Bay Shrimping in the Coastal Bend: A Summary of Current Conditions

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EXECUTIVE SUMMARY

Penaeid shrimp (Family Penaeidae) are economically valuable, commercially harvested shellfish as well as ecologically important components of estuarine food webs. Annual per capita consumption of shrimp has more than doubled since 1980. In the 1990s, Texas was second only to Louisiana in Gulf of Mexico shrimp landings and was first in shrimp ex-vessel value among Gulf states. The Texas shrimp fishery is the most valuable commercial fishery in the state, comprising an average of 84% of Texas commercial landings and 92% of ex-vessel value between 1972-1999. For 1999, the total economic impact of the Texas shrimp fishery at the wholesale level (including live and dead bait) was estimated at $510,000,000.

Collapse of the Texas shrimp fishery has been feared since the early part of the last century. Although overall harvest along the Texas Gulf Coast has changed little over the last 30 years, the fishery exhibits some characteristics of overfishing. Persistent overexploitation of either component of the Texas shrimp fishery has both economic and ecologic consequences. Recognition of this potential problem provided the impetus for this comprehensive characterization of the bay shrimp fishery, with a focus on the bays of the Coastal Bend (Aransas Bay, Corpus Christi Bay, and upper Laguna Madre). This synthesis will provide: 1) the results of a survey on the attitudes and perceptions of the fishery's local participants; 2) a description of the shrimp fishery including summarization of commercial fishery statistics; 3) a brief description of the ecology of penaeid shrimp in the Texas Coastal Bend; 4) a characterization of shrimp populations in Corpus Christi, Aransas and upper Laguna Madre bay systems using fishery independent data collected by TPWD; and 5) and recommendations concerning management of the resource.

The Texas shrimp fishery has two components, the food fishery that mainly targets larger mature white (*Litopenaeus setiferus*) and brown (*Farfantepenaeus aztecus*) shrimp offshore and in primary bays, and the bait fishery that targets smaller shrimp of all species (including pink shrimp, *F. duorarum*) in primary bays, some secondary bays and other areas designated "bait bays". Most inshore fishers hold bay and bait licenses, allowing participation in both fisheries. Larger bay shrimp are harvested for sale as food from major bays only and are sold to wholesalers or directly to the consumer from the boat. In 1999 there were 1,649 boats in the bay and bait shrimping fleets. In 2002, only 225 boats, or about 8% of the statewide total, were licensed in Aransas, Kenedy, Kleburg, Nueces, Refugio and San Patricio counties

From the responses to the questionnaire we can begin to paint a "broad brush" characterization of the typical bay shrimper of Aransas, San Patricio, and Nueces counties. In general, the typical Coastal Bend shrimper is Asian-American or Anglo male 40 years old or older. They personally operate a boat that is 10 years old or older and employ only one other person. Most bay shrimpers operate with a Bay and Bait license. Business expenses run about $23,000 per year including hired labor. Typically, labor costs are less than $10,000 annually. Bay shrimping is their sole or primary source of income. They are happy with their profession, but do not believe it will be viable occupation/business for their children.

Coastal Bend bay shrimpers believe that overall resource management regulations are overly burdensome and some unnecessary. They do not feel that they have enough input into the development of regulations. They are not interested in a license buy back program because it does not pay enough, decreases the value of their boat, and/or they are not prepared to move into other businesses or professions.

Total shrimp landings ranged from a low of 64,603,000 lbs in 1997 to a high of 98,140,000 lbs in 1972. Percentage total Texas commercial landings attributed to shrimp ranged from 77% in 1999 to 90% in 1981. The ex-vessel value of shrimp ranged from $67,740,000 (1974) to $229,110,000 (1986) with percentage of total Texas commercial ex-vessel value ranging from 86% (1996, 1999) to 96% (1979, 1981).

Fishery independent data on shrimp size and abundance collected by TPWD was summarized for Aransas Bay, Corpus Christi Bay and upper Laguna Madre (including secondary bays). Yearly summary data compiled by TPWD was available through 1996 only and was used to depict overall trends in mean abundance and mean length through time.
When bag seine data from Aransas Bay, Corpus Christi Bay and upper Laguna Madre were combined and analyzed together for trends in abundance and size over time, both brown and pink shrimp exhibited significant trends whereas white shrimp did not. Regional brown shrimp abundances appear to have increased through the early 1990s, peaking in 1990 but appear to have declined since then. The trend for pink shrimp was one of increased abundance since the 1970s. No significant trends were exhibited in the sizes of either brown or white shrimp (Figure 30). Regionally, pink shrimp size declined through the mid-1980s. Year to year variation in shrimp sizes is much less within the region when compared with data for the entire coast. In general, the peaks monthly abundances and sizes of each species in each bay system occur during the same months. Monthly abundances of each shrimp species in each local bay system are similar to that seen for the entire coast.

When trawl data from Aransas Bay, Corpus Christi Bay, and upper Laguna Madre were analyzed together, a significant trend was exhibited by pink shrimp. Pink shrimp generally increased through the early 1990s and appear to be declining currently. Brown shrimp exhibited a slight decline in size. Peaks in monthly abundances of each species generally occurred in the same months in all three bay systems.

Compared to a hypothetically ideal fishery, the Coastal Bend inshore shrimp fishery is lacking, as is every fishery. Subsequently, the existence of the inshore shrimp fishery and management of the fishery are the result of compromise – compromise that is bounded by the laws of nature controlling reproduction and recruitment of the resource. Effective management must achieve a balance of exploitation, conservation, economics, natural conditions, and societal demands.

Coastal Bend bay shrimpers (inshore) and Gulf shrimpers (offshore) harvest from the same resource pool, serve the same consumer groups, and face the same challenges to the sustainability of their respective industries. Any action by either fishery group that destabilizes the reproductive potential of penaeid shrimp in Texas waters will adversely affect both fisheries. The inshore fishery is based on a one owner/operator – one boat business model and the offshore fishery is in general a corporate structure where owners have more than one boat and hire captains to operate them. A win/win solution would be the development and implementation of a business model that joins the two fisheries, provides acceptable return on investment, and to a significant degree places the onus of resource and habitat conservation upon the harvester.

The future of shrimping in the bays of the Coastal Bend region is uncertain. It can be concluded that shrimping in the bays of not only the Coastal Bend, but, all of Texas, will eventually decrease to a level to be almost non-existent. However, for the sake of this discussion, we assume that the management goal is to support sustainability and productivity of the living resource, habitats, and fishers. We advocate that the most effective form of management will be one that uses the power of comprehensive long-term business strategies that encourage voluntary proactive conservation efforts by the harvesters. We consider the following management strategies: restriction of fishing areas, seasonal closures, and resource allocation.

Restriction of fishing areas has two primary ecological impacts: 1) it provides "protected" areas for the shrimp to progress to maturity relatively undisturbed, and 2) it reduces the impact of fishing technology on benthic habitats. In effect, the closed secondary bays of the Coastal Bend bay system are reserves and offshore, the temporary closure of zones to shrimping activity is another form of a reserve system. Texas shrimp stocks are fished during both spawning (offshore) and juvenile growth (inshore) periods. Seasonal closures of both inshore and offshore fisheries results in a rotating system of temporary marine reserves based on a time scale adjusted to the behavior patterns of the shrimp.

The trend in fisheries management is toward management through the issuance of Individual Fishing Quotas (IFQ). Harvest quota based management is more responsive to changing environmental and resource conditions, and subsequently is more effective in guarding against a total collapse of a fishery. A derivation of an IFQ is the Individual Transferable Quotas (ITQs). Being transferable, the quotas become a marketable commodity subject to the standard influences of a free market. It has been argued that ITQs are a more effective and rational way of dealing with overcapacity in fisheries. Could ITQ management be applied to the Texas inshore shrimp fishery? The historical model for the management of the inshore shrimp fishery has served its purpose to this point in time, but there are indications such as falling catch per unit effort and higher counts per pound that indicate a new model needs to be applied. The model should be more holistic taking into account not only stock density and size, but also ecosystem dynamics and the socioeconomics of the fishery. An Individual Transferable Quota (ITQ) management strategy with a "protected reserves" system appears to have the greatest potential for achieving this goal.

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CHAPTER 1
INTRODUCTION

Penaeid shrimp (Family Penaeidae) are economically valuable, commercially harvested shellfish as well as ecologically important components of estuarine food webs. Commercially, shrimp are considered an "annual crop", and what is not harvested is lost revenue. The ecological role of shrimp is one of nutrient and energy transfer to top-level consumers including finfish and larger crustaceans (Patillo et al. 1997). As they grow, their trophic roles change and shrimp link a variety of food chains together depending on their life stage. Shrimp, particularly juveniles, are important prey for many juvenile finfish, and may indirectly support several important fisheries, such as the recreational fisheries for spotted seatrout (*Cynoscion nebulosus*) and red drum (*Sciaenops ocellatus*) and the commercial fishery for southern flounder (*Paralichthyes lethostigma*).

Annual per capita consumption of shrimp has more than doubled from 1.4 lbs/yr in 1980 to 3.0 lbs/yr in 1999 (NMFS 2000). In the 1990s, Texas was second only to Louisiana in Gulf of Mexico shrimp landings (Figure 1) and was first in shrimp ex-vessel value among Gulf states. The Texas shrimp fishery is the most valuable commercial fishery in the state, comprising an average of 84% of Texas commercial landings (Figure 2) and 92% of ex-vessel value (Figure 3) between 1972-1999. For 1999, the total economic impact of the Texas shrimp fishery at the wholesale level (including live and dead bait) was estimated at $510,000,000 using an expansion factor of three (Auil-Marshalleck et al., 2001).

In Texas, shrimp are targeted for harvest during nearly all parts of their life cycle due to the dual nature of the fishery (food and bait). Collapse of the Texas shrimp fishery has been feared since the early part of the last century (Maril, 1995; Ponwith and Dokken 1996). However, although the Gulf harvest has significantly declined since 1972 (df 1, 26; $F = 9.2634$; $p = 0.0053$; Figure 4) and bay harvest significantly increased at least through the early 1990s (df 1, 26; $F = 22.1055$; $p = 0.0001$), overall state harvest has remained relatively stable (see Figure 2; regression was not significant) and the fishery has not collapsed. However, fisheries in general exhibit a syndrome of overexploitation and the Gulf of Mexico shrimp fishery is no exception. The offshore fishery was declared overcapitalized and overexploited in 1990 with more effort expended for shrimp harvest than was economically sustainable (SFSC 1992). In addition, increased harvest of smaller bay shrimp since 1972 and concomitant decreased offshore catch suggest that most shrimp are harvested before they have a chance to move out of the bays to spawn (TPWD 1999). Thus, despite the fact that overall harvest along the Texas Gulf Coast has changed little over the last 30 years, the fishery exhibits some characteristics of overfishing.

Persistent overexploitation of either component of the Texas shrimp fishery has both economic and ecologic consequences. Recognition of this potential problem provided the impetus for this comprehensive characterization of the bay shrimp fishery, with a focus on the bays of the Coastal Bend (Aransas Bay, Corpus Christi Bay, and upper Laguna Madre). Characterization of a fishery system requires examination of the three

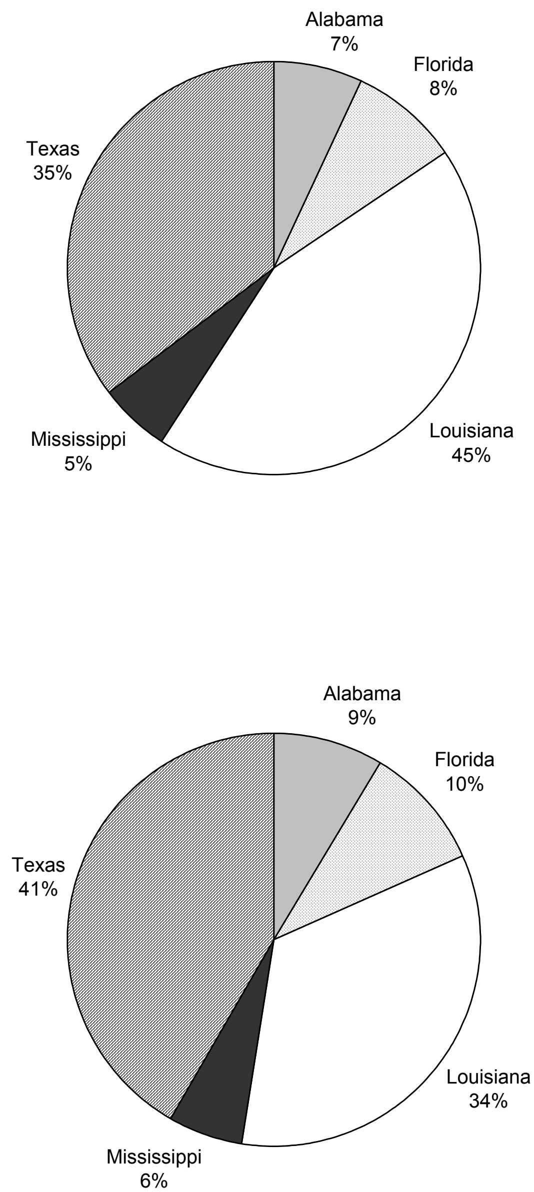
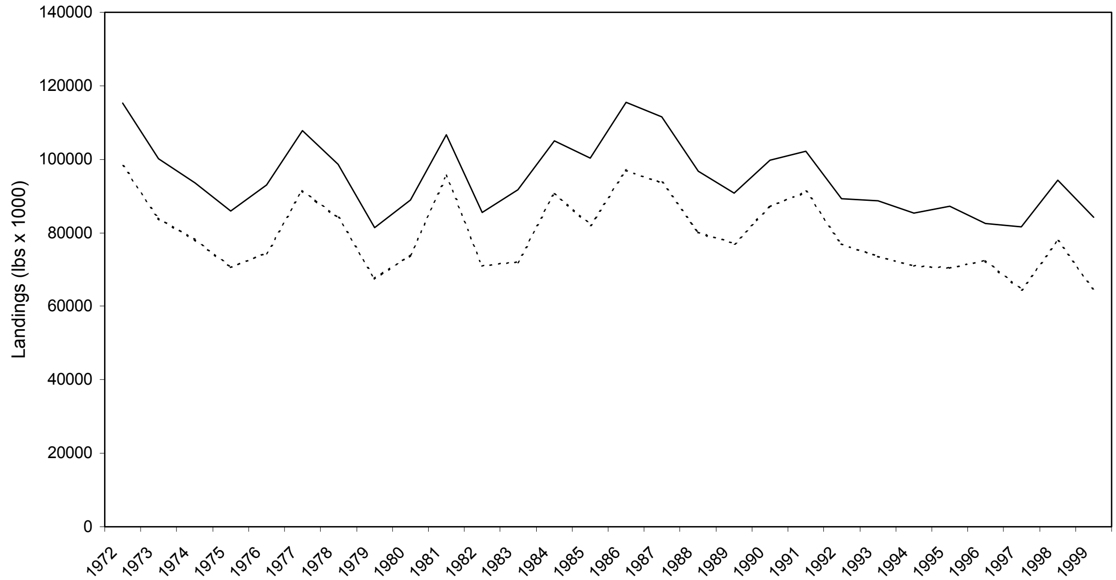


Figure 1. State contributions to overall Gulf of Mexico shrimp landings (top) and ex-vessel value (bottom), 1990-1999. Data from NMFS (personal communication).



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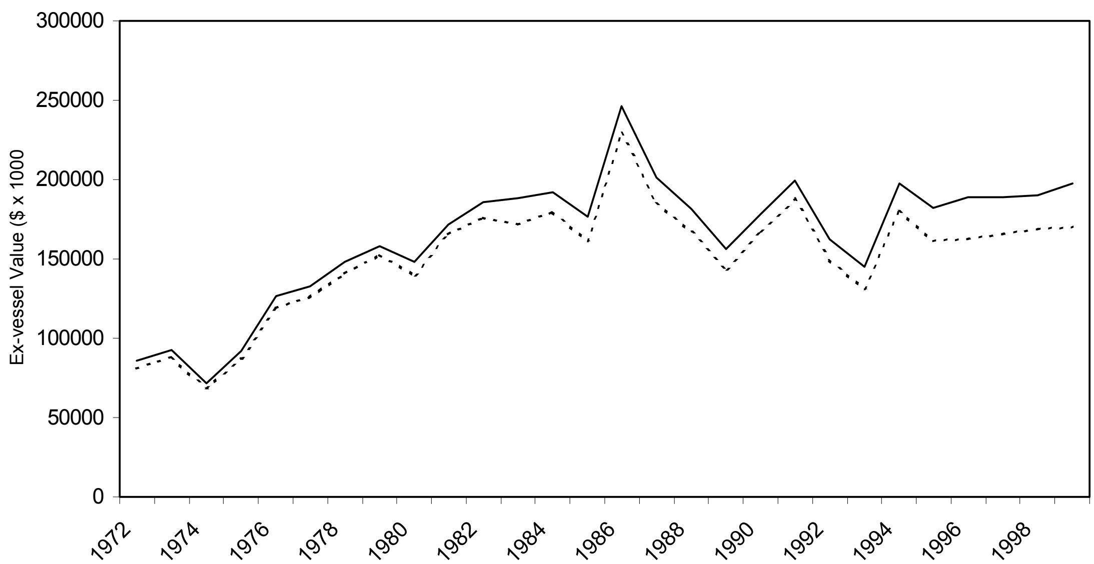

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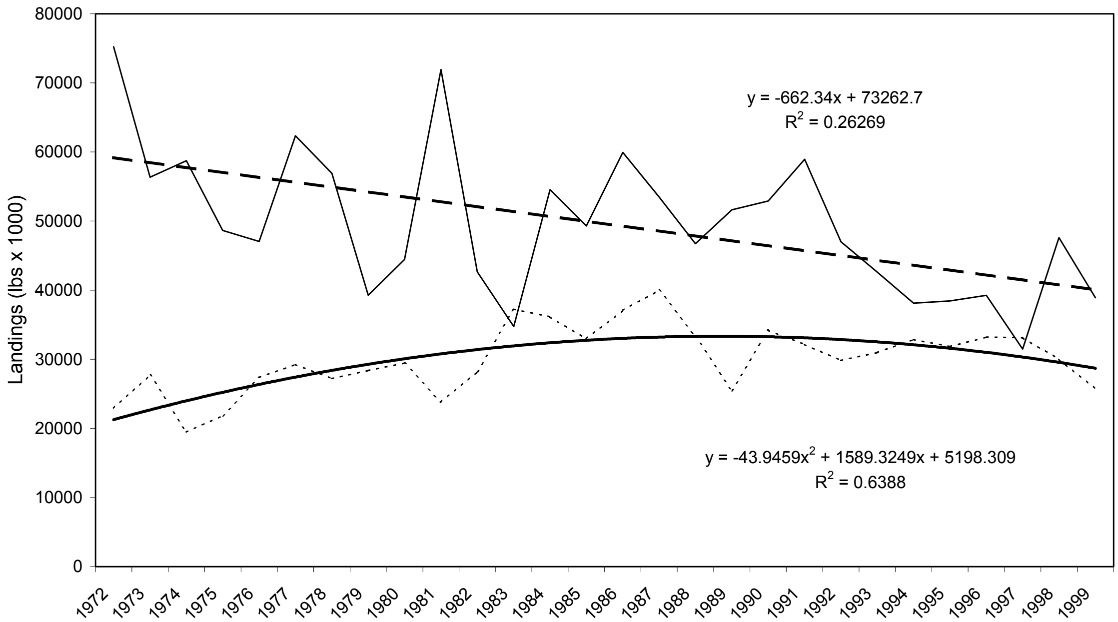


Figure 4. Texas Gulf shrimp landings (solid line, thousands of pounds) and Texas bay shrimp landings (broken line), 1972-1999 (data from Auil-Marshalleck et al. 2001).

interacting subsystems of which it is composed (Seijo et al. 1998): 1) the resource; 2) resource users; and 3) resource management (Figure 5). The resource subsystem includes all aspects of the life history of the species, environmental factors that affect its abundance and spatial-temporal distribution, and its ecological interdependencies. The resource users subsystem encompasses both quantitative measures of effort, species selectivity, and target price as well as the attitudes and perceptions of the fishery participants. The resource management subsystem includes management strategies and regulatory processes. This synthesis will provide: 1) the results of a survey on the attitudes and perceptions of the fishery's local participants; 2) a description of the shrimp fishery including summarization of commercial fishery statistics; 3) a brief description of the ecology of penaeid shrimp in the Texas Coastal Bend; 4) a characterization of shrimp populations in Corpus Christi, Aransas and upper Laguna Madre bay systems using fishery independent data collected by TPWD; and 5) and recommendations concerning management of the resource.

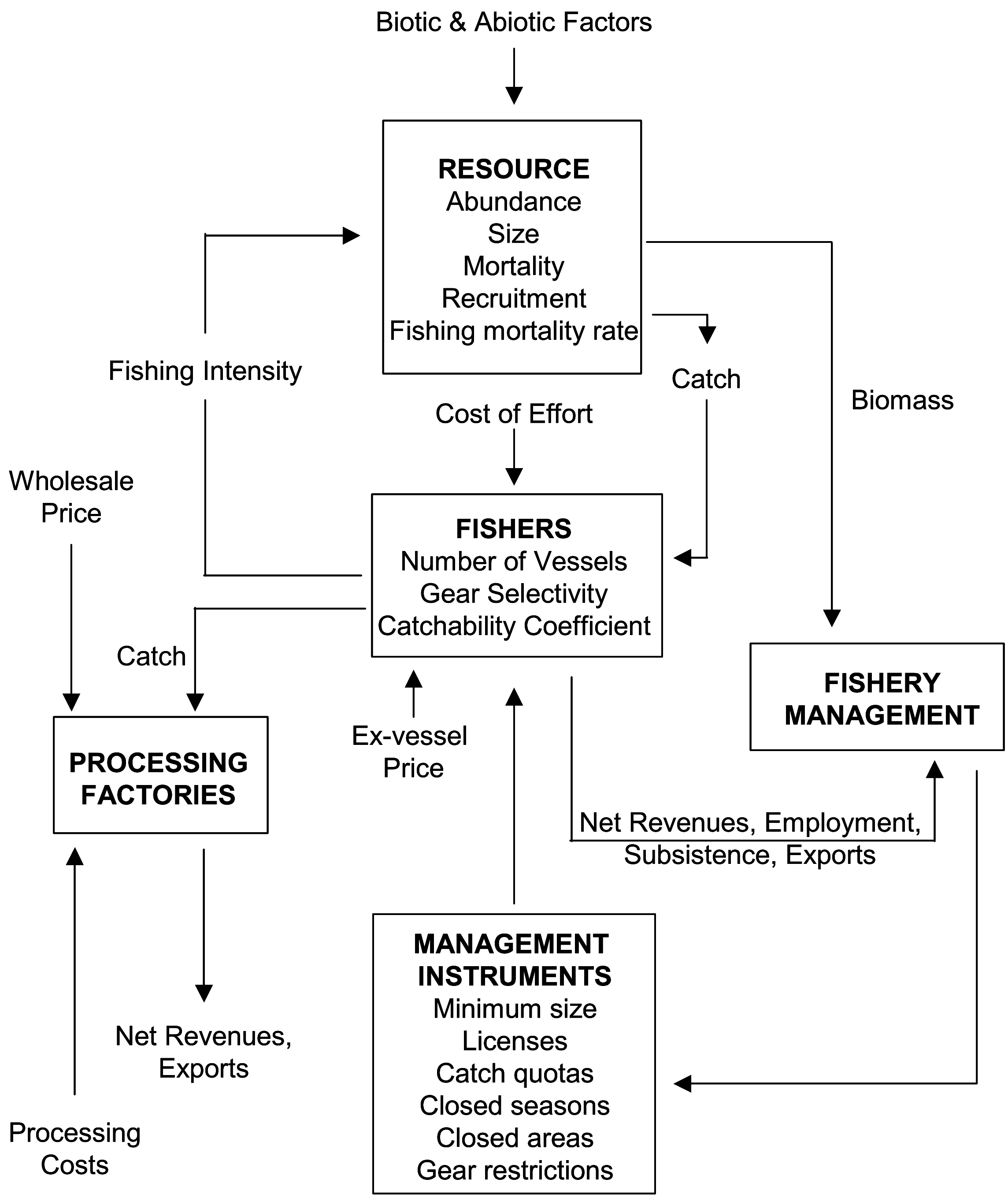


Figure 5. Fishery subsystems, major factors that affect them, and their interactions (modified from Seijo et al. 1998).

CHAPTER 2
THE BAY SHRIMPER

From the responses to the questionnaire (Appendix 1) summarized below we can begin to paint a "broad brush" characterization of the typical bay shrimper of Aransas, San Patricio, and Nueces counties. In general, the typical Coastal Bend shrimper is Asian-American or Anglo male 40 years old or older. They personally operate a boat that is 10 years old or older and have one or less employees. Bay shrimping is their sole or primary source of income that generally ranges from $20-30,000 annually. However, there are those that live on the extreme ends of the shrimping income scale (i.e. <$10,000 and >$40,000 annually). They are happy with their profession, but do not believe it will be viable occupation/business for their children.

Coastal Bend bay shrimpers believe that overall resource management regulations are overly burdensome and some unnecessary. They do not feel that they have enough input into the development of regulations. They are not interested in a license buy back program because it does not pay enough, decreases the value of their boat, and/or they are not prepared to move into other businesses or professions.

Most bay shrimpers operate with a Bay and Bait license. Business expenses run about $23,000 per year including hired labor. Typically, labor costs are less than $10,000 annually.

Summary of Survey Responses

Coastal Bend bay shrimpers were surveyed (n = 49; not all survey respondents answered each question) to create a data base on the demographics of the industry and to get a view of the industry from those who have a direct dependency upon it for sustaining there families and lifestyles. The results of the survey are summarized as follows:

Demographics

Residence – Greater than 57% of the bay shrimpers live in Aransas County and about 31% live in Nueces County. Less than 12% reside in San Patricio County.

Ethnicity/Age – More than half, 51%, of the bay shrimpers are of Asian heritage, followed by Anglo, ~30%, and Hispanic, ~16%. Anglo shrimpers tended to be older with nearly 87% falling in the 40 to 60 year old age bracket. All Anglo respondents were ≥ 40 years old. Seventy-five percent of the Hispanic shrimpers were in the 31 to 50 year old age brackets with the remaining 25% being > 60 years old. Nearly 83% of the Asian-American shrimpers were between the ages of 31 and 50 years with 17.4% being 51 – 60 years old. Noticeably absent were shrimpers less than 30 years old.

Years Shrimping – Slightly more than 57% of the survey respondents were first generation bay shrimpers, and greater than 65% of them have been in the business for more than 15 years. Nearly 84% have been in the business $\geq$ 10 years. Only 16.3% have been shrimping < 10 years.

Future Opportunity – Nearly 87% of the Anglo and 74% of the Asian respondents did not believe that bay shrimping was a viable career opportunity for their children. About 57% of the Hispanic respondents did see future opportunities in bay shrimping for their children. Maril (1995) reported that bay shrimpers do not see bay shrimping as a viable occupation for the future. However, 71.9% of Maril's respondents said they would like for their son (if they had one) to work in bay shrimping. The surveys and workshops of Dokken et al. (1998) highlighted the fact that the fisheries labor force is aging because younger members of the communities were opting to pursue jobs and careers other than commercial fishing and those in the seafood processing industries.

Family Members – Greater than 71% of the Hispanic and 62% of the Asian respondents reported other family members involved in the business. Forty percent of the Anglo respondents reported other family members involved.

Economics

Income - Seventy-six percent of the Asian and about 73% of the Anglo bay shrimpers reported this business as their sole source of income. Hispanic respondents were equally divided at 50% on this question. Of those Hispanic shrimpers who had other incomes, 60% reported shrimping produced < 25% of their income in 1997 and 40% reported shrimping income to be 51 – 75% of their income in 1997. In 1998, 1999, and 2000 the proportion of income derived from bay shrimping by Hispanic respondents dropped with 75% of the respondents with other incomes reporting that shrimping produced < 25% of their annual income.

In the years 1997 through 2000, the relative percentages of gross income/boat remained consistent within the ethnic groups. Using 1999 gross income/boat, 12.5% of the Anglo shrimpers reported < $10,000, 50% reported $10-20,000, 25% reported $20-30,000, 0% reported income of $30-40,000, and 12.5% reported income > $40,000. 50% of the Hispanic bay shrimpers reported gross income in 1999 < $10,000, 16.7% reported income in the $10-20,000 and $20-30,000 ranges, 0% reported income in the $30-40,000 range, and 16.7% reported gross annual income per boat >$40,000. 18.2% of the Asian shrimpers reported < $10,000 gross income, 40.9% grossed $10-20,000, 27.3% grossed $20-30,000, 9.1% grossed $30-40,000, and 4.5% grossed > $40,000 in annual income per boat.

Maril (1995) reported that Texas bay shrimpers averaged an income of $19,859 in 1988 and 1989. Regarding personal income from shrimping, Maril stated

> A significant number of bay shrimpers in the survey sample (about 40 percent) earned annual incomes from shrimping that were below or just slightly above the poverty line. Another 40 percent were just getting by, their incomes from shrimping ranging from $15,000 to $29,000. At the other end of the scale, about 12 percent earned $40,000 or more.

For Texas, Maril estimated earnings for all bay shrimpers to be $138.7 million. Using a multiplier of 2.37 to estimate the economic impact of the Texas bay shrimper labor force, the total economic impact was $328.7 million annually.

Boats – Nearly 63% of the Hispanic bay shrimpers reported having two or more bay shrimp boats. Greater than 86% of Anglo and Asian shrimpers reported owning only one vessel. No respondent reported owning a boat < 5 years in age. 33.3% of the Anglo shrimpers reported owning boats 5 – 10 years old and 66.7% owned boats > 10 years old. The majority of Asian shrimpers, 84%, owned boats > 10 years old and only 16% owned boats 5 – 10 years old. Hispanic shrimpers tended to have newer boats with 62.5% having boats 5 – 10 years old and the remainder owning boats > 10 years old.

About 30% of the Anglo and Asian respondents reported purchasing a boat in the last five years while ~62% of the Hispanic shrimpers reported purchasing a boat in the last five years. Financing for boat purchases varied. 100% of the Anglo shrimpers purchasing boats obtained a bank-financed loan. Hispanic shrimpers obtained financing on an even split between bank and family. Asian shrimpers reported 100% of financing from family or other personal sources. Anglo and Hispanic shrimpers had finance terms less ≤ 5 years. Nearly 67% of the Asian shrimpers had terms less than 5 years and 100% had terms less than 10 years. Those respondents reporting boat loans received an average loan of $13,000, made a $5,500 down payment, and paid $1,608.33 until the balance was paid off.

One Anglo and 5 Hispanic respondents reported securing operational loans during the period 1997 through 2000. 13 Asian respondents utilized operational loans during the same period. Operational loans were typically < $10,000 and in all cases less than $20,000.

Expenses – Average operational costs are summarized in Table 1. Sixty-percent of the Anglo and 100% of the Hispanic bay shrimpers reported having 1-3 employees. 17.4% of the Asian shrimpers reported 1-3 employees. One Anglo respondent each reported 7-10 employees and > 10 employees. All others reported zero employees.

Anglo respondents reported employee workdays to be 91-120 (22.2%) and >120 days (77.8%). 12.5% of the Hispanic shrimpers reported employment days in each of the categories, 1-30, 31-60, and 61-90 days. 62.5% of the Hispanic shrimpers had employees for >120 days. Asian shrimpers split their employment days evenly between the 1-30 and 61-90 day categories.

The average rate of payment of employees was reported at 20% of the catch or about $52.00/day. 85.8% and 83.4% of the Anglo and Hispanic shrimpers, respectively, reported gross income per employee to be $10,000 annually or less with at least half of this subgroup being less than $5,000/year. 71.4% of the Asian shrimpers with employees reported paying less than $10,000/year/ employee and 28.6% paying $10-20,000/year/employee. 14.3% of Anglo respondents reported employee salaries in the

Table 1. Average operational costs reported by shrimp survey participants.

Expense Type	Amount
Licences	$ 841.25
Fuel	6,655.17
Dock Fees	1,636.13
Boat Maintenance	4,245.16
Labor	3,410.53
Nets	3,585.71
Supplies	1,859.09
Insurance	636.04
Loan Interest	173.92

$10-15,000 range and 16.7% of the Hispanic respondents reported employee income in the $15-20,000 range.

Product Pricing – All Anglo and Hispanic shrimpers were independent producers selling to the highest buyer each day. 31.6% of the Asian shrimpers were contracted to a buyer for their catch. Greater than 84% of all bay shrimpers believe that dock prices for shrimp have either stayed the same or decreased over the past 5 years. Average wholesale rates are listed in Table 2.

Maril (1995) reported that dockside prices paid for bay shrimp increased 177% from 1964 to 1981. Prices then leveled off and began a downward slide. Maril refers to 1986 when landings increased by 60 million pounds, but the value of the product was only marginally greater than the year before.

Catch Rates – Greater than 87% of all respondents reported that catch rates have decreased or stayed the same over the past 5 years. 84.6% of the Anglo, 75.0% of the Hispanic, and 55.6% of theAsian respondents reported catch rates decreasing over the past 5 years. 60% or greater of all the shrimpers believe the bay shrimp fishery is decreasing. 50% or more believe that the sustainability of the fishery is questionable. Respondents reported average landings of 9,532.35 lbs/boat.

Dockside wholesale prices have not kept pace with inflation, either staying stable or actually falling over the past decade. There does not seem to be a direct relational link between the wholesale prices the shrimpers receive, product volume, and consumer demand. Bait prices offer an alternative. Whereas dead bait will wholesale for $1.50/pound, live bait will wholesale for $4.00/pound (Fraser 2002). Table shrimp caught with a Bay license will range from $0.88/pound for 101+ count shrimp and $5.40/pound for 6-8 count shrimp (count = number of shrimp per pound). Size and

Table 2. Average wholesale prices paid to shrimp survey participants for their catch.

Size (#/lb)	Price
6-8	$ 5.40
9-12	4.83
13-15	4.28
16-18	3.62
19-21	3.00
22-25	2.61
26-30	2.30
31-35	2.16
36-40	2.10
41-50	1.47
51-60	1.51
61-70	1.66
71-80	1.14
81-100	1.04
101+	0.88

value, Coastal Bend bay shrimp typically fall in the mid to lower end of the range (i.e. 16-18 count at $3.62/pound and 51-60 count at $1.51/pound).

Bycatch – 33.3% of the Asian, 71.4% of the Hispanic, and 50% of the Anglo shrimpers sell bycatch. Bycatch was reported to be <10% of the total landings and comprised primarily of squid, croaker, mullet, other baitfish such as ribbon fish, and crab.

Public Demand – More than 86% of the Anglo and Hispanic shrimpers believe that public demand for shrimp is increasing. Asian shrimpers are about evenly divided between increasing, decreasing, and stable. Shrimp is a staple of the coastal Texas seafood restaurant business, and Maril (1995) discussed reports that per capita consumption had increased from less than a pound per person in the 1960's to 2.2 pounds by 1986.

Competing Suppliers – 78.6% and 64.7% of the Anglo and Asian respondents, respectively, believe that the import of frozen shrimp has a negative effect on their industry. 37.5% of the Hispanic shrimpers believe that imported frozen shrimp is a threat. 93.3%, 57.1%, and 75.0% of the Anglo, Hispanic, and Asian respondents, respectively, believe that pond raised (i.e. cultured) shrimp has an impact on their industry.

From 1951 to 1989, shrimp imports into the United States increased 1,254% (Maril 1995). Aquaculture imports, 176.2 million pounds in 1988 and 1989 held dockside prices on American shrimp down. Without these imports, Texas bay shrimpers would have received up to 60% more for their product. Low prices were a windfall for processors and buyers, and subsequently they had little sympathy for the shrimpers.

Operations

Licenses – Anglo shrimpers, 86.7%, reported purchasing Bay and Bait licenses only, and 13.3% reported purchasing all available licenses including Bay and Bait and Offshore. Asian shrimpers primarily bought Bay and Bait, 88%, with 8% purchasing all available licenses and 4% buying only a Bay license. Hispanic shrimpers were 50/50 on purchasing Bay and Bait licenses and all licenses.

Boat Operations – For all ethnic groups, more than 86% reported that they personally operated their boats. 40% of the Anglo, 37.5% of the Hispanic, and 47.8% of the Asian respondents shrimp 3-5 days/week during the season. 60% of the Anglo, 62.5% of the Hispanic, and 39.1% of the Asian shrimpers shrimp > 5 days/week during the season. The hours actually trawling during each trip varies between ethnic groups. 37.5% and 39.1% of the Hispanic and Asian respondents, respectively, report trawling ≤ 2 hours/trip. 93.4% of the Anglo, 62.5% of the Hispanic, and 39.1% of the Asian shrimpers trawl between 2 – 7 hours/trip. 21.7% of the Asian shrimpers trawl more than 7 hours/trip. On the average, respondents reported spending ~33 hours/week on the water trawling, nearly 13 hours/week selling the product, and nearly 12 hours/week on boat maintenance. Maril (1995) reported that bay shrimpers, using the bay and bait licenses, shrimp 7.23 months per year.

Regulatory Management

Regulatory Process – Between 50 and 56.3% of the respondents believed that the regulatory process is fair. Less than 36.4% believed that the data used by the Texas Parks and Wildlife Department and National Marine Fisheries Service was accurate or presented accurately. 41.7% of the Anglo, 71.4% of the Hispanic, and 53.8% of the Asian respondents replied affirmatively when asked if they would be willing to provide data to support management efforts. 69.2% of the Anglo, 57.1% of the Hispanic, and 40.0% of the Asian shrimpers reported that they trust other organizations interested in fishery resources such as non-profit conservation groups.

Unstructured comments regarding the regulatory process communicated common themes. Turtle Excluder Devices (TED) and Bycatch Reduction Devices (BRD) were universally disliked. Most felt that they were unnecessary in local bays, not effective, and caused an unacceptable amount of shrimp catch to be lost. Other regulation commonly reported to be "most burdensome" was the requirement to maintain ½ of the catch alive when fishing under the Bait License.

Suggestions for improving the regulations included:

1) Remove daily time restrictions (catch limits adequate)
2) Lower license fees
3) Increase fees paid on License Buy Back Program
4) Have TPWD on board to collect data in full view and cooperation with the boat captain.

5) Limit "drags" to 45 minutes
6) Open currently closed areas
7) Limit net sizes (i.e. mouth opening) to 34 feet during "brownie" season and 65 feet during the white shrimp season

In Maril's (1995) surveys, many shrimpers believed the regulations to be so restrictive that the only option to stay economically viable was to break the laws when the opportunity existed. Most commonly, daily catch limits were exceeded when the shrimp were running. This was consistent with the co-author's (Q. Dokken) personal experience when operating a bay shrimp boat in the late 1970's. The guiding philosophy was to "Get while the getting is good because tomorrow there may be nothing to get!"

<u>License Buy Back Program</u> – 53.8% of the Anglo shrimpers, 57.1% of the Hispanic and 27.8% of the Asian shrimpers were interested in the License Buy Back Program. Reasons for not being interested in the License Buy Back Program were most frequently: 1) doesn't pay enough and a boat without a license has drastically reduced value; 2) a desire to continue shrimping; 3) only source of income; and 4) inadequate funds to start another career.

<u>Fishing Fleet</u> – 80.0% of the Anglo, 42.9% of the Hispanic, and 50.0% of the Asian shrimpers believed that there are too many licensed bay shrimpers working. 86.7% Anglo, 28.6% Hispanic, and 64.3% of the Asian shrimpers believed that entry into the fishery should be restricted. In 1981, 5,000 bay licenses were sold, up from 1,200 in 1964 (Maril 1995). A temporary freeze on bay license sales imposed by the Texas legislature and market forces caused a reduction in the demand for bay licenses and by 1988, only 2,908 licenses were issued.

CHAPTER 3
THE TEXAS SHRIMP FISHERY

The shrimp fishery in southern Texas is part of a larger stock that encompasses the entire western Gulf of Mexico (Patillo et al. 1997). The Texas shrimp fishery has two components, the food fishery that mainly targets larger mature white (*Litopenaeus setiferus*) and brown (*Farfantepenaeus aztecus*) shrimp offshore and in primary bays, and the bait fishery that targets smaller shrimp of all species (including pink shrimp, *F. duorarum*) in primary bays, some secondary bays and other areas designated "bait bays". Because shrimp are an annual crop, a commercial fishery focused entirely on the most valuable shrimp, the larger mature adults nearing the end of their lives, is able to significantly reduce parental stocks without affecting recruitment of young into the fishery the next year (Patillo et al. 1997). Even in areas where most shrimp are harvested before they are 6 months old (inshore fisheries), there has been no demonstrable stock-recruitment relationship (Turner and Brody 1983). It is thought that current fishing methods and technology are unable (economically) to take so many shrimp that too few survive to provide an adequate supply for the following year. However, because the Gulf fishery has been declared overexploited, it seems likely that fishing or a combination of fishing and other factors (e.g., environmental conditions, natural and/or anthropogenic disturbance) have modified the theoretical lack of relationship between stocks and recruitment.

Dokken et al. (1998) completed a comprehensive economic development report of Texas fisheries including the bay/bait shrimping industry. From this report, based on employment records it is evident that commercial fishing industries in Texas are declining, but retail sales jobs related to seafood are increasing. Between 1990 and 1995, overall in Texas coastal counties employment in commercial fishing fell 24.9%, fishery product processing fell 0.4%, wholesale product employment fell 14.7%, but seafood retail sales employment increased 4.3%. In Aransas, Nueces, and San Patricio counties, fishery related employment change (i.e. percent change 1990 – 1995) are reported in Table 3. These statistics clearly show a declining shrimping culture and the influence of imported product for sale at the retail level.

Increase in landings by the bay/bait shrimp industries from 1966 to 1991 prompted the creation of a Limited Entry Plan in 1995 for the Texas inshore shrimp fishery. It allowed the state to restrict the number of licenses sold and provided funding for a voluntary license buyback program. The objectives were to reduce the fishing fleet, increase catch per unit effort, and to stabilize the inshore industry. With average prices for "buy back" of licenses being about $3,500 in 1997 and 1998 (Dokken et al. 1998), one can question whether or not the more active (i.e. full time) shrimpers will be interested in the buy back program as was indicated in the survey responses. It is possible that the licenses being sold back to the state were those that were marginally utilized.

Table 3. Percent change in employment in fishing industries in the Coastal Bend, 1990-1995 (from Dokken et al. 1998).

Employment Sector	Aransas County	Nueces County	San Patricio County
Commercial Fishing	-27.8%	-31.7%	-24.5%
Processing	-94.1%	0%	0%
Wholesaling	-10.0%	+24.1%	-92.4%
Retailing	+48.9	+24.0 %	+20.2%

Vessels and Licenses

In 1999 about 2,922 shrimping vessels worked the major and "bait bays" and Gulf waters along the Texas coast with 1,649 boats in the bay and bait shrimping fleets, and another 1,273 vessels in the offshore fleet (TPWD 2000). The number of boats in the 1999 fleet was only about 40% of the number recorded in 1983 (data from Crowe and Bryan 1986). Both bay and bait shrimp boats are generally less than 40 ft long, are independently owned and return to port every day. These vessels usually have a crew of 2-3, including the captain. Galveston, Matagorda, San Antonio, Aransas and Corpus Christi bays have the largest inshore shrimping fleets. Vessels employed in the Gulf shrimp fishery are usually 40 – 100 ft long, are capable of pulling multiple nets and are often owned by corporate interests. Gulf boats usually have crews of 3 or more and can stay offshore for up to 2 weeks.

Most inshore fishers hold bay and bait licenses, allowing participation in both fisheries. The number of commercial shrimp licenses (regardless of type) generally increased from 1964 (when numbers of bay and bait shrimp licenses were separated in the statistics) until the early 1980s (Figure 6) after which they began to decline. The numbers of licenses issued in 1995 (1,841) were about the same as the numbers issued in 1964 (1,849). In 2002, residents of Aransas, Kenedy, Kleberg, Nueces, Refugio and San Patricio counties held 181 bay shrimp licenses and 193 bait shrimp licenses (TPWD personal communication).

Between 1979-1983, the shrimping fleet based in the Rockport-Corpus Christi area grew from 911 to 981 boats and represented 13-14% of the statewide total (data from Crowe and Bryant 1986). The increase was attributed to increased demand for shrimp and modifications in shrimping regulations. The majority of boats (≈65%) were part-time commercial bay boats (≤25') and commercial bay boats (25-55') (Figure 7). Most commercial bay boats held combination bay/bait licenses in 1983. In 2002, only 225 boats, or about 8% of the statewide total, were licensed in Aransas, Kenedy, Kleburg, Nueces, Refugio and San Patricio counties (Art Morris, TPWD personal communication). This represents a more than 80% decline in the numbers of boats in the Rockport-Corpus Christi area since 1983. There were a total of 374 licenses associated with these boats, indicating that many, if not most, held combination bay/bait licenses.

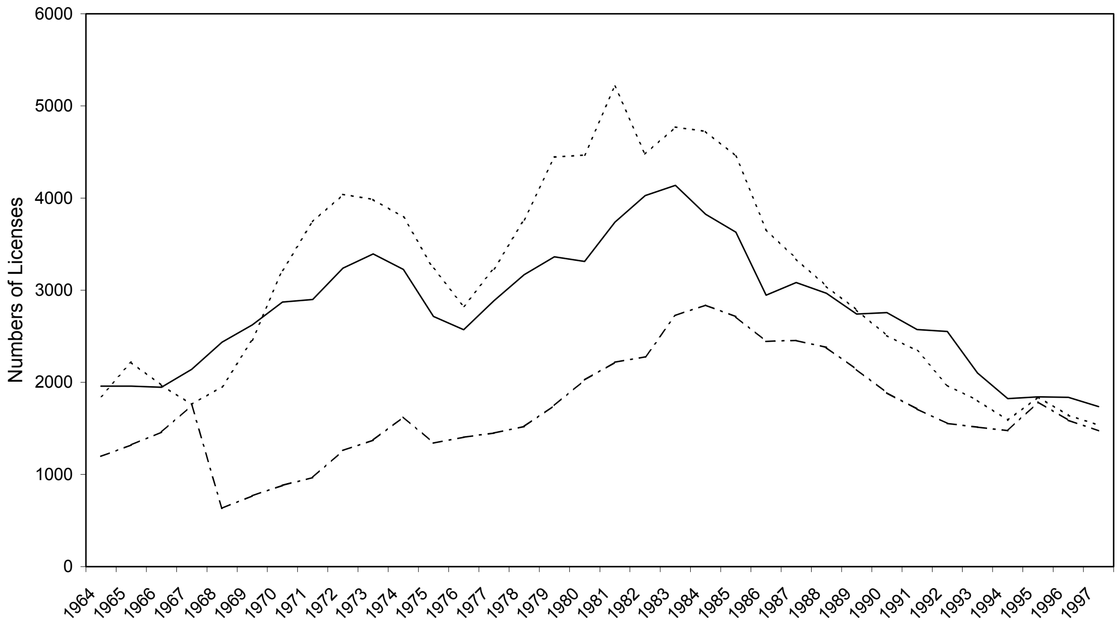


Figure 6. Numbers of commercial shrimping licenses on the Texas Coast, 1964-1997 (data from Robinson et al. 1998). Solid line is gulf licenses; dotted line is bay licenses; dashed line is bait licenses.

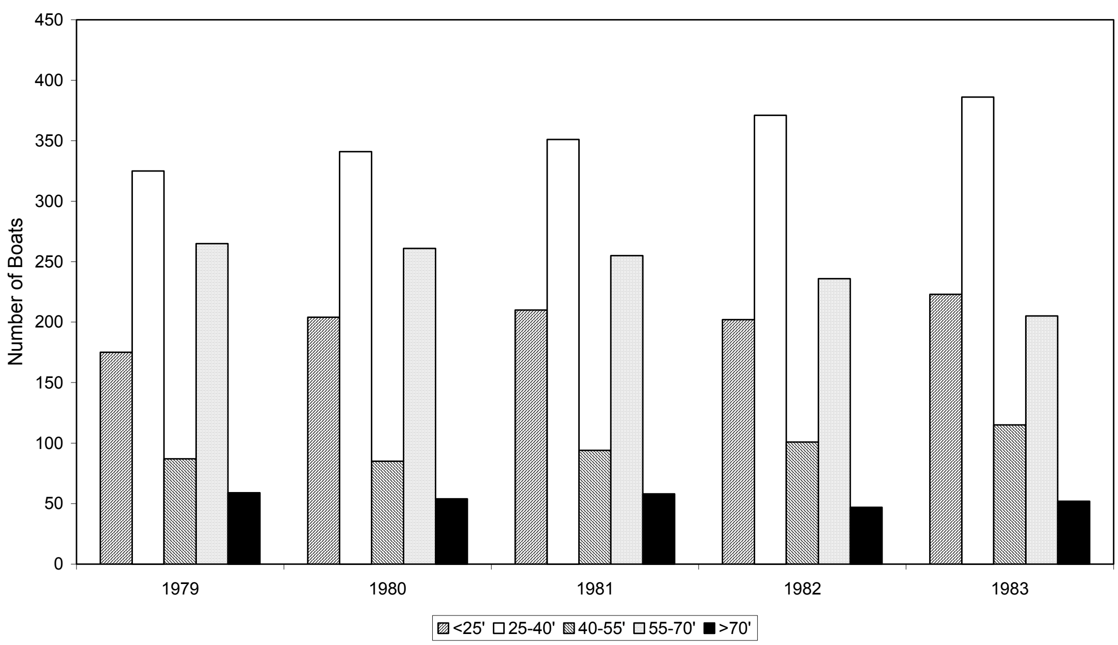


Figure 7. Numbers of boats in the Rockport-Corpus Christi shrimp fleet by size class, 1979-1983 (data from Crowe and Bryan 1986).

Harvest Focus and Product Distribution

Larger bay shrimp are harvested for sale as food from major bays only and are sold to wholesalers or directly to the consumer from the boat. Gulf shrimp are generally sold to wholesalers for distribution although a small proportion is sold for bait (≈2% of all bait landings, 1999; data from Auil-Marshalleck et al. 2001). Of shrimp likely to be captured in the bay, brown/pink shrimp brought the highest price up until 1989, after which white shrimp were generally more valuable (Figure 8). Bait shrimp are harvested from both bay and Gulf waters, although most bait comes from bays, particularly bait bays where only bait shrimping is permitted. Bait shrimp are sold directly to consumers or to bait stands. Live shrimp bring up to 3 times the price of dead, (Fraser 2002) thus fishers targeting bait generally trawl for shorter times and return to the dock daily in order to maximize their live catch.

Landings & Value

Historical Perspective (1890 – 1972)

Shrimp were not listed in the 1890 commercial harvest statistics for Refugio, Aransas and Nueces counties (Evermann and Kendall 1894). The commercial fishers in the Texas Coastal Bend focused primarily on oysters, spotted seatrout, and sheepshead during the 1890s and concentration on finfish and oysters continued until after WWI. Prior to 1920, fishers harvested shrimp using cast nets and drag seines (TGFOC 1923). Long seines were set close to shore and hauled in by men or horses until 1920 when the Texas Game, Fish and Oyster Commission (TGFOC) demonstrated that shrimp could be harvested in the Gulf using a trawl and motorized boat. Bay shrimpers embraced the new technology and the amount of shrimp landed in Corpus Christi Bay increased dramatically in subsequent years. In 1923 white shrimp landings for the entire Texas coast were estimated at 3.5 million lbs (Maril, 1995). Landings nearly tripled by 1927. Harvest declined in 1928-1929 but rebounded to 10 million lbs in 1930. Since at least 1942, shrimp have dominated local commercial landings (Ponwith and Dokken 1996, Figure 9). Prior to 1950, when offshore shrimp were not included in statistics, shrimp comprised 37-85% of landings from Aransas and Laguna Madre districts; after 1950, they comprised at least 89% of landings.

Recent Statistics (1972-1999)

Total shrimp landings ranged from a low of 64,603,000 lbs in 1997 to a high of 98,140,000 lbs in 1972 (see Figure 1). Percentage total Texas commercial landings attributed to shrimp ranged from 77% in 1999 to 90% in 1981. The ex-vessel value of shrimp (see Figure 2) ranged from $67,740,000 (1974) to $229,110,000 (1986) with percentage of total Texas commercial ex-vessel value ranging from 86% (1996, 1999) to 96% (1979, 1981).

Maril (1995) reported Texas bay shrimp landings to be greater than the total landings of both Gulf and bay shrimp in Alabama, Mississippi, and Florida. The contribution of the

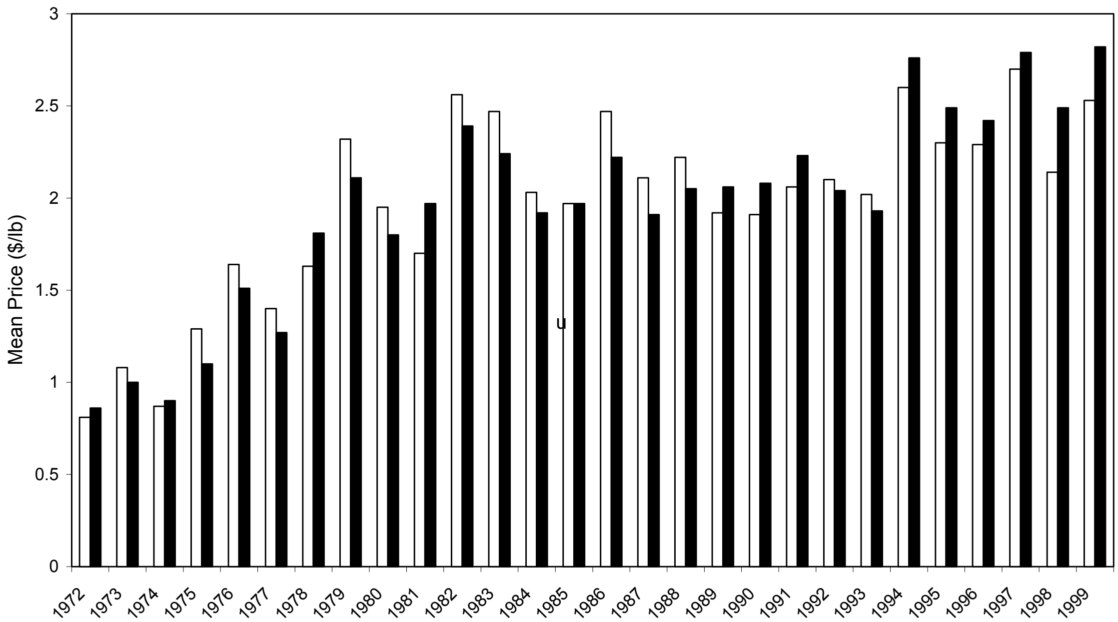


Figure 8. Average coastwide price per pound ($) of brown/pink (white bar) and white shirmp (black bar) in Texas, 1972-1999 (data from Auil-Marshalleck et al. 2001).

Figure 9. Commercial landings of shrimp (solid line; thousands of pounds) and all other species (broken line) in Aransas and Laguna Madre districts, 1942-1969 (no landing data were available for 1955). Data compiled from TGFOC, Texas Game and Fish Commission and TPWD annual reports (Ponwith and Dokken 1996).

bays to total shrimp landings (Figure 10) ranged from 661,300 lbs (1974) to 22,713,000 lbs (1990) and averaged about 20% over the same time period (8.2% [1972] – 30.3% [1997]). The ex-vessel value of bay shrimp (Figure 11) ranged from $3,953,000 (1974) to 32,684,000 (1994) and averaged about 12% of total Texas shrimp ex-vessel value (5.8% [1974] – 19.2% [1997]. For 1999, the total economic impact of the Texas bay shrimp fishery at the wholesale level is estimated at $38,916,000 (expansion factor of 3).

Shrimp landings in Aransas Bay, Corpus Christi Bay and upper Laguna Madre (Figure 12) ranged from 1,101,000 lbs (1974) to 10,564,000 lbs (1991) averaging about 30% (14.5% [1999] – 48.2% [1991]) of all bay shrimp landings and from 1.4% (1972) to 11.6% (1993) of Texas shrimp landings. Landings from the bays of the Coastal Bend peaked in 1991. The ex-vessel value of shrimp from the Coastal Bend (Figure 13) ranged from $767,000 (1974) to $13,640,000 (1991) and averaged 30% of total Texas bay shrimp ex-vessel value (12.6% [1999] – 50.4% [1991]). Ex-vessel value of Coastal Bend shrimp ranged from 1% (1999) to 8% (1992) of the ex-vessel value of Texas shrimp. For 1999, the total economic impact of the Coastal Bend bay shrimp fishery at the wholesale level is estimated at $4,911,000.

Shrimp landings (Figure 14) in Aransas Bay ranged from 659,000 lbs (1974) to 7,122,000 lbs (1991), Corpus Christi Bay landings ranged from 442,000 lbs (1974) to 3,904,000 lbs (1984) and upper Laguna Madre landings ranged up to 271,000 lbs (1988). An average of 62% of Coastal Bend shrimp landings were from Aransas Bay, followed by Corpus Christi Bay with 37%; upper Laguna Madre contributed less than 2% overall. Ex-vessel values (Figure 15) in Aransas Bay ranged from $433,000 (1974) to $9,072,000 (1991), Corpus Christi Bay values ranged from $275,000 (1972) to $5,303,000 (1992) and upper Laguna Madre ranged up to $602,000 (1998).

Management

In order to manage a fishery successfully, resource biology and ecology must be integrated with the social, economic, and institutional factors that affect the behavior of fishers (Seijo et al. 1998). The goal of fishery management is to achieve sustainable development of the resource so that the economic benefits of its exploitation will be available not just for its current users but also for future generations. This goal is similar to the concept of optimal sustainable yield. Optimal yield is the objective of the Gulf of Mexico Shrimp Fishery Management Plan as well as the Texas Shrimp Fishery Management Plan (Cody et al. 1989). Optimal yield is defined as the yield from a fishery that provides the greatest overall benefit to the nation in terms of food production and recreational opportunities; that is the maximum sustainable yield (the largest average catch that can continuously be taken from a stock under existing environmental conditions) modified by economic, social or ecological factors.

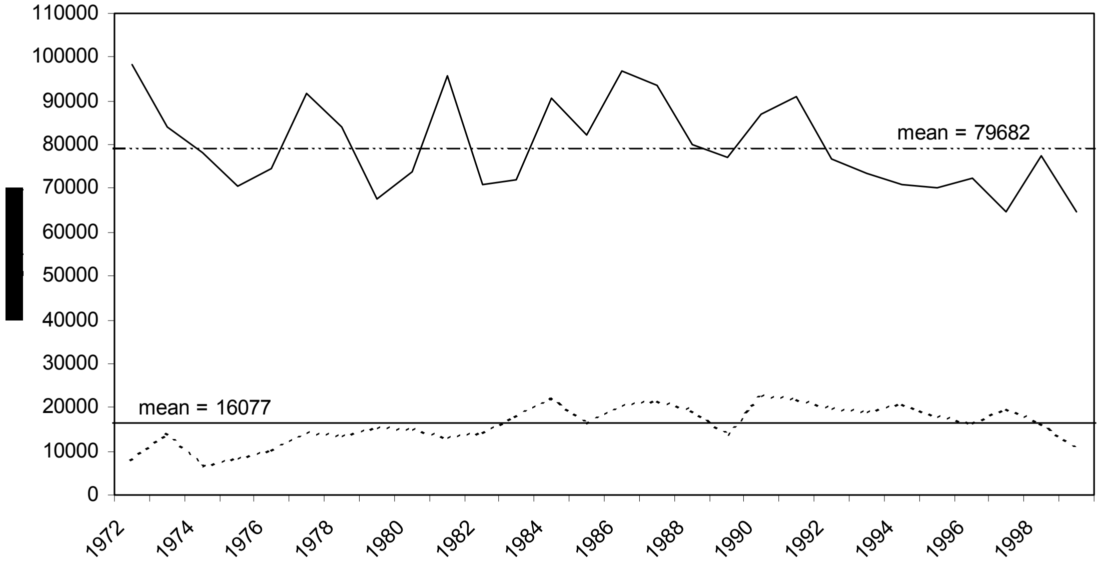


Figure 10. Total shrimp landings (thousands of pounds; solid line) and bay shrimp landings (broken line) in Texas, 1972-1999 (data from Auil-Marshalleck et al. 2001).

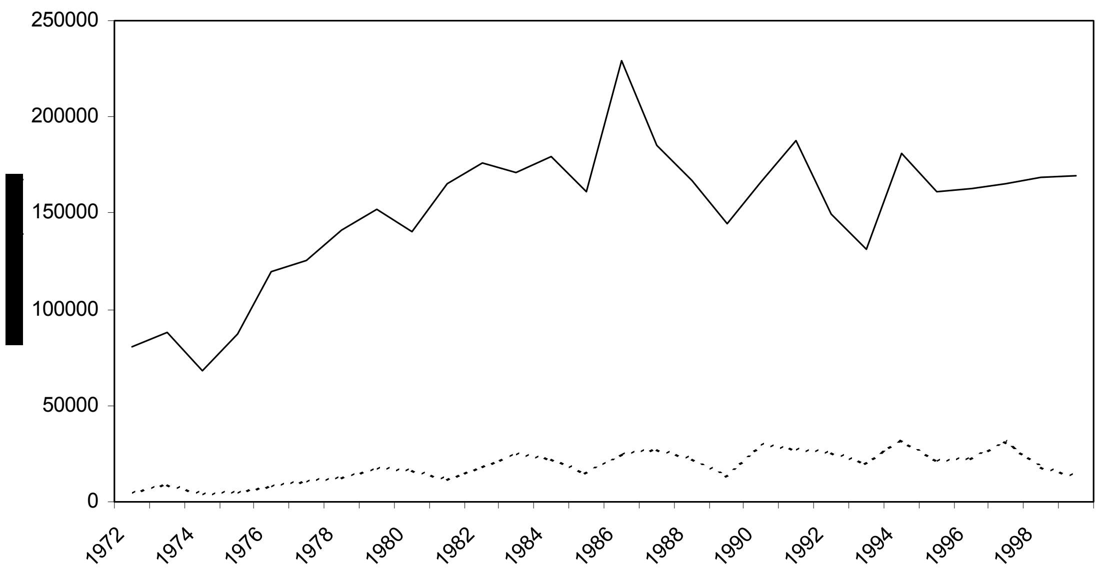


Figure 11. Total ex-vessel value (thousands of dollars; solid line) of Texas shrimp landings and total ex-vessel value of bay shrimp landings (broken line), 1972-1999 data from Auil-Marshalleck et al. 2001).

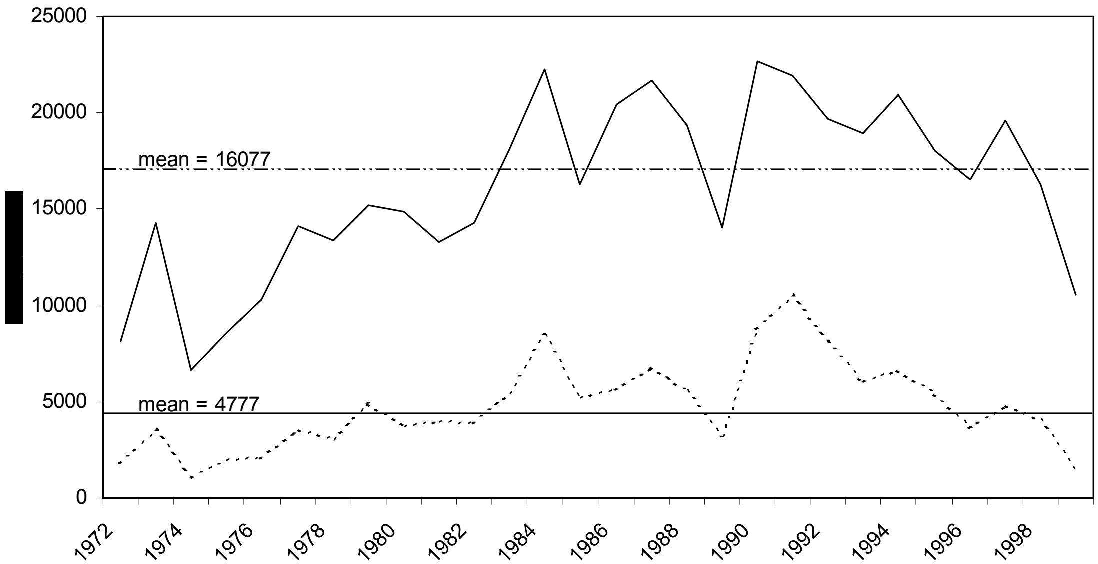


Figure 12. Total bay shrimp landings (solid line) and shrimp landings from Aransas and Corpus Christi bays and upper Laguna Madre combined (broken line), 1972-1999 (data from Auil- Marshalleck et al. 2001).

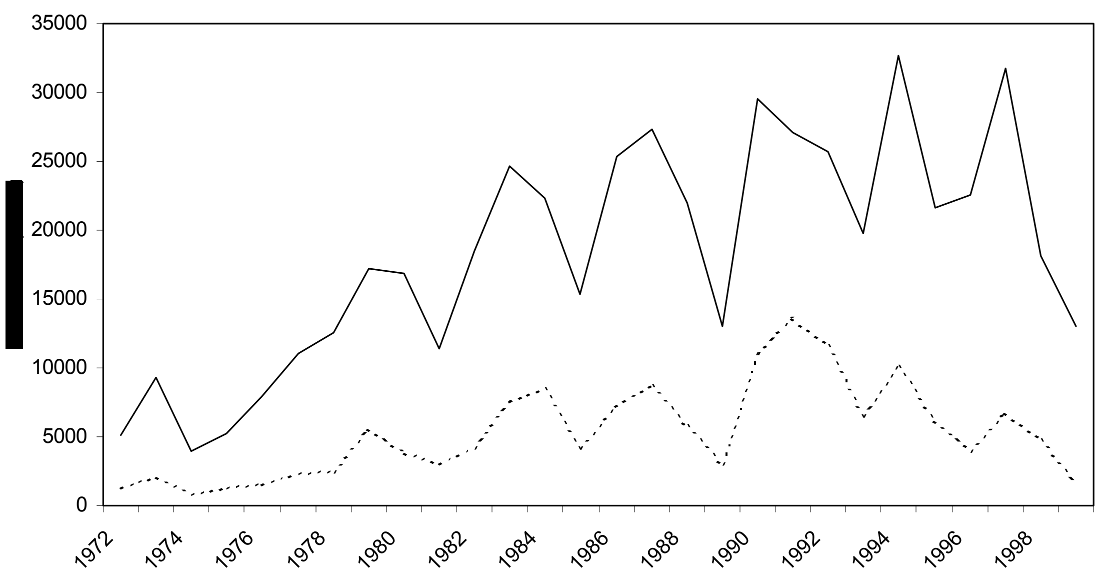


Figure 13. Total ex-vessel value of bay shrimp landings (solid line) and shrimp landings from Aransas and Corpus Christi bays and upper Laguna Madre combined (broken line), 1972-1999 (data from Auil- Marshalleck et al. 2001).

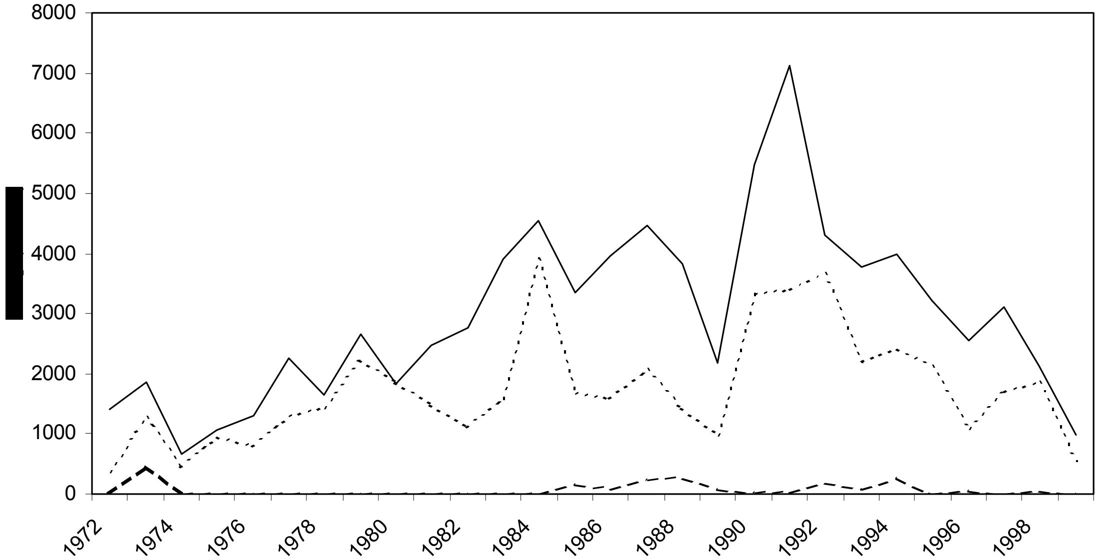


Figure 14. Total shrimp landings from Aransas Bay (solid line), Corpus Christ Bay (dotted line) and upper Laguna Madre (dashed line), 1972-1999 (data from Auil-Marshalleck et al. 2001).

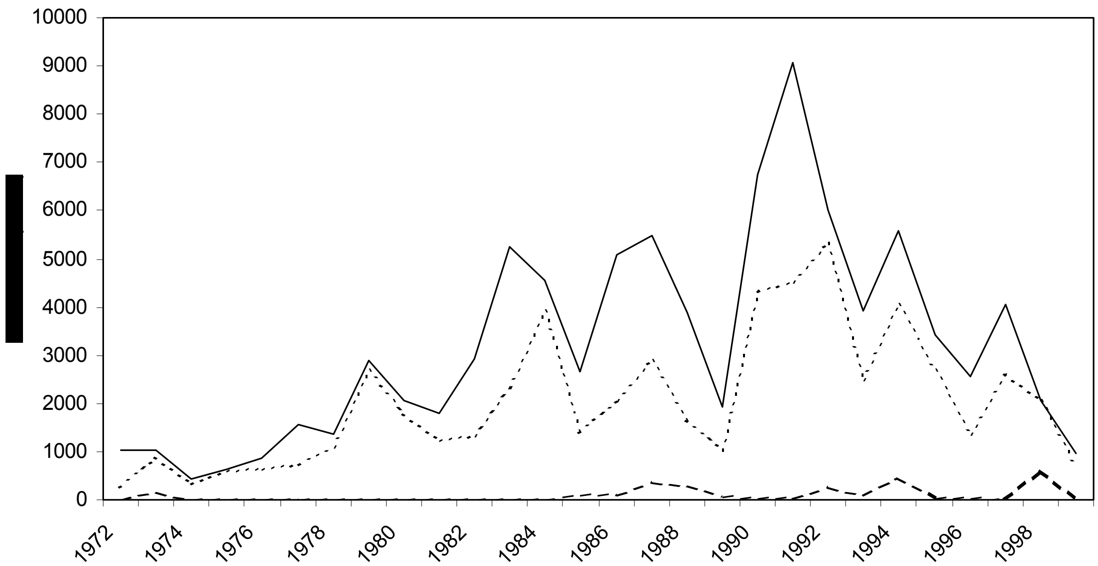


Figure 15. Total ex-vessel value of shrimp landings from Aransas Bay (solid line), Corpus Christ Bay (dotted line) and upper Laguna Madre (dashed line), 1972-1999 (data from Auil- Marshalleck et al. 2001).

Because of the overlap of state and federal jurisdiction over shrimp, Texas, along with the U.S. Department of Commerce, exercise joint management of the Texas fishery through the Gulf of Mexico Fishery Management Council's Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico – United States Waters. Beyond the control of US managers, shrimp fishery management in Mexico also affects the stocks available to Texas shrimpers. Management of the Texas shrimp fishery is complicated by its dual nature and because the food and bait fisheries have different purposes, impacts, and values, each requires separate evaluation and management.

Historical Perspective (1922 – 1972)

The Texas Game Fish and Oyster Commision had little authority over the Texas shrimp fishery because the state's fisheries were managed by the state legislature until 1985. The first fishery regulation that impacted shrimpers was the 1922 ban on drag seining in bays during June-August (TGFOC 1923). This ban was not enacted to manage shrimp, but to protect spawning finfish. It was lifted briefly in 1923, but was reinstated in 1924 because seagrasses were being destroyed by drag seining and the catch consisted of about 90% undersized finfish (TGFOC 1924). This ban included Shamrock Cove, Nueces Bay, Ingleside Cove, Copano Bay, Mission Bay, much of Aransas Bay, and all Gulf passes (TGFOC 1926).

The shift by bay shrimpers from cast nets and seines to motorized boats and trawls resulted in the catch and discard of large numbers of small shrimp with little market value (TGFOC 1926). This waste caused the closure of back bays to trawling in 1926. Minimum size restrictions on shrimp (no more than 15% of catch <5 in long) were imposed in 1927 to provide additional protection to young shrimp (TGFOC 1927). In the 1930s, the Texas Legislature established a 5½ in minimum size limit, set the maximum trawl width at 10 ft and implemented a closed season during May-July (TPWD 2002). This measure discouraged netting of smaller white shrimp found in bays in favor of larger shrimp offshore (Maril 1995) and further depressed the white shrimp bay fishery. Fishery regulations were temporarily relaxed during WWII (Ponwith and Dokken 1996). During the late 1940s, the Texas shrimp fishery was managed to maximize ex-vessel value (Cody et al. 1989). Generally, this meant that the emphasis of fishery management was on the larger offshore shrimp rather than bay shrimp. In 1947-1948, Texas bay shrimpers successfully called for a repeal of the size limits imposed in the 1920s and early 1930s.

In response to increasing competition between Gulf, bay and bait shrimpers, the Texas Legislature enacted the Shrimp Conservation Act of 1959 (Maril, 1995). This law favored Gulf shrimpers by limiting the inshore white shrimp season and prohibiting harvest of brown shrimp from bays. Bay shrimpers were allowed to take white shrimp between August 15 and December 15 but bays were closed to bay shrimpers between June 1 and July 15. The bay shrimp bag limit was set at 250 lb/day. In response to outcries from economically strapped bay shrimpers, the quota was raised to 300 lbs/day and a spring bay season for brown shrimp (May 15 to July 15) was instituted.

Gulf shrimping boomed during the 1950s, 1960s and early 1970s while bay shrimping languished. Declines in white shrimp stocks during the mid 1940s (Moffet 1990), further development of trawling technology, and improved transportation and refrigeration had allowed shrimpers to switch their focus to the vast offshore stocks of brown shrimp. The Shrimp Conservation Act reinforced the shift from small bay shrimp to the larger offshore stocks of brown shrimp. Their size and perceived better quality meant that brown shrimp were significantly more valuable than the smaller white shrimp (Maril 1995).

Recent (1970-Present)

In 1976, in response to an expanding national fishing fleet and a growing public concern about overfishing, the United States Congress enacted the Magnuson Fishery Conservation and Management Act. This act extended national jurisdiction over fisheries from the "borders of states", seaward to 200 nautical miles from shore (Moffett 1990) and prompted the National Marine Fisheries Service to take action to maintain sustainable yield of wild caught shrimp (Warren 1980; McKee 1986; SFSC 1992; Nance 1993). These actions laid the foundation for national shrimp fishery management and establishment of the Gulf of Mexico Shrimp Management Plan (1981).

In response to the Magnuson Act, TPWD began collecting fishery-independent data in 1976 to determine population densities and recruitment of shrimp in Texas inshore waters. These data provide objective information and are used to help determine seasons, bag limits, and closures in an effort to promote and support optimal fishery yields for managed species.

In 1986, the Texas Legislature delegated regulatory responsibility and authority over the inshore fishery to TPWD, allowing it to regulate by proclamation. A proclamation may limit the quantity and size of shrimp caught, possessed, sold or purchased and may prescribe the times, places, conditions and means and manner of catching shrimp. The Legislature also instructed TPWD to draft a plan to manage the inshore shrimp fishery.

The objective of the resulting Shrimp Fishery Management Plan (Cody et al. 1989) is to achieve optimum yield for the fishery. The Legislature clearly stated that "management measures beyond those concerned with economics be considered". To determine the need for a regulatory proclamation, the Legislature requires TPWD to 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 current goal of shrimp management is to increase recruitment by allowing more adult shrimp to reach offshore spawning grounds. More stringent licensing requirements and a license buy-back program have been put in place to in an effort to reduce fishing effort by 18%. In addition, increased restrictions on shrimp count size, increased net mesh size and shorter seasons have been implemented.

Designed to promote economic stability in the shrimp industry while providing for long-term conservation of shrimp stocks TPWD imposed new regulations on bait-shrimpers (TPWD 2002). By creating stricter eligibility standards for licensees, this bill limits the availability and number of future bay bait-shrimping licenses in order to reduce the bait fishing fleet.

In another measure to reduce the shrimping fleet, Texas stopped issuing new commercial bay or bait shrimp licenses in 1996. At the same time it implemented a statewide license buyback program in which the state purchases the licenses from commercial fishers who wish to leave the industry. The buyback program uses a reverse bid system. License holders provide TPW the price for which they are willing to sell their licenses back and then TPW decides which licenses to purchase during a given round of buy-backs. Under the current limited entry plan, license holders are allowed to maintain their licenses and are "grandfathered" as long as they do not retire a license under the buy-back program. If a license is retired under the buy-back it will not be replaced until the fishery can sustain increased effort. To date, TPW has purchased 815 commercial shrimp boat licenses including 422 bay licenses and 393 bait shrimping licenses at a cost of $4.3 million (Art Morris, TPWD, August 2002). This represents a 25% decrease in the number of licenses grandfathered in 1995. In addition, during the time period from 1995 to 1999, the total number of licensed shrimp vessels working in Texas waters dropped from 3370 to 2922, a decrease of 13%. The total number of persons employed on licensed vessels also declined 10% during the same period, from 5072 to 4571 (TPWD, 2002).

Bay and Bait Shrimping Regulations (1970 – 2003)

Bays are classified as either Major or Bait (Table 4); bait can be taken from Major bays, but only bait shrimping is allowed in Bait bays. According to the Texas Legislative code, "major bays" means the deeper, major bay areas of the inside waters exclusive of tributary bays, bayous, and inlets, lakes, and rivers. Outside waters are defined as that part of the Gulf of Mexico extending from the shoreline seaward to 9 nm.

Different seasons, regulations and licenses apply to Gulf, bay and bait shrimp fisheries (Table 5). A boat having onboard or displaying a bait shrimp license must operate only under commercial bait shrimp regulations. A boat licensed for both bay and bait shrimping may not shrimp in both major and bait bays on the same calendar day during the period May 15 through July 15. A boat with both bay and bait licenses may not take more than 600 lbs. of heads-on shrimp per calendar day during the period May 15 –

Table 4. Definitions of bays in the Coastal Bend area related to shrimping (TPWD 2002). A complete description of major and bait bays and regulations pertaining to each can be found in Chapter 77. Shrimp, Subchapter A. General Provisions of the Texas Legislative Code (www.capitol.state.tx.us/statutes/pa/pa0007700toc.html)

Major Bays	Bait Bays
San Antonio Bay[1]	Major Bays
Aransas Bay	Gulf Intracoastal Waterway (exclusive of tributataries)
Corpus Christi Bay[1]	Upper Laguna Madre
	Alazan Bay
	Baffin Bay

[1]the entire bay is not considered a "major bay"; see TPWD (2002) for specifics

July 15. In addition, commercial bay shrimp boats operating in major bays must use no more than 1 trawl, and that trawl must be equipped with an approved Turtle Excluder Device (TED) and an approved By-catch Reduction Device (BRD) (TPWD 2002).

Bait fishers must keep 50% of their catch alive during most of the year. In all bait bays except upper Laguna Madre, shrimping is not permitted at night. In upper Laguna Madre (Nueces County), much of the bait is harvested at night using shallow draft boats equipped with push nets**.** These boats are able to work the seagrass beds along the edge of the GIWW.

Review of Available Fishery Models

The goal of most fisheries management organizations is to maximize the social benefits gained from a fishery. This is usually done through regulation of fishing activities and methods, and increasingly through modification of environmental factors (ie. regulating freshwater inflow). The use of ecological and statistical modeling as a tool for predicting changes due to changing regulation and environmental factors is becoming more widespread in fisheries management. Models try to predict the response of a fishery or fishery stock to changes in management policy or environmental factors or both. This approach allows management personnel to explore the possible results of management decisions yet to be made or environmental changes yet to occur.

The general process of modeling involves developing a conceptual model, which explains the most important aspects of a fishery based on the best available knowledge. Modelers then develop a set of equations that describe the relationships seen in the conceptual model. The equations are then applied to existing data in a simulation model in an attempt to form predictions. These predictions are "ground truthed" to determine the accuracy of the model. Based on the accuracy of the model, equations may be modified to more accurately reflect the outcome. Once a modeler is satisfied with the accuracy of a model, the parameters may be altered to predict future changes.

Table 5. Bay/bait shrimping seasons and regulations, 2002-2003 (TPWD 2002).

Type	Location	Season	Hours	Limits	Trawl[1]
Bay	Major Bays	Spring Open: 15 May –15 July	30 min before sunrise to 2 pm	Bay: 600 lbs Size: no minimum or maximum	Net: - 1; ≤ 54 ft wide BRD/TED: yes Mesh: ≥ 6.5 in over 5 stretched meshes
	Major Bays	Fall Open: 15 August – 30 November	30 min before sunrise to 30 min after sunset	Bag: none Size: 8/15-10/31 – 50 count/lb minimum heads-on 11/1-11/30 – no minimum or maximum	Net: 1; ≤ 95 ft wide BRD/TED: yes Mesh: 8/15-10/31 - ≥8.75 in over 5 stretched meshes 11/1-11/30 - ≥ 6.5 in over 5 stretched meshes
	Major Bays south of Colorado River only	Winter Open: 1 Feb – 15 April	30 min before sunrise to 30 min after sunset	Bag: no limit Size: no minimum or maximum	Net: 1 ≤ 54 ft wide BRD/TED: yes Mesh: ≥ 6.5 in over 5 stretched meshes
Bait	Major & Bait Bays	Year round	15 Aug – 31 Mar: 30 min before sunrise to 30 min after sunset[2] 1 Apr – 14 Aug: 30 min before sunrise to 2 pm	Bag: 200 lbs Size: no minimum or maximum 11/15-8/15: at least 50% must be live 8/16-11/14: all shrimp must be heads on	Net: 1; ≤ 54 ft BRD/TED: TED only Mesh: ≥ 6.5 in over 5 stretched meshes

[1]These requirements are condensed and apply to otter trawls; for beam trawls and specifics (i.e., door sizes) see TPWD (2002).
[2]Nueces County, upper Laguna Madre allows shrimping from 1 am to 30 min before sunrise with a legal beam trawl only; see TPWD for specifics of location and trawl requirements.

In most coastal communities along the Gulf of Mexico, the shrimp fishery represents a significant economic impact. As a consequence the management of shrimp fisheries has received much attention from both biologist and economists. Several bioeconomic models of the shrimp fisheries of the Gulf of Mexico have been produced. In this section we will explore several of these models.

In an effort to predict Texas Gulf fishery harvests, the National Marine Fishery Service (NMFS) uses a combination of somewhat simplistic models. One such model is the Baxter-Bait Index (BBI). The BBI is an index predicting harvest levels for Brown shrimp in the Texas Gulf fishery that is developed by monitoring the Galveston Bay Bait shrimp fishery during late April through mid-June. NMFS states that, the BBI has been its most reliable estimate of subsequent brown shrimp production for over 40 years.

Another model used by NMFS is known simply as the Environmental Model. This model is used to predict the relative direction of Brown shrimp harvest with respect to the historical average. The model uses Galveston air temperature during mid-april, rainfall amounts during early March and water levels during April and May to predict harvest levels. Temperature is the key component. The components are additive to that higher cumulative levels indicate higher predicted catch levels.

Grant and Griffin (1979) produced both conceptual and simulation models of the Brown shrimp fishery of Galveston Bay. The conceptual model is comprised of two sub-models, the biological sub-model and the economic sub-model. The components of the biological sub-model include life history aspects including recruitment and mortality and the effects of bay and shrimp fisheries. The economic sub-model includes harvest and marketing sectors. Harvest sectors include parameters based on vessel characteristics, real and nominal days fished and unit cost of fishing effort. The marketing sub-model includes parameters such as supply, price and demand of shrimp, consumer income and imports. A simulation model based on these parameters was developed to examine differences in recruitment, number of days fished, closure of the fishery, and changes in size restrictions. A simulation model using landings data from 1963-1971 was developed as a baseline model. In this case, actual landings for the period were about 61% of the models baseline harvest predictions. This model was only moderately successful at predicting general trends in system behavior due to changes imposed by management of environmental conditions. The authors cite lack of specific life history data including recruitment and mortality levels as reasons for the failure of the model to accurately predict harvest levels.

Brunenmeister (1984) developed models to predict Catch Per Unit Effort (CPUE) for vessels fishing for Brown, Pink and White shrimp in offshore waters. These models were based on regression equations with specific variables such as month, area, depth, bycatch and vessel characteristics or fishing power. Months had the greatest effect on CPUE. The difference reflects the seasonal availability of each species. Although fishing power (the average size, net number and horsepower of vessels) increased between the years 1965-1977, it had less of an effect on CPUE than did the specific month fished.

Carothers and Grant (1987) used a simulation model of recruitment and seasonality to examine the management implication of the Texas Brown shrimp industry. The model explores Brown shrimp harvest dynamics based on finite differences in recruitment, growth, migration mortality and fishing effort. Parameters of the model were changed to reflect differences in recruitment dynamics. Four different management policy options involving changes in minimum size restrictions and varying seasonal closures were compared to current management plans. The models defined significant interaction between differences in recruitment and alternative management policies. The interaction indicates a failure the alternative recruitment model to consistently predict harvest response. No significant differences in management option performance were detected although two of the models did detect significantly lower harvest based on recruitment differences.

Lam et al. (1989) modeled white shrimp landings along the central coast of South Carolina. This model is based on stock-recruitment relationships developed by use of a stepwise regression technique using salinity and temperature as a variables. The model was successful in explaining 86.6% of variability seen in average White shrimp landings between August and January. Findings indicate that White shrimp landings and salinity had an inverse relationship while winter temperature and recruitment have a direct relationship.

In an effort to model the effects of artisanal shrimp fisheries on stocks of Penaeid shrimp in the Gulf of Mexico, Gracia and Vazquez-Bader (1998) developed a model based on stock recruitment curves across main life-history stages. The age-structure simulation model was used to assess the effects of different fisheries in Mexican waters along the Gulf. Variables used in the model are both estuarine and offshore natural mortality, fishing mortality and growth parameters such as length and weight. Although the effects varied with locality, the model shows that the artisanal White shrimp fishery in the Terminos Lagoon-Campeche Sound area are negatively effecting offshore harvests. Data indicates that the majority of White shrimp taken in the artisanal fishery are juveniles, 2-4 months in age. The model predicts that the total loss to the offshore fishery due to the inshore artisanal fishery could be as much as 20%. For Pink shrimp, the artisanal fishery also has a significant impact. The simulation model predicts that the harvest of 1 kg of juvenile shrimp represents a loss of 9 kg of adult shrimp in the offshore fishery. This represents a 10-20% decline in harvest.

All fisheries models are mathematical expressions of the conditions (variables) known to influence the fishery. In the broadest terms, these elements are biological, harvest or market related. Each of these broad categories can be further subdivided into an almost infinite number of sub-catagories each with a number of variables. Mathematically describing the intricate relationships and interactions between these sub-catagories or base variables is often difficult at best. Extensive data sets describing interactions between organisms and environmental and economic variables is often lacking for many fisheries. As a consequence, most models must make specific assumptions about the stocks they attempt to model. For example; The Gordon-Schaefer Bioeconomic model (Gordon, 1954) makes a number of assumptions about both the fishery and the market.

The model assumes a population is at equilibrium. Under this assumption, in a population at equilibrium, natural and fishing mortalities are compensated by an increase in individual and recruitment growth. The model further assumes that fishing effort and mortality are proportional and that CPUE is a relative index of population abundance. This assumption is not likely to be met in an overcapitalized fishery such as the shrimp fisheries in Texas (SFSC 1992; TPWD 1993).

Under many model assumptions, stocks are usually constrained by a constant carrying capacity within an environment (Seijo et al., 1998). This is seldom the case for shrimp stocks especially in south Texas where highly variable freshwater inflow events can drastically alter environmental conditions and thus carrying capacity of an environment.

All models have limitations. It is simply not possible to mathematically describe all possible biotic, abiotic and economic interactions. Some common limitations of models are described by Seijo et al. (1998).

Threats to the Fishery

Freshwater inflow has long been an issue for shrimp production. Drought conditions are common in south Texas. In addition to a lack of rainfall, water from rivers and streams that would otherwise flow to the estuary is diverted for residential, industrial, and agricultural uses. The lack of fresh water mixing with seawater causes pollutants to concentrate in the estuary and contributes to losses of oysters and white shrimp. Within the Corpus Christi Bay watershed, two reservoirs restrain much of the freshwater inflow into Corpus Christi Bay. These reservoirs, Choke Canyon and Lake Corpus Christi, are the main water supply for both the Corpus Christi Bay System and the City of Corpus Christi and surrounding municipalities. Consequently, in times of drought, municipalities drawing from these reservoirs are reluctant to release freshwater into the bay. State mandated water releases have increased freshwater inflow supporting shrimp production.

A strong decline in white shrimp was observed in Galveston bay from 1982 through 1990, leading to concern about the condition of the bay's white shrimp population (Green et al. 1993). Similar declines were noted in the Aransas Bay, Corpus Christi Bay, and Laguna Madre estuaries. However, sampling results from 1991 show a large rebound to 1983 population levels. The rebound is probably at least partially the result of increased fresh water inflow due to extremely wet conditions in 1990 and 1991, and management actions discussed below.

Three potential causes for the observed decline in white shrimp, 1982-1992 were discussed by Green et al. (1993): overfishing, pollution, and low fresh water inflows. Overfishing was deemed the most obvious possibility for the decline. Several other factors such as loss of wetlands, a change in the food chain, and increased predation were considered but ruled out because similar species such as brown shrimp did not exhibit a similar decline.

Overfishing

The Texas bay and bait shrimp fisheries are over-capitalized with too many boats fishing for a dwindling stock. Shrimp in Texas bays tend to be small juveniles that bring a lower price than the larger adults found in the Gulf. Small shrimp that are not captured as bait in the smaller bays escape to larger bays where they are targeted as a food commodity by the bay shrimp industry. Shrimp that escape both bait and bay fishers may migrate to Gulf waters where they spawn. Over-exploitation of these stocks can seriously reduce recruitment of spawning adults in the Gulf of Mexico.

Fishing effort has steadily increased since 1961, as demonstrated by a 400% increase in hours trawled by bay shrimp fleet and a 95% increase in effort by the Gulf fleet. Shrimp in the bays are generally small juveniles whereas shrimp in the Gulf are larger juveniles and adults. Since 1972, bay shrimp landings have increased 135% while Gulf landings have decreased by 18% indicating that most shrimp are harvested in the bays before they have a chance to move offshore and spawn as adults (TPWD, February 1998). The Department's shrimp management plan suggests that the continued increase in harvest of small shrimp (>67 count) is ecologically unsustainable and will cause shrimp stocks to collapse (TPWD 1993).

Based on the supposition that over-harvest can be a factor for white shrimp, changes in fisheries regulations have been implemented by the Texas Parks and Wildlife Department at various times to protect the white shrimp resource. Shrimping in nursery areas was prohibited in 1979, except for 'grandfathered' shrimpers, who continued to shrimp these areas until 1989. Night shrimping was banned during spring months in 1990. Most importantly, starting in 1990, all shrimping was banned for two summer months in the Gulf of Mexico, a major white shrimp spawning area (Green, et al., 1993).

Due to dramatic increases in fishing effort and a 50% decline in the catch rate (pounds/hr), TPWD determined that regulation changes were necessary in order to protect the smallest shrimp (TPWD 2000). The license buy-back program and increased restrictions on bay shrimp count size, an 18% decrease in waters open to shrimping, larger net mesh size, and decreased season length are aimed at allowing more adult shrimp to migrate to the spawning grounds to bolster recruitment. If effective, these changes should result in increased shrimper efficiency and concomitant increased profit (Hal Osburn, personal communication).

Aquaculture

Texas leads the U.S. in the lucrative and potentially environmentally damaging field of shrimp aquaculture production (MacFarlane 2001). Texas shrimp aquaculture is responsible for producing 70-80% of farm-raised shrimp in the U.S. However in 1996, the shrimp harvest from eight shrimp farms in Texas harvested grossed only $6,000,000, less than 1% of the ex-vessel value of shrimp harvest from Texas coastal waters during the same year. Because market demand requires shrimp aquaculture production to supplement the wild shrimp capture fishery, it appears that shrimp culture is here to stay and as such, must adopt techniques that are ecologically sustainable.

Research with shrimp culture in Texas dates back to the mid 1950's, with greatest effort in 1963 (Hightower and Treece 1992). As larval rearing techniques improved by the late 1960s, researchers shifted their efforts toward the grow-out phase of production. Non-indigenous species (*Penaeus vannamei, P. stylirostris*) were first imported in 1968. These required captive reproduction to isolate them from native populations. Large-scale commercial operations began in 1981. Both successes and failures have resulted, with frequent changes in ownership and names. Taiwanese investors purchased and expanded existing farms in 1989 and 1990, introducing Asian techniques and migrant workers to the industry in Texas (McFarlane, 2001).

Shrimp aquaculture research has been subsidized with public funds from both state and federal programs. Agencies such as U.S. Department of Agriculture Marine Shrimp Farming Program, the U.S. Department of Commerce Sea Grant program, the U.S. Bureau of Commercial Fisheries (now NMFS), the U.S. Army Corps of Engineers, the U.S. Fish & Wildlife Service, the Texas A&M University System, the University of Texas, and the Texas Department of Agriculture and Texas Parks and Wildlife Department have all contributed to the development of the shrimp aquaculture industry in Texas.

Although the industry has garnered significant governmental support, it is not without serious economic challenges and ecological concerns for the wild-caught fishery. A high volume of aquaculture-produced imports has depressed prices for wild-caught U.S. shrimp (TPWD 1995). This equates to a significant decrease in profits for Texas shrimpers since in 1996, nearly 69% of the wild shrimp harvested in the U.S. are produced in the Gulf of Mexico and some 35% (76 million lbs) of that was landed in Texas.

Problems of poor water quality, exotic diseases, and potential release of non-indigenous species plague intensive aquaculture and native stocks. The challenge is to ensure that aquaculture is conducted in an environmentally responsible and ecologically sustainable manner. Shrimp ponds are the aquatic equivalent of terrestrial feedlots regarding the concentration of husbanded animals, the input of nutrients, from feeds, fertilizer, antibiotics and animal waste. Ponds become acidic and anaerobic, conditions that are not optimum for shrimp production. Water exchange and aeration can resolve these conditions, but that usually entails the release of nutrient rich, anaerobic and possibly disease-contaminated water into the estuarine environment where it may overwhelm the assimilative capacity of the receiving water body (McFarlane, 2001).

Most profitable shrimp farms employ intensive aquaculture techniques, increasing the density of shrimp in ponds until high levels of metabolic wastes lower water quality, creating physiological stress, at which time disease epidemics erupt. To combat the problems of over-crowding and stress, many operations have begun raising non-indigenous species in intensive culture systems because of their faster growth or resistance to stress and/or disease. Non-indigenous species may also bring non-indigenous diseases, which threaten not only farmed animals but also wild stocks. Intensive shrimp aquaculture facilities also have a tendency decrease regional water quality to the point that the facility becomes unprofitable, forcing relocation (Chen 1995; Lin, 1995; Qingyin et. al 1995; Winarno 1995; Stern 1995).

McFarlane (2001) suggests that ecological sustainability will be possible by: (1) reducing nutrient input and treating shrimp pond effluent with simple, well-demonstrated techniques such as sedimentation ponds, polyculture with filter-feeding species like clams and oysters, and excess nutrient removal by passage through especially-designed wetlands; (2) shifting emphasis to the culture of indigenous shrimp species which do not pose a threat to coastal ecosystems; and (3) raising shrimp at lower, but still profitable, densities to avoid epidemics of non-indigenous pathogens. Until these problems are solved, the shrimp aquaculture in Texas will continue to be a necessary supplement to, and a dangerous threat to the Texas native wild-caught fishery. Texas Parks and Wildlife Department increased monitoring of commercial shrimp farms after tests confirmed the presence of exotic shrimp in Matagorda Bay.

CHAPTER 4
ECOLOGY OF PENAEID SHRIMP

Life History

The biology and life histories of penaeid shrimp are complex, but fairly well known. The following synthesis presents a brief overview of shrimp life history and relies heavily on Turner and Brody (1983), Moffett (1990) and Patillo et al. (1997). A diagrammatic representation of the shrimp life cycle is presented in Figure 16.

Penaeid shrimp are estuarine-dependent organisms, that is, estuarine habitats are required to complete their life cycle. Required habitats range from neritic to estuarine and pelagic to demersal depending on life stage and species. They are primarily omnivorous although brown shrimp tend to be more carnivorous than either white or pink shrimp. Environmental conditions, particularly habitat alteration, changing food availability and substrate type affect distribution as well as mortality. Shrimp generally prefer vegetated habitats but salinity, turbidity and light conditions may cause them to move into unvegetated areas where they are more susceptible to predation. Predation is the primary cause of mortality although disease and episodic natural catastrophes (drought, flood, red tide) are also major causes of death.

Most adults are found offshore where spawning occurs. Shrimp become sexually mature when they reach 114-140 mm long, depending on species and sex. Reproduction begins when the male transfers a sperm capsule (spermatophore) to the female who carries it, along with 500,000-1,000,000 eggs, until conditions are right for spawning. Brown shrimp spawning is concentrated in fall months, but occurs throughout the year. They generally spawn in waters 46-110 m deep but may spawn in waters as shallow as 27 m between March-December. White shrimp spawn in offshore waters up to 18 m deep between April and September. Pink shrimp spawn at depths from 4-46 m and probably in deeper water as well. Most spawning by pink shrimp occurs during waning moons and in water temperatures from 20-31º C (maximum activity from 27-31º C), mainly during late summer and fall, but with a secondary peak in spring. It is unlikely that most shrimp spawn more than once, primarily because very few individuals live past 1 year old.

Shrimp eggs and early larval stages are planktonic or demersal. Fertilized eggs are semi-buoyant and hatch within 24 hours. The larvae are planktonic and highly susceptible to predation. The first five larval stages (nauplii) rely on a yolk sac for nourishment. The next six stages (three protozoea, three mysis) feed on phyto- and zooplankton. Shrimp in this stage of life are poor swimmers and their movements are governed by tides and currents.

Shrimp postlarvae and early juveniles migrate through passes into estuaries on incoming tides. Brown shrimp postlarvae enter bays during late winter and spring, white shrimp between May-October with a peak in September, and pink shrimp from August through April. These small shrimp seek out shallow, often vegetated areas such as seagrass meadows, salt marshes, or mangroves (nurseries) where they can grow up in relative

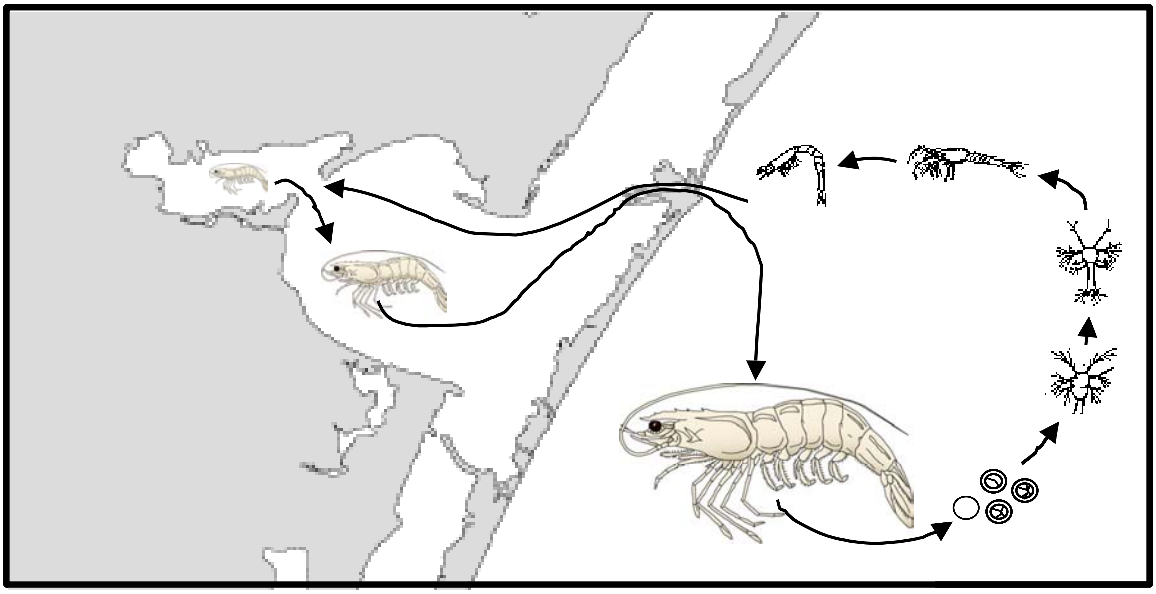


Figure 16. Life cycle of penaeid shrimp (modified from Moffett 1990).

protection from predation and have abundant food resources. White shrimp migrate farther inland than brown shrimp. Pink shrimp juveniles are noted for their preference for seagrass habitats, particularly shoal grass. Optimum habitat consists of dense seagrass meadows with daily tidal flushing. Pink shrimp postlarvae actively select vegetated habitats and can be found burrowed into the substrate during the day.

Once postlarval shrimp settle into the nursery habitat, they become demersal and omnivorous, eating a variety of plants and animals. Water temperature and salinity govern the rate at which they grow and, to some extent, mortality. Shrimp growth is very slow at water temperatures less than 20º C but increases rapidly as temperatures increase. Peak growth rates of brown shrimp occur at water temperatures of 25º C. Water temperatures less than 4º C or above 32º C may cause severe stress and mortality. Optimum salinity ranges from 10-20 ppt, with the optimum for brown shrimp higher than that of white shrimp. Although the majority of juvenile shrimp mortality is due to predation, the interaction of salinity and water temperature can be the source of significant mortality. Shrimp are able to adapt to a wide range of temperatures and salinities but they are usually unable to adapt to rapid onset or prolonged periods of extremes of either factor. A combination of very low salinities and water temperatures (<10º C) can cause massive postlarval mortalities.

About one month after entering estuarine nurseries, shrimp transform into juveniles. They remain near vegetated areas until they reach 63.5-76 mm long, then move into deeper open water. Shrimp at this life stage are still typically associated with vegetated habitats, but may also be found over silty sand or muddy unvegetated bottoms. Once they reach 89-109 mm long, they begin migrating back to the gulf. This migration is influenced by tides, lunar cycles, maturation state and estuarine temperature changes.

Brown shrimp migrate mostly during May and June primarily at night during full moons and ebb tides. White shrimp migrate during November and December and are not nocturnal.

Environmental Factors Affecting Penaeid Shrimp

Temperature

Penaeid shrimp can be found in waters ranging from 6-38º C (Zien-Eldin and Renaud 1986; Table 1). Mortality due to cold is common and winter kills following cold fronts have been documented on numerous occasions (e.g., Gunter and Hildebrand 1951). Although both brown and white shrimp have been found in thermal effluents, their tolerance of high temperatures is not well documented. In the laboratory, postlarval growth has been shown to increase with increasing water temperature up to about 32º C (Zien-Eldin and Griffith 1969). Small white shrimp appear to be more tolerant of high temperatures (up to 35º C) than brown shrimp, whose survival declined at temperatures above 30º F.

Salinity

Penaeid shrimp are tolerant of a wide range of salinities (Table 6); juveniles tend to be better osmoregulators than adults (Zien-Eldin and Renaud 1986). White shrimp have been found in waters from 1-45 ppt and brown shrimp from 1-70 ppt. Postlarvae have been found in nearly fresh water and in the laboratory survive and continue to grow at 5 ppt and lower (Zien-Eldin 1963; Zien-Eldin and Aldrich 1965; Zien-Eldin and Griffith 1969). There is some evidence that white shrimp grow faster in nursery areas with relatively low salinities. In the laboratory, postlarval growth and survival decreased at 35 ppt when compared with growth and survival at 25 ppt (Zien-Eldin and Griffith 1969). Juvenile growth was retarded at 35-40 ppt. Growth of pink shrimp postlarvae did not change at salinities between 2-43 ppt (Willams 1955; Zien-Eldin 1963). Salinity does not appear to control the distribution of adults or spawning activity (Roessler et al. 1969).

Temperature-Salinity Interaction

The combination of low salinity and low temperature is not tolerated by penaeid shrimp as well as other combinations of temperature and salinity (Zien-Eldin and Griffith 1969). At 5 ppt, shrimp mortality occurred at temperatures of 11-15º C, but at salinities of 25-40 ppt, no mortality occurred at the same range of temperatures. Young white and brown shrimp respond differently than adults to different combinations of temperature and salinity. Young brown shrimp mortality increased at high temperatures (>30º C) and low salinities (≤ 5 ppt). Survival of young white shrimp in constant warm water temperatures decreased as salinity was increased from 25 ppt to 35 ppt. Pink shrimp are superior osmoregulators at lower temperatures and have a greater ability to overwinter in northern areas (Williams 1955).

Table 6. Salinity, temperature, dissolved oxygen and depth ranges and optimums by life stage for white, pink and brown shrimp. White and brown shrimp information compiled by Ward and Armstrong (1980); pink shrimp information from Patillo et al. (1997).

	Salinity (ppt)		Temperature (ºC)		D. O. (mgl/l)	Depth (ft)	
	Range	Optimum	Range	Optimum	Range	Range	Optimum
White Shrimp						7-46	8-31
Spawning	marine			20-35		7-46	8-31
Hatching	marine			17-28.5		7-46	8-31
Nauplii	marine			17-28.5		7-46	8-31
Protozoeae	marine			17-28.5		3-23	4-15
Mysis	marine					surface	
Postlarvae	0.4-40			25-32		>1-20	>1
Juveniles	0.3-48	<10	4-36	18-32	>1.5	1-3	2-3
Adults	0.1-40	18-34	9-36	25-32	>3.8	7-50	18-36
Brown Shrimp							
Spawning	marine	marine				18-120	70-120
Hatching	marine	marine		17-28		18-120	70-120
Nauplii		marine		17-28		18-120	70-120
Protozoeae	27-35	marine		20-32		9-60	35-60
Mysis		marine		20-32		surface	
Postlarvae	2-40	21-40	11-35	15-32		surface	<1
Juveniles	0.2-69	10-30	4-36	11-32	>1.5	<1-3	2-3
Adults	0.8-45	24-39	4-36	15-31	>3.8	<120	18-120
Pink Shrimp							
Spawning	marine						
Hatching	marine						
Nauplii	marine			21-26			
Protozoeae	marine			21-26		15-48	
Mysis	marine			21-26		15-48	
Postlarvae	12-43		4-38	20-38			
Juveniles	<1-47	>20	4-38	20-38			
Adults	25-69	25-45	10-35			1-64	9-44

Freshwater Inflow

Freshwater from rivers and/or rainfall is the major factor influencing estuarine salinities and has been shown to impact abundance of shrimp (as measured by commercial catch data) (TDWR 1983; Zien-Eldin and Renaud 1986; Solana-Sansores and Arreguín-Sánchez 1993). White shrimp are more abundant in bays of the upper Texas coast where there is more rainfall and brown shrimp are more abundant along the central and southern coast where there is less rainfall and higher salinities (Ward and Armstrong 1980). In Laguna Madre, year-to-year variability in surplus shrimp production (i.e., the portion available for harvest) was affected by the timing and amount of freshwater inflows that affected salinity, nutrient types and availability, prey production and habitat availability (TDWR 1983). Harvest of white shrimp in upper Laguna Madre was positively correlated with freshwater inflows during April-June. Brown and pink shrimp harvest was negatively correlated with freshwater inflow during January-March. Overall penaeid harvest was positively correlated to freshwater inflow during April-June and November-December and negatively correlated to freshwater inflow during January-March and July-August.

Dissolved Oxygen

Hypoxia may affect shrimp stocks by increasing natural mortality through increased physiological stress, inter- and intraspecific competition, and predation (Renaud 1986). In the laboratory, 95% of the brown shrimp tested avoided waters with less than 2 mg/l dissolved oxygen and 62% avoided water with 3 mg/l dissolved oxygen. White shrimp appear to be somewhat more tolerant of hypoxic water with 90% avoiding waters with less than 1.5 mg/l dissolved oxygen but only 51% avoiding water with 2 mg/l dissolved oxygen. Both brown and white shrimp exhibit stress at dissolved oxygen levels of 2 mg/l. At dissolved oxygen levels of 4 mg/l or greater, no problems have been noted. Offshore bottom water dissolved oxygen has been shown to be significantly correlated with penaeid shrimp catch (Renaud 1986).

Pollutants

Penaeid shrimps are very sensitive to a number of pollutants. Juvenile brown shrimp are the estuarine organism most sensitive to pesticides (e.g., organochlorines, DDT, dieldrin, mirex); PCBs and carbamate are also toxic to juveniles (Zien-Eldin and Renaud 1986). Brown shrimp juveniles and adults are also sensitive to malathion and No. 2 fuel oil. Other substances that may affect brown shrimp during any life stage include sulfides, phenols and oils, formalin, $KMnO_2$, and Aroclor. Pesticides and other organic chemicals cause mortality in pink shrimp (Christmas and Etzold 1977; Couch 1978). Heavy metals are toxic to both brown and pink shrimp. White shrimp do not appear to be especially sensitive to organic pesticides or other pollutants. Juveniles are sensitive to malathion, No. 2 fuel oil and quinaldine (Zien-Eldin and Renaud 1986).

Habitat (Substrate, Vegetation)

Strong correlations have been demonstrated between penaeid shrimp yield and the areal extent of estuarine vegetation in the Gulf of Mexico (Turner 1977, 1979, 1982; Turner and Boesch 1988). These habitats provide food and protection for young shrimp (Minello and Zimmerman 1983; Boesch and Turner 1984; Minello et al. 1989; Peterson and Turner 1994; Kneib 1997) and are considered "essential" habitat (TPWD 2002). Both the quantity and quality of estuarine vegetated habitats (marshes, seagrasses, mangroves) available to postlarval and juvenile shrimp directly affect total yields of penaeid shrimp (Turner and Brody 1983).

Although overall shrimp yield is related to estuarine vegetation extent and quality, the three species exhibit varying degrees of preference for vegetated habitats. Shrimp are generally more abundant in areas with dense vegetation (Zimmerman et al. 1982). Habitat selection and value may vary with environmental conditions (Minello et al.

1990). For example, in Louisiana, brown and pink shrimp postlarvae and juveniles were found in significantly greater densities in widgeon grass (*Ruppia maritima*) habitats than in either salt marsh or unvegetated habitats (Howe and Wallace 2000). However, there were no significant differences in densities of white shrimp among the three substrate types. In Texas, brown, white and pink shrimp were found in equal numbers in salt marsh and seagrass habitats during fall but in spring, brown shrimp were more abundant in seagrass (Rozas and Minello 1998). In another study, juvenile brown shrimp were more abundant in unvegetated substrates during spring (Zimmerman and Minello 1984). Use of estuarine vegetation by white shrimp was sporadic, possibly because it does not obtain the same benefits from vegetation as other species (Minello et al. 1990). Pink shrimp optimum habitat has been described as dense shoalgrass that is flushed by tides daily (Patillo et al. 1997).

Although brown shrimp exhibit a preference for the structure presented by estuarine vegetation, the behavior was influenced by salinity, turbidity, and light as well as the distribution of food and substrate suitable for burrowing (Minello et al. 1990). Distribution of food and substrate were the dominant factors affecting brown shrimp habitat selection. The ability of the shrimp to burrow into substrates declined in the presence of root mats and compacted clay soils and this may account for brown shrimp selection of unvegetated habitats over vegetated habitats in many instances. On the other hand, environmental variables did not appear to affect white shrimp habitat selection, but they did exhibit a preference for structure in contrast to most other studies. Selection of seagrasses by pink shrimp was not modified by circadian or seasonal variations but did vary with dark-high tide and light-low tide conditions (Sánchez 1997).

CHAPTER 5
SHRIMP POPULATIONS IN COASTAL BEND BAYS

Fishery independent data on shrimp size and abundance collected by TPWD was summarized for Aransas Bay, Corpus Christi Bay and upper Laguna Madre (including secondary bays). Yearly summary data compiled by TPWD was available through 1996 only (Hensley and Fuls 1998) and was used to depict overall trends in mean abundance and mean length through time. In general, bag seine data represents small or juvenile shrimp whereas trawl data represents larger or adult shrimp. Monthly abundance and lengths for each species, each size (juveniles vs adults) and each bay were determined through analysis of fishery independent data provided to the authors by TPWD. These data extend through 2000. Means were calculated for each month based on the effort (number of hectares sampled, minutes trawls were pulled) associated with each sample.

Bag Seine Data

Aransas Bay

Numbers of small shrimp were variable, but all three showed peaks in abundance during the 1980s and early 1990s (Figure 17). Brown and white shrimp were the most abundant overall. All three species exhibited significant trends based on regression analysis. Abundances of small brown and white shrimp currently appear to be declining. Abundances of small pink shrimp generally increased since 1977. No significant trends were detected in the mean lengths of any species (Figure 18). Brown shrimp were the largest overall.

Monthly abundance data calculated from data collected between 1976 and 2000 (Figure 19) indicate peak abundances of brown shrimp during May, pink shrimp during November, and white shrimp during October. The large standard deviations exhibited by all three species indicate a high degree of year-to-year variability in peak numbers. Brown shrimp were generally more abundant than either white or pink shrimp. Although all three species were present throughout the year, each exhibited a period of several months when they were most abundant. These corresponded to late spring-early summer for brown shrimp, late summer-late fall for pink shrimp and early summer-late fall for white shrimp.

Monthly length data calculated from the same data (Figure 20) show that the largest brown shrimp were collected from June-December, the largest pink shrimp from April-June and the largest white shrimp from March-May. In the case of brown shrimp, both size and abundance peak at nearly the same time whereas for both white and pink shrimp, peaks in size are during months when abundance is low.

Corpus Christi Bay

Brown and white shrimp were the most abundant species in the system. Abundances of small brown and pink shrimp appeared to be increasing overall since 1977 (Figure 21). No significant trend was exhibited by small white shrimp abundances, however, white shrimp appear to be getting larger (Figure 22). No significant trends were detected in the lengths of small brown or white shrimp. Brown and white shrimp were similar in size and generally larger than pink shrimp.

Small brown shrimp were most abundant between April and July (Figure 23). Pink shrimp abundances appear to be somewhat bimodal, with a small peak in April and another larger peak in November. White shrimp were most abundant between June and November. Brown shrimp were largest at the same time they were most abundant (Figure 24), but overall, there was not much variability in size through the year. Pink shrimp were somewhat larger during the spring, but like brown shrimp, size was relatively stable throughout the year. White shrimp were largest during April.

Upper Laguna Madre

Brown shrimp were by far the most abundant species. Abundances of small brown shrimp appeared to be generally increasing since 1977 (Figure 25). The fitted line (cubic function) estimated for pink shrimp indicates a down turn in abundance since a peak in 1992. No significant trend was detected in abundances of small white shrimp. Mean lengths of small pink and white shrimp have significantly declined (Figure 26). Lengths of small brown shrimp showed no significant trend.

Abundance of small brown shrimp was highest during May (Figure 27). Pink shrimp showed a bimodal pattern of monthly abundance with peaks in February and October. Small white shrimp were most abundant during August. Brown shrimp were largest from May-July (Figure 28). Pink shrimp were largest during late winter-early spring. The largest white shrimp was collected during May, but there was a great deal of variability in the lengths recorded for this species.

Regional Composite

When data from Aransas Bay, Corpus Christi Bay and upper Laguna Madre were combined and analyzed together for trends in abundance and size over time, both brown and pink shrimp exhibited significant trends whereas white shrimp did not (Figure 29). Regional brown shrimp abundances appear to have increased through the early 1990s, peaking in 1990 but appear to have declined since then. Current declines in abundances in Aransas Bay appear to be overshadowing the increasing trends for brown shrimp in both Corpus Christi Bay and upper Laguna Madre. The trend for pink shrimp was one of increased abundance since the 1970s. Since no overall trend was observed for white shrimp, it seems likely that recent declines in Aransas Bay are not affecting overall numbers within the region. These results are in general agreement with those for the entire Texas coast (through 1986) (Fuls et al. 2000).

No significant trends were exhibited in the sizes of either brown or white shrimp (Figure 30). This suggests that the trends in Corpus Christi Bay and upper Laguna Madre are not affecting overall size in the region. Regionally, pink shrimp size declined through the mid-1980s suggesting that the declining trend noted for upper Laguna Madre is having an effect at the regional level. Year to year variation in shrimp sizes is much less within the region when compared with data for the entire coast (Fuls et al. 2000).

In general, the peaks monthly abundances and sizes of each species in each bay system occur during the same months. Monthly abundances of each shrimp species in each local bay system are similar to that seen for the entire coast (Fuls et al. 2000)

Trawl Data

Aransas Bay

No significant trends in abundance were detected for any species (Figure 31). Brown shrimp were the most abundant species in the system, followed by white shrimp. Abundances of larger brown and pink shrimp peaked in 1991. Both species appeared to generally increase from 1982 until the peak, after which they declined. Abundances of white shrimp peaked in 1984 and 1992. Only pink shrimp sizes exhibited a significant trend (Figure 32). White shrimp were generally larger than either brown or pink shrimp.

Mean monthly abundances were calculated from data collected between 1986 and 2000 (Figure 33) indicate peak abundances of subadult and adult brown shrimp from April-July, pink shrimp during April-May, and white shrimp from October-December. The large standard deviations for pink and white shrimp indicate a high degree of variability in their numbers from year to year.

Monthly mean lengths were calculated from the same data (Figure 34). Lengths of all three species were highly variable from year to year as indicated by the relatively large standard deviations. Brown shrimp lengths exhibited the least amount of month to month variability and peaked in July and August. Pink shrimp lengths generally increased January-May, and were generally longer during periods of peak abundance. White shrimp lengths generally increased January-April, with smaller shrimp occurring during periods of peak abundance.

Corpus Christi Bay

No significant trends in abundance were detected for any species (Figure 35). Brown shrimp were generally more abundant than either white shrimp and both white and brown shrimp were almost always more abundant than pink shrimp. Brown shrimp abundances were highest during the mid 1980s and appeared to have stabilized at a relatively low level during the late 1980s through 1996. Pink shrimp exhibited peak abundances in 1986-1987, 1992 and 1995. White shrimp were most abundant in 1984, 1990-1991 and 1994. Sizes of all three species were similar and only brown shrimp exhibited a significant trend, declining slightly through the mid 1980s and early 1990s (Figure 36).

Peak abundances of subadult and adult brown shrimp occurred in May, pink shrimp during April; white shrimp abundances were generally low, but they were most abundant July-December (Figure 37). Lengths of all three species were highly variable from year to year (Figure 38). Brown and white shrimp lengths were relatively stable throughout the year. Pink shrimp were largest during late spring, the same period as peak abundance.

Upper Laguna Madre

No significant trends in abundance were detected for any species (Figure 39). Brown shrimp were most abundant in the early-mid 1980s and the early 1990s. Pink shrimp abundances peaked in 1992. Patterns of abundance for white shrimp were similar to those for brown shrimp. No significant trends in size were detected for any species (Figure 40). Brown and pink shrimp were generally smaller than white shrimp.

Brown shrimp were most abundant during May and June (Figure 41). Pink shrimp abundance peaked just before brown shrimp in March and April, with another minor peak during November. White shrimp were most abundant August-December. Monthly mean lengths were highly variable from year to year for all three species resulting in large standard deviations (Figure 42). Brown shrimp length was relatively stable throughout the year, but was slightly higher during May-June, the period of peak abundance. Pink shrimp lengths were relatively stable January-August, with a fairly steep decline in fall and early winter. White shrimp were largest in April-May, the period of lowest abundance.

Regional Composite

Unlike the individual bays where no significant trends abundance were noted for any species, when data from Aransas Bay, Corpus Christi Bay, and upper Laguna Madre were analyzed together, a significant trend was exhibited by pink shrimp (Figure 43). Pink shrimp generally increased through the early 1990s and appear to be declining currently. Brown shrimp exhibited a slight decline in size (Figure 44).

Peaks in monthly abundances of each species generally occurred in the same months in all three bay systems. Monthly mean lengths were somewhat variable among the bays, especially for white shrimp.

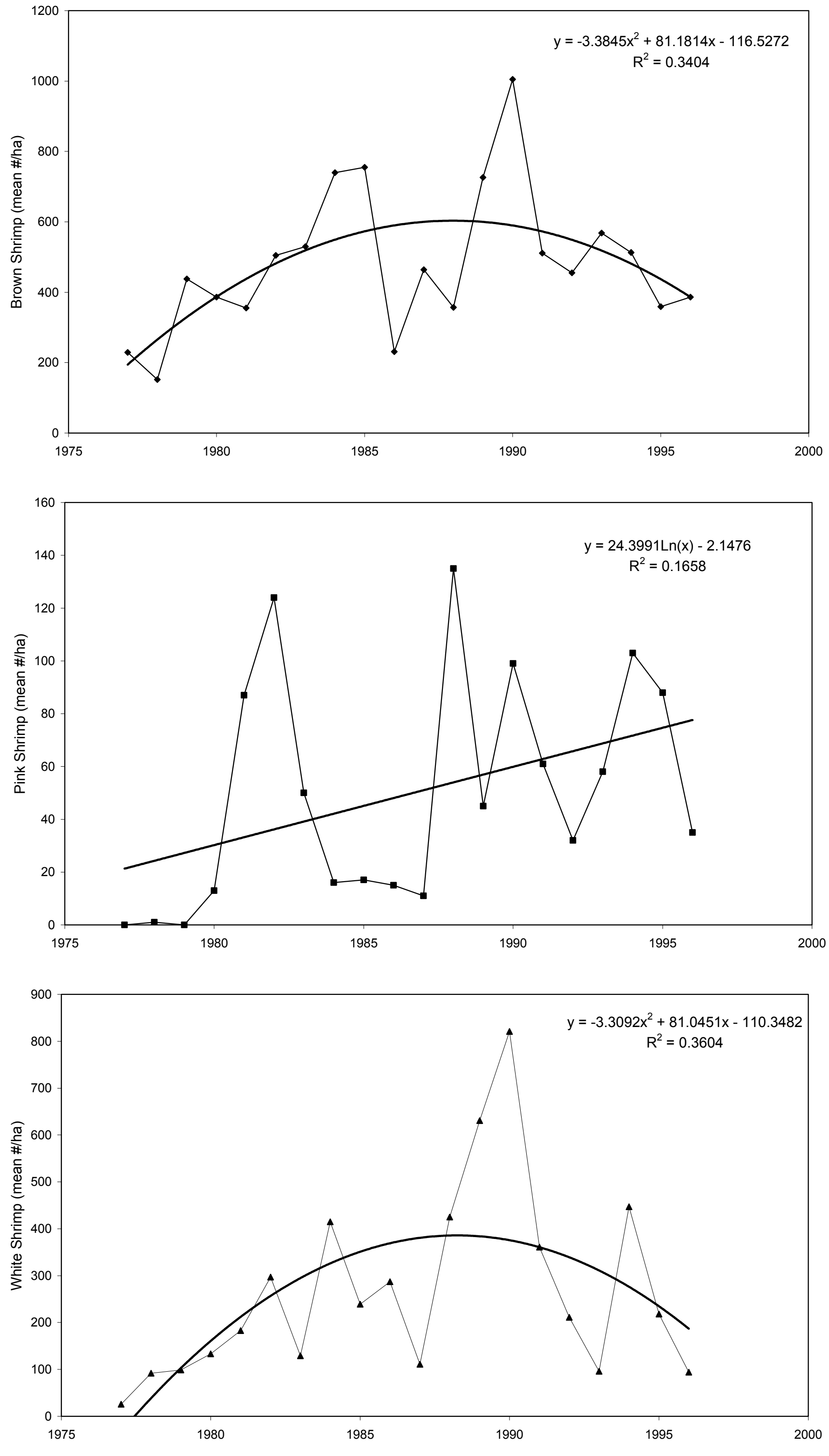


Figure 17. Numbers of small brown (top), pink (middle) and white (bottom) shrimp in Aransas Bay from fishery independent data collected by TPWD, 1977-1996 (data from Hensley and Fuls 1998).

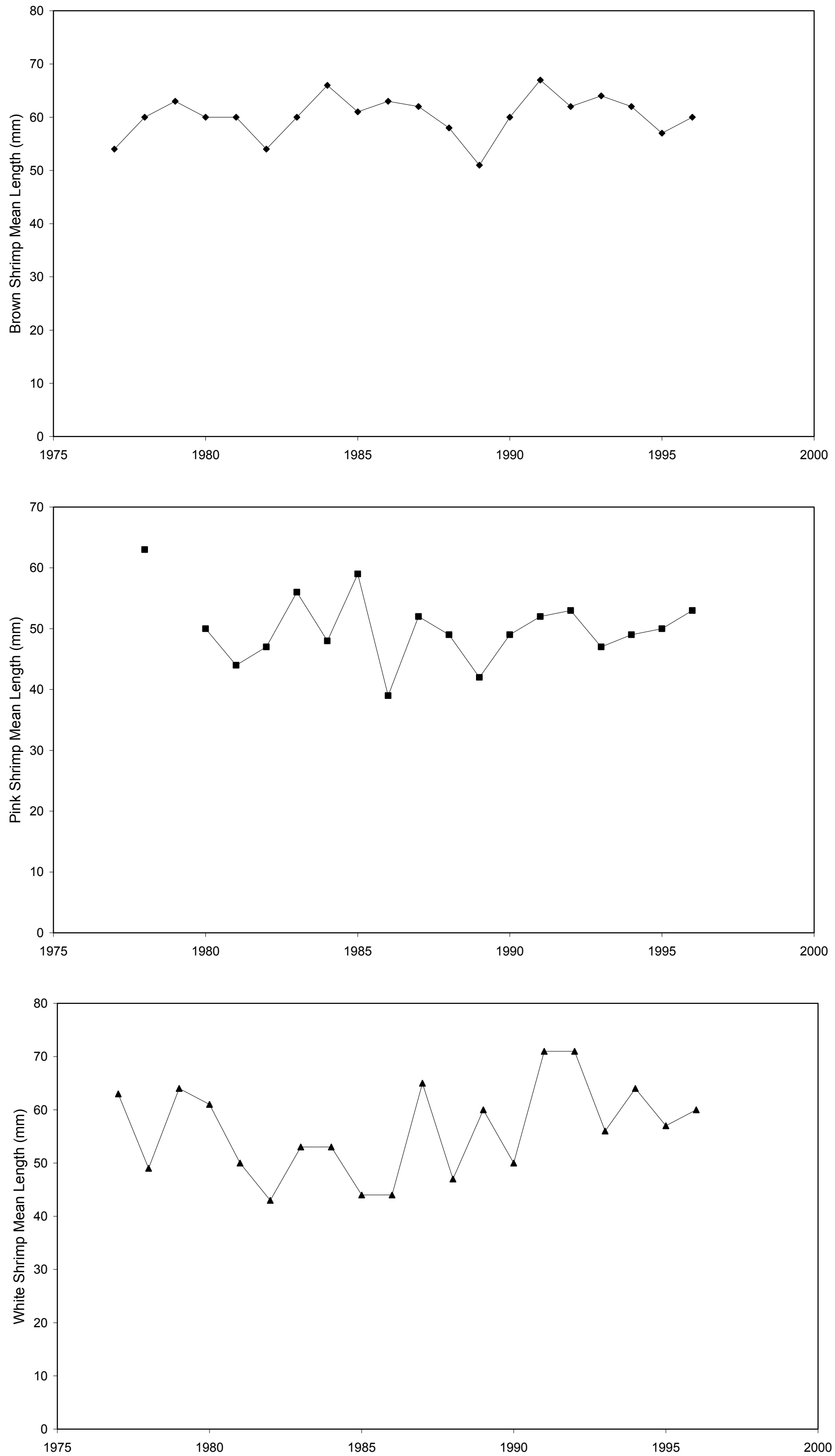


Figure 18. Mean lengths (mm) of small brown (top), pink (middle) and white (bottom) shrimp in Aransas Bay from fishery independent data collected using bag seines 1977-1996 (data from Hensley and Fuls 1998).

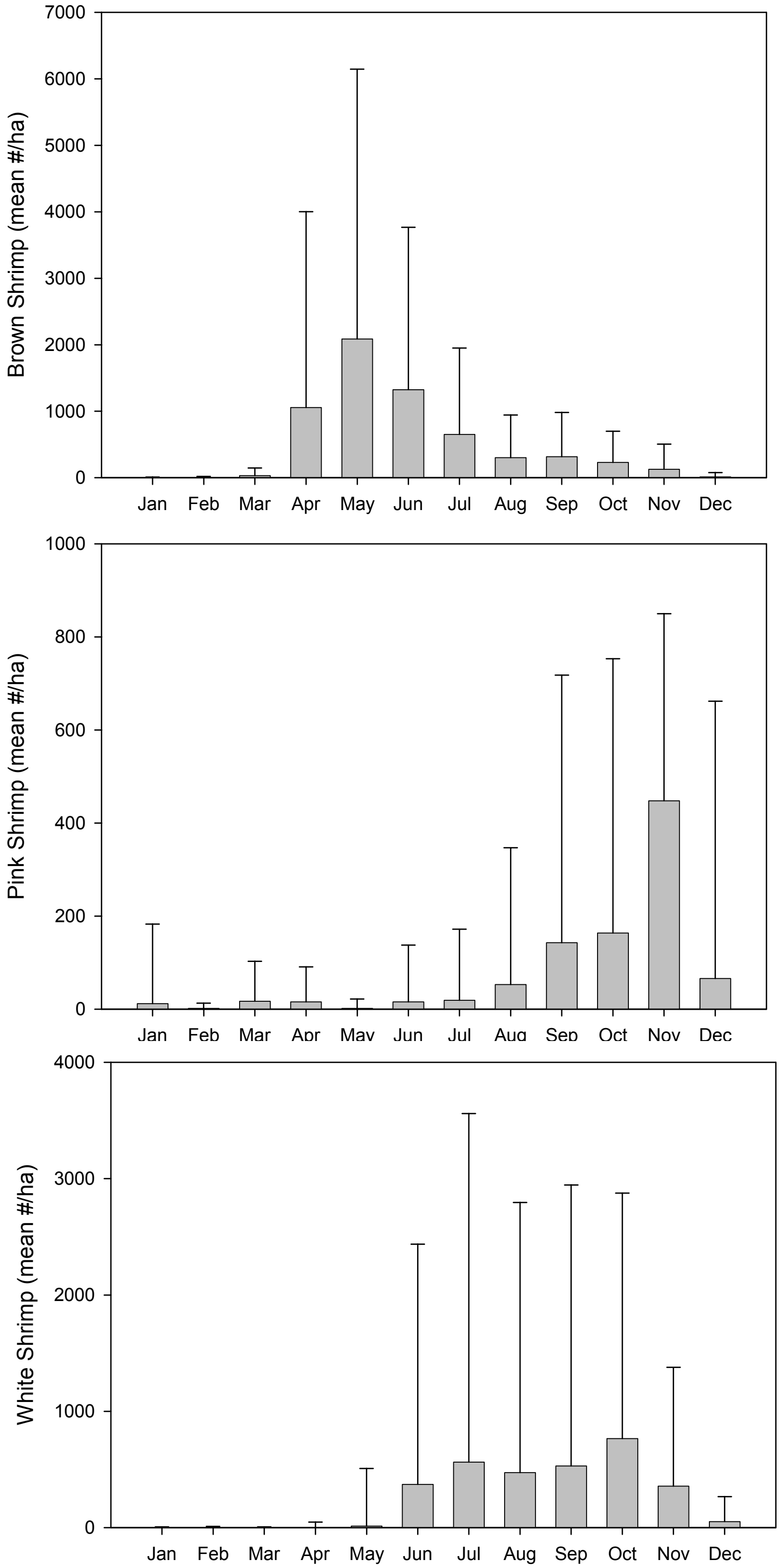


Figure 19. Monthly mean abundance with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Aransas Bay from fishery independent data collected by TPWD using bag seines 1977-2000.

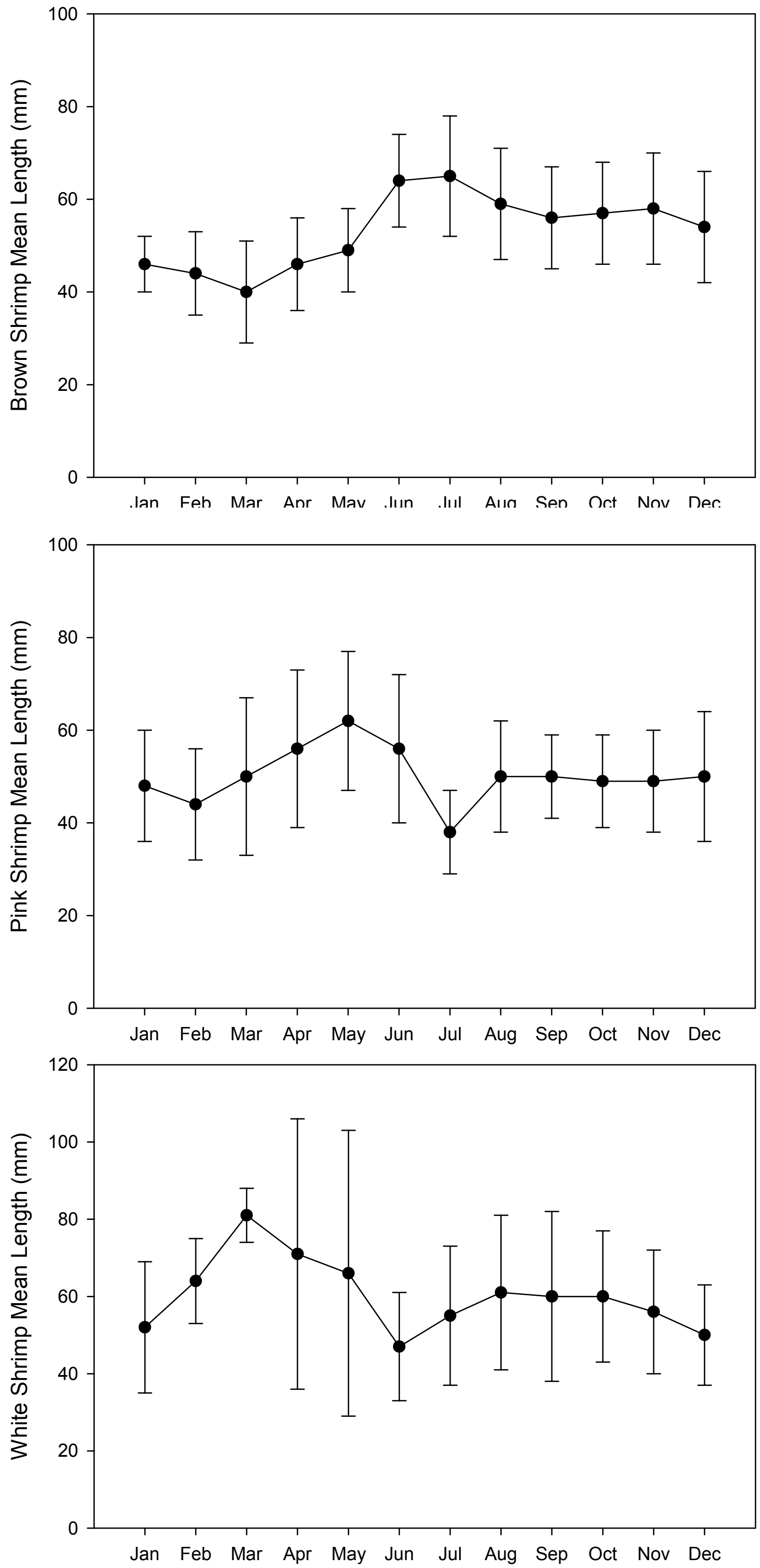


Figure 20. Monthly mean lengths with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Aransas Bay from fishery independent data collected by TPWD using bag seines 1977-2000.

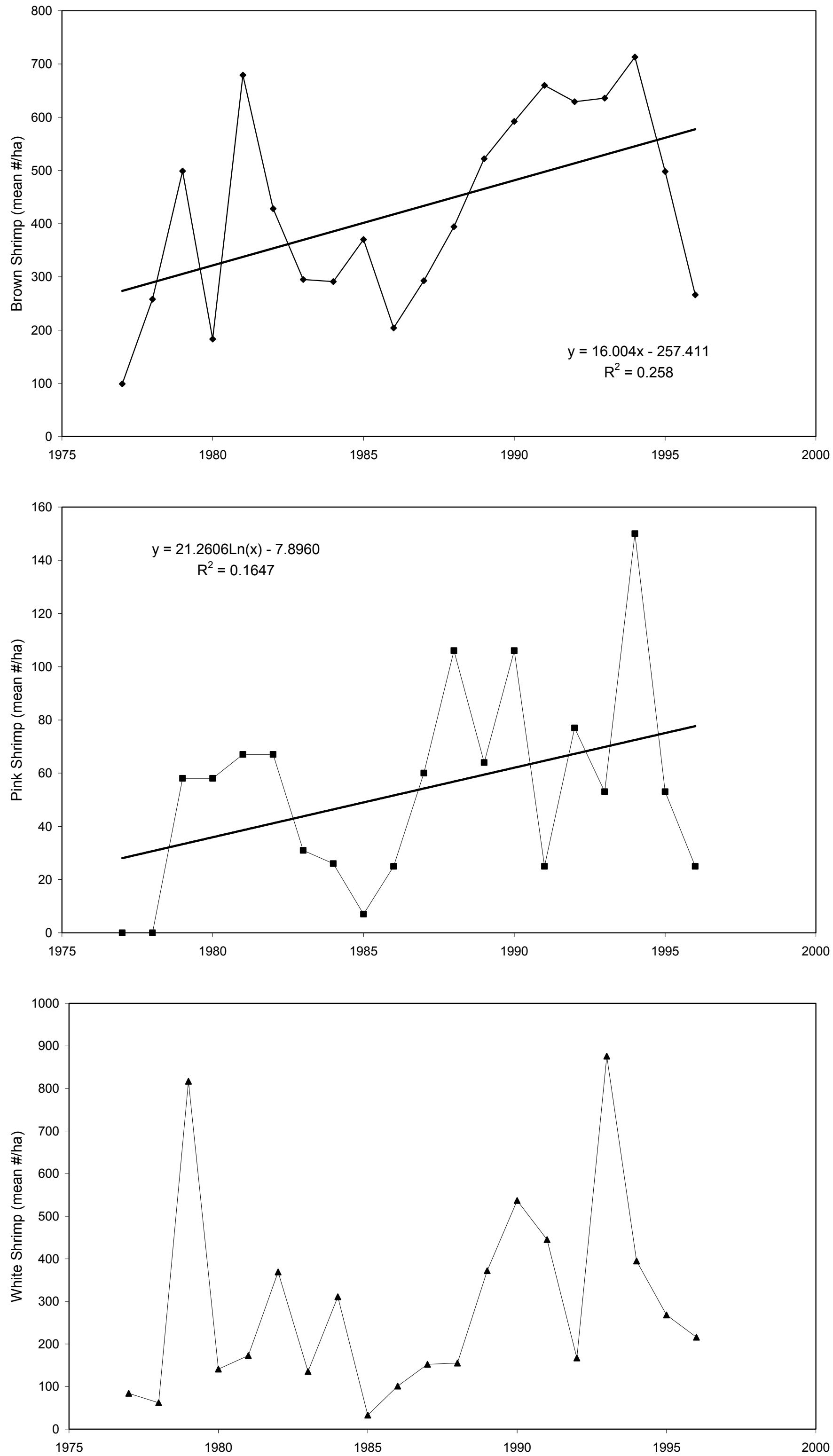
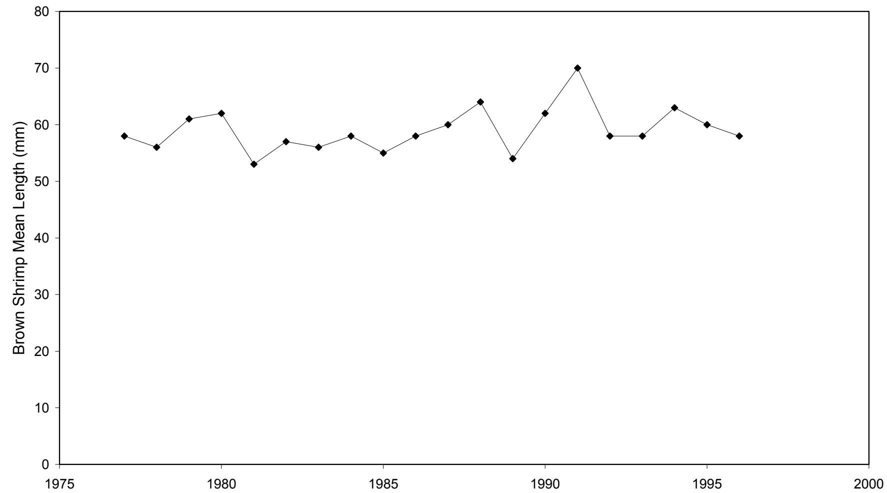
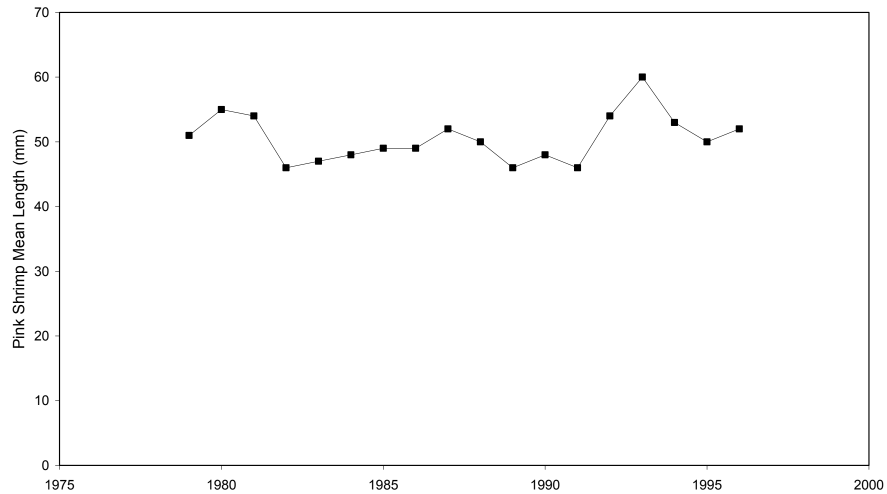


Figure 21. Numbers of small brown (top), pink (middle) and white (bottom) shrimp in Corpus Christi Bay from fishery independent data collected using bag seines 1977-1996 (data from Hensley and Fuls 1998).





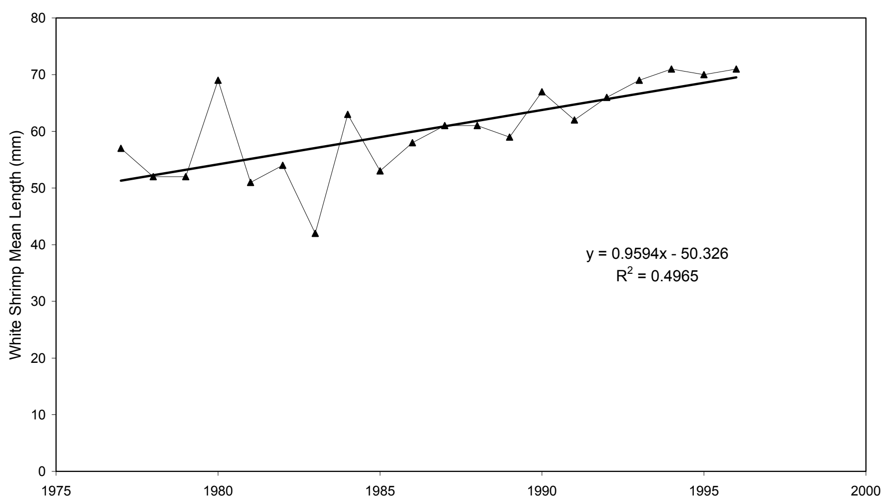


Figure 22. Mean lengths (mm) of small brown (top), pink (middle) and white (bottom) shrimp in Corpus Christi Bay from fishery independent data collected using bag seines 1977-1996 (data from Hensley and Fuls 1998).

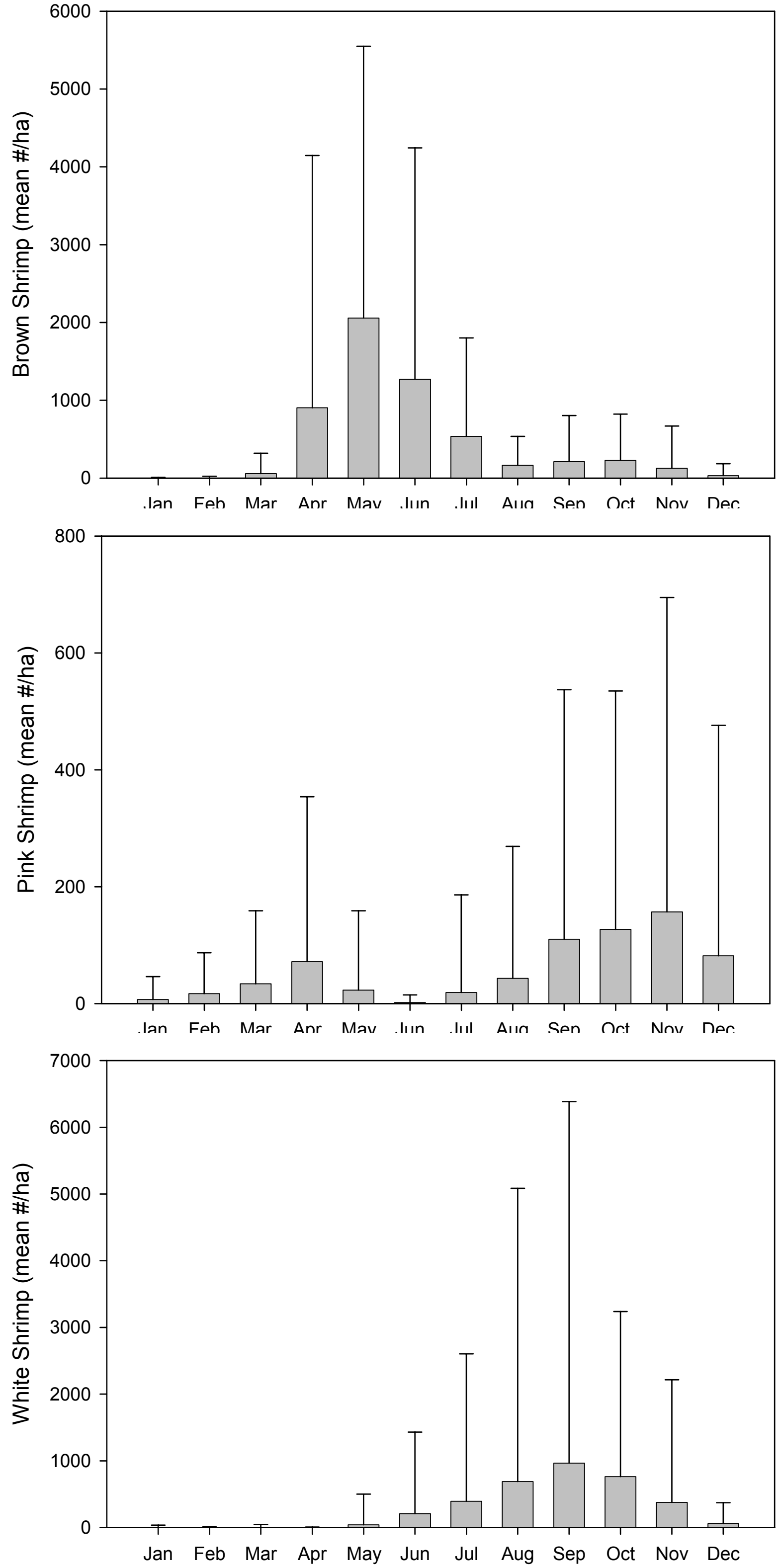


Figure 23. Monthly mean abundance with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Corpus Christi Bay from fishery independent data collected by TPWD using bag seines 1976-2000.

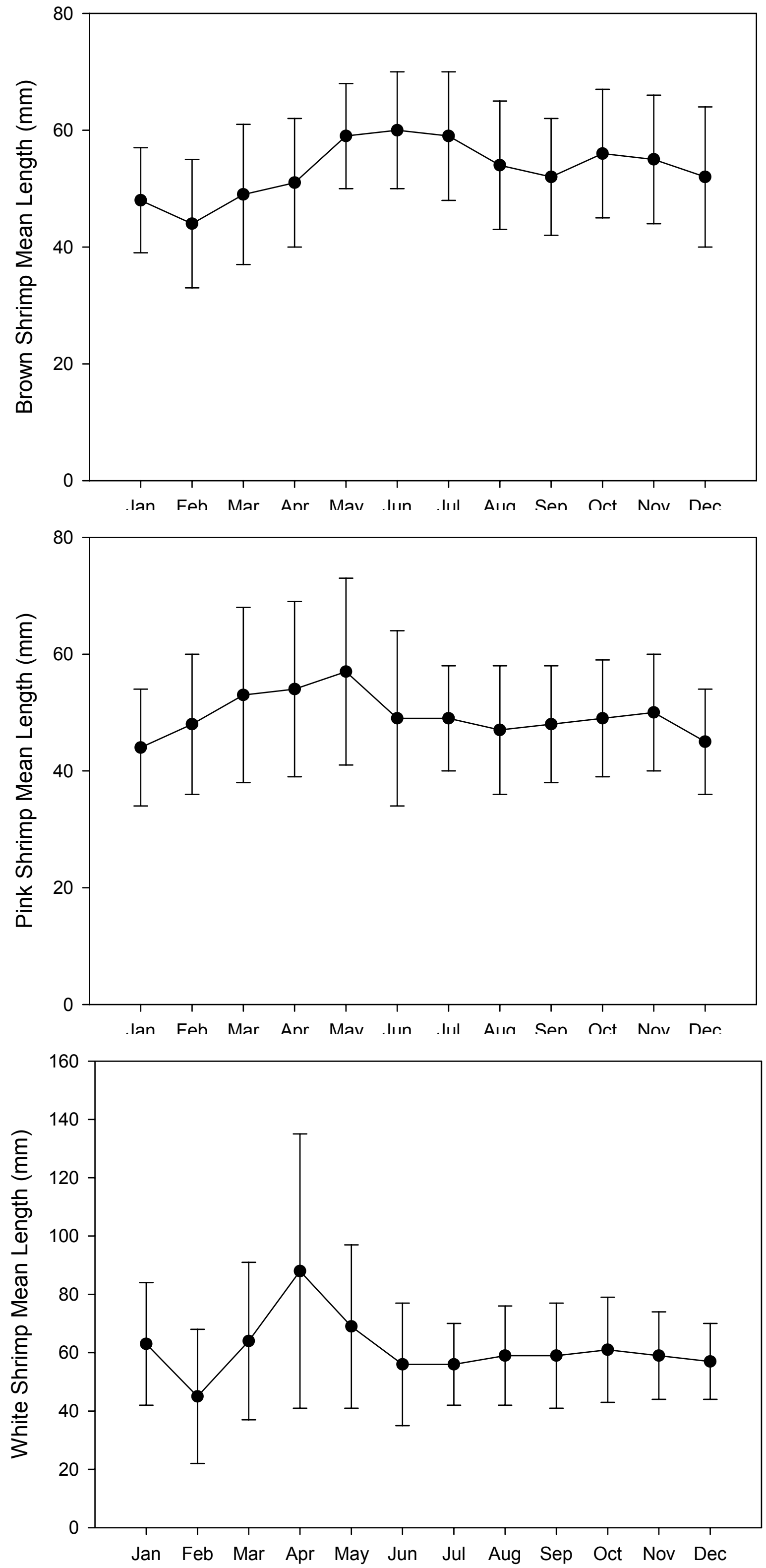


Figure 24. Monthly mean lengths with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Corpus Christi Bay from fishery independent data collected by TPWD using bag seines 1977-2000.

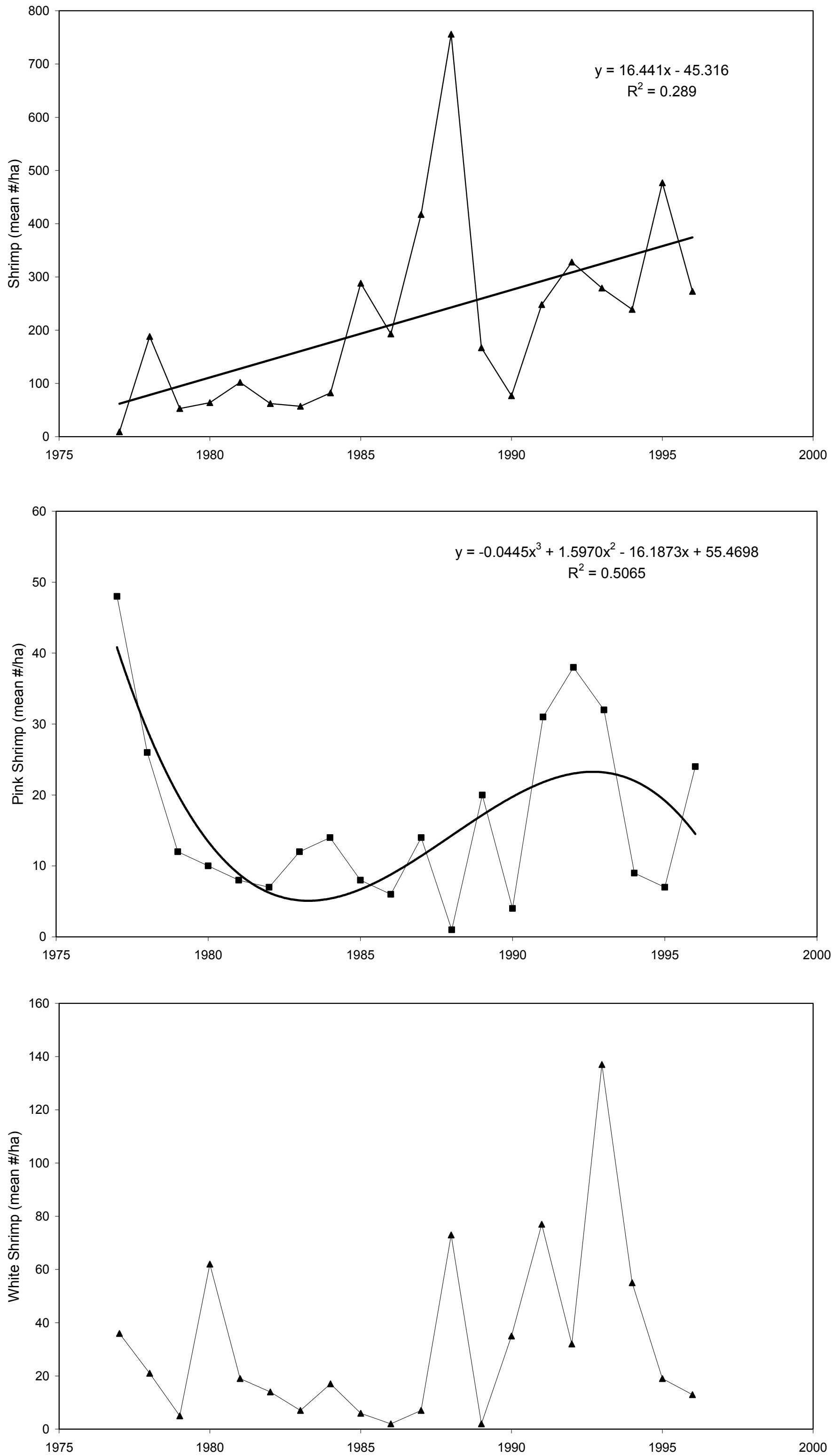


Figure 25. Numbers of small brown (top), pink (middle) and white (bottom) shrimp in upper Laguna Madre from fishery independent data collected using bag seines 1977-1996 (data from Hensley and Fuls 1998).

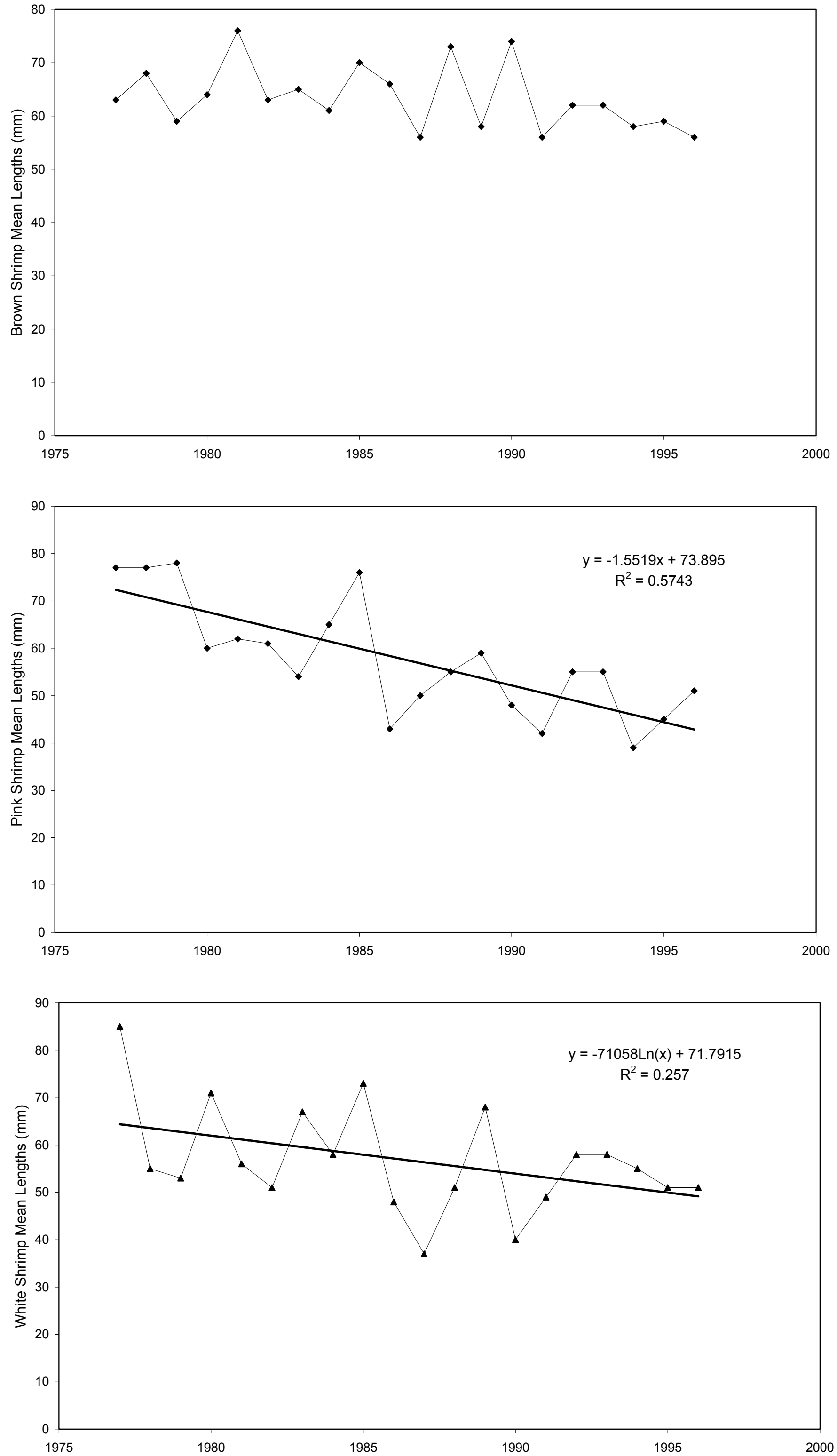


Figure 26. Mean lengths (mm) of small brown (top), pink (middle) and white (bottom) shrimp in upper Laguna Madre from fishery independent data collected using bag seines 1977-1996 (data from Hensley and Fuls 1998).

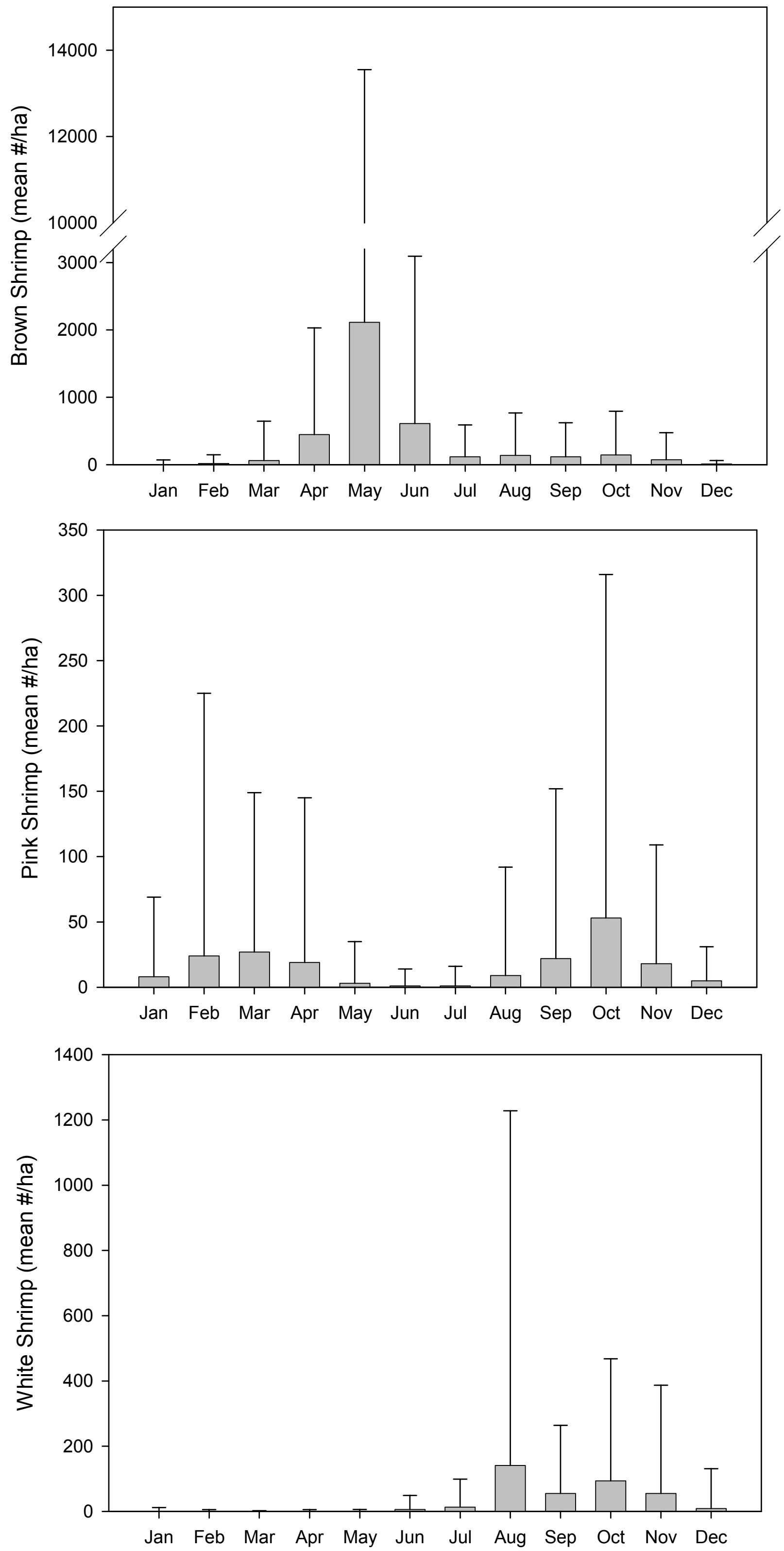


Figure 27. Monthly mean abundance with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in upper Laguna Madre from fishery independent data collected by TPWD using bag seines 1976-2000.

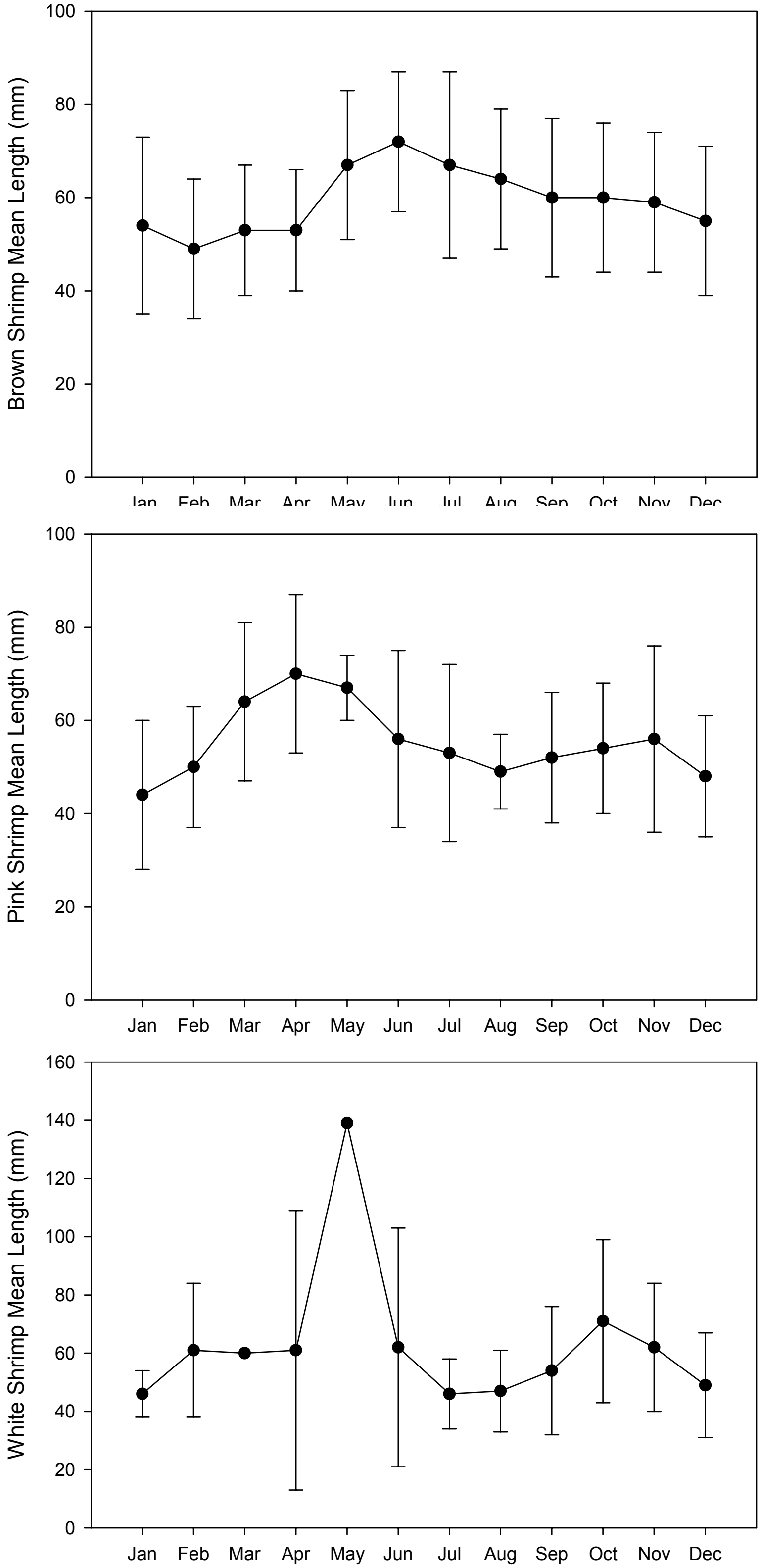


Figure 28. Monthly mean lengths with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in upper Laguna Madre from fishery independent data collected by TPWD using bag seines 1977-2000.

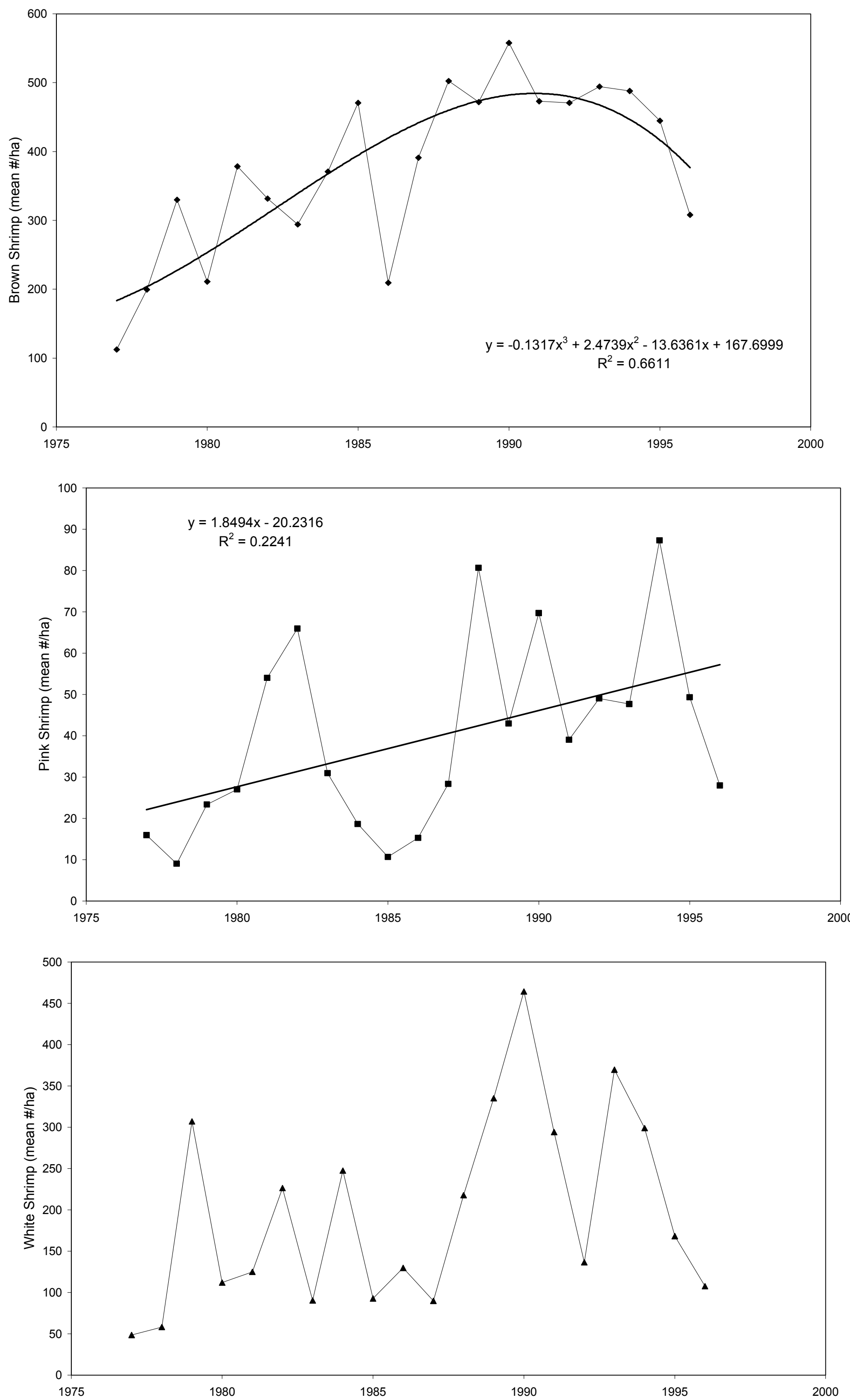


Figure 29. Mean numbers of small brown (top), pink (middle) and white (bottom) shrimp in Coastal Bend bays, 1977-1996.

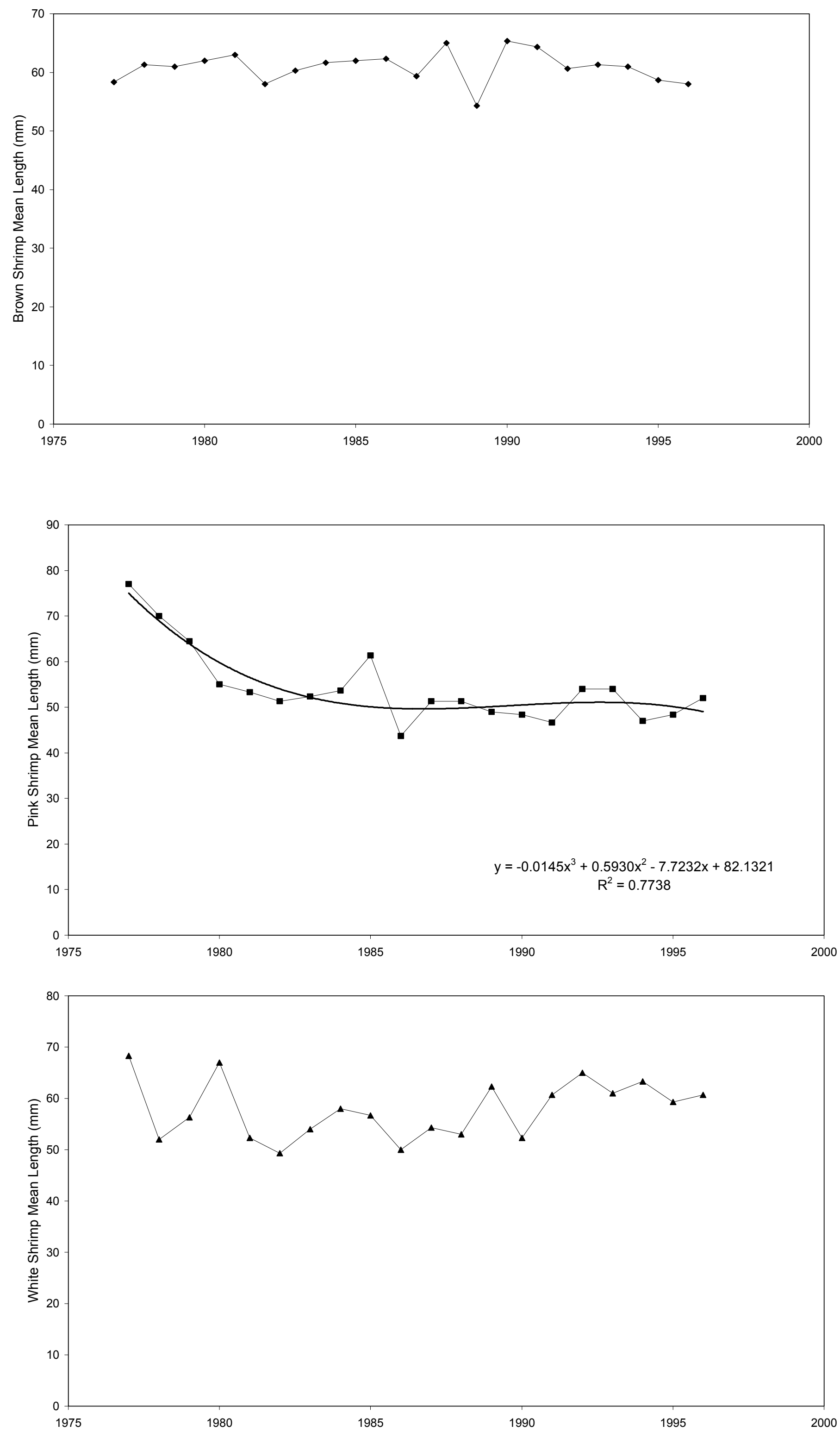


Figure 30. Mean lengths of small brown (top), pink (middle) and white (bottom) shrimp in Coastal Bend Bays, 1977-1996.

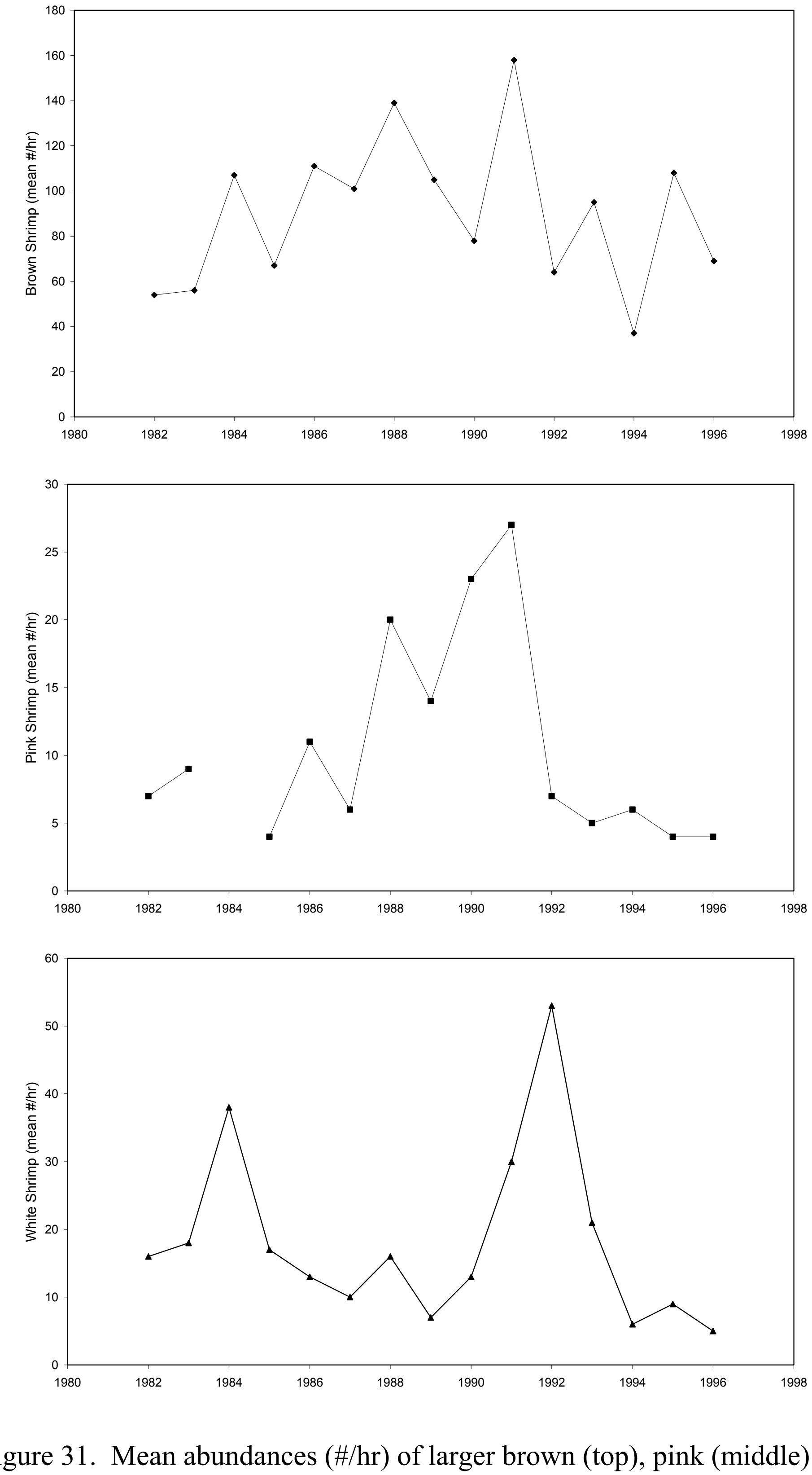


Figure 31. Mean abundances (#/hr) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in Aransas Bay, 1982-1996 (data from Hensley and Fuls 1998)

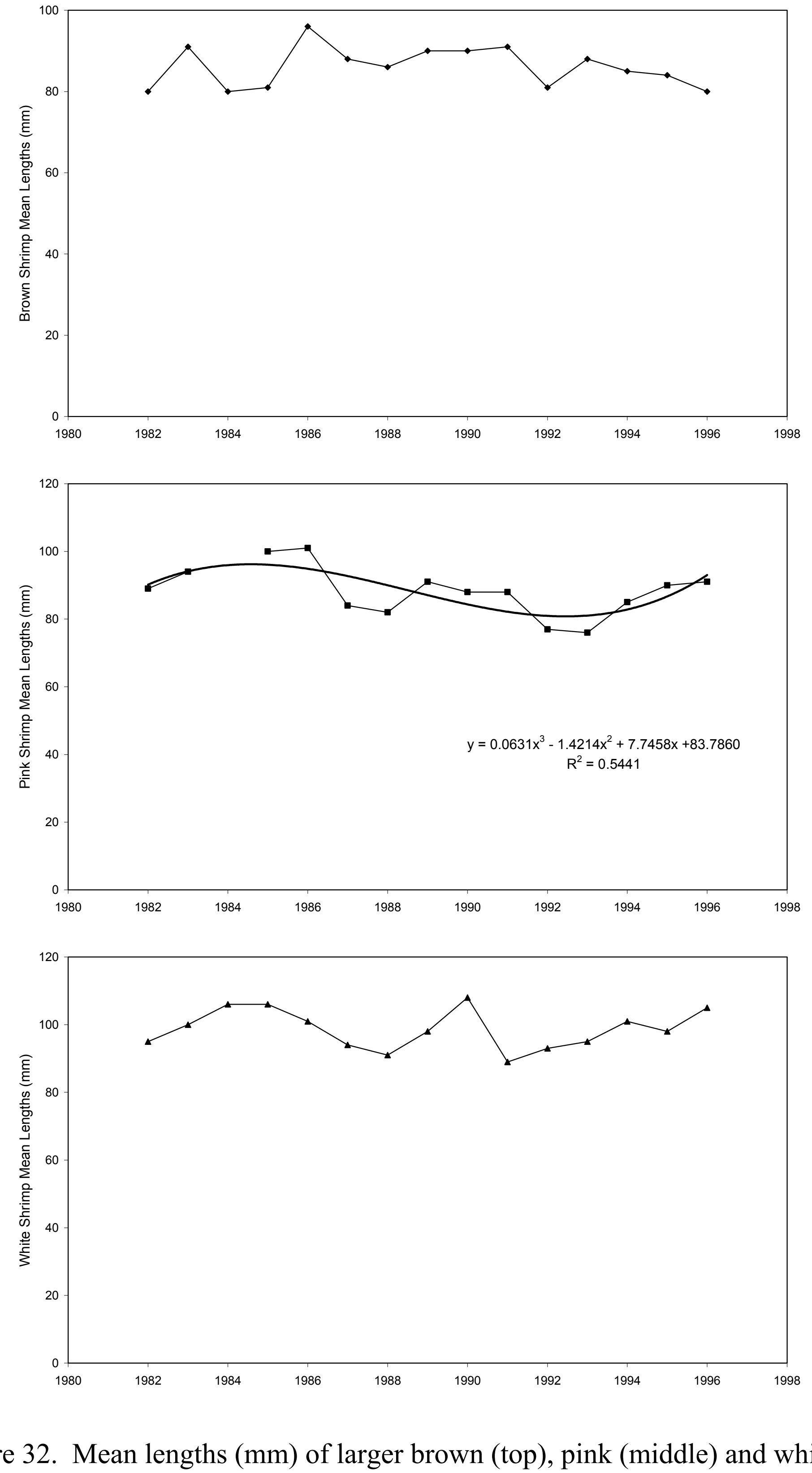


Figure 32. Mean lengths (mm) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in Aransas Bay, 1982-1996 (data from Hensley and Fuls 1998).

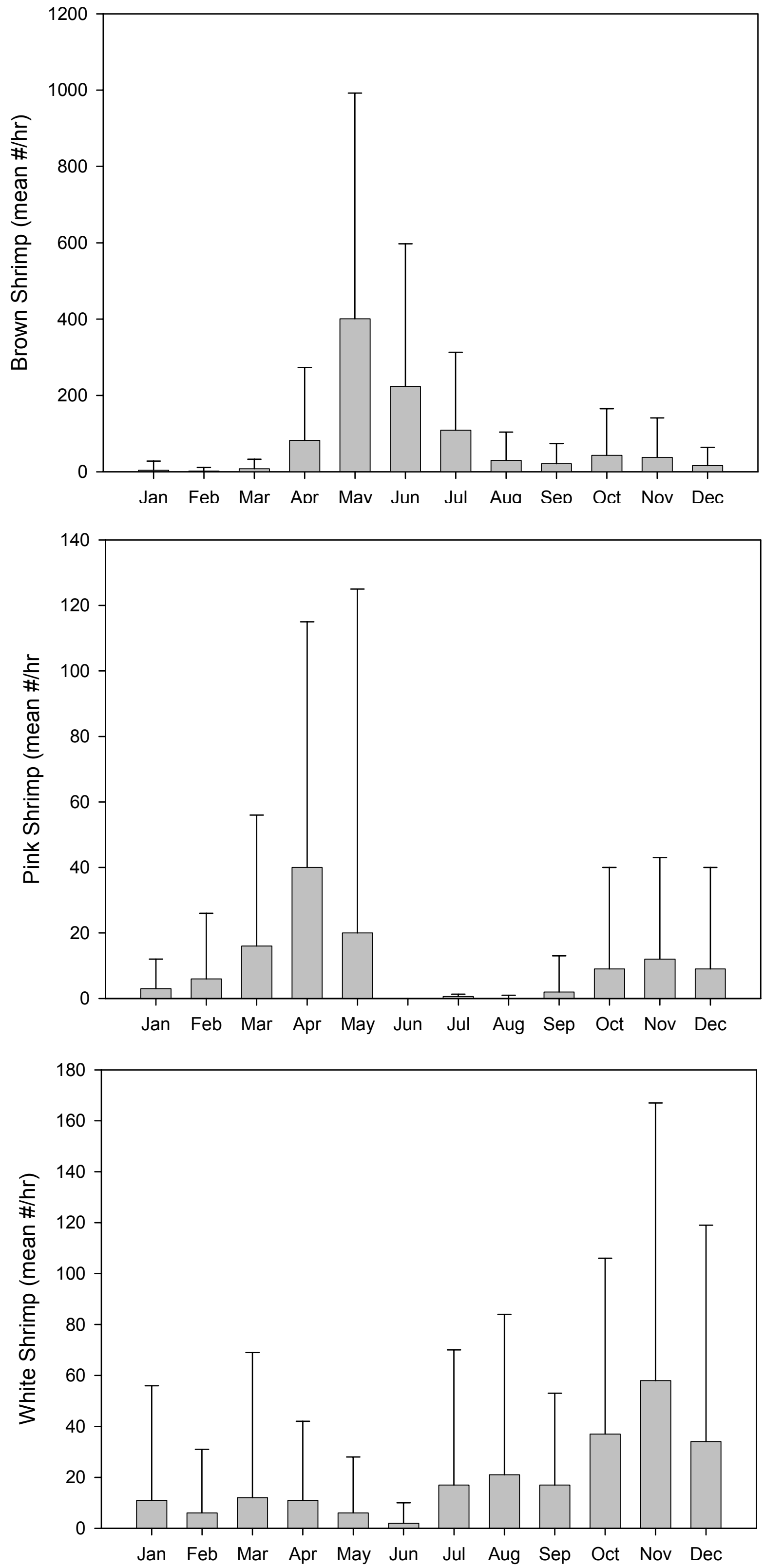


Figure 33. Monthly mean abundance with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Aransas Bay from fishery independent data collected by TPWD using trawls 1986-2000.

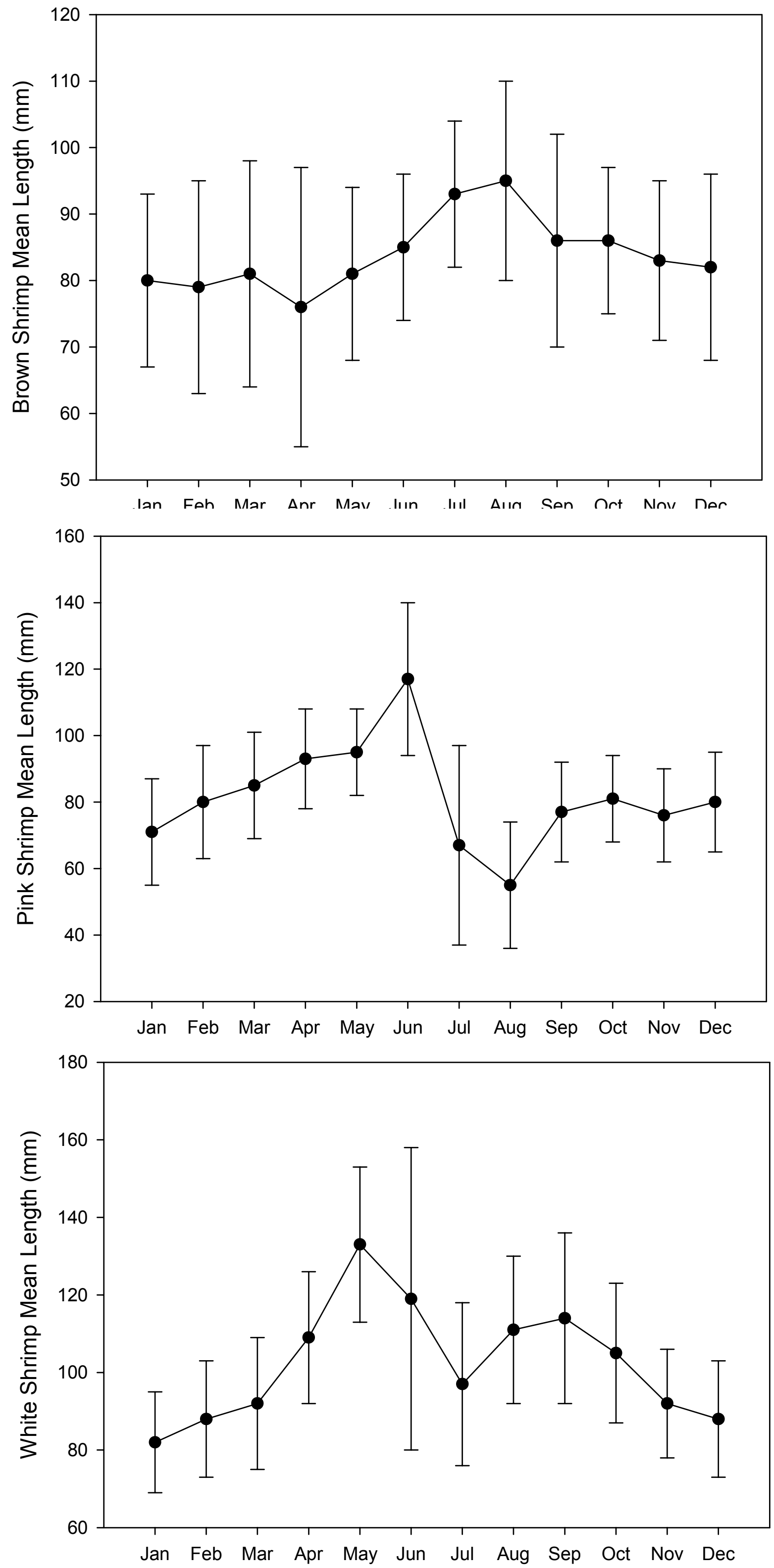


Figure 34. Monthly mean lengths with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Aransas Bay from fishery independent data collected by TPWD using trawls 1986-2000.

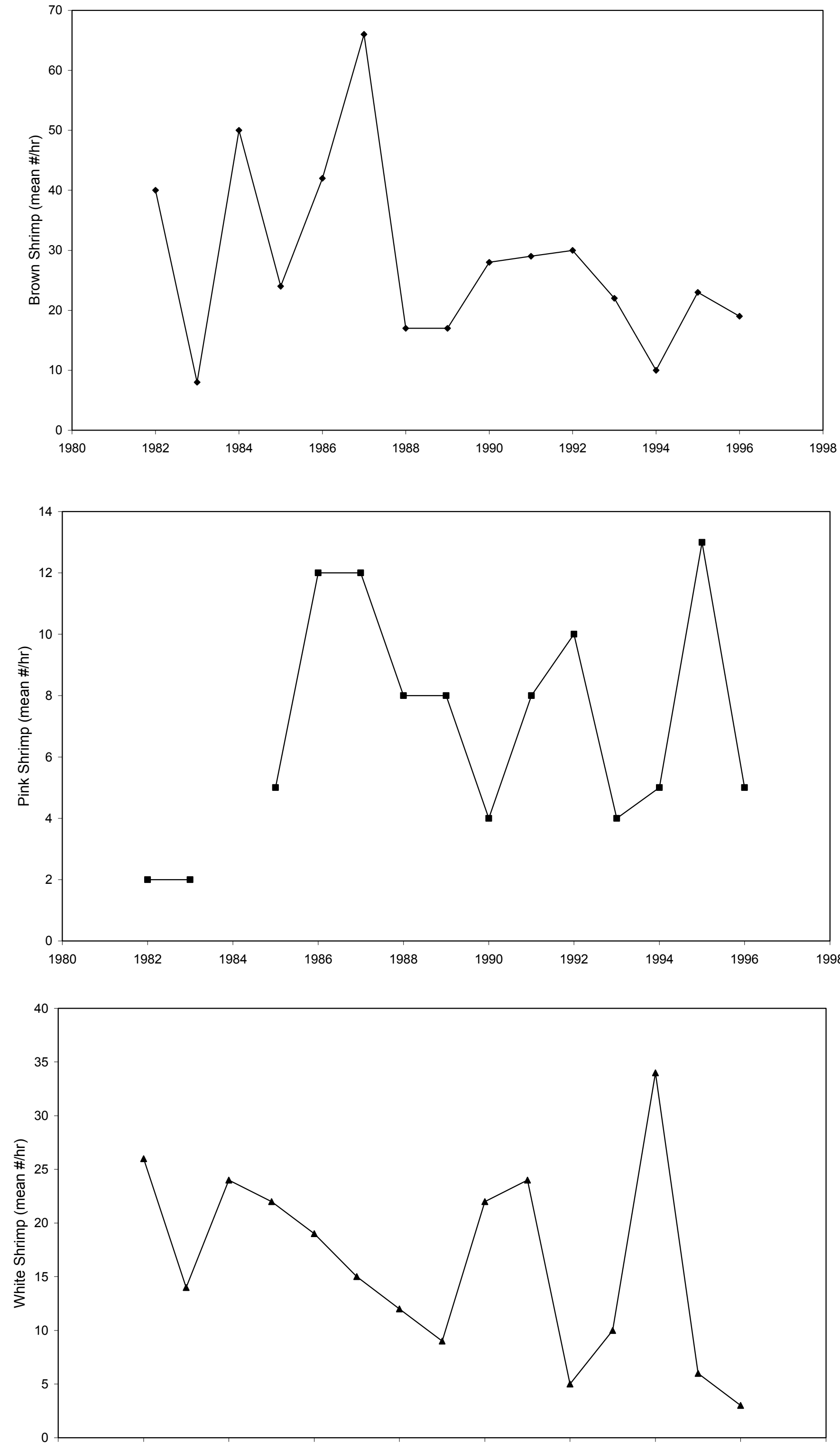


Figure 35. Mean abundances (#/hr) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in Corpus Christi Bay, 1982-1996 (data from Hensley and Fuls 1998).

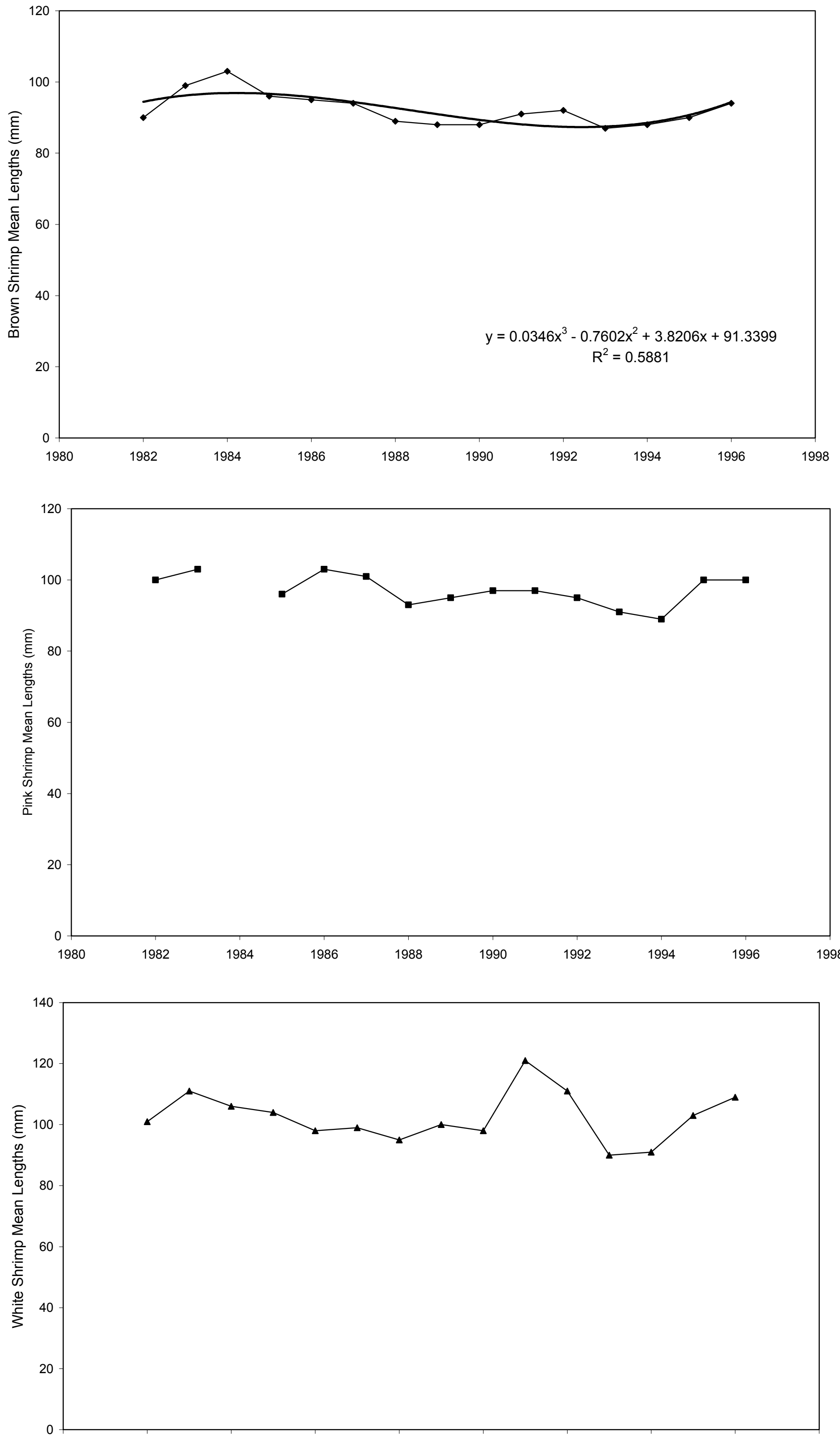


Figure 36. Mean lengths (mm) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in Corpus Christi Bay, 1982-1977 (data from Hensley and Fuls 1998).

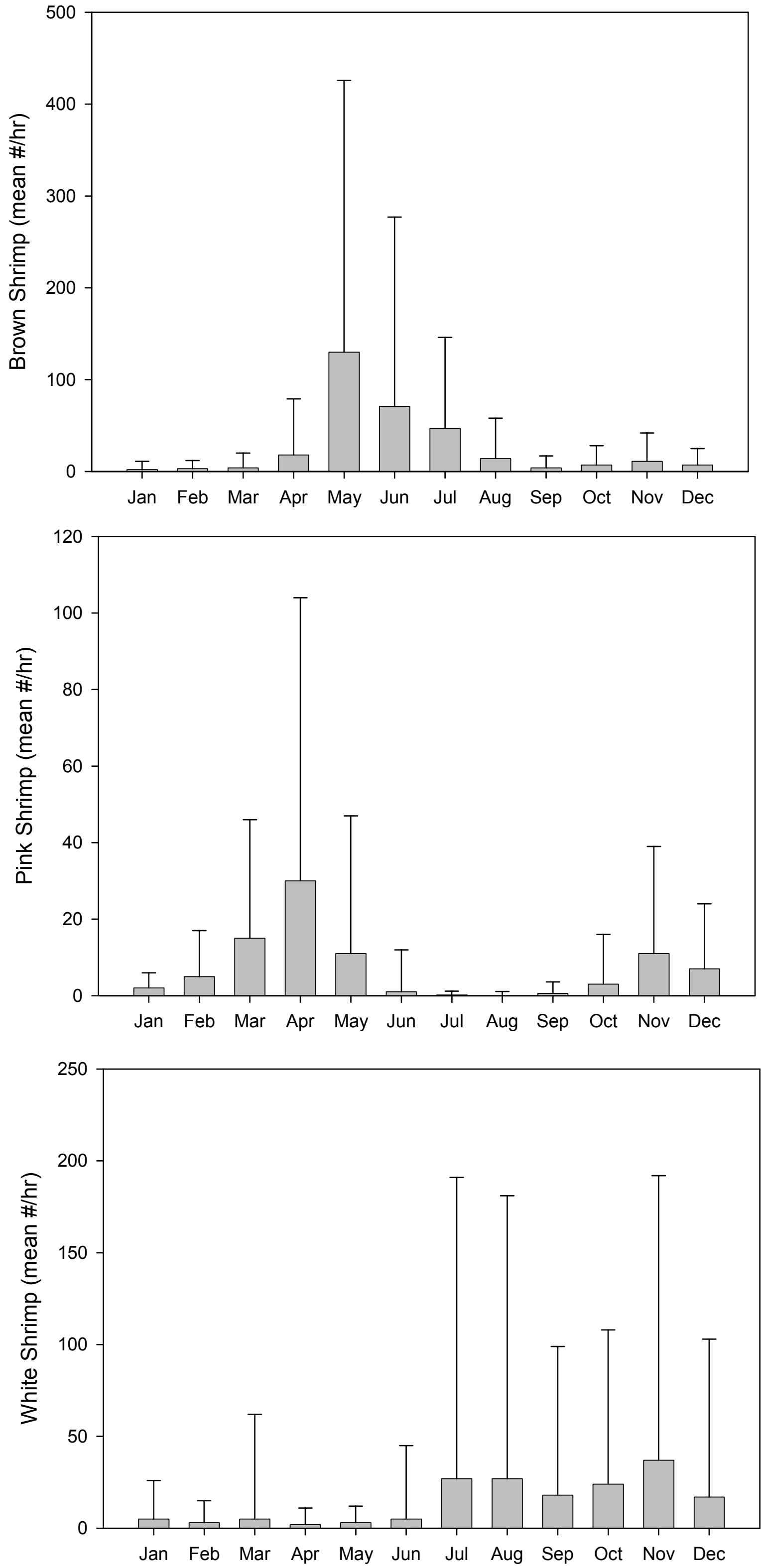


Figure 37. Monthly mean abundance with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Corpus Christi Bay from fishery independent data collected by TPWD using trawls 1986-2000.

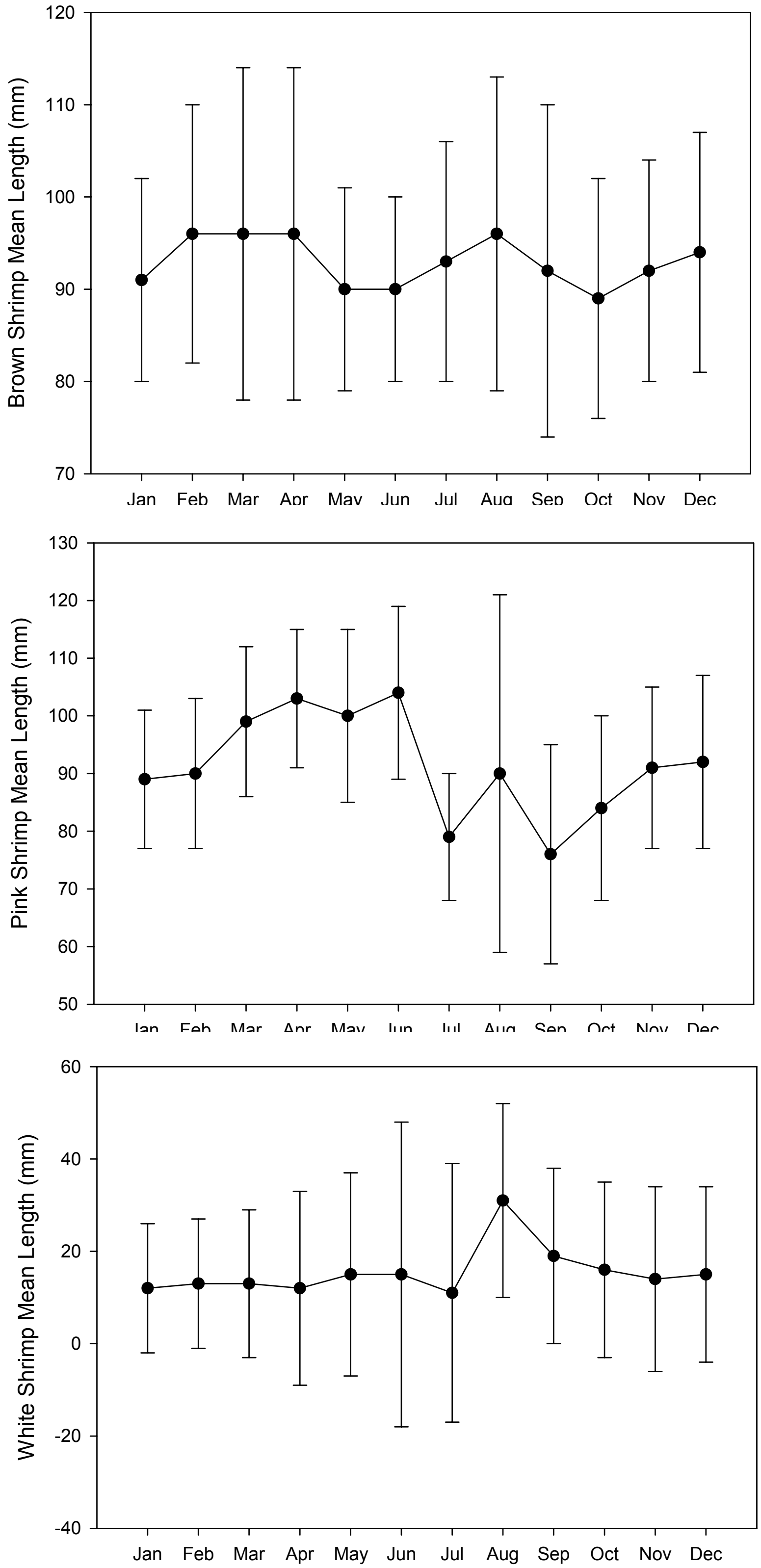


Figure 38. Monthly mean lengths with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Corpus Christi Bay from fishery independent data collected by TPWD using trawls 1986-2000.

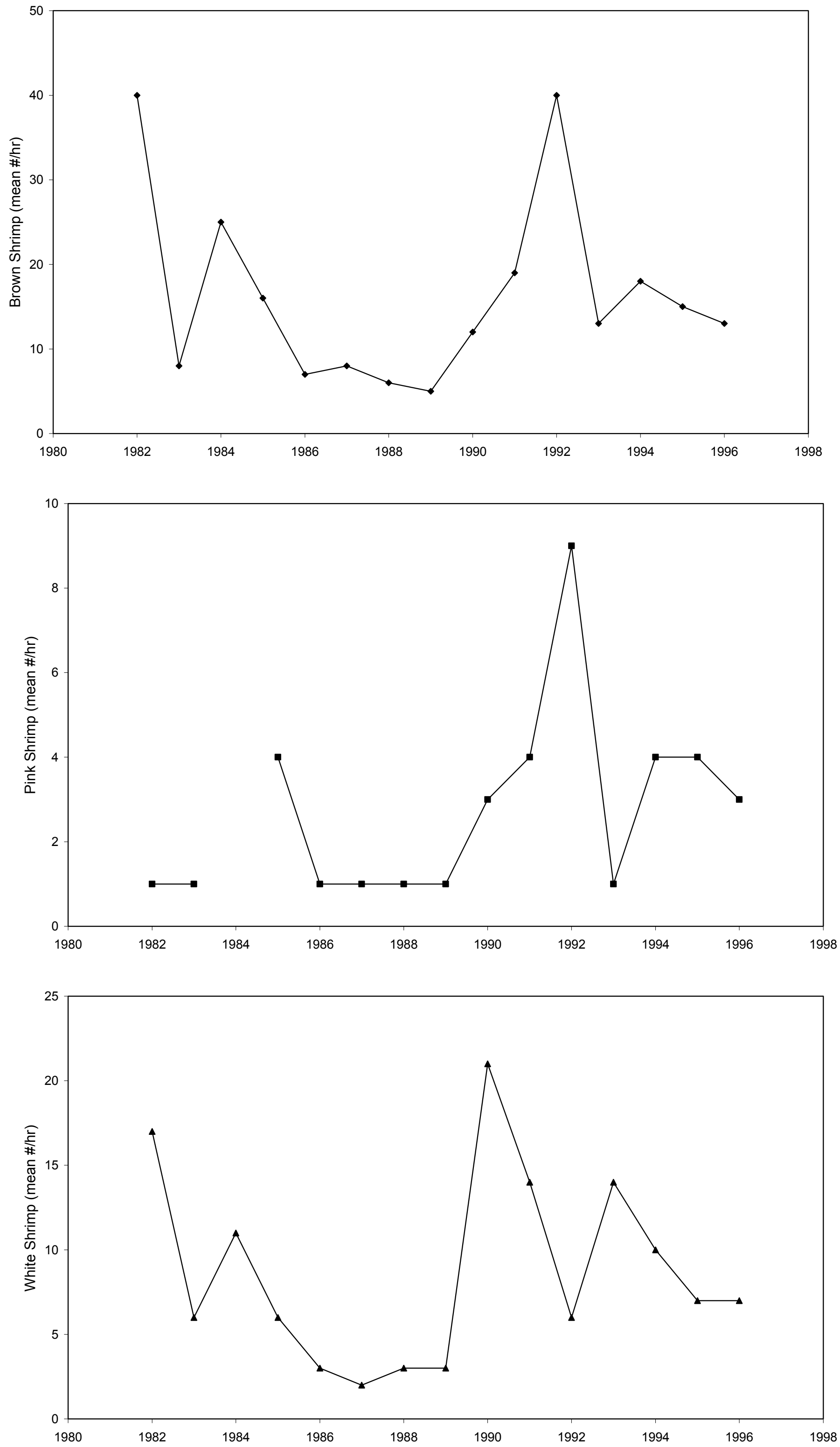


Figure 39. Mean abundances (#/hr) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in upper Laguna Madre, 1982-1996 (data from Hensley and Fuls 1998).

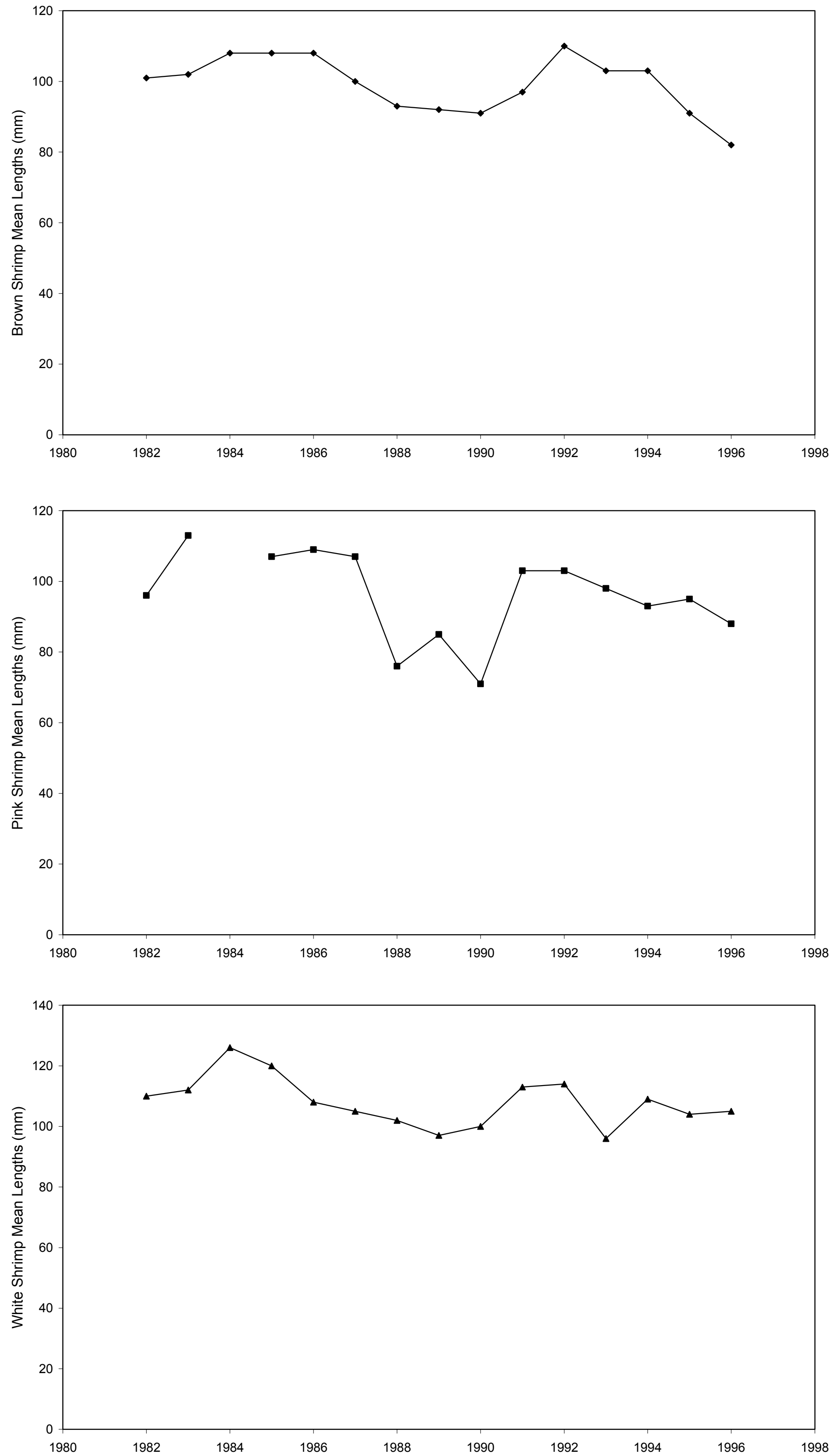


Figure 40. Mean lengths (mm) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in upper Laguna Madre, 1982-1996 (data from Hensley and Fuls 1998).

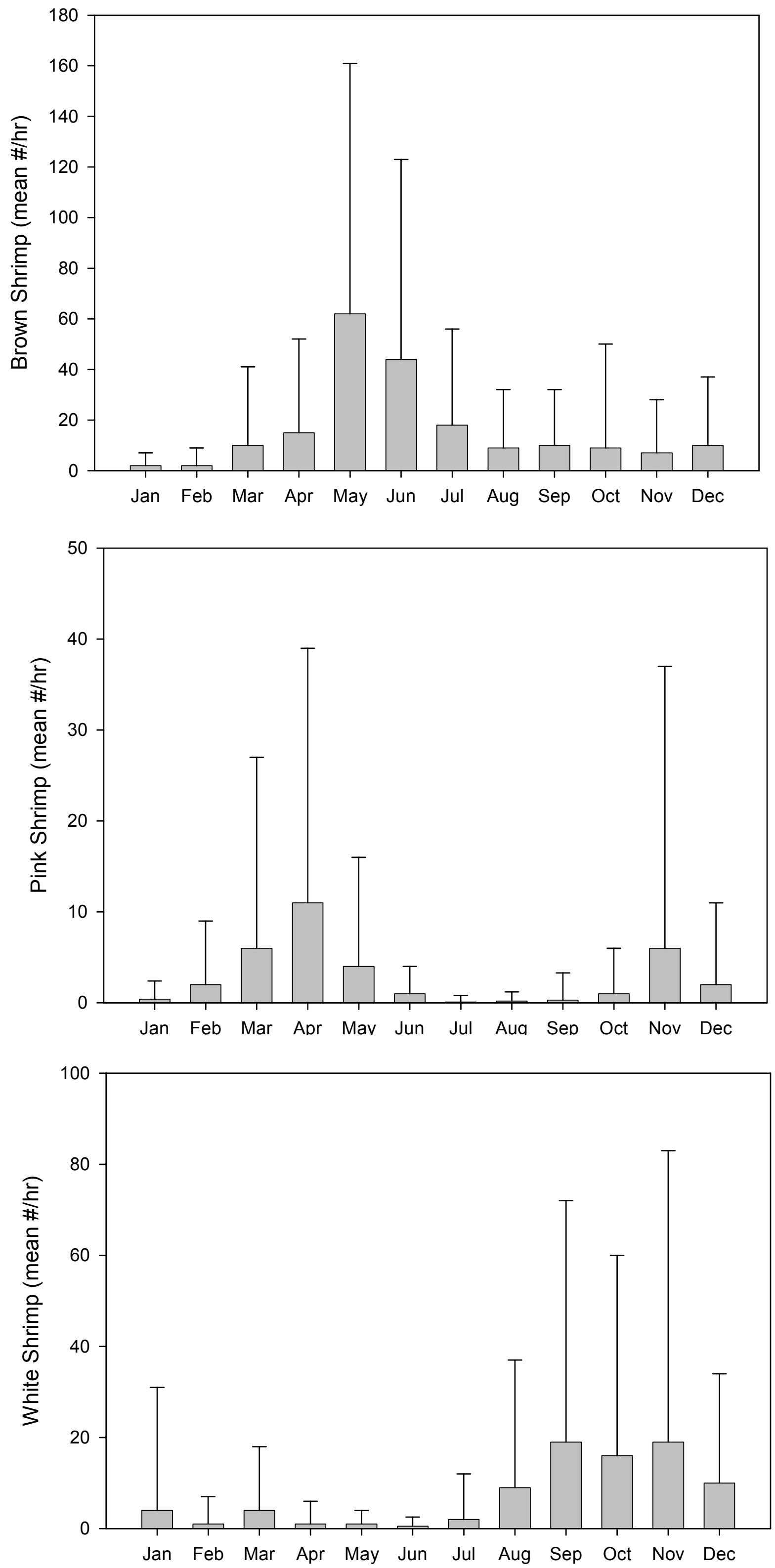


Figure 41. Monthly mean abundance with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in upper Laguna Madre from fishery independent data collected by TPWD using trawls 1986-2000.

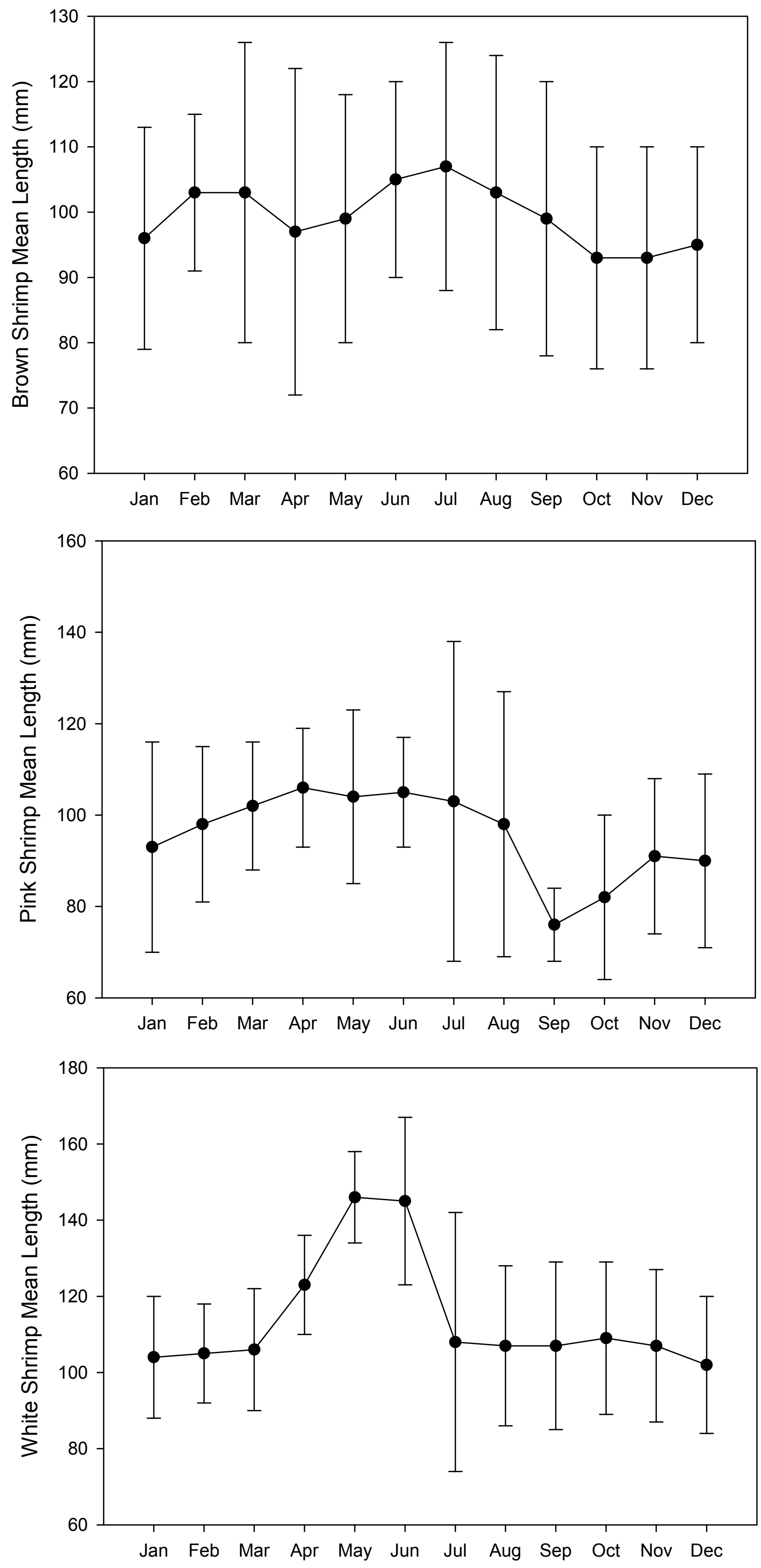


Figure 42. Monthly mean lengths with standard deviations for brown (top), pink (middle) and white (bottom) shrimp in Corpus Christi Bay from fishery independent data collected by TPWD using trawls 1986-2000.

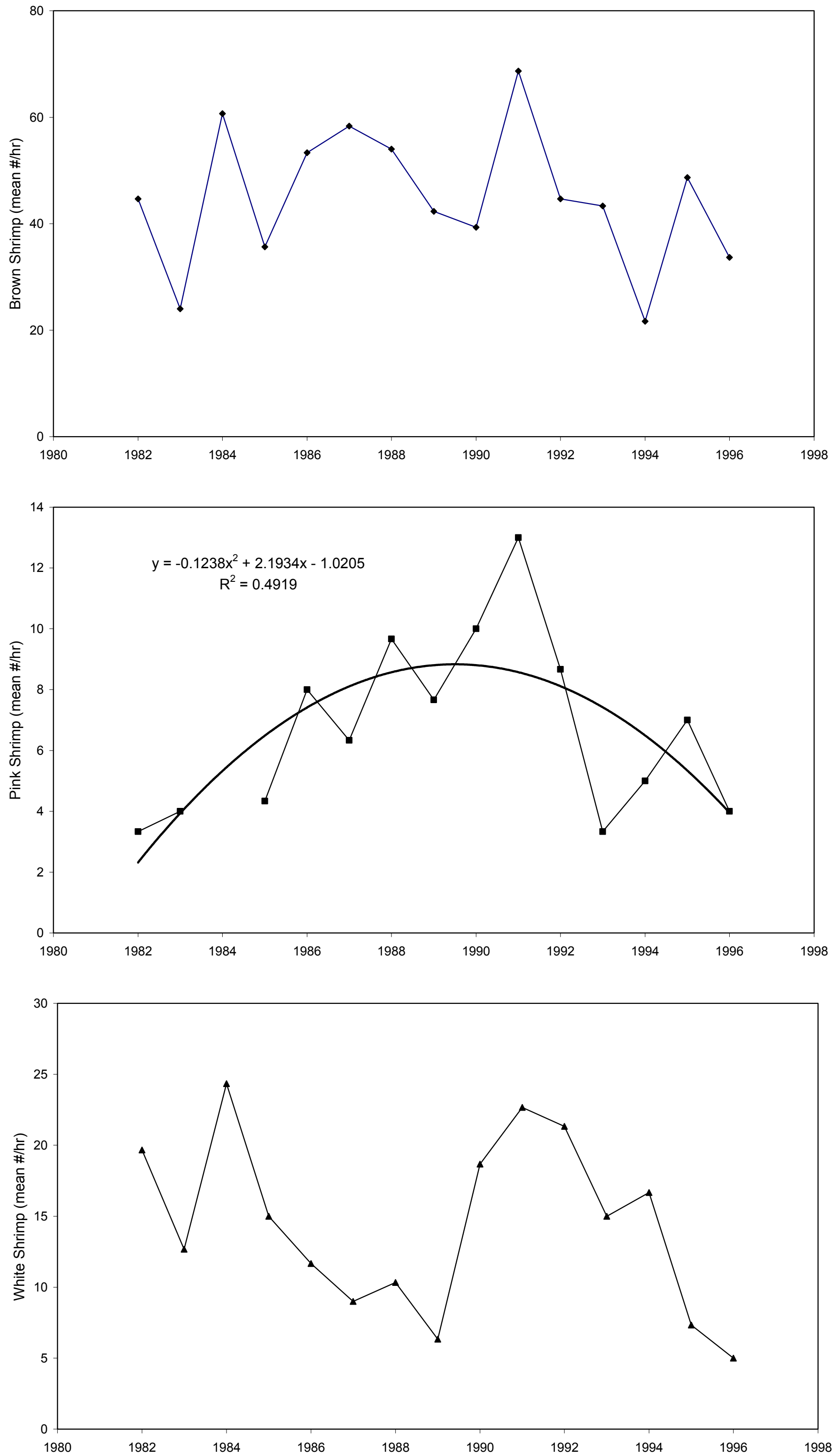


Figure 43. Mean abundances (#/hr) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in Coastal Bend bays, 1982-1996 (data from Hensley and Fuls 1998).

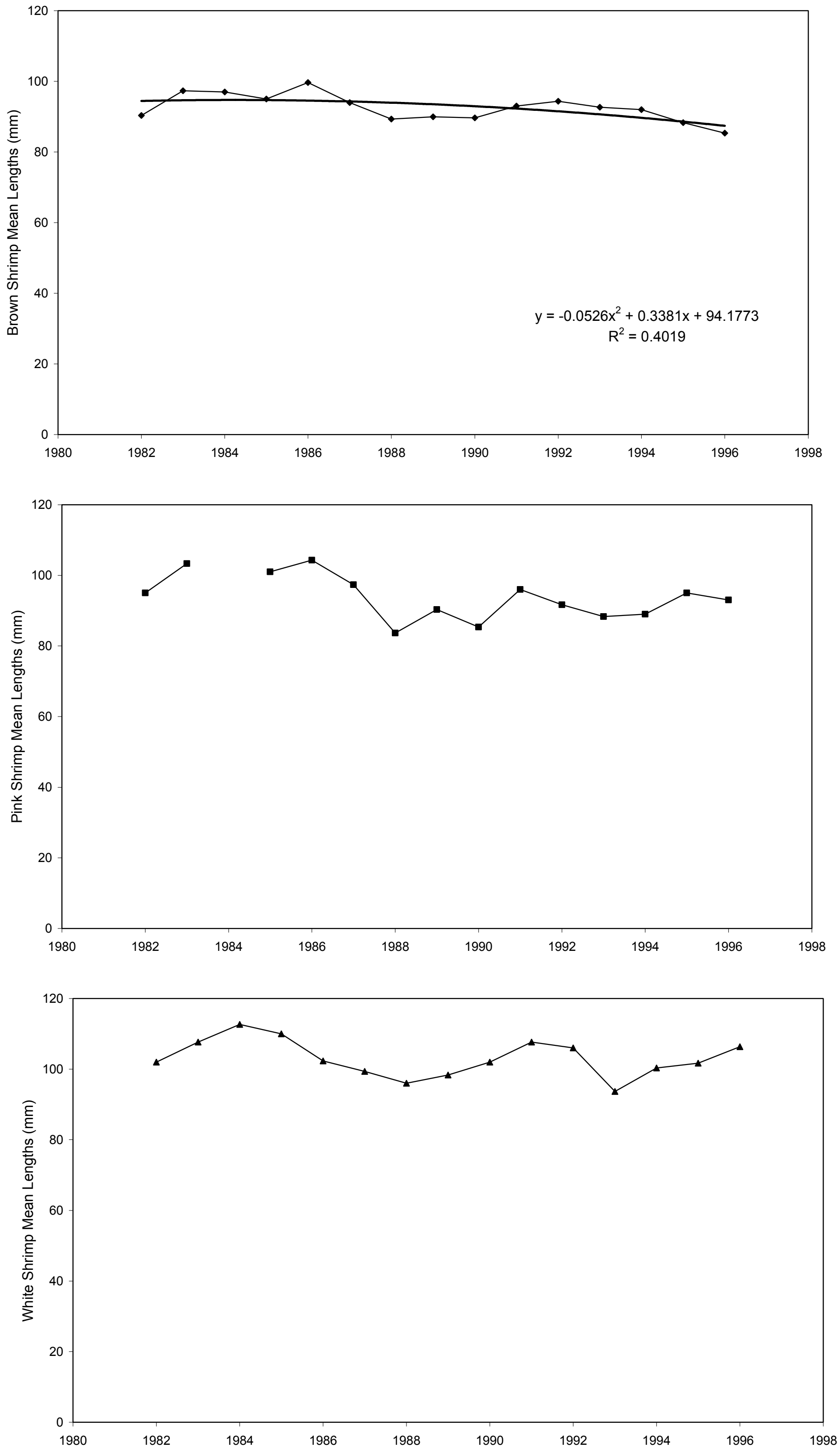


Figure 44. Mean lengths (mm) of larger brown (top), pink (middle) and white (bottom) shrimp captured in trawls in Coastal Bend bays, 1982-1996 (data from Hensley and Fuls 1998).

CHAPTER 6
MANAGEMENT DISCUSSION

In the ideal fishery, the fishery would be stable and adequate in terms of economic return for the fishers and reproduction/recruitment success of the target resource. The status of the resource would be easily measured and monitored. The capacity of the fishing fleet would be stable and in balance with the resource dynamics. Supporting habitats would be plentiful, healthy, and stable. Fishing methods would be target selective and have little to no impact on ecosystem dynamics or habitat integrity. Harvest of the resource would not affect the trophic system of the habitat. And, there would be no competition or user conflicts associated with the resource. Obviously, compared to this hypothetically ideal fishery, the Coastal Bend inshore shrimp fishery is lacking, as is every fishery. Subsequently, the existence of the inshore shrimp fishery and management of the fishery are the result of compromise – compromise that is bounded by the laws of nature controlling reproduction and recruitment of the resource. Effective management must achieve a balance (Figure 45) of exploitation, conservation, economics, natural conditions, and societal demands.

"The purpose of fisheries management is to control the exploitation of fish populations so that the fisheries they support remain biologically productive, economically valuable, and socially equitable" (NRC 1999). The challenge of fishery management is to identify that cumulative level of population impact, natural and anthropogenic, which can occur without degrading the ability of the resource to regenerate to population densities that are sustainable at commercially viable levels. Fishery management is complicated by the uncertainties of resource assessment, inter-jurisdictional authority (i.e. state, federal, and international) over common resources, economics (supply, demand, and competition), changing social values and demographics, political actions, and jurisprudence. Frequently, industry participants actively seek political and legal actions affording protection to their "piece of the pie." Changing social norms have brought well-funded and networked recreational fishery and environmental conservation groups into the debate. Historically, legislative bodies have been influenced to pass legislation giving preference to one or the other user group (Maril 1883, 1995). And, most commonly the placement of "burden of proof" has been attributed to the resource managers and conservation advocates rather than the resource exploiters (Dayton 1998; Gerrodette et al., 2002; Charles 2002).

In actuality, Coastal Bend bay shrimpers (inshore) and Gulf shrimpers (offshore) harvest from the same resource pool, serve the same consumer groups, and face the same challenges to the sustainability of their respective industries (Figure 46). They differ in that the inshore fishery accesses younger pre-spawning age animals and the offshore industry targets spawning and post spawning individuals. Any action by either fishery group that destabilizes the reproductive potential of penaeid shrimp in Texas waters will adversely affect both fisheries. The inshore fishery is based on a one owner/operator – one boat business model and the offshore fishery is in general a corporate structure where owners have more than one boat and hire captains to operate them. The Texas Shrimp Association represents the offshore industry, while the inshore industry has little to no

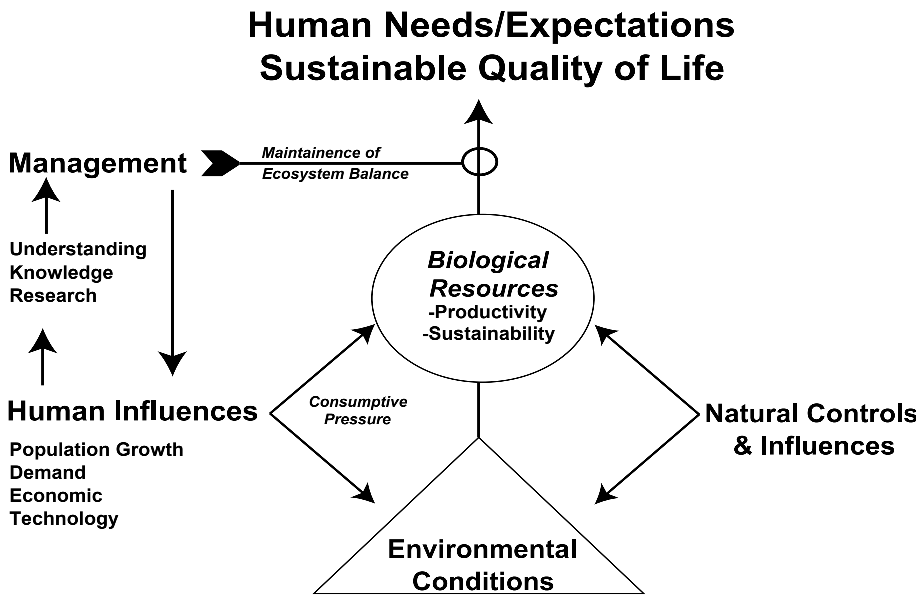


Figure 45. Management of living natural resources.

organized representation in political, legal, and financial arenas. This is likely the result of the relative difficulties of organizing the large number of owner/operators in the inshore fishery versus organizing a fewer number of corporate owners.

One could argue that priority should be given to one fishery over the other. Offshore fleet owners, not necessarily captains, have done just that since the early 1970's arguing that all juveniles should be left undisturbed to migrate offshore to achieve spawning size and be harvested at a size with greater per unit value (Maril 1983). Inshore fishers could argue that the spawning adults should be left undisturbed to increase the potential recruitment into the nursery where the resource could be harvested in a more cost/energy efficient manner. Maril described it as a skewed debate with the offshore owners having greater financial resources and political influence to push their agenda.

As with the recreational versus commercial fishing debate, often the debate centers on which industry has the greatest gross financial impact – perhaps a flawed concept. In a political and legal system based on the rights of the individual and an economic system based on the theory of free enterprise the relative value of a job, business, or industry cannot simply be based on gross revenues. The offshore industry has argued that "we are bigger" and subsequently of greater value to society. This reasoning ignores the economics of the individual within each industry. As described by Maril (1995), workers in the inshore fishery are compensated at levels equal to or greater than offshore fishers. Following the theory of free enterprise, it should be economics at the individual and business level that determines whether or not an industry will flourish or cease to exist.

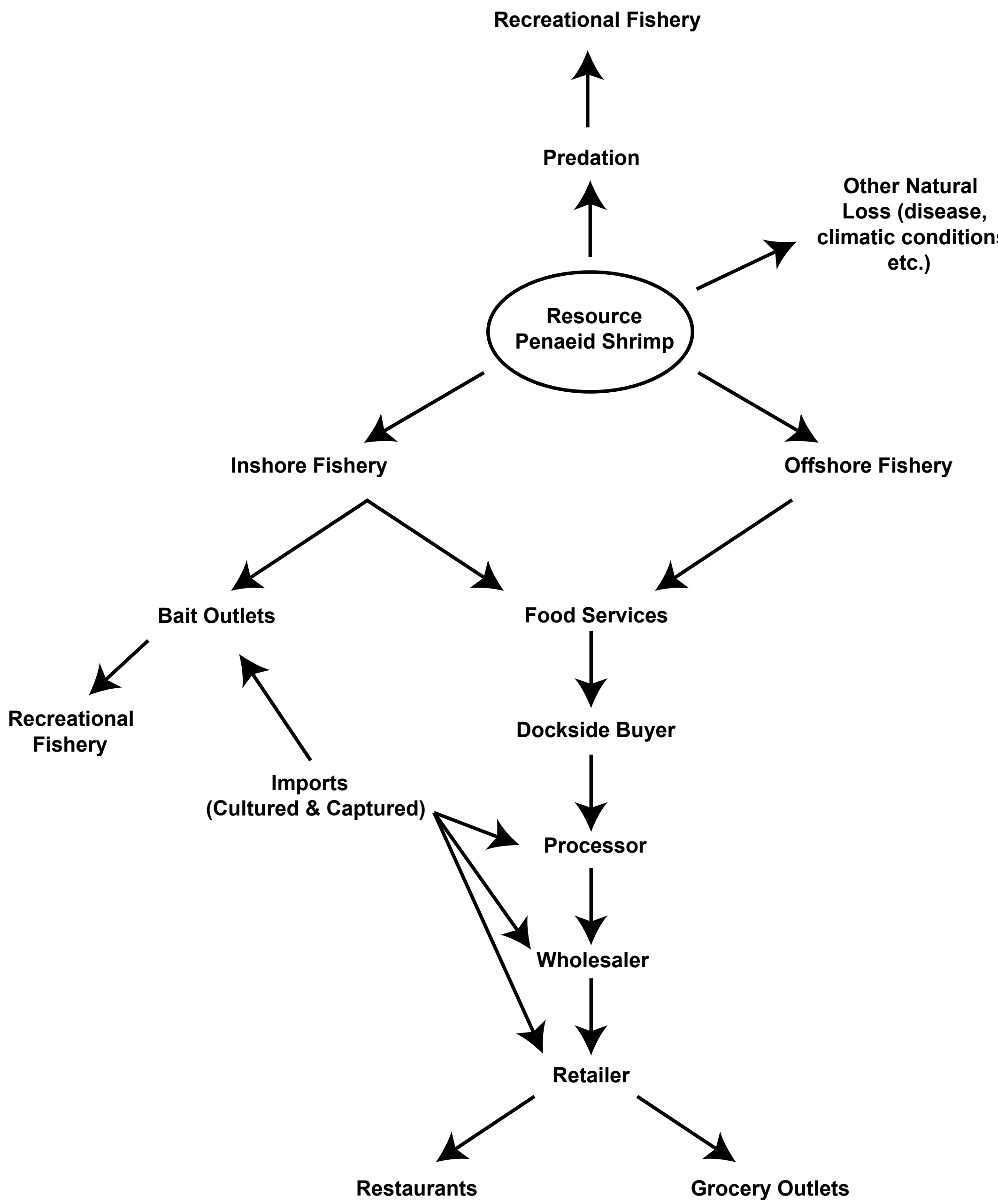


Figure 46. Schematic representation of connectivity between inshore and offshore shrimp fisheries.

A win/win solution would be the development and implementation of a business model that joins the two fisheries, provides acceptable return on investment, and to a significant degree places the onus of resource and habitat conservation upon the harvester. This would encourage the industry to analyze the resource on a long-term scale rather than a season-to-season approach, which would in turn encourage management to move toward a more ecosystem approach. Walters and Martell (2002) stated that, "*A much more important reason for investment in ecosystem modeling exists, however: single-species approaches do not even allow us to ask many of the important policy questions that are being directed to fisheries scientists and administrators today. These are `ecosystem-management' questions, like (1) Will changes in primary productivity associated with physical regime shifts driven by climate change be amplified or dampened by food web interactions? (2) Are fishers seriously affecting the capacity of marine ecosystems to support `charismatic megafauna', particularly marine mammals, and how can these effects be mitigated? (3) Is over fishing leading to `perverse' changes in community structure (competitors/predators) that will cause apparent and persistent depensatory recruitment patterns in naturally dominant fish species that have been severely reduced in abundance? (4) How large do marine protected areas need to be to maintain the full structure of marine food webs, and how do food-web interactions affect the performance of MPAs? (5) Will selective fishing practices like by-catch-reduction devices actually help to restore marine community structure, or will they `backfire' by causing even more severe distortions in food web structure? (6) How much impact will our tendency to fish down marine food webs, shifting more toward harvesting at lower trophic levels, have on our ability to harvest sustainably and restore abundances of predatory fishes and mammals? (7) How will the physical habitat and epifaunal community changes caused by some fishing practices affect future recruitment and productivity of valued species?"* As described by Brodziak and Link (2002) ecosystem management is evolving as a more holistic management paradigm.

A management objective in every fishery is to maintain the stock at a productive and sustainable level, which in-turn will support the maintenance of healthy fishing industries (Gerrodette et al. 2002). Maintaining a fishery stock at a productive and sustainable level requires:

1) Comprehensive understanding of the biology of the resource.
2) Understanding of the dynamics of the ecosystem in which it flourishes.
3) Technical mechanisms to continuously monitor population stability of the resource and the condition of its habitats.
4) The will and financial resources to monitor the resource and its habitats.
5) A long-term approach to predicting change in conditions and assessing the direct and indirect impacts of change.
6) Universal understanding that although the resource is renewable, it is a finite resource in terms of allowable harvest rates, a fact that cannot be subjugated by the will of mankind.
7) Industry participants committed to the long-term future of the industry.
8) Application of fishery business models that promote harvest in a sustainable manner.

The inshore fishery of Texas is managed by the Texas Parks and Wildlife Department (TPWD) primarily through the use of "input" controls (NRC 1999), which include restrictions on gear, season and hours fished per day, area fished, numbers of fishers, and daily catch limits for each licensed boat. The offshore fishery is managed primarily with gear and season restriction. Resource assessment is accomplished with independent fishery measurements; bag seine surveys inshore and trawl surveys both inshore and offshore within Texas Gulf waters to 9 nautical miles offshore. Fishery dependent measures, commercial landings, are also monitored by TPWD and the National Marine Fisheries Service (offshore only).

Both the inshore and offshore fisheries are managed in a linear fashion that has developed over time. Management of the fisheries through an ecosystem management approach is not employed with the exception of gear requirements intended to reduce bycatch (i.e. Turtle Excluder Devices and By-catch Reduction Devices). Although TPWD can manage the effort and effectiveness of the fishers, TPWD does not have control over other human activities such as shore side development and its collateral destruction of habitat that can also affect the population stability of shrimp.

The linear management of the inshore fishery promotes a competitive relationship between each fisher and a myopic drive to "get while the getting is good." Although the fishers fully recognize the need for conservation management, there is little room for voluntary conservation actions. The relatively low level of fishers' income, both gross and net, exasperates this situation. As a substantial proportion of the fishers struggle to stay solvent from year to year, their freedom of choice in terms of voluntary conservation is hindered; after all, they must meet the needs of their families, communities, customers, and creditors.

Management Options

The future of shrimping in the bays of the Coastal Bend region is uncertain. Considering the following:

1) Shrimp populations are reported as a dwindling resource.
2) The quality and abundance of shrimp habitat is decreasing.
3) User conflicts and pressures (e.g. offshore fishers versus bay fishers) are more common, costly, litigious, and political.
4) The inshore fleet is aging.
5) The average age of the shrimpers is increasing.
6) There is little if any inflow of young shrimpers into the business of inshore shrimping.
7) There is an aggressive license buy back program implemented by the Texas Parks and Wildlife Department and supported by well-funded conservation groups.
8) There is a moratorium on the issuance of new licenses.
9) The possibility of increased regulations limiting catch is always a possibility.
10) Business costs are increasing.

11) Competition with imported shrimp forces the wholesale market price to be depressed and static.

It can be concluded that shrimping in the bays of not only the Coastal Bend, but, all of Texas, will eventually decrease to a level to be almost non-existent. However, for the sake of this discussion, we assume that the management goal is to support sustainability and productivity of the living resource, habitats, and fishers. Texas inshore and offshore shrimp fisheries are not unique in their precarious situations. Globally, most fisheries are already over fished or near so and essential habitats are being destroyed. Management professionals, scientists, and fishers are striving to develop new and more effective management strategies that will ensure the survival of resource in the face of both natural and anthropogenic negative pressures (Sissenwine and Rosenberg 1993; Seijo et al. 1998; NRC 1999a,b; Hanna 2000; Shotton 2001a,b; TPWD 2002). Herein we advocate that the most effective form of management will be one that uses the power of comprehensive long-term business strategies that encourage voluntary proactive conservation efforts by the harvesters. In discussing management opportunities for the Coastal Bend inshore shrimp fishery we will consider management of areas that can be fished, time periods, and resource allocation.

Management of Fishing Areas

For the purpose of this discussion, the Coastal Bend bay system is limited to Aransas Bay, Corpus Christi Bay, Nueces Bay, and the Upper Laguna Madre (Figure 47). Redfish Bay and all secondary bays are closed to shrimping. Restriction of fishing areas has two primary ecological impacts: 1) it provides “protected” areas for the shrimp to progress to maturity relatively undisturbed, and 2) it reduces the impact of fishing technology on benthic habitats. Nowlis and Bollerman (2002) stated that, “*Highly responsive systems, where a reserve population is protected from fishing, are highly effective ways to manage in a precautionary manner.”* In effect the closed secondary bays of the Coastal Bend bay system are reserves; and offshore, the temporary closure of zones to shrimping activity is another form of a reserve system. Ricker (1958) reported that reserves also provide the opportunity to minimize impacts of by-catch. Trawling disturbs benthic communities (Auster 1998; Engel and Kvitek 1998; Kaiser 1998; Pilskaln et al. 1998; Watling and Norse 1998) and trawling in Coastal Bend bays is no exception (Montagna et al. 1998). Reserves protect habitat features and functioning ecosystems within their borders (Nowlis and Bollerman 2002).

Non-quantified observations suggest that the inshore shrimping fleet generally follows the movement of the shrimp as they migrate from closed nursery areas (i.e. secondary bays) to the Aransas Pass that provides access to open Gulf waters. The fleet becomes concentrated in the channels (i.e. Corpus Christi Ship Channel, Intracoastal Waterway, and Aransas Channel) as the stock moves toward offshore waters. Prior to this, for short periods the fleet concentrates in those areas where secondary bays empty into the primary bays, presumably at the time of migration out of the secondary bays. An expansion of reserve area could be accomplished by limiting inshore fishing to the dredged channels out to 150m on either side of the mid-line of the channel. This would in effect reduce habitat impact, but still give the fisher access to the stock as it moves through the channels to the Aransas Pass exit.

Fishers working in the Upper Laguna Madre and Aransas Channel are already confined to the dredged channels. Such a strategy would be most effective with a reduced fishing fleet. If the fleet is too large safety issues come to the forefront. Further study would be necessary to fully understand the impact such reductions of fishing area would have upon the fishers.

Management of Fishing Times

Ideally, a living resource would not be disturbed during either its reproductive period or juvenile growth periods. Texas shrimp stocks are fished during both spawning (offshore) and juvenile growth (inshore) (Figure 48) periods. Assuming that fishing effort does not affect the immigration of larvae and post-larvae into the nursery areas, inshore fishers impact seaward migrating stocks only during the May 15 – July 15 summer season and during November at the end of the fall season. Offshore fishers can access the spawning stock year round with the exception of the midsummer no fishing period that corresponds with the seaward migration of the brown shrimp and pink shrimp. Restricting the offshore fishers to specific zones during designated time periods is intended to afford the migrating and spawning stocks some measure of protection. In effect, this is a rotating system of temporary marine reserves based on a time scale adjusted to the behavior patterns of the shrimp.

Individual Fishing Quotas

The trend in fisheries management is toward management through the issuance of Individual Fishing Quotas (IFQ) (NRC 1999a). Although this is contrary to the tradition of open and free fisheries, today it is widely believed that:

1) Fishery resources should be a marketed commodity in the manner of offshore mineral lease blocks, timber resources, and public grazing lands.
2) That through the conveyance of ownership rights motivation for conservation increases.

Harvest quota based management is more responsive to changing environmental and resource conditions, and subsequently is more effective in guarding against a total collapse of a fishery.

A derivation of an IFQ is the Individual Transferable Quotas (ITQs) (Shotton 2001a, b). Being transferable, the quotas become a marketable commodity subject to the standard influences of a free market. Clark and Munro (2002) argue that ITQs are a more effective and rational way of dealing with overcapacity in fisheries. Buyback programs are in-effect subsidies that do not encourage active resource management by the fishers', usually remove only the marginal fishers from the fishery, and do not remove the competitiveness between fishers for the resource. ITQs on the other hand, do eliminate

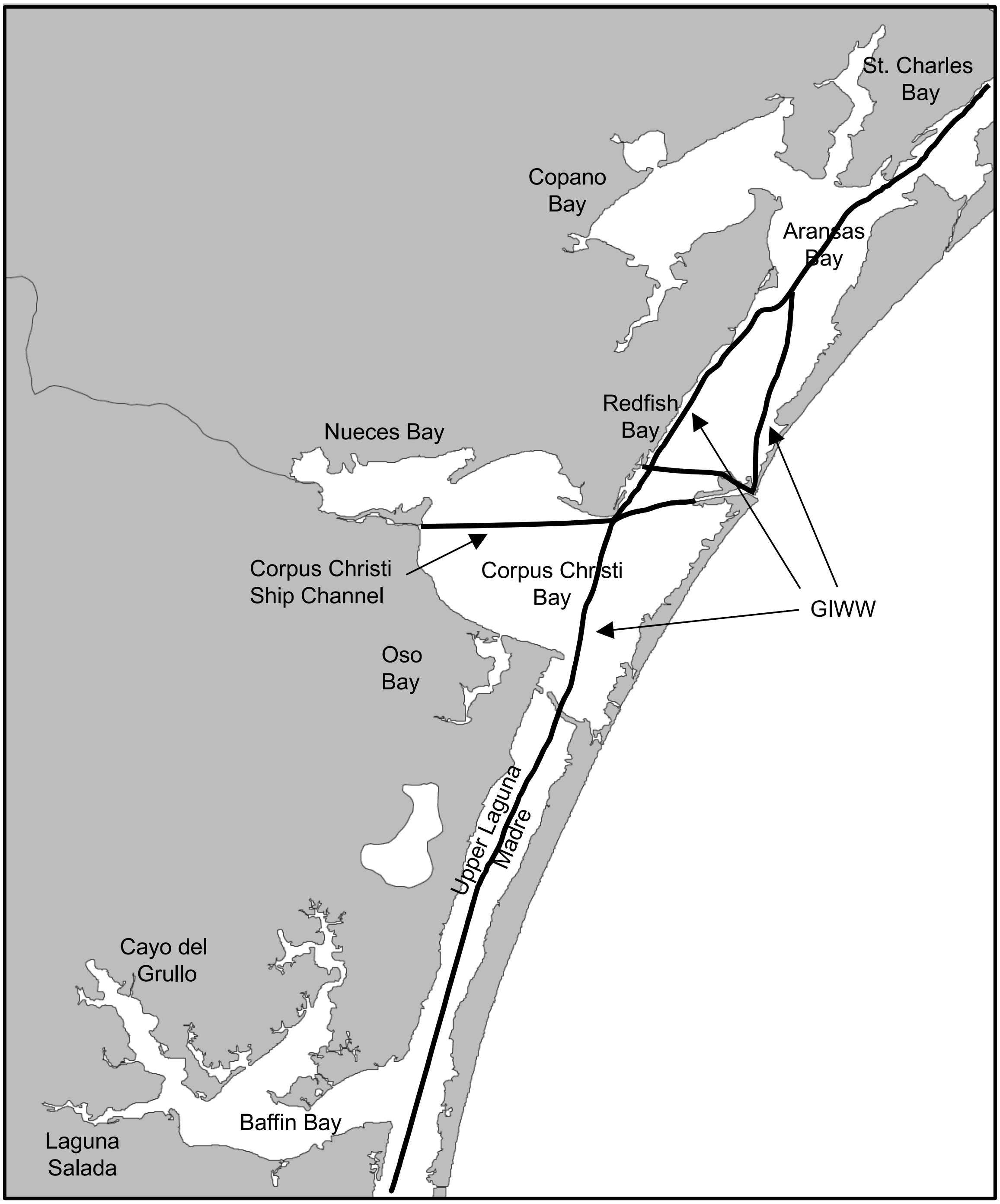


Figure 46. Map of local bays showing areas currently closed to shrimping (hatched areas) and major channels.

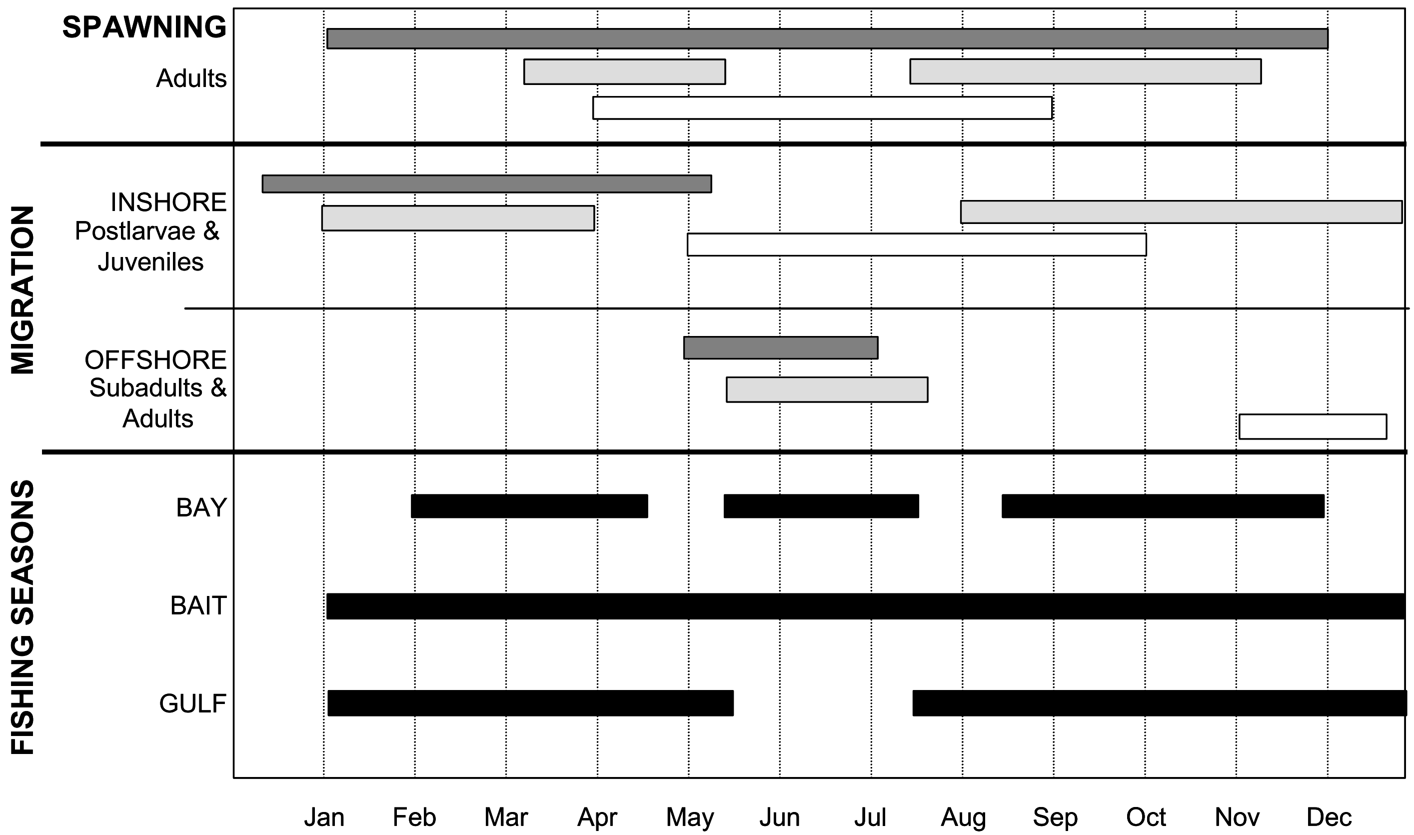


Figure 48. Schematic showing relationships between shrimp life cycle events and fishing seasons. Dark gray bars represent brown shrimp, light gray bars represent pink shrimp and white bars represent white shrimp.

competitiveness between fishers, do not encourage increases in "fishing power" of each vessel (Note: "Fishing power" is the efficiency of a vessels capability to harvest the resource.), eliminate incentives for overfishing and overcapacity, and support the development of "quota markets." Clark and Munro also suggest that the government could/should sell fishing rights just as logging rights and offshore oil and mineral rights are sold. This too would force the evolution of a more profitable business model for fisheries; one that incorporates responsibility for conservation and sustainability of the resource. Marginal fishers would phase out due to financial limitations and more profitable fishers would gain prominence.

Could ITQ management be applied to the Texas inshore shrimp fishery? First, to do so would require that an annual harvest limit be established. Using the principals of "precautionary management" theory (FAO 1996; Restrepo 1998, 1999a, b; Weeks and Berkeley 2000; Ludwig 2002; McAllister and Kirchner 2002; Rosenberg 2002), historical harvest records could be used to set a maximum allowed harvest. This could be done on a number of spatial scales including: by bay system, by region, or by state boundaries. A recruitment-monitoring program would be necessary to make adjustments to the total allowed harvest limits as dictated by stock abundance; and a near real time landings monitoring program would be required. Secondly, an optimum size for the fishing fleet would have to be determined. The TPWD has already begun to reduce the fleet with a license buy back program and commitment to limited entry for the future (TPWD 1999; Riechers 2000; TPWD 2002). In determining the optimum size of the fishing fleet, fishing power and economics must be considered. What level of gross income should be attributable to each license sold recognizing that this is determined by quantity and price/unit determined by the shore side market system? What is the maximum catch per unit effort (CPUE) that can be achieved by a single boat assuming that stock density is not the limiting factor? Can fishing power be improved to increase CPUE, and subsequently decrease the habitat impact of trawling through a reduction in tows?

ITQ management is an attractive alternative. It can potentially increase the annual income of the owner/operator, reduce fishing effort, support a business model that could be melded into a comprehensive model linking the inshore and offshore fisheries, and provide resource managers greater ability to respond to sudden changes in resource abundance. And, it creates an opportunity for state management to allocate a dollar value to each quota allocation and collect revenues. On the down side, it eliminates free entry into the industry based on a resource traditionally considered to be "public property – free for the taking."

ITQ management could possibly eliminate the need for other input management controls such as daily time periods during which fishing is allowed and daily bag limits. Assuming that the established quota limits are adequate to ensure the necessary number of potential spawners escape, the fishers could be given more freedom to manage his fishing effort.

Seijo, et al. (1998) described basic property rights that must be specified for optimal allocation of renewable resources. Those rights (Randal, 1981; Schimd, 1978) must be:

1) completely specified in terms of the rights that accompany the property over the resource, the restrictions over those rights, and the penalties corresponding to their violation; 2) exclusive, so that the person who has those rights will also be responsible for any retributions and penalties corresponding to the use of the natural resource; 3) transferable, in order to have those rights in the hands of those who have the capability to convey them to the highest use value; and 4) effectively enforced, because a non-policed right becomes an empty right.

ITQ Management Implementation

It is not reasonable to expect that resource managers or resource harvesters can successfully make or respond to a change in management strategy overnight. For the sake of planning, we suggest a five-year implementation program beginning with the establishment of a working group composed of managers, fishers, and scientists to create a detailed ITQ management plan. This group will:

1) Determine optimal total catch allowed. This can be done by bay system, region, or state boundaries. Historical catch data along with adjustments to precautionary management could be used to establish a total catch quota that would then be allocated to the individual licenses. With appropriate monitoring of recruitment and harvest, managers could adjust this quota to fit stock densities in any given time period.
2) Determine the optimal fleet size, which could also be done either by bay system, region, or state boundaries. This will require consideration of economics, fishing power, annual harvest quota, fishing patterns (i.e. do they fish their home bays or do they move up and down the coast?). It is accepted that a viable inshore fishery is an asset to the local and regional communities and as such should be developed to its optimum status. It is also accepted that the shrimp stocks are not adequate to survive unlimited fishing pressure. Subsequently, the fleet size must be restricted to a level that allows individual fishers to harvest an adequate amount of shrimp to remain financially satisfied while ensuring the sustainability and productivity of the resource. It is anticipated that with adequate cash flow, the vessel owner/operators could enhance their boats to improve fishing power. This would allow a reduction in the number of trawls required to harvest each individual quota further reducing the cost to catch and enhancing habitat protection.
3) Determine how other management options such as protected reserve areas can be used to enhance the ITQ effectiveness. Current management guidelines need to be addressed to determine which if any should be eliminated. For example, restriction of shrimping to daylight hours and daily bag limits would likely not have much value in a quota management system.
4) Design a monitoring program of recruitment and harvest.

Conclusion

The historical model for the management of the inshore shrimp fishery has served its purpose to this point in time, but there are indications such as falling catch per unit effort and higher counts per pound that indicate a new model needs to be applied. The model should be more holistic taking into account not only stock density and size, but also ecosystem dynamics and the socioeconomics of the fishery. The goal is to preserve the resource, the habitats, and the fishery. An Individual Transferable Quota (ITQ) management strategy with a "protected reserves" system appears to have the greatest potential for achieving this goal.

Transition from the current management system to ITQ plan will require time, perhaps five years. During the transitional period, managers, fishers, scientists, and other interested groups will need to work together to develop plans to enhance the resource, the ecosystem, and the business of bay shrimping.

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APPENDIX 1

BAY SHRIMP INDUSTRY SURVEY – PLEASE RETURN TO

Kim Withers, TAMU-CC, Center for Coastal Studies, 6300 Ocean Dr. Corpus Christi, Texas 78412

Bold and bracketed terms indicate fishermen's answers [number answered; percent of total answered] for each question.

1. County of Residence ______________________________
   - **Aransas: 26; 57.8%**
   - **Nueces: 14; 31.1%**
   - **San Patricio: 5; 11.1%**

2. Age _________________________
   - **20-30: 2; 4.44%**
   - **31-40: 12; 26.67%**
   - **41-50: 16; 35.56%**
   - **51-60: 12; 26.67%**
   - **>60: 3; 6.67%**

3. Ethnicity
   a. Anglo **[15; 30.6%]**
   b. Hispanic **[8; 16.3%]**
   c. African American **[0; 0%]**
   d. Asian **[25; 51%]**
   e. Other **[1; 2.04%]**

4. Are you a first generation commercial bay shrimper?
   a. Yes **[28; 57.1%]**
   b. No **[21; 42.9%]**

5. How many years have you been in the bay shrimping business?
   a. 1-5 **[4; 8.16%]**
   b. 5-10 **[4; 8.16%]**
   c. 10-15 **[9; 18.4%]**
   d. 15+ **[32; 65.3%]**

6. Is shrimping your sole source of income?
   a. Yes **[35; 71.4%]**
   b. No **[14; 28.6%]**

If shrimping is not your sole source of income, please answer Question 7, otherwise go on to Question 8.

7. What percentage of your annual income was from shrimping during (circle the appropriate amount)

	<25%	26-50%	51-75%	>75%
1997?	**[6; 54.5%]**	**[1; 9.09%]**	**[3; 27.3%]**	**[1; 9.09%]**
1998?	**[5; 50%]**	**[2; 20%]**	**[2; 20%]**	**[1; 10%]**
1999?	**[6; 60%]**	**[1; 10%]**	**[2; 20%]**	**[1; 10%]**
2000?	**[6; 60%]**	**[2; 20%]**	**[2; 20%]**	**[0; 0%]**

8. Are other members of your family involved in the bay shrimping industry?
    a. Yes **[27; 57.4%]**
    b. No **[20; 42.6%]**

9. Do you consider the bay shrimping industry a career/business opportunity for your children?
    a. Yes **[12; 26.1%]**
    b. No **[34; 73.9%]**

10. How many shrimp boats do you own?
    a. 1 **[39; 79.6%]**
    b. 2-3 **[8; 16.3%]**
    c. 3-5 **[2; 4.08%]**
    d. more than 5 **[0; 0%]**

11. Do you or your family personally operate your boat(s)?
    a. Yes **[42; 87.5%]**
    b. No **[6; 12.5%]**

12. What licenses do you possess?
    a. Bay only **[1; 2.04%]**
    b. Bait only **[0; 0%]**
    c. Offshore only **[0; 0%]**
    d. Bay & Bait **[40; 81.6%]**
    e. All **[8; 16.3%]**

13. What is the average age of the boat(s) you own?
    a. 1-5 years old **[0; 0%]**
    b. 5-10 years old **[14; 28.6%]**
    c. more than 10 years old **[35; 71.4%]**

14. What was the average gross annual income for each bay shrimp boat you owned during

1997?	<$10,000	$10-20,000	$20-30,000	$30-40,000	>$40,000
	[9; 24.3%]	**[13; 35.1%]**	**[9; 24.3%]**	**[3; 8.11%]**	**[3; 8.11%]**
1998?	<$10,000	$10-20,000	$20-30,000	$30-40,000	>$40,000
	[8; 22.2%]	**[15; 41.7%]**	**[9; 25%]**	**[2; 5.56%]**	**[2; 5.56%]**
1999?	<$10,000	$10-20,000	$20-30,000	$30-40,000	>$40,000
	[8; 22.2%]	**[14; 38.9%]**	**[9; 25%]**	**[2; 5.56%]**	**[3; 8.33%]**
2000?	<$10,000	$10-20,000	$20-30,000	$30-40,000	>$40,000
	[9; 23.7%]	**[17; 44.7%]**	**[7; 18.4%]**	**[2; 5.26%]**	**[3; 7.89%]**

15. Approximately how much do you spend on each of the following each year? License, fuel, dock space/fees, boat maintenance, labor, nets, supplies, insurance, interest on bank loans (see table on next page)

Question 15.

License(s)		Fuel		Dock Fees		Boat Maintenance		Labor		Nets		Supplies		Insurance		Interest on Loans	
Amt.	**#**	**Amt.**	**#**	**Amt.**	**#**	**Amt.**	**#**	**Amt.**	**#**	**Amt.**	**#.**	**Amt.**	**#**	**Amt.**	**#.**	**Amt.**	**#**
$295	**1**	$1000	**1**	$0	**3**	$700	**1**	$0	**12**	$500	**1**	$0	**1**	$0	**16**	$0	**20**
$350	**1**	$2000	**1**	$168.50	**1**	$800	**1**	$1000	**1**	$600	**1**	$200	**2**	$565	**1**	$2000	**2**
$400	**1**	$3000	**3**	$250	**1**	$1000	**2**	$4500	**1**	$750	**2**	$500	**1**	$600	**2**	9%	**1**
$405	**1**	$3500	**1**	$600	**1**	$1200	**3**	$4800	**1**	$800	**1**	$1000	**5**	$700	**1**		
$415	**2**	$4000	**3**	$720	**1**	$2000	**5**	$5000	**1**	$1000	**3**	$1500	**2**	$800	**1**		
$580	**1**	$5000	**3**	$800	**2**	$3000	**4**	$7500	**1**	$1400	**1**	$2000	**5**	$3000	**1**		
$600	**4**	$6000	**2**	$840	**1**	$3500	**1**	$12000	**1**	$1500	**3**	$2500	**3**	$4000	**1**		
$605	**8**	$6500	**2**	$900	**2**	$4000	**3**	$30000	**1**	$1600	**1**	$4000	**1**	$5000	**1**		
$620	**1**	$7000	**3**	$924	**1**	$4500	**2**	20% of catch	**1**	$2000	**6**	$5000	**1**				
$625	**1**	$8000	**3**	$1000	**4**	$5000	**3**			$2500	**1**	$5500	**1**				
$635	**1**	$9000	**1**	$1032	**1**	$6500	**2**			$3000	**3**						
$700	**1**	$9500	**1**	$1150	**1**	$10000	**3**			$4000	**1**						
$850	**2**	$10000	**2**	$1200	**4**	$20000	**1**			$5000	**2**						
$855	**1**	$12000	**1**	$1800	**2**					$7000	**1**						
$900	**2**	$15000	**2**	$2400	**1**					$42000	**1**						
$950	**1**	$170/day	**1**	$3000	**1**												
$1000	**3**			$3444	**1**												
$1300	**1**			$3500	**1**												
$2000	**1**			$4000	**2**												
$3000	**2**			$4200	**1**												
				$4800	**2**												

16. Besides yourself and your family, how many people do you employ?
    a. 0 **[24; 51.1%]**
    b. 1-3 **[21; 44.7%]**
    c. 3-7 **[0; 0%]**
    d. 7-10 **[1; 2.13%]**
    e. more than 10 **[1; 2.13%]**

If you employ people other than yourself and your family, please answer Questions 16-18, otherwise go on to Question 19.

17. How many days do you employ people each year?
    a. 1-30 days **[3; 14.3%]**
    b. 31-60 days **[1; 4.76%]**
    c. 61-90 days **[3; 14.3%]**
    d. 91-120 days **[2; 9.52%]**
    e. more than 120 days **[12; 57.1%]**

18. What is the average rate of payment? _______ per (circle one) day week month

Per Day		**Per Week ($)**		**Per Catch (%)**	
Amt.	**No.**	**Amt.**	**No.**	**Amt.**	**No.**
$40	**1**	$175	**1**	15%	**1**
$50	**3**	$350	**1**	20%	**4**
$70	**1**			25%	**1**

19. What is the average annual income for an employee on your bay shrimp boat?
    a. <$5,000 **[8; 40%]**
    b. $5,000-$10,000 **[8; 40%]**
    c. $10,000-$15,000 **[2; 10%]**
    d. $15,000-$20,000 **[2; 10%]**
    e. >$20,000 **[0; 0%]**

20. Have you secured an operational loan in any of the past 5 years?
    a. Yes **[7; 16.3%]**
    b. No **[36; 83.7%]**

    If yes, please circle the appropriate dollar amount for each year

1997	<$10,000 **[5; 83.3%]**	$10,000-20,000 **[1; 16.7%]**	>$20,000 **[0; 0%]**
1998?	<$10,000 **[4; 80%]**	$10,000-20,000 **[1; 20%]**	>$20,000 **[0; 0%]**
1999?	<$10,000 **[3; 75%]**	$10,000-20,000 **[1; 25%]**	>$20,000 **[0; 0%]**
2000?	<$10,000 **[6; 85.7%]**	$10,000-20,000 **[1; 14.3%]**	>$20,000 **[0; 0%]**

21. Have you purchased a bay shrimp boat in the past 5 years?
    a. Yes **[15; 35.7%]**
    b. No **[27; 64.3%]**

If you purchased a bay shrimp boat in the past 5 years AND you borrowed money to buy the boat, please answer Questions 21-25, otherwise go on to Question 26.

22. What was the source of the loan?
    a. Bank **[2; 33.3%]**
    b. State or Federal Program (e.g., Small Business Administration) **[0; 0%]**
    c. Family or Personal **[4; 66.7%]**
    d. Other (please specify) ______________________ **[0; 0%]**

23. Amount of loan

24. Down payment, monthly payment

Loan Amount	**Monthly Payment**	**Down Payment**
$8000		
$10000	$325	$10000
$12000	$4000	
$15000	$500	$1500
$20000		

25. Term of loan
    a. 1-5 years **[5; 83.3%]**
    b. 5-10 years **[1; 16.7%]**
    c. more than 10 years **[0; 0%]**

26. In selling your product, are you independent or do you work on contract for a seafood company?
    a. Independent **[31;83.8%]**
    b. Contract **[6; 16.2%]**

27. If you are independent, what price/pound do you get for each size class (count) you sell (see table on the next page)

6-8 __________ 9-12 __________ 13-15 __________ 16-18 __________

19-21 __________ 22-25 __________ 26-30 __________ 31-35 __________

36-40 __________ 41-50 __________ 51-60 __________ 61-70 __________

71-80 __________ 81-100 __________ 101+ __________

28. If you work on contract, what price do you get for your catch?

Price of Catch	**Number**
$4.00 live; $1.50 dead	**1**
$400/day	**1**
$3.50/lb.	**1**

Question 27.

6-8		9-12		13-15		16-18		19-21		22-25		26-30		31-35		36-40		41-50		51-60		61-70		71-80	
$	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**	**$**	**#**
3.00	**1**	3.00	**1**	2.90	**1**	2.60	**1**	2.50	**2**	1.70	**1**	1.54	**2**	1.25	**1**	1.24	**1**	1.15	**1**	1.10	**1**	1.00	**2**	0.80	**1**
4.00	**1**	3.50	**1**	3.09	**1**	2.90	**1**	2.54	**1**	1.89	**3**	1.59	**2**	1.34	**1**	1.29	**1**	1.19	**1**	1.14	**1**	1.04	**1**	0.85	**1**
5.00	**1**	4.50	**1**	3.30	**1**	3.00	**1**	2.59	**2**	2.20	**1**	1.60	**1**	1.39	**1**	1.30	**1**	1.20	**3**	1.15	**2**	1.10	**1**	0.90	**1**
6.00	**1**	5.00	**1**	3.50	**1**	3.09	**1**	2.65	**1**	2.25	**1**	1.80	**2**	1.55	**1**	1.50	**1**	1.24	**1**	1.20	**1**	1.20	**1**	0.94	**1**
9.00	**1**	8.00	**1**	3.75	**1**	3.10	**1**	2.75	**2**	3.00	**1**	2.00	**1**	1.65	**1**	1.55	**1**	1.25	**1**	1.24	**1**	1.50	**1**	1.00	**1**
				3.80	**1**	3.20	**1**	2.80	**4**	3.50	**1**	3.00	**2**	3.00	**3**	1.85	**1**	1.35	**6**	1.25	**1**	2.00	**2**	1.10	**1**
				4.00	**1**	3.30	**1**	3.00	**1**	3.75	**1**	3.50	**3**	3.25	**1**	2.00	**1**	1.45	**1**	1.30	**1**	2.80	**1**	1.50	**1**
				7.00	**2**	3.40	**1**	4.00	**2**	4.00	**1**					2.50	**1**	1.75	**1**	1.35	**1**	3.00	**1**	2.00	**1**
						3.50	**1**	5.00	**1**							2.80	**1**	2.00	**2**	1.50	**1**				
						4.00	**1**									5.00	**1**	2.80	**1**	2.00	**3**				
						4.50	**2**													2.80	**1**				
						6.00	**1**																		

81-100		101+	
$	**#**	**$**	**#**
0.60	**1**	0.30	**1**
0.65	**1**	0.50	**1**
0.80	**2**	0.60	**1**
0.89	**1**	1.50	**2**
1.00	**2**		
1.15	**1**		
1.50	**1**		
2.00	**1**		

29. In the last five years, have prices
    a. Increased **[6; 14.3%]**
    b. Decreased **[15; 35.7]**
    c. Stayed the same **[21; 50%]**

30. What bay(s) do you usually trawl?

Bay	Number
All	**1**
Aransas	**25**
Corpus Christi	**26**
Laguna Madre	**2**
Nueces	**3**
Palacios	**2**
Port Lavaca	**1**
San Antonio	**5**
Espirtu Santo	**1**

31. In the last five years, has the catch in the bay(s) you usually trawl
    a. Increased **[3; 7.5%]**
    b. Decreased **[27; 67.5%]**
    c. Stayed the same **[10; 25%]**

32. What is the average number of hours spent trawling during each trip you make?
    a. 2 or less **[12; 25.5%]**
    b. 2-5 **[13; 27.7%]**
    c. 5-7 **[16; 34%]**
    d. more than 7 **[6; 12.8%]**

33. What is the average number of trawls per trip?
    a. 1-2 **[15; 33.3%]**
    b. 3-5 **[22; 48.9%]**
    c. 5-7 **[6; 13.3%]**
    d. more than 7 **[2; 4.44%]**

34. How many days a week do you shrimp during shrimping season?
    a. 1-3 **[3; 6.38%]**
    b. 3-5 **[20; 42.6%]**
    c. more than 5 **[24; 51.1%]**

35. How many hours do you spend each week during shrimp season trawling, selling product, doing boat maintenance

36. On average, how many pounds of shrimp do you land annually?

Questions 35 & 36.

Trawling		**Selling Product**		**Boat Maintenance**		**Annual Landings**	
Hours/week	Number	Hours/week	Number	Hours/week	Number	Lbs.	Number
2	**1**	0	**1**	2	**2**	40	1
4	**1**	1	**2**	3	**1**	60	1
6	**2**	3	**1**	4	**2**	100	1
9	**1**	4	**1**	5	**1**	600	1
25	**1**	5	**6**	6	**1**	2000	1
30	**5**	7	**2**	7	**1**	5000	1
35	**3**	8	**2**	10	**10**	6000	2
36	**1**	10	**1**	12	**1**	7500	1
40	**4**	15	**1**	15	**1**	8000	1
42	**2**	18	**1**	20	**2**	10000	3
45	**2**	20	**1**	22	**1**	15000	1
50	**3**	35	**1**	30	**1**	20000	1
65	**1**	40	**2**	40	**1**	25000	1
		50	**1**			36750	1

37. Do you sell other organisms that might be considered bycatch (e.g., squid, croaker)
    a. Yes **[20; 44.4%]**
    b. No **[25; 55.6%]**

If yes, please answer Questions 38 and 39, otherwise go on to Question 39.

38. Which of the following do you sell?
    a. squid **[17; 85%]**
    b. croaker **[13; 65%]**
    c. mullet **[9; 45%]**
    d. other baitfish **[8; 40%]**
    e. crab **[16; 80%]**
    f. other (please specify) ________________________ **[2; 10%]**

39. What percentage of your saleable catch do these organisms make up?
    a. <5% **[13; 61.9%]**
    b. 5-10% **[5; 23.8%]**
    c. >10% **[3; 14.3%]**

40. If you sell directly to the consumer from your boat, are there any fees associated with selling from the boat that must be paid to the city or county where your boat is docked?
    a. Yes **[11; 40.7%]**
    b. No **[16; 59.3%]**

41. Are you interested in Texas Parks and Wildlife Department's license buy back program?
    a. Yes **[16; 41%]**
    b. No **[23; 59%]**

If you answered no, why aren't you interested?

Reason	Number
Already sold unwanted boats	**1**
Can't sell boat	**1**
Doesn't pay enough	**3**
Intend to keep boat & licenses	**2**
No other profession	**4**
Not sufficient money to start new career	**1**
Not ready to quit	**2**
Not worth it	**1**
Shrimping is only income	**2**

42. Do you believe there are too many boats fishing for shrimp in Corpus Christi Bay and surrounding bay systems?
    a. Yes **[25; 58.1%]**
    b. No **[18; 41.9%]**

43. Do you think your interests would be better served and the resource protected if the number of licensed shrimp boats is restricted or do you prefer an open participation policy?
    a. Restricted **[24; 64.9%]**
    b. Open **[13; 35.1%]**

44. Do you think the regulatory process is fair?
    a. Yes **[19; 52.8%]**
    b. No **[17; 47.2%]**

45. How could it be made fairer?

Suggestion	Number
Apply laws equally to everyone.	**1**
There are enough regulations already.	**1**
Get rid of TEDS.	**2**
Get rid of TEDS and 45 minute drags.	**1**
Different hours.	**1**
Leave things as they are.	**1**
Lower license fees; let shrimpers make rules. TPWD does not know laws and should listen to biologists.	**1**
Pay more on buy back program.	**1**
Remove time limit. (Catch limit is enough.)	**2**
Remove law that 50% of shrimp must be alive.	**1**
Samples should be taken by TPWD and commercial fishermen with TPWD personnel on board. Fishermen should be able to look at data as TPWD looks at fishermen's data. Horsepower of vessels in bay should be limited.	**1**
Some areas that are closed should be opened. Areas should be open to everyone or no one, not open to the government only.	**1**

46. Which regulations are the most burdensome to you?

Burdensome regulations	Number
½ live, ½ dead shrimp	**6**
Bycatch	**1**
Hours	**2**
Losing area in the bays	**1**
Net and webbing sizes	**1**
TEDs	**10**
BRDs	**2**
Standing laws not enforced all of a sudden enforced.	**1**

47. Which regulations affect you the least?

Regulations that affect fishermen the least	Number
BRDs	**1**
Hours	**2**
Mesh size	**2**
Net size	**1**
None	**3**
Poundage in spring season	**1**
TEDs	**1**

48. Do you have concerns about the sustainability of the shrimp fishery?
    a. Yes **[19; 54.3%]**
    b. No **[16; 45.7%]**

49. Overall, do you think the shrimp fishery is
    a. Increasing **[2; 5.41%]**
    b. Decreasing **[24; 64.9%]**
    c. Stable **[11; 29.7%]**

50. Do you believe the catch data presented by Texas Parks and Wildlife Department (TPWD) and National Marine Fisheries Service (NMFS) is an accurate representation of the fishery?
    a. Yes **[9; 26.5%]**
    b. No **[25; 73.5%]**

51. Would you be more inclined to trust data used in the regulatory process if it were collected by an organization other than TPWD or NMFS?
    a. Yes **[18; 58.1%]**
    b. No **[15; 45.5%]**

52. Would you be willing to provide information about your effort (time, money, # trawls, location, catch, etc.) on a weekly basis is it would help in the regulatory process?
    a. Yes **[18; 54.5%]**
    b. No **[15; 45.5%]**

53. What is your perception of the public demand for shrimp?
    a. Increasing **[26; 60.5%]**
    b. Decreasing **[7; 16.3%]**
    c. Stable **[10; 23.3%]**

54. Do you think the availability of imported, frozen shrimp affects demand for your product?
    a. Yes **[26; 65%]**
    b. No **[14; 45%]**

55. Do you think the availability of pond-raised shrimp affects or would affect demand for your product?
    a. Yes **[28; 80%]**
    b. No **[7; 20%]**

Please feel free to provide any additional comments you have in the space below or on another sheet of paper. Thank you for your participation.

Additional Comments

No ½ live shrimp for bait.
I would trust data if not controlled by any department and could make recommendations and not be influenced (reference to #51). I think that the frozen shrimp industry may influence regulations to be made against shrimpers (regarding #54).
I didn't like the free trade import prices 4-5 years ago. It went down and I don't like it.
I think the import of frozen shrimp hurts our income because fuel is higher now and parts and supplies are higher. The shrimp prices are lower. For example, in Mexico, shrimp are cheaper so it's been imported for less. We here cannot compete with the Mexicans because our cost of living is higher. The dollar in Mexico is worth a lot. But the dollar in the United States is just a dollar. I hope you understand what I'm trying to say.
Pollution in Corpus Christi Bay is killing the bay system, not shrimpers. Compare the shrimp boat in Matagorda Bay and Corpus Christi Bay. There are more boats in Matagorda Bay and the bay produces more shrimp than Corpus Christi Bay with less boats. Example: CPL cooling system, all surrounding refineries, and freshwater way are close. All this is killing the bay.
I was born and raised in Rockport, Texas. I have worked off and on in the bay and gulf and have seen many changes, most I don't like. I now work totally in the bay catching bait. Over my life span I have put in about 38 years in seafood for I also oyster for a living when shrimping is over with. In shrimping seasons, I think no one should be able to pull bigger than 34' during brownie or no bigger than 65' in big net season.
Please don't change any more regulations on bay shrimpers. And throw out the TEDs because they hurt us.
BRDs are not heavy duty enough for shrimping.