V. WHITE SHRIMP

A strong linear decrease in trawl catches of white shrimp (Penaeus setiferus) from 1982 through 1990 was documented by Osborn et al. (1992), but newly available monitoring results for 1991 showed a rebound to 1983 levels (Figure 2D). The 1991 rebound probably resulted from two events: El Niño conditions during 1990-91 (associated with high freshwater inflows and mild winters), and new regulations that make shrimping illegal during two months in the summer in Texas waters. How much of each these factors contributed to the rebound cannot be determined because they occurred at the same time.

Geographic extent

Figures 7 and 8 show bag seine and trawl catches of white shrimp from all major bays in Texas. The largest catches as well as the strongest decline came from the Galveston Estuary, which is also the area of highest white shrimp abundance in Texas (Figure 7A, 8A). The decline was not unique to the Galveston Estuary nor was it confined to any one part of the system.

White shrimp caught by trawl also declined from 1982 through 1990 in three southern estuaries (Aransas, Corpus Christi, and Laguna Madre; Figures 8D, 8E, 8F). The rebound appeared to be coast-wide; white shrimp abundances for 1990 and/or 1991 appeared higher in both bag seine and trawl catches in most major bays. In the Gulf, however, only Statistical Zone 19 (offshore of San Antonio and Matagorda Bays) showed an analogous increase (Figure 9). Fishery-independent sampling in the Gulf has only been underway since 1986, so the available time series for Gulf data is very short.

It was no surprise that plots of the spatial distribution of CPUE (Osborn et al. 1992, figs. III.40, III.41, III.42, and III.43) show that white shrimp do not occur everywhere homogeneously. The estuary was subdivided spatially into areas of high and low catch rate using an analysis of variance. After two areas were identified, an analysis of deviance was performed in which Area was included as a categorical variable. The results show no differences in the slope or direction of the trends for the two areas (Figure 10). This indicates the 1982-90 decline was not confined to one part of the bay system.

Temporal extent and reliability

Differences in sample site selection and gear (Osborn et al. 1992) make it statistically inappropriate to directly compare the TPWD/NMFS historical data set (Figure 11A) with the CF data set (Figure 11B). By visual inspection white shrimp appeared to reach a maximum in 1980. There are no data for 1981, but juveniles (Figures 12A and 12B) and the spring catch of subadults (Figure 10B) in the CF data set showed a decline after the 1982 El Niño event. The fall catch of subadults (Figure 10C, 11B) declined after 1984.

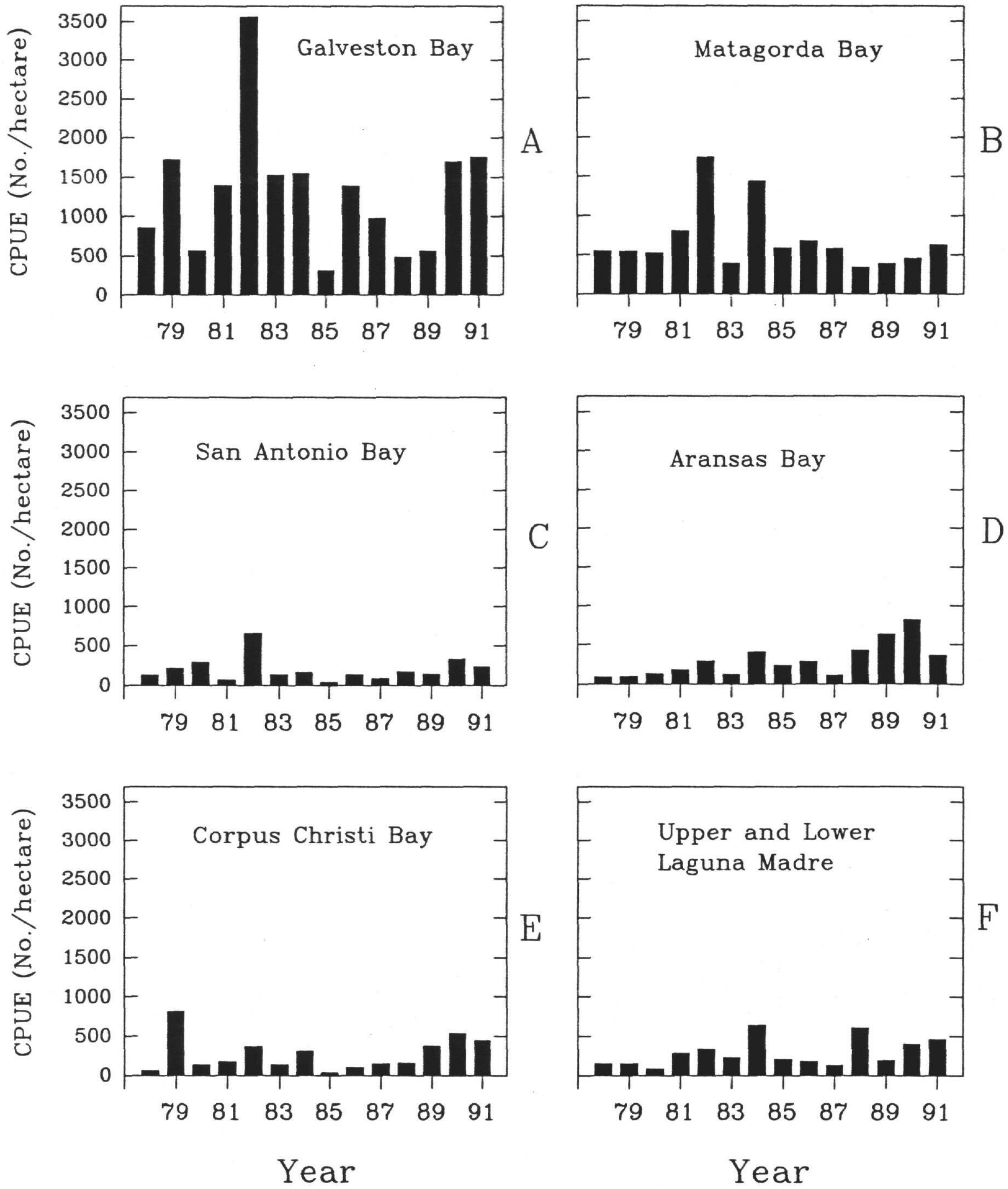

Figure 7. Mean annual CPUE for all sizes of white shrimp caught by bag seine in major estuaries in Texas. Data from Dailey et al. (1991) and McEachron (pers. comm.)

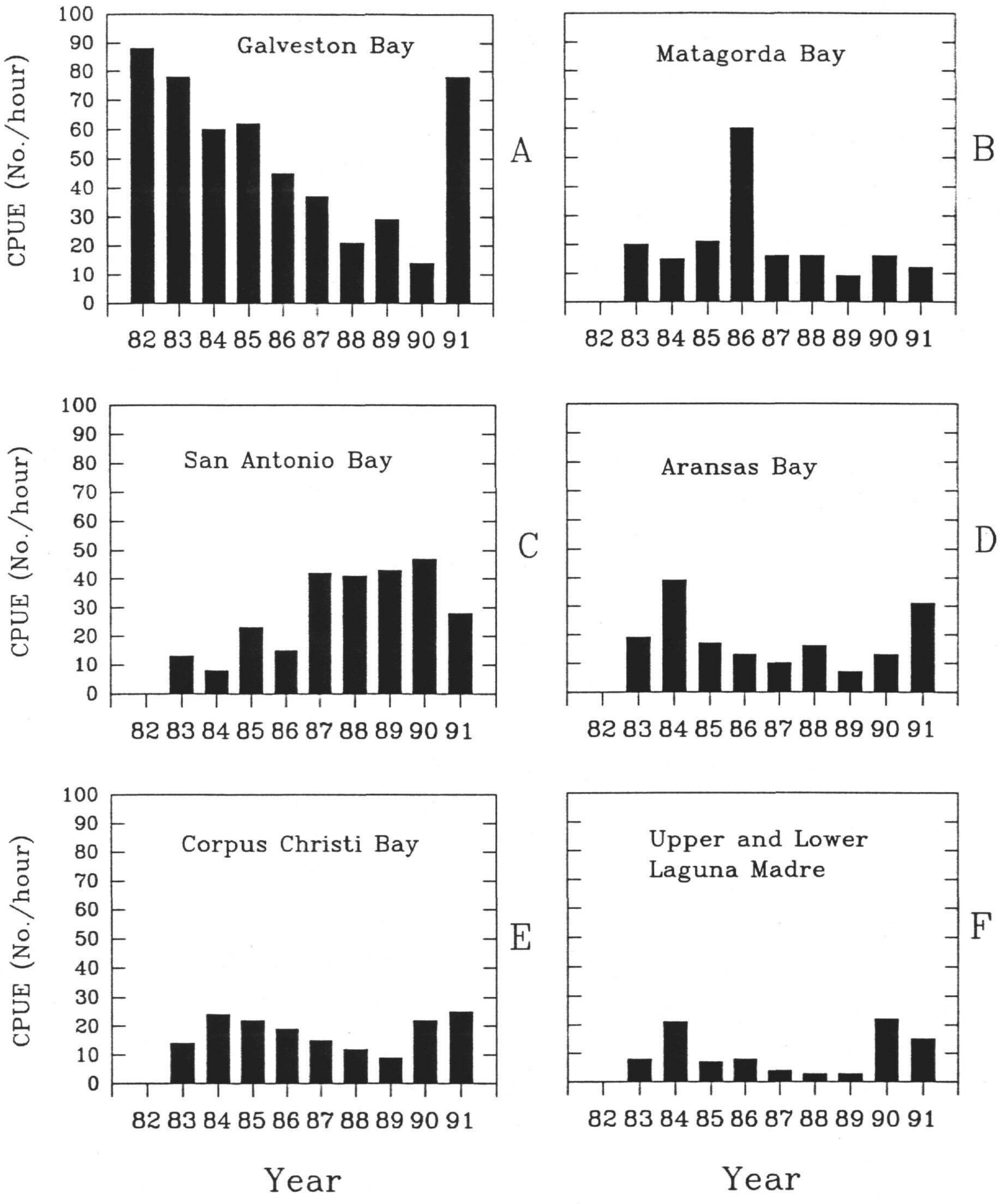

Figure 8. Mean annual CPUE for all sizes of white shrimp caught by trawl in major bays in Texas. Data from Dailey et al. (1991) and McEachron (pers. comm.).

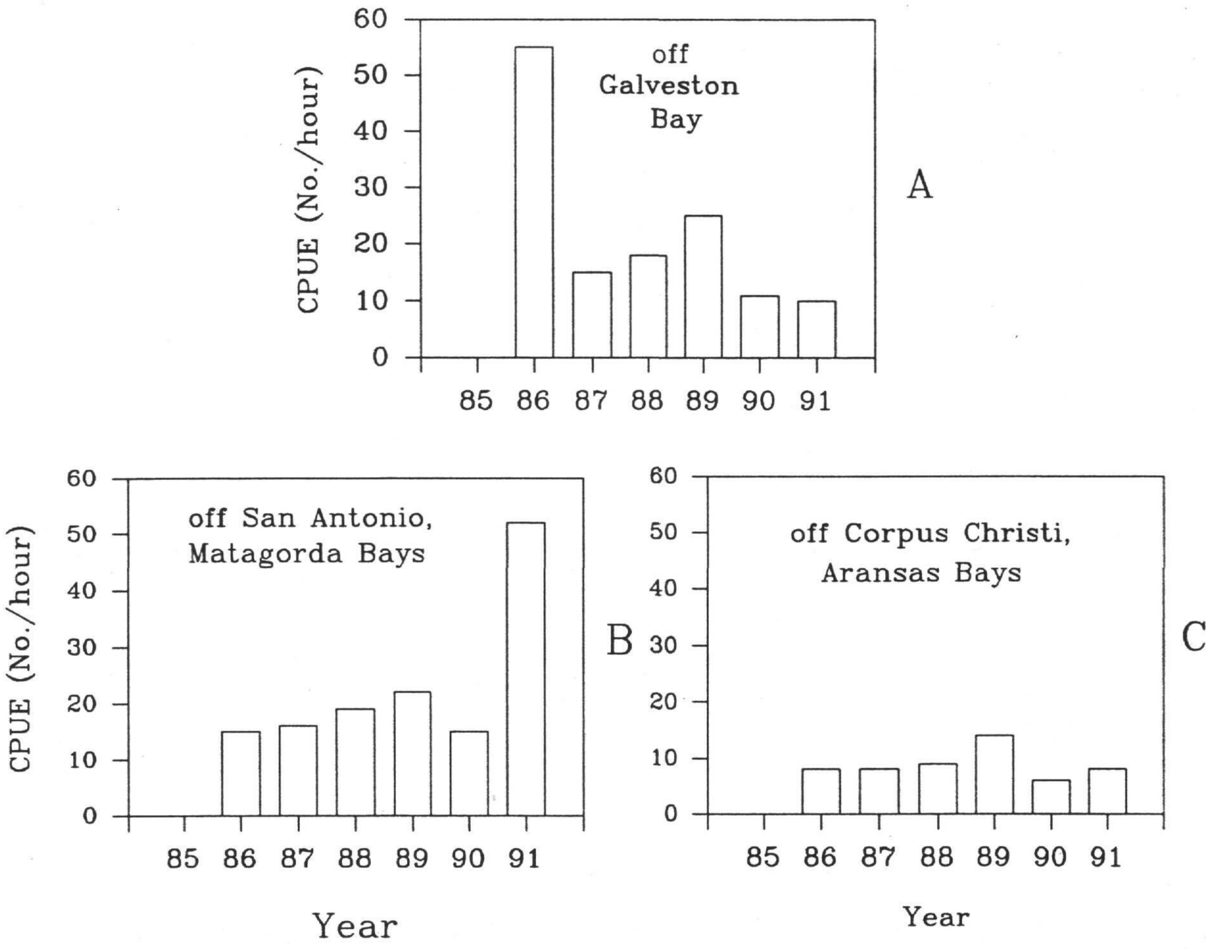

Figure 9. Mean annual CPUE for all sizes of white shrimp caught by trawl in the Gulf of Mexico. A. Statistical Zone 18. B. Statistical Zone 19. C. Statistical Zone 20. Data from Dailey et al. (1991) and McEachron (pers. comm.).

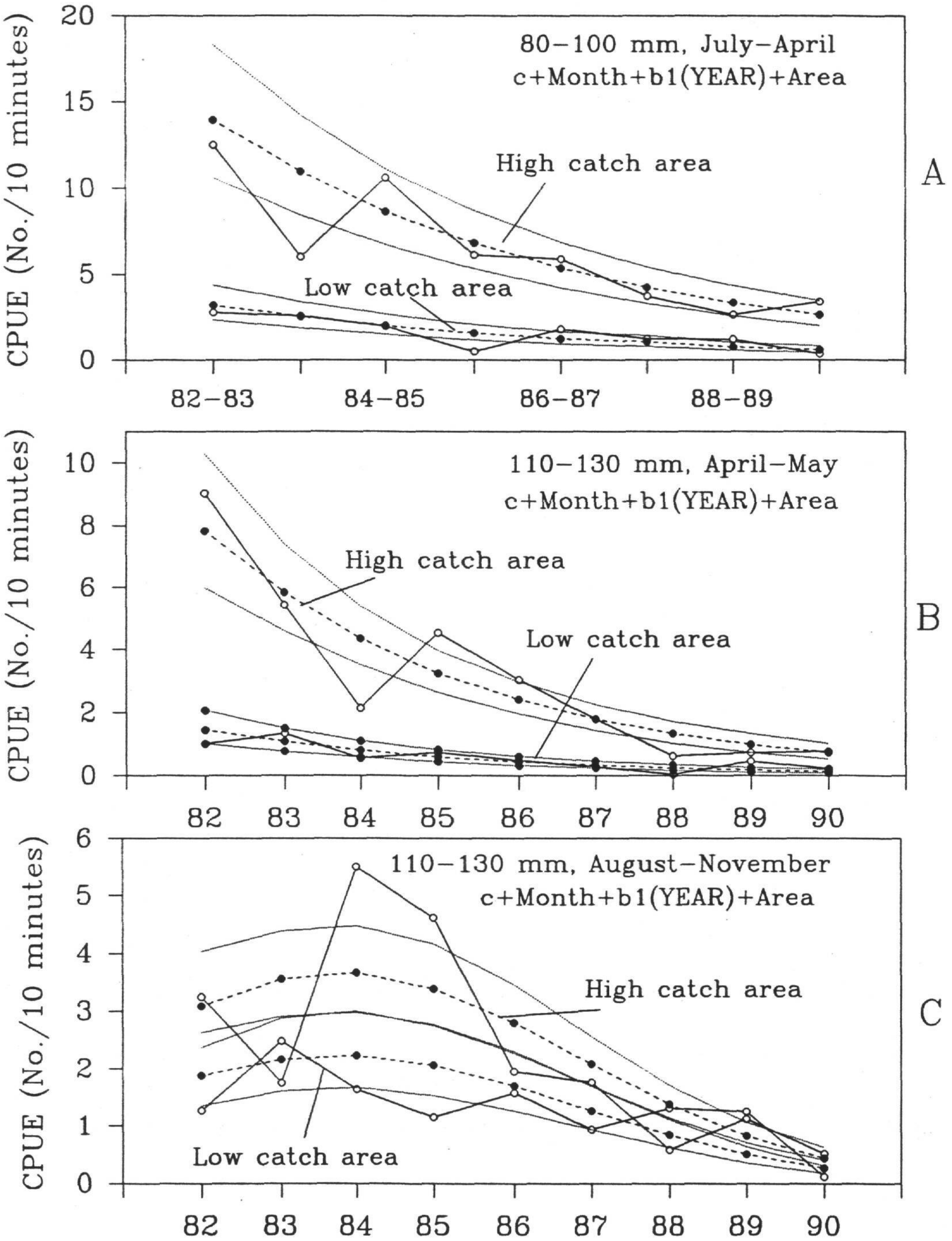

Figure 10. Mean annual CPUE with fitted values and confidence intervals (±S.E.) for white shrimp caught by trawl in areas of high– and low–catch density. Area included in analysis of deviance as categorical variable. A. Juveniles, 80–100 mm, July–April. B. First–time spawners, 110–130 mm, spring C. First–time spawners, 110–130 mm, fall.

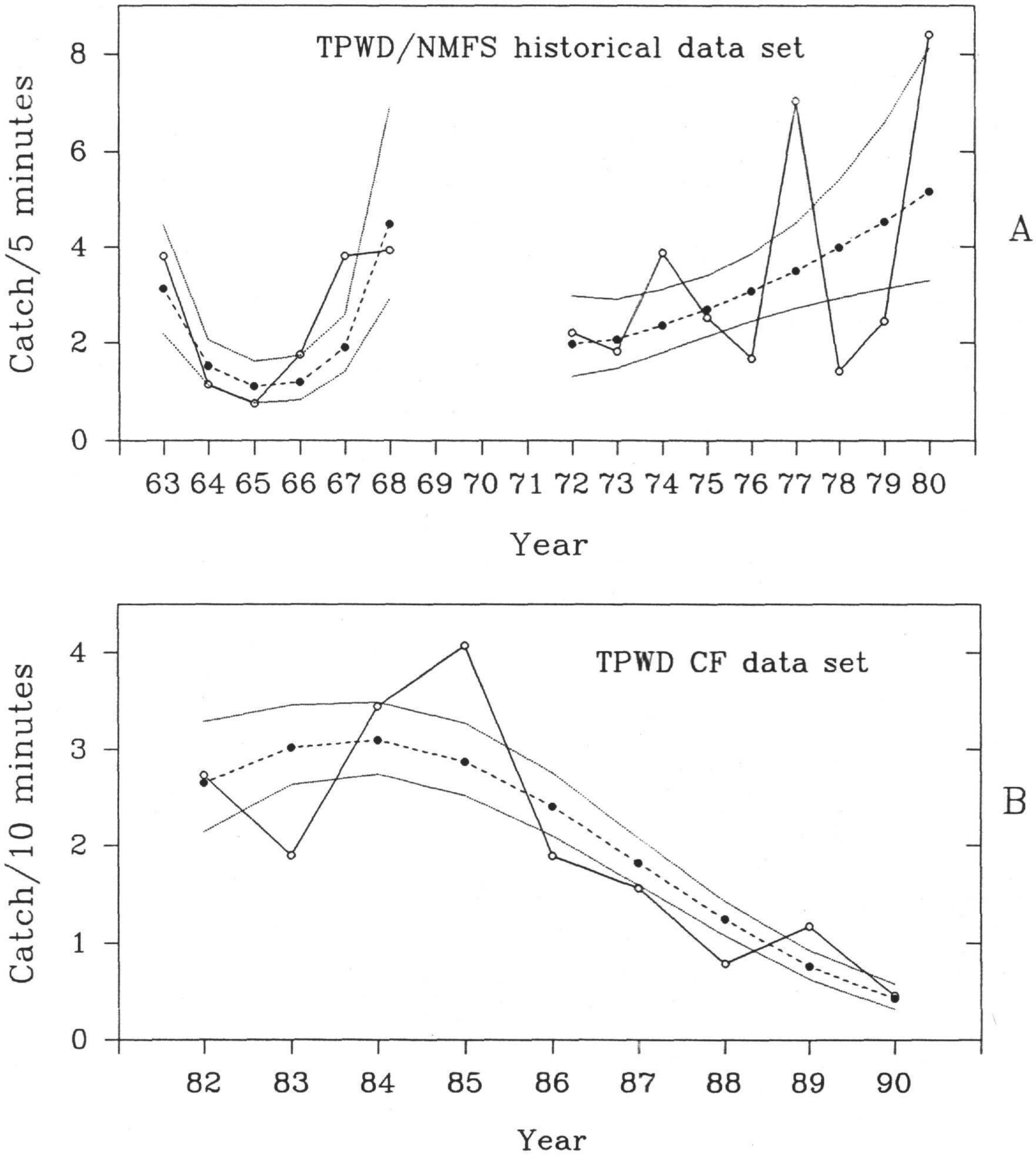

Figure 11. Mean annual CPUE with fitted values and confidence intervals (±S.E.) for white shrimp, 110–130 mm TL, August–November. A. 1963–1968 and 1972–1980, TPWD/NMFS data set. B. 1982–1990, CF data set.

Bag seine data for young of the year showed no trend, while all size ranges caught by trawl showed declines until 1991. However, when bag seine data are confined to the years 1982-1990, the same years analyzed for trawl, the results show a nonlinear decline (Figure 12A). This suggests that trawl data and bag seine data are not as different as they appear. Trawl samples, however, are less constrained geographically and taken more frequently than bag seine samples.

The 1991 rebound and the recognition that white shrimp catches correlate with the Southern Oscillation Index (discussed in Chapter III), suggested that the declining trend in the trawl data was probably part of a larger, cyclical pattern, related to climatic cycles. However, the data may also indicate a real decline superimposed on natural population cycles. One reason not to dismiss the 1982-1990 decline is the possibility that it may indicate a problem with overfishing. Caillouet et al. (1980) observed a Gulf-wide decline in the size of white shrimp from 1959-1976, that continued through 1986 (Cody et al. 1989, Nance et al. 1989). The decline in size is suggestive of growth overfishing.

Harvest and regulation

Shrimpers are highly mobile and efficient. Shrimp boats have become larger and faster in recent years and selective pressure on shrimp is intense. The harvest of white shrimp takes place throughout the year within the estuary (most intensely during April-May and July-December), and until recently, within the nearshore Gulf of Mexico waters along the Texas Coast. This "inshore fishery" was often more intense than fishing offshore.

Until 1989, shallow Gulf waters (0-4 fathoms; 0-7.7 m) were open to trawling throughout the year, saltmarsh nursery areas were open to some bait shrimping, and bay waters could be trawled 24 hours a day. With the adoption of the 1989 Shrimp Management Plan (Cody et al. 1989), regulations designed to protect brown shrimp were changed to extend protection to white shrimp. Shrimping in jurisdictional nursery areas was banned in 1979, with the exception of those shrimpers who were "grandfathered". In 1989 the "grandfather" clause expired and nursery areas became completely closed to shrimping. In 1990, night fishing was banned in the bay during the spring season. In 1990 and 1991, the 0-4 fathom zone of the Gulf was included in the rest of the Texas closure and, for the first time, all shrimping in the Gulf off Texas was banned for two months during the summer. The rebound in white shrimp CPUE in 1990 and/or 1991 may be partially a result of these regulatory changes.

According to data provided by the National Marine Fisheries Service, the number of pounds of white shrimp harvested from Galveston Bay remained fairly steady during the 1970s and 1980s (Figure 13A), though the number of pounds per trip declined during the same time (Figure 13B). The CPUE decreased because effort increased while total harvest remained relatively constant. Reduced landings in 1989, 1990, and 1991 (affected by the regulatory changes discussed above) correspond to a small rebound in CPUE during 1990-1991. Mean size of the shrimp landed also increased. Landings (total pounds) of white shrimp from offshore Gulf waters for Texas as a whole decreased after 1984 but rebounded slightly in 1990 and 1991 (Figure 13C, filled circles).

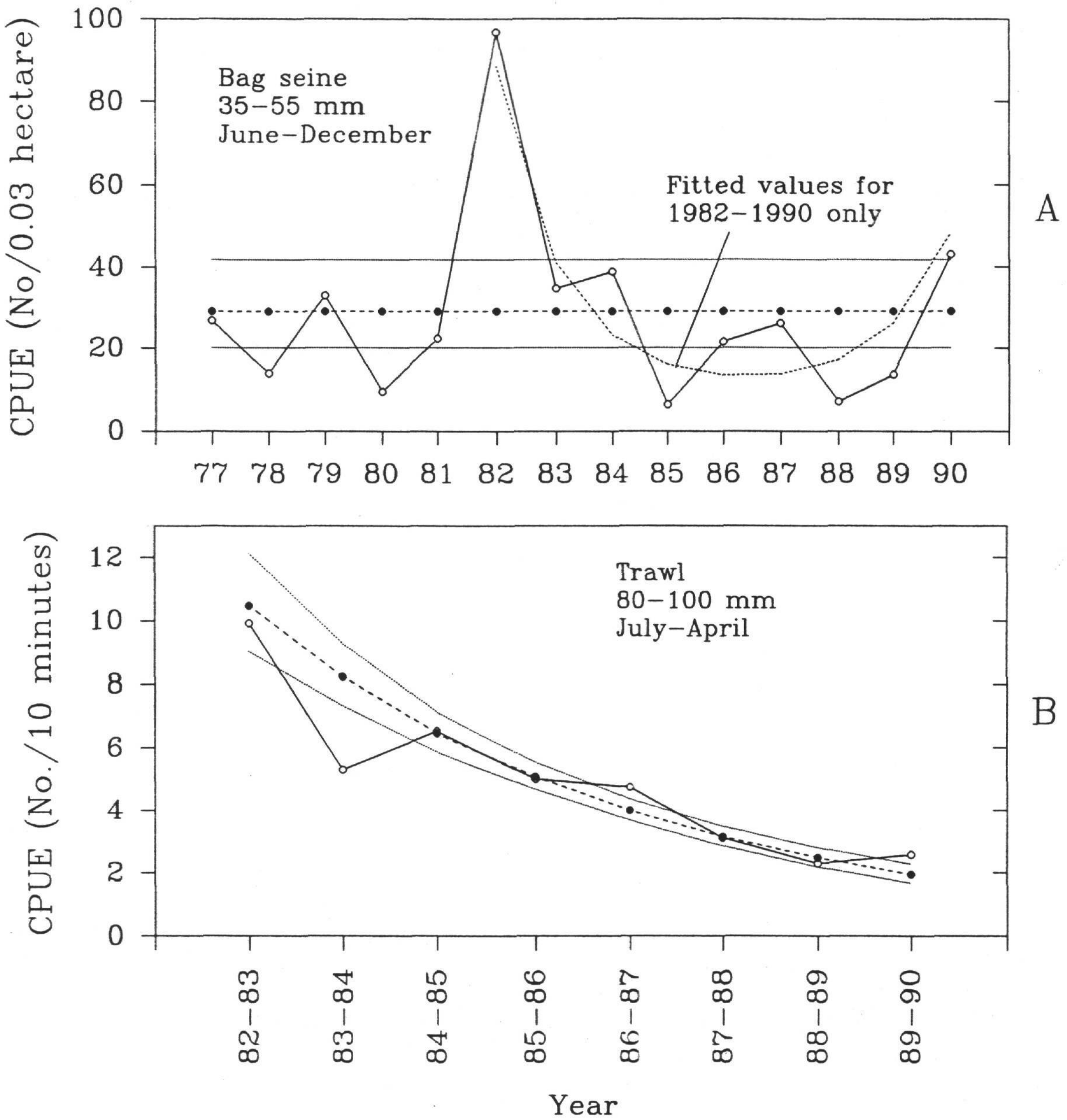

Figure 12. Mean annual CPUE with fitted values and confidence intervals (±S.E.) for juvenile white shrimp. A. Young of the year caught by bag seine, 35–55 mm TL, June–December. Fitted values shown for 1977–90 and 1982–90. B. Juveniles caught by trawl, 80–100 mm TL, July–April, 1982–1990.

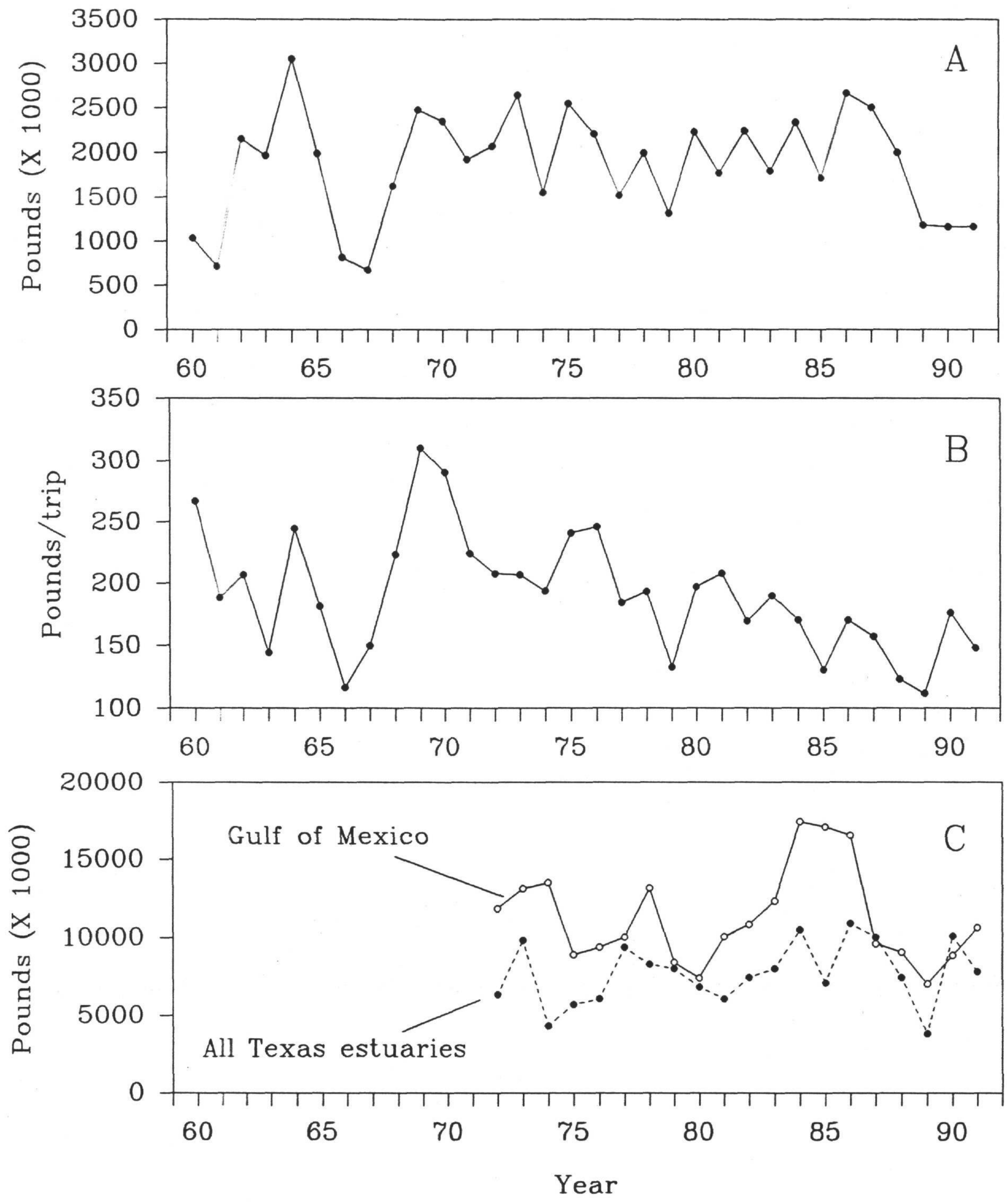

Figure 13. A. Annual commercial landings of white shrimp from the Galveston Estuary. B. Mean annual commercial CPUE (pounds per trip) of white shrimp from the Galveston Estuary. Data from National Marine Fisheries Service. C. Total annual white shrimp landings from Texas estuaries and Gulf of Mexico. Data from Campbell et al. 1992.

Probable causes of 1983-1990 decline

Obvious (but not all) candidates for the cause of the 1983-1990 decline are listed here in order of confidence and probability.

1) **Natural cycles** related to interannual variation in climate. As described in Chapter III, bag seine catches of white shrimp are correlated with El Niño-Southern Oscillation cycles, though the exact effect of large-scale climatic patterns on juvenile shrimp is unclear. The pattern for subadults caught by trawl (Figure 2D) is compatible with a peak during the severe El Niño of 1982-83, no response to the mild El Niño of 1986-87, a possible negative response to the La Niña of 1988-89, and another peak with the development of a moderate El Niño in 1991.

Spring trawl catches of large white shrimp (spawned during fall of the previous year) correlate with SOI on the 93 percent confidence level. This result is not statistically significant by most standards ($p < 0.10$), and suspect because of the short time series. Nevertheless it suggests that the same environmental factors that favor juvenile white shrimp during an El Niño year also favor adults in mid-bay habitats.

2) **Overfishing**. This is an obvious probable cause of declining shrimp populations, given the intensity of the shrimp harvest (Figure 13) and the vulnerability of white shrimp in the nearshore Gulf. In addition, mariculturists have observed that relatively minor disturbances can interrupt white shrimp spawning or even cause gravid females to abort (Lawrence, pers. comm.). The harm caused by shrimping in the spawning area may not be restricted to those shrimp that are actually caught.

Changes in shrimping regulations, specifically the complete closure of Texas bays and the near-shore Gulf to shrimping for two months during the time of most intense white shrimp spawning (effective 1990), correlate with the 1991 rebound in white shrimp. However the effects of regulation cannot be separated from those of El Niño with the available data sets.

3) **Variation in freshwater inflow**. This is separated with difficulty from the El Niño-climate explanation. The relationship between inflows and large-scale climate cycles exists, though it is ambiguous. White shrimp abundances did not decline in step with freshwater inflows. However, high inflows are sometimes correlated with population peaks in white or brown shrimp during the following year (Gunter and Hildebrand 1954, Gunter and Edwards 1969). The influx of nutrients during wet years probably cause high productivity of diatoms, an important part of the white shrimp diet (McTigue and Zimmerman 1991). The heavy rains of 1990-1991 may also have affected shrimp populations by flushing contaminants from the estuary, causing low salinities that repel predators, or facilitating larval recruitment to marsh habitat (Chapter IV).

From 1980 through 1989, inflows averaged 442,000-822,000 acre-feet/month. During 1979 and 1990, in contrast, inflows averaged in excess of 1,000,000 acre-feet/month (Figure 3C). The apparent peak in the fall catch of large shrimp in 1980 (Figure 11A) and the 1991 rebound (Figure 2D) follow years of unusually high average inflows. A gradual decline in shrimp numbers may be a consequence of the relatively moderate inflows that prevailed between 1980 and 1989 and reduced cycling of the nutrients brought in during floods. After the construction of the Aswan Dam in 1965 eliminated Nile flooding, nutrient levels in the Delta region dropped, phytoplankton blooms declined, and shrimp populations in the southeastern Mediterranean also declined gradually (Aleem 1972, Wadie and Abdel Razek 1985). Excessive moderation of flow into Galveston Bay may have a similar effect.

4) **Interactions with other organisms**: disease, parasitism, competition, and non-human predation. There are few data available on shrimp morbidity. Brown shrimp (Penaeus aztecus), a possible competitor with white shrimp during at least part of the year, showed no significant trends during the same time periods (Figures 1D, 2H). It is unclear what other species are potential competitors because white shrimp occur in large numbers in the estuary at a season (late summer-winter) when other species are not highly abundant (Figure 5).

The success of restoration efforts for spotted seatrout and red drum raises the possibility that shrimp population trends are affected by trends in their predators. White shrimp are an important prey species (Muncy 1984). Potential predators on white shrimp include: Atlantic croaker (Figures 1C, 2A, 14A), southern flounder (Figures 1V, 14D), pinfish (Figures 1K, 14B), spot (Figures 1G, 2E), Gulf killifish (Figure 1M), spotted seatrout (Figures 1T, 14G, 14H) , and red drum (Figures 1R, 14E, 14F; Matlock and Garcia 1983, Minello, Zimmerman, and Czapla 1989, Minello, Zimmerman and Martinez 1989). Pinfish and spot both showed increases in adult populations while southern flounder showed no trend. Atlantic croaker, black drum, red drum, and spotted seatrout, the four species of Sciaenidae analyzed by Osborn et al. (1992), all showed increases in adult populations. Predation on white shrimp probably increased during the 1980s. How this natural predation compared to freshwater inflow, harvest by humans, or other factors is unknown.

5) **Water and sediment quality**. White shrimp are affected by pollution and have been affected in the Galveston Estuary in the past (Gordon et al. 1972). Water quality has improved in terms of dissolved oxygen and nutrient loading, but heavy metals and other sediment contaminants remain a problem locally (Chapter IV). A widespread pollution problem would be expected to affect other shrimp species as well, especially infaunal brown shrimp. Neither brown shrimp nor grass shrimp, however, show signs of decline (Figures 1D, 1 I, and 2H). The data do not indicate pollution was responsible for the decline in white shrimp (though the flushing and dilution effects of recent high inflows certainly have not been detrimental).

6) **Loss of habitat**. White et al. (1993) estimated a net loss of 19 percent of the Galveston Bay area's vegetated wetlands (32,400 acres) between the 1950s and 1989, of which the greatest proportion was probably intertidal marsh. Marsh and seagrass beds are prime nursery areas for juvenile white shrimp. However, lab experiments (Minello and Zimmerman 1985, Minello et al. 1990) show that white shrimp are not as strongly selective for vegetation as are brown shrimp, which do not show a decline. Drop

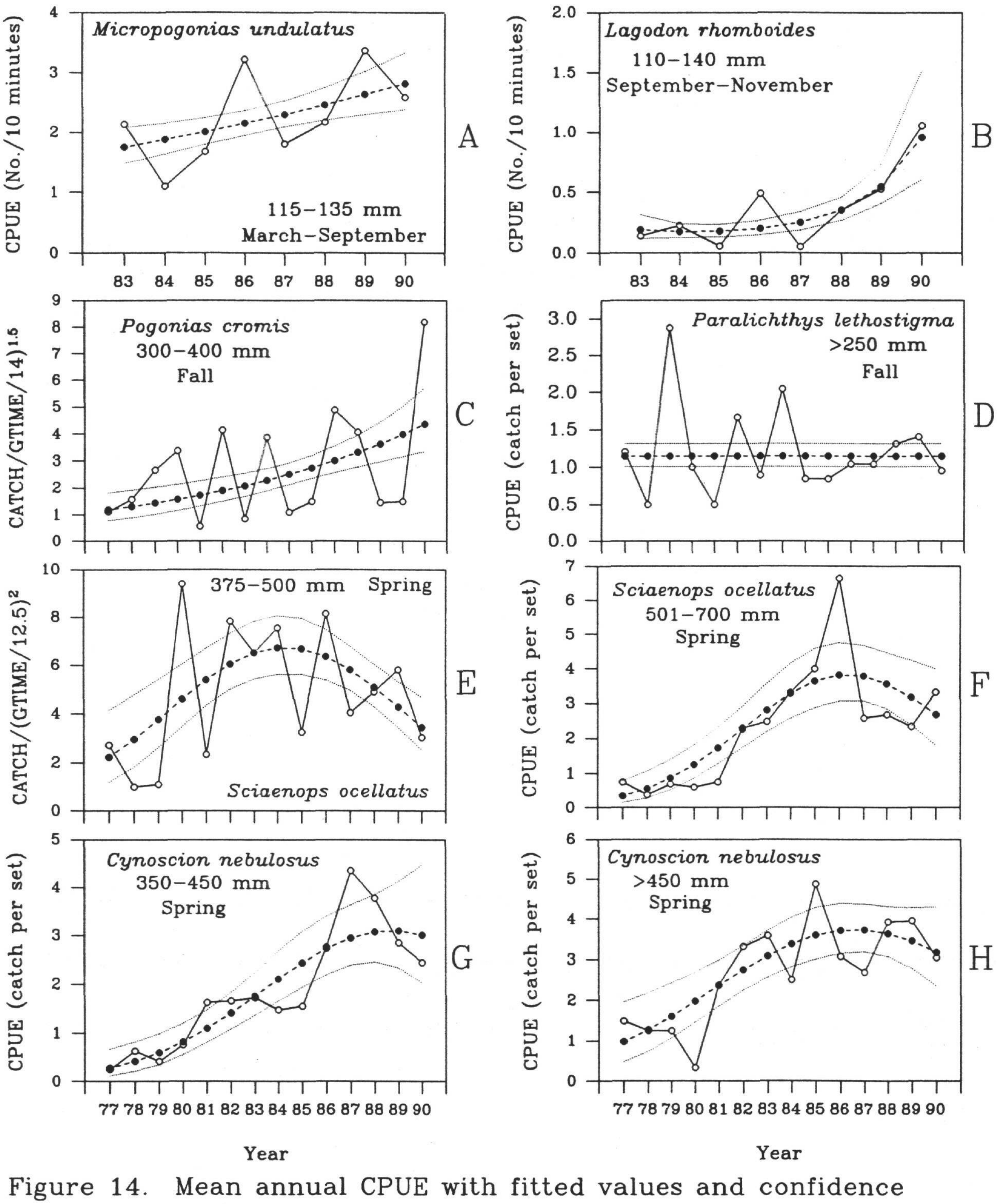

Figure 14. Mean annual CPUE with fitted values and confidence intervals (±S.E.) for large size classes of 6 predatory fish species caught by trawl (A, B) and gill net (C–H). CPUE as defined in Osborn et al. (1992). A. Atlantic croaker. B. Pinfish. C. Black drum. D. Southern flounder. E, F. Red drum. G, H. Spotted seatrout.

samples in the field show white shrimp are common on bare substrate and less dense in marsh vegetation than other crustaceans (Zimmerman and Minello 1984). White shrimp nursery habitat is also crucial to other species, such as Atlantic croaker (Parker 1970, 1971), that do not show a decline (Figures 1D, 2B). Consequently wetland loss alone is probably not responsible for trends in white shrimp abundance. However, disturbance of spawning grounds in the Gulf (discussed above) is a form of habitat loss and may have been a contributing factor to the decline.

7) **Change in forage base**. Shifts in the food chain, such as a decline in the benthic marine worms or algae (especially diatoms) important to white shrimp survival and growth (McTigue and Zimmerman 1991), would be expected to affect other species as well. Unfortunately, the data to evaluate long-term changes in the biomass or composition of the benthos are not available.

Conclusions

It is important to distinguish natural climatically-influenced population cycles from the possible effects of overfishing. If ENSO is the predominating influence, a predicted switch to La Niña conditions during the latter half of 1993 (Keppenne and Ghil 1992) will result in low shrimp catches during 1993-94. If high inflows alone resulted in high catches of white shrimp, the resumption of normal inflows or drought conditions will result in declining shrimp catches until the next period of flooding. In either case, declines in dry years and increases after wet years are normal processes. If changes in fishing regulations are responsible for the high 1991 CPUE, then the rebound should be coastwide and long term.

A continued decline in white shrimp would be directly detrimental to a major commercial fishery. Other commercial and recreational fisheries would be indirectly affected in that a major food source would be removed for southern flounder, spotted seatrout, sand seatrout, and red drum.

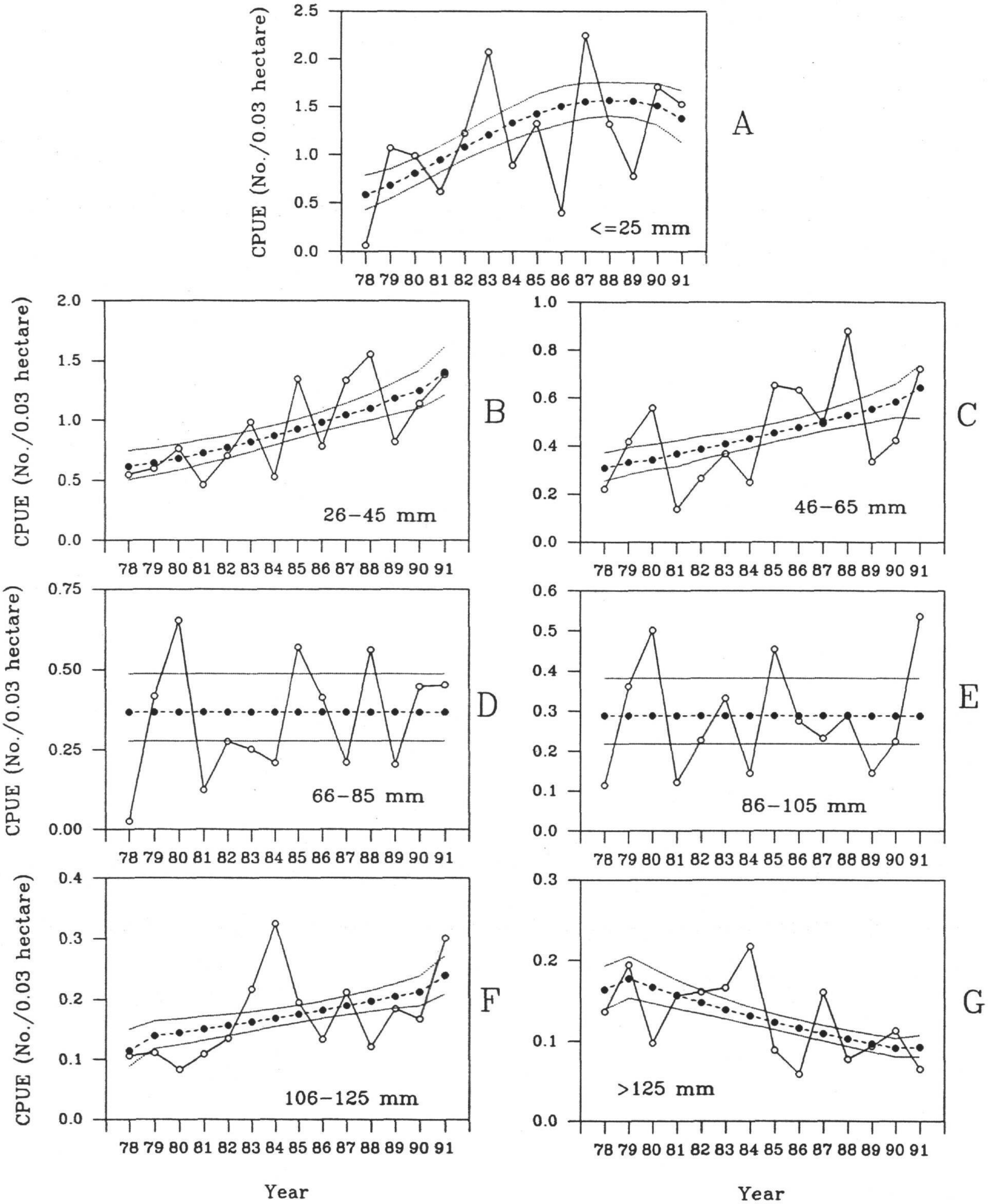

Figure 15. Mean annual CPUE with fitted values and confidence intervals (±S.E.) for seven size classes of blue crab caught by bag seine.