg)
(Millions)
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Sab
Gal
Mat
SA
Ara
CC
ULM
LLM
Bay System

Figure 3.13. Number of trips by vessels fishing in Texas bays and gulf waters (1966-1986). (From: Gulf Coast Shrimp Data--various years, and National Marine Fisheries Service).


Bays
Number of Bay Trips (Thousands)
110
100
90
80
70
60
50
40
30
20
66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86
YEARS

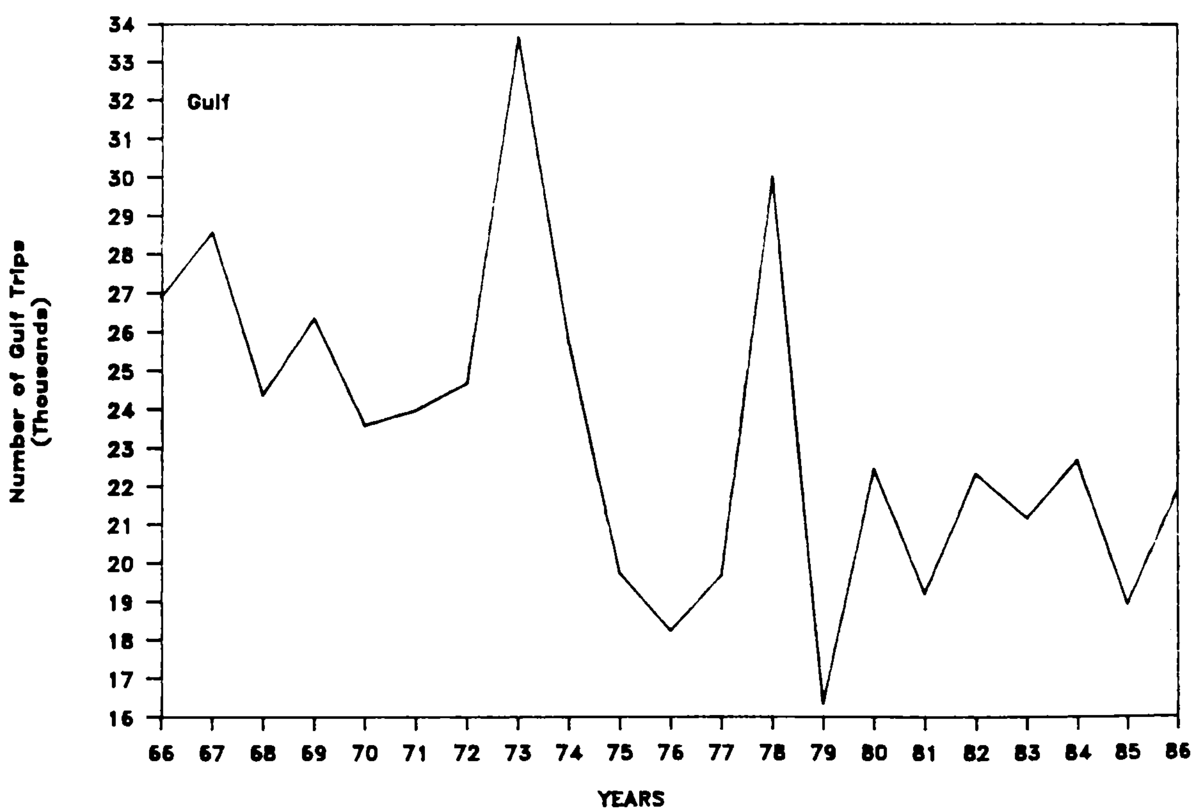

Gulf
Number of Gulf Trips (Thousands)
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86
YEARS

Figure 3.14. Number of Texas shrimp boat licenses sold by year (1959-1988).

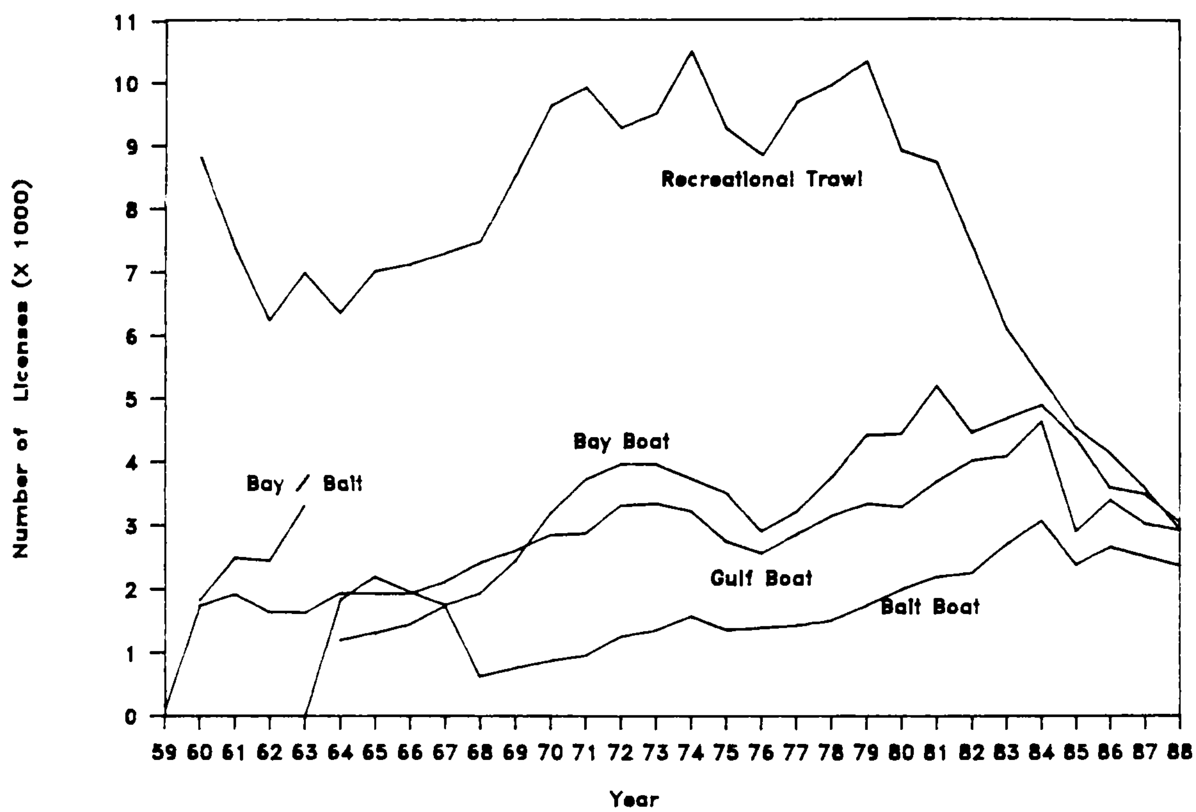
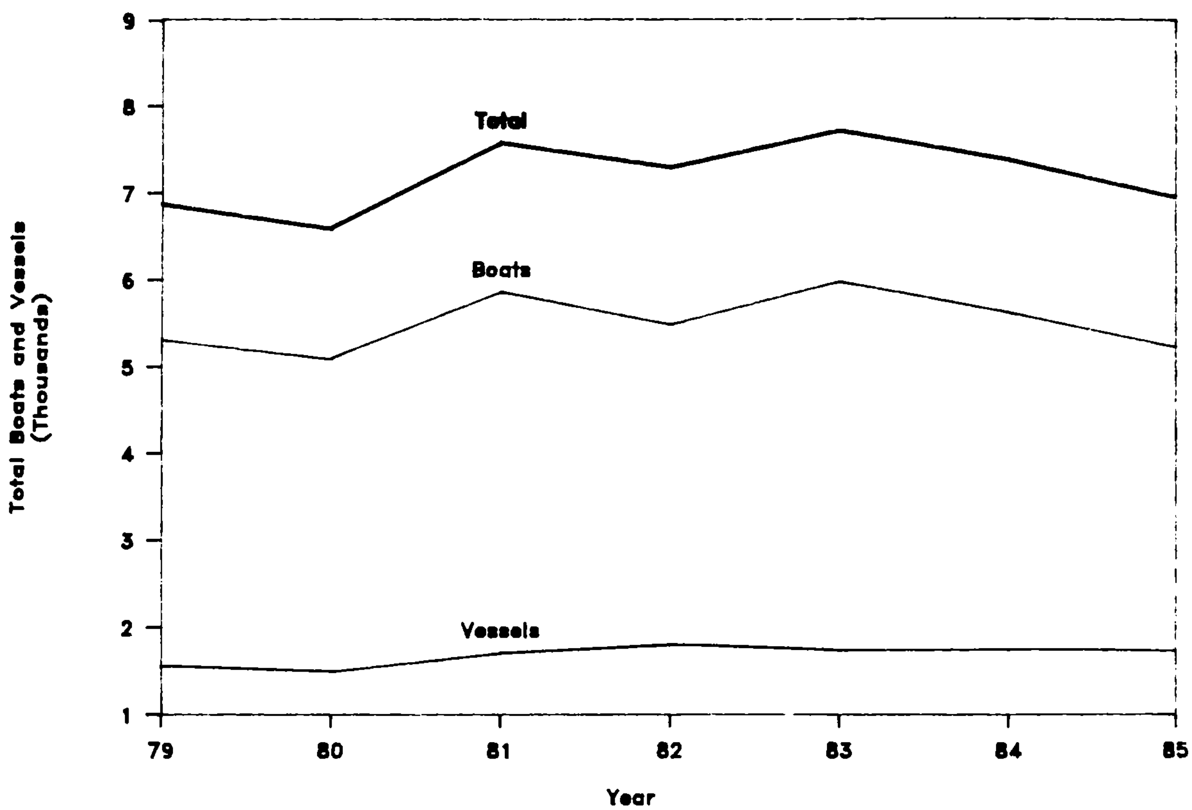

11
10
9
8
7
6
5
4
3
2
1
0
Number of Licenses (X 1000)
59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88
Year
Recreational Trawl
Bay Boat
Bay / Bait
Gulf Boat
Bait Boat

Figure 3.15. Total number of boats (<16.8 m) and vessels (>16.8 m) in Texas during 1979-1985 based on license sales by Texas Parks and Wildlife Department. (From: Crowe and Bryan 1987).

TEXAS



Total
Boats
Vessels
9
8
7
6
5
4
3
2
1
Total Boats and Vessels (Thousands)
79
80
81
82
83
84
85
Year

Figure 3.16. Total number of individual boats licensed (exclusive of duplication) with bay only, gulf only, bait only and any combination of licenses (1979-1985). (From: Crowe and Bryan 1987).

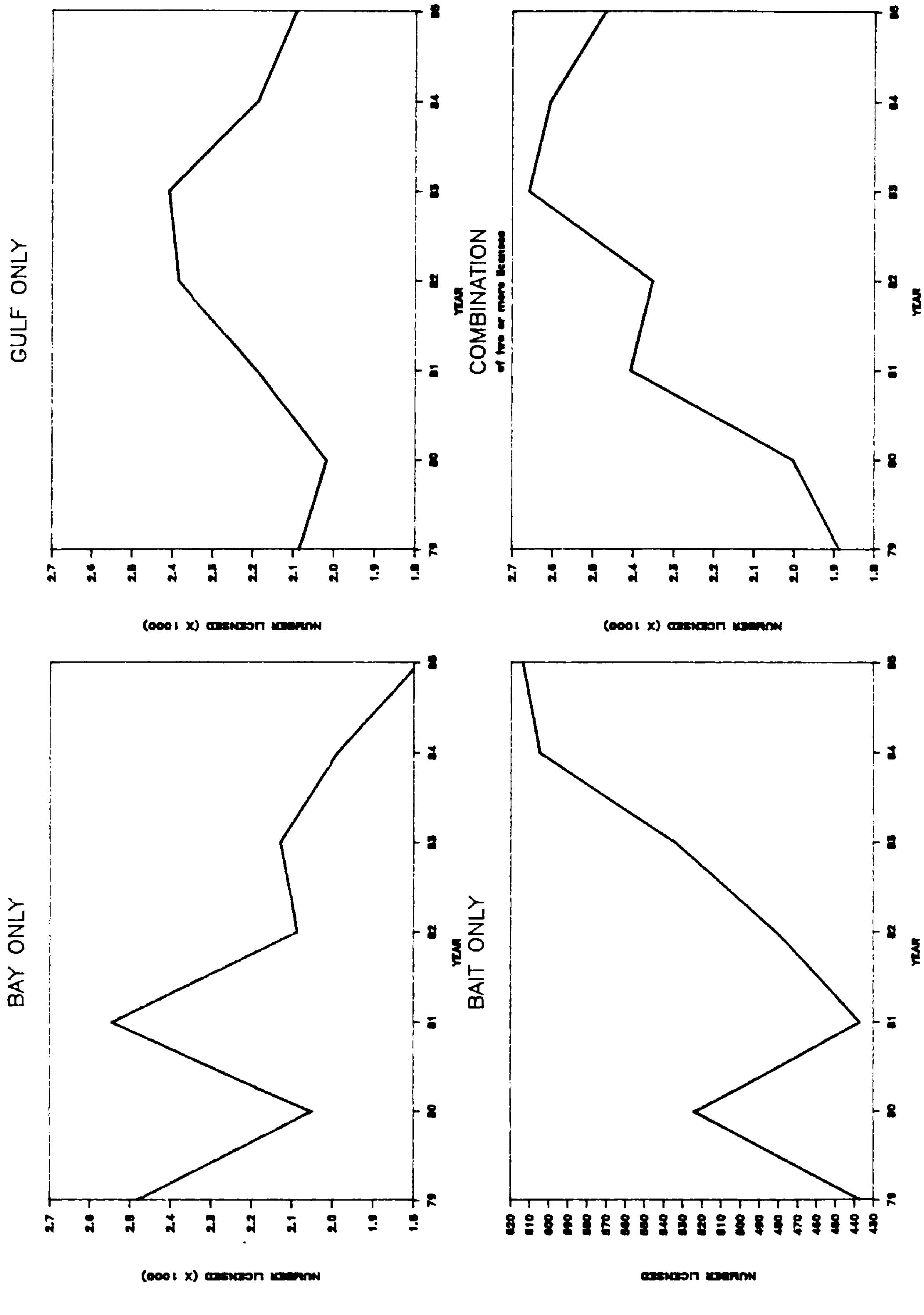

GULF ONLY
BAY ONLY
COMBINATION
of two or more licenses
BAIT ONLY
YEAR
NUMBER LICENSED (X 1000)
NUMBER LICENSED

Figure 3.17. Total number of combination licensed boats (1979-1985). (From: Crowe and Bryan 1987).

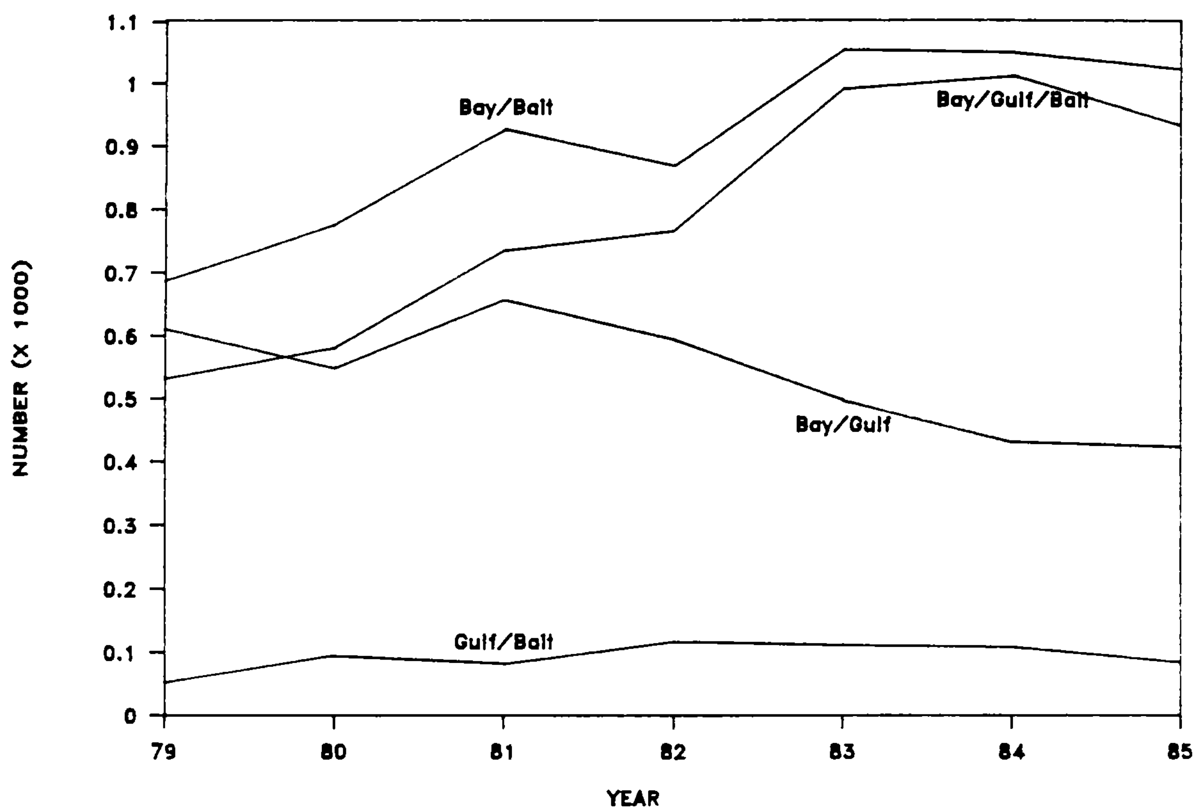

Bay/Balt
Bay/Gulf/Balt
Bay/Gulf
Gulf/Balt
NUMBER (X 1000)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
79
80
81
82
83
84
85
YEAR

Figure 3.18. Landings (kg) per license for the Gulf of Mexico and Texas bays combined (1964-1987).

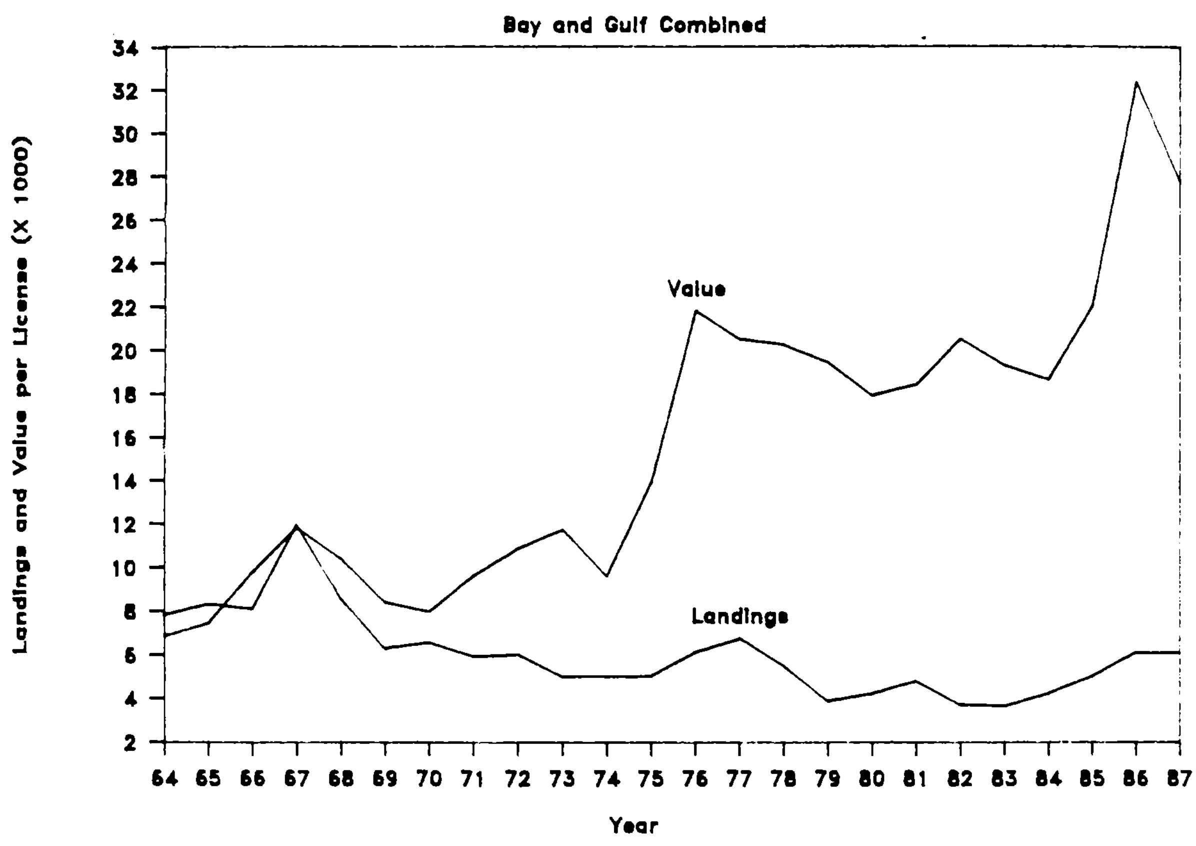
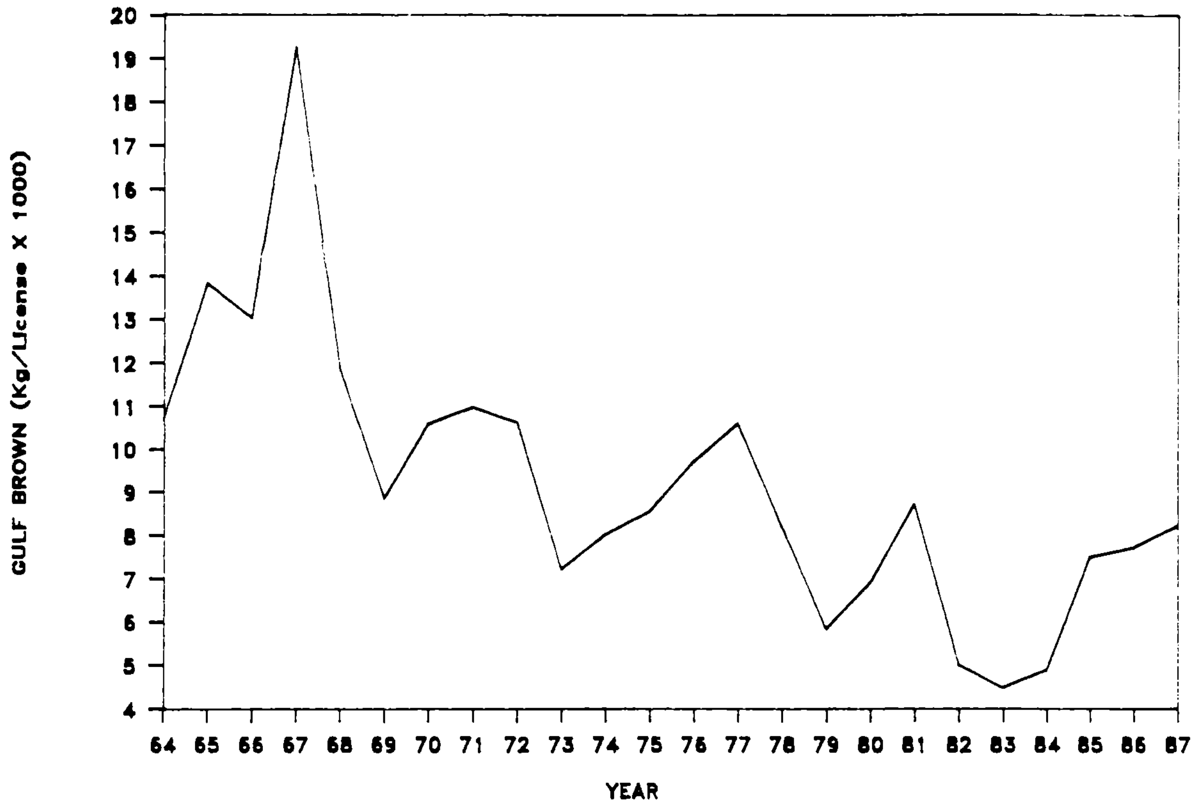

Bay and Gulf Combined
Landings and Value per License (X 1000)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
Value
Landings
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.19 Brown and pink shrimp landings (kg) per license from the Gulf of Mexico and Texas bays (1964-1987).


GULF BROWN (Kg/License X 1000)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
YEAR

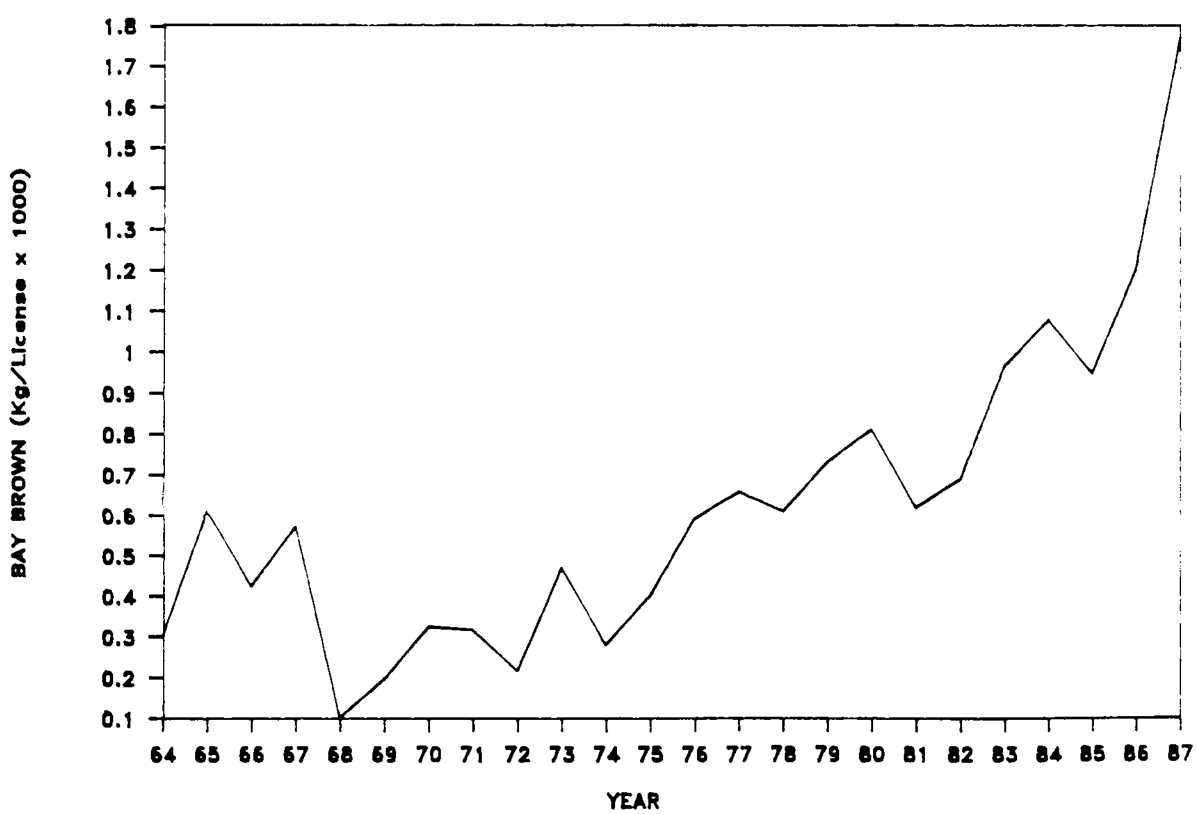
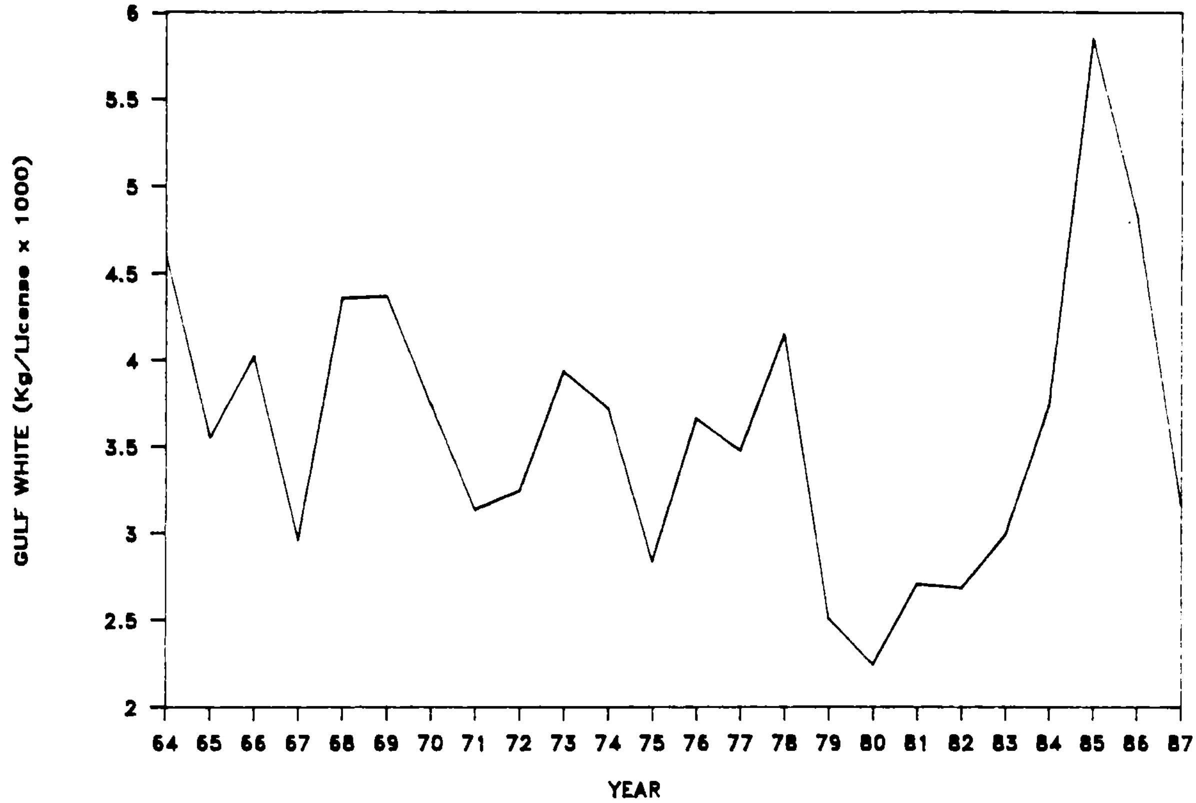

BAY BROWN (Kg/License x 1000)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
YEAR

Figure 3.20 White shrimp landings (kg) per license from the Gulf of Mexico and Texas bays (1964-1987).


GULF WHITE (Kg/License x 1000)
6
5.5
5
4.5
4
3.5
3
2.5
2
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
YEAR

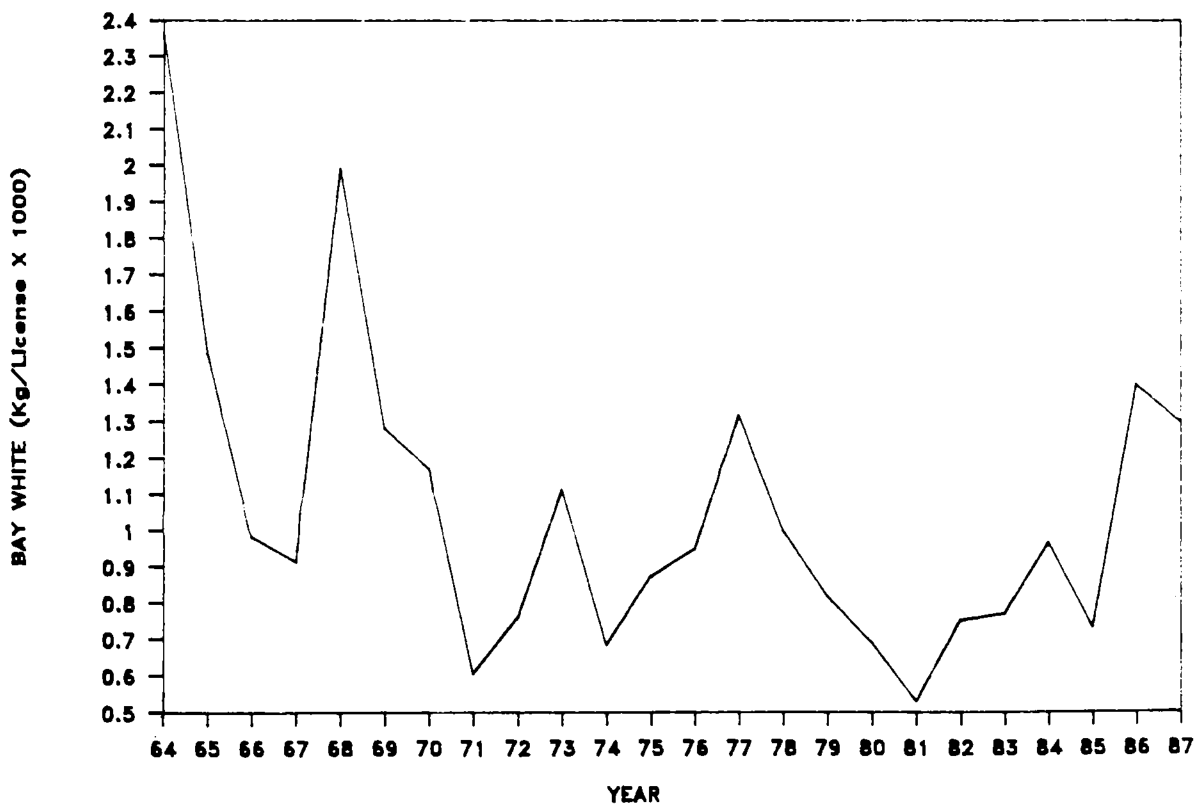
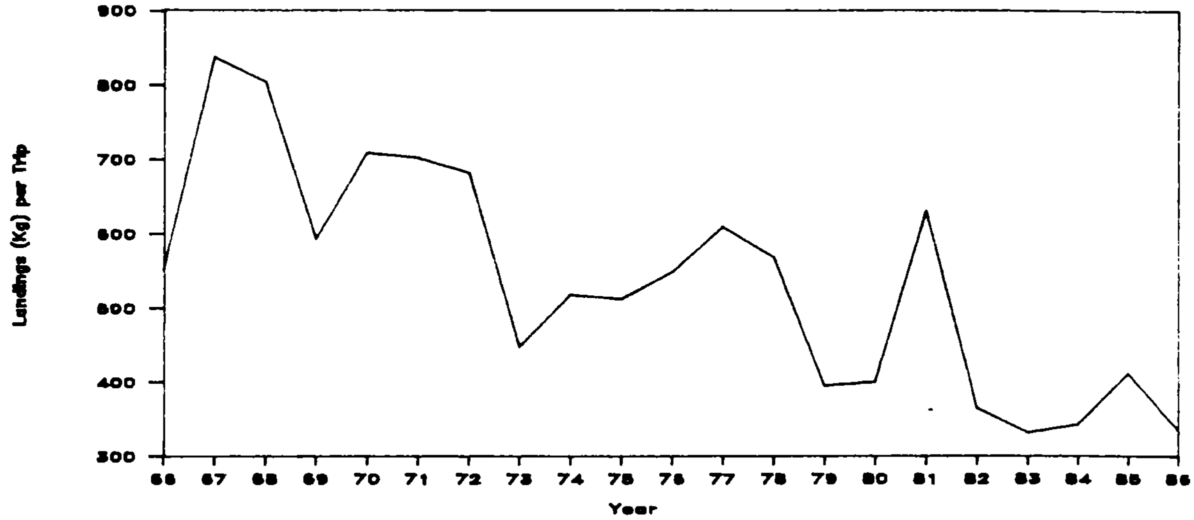
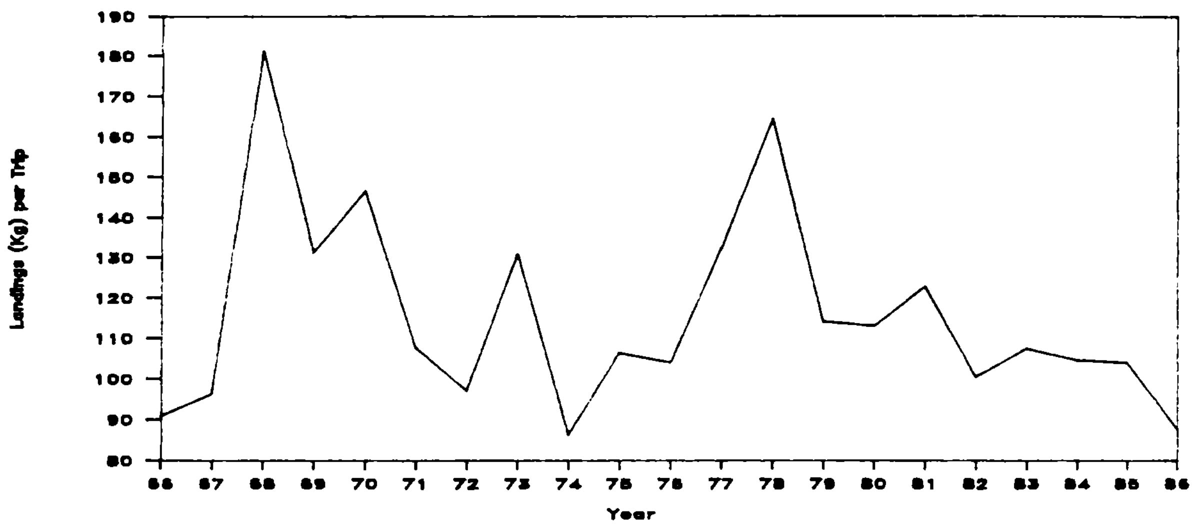

BAY WHITE (Kg/License X 1000)
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
YEAR

Figure 3.21. Total Texas landings (kg) per trip for bay and gulf combined, and bay and gulf separately (1966-1986).

Bay and Gulf



Bay



Gulf

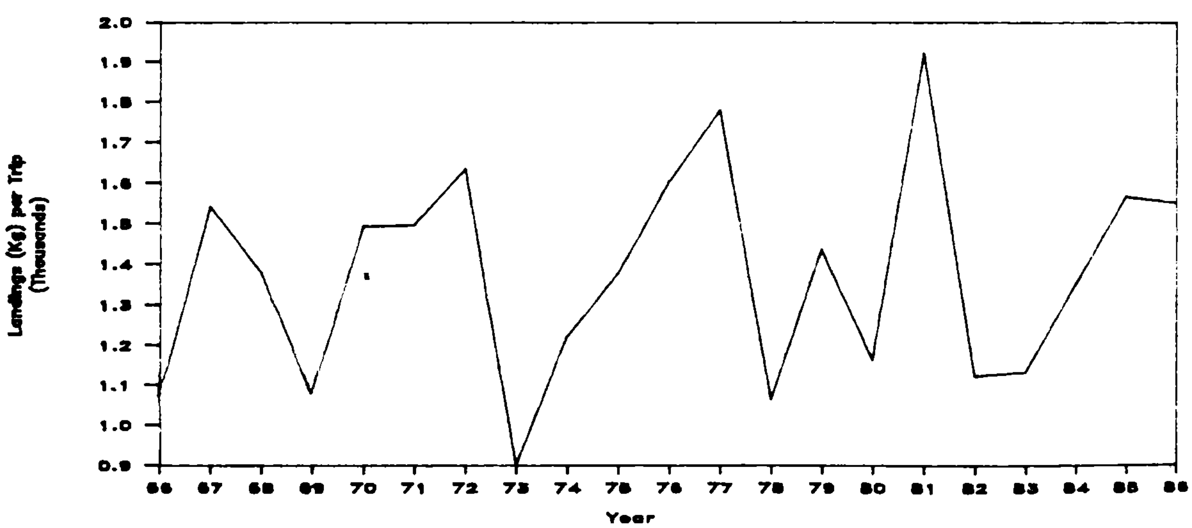


Figure 3.22. Value of product landed from the Brownsville/Port Isabel area and the Aransas Pass/Rockport area in relation to the top six seafood ports in the United States (1984-1986).

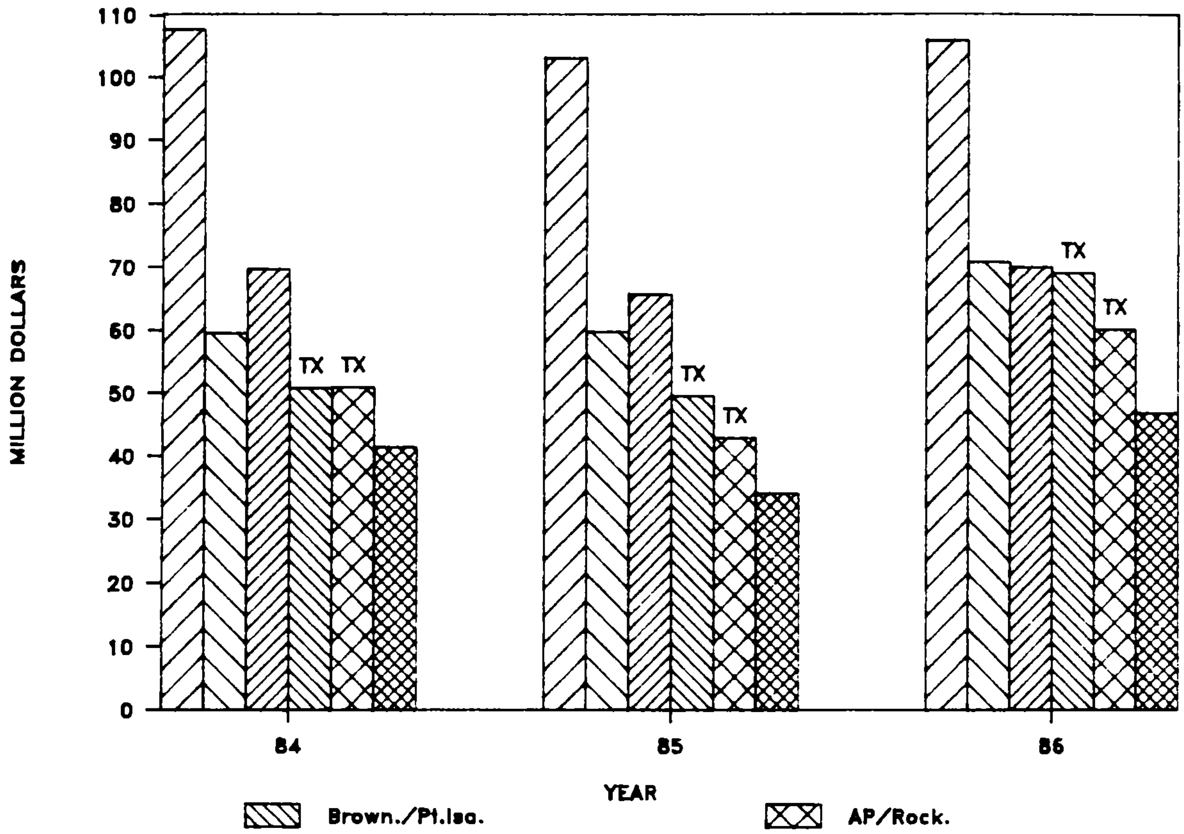

110
100
90
80
70
60
50
40
30
20
10
0
MILLION DOLLARS
TX
TX
TX
TX
TX
TX
84
85
86
YEAR
Brown./Pt.Isa.
AP/Rock.

Figure 3.23. Ex-vessel value of shrimp landings in the United States, the Gulf of Mexico and Texas (1984-1987).

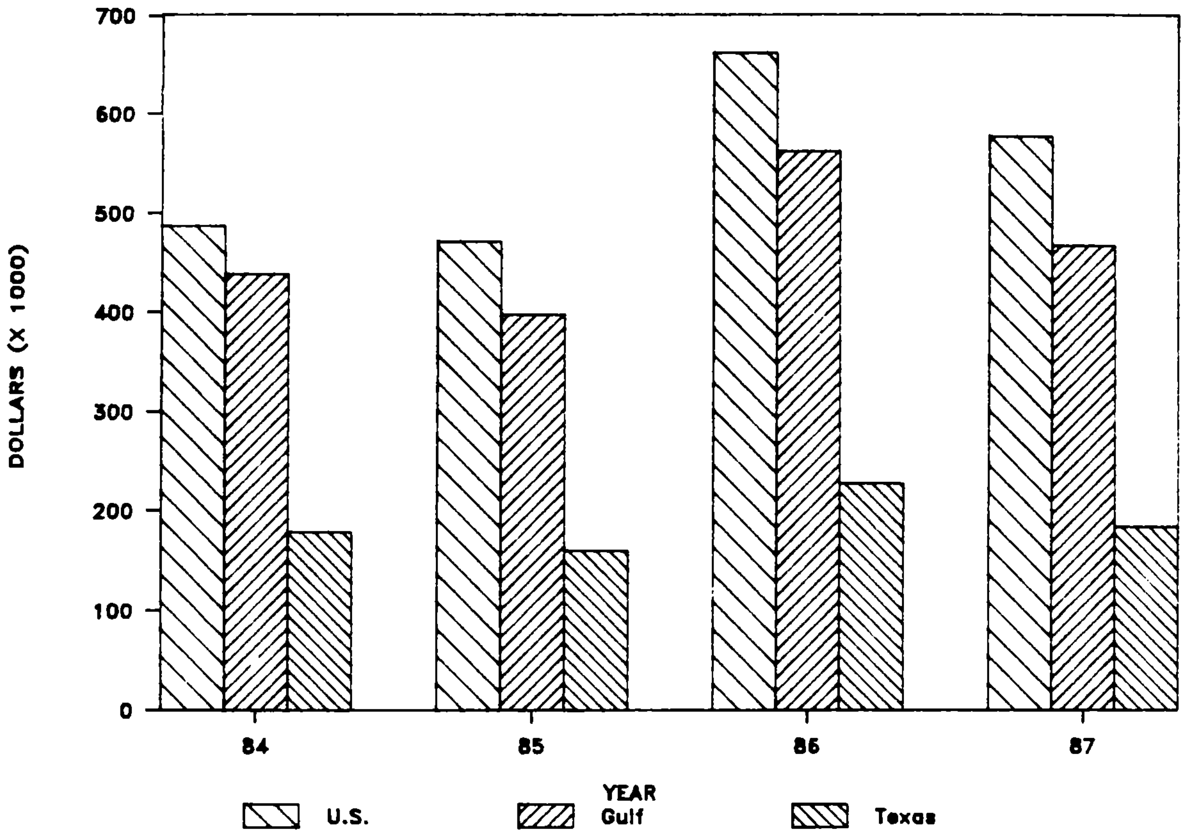

700
600
500
400
300
200
100
0
DOLLARS (X 1000)
84
85
86
87
YEAR
U.S.
Gulf
Texas

Figure 3.24. Total ex-vessel value of shrimp landed in the Gulf of Mexico (1958-1987).

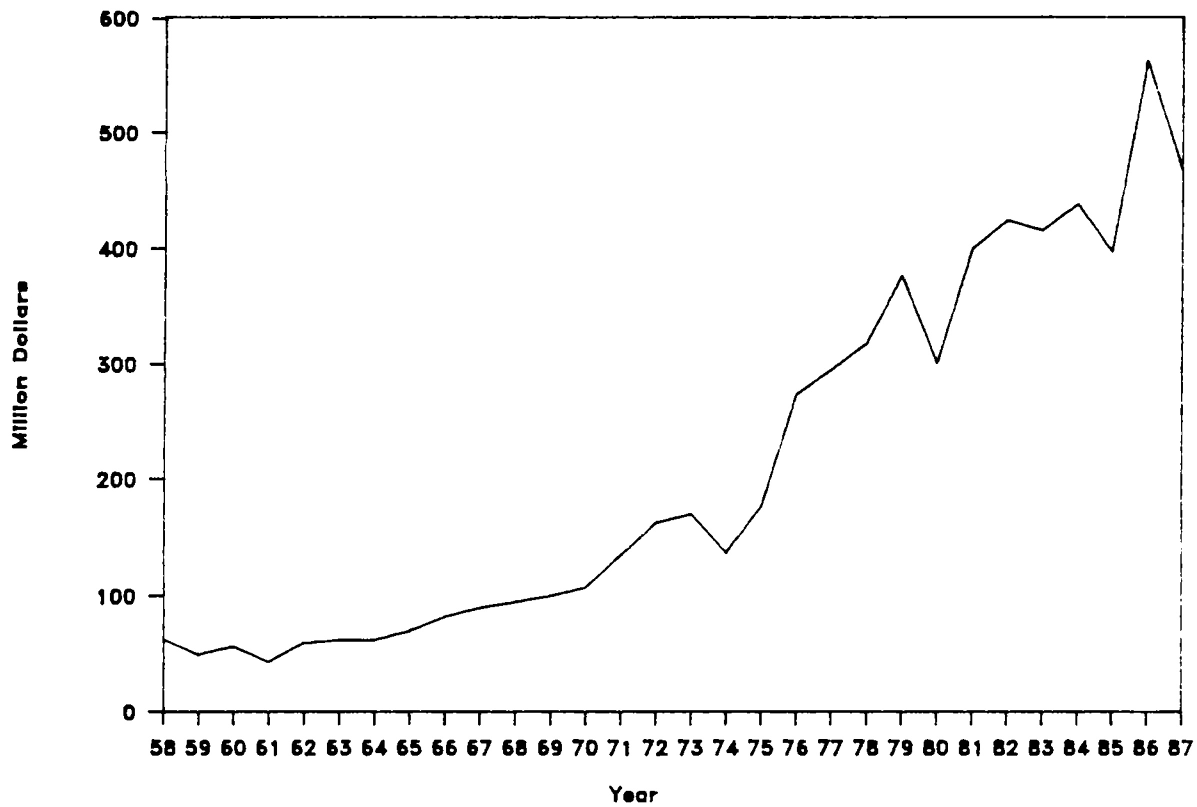
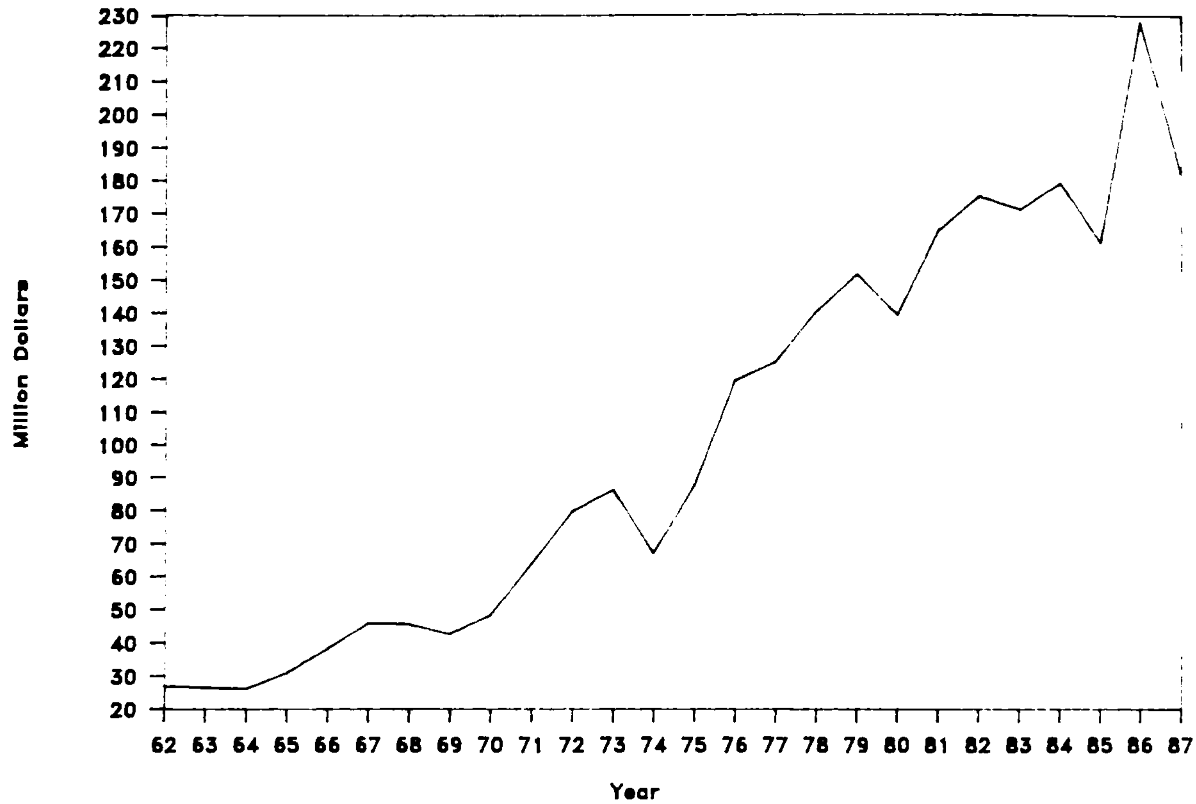

600
500
400
300
200
100
0
Million Dollars
58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.25. Total ex-vessel value of penaeid shrimp landed in Texas and ex-vessel value by species (1962-1987).


Million Dollars
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

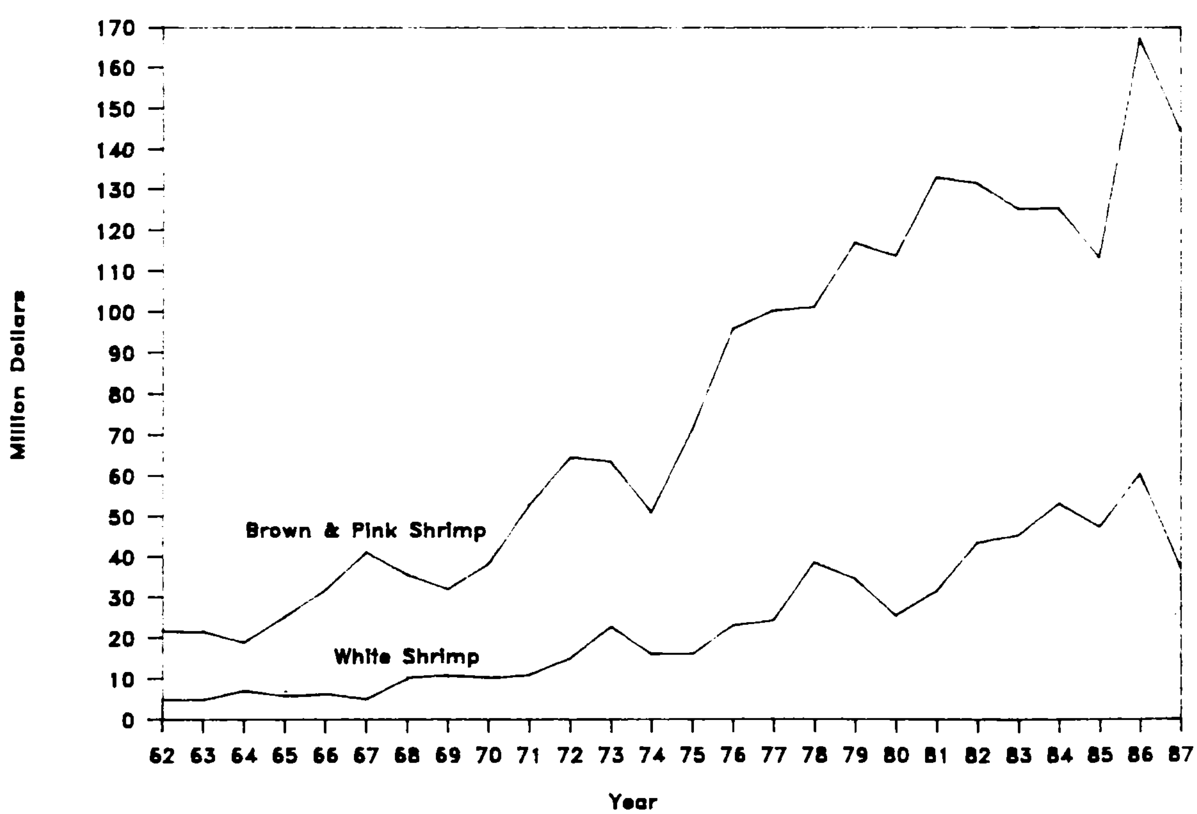

Million Dollars
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Brown & Pink Shrimp
White Shrimp
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.26. Average ex-vessel value/kg for shrimp from the Gulf of Mexico and Texas (1978-1987).

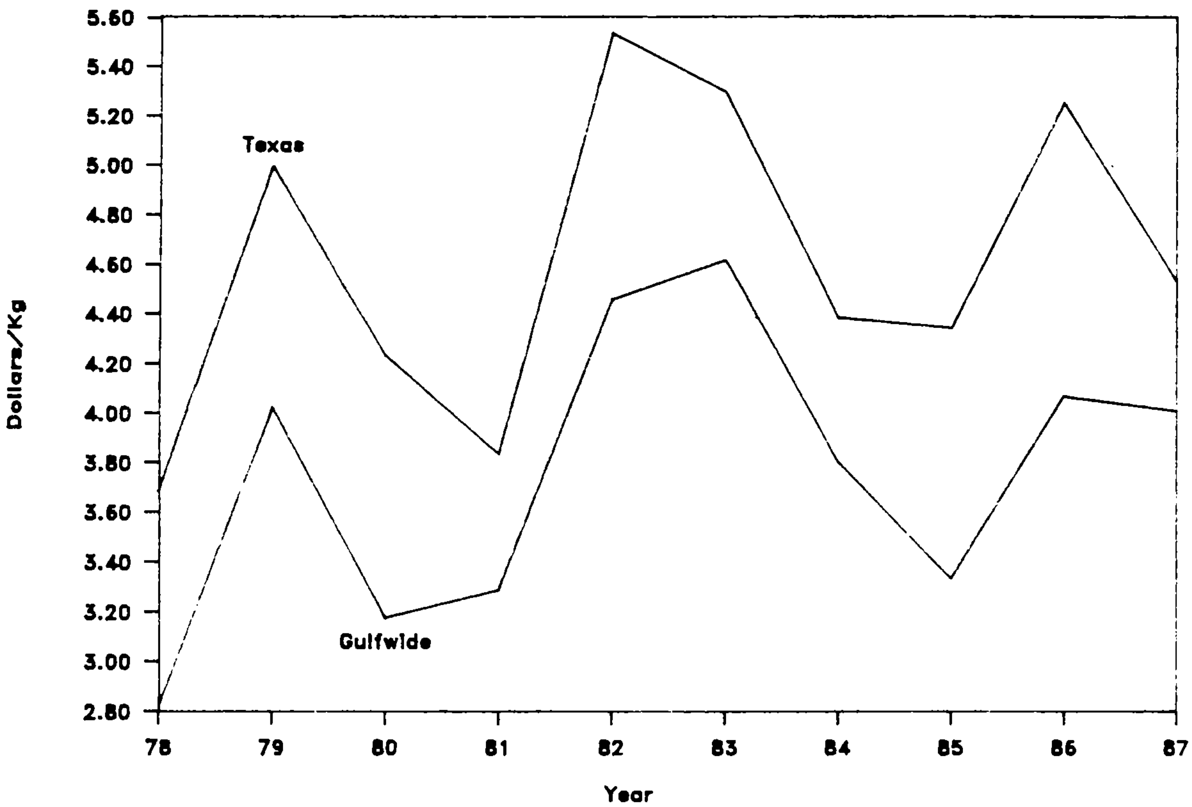
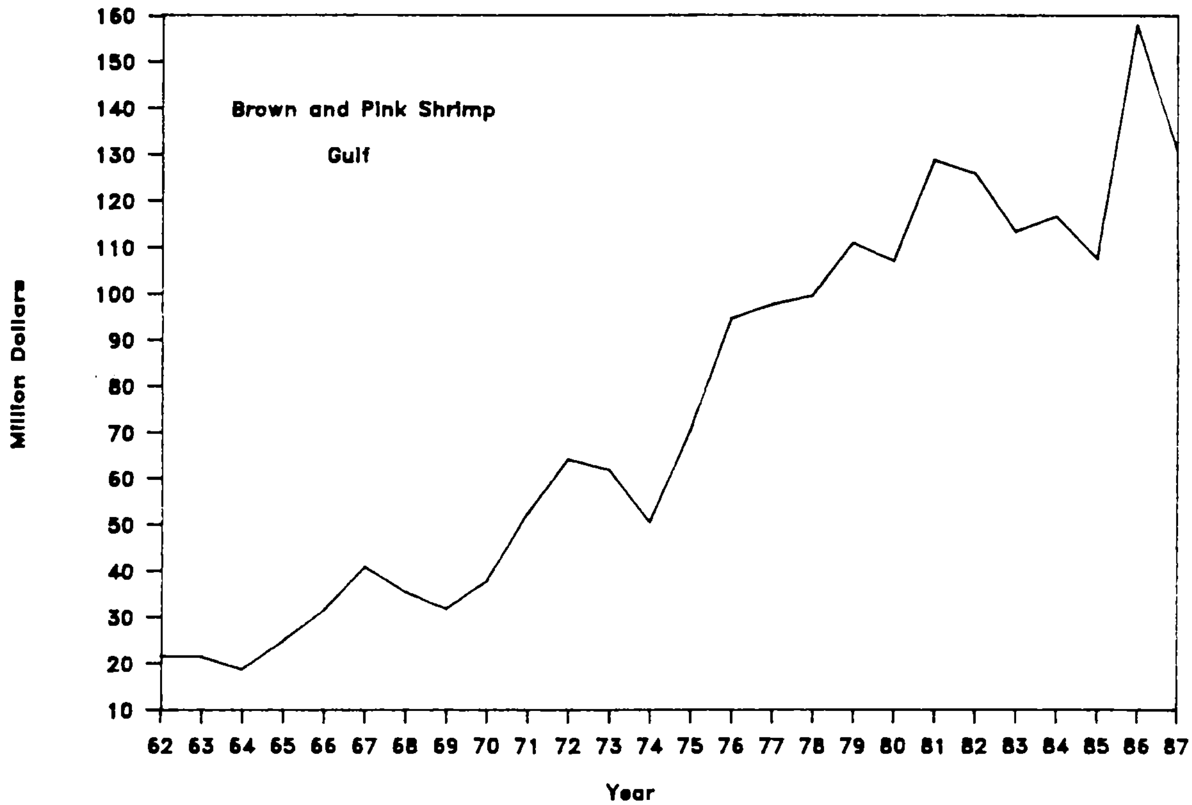

Dollars/Kg
5.60
5.40
5.20
5.00
4.80
4.60
4.40
4.20
4.00
3.80
3.60
3.40
3.20
3.00
2.80
Texas
Gulfwide
78
79
80
81
82
83
84
85
86
87
Year

Figure 3.27. Ex-vessel value of brown shrimp and pink shrimp landed from the Gulf of Mexico and bays in Texas (1962-1987).


Brown and Pink Shrimp
Gulf
Million Dollars
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

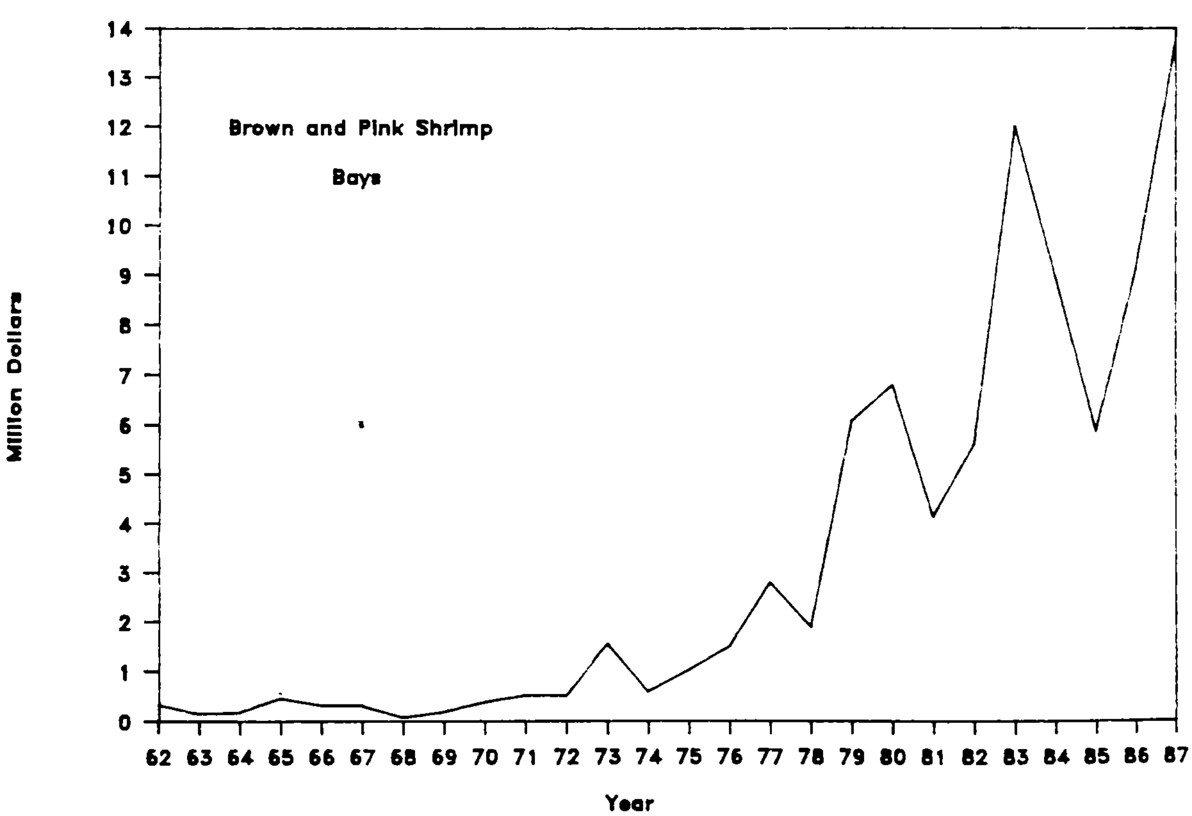
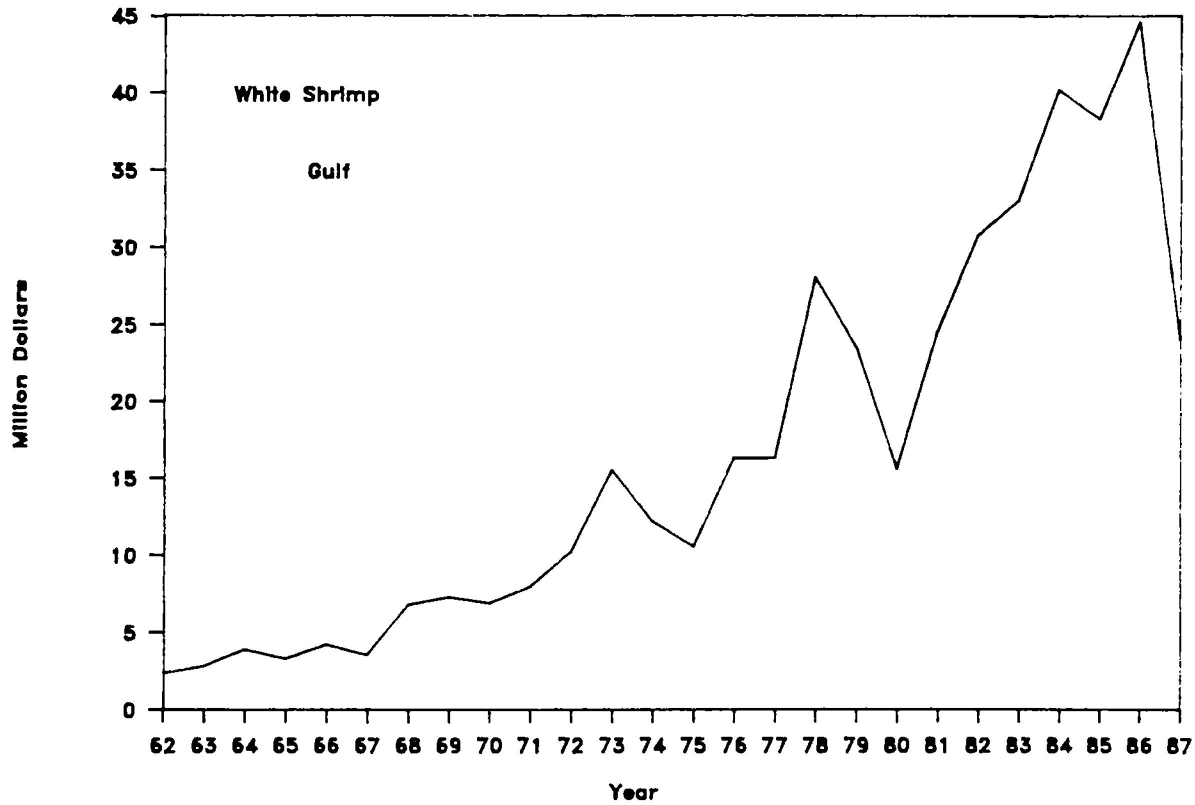

Brown and Pink Shrimp
Bays
Million Dollars
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.28. Ex-vessel value of white shrimp landed from the Gulf of Mexico and bays in Texas (1962-1987).


White Shrimp
Gulf
Million Dollars
45
40
35
30
25
20
15
10
5
0
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

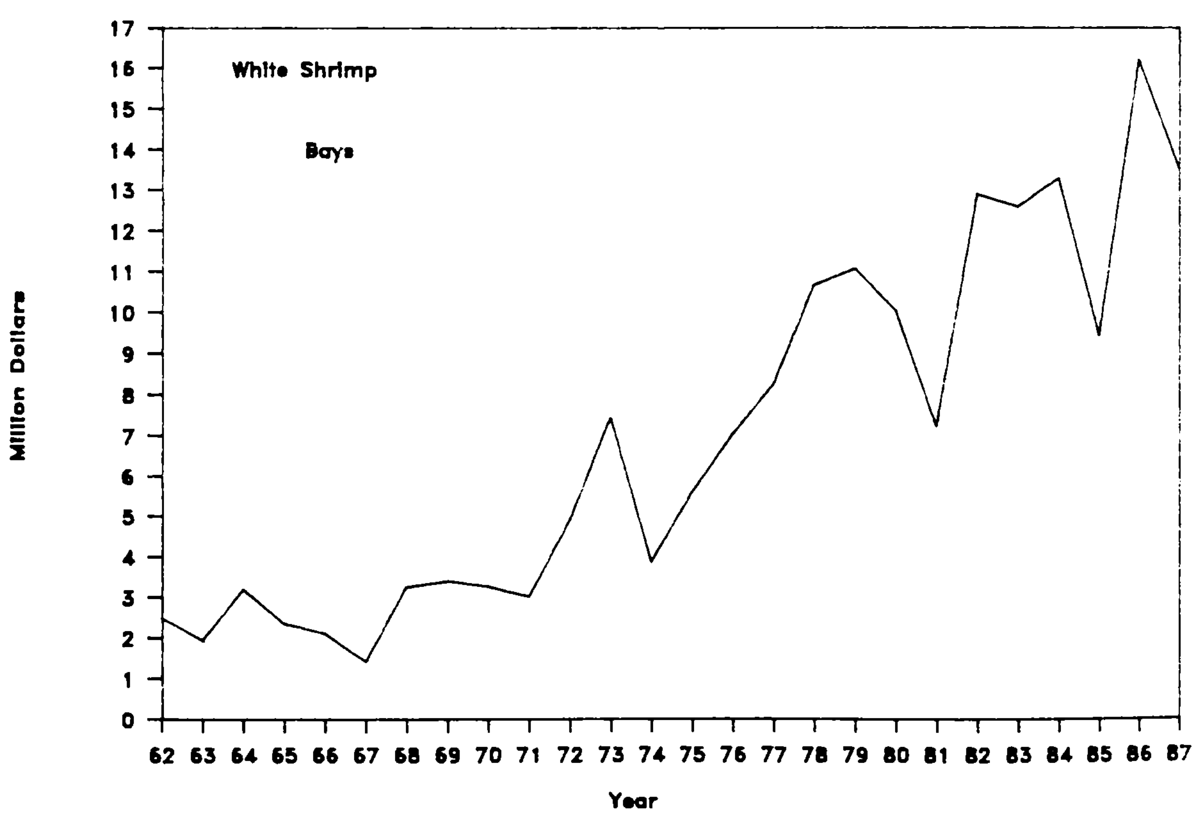
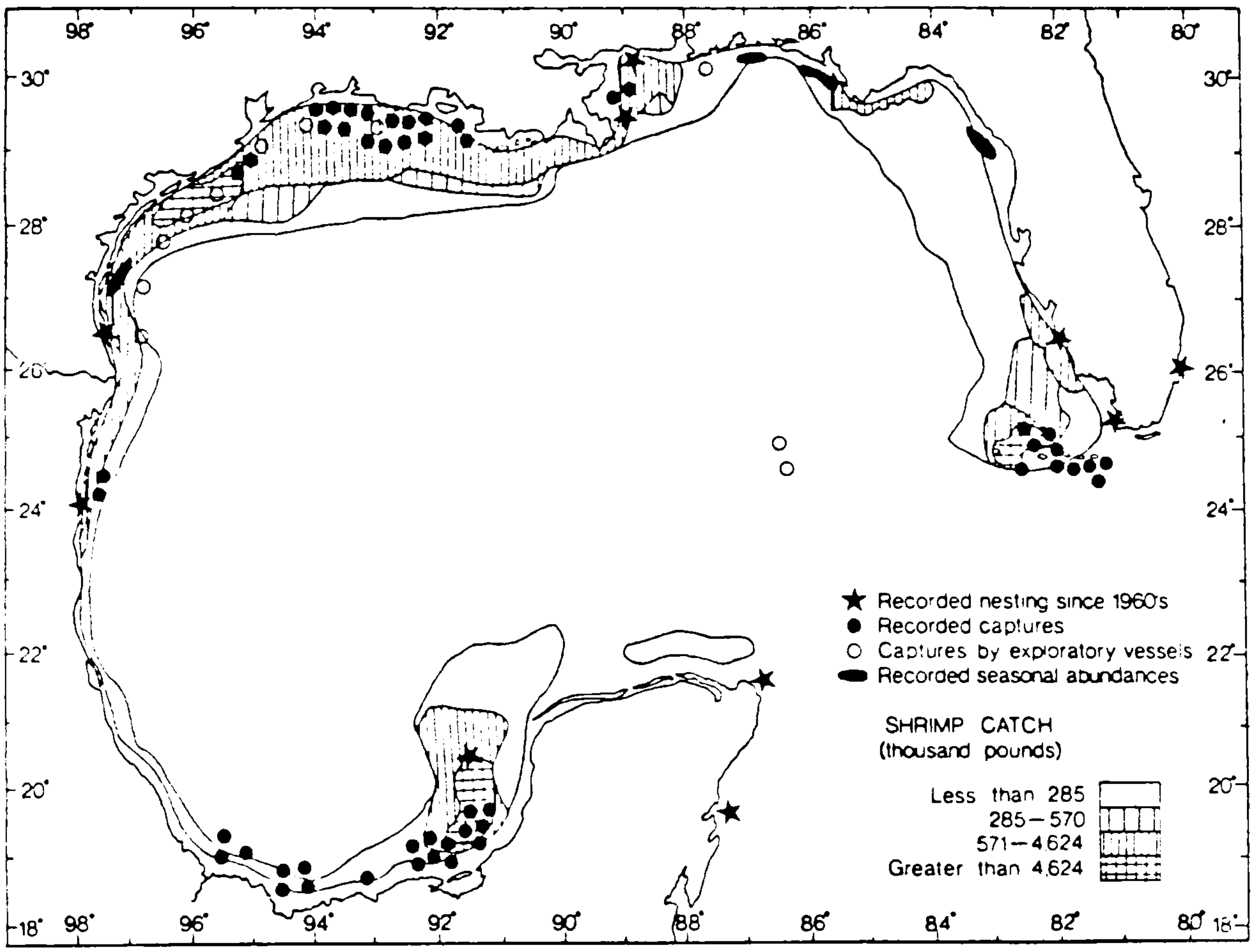
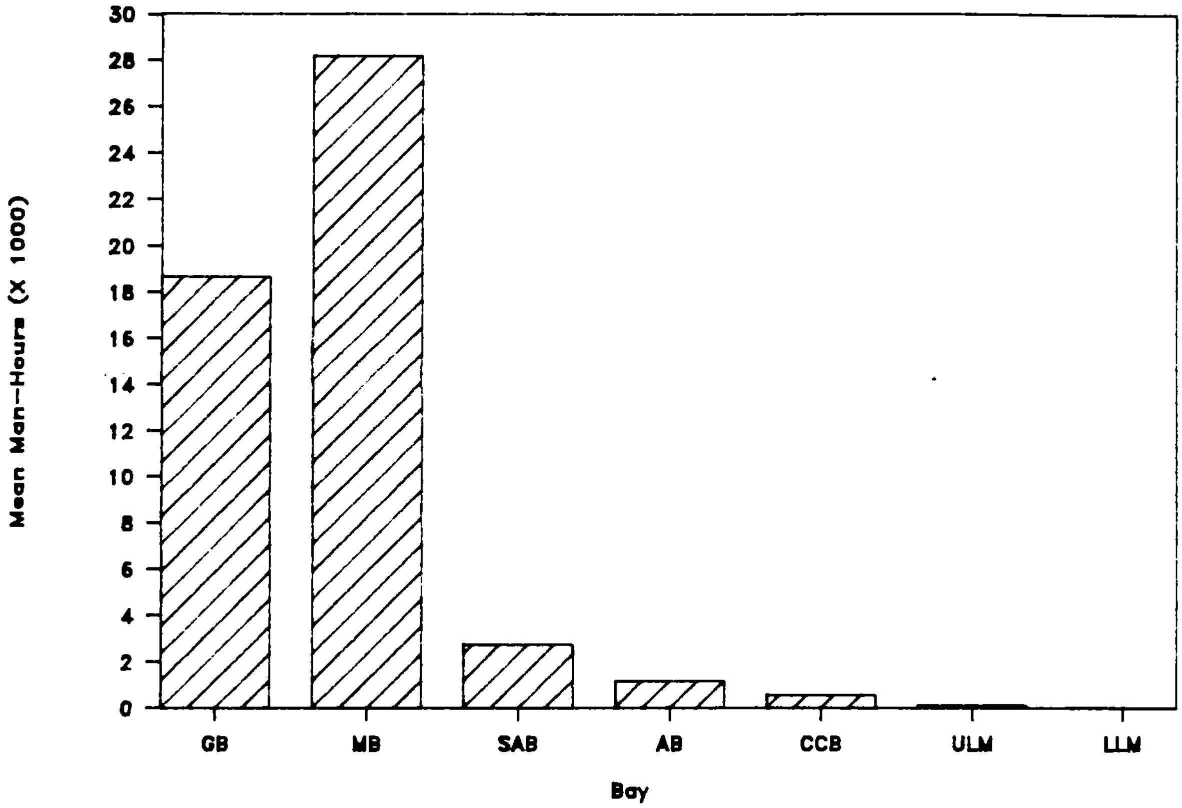

White Shrimp
Bays
Million Dollars
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87
Year

Figure 3.29. Reported sea turtle nesting and recaptures in relation to shrimping effort. (From: Van Lopik et al. 1980).

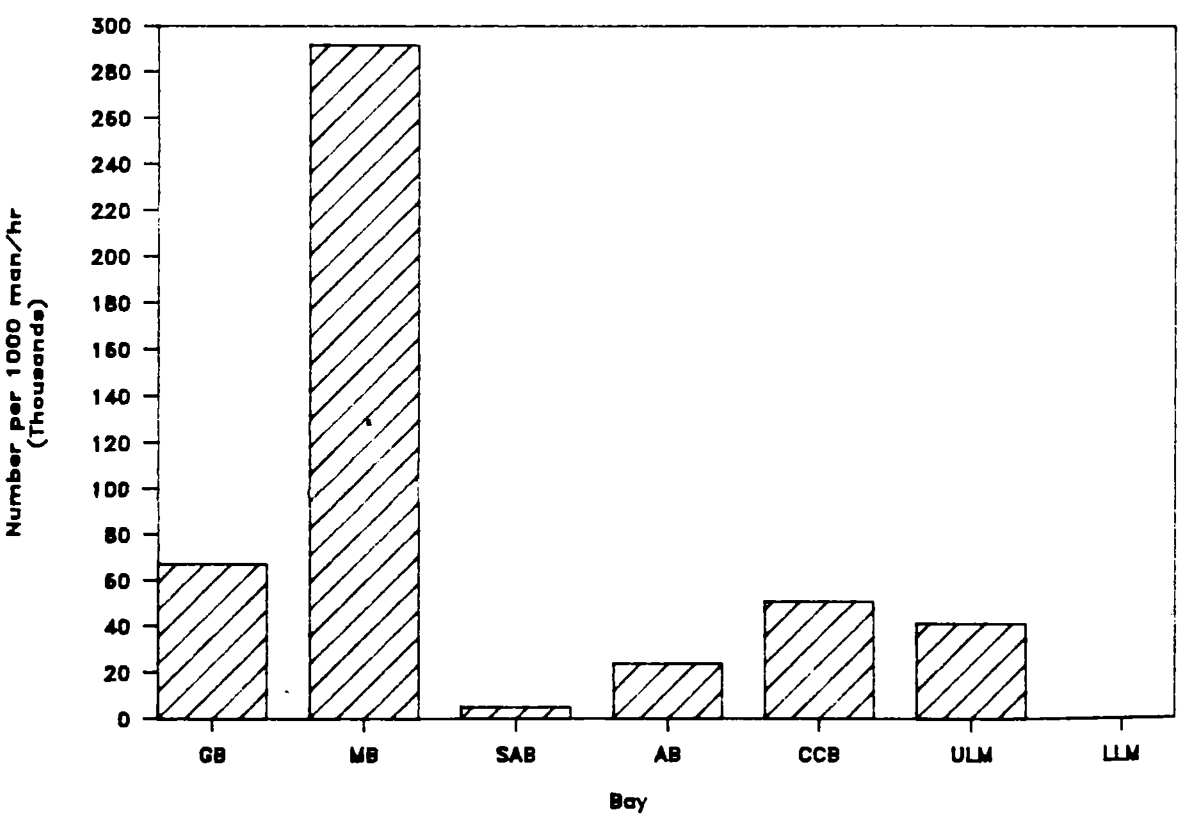


98° 96° 94° 92° 90° 88° 86° 84° 82° 80°
30° 28° 26° 24° 22° 20° 18°
Recorded nesting since 1960's
Recorded captures
Captures by exploratory vessels
Recorded seasonal abundances
SHRIMP CATCH
(thousand pounds)
Less than 285
285—570
571—4,624
Greater than 4,624

Figure 3.30. Mean man-hours exerted by recreational shrimpers by bay system, and mean number of shrimp per 1,000 man-hours (1983-1984). (GB = Galveston Bay, MB = Matagorda Bay, SAB = San Antonio Bay, AB = Aransas Bay, CCB = Corpus Christi Bay, ULM = upper Laguna Madre, LLM = lower Laguna Madre).



Mean Man-Hours (X 1000)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
GB
MB
SAB
AB
CCB
ULM
LLM
Bay



Number per 1000 man/hr
(Thousands)
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
GB
MB
SAB
AB
CCB
ULM
LLM
Bay

Figure 3.31. Major marketing channels for shrimp products. (Bold lines indicate major channels). (From: Gulf of Mexico Fishery Management Council 1981).

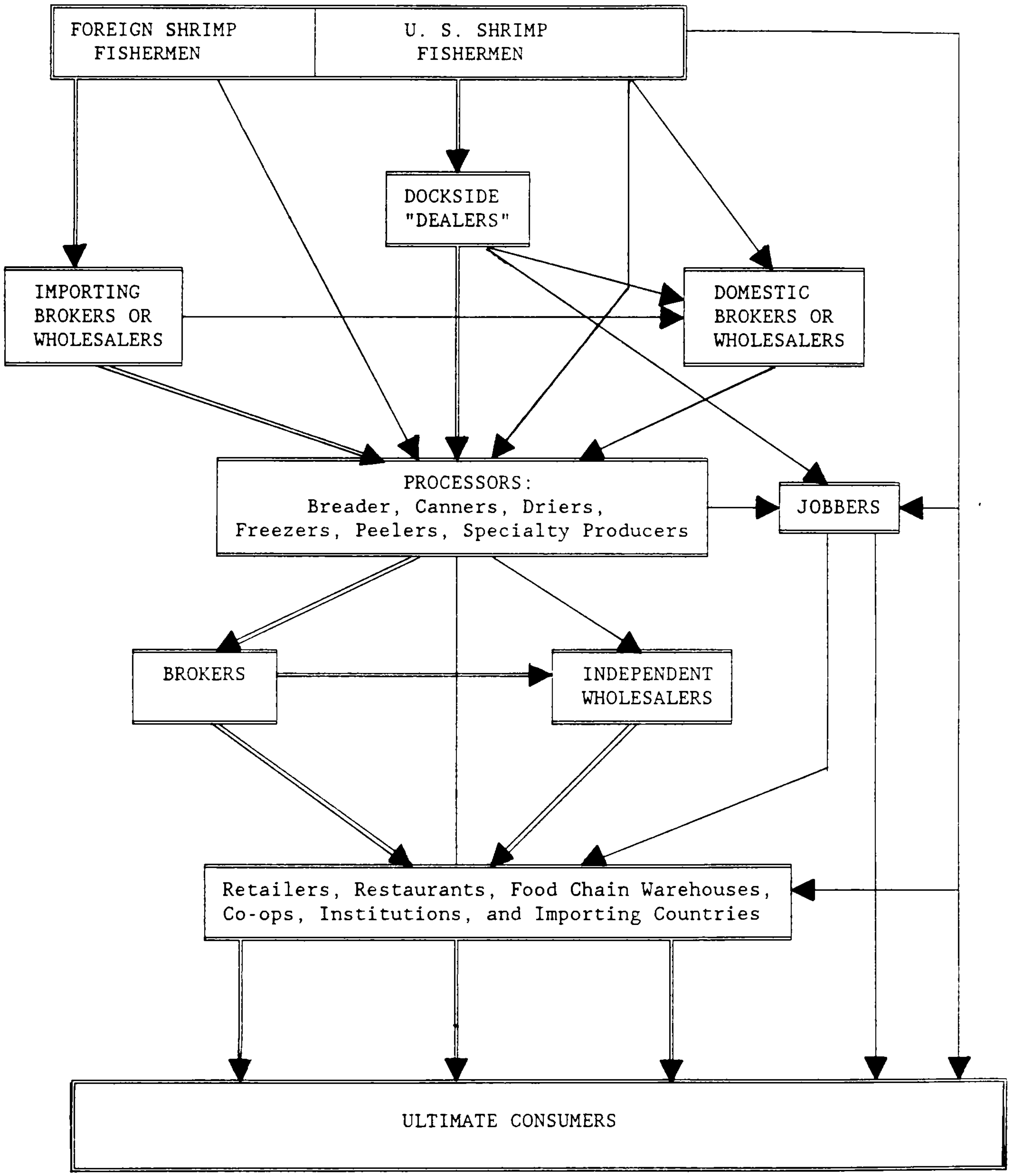

FOREIGN SHRIMP FISHERMEN
U. S. SHRIMP FISHERMEN
DOCKSIDE "DEALERS"
IMPORTING BROKERS OR WHOLESALERS
DOMESTIC BROKERS OR WHOLESALERS
PROCESSORS: Breader, Canners, Driers, Freezers, Peelers, Specialty Producers
JOBBERS
BROKERS
INDEPENDENT WHOLESALERS
Retailers, Restaurants, Food Chain Warehouses, Co-ops, Institutions, and Importing Countries
ULTIMATE CONSUMERS

Figure 3.32. World shrimp landings, 1956-1982 and estimated landings for 1983-1990. (From: Chamberlain 1985 adapted from Vondruska 1984).

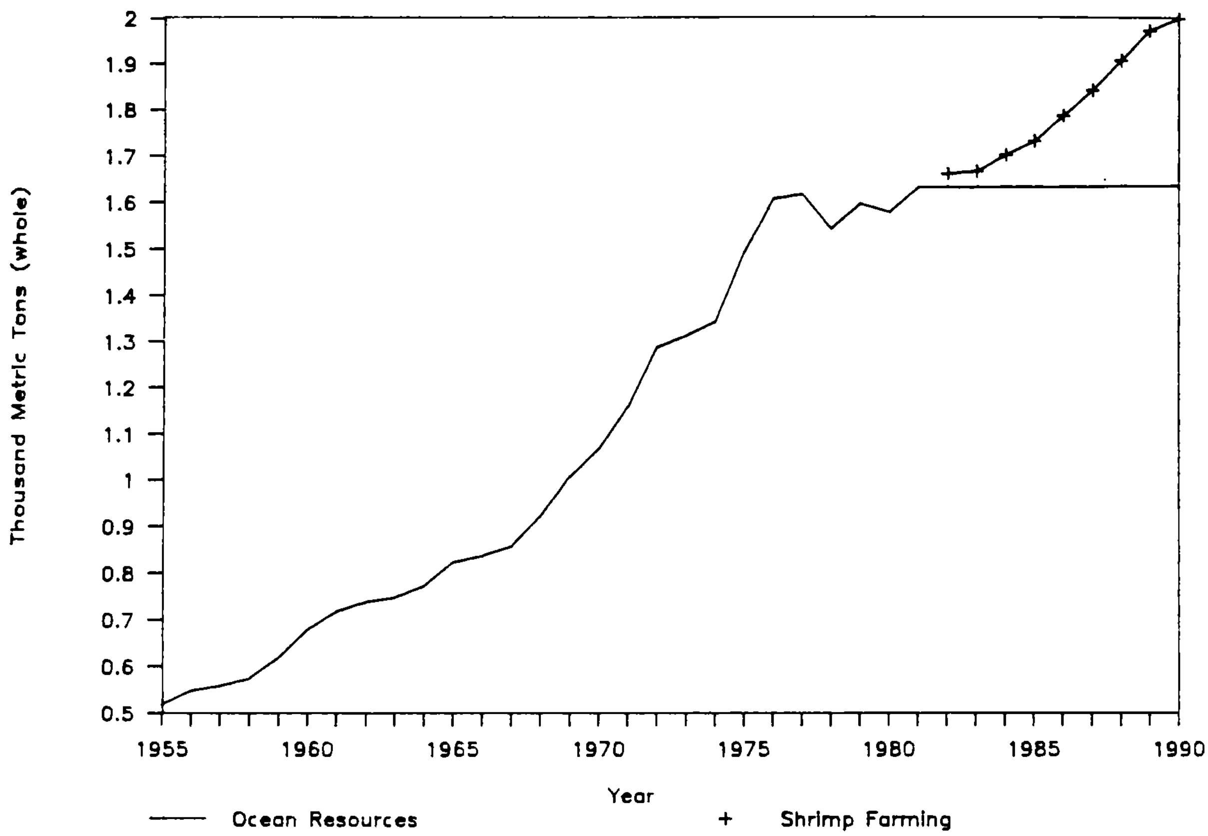
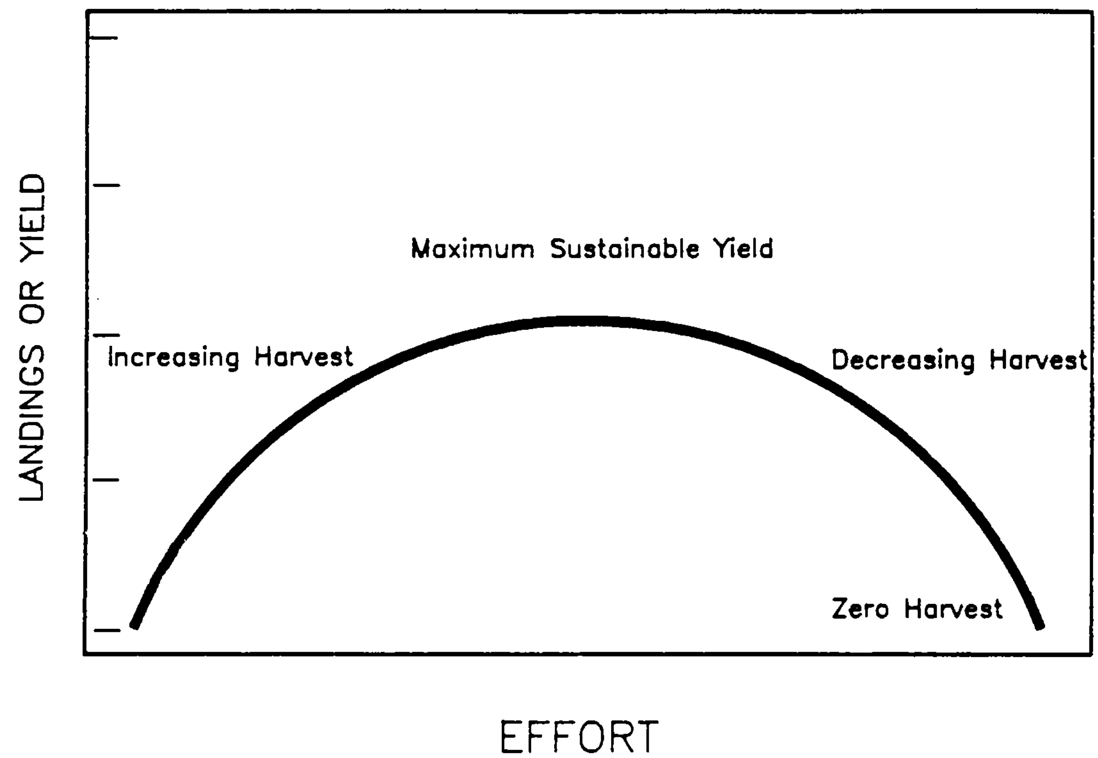

2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
Thousand Metric Tons (whole)
1955
1960
1965
1970
1975
1980
1985
1990
Year
Ocean Resources
Shrimp Farming

Figure 3.33. Top graph is a typical sustainable yield-effort curve, showing maximum sustainable yield (MSY). Bottom graph is the relationship between total revenue of the fishery and the costs of fishing.


LANDINGS OR YIELD
Maximum Sustainable Yield
Increasing Harvest
Decreasing Harvest
Zero Harvest
EFFORT

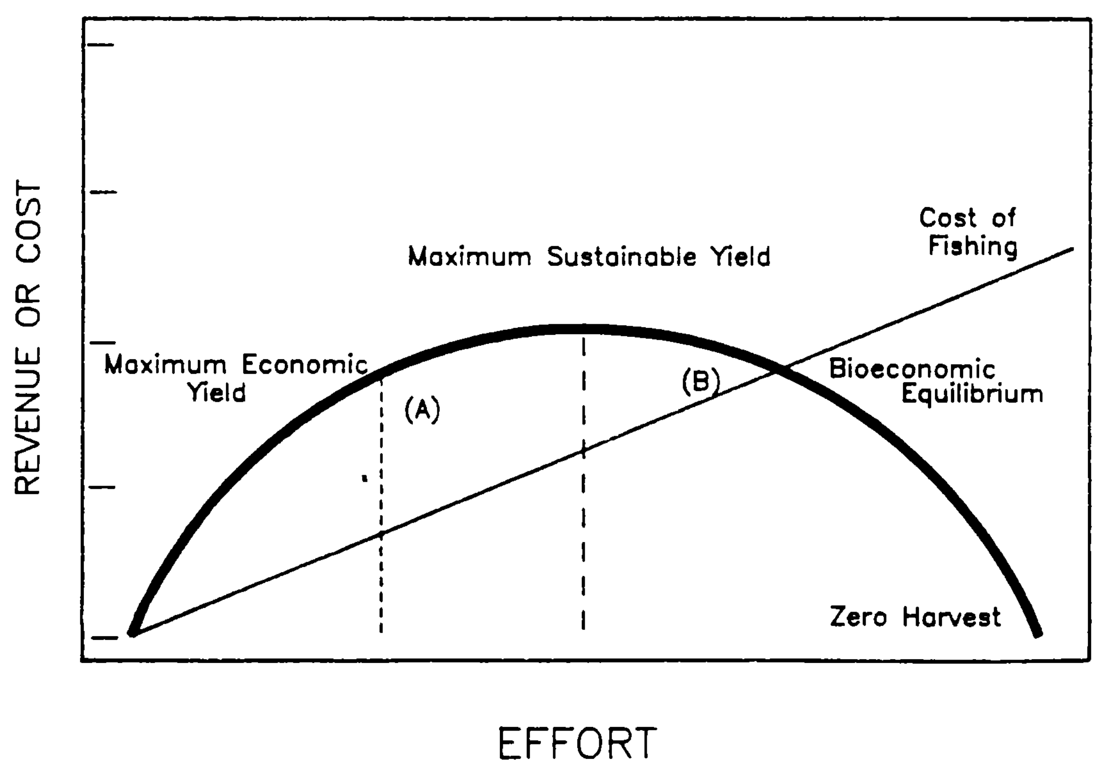

REVENUE OR COST
Maximum Sustainable Yield
Cost of Fishing
Maximum Economic Yield
(A)
(B)
Bioeconomic Equilibrium
Zero Harvest
EFFORT

Figure 4.1. Current management structure for the shrimp fishery in Texas.

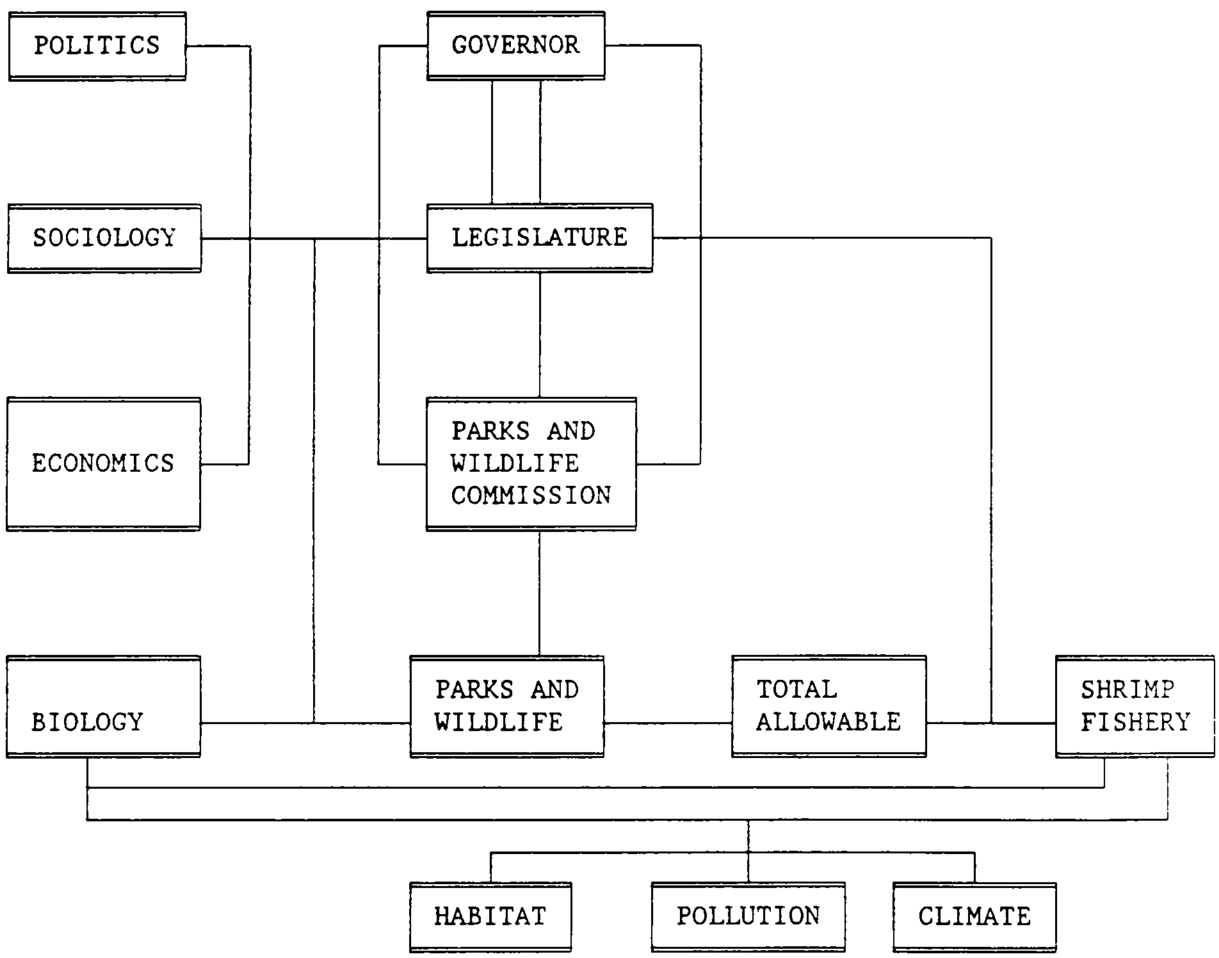
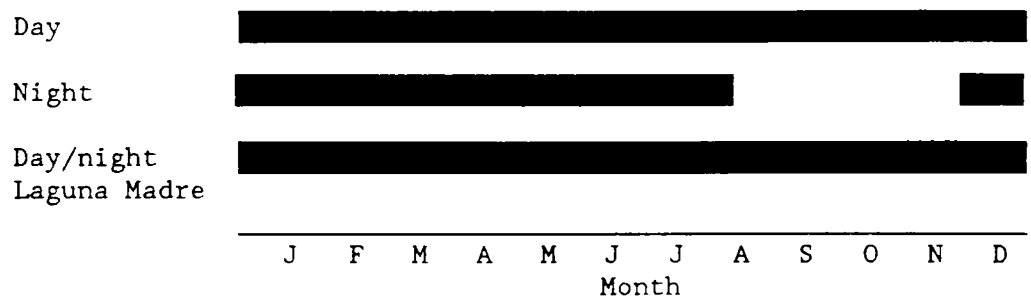

POLITICS
GOVERNOR
SOCIOLOGY
LEGISLATURE
ECONOMICS
PARKS AND WILDLIFE COMMISSION
BIOLOGY
PARKS AND WILDLIFE
TOTAL ALLOWABLE
SHRIMP FISHERY
HABITAT
POLLUTION
CLIMATE

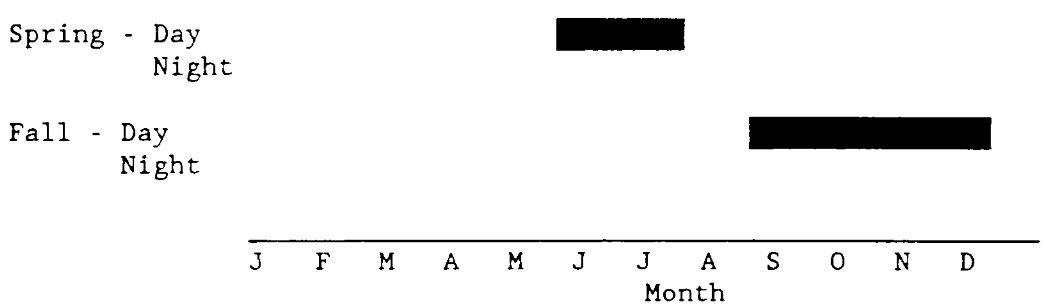
Figure 4.2. Summary of open shrimping seasons and associated regulations.

Bait season	Location	Gear	Restrictions
Year around	Major bays Bait bays Nursery areas	1 Trawl (16.5 m) 1 Try Net (3.7 m) 33 mm min. mesh	90.7 kg/boat/day (November 15-August 15 50% must be alive)



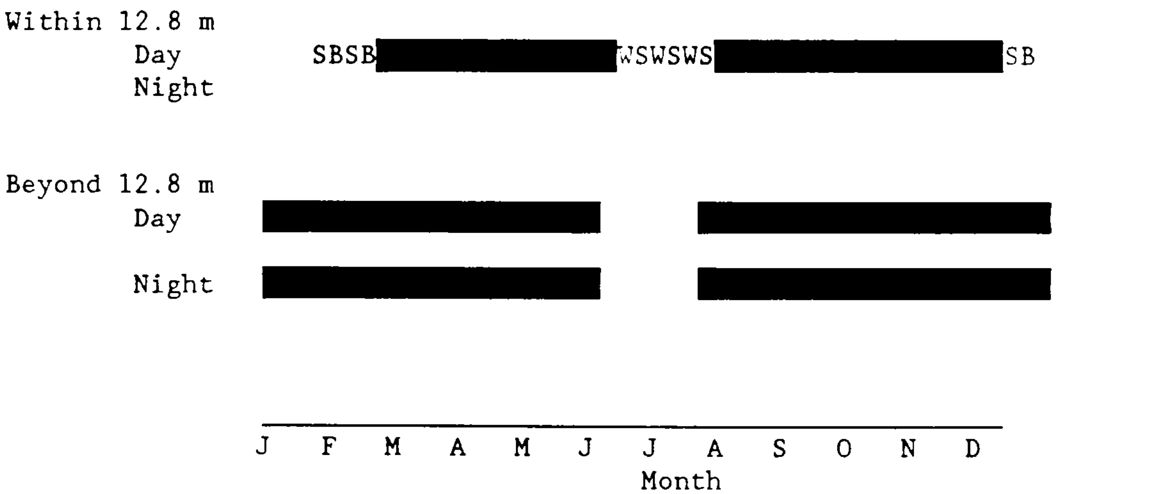
Black bars indicate periods when shrimping is allowed.

Bay season	Location	Gear	Restrictions
Spring	Major bays (May 15-Jul 15)	1 Trawl (16.5 m) 1 Try Net (6.4 m) 33 mm min. mesh	136.1 kg/boat/day
Fall	Major bays (Aug 15-Dec 15)	1 Trawl (29.0 m) 1 Try Net (6.4 m) 44.4 mm min. mesh	None



Black bars indicate periods when shrimping is allowed.

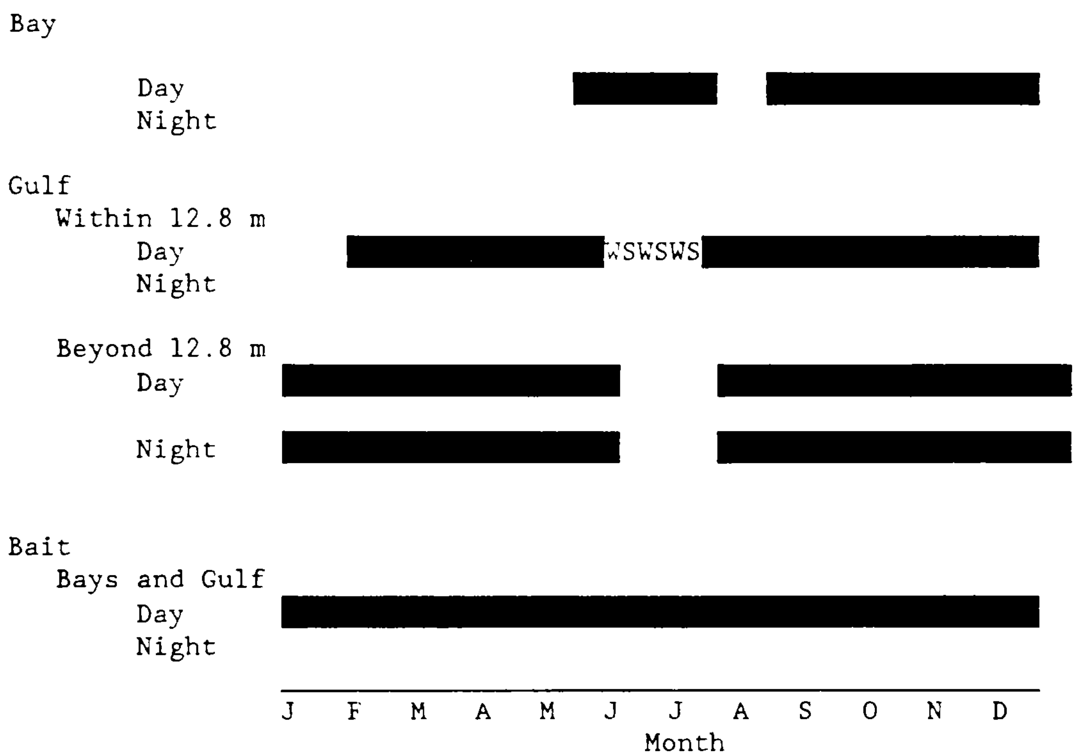
Gulf season	Location	Gear[a]	Restrictions
Within 12.8 m	Gulf within 12.8 m Feb 2-Jun 1 Jul 16-Dec 15	No restrictions except 44.4 mm	None
	Seabob season (SB) Dec 16-Feb 1	1 Trawl (7.6 m) 33 mm mesh	90% Seabobs
	Gulf within 7.3 m (WS) Feb 2-Dec 15	1 Trawl (16.5 m) 1 Try Net (6.4 m) 44.4 mm min. mesh	White shrimp only Jun 1-Jul 15
Beyond 12.8 m	Gulf beyond 12.8 m Jul 16-May 31	No restrictions except 44.4 mm mesh	None



Black bars indicate periods when shrimping is allowed.

[a]Nets are measured from tip of door to tip of door. These measurements are maximum size and include doors.

Noncommercial season	Location	Gear	Restrictions
Bay	Major bays Aug 15-Dec 15 May 15-Jul 15	Bait trawl Cast net Dip net Bait trap Minnow seine	6.8 kg/day
Gulf	Outside waters Open seasons and depths	Bait trawl Cast net Dip net Bait trap Minnow seine Seine (400 ft)	45.4 kg/day
Bait	Bait bays and Gulf Year-round	Bait trawl Cast net Dip net Bait trap Minnow seine	1.9 liter/person or 3.8 liter/boat



Black bars indicate periods when shrimping is allowed.

APPENDIX A. SUMMARY OF PUBLIC COMMENTS FROM PUBLIC HEARINGS AND OTHER SOURCES.

1.0 Bag and Possession Limits: The intent of this action is to allocate the resource to the various user groups. There are no possession limits in the shrimp fishery. Current statutes impose catch limits on bay, bait and noncommercial shrimp fishermen. Bay fishermen are limited to 300 lb/boat/day from 15 May-15 July. Bait shrimpers are restricted to 200 lb/boat/day all year (50% of all bait shrimp must be kept alive) from 15 November-15 August. There are no bag limits for gulf commercial shrimp fishermen. Noncommercial shrimpers are limited to 15 lb/day/person from 15 August-15 December and from 15 May-15 July in bays. The daily limit for noncommercial shrimp in the gulf is 100 lb/boat/day in season. Noncommercial shrimpers shrimping outside the above seasons are limited to 2 qt/person/day or 4 qt/boat/day for bait.

Public comments: Public comments centered on changes in the daily bag limit for bay and bait shrimpers and exploring acceptable alternatives to the daily bag limit.

1.1 Several speakers felt the 300 lb limit was being abused by fishermen who made multiple trips or used their bait license to get around the limit. Suggested limits ranged from 500 lb to no limit. Decreased limits were suggested for the bait shrimp fishery where suggestions ranged from 50-200 qt/day. The public would like the live box requirement eliminated. No changes were suggested for the gulf shrimp fishery or noncommercial shrimpers. The public would like a system where an accidental catch over the limit could be sold; and an identification card or tag system to regulate multiple sales in one day. They suggested studies be made to determine mortality rates of shrimp passing through a net or thrown overboard after capture. General feeling was that a caught shrimp should be considered a dead shrimp.

Staff Response: Bag and possession limits potentially encourage waste of the resource through discarding of dead and illegally captured shrimp (Section 3.1.4) and are difficult to enforce (Section 5.3.2). For bag limits to be successful, most of the animals released must survive. This is not generally the case in the shrimp fishery. However the magnitude of the waste varies with the means and methods of catching shrimp.

1.2 Several speakers suggested time and/or mesh size regulations (from sunrise to noon to sunrise to sunset) with higher or no bag limit as a means of controlling the harvest of shrimp in bays.

Staff Response: Other methods to control harvest of shrimp are available and will be discussed in Sections 2.0-8.0 of the Public Comments.

1.3 The public would like the live box requirement eliminated.

Staff Response: There are no specific requirements for a live box, however commercial bait shrimpers must keep 1/2 of the shrimp in their possession alive.

1.4 <u>Heading of shrimp in inside waters should be allowed.</u>

<u>Staff Response:</u> In the absence of a bag limit, there is no biological reason to restrict heading of shrimp in inside waters. The original intent of this regulation is unknown but two results of the regulation are to aide law enforcement in determining count and size limits, and to legitimize the bait shrimp industry.

2.0 <u>Size (Count) Limits</u>: Size and count limits are intended to provide maximum distribution of participation in the fishery. The only size restriction in effect occurs in major bays from 15 August-31 October when the legal shrimp count is 50 heads-on fresh shrimp/lb. Minimum shrimp size restrictions from outside waters have been exempted as long as the Gulf of Mexico Fishery Management Council's management plan is in effect and the taking of shrimp in at least part of the Exclusive Economic Zone is restricted during the Texas Gulf Closed Season. No size limits are imposed on bait shrimping.

<u>Public Comments:</u> Public comments suggested alternatives to a count limit such as regulating mesh size, time limits or trawl size as a means of regulating the harvest of small shrimp.

2.1 <u>Some speakers felt a count law was needed because bay fishermen were catching too many small shrimp. Specific examples mentioned small shrimp being harvested for canneries; and no size limit in November harming the spring white shrimp crop. They felt the count should be based on shrimp caught not shrimp kept.</u>

<u>Comments on the gulf fishery ranged from the need for a count limit during the 45-day closed season of 50-60 shrimp/lb to elimination of the minimum count as long as a closure is in effect.</u>

A 100 shrimp/lb count limit was suggested for the bait fishery.

<u>Staff Response</u>: For count size to work, discarded shrimp must survive. Size limits potentially encourage waste of the resource through the practice of culling unwanted shrimp and the additional handling required to sort shrimp. Since the inception of the Shrimp Conservation Act of 1959, the Texas Parks and Wildlife Commission has advocated the elimination of size limits on shrimp and supported time and area closures in place of size limits. In an annual assessment of the Texas Closure, National Marine Fisheries Service estimated that replacing the count law with the closure has resulted in a 95% decrease in culling by gulf shrimpers. Alternate management actions are possible and will be discussed in Sections 3.0-8.0 of the Public Comments.

3.0 <u>Time Periods</u>: Establishing periods of time to harvest shrimp may offset environmental impacts, ensure adequate spawning stock, make maximum use of environmental potential, provide maximum economic benefit to the state, and provide for maximum distribution of participation in the fishery. The Legislature has regulated the time period within which the taking of shrimp is allowed by setting seasons and day/night restrictions. This has resulted in a complicated scenario of seasons.

Bait shrimp may be taken at any time of the day or night except during a short period (fall) when bait shrimping is permitted only during the day in all bay systems except the Laguna Madre where bait shrimping is permitted at night year around.

Major bays are open during the day for food shrimp from 15 May through 15 July and from 15 August through 15 December. Outside waters beyond 7 fm are open year around, day and night, except during the flexible summer closed season. Except for summer and winter closed seasons, waters within 7 fm are open during the day. In addition, during the summer closed season, waters inside 4 fm are open during the day for the taking of white shrimp only.

Noncommercial shrimpers in both inside and outside waters have the same season restrictions as commercial shrimpers.

Shrimp may not be taken at night except in outside waters of more than 7 fm in depth and as provided for commercial bait shrimp boats. Bait shrimp may be taken at any time of the day or night except during the fall open season when bait shrimping is permitted only during the day. In the Laguna Madre, bait shrimp may be taken at any time of the day or night year around. Major bays are open during the day for food shrimp from 15 May through 15 July and from 15 August through 15 December. Outside waters are open year around except 1: during the gulf closed season from 1 June through 15 July (The closing and opening dates may be changed by the Texas Parks and Wildlife Commission or Executive Director to provide for an earlier, later or longer season not to exceed 60 days). During this season, there is also an exception that allows the catch of white shrimp in outside waters not exceeding 4 fm during daytime only, and 2: outside waters up to 7 fm deep are closed from 16 December through 1 February. (Seabobs may be caught and retained during in this closed season during daylight hours only as long as restrictions on gear and composition of catch are met.) Noncommercial shrimpers in both inside and outside waters have the same season restrictions as commercial shrimping.

Public comments: Comments focused on night shrimping, alternatives for the spring and fall open seasons in the bays, and the gulf closed season.

3.1 The public felt there was too much night fishing but several exceptions to the rule of no night shrimping were proposed as "necessary".

Staff Response: Numbers of brown shrimp landed from Texas bays is increasing, whereas, numbers of brown shrimp landed from the gulf are decreasing (Section 3.1.1). Brown shrimp are most vulnerable to a trawl fishery at night (Section 3.0). The bait shrimp fishery operates on a 24 hour basis virtually year around. The Gulf of Mexico Fishery Management Council has documented that the benefits of the Texas Closure have been reduced because of the increased catch of brown shrimp in the bays.

3.2 Suggestions for the spring open season ranged from elimination of the season, to substitution of an earlier "hopper" (pink shrimp) season, to more flexibility in the opening and closing dates. The Gulf of Mexico Fishery Management Council suggested Texas reduce the take of brown shrimp during the bay spring season. The increased catch of brown shrimp in recent years has reduced the benefits of the cooperative closure.

Staff Response: Just as in the case for night shrimping, and because 90% of the bay brown shrimp catch occurs during May-July, there is even greater impact on brown shrimp than by night shrimping alone. This is compromising the objectives of the management of the shrimp fishery in Texas. Texas has been managing the fishery to maximize ex-vessel value and the Gulf of Mexico Fishery Management Council has adopted a goal of 65 count (tails) in Texas offshore waters. The elimination of night shrimping for brown shrimp in the bays would help accomplish these goals.

3.3 Suggestions for the fall shrimp season were aimed at reducing the number of days or the dragging time per day.

Staff Response: Fall shrimp season targets white shrimp, but some brown shrimp are left in the bays. Juvenile white shrimp recruitment appears stable but trawl data indicate a decline in recruitment to the fishery (Section 2.4.8). This implies possible increased fishing pressure and a potential overall recruitment problem.

3.4 Comments on the gulf closed season and the closure of the Exclusive Economic Zone ranged from "keep it closed out to 200 miles" to "a total failure". The public suggested more flexibility in all seasons and investigation into alternatives to the closure of gulf waters. Seasons should be coastwide to prevent economic problems.

Staff Response: The current closed season in the gulf during May-July has met the management objective of the Gulf of Mexico Fisheries Management Council's management plan, and the majority of the small brown shrimp can be protected by closing the gulf out to 20 nautical miles.

3.5 Suggestions for protecting spawning white shrimp ranged from closing the 4 fm zone during the summer to keeping it open and using the same trawl as in the bay.

Staff Response: The open 4 fm zone harvests spawning white shrimp and emigrating brown shrimp. This is not consistent with current management objectives since the potential for impacting white shrimp recruitment increases as the catch of adult white shrimp increases. Other species caught are wasted because only white shrimp can be legally retained. Other species are thrown back dead. Exceptions to closed seasons which allow retention of one species through the discarding of other non-target species is wasteful.

3.6 There were several suggestions for limiting the fishing time in combination with increasing the bag limit during the spring season.

Staff Response: The bay fishery harvests increasing numbers of juvenile brown shrimp while they are being protected in gulf waters. From a biological point of view this is inconsistent with our management objectives; but an increase in the bag limit coupled with a decrease in fishing time would reduce waste as discussed in section 1.0 of the Public Comments on bag limits.

3.7 Some thought the bays should be closed at the same time as the gulf.

Staff Response: This closure would reduce the catch of brown shrimp. However, it would directly impact the spring bay brown shrimp fishery and bait fishery by eliminating 90% of the bay brown shrimp fishery which comprises approximately 2,100 full-time boats and 4,200 shrimpers. It would also eliminate much of the spring bait shrimp fishery upon which nearly 1.6 million resident fishermen depend for live bait. Finally it would eliminate much of the noncommercial fishery. Given all these factors, the elimination of the spring season in the bays would reduce the overall value of the shrimp fishery in Texas.

3.8 The gulf season should be closed and re-opened at 30 minutes after sunset (not midnight).

Staff Response: During years in which Texas Parks and Wildlife Commission sets the closing and opening dates, this is currently done.

3.9 There should be no weekend ban on shrimping.

Staff Response: A weekend ban would reduce total time available to shrimp and reduce amount of fresh bait for sport fishermen. In other Texas commercial fisheries, weekend closures are used to reduce total fishing effort.

4.0 Closed Areas: The Legislature regulates the shrimp fishery by designating areas where shrimp may be caught. Intent of these areal regulations is to prevent recruitment overfishing and to achieve optimum yield. No person may catch shrimp within natural or man-made passes leading from inside water to outside water. Commercial and noncommercial shrimping in inside waters is restricted to major bays.

Bait shrimping is restricted to bait bays and major bays but certain bait shrimp dealers have been authorized to fish in designated nursery areas under a "grandfather clause" that will expire in 1991.

The Texas Territorial Sea is closed during the Texas Closure except in water <4 fm deep where white shrimp may be taken. Outside waters up to 7 fm deep are closed at night year around and during the day from 16 December through 1 February.

Public Comments: Comments focused on protecting nursery areas, endangered sea turtles, and spawning white shrimp.

Staff Comments: Historically, areas have been closed either completely or during certain times of the year to eliminate or reduce harvest of shrimp at certain sizes. Primary information used in determining those areas to close have been shrimp life cycles and growth rates. For example, upper parts of many bays (where small shrimp occur) have been designated nursery areas. There will be no shrimping allowed in nursery areas after 1991 to insure that the maximum number of harvestable shrimp be available after they leave nursery areas.

4.1 The public suggested that a set of criteria should be developed for designating nursery areas that are uniformly applied coastwide and that more nursery areas be added. Termination of shrimping in nursery areas should be accelerated.

Staff Response: There are criteria developed to establish nursery areas (Section 77.001, Parks and Wildlife Code), however, criteria are very general. Current criteria prevents uniformity of application. Additional nursery areas would increase yield in the fishery. Shrimping in nursery areas will terminate in 1991.

4.2 Special interest laws (Jackson County) should be eliminated.

Staff Response: Non-uniformity of shrimp fishery laws makes enforcement difficult.

4.3 Texas Parks and Wildlife Department should do what is necessary to protect sea turtles and mammals which could include closing areas with headstarted (stocked) turtles. Concern was expressed that the reduced area closure (15 miles vs 200 miles) in the Exclusive Economic Zone would not protect as many turtles.

Staff Response: Current Parks and Wildlife Department Code and proclamations issued by the Texas Parks and Wildlife Commission substantially concur with present Federal laws to protect endangered sea turtles and mammals (see Section 5.1 of the Public Comments for further discussion).

4.4 Texas Parks and Wildlife Department should prohibit shrimping in channels and passes. A specific problem area was the ICWW near Sargent, Texas.

Staff Response: Shrimping in passes between bays and the gulf is currently prohibited (Section 77.082, Parks and Wildlife Code). However, none of the passes have been clearly defined through proclamation. Inability to have all passes defined creates an enforcement problem. Closing the channels to the shrimp fishery will reduce fishing mortality just as time and area closures do. Impact on the fishery of closing channels is unknown.

4.5 There was concern about expiration of permits to shrimp in the Arroyo Colorado (under the nursery area "grandfather clause"); petitions were presented to keep the bait house open.

Staff Response: Shrimping in nursery areas will terminate in 1991.

5.0 Means and Methods: The Legislature has regulated the taking of shrimp by imposing limits on the dimensions, mesh size, configuration and number of gear units allowed within each fishery. The intent of these regulations is to prevent recruitment overfishing and achieve Optimum Yield.

The bait shrimp fishery is limited to one main trawl 32-34 ft along headrope, and one try net <12 ft along the headrope from the leading tip of each door. Beam trawls <25 ft along the beam and try nets <5 ft are also legal. Minimum mesh size is 6.5 inches/5 stretched meshes.

For the spring open season, one main net (otter trawl or beam trawl with the same restrictions as above) and one try net <21 ft or beam trawl <10 ft may be used. Minimum mesh size is 6.5 inches/5 stretched meshes.

During the fall open season, only one otter trawl and one try net may be used. Total width of the otter trawl and doors must be <95 ft. The try net must be <21 ft. A beam trawl used as a try net must be <10 ft. Minimum mesh size is 8.75 inches/5 stretched meshes from 15 August-31 October and 6.5 inches/5 stretched meshes from 1 November-15 December.

There are no restrictions on number or size of trawls in outside waters except when fishing for white shrimp within 4 fm during the Texas Closure (one main trawl, 32-34 ft, and one try net may be used; if a beam trawl is used it must be <25 ft), or when fishing for seabobs during the closed winter season inside 7 fm (one trawl <25 ft in width with a stretched mesh size ≥6.5 inches/5 stretched meshes). Electro-trawls may have an applied voltage of <3 volts.

A person may catch shrimp for personal use with an individual bait shrimp trawl (minimum mesh size 8.75 inches/5 stretched meshes; <20 ft in width), cast net, dip net, bait trap or minnow seine <20 ft in length.

During the open season in outside waters a seine <400 ft in length with certain mesh restrictions may also be used.

Public Comments: Comments mainly involved use of Turtle Excluder Device's, debate on size of trawls and mesh size, and elimination of loopholes in the laws. Additional comments concerned by-catch of other organisms, directed catch of black drum in shrimp trawls, and elimination of salt boxes.

5.1 A large segment of the public supports the mandatory use of Turtle Excluder Device's and restriction of tow times to protect sea turtles. Most of the fishermen, however, did not feel they were necessary in Texas and did not support their use. Total width of all trawls in any combination should be limited to 100 ft/boat in the gulf to protect turtles. Regulations for Turtle Excluder Device construction should be flexible to allow for improvements.

Staff Comments: Current Federal regulations have set times and places when Turtle Excluder Device's are required and have defined exceptions to the requirements by size of vessel, tow times, and areas. Federal rules also allow for certification of additional Turtle Excluder Device designs.

5.2 Trawl size should be standardized in the bays at 34 or 50 ft with 1 3/4 inch mesh for food and bait shrimpers. Loopholes allowing two different sizes of trawls should be eliminated.

Staff Response: Standardization of gear is desirable to reduce confusion and enhance law enforcement. However, impact of complete standardization on a complex fishery that includes several species, is prosecuted during different times of the year on different sized organisms and provides varying products for different purposes is unknown. Complete standardization year around could be difficult to implement. Standardizing mesh size to 1 3/4 inches will reduce catch of small shrimp. A 34-ft net is currently legal gear in the spring season but will reduce harvest during the fall season. A 50-ft intermediate net will increase harvest during spring and decrease harvest during fall.

5.3 Twin rigs should be allowed in the bays.

Staff Response: By allowing twin rigs in the bays, fishing mortality will increase. The numbers of brown shrimp landed is increasing in the bays while decreasing in the gulf. The Gulf of Mexico Fishery Management Council has documented that the benefits of the Texas Closure have been reduced because of increased catches of brown shrimp in the bays. Recruitment of juvenile white shrimp appears stable in Texas Parks and Wildlife Department bag seines while Texas Parks and Wildlife Department trawls indicate a decline in catch rates (Section 2.4.8). This implies increased fishing pressure and a potential recruitment problem.

5.4 Salt boxes should be banned.

Staff Response: The purpose of a salt box is to facilitate separation of shrimp from bycatch (Section 3.1.4). However, the high brine content of the salt box results in a high mortality rate of juvenile fishes and other bycatch.

5.5 Trawls for seabobs should be larger.

Staff Response: Increasing trawl size will increase catch of seabobs and bycatch. Since juvenile white shrimp are caught in association with seabobs (Section 2.4.8), increased trawl size will increase fishing mortality on white shrimp. Exceptions to closed seasons which allow retention of one species through discarding of other non-target species is wasteful.

5.6 Butterfly nets and push nets should be banned.

Staff Response: Butterfly nets and push nets are not legal fishing gear in Texas. In some areas a beam trawl is pushed in front of the boat.

5.7 New gear requirements should have a one year lead time.

Staff Response: Adequate lead time for new gear requirements would impose less economic hardship on the fishery.

5.8 A standard device should be used to measure trawls and webbing.

Staff Response: Standardizing gear calibration will reduce conflict and enhance law enforcement.

6.0 Licenses: The Texas Parks and Wildlife Department has the responsibility of issuing licenses, established by the Legislature, for the privilege of catching, buying, selling, unloading, transporting or handling shrimp within the jurisdiction of the state. The intent of licenses is to raise revenue. There are usually different fees for residents and non-residents. The Texas Parks and Wildlife Commission can increase license fees above that set by the Legislature. License documentation provides Texas Parks and Wildlife Department with a universe of fishery participants.

A General Commercial Fisherman's License is required for residents or nonresidents who catch edible aquatic products from the waters of the state. For boats having a Commercial Shrimp Boat License, one license may be bought in the name of the boat to cover captain and crew.

Boat licenses include 1) Bait Shrimp Boat, 2) Bay Shrimp Boat and 3) Gulf Shrimp Boat. For noncommercial shrimping, a person must have a General Fishing License, a Saltwater Stamp and, if a trawl is used, an Individual Bait Shrimp Trawl Tag.

A Bait Shrimp Dealer License is required of any person selling shrimp for fish bait in coastal counties. Other business licenses include 1) Wholesale Fish Dealer, 2) Wholesale Fish Truck Dealer, 3) Retail Fish Dealer, 4) Retail Fish Truck Dealer, 5) Shrimp House Operator, and 6) Shellfish Culture License.

Public Comments: Comments concerned abuse of the intent of the bait shrimp license (used for other than bait shrimping), whether or not dealers should be licensed to sell both bait and food, and restrictions on the sale of licenses to those who showed a knowledge of marine laws and a willingness to abide by regulations. Several suggestions were presented to alleviate the misuse of bait shrimp licenses.

6.1 Bait shrimpers should get their license through a dealer and sell to only legitimate bait dealers. Shrimpers should not have a commercial bay license and a bait license. Bait dealers should report their catches. Comments were divided on whether dealers should have a license to sell bait and food shrimp at the same place of business (or combine the license).

Staff Response: The intent of the bait license is being abused. The bait shrimp license requirement was developed to allow the harvest of shrimp for sale as live bait. Shrimpers currently use this license to harvest shrimp year around. These shrimp are then sold for other purposes, including dead bait and food. Once the product reaches shore, it is virtually impossible to make certain that shrimp caught under a bait license are sold as bait, especially beyond point of first sale. None of the recommendations made by the public will solve the problem. Landings from all user groups are important to assess. Bait dealers are not required to report their purchases, however, those who land shrimp are currently required to report their catch (Chapter 77.005, Parks and Wildlife Code). The law currently states that Shrimp House Operator and Bait Shrimp Dealer licenses cannot be held in combination simultaneously.

7.0 Penalties and Compliance: The Legislature sets penalties and fines on those persons found violating fish and game laws. The Texas Parks and Wildlife Commission has authority to develop guidelines for recovering values of illegally taken or killed shrimps (Chapter 12.302-12.307, Parks and Wildlife Code) and authority to revoke or suspend any license.

Public Comments: Public comments stressed the need for better enforcement, clarification of existing laws, and higher penalties for violators. General suggestions were made to help solve enforcement problems.

7.1 Laws should be clear and easy to enforce to reduce judgement calls.

Staff Response: In order to insure compliance , laws should be easy to understand to eliminate confusion and enhance enforcement.

7.2 Wardens should have the option of filing in Justice of the Peace or County Courts.

Staff Response: The mechanism whereby game wardens file cases in other courts is already in place (Section 77.020, Parks and Wildlife Code). All class C misdemeanor charges are filed in Justice of the Peace Court. All class B and class A misdemeanor charges are filed in County Court.

7.3 High fines ($1,000-2,500 for 1st offense), confiscation of gear and license revocation are needed as deterrents. Minor violations need a sliding scale geared to the offense. Recommended penalties for flagrant violators were:

1st offense - $250 and confiscation of net and doors
2nd offense - $500 and confiscation of net and doors
3rd offense - 30 day loss of license and loss of gear
4th offense - 60 day loss of license and loss of gear
5th offense (within 1 yr) - Loss of license

Staff Response: Studies indicate that higher fines decrease shrimp law violations (Matlock and Bryan, 1987). Mechanisms for assessing fines are currently in place (Chapters 12 and 77, Parks and Wildlife Code).

7.4 An identification card or tag system should be implemented to detect multiple sales of daily bag limits.

Staff Responses: This is a self-reporting system that could allow detection of multiple landings of a daily bag limit. However, self-reporting systems have been found to be unreliable (Matlock 1986, Green and Thompson 1981, Osburn et al. 1987).

7.5 Comments were divided on what to do with confiscated catches--some felt wardens should not sell undersized shrimp and oysters, while others felt it was wasteful to shovel dead shrimp over the side.

Staff Response: The practice of wardens selling confiscated shrimp prevents waste of the resource. It also protects the fisherman if found not guilty, because he then receives the money for the shrimp.

7.6 Provisions should be made to extend coverage of Chapter 77 to the first point of sale where appropriate. If first point of sale violations are included, restitution (recovery value) should apply to only one party. Others felt restitution should be shared by both parties--but not duplicated.

Staff Response: Enforcing shrimp laws at first point of sale, where both parties are in violation, is a method of ensuring compliance to shrimp laws.

7.7 Violations should be charged against the fisherman and the boat owner to make the owner more responsible.

Staff Response: Establishing dual responsibility for shrimp law violations is a method of ensuring compliance.

7.8 Recommendations were made to move wardens every three or four years.

Staff Response: The longer a warden stays in one area the more effective he becomes.

7.9 Prohibit scanners from having warden frequencies.

Staff Response: This is not under the authority of Chapter 77, Parks and Wildlife Code.

7.10 There was also concern over sanitation and safety equipment on the large number of vessels and rigs in our waters.

Staff Response: The Texas Parks and Wildlife Department adheres to the objectives of the MARPOL agreement and has supported and participated in numerous gulf beach cleanup operations.

8.0 Allocation: Allocation is that portion of fisheries management that is implemented after protection of spawning stock has been accomplished. The goal of managing the shrimp fishery as set by the Legislature has been to maximize ex-vessel value of shrimp landed. The Texas Parks and Wildlife Commission has supported this goal with the summer closed season. The GMPC also as adopted this goal through the Texas Closure option and has recommended:

> "that the Legislature clarify the state's policy on shrimp management objectives in regard to the Texas shrimp industry in order to ensure that the full economic value of the state's shrimp resources benefit Texas residents to the fullest possible extent."

Allocation can be accomplished directly (by quotas, limited entry, etc.) or indirectly by regulation of means, manners, time limits, gear, etc. Historically, the Legislature has allocated the fishery by the indirect method.

Public comments: There were several comments dealing with the number of boats and dealers.

8.1 The management plan should contain clearly stated objectives of management similar to the original Shrimp Conservation Act of 1959 or the amended version found in the Shrimp Conservation-Research and Studies Act of 1963 which reflect on the issues of depletion, waste, public ownership and law enforcement. It should make explicit those elements of state policy protecting equitable privileges in the taking of shrimp and assure that future regulations by proclamation are consistent with the principles of good management such as those stated in the Magnuson Fisheries Conservation Act (sustained optimum yield, assure fair and equitable treatment, promote efficiency, minimize cost, unit management and management decisions based on the best available scientific data). One role of government is to reduce conflicts among user groups. The management plan needs to be fair to all groups. An equitable division of the harvestable resource is worth seeking, but in order to do that, a comprehensive analysis and resolution of intra-industry conflicts is essential. Suggestions were made to include recommendations of the Texas Coastal and Marine Council. A dissenting viewpoint suggested the Shrimp Conservation Act promotes waste.

Staff Response: The Legislature requires a management plan be developed and the objectives of management be addressed by the Texas Parks and Wildlife Commission (Section 77.007 Parks and Wildlife Code). The objectives are stated in this Shrimp Fishery Management Plan (Section 1.2). This Shrimp Fishery Management Plan has considered these and the objectives of the Texas Coastal Marine Council, the Gulf of Mexico Fishery Management Council, the Gulf States Marine Fisheries Council, and the Shrimp Conservation Acts of 1959 and 1963.

8.2 Texas Parks and Wildlife Department should not consider changes in regulations without an economic study and should be clear whether a regulation is for conservation or is an intervention in the market structure. The Legislature and Texas Parks and Wildlife Department should resist pressure to take measures that favor the large fleet-owned gulf sector. Bay shrimpers may provide more benefit to the Texas economy than gulf shrimpers. Some felt the fact that Texas is the leader in value of shrimp landed should not be overlooked, while others questioned the rationale of management for a higher priced product. The cost to harvest shrimp should be considered, not just the preferred size.

Staff Response: The Legislature requires a management plan be developed and the objectives of management be addressed by the Texas Parks and Wildlife Commission (Section 77.007 Parks and Wildlife Code). The objectives are stated in this Shrimp Fishery Management Plan. The Administrative Procedures Act and Section 77.007 Parks and Wildlife Code require a statement of economic impact on the administration and the public for any proposed regulation.

8.3 Shrimp should be declared commodities to help the fair trade business and take price control out of the hands of a few individuals. The resulting better price would require less shrimp to make a living.

Staff Response: Inadequate information was provided in this statement as to what role the Texas Parks and Wildlife Commission could play in declaring shrimp a commodity.

8.4 Harvest should be restricted to Texas residents or at least non-Texas vessels should pay a landing fee and maintain records of harvests from Texas waters. There was concern about overfishing, especially by orientals, but also statements that shrimp were not being biologically overfished.

Staff Response: The United States Constitution and other Federal laws make it illegal to restrict the harvest of a state's resources to its residents only. For the same reason, it is also illegal to discriminate against residents of other states with respect to fishing rights. However, it is legal for states to impose higher fees on non-resident fishermen. Texas currently does this. Texas cannot discriminate on the basis of race, creed, color, sex, age, religion, national origin, political affiliation or physical disability.

8.5 Comments on limiting entry ranged from too many boats in the fishery to statements that the fishery could withstand 100 times more boats. Specific suggestions were aimed at limiting the number of bait stands and bait boats and eliminating part-time shrimpers. Texas Parks and Wildlife Department needs to enforce the license affidavit and limit the number of boats to the size of the bay.

Staff Response: Limited entry is a valid, direct, fishery management tool. It is used most often in commercial fisheries to meet the primary goal of fishery management, Optimum Yield. However, at this time, Texas

Parks and Wildlife Department does not have the data nor has it completed the research necessary to recommend nor implement a limited entry program. Obtaining this information is a high priority of the Texas Parks and Wildlife Department staff. For limited entry to be successful, it must allow the transfer of licenses and will eliminate some fishery components.

9.0 Stocking: Stocking of shrimp into public waters has not been done in Texas. Current law allows the raising of shrimp in the private waters of the state by holders of a Shellfish Culture License.

Public Comments: No public comments on stocking were received.

Staff Response: Stocking techniques are being explored to provide a potential method of augmenting natural recruitment and to offset effects of overfishing should it occur. Stocking of white shrimp is part of the Texas Parks and Wildlife Department 6-yr Plan.

10.0 Mariculture Development: Current law allows the raising of shrimp in private waters of the state by holders of a Shellfish Culture License. Current statutes and Texas Parks and Wildlife Commission rules allow the take of limited quantities of wild brood stock by permit (Chapter 51, Parks and Wildlife Code).

Public Comments: The public was against the Texas Parks and Wildlife Department providing brood stock or allowing wild brood stock be taken for mariculture purposes.

Staff Response: Chapter 77, Parks and Wildlife Code is the authority under which this Shrimp Fishery Manangement Plan is being developed and does not allow the Texas Parks and Wildlife Commission authority to change mariculture regulations.

11.0 Habitat Maintenance, Restoration, and Enhancement: Under Section 77.004, Parks and Wildlife Code, the Texas Parks and Wildlife Department is required to conduct continuous research and study of environmental factors in areas that may serve as limiting factors of shrimp population abundance, and industrial and other pollution of the water naturally frequented by shrimp.

Public Comments: The public was concerned about the health of the bays and the effects on other species.

11.1 Texas Parks and Wildlife Department should continue monitoring water quality, freshwater inflow, and spoil deposition. Texas Parks and Wildlife Department should exercise their clout on water releases and water quality.

Staff Response: The Texas Parks and Wildlife Department continuously monitors water quality, fresh water inflow, and spoil deposition. In addition, the Texas Parks and Wildlife Department recently received automatic party status on any water diversion or water use plans proposed by the Texas Water Commission.

11.2 Specific suggestions involved opening up the north and south jetties at Galveston to improve flow (and therefore ingress of organisms) into the bay.

Staff Response: Any modifications of the Galveston jetties is under the jurisdiction of the United States Army Corps of Engineers.

11.3 Texas Parks and Wildlife Department should study the effects of trawls on the bay bottom and oyster reefs. Shrimpers felt trawls cultivate the bottom while oystermen said trawls were harmful to the reefs.

Staff Response: Present trawl designs make it impractical to pull trawls over oyster reefs sufficiently often to destroy reefs. Also, present trawl designs probably have less impact on oyster reefs than do oyster dredges. Shrimp trawls disturb the bottom and resuspend materials. However, the cumulative effect on the shrimp fishery is unknown.

11.4 Additional concerns focused on seismic operations in bay and offshore waters. The public felt these operations were detrimental to fish, shrimp, and oysters and killed more turtles and aquatic organisms than commercial and sports fishermen.

Staff Response: Seismic operations and removal of offshore platforms can adversely impact marine organisms (Gowanloch and McDougall 1946, Kemp 1956, Klima et al. 1988). These operations are regulated by the General Land Office which works closely with the Texas Parks and Wildlife Department and National Marine Fisheries Service to minimize harmful effects.

12.0 Fishery Independent Monitoring: The objectives of this monitoring are to develop long-term trend information on shrimp population abundance and stability in Texas bays and the gulf, and to monitor environmental factors which may influence shrimp availability. To accomplish these objectives, long-term trend information is collected with 60-ft bag seines and 20-ft otter trawls in the bays and gulf.

Public Comments:

12.1 Texas Parks and Wildlife Department needs more studies on the cause of fluctuations in the shrimp crop, mortality rates of shrimp passing through a net, and better sampling in the gulf for setting the seasons.

Staff Comments: The Texas Parks and Wildlife Department Coastal Fisheries Branch collected 1,632 bag seine samples and 2,760 trawl samples in the bays and gulf during Fiscal Year 1988. In addition, 760 gill net samples and 4,992 oyster dredge samples were taken. Water quality factors are measured with each sample.

13.0 Fishery Dependent Monitoring: The objectives of this monitoring are to determine size, catch per effort, and value of shrimp caught by commercial fishermen in eight bay systems and the Gulf of Mexico, and to determine monthly and annual purchases of edible seafood products by commercial dealers using Monthly Marine Products Reports. To accomplish these objectives, daylight commercial-vessel landings and fisherman activity are estimated from on-site samples at seafood and bait dealers, boat access sites with known historical commercial activity, boat access sites with no historical commercial activity, and commercial-vessel docking structures.

Public Comments:

13.1 Wardens should not be used to collect data because fear of citations reduces cooperation.

Staff Response: Wardens do not collect data. All data collected for the study of the biological, economic, and sociological aspects of the shrimp fishery are by non-law enforcement personnel.

13.2 The greatest needs for data are in economics and socioeconomics.

Staff Response: The Texas Parks and Wildlife Department routinely monitors landings and value of shrimp resources in Texas. The goal of the management plan is to manage for Optimum Yield. Optimum Yield considers economic and sociological factors of a fishery.

14.0 Assessment and Evaluation: The Texas Parks and Wildlife Department is mandated by Section 77.006, Parks and Wildlife Code to annually assess and publish the status of shrimp populations and associated environmental variables. The Texas Parks and Wildlife Department is responsible for making management recommendations regarding the Texas shrimp fishery within the bays and estuaries and out to nine nautical miles in the gulf.

Public Comments:

14.1 The public is skeptical of some of the Texas Parks and Wildlife Department's data.

Staff Response: The regulated public is always skeptical of the regulator's data. The Federal Government has used Texas Parks and Wildlife Department data to regulate the shrimp fishery in Federal waters. The design of Texas Parks and Wildlife Department sampling programs is developed by highly trained individuals. The Texas Parks and Wildlife Department Coastal Fisheries Branch Staff generated 34 peer-reviewed publications and reports and made 16 scientific presentations to professional organizations during Fiscal Year 1987. Other gulf coast states and countries have expressed interest in the Texas Parks and Wildlife Department monitoring program and some have implemented procedures developed in Texas.

15.0 Communication and Education: The Texas Parks and Wildlife Department is required to report on findings of fishery research, assessments and evaluations and to make recommendations for further actions when studies indicate they are appropriate to accomplish the objectives of this Shrimp Fishery Management Plan (Sections 61.051, 77.004, 77.006, Parks and Wildlife Code).

Public Comments: There was support for the Shrimp Fishery Management Plan being developed by the Texas Parks and Wildlife Department and the present Commission's efforts.

15.1 Texas Parks and Wildlife Department did a good job of informing the public of the hearings. They supported public input and Interim Committee efforts in the management plan development, and recommended more public hearings where Texas Parks and Wildlife Department people could answer questions. Texas Parks and Wildlife Department should have another series of public hearings on the draft management plan and give details of the draft management plan to the public prior to the hearings. Texas Parks and Wildlife Department needs representatives from the fishing industry on an advisory panel and could form a group of industry and government people to devise model legislation. Suggestions were made to continue the public input process.

Staff Response: The Texas Parks and Wildlife Department communicates to the public routinely through the following arenas:

1. Public hearings when proclamations are being considered.
2. Gulf States Marine Fisheries Commission.
3. News media, such as newspapers, magazines, and television.
4. Gulf of Mexico Fisheries Management Council.
5. Texas Parks and Wildlife Department Information and Education Division.
6. Personally via telephone conversations, letters, and personal contact.
7. Through surveys of the public such as mail studies and on-site harvest programs.

The Interim Committee has had an active role throughout development of this Shrimp Fishery Management Plan. Public hearings will be held prior to consideration and adoption of this Shrimp Fishery Management Plan by the Texas Parks and Wildlife Commission. Representatives of the shrimp fishery have participated as members of the Interim Committee in developing the Shrimp Fishery Management Plan.

15.2 The public asked for better communication between wardens and fishermen and notification of regulation changes. Suggestions were made to notify the public of changes by a mailing list and publication in Texas Parks and Wildlife Department Magazine.

Staff Response: The public is notified of regulation changes by the methods described in Section 15.1 of the Public Comments. It would be impossible to notify by mail all affected parties of every regulation change. All law enforcement offices and personnel are available to give information on request. All wardens are available to give programs and answer questions from the public.

15.3 Texas Parks and Wildlife Department should consult fishermen on the opening and closing of seasons.

Staff Response: The public is notified of regulation changes by the methods described in Section 15.1 of the Public Comments.

15.4 The management plan should recommend two Parks and Wildlife Commissioners be from the seafood industry.

Staff Response: State law (Section 11.0121, Parks and Wildlife Code) specifically forbids members of any industry regulated by Texas Parks and Wildlife Department to be members of its Commission.

15.5 Changes should be gradual to provide adequate lead time to the fishing industry.

Staff Response: Gradual changes in regulations will reduce economic disruption on the fishery as long as it does not compromise the intent of the proclamation and the Shrimp Fishery Management Plan.

16.0 Regulatory Authority: The purpose of regulatory authority, as defined in Chapter 61, Parks and Wildlife Code, is to provide a flexible mechanism to enable the Texas Parks and Wildlife Commission to deal effectively with changing conditions to prevent depletion and waste of wildlife resources.

Public Comments:

16.1 Texas Parks and Wildlife Department should embody the entirety of Chapter 77 of the Parks and Wildlife Code as the basis for the management plan, then any areas having significant interest by the public could be reviewed by Texas Parks and Wildlife Department staff and considered during the annual review of the Parks and Wildlife regulations in the public hearings.

Staff Response: Chapter 77, Parks and Wildlife Code is the current management regime for the shrimp fishery of Texas. As such, it has embodied the wishes of various legislators, congressional representatives, and citizens of Texas over a period of many years. Therefore, it must be the basis of the development of the Shrimp Fishery Management Plan. Proclamations issued under the Shrimp Fishery Management Plan will be considered during review of the Texas Parks and Wildlife Department proclamations in public hearings.

16.2 <u>Comments were divided on whether or not Texas Parks and Wildlife Department should be given Regulatory Authority; one suggestion was to place the fishing industry under authority of the Railroad Commission.</u>

<u>Staff Response</u>: By statute (Section 12.001, Parks and Wildlife Code), the Texas Parks and Wildlife Department must administer the laws relating to game, fish, oysters, and marine life.

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