Status and Trends of Selected Marine Fauna In the Corpus Christi Bay National Estuary Program Study Area

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EXECUTIVE SUMMARY

The Resource Protection (RP) Division of the Texas Parks and Wildlife Department (TPWD) evaluated status and trends of Aransas Bay, Corpus Christi Bay, and Upper Laguna Madre populations of red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), black drum (*Pogonias cromis*), Atlantic croaker (*Micropogonias undulatus*), Southern flounder (*Paralichthys lethostigma*), Gulf menhaden (*Brevoortia patronus*), white shrimp (*Penaeus setiferus*) brown shrimp (*P. aztecus*), pink shrimp (*P. duorarum*), and blue crab (*Callinectes sapidus*). Relative abundance was analyzed using catch per unit of effort (CPUE) data from otter trawl samples collected from 1982-1993, and bag seine and gill net samples collected from 1976-1993. CPUE data conformed generally to one of four statistical distributions: 1) *Poisson*; 2) overdispersed *Poisson*; 3) negative binomial, or; 4) overdispersed negative binomial. These probability distributions typify data sets wherein many sampling efforts yield CPUE of zero, while occassionally other samples have a very high CPUE. This situation is common in sampling of estuarine nektonic communities. CPUE in relation to gill net set time was analyzed to determine if CPUE increases or decreases with set time. Annual estimates of CPUE were statistically tested for fit to linear or curvilinear growth or decline. To depict relative abundance in relation to spatial distribution, maps were created which show areas of high, medium, low, and lowest catch.

Finfish

In all three bays, modelled gill net CPUE of subadult red drum (545-749 mm TL) increased during the study. In Corpus Christi and Aransas Bays the increasing trend was linear, whereas in Upper Laguna Madre, the model curved upward after 1982. By contrast, no trend was detected in modelled CPUE of young-of-the-year ([YOY] 20-39 mm TL) red drum in Corpus Christi and Aransas Bays. The best fit model for red drum bag seine CPUE in Upper Laguna Madre exhibited upward curvature after 1985. Red drum populations in the CCBNEP were low during 1983-1986. This finding was expected because of overfishing in the early 1980s, a severe freeze in Texas in 1983, and a red tide in 1986. Probable causes for the resurgence of red drum populations after the 1983-1986 bottleneck include changes in size and bag limits, the restocking program, and stricter management measures.

Modelled bag seine and gill net catches of spotted seatrout within Upper Laguna Madre exhibited upward curvature, with model minima occurring one year apart (1986 for bag seine and 1987 for gill net). In Upper Laguna Madre, the poorest gill net CPUE of reproductively mature (300-449 mm TL) spotted seatrout occurred in 1984, probably as an after-effect of the 1983 freeze. Bag seine CPUE of YOY (60-79 mm TL) in Corpus Christi Bay exhibited no trend, but modelled gill net CPUE increased linearly. In Aransas Bay, modelled bag seine and gill net CPUE exhibited no linear or curvilinear trends. Spotted seatrout in Upper Laguna Madre were apparently not affected by brown tide and actual CPUE increased noticeably as of 1993. Based on these results, yields of spotted seatrout in Aransas Bay are not improving as vigorously as they are in Corpus Christi Bay and Upper Laguna Madre.

In Corpus Christi and Aransas Bays, modelled gill net CPUE of black drum curved upward after 1985. In Upper Laguna Madre, the upward curve of the model began one year earlier. Although the same size range of black drum (375-449 mm TL) was analyzed in all three bays, fish of this size in the Upper Laguna Madre are thought to be reproductively active, whereas Corpus Christi and Aransas Bay fish of this size are still considered subadults by TPWD researchers. This apparent difference in size at reproduction itself suggests that black drum inhabiting Upper Laguna Madre represent a unique fishery with distinctive population dynamics. In the CCBNEP, declines in actual catch centered around 1984 and 1985 were probably due to high mortality of cohorts of young black drum during the 1983 freeze. Actual black drum gill net CPUE in Corpus Christi Bay was phenomenal commencing in 1991. Clearly, yields of subadult black drum in Corpus Christi and Aransas Bays and of reproductively mature fish in Upper Laguna Madre were on the upswing during the latter years of the survey. Based on data through 1993, incurrence of the brown tide did not have an adverse effect on adult black drum within Upper Laguna Madre.

No trends were detected for YOY (60-79 mm TL) Atlantic croaker caught by bag seine within the CCBNEP, but they were caught in relatively large numbers in 1984 in Corpus Christi and Aransas Bays. In all three bays, YOY Atlantic croaker were caught infrequently in 1986 and 1987, possibly as a result of high mortality during the red tide. In Upper Laguna Madre, very few YOY Atlantic croaker were caught until 1992. Although actual bag seine CPUE generally increased from 1989 to 1992 in Aransas Bay, the increase was not sufficient to give the model a statistically positive slope. Declines in bag seine yields were evident in all three bays in 1993. No trends were detected in Corpus Christi Bay and Aransas Bay gill net CPUE of reproductively mature Atlantic croaker (225-299 mm TL). Modelled gill net CPUE within Upper Laguna Madre curved downward after a maximum in 1981. With regard to the relative timing of high CPUE in both bag seine and gill net collections, Corpus Christi Bay and Aransas Bay were more similar to each other than either one was to Upper Laguna Madre. Thus, of the four sciaenids (members of the drum family) examined in the CCBNEP, the Atlantic croaker shows the least improvement in population dynamics.

Modelled bag seine CPUE of YOY (20-39 mm TL) Southern flounder in Corpus Christi Bay curved downward after 1989, even though actual maximum CPUE was recorded in 1990. No significant trend was detected in gill net CPUE of reproductively mature (300-375 mm TL) Southern flounder in Corpus Christi Bay. Yields by both gear types were poor in Corpus Christi Bay during 1986-1989. Bag seine yield in Corpus Christi Bay was very poor during 1978-1984 and many more YOY Southern flounder were caught during the latter half of the survey period (1985-1993). Modelled bag seine CPUE of Southern flounder in Aransas Bay also exhibited downward curvature after 1985, whereas no significant trend was detected in gill net CPUE. Poor actual yields of both size classes of Southern flounder were recorded during 1983-1988, and in earlier years of the study period (1978-1981 for bag seine and 1979-1980 for gill net) in Aransas Bay. In Upper Laguna Madre, actual yield of reproductive Southern flounder decreased sharply after 1985. Furthermore, gill net yields in Upper Laguna Madre during 1987-1989 were poorest on-record during the survey. These data resulted in a gill net model for Upper Laguna Madre with downward curvature after 1983. Bag seine yields in Upper Laguna Madre were also extremely poor during 1987-1989, leading to a linear model with negative slope.

Modelled bag seine, trawl, and gill net CPUE of Gulf menhaden within Upper Laguna Madre exhibited decreasing linear trends. In Aransas Bay, Gulf menhaden bag seine, trawl, and gill net

CPUE decreased: for modelled bag seine and trawl catches, the decrease was linear, whereas gill net catch curved downward after 1984. Models for bag seine, trawl, and gill net catch in Corpus Christi Bay also exhibited downward curving trends with interpolated maxima in 1984, 1988, and 1982, respectively. In Aransas Bay, all three gears yielded low numbers of Gulf menhaden in 1986 and yields decreased further until 1989. Very few YOY Gulf menhaden were caught by bag seine and trawl during 1985-1988 in Corpus Christi Bay. This suggests high mortality during the 1986 red tide. In general, substantially more reproductive-sized Gulf menhaden were caught within the CCBNEP during 1979-1987 versus 1987-1993. Thus, in all three bays there was evidence that Gulf menhaden representing three life stages were caught in generally decreasing numbers during the survey.

Macroinvertebrates

In Upper Laguna Madre, bag seine CPUE of juvenile white shrimp (40-59 mm TL) and trawl CPUE of emigratory-sized (100-124 mm TL) shrimp increased linearly, despite minimal actual bag seine and trawl CPUE values recorded during 1985-1987. The best-fit model for bag seine in Aransas Bay curved downward after 1988. This contrasted with the trawl model for Aransas Bay, which curved upward after 1988. In Corpus Christi Bay, there was no trend in trawl catch, but the model for bag seine catch curved upward slightly after 1988. Of the three bays, Upper Laguna Madre has generally yielded the least white shrimp. This was the expected result because of high salinity in Upper Laguna Madre compared to other Texas estuaries. However, white shrimp yield of both size classes increased linearly by almost two-fold during the study in Upper Laguna Madre.

Whereas bag seine CPUE of juvenile brown shrimp increased curvilinearly after 1986, trawl catch of emigratory-sized brown shrimp decreased gradually after the same year. This was a curious result similar to that found in the case of white shrimp caught in Aransas Bay. Opposing trends were also seen in Upper Laguna Madre, where bag seine yield of juvenile brown shrimp (40-59 mm TL) curved downward after 1988, whereas trawl catch curved upward after 1987. Bag seine CPUE of brown shrimp in Upper Laguna Madre was routinely poor and reached lowest levels in 1981, 1983, and 1990. The characteristic feature of bag seine data for Upper Laguna Madre was the sole peak in catch clearly evident in 1987: such a well-defined peak in bag seine actual catch was not evident in the other two bays. Actual trawl CPUE of brown shrimp in Upper Laguna Madre was obviously much greater after the incurrence of brown tide in late spring/early summer of 1990. In Aransas Bay, the model derived for bag seine catch was linear with a decreasing slope, whereas the model derived for trawl catch of emigratory-sized shrimp (100-124 mm TL) was curvilinear with an estimated maximum in 1989; there was also a major peak in actual catch by trawl in 1991.

Upper Laguna Madre exhibited the most improvement in CPUE of YOY (40-59 mm TL) and emigratory-sized (100-124 mm TL) pink shrimp. Bag seine CPUE in Upper Laguna Madre was negligible during 1978-1983, but sporadic small peaks in actual catch were detected in 1987, 1989, and 1991; improved yields in these latter years influenced the positive linear component of the bag seine model. In Aransas Bay, the bag seine model increased linearly whereas the trawl model curved downward after 1987; actual trawl yields began to increase in 1985, then peaked in 1986 in Aransas Bay. It is important to note that even though the modelled curve for Aransas

Bay trawl CPUE reached a maximum in 1987, actual trawl CPUE was minimal during 1987. The resultant model for Corpus Christi Bay trawl catch resembled that of Aransas Bay except that downward curvature was evident after 1989. Modelled bag seine CPUE of pink shrimp in Corpus Christi Bay exhibited no trend. In general, the modelled trends indicate that catches in Corpus Christi Bay and Aransas Bay were more similar in magnitude and timing to each other than either one was to Upper Laguna Madre.

Analysis of bag seine CPUE of blue crab revealed no significant linear or curved trend in any of the bays; all three bays yielded low numbers of YOY (20-39 mm TW [total width]) blue crab in 1984. The same result was obtained for trawl catches of juveniles (50-74 mm TW) in Corpus Christi and Aransas Bays. Of all the models tested, only Upper Laguna Madre trawl CPUE curved upward (after 1988). Actual trawl CPUE in Aransas Bay was generally greater than catches in either Corpus Christi Bay or Upper Laguna Madre. Actual catch by gill net of adult blue crab (150-224 mm TW [total carapace width]) peaked in 1983 and 1987 in all three bays, although mean number of blue crab caught in Corpus Christi Bay in 1987 was about twice that caught in Aransas Bay. Synchronicity of peaks in actual gill net catch resulted in similar models for the three bays: all exhibited significant curvature with interpolated maxima in 1986 (Aransas Bay), 1987 (Upper Laguna Madre), and 1988 (Corpus Christi Bay). These results confirm that blue crab of reproductive size were most plentiful within the CCBNEP sometime within 1986-1988. Catches of blue crab have declined since then, even though some peaks in actual CPUE were recorded in latter years.

INTRODUCTION

In recent collaborative work with the Galveston Bay National Estuary Program, investigators affiliated with the Texas Parks and Wildlife Department (TPWD) examined the status and trends of estuarine fish and invertebrate populations of ecological and commercial value within Galveston Bay (Green et al. 1992). The study was a model for the present work, in which we evaluated Aransas Bay, Corpus Christi Bay, and Upper Laguna Madre populations of red drum, spotted seatrout, black drum, Atlantic croaker, Southern flounder, Gulf menhaden, white shrimp, brown shrimp, pink shrimp and blue crab. The objectives of this project were to evaluate stability, growth, or decline of populations of these species in the CCBNEP area during the last one/two decades and to explore reasons for detectable trends or lack thereof.

The Galveston Bay project revealed two characteristics of bag seine, otter trawl, and gill net CPUE data. Generally, the statistical distribution of CPUE data for species collected by these gears conformed to negative binomial or Poisson statistical distributions: that was evident from results of routine preliminary data screens which indicated that often very few or very many individuals of a species are caught in sample. This first characteristic of CPUE data is expected, given that schooling behavior is typical during at least one stage of the species' lives. The second characteristic apparent from the Galveston Bay CPUE data was that highest CPUE for particular size-classes were recorded during the time of year when they were expected to be highest. In other words, there was a remarkable concordance of peak CPUE per size class of a species with historical seasonal peak abundances within the estuary.

Because of the success of the Galveston Bay status and trends methodology and the wealth of biological collection records residing in the TPWD Coastal Fisheries (CF) Data Base, TPWD personnel were engaged as collaborators to complete an analogous study for Aransas and Corpus Christi estuaries, and the Upper Laguna Madre. These bays have also been sampled randomly by bag seine and gill net since the mid-1970s and otter trawl since the early 1980s. This study affords us the opportunity to compare relative abundances of fishes and macroinvertebrates in the ecologically unique hypersaline Upper Laguna Madre and the more typical Aransas and Corpus Christi estuaries. It also affords us the opportunity to evaluate potential differences in CPUE of these fishes and macroinvertebrates before and during the brown tide, a pervasive brown algal bloom which has persisted in Upper Laguna Madre since summer 1990.

The body of data analyzed in the present work will be discussed at length in ensuing sections. In summary, these data are a very small subset of a massive information bank compiled by TPWD CF Division. As mentioned previously, CF Division personnel have been routinely sampling biota of estuarine and coastal waters for more than two decades. In fact, the CCBNEP study area represents less than half of the water systems surveyed by the TPWD Coastal Fisheries Division. TPWD personnel identify specimens down to the lowest taxon, then measure each specimen according to procedures specified by a TPWD field manual (TPWD 1995): all relevant data regarding gear type, location and time of sampling, hydrologic and ambient conditions at time of sampling are recorded along with the biological data. These records are transcribed into a mainframe computer data base.

This report contains the usual components of a scientific contribution, except that highly technical results of statistical analyses are appended. It concludes with recommendations regarding the need for continued analyses of the data base available at TPWD, particularly with regard to developing a type of biotic integrity index for the estuaries. Such a biotic integrity index would be a useful indicator of overall diversity and abundance of representatives of crucial trophic levels within Texas estuaries.

LITERATURE REVIEW

The purpose of this review is to provide information (Table III.1) used for determining size categories, i.e., young-of-the-year, juvenile, subadult, reproductively mature, or in the case of shrimp, of emigratory size. We also reviewed aspects of the biology of the species, particularly in relation to salinity and temperature, for which abundant literature was available (Tables III.2-III.11). As much as possible of the literature concerning the biology of study species in Texas was gathered, but a great deal of literature from other sources was included by necessity.

In setting appropriate time frames and upper and lower size limits for the various life stages selected for analysis in Table III.1, two conventions were adopted: 1) size categories were set by seeking a consensus in the literature on appropriate sizes for YOY, juvenile, subadult, or reproductively mature individuals, and; 2) time frames for analysis of CPUE were set to minimize repetitive sampling of the same cohorts, i.e., we accounted for the reported growth rate during a particular life stage of the species, while delimiting the sampling period under analysis. For example, we have extrapolated from the literature that red drum, black drum (both estimated to grow at ~ 0.7 - 1.7 mm/day during the first year; Swingle et al 1983; Sutter et al 1986; Beckman et al 1990)), spotted seatrout (~ 0.82 mm/day, McMichael and Peters 1989), and Atlantic croaker (~ 0.5 mm/day, Ross 1988) grow rapidly as YOY: we have accounted for this growth in setting size and time frames specified in Table III.1. In the case of YOY collected by bag seine, the earliest and most obvious seasonal CPUE peak was identified from graphs of raw data (all years pooled) and used to establish a time frame delimiting the CPUE data subset which was analyzed. This method was used because some study species are known to spawn intermittently during the year.

Classification of sciaenids by life stage was based on surveys of the literature for black drum (Bumguardner et al. 1995, Murphy and Taylor 1989, Nieland and Wilson 1993), red drum (Pearson 1929, Simmons and Breuer 1962, Murphy and Taylor 1990, Wilson and Nieland 1994), and spotted seatrout (Brown-Peterson and Thomas 1988; Colura et al. 1988) as well as on recent work by investigators focusing on the biology of these species in Texas waters. The size range representing reproducing subadult red drum (525-749 mm TL) was selected because preliminary analysis of the data indicated that the largest fraction of red drum caught by gill net fell within this size bracket; red drum within this size range in Texas waters are capable of reproducing but are generally more fecund upon achieving greater total length (G. J. Holt, personal communication). Black drum from the Upper Laguna Madre are known to mature early (by their second year) and at a smaller size than fish from typical Texas bays to the north (Bumguardner et al 1995): thus, fish in the size range 375-449 mm TL were considered to be adult in Upper Laguna Madre, but subadult in Corpus Christi and Aransas Bays. The mean lengths at maturity for Chesapeake Bay male and female Atlantic croaker were reported to be 182 and 173 mm, respectively (Barbieri et al 1994) so we set 225 mm as a conservative lower cut-off for Gulf of Mexico Atlantic croaker (Table III.1).

Southern flounder are known to be reproductively mature after age two, at which point males and females are about 231-280 mm and 301-450 mm, respectively. Thus, our size category of 300-395 mm safely represents individuals in their first year of spawning. McEachron et al (1977) reported juvenile flounder may grow at a rate of 20 mm/month. This rapid growth rate is accounted for in our selection of a very narrow size range (20-39 mm for YOY) and limited time frame (April and May) indicated in Table III.1. Gulf menhaden are very infrequently caught by trawl if they are larger than 124 mm, hence our cut-off at 124 mm for subadults coincides well with the 0-1 year class size range of <130 mm reported by Etzold and Christmas (1979) and confirmed by Deegan (1990). Gill nets typically catch individuals in the size range 225-259 mm, which would correspond to Deegan's (1990) reproductive three-year-old class (205 mm and greater).

Prior to emigration from the estuary at an approximate size of 100 mm (Parker 1970, Muncy 1984), brown and white shrimps in Texas are estimated to grow at ~ 1.0-1.3 mm/day (Nichols 1981). Data are scant for pink shrimp, for which we can only estimate similar values based on a report by Cummings (1961) indicating the carapace length of mature female pink shrimp is about 22 mm. From larval to juvenile stages, blue crab grow at an estimated rate of ~ 0.93-1.17 mm/day carapace width. Blue crab are generally considered to be reproductive at lengths greater than 139 mm (Tagatz 1968). The cut-off point for juvenile crab size range (39 mm upper limit) was adopted from Thomas et al (1990). According to Newcombe et al. (1949), average size at which male blue crabs attain maturity is 89 mm CW, so we have set conservative limits for juvenile and reproductive categories in Table III.1. It should also be noted that blue crabs smaller than 150 mm CW are seldom caught by gill net, so a lower setting of 150 mm in Table III.1 was necessary. The biology of each study species in relation to salinity is reviewed in Tabular form (Tables III.2-III.11).

Table III.1. Study species, gear types used for collection, life stage of species caught by corresponding gear type, size class corresponding to life stage, and months during which collections represent the largest fraction of the species' population within the Corpus Christi Bay National Estuary. BS = bag seine; TR = trawl; GN = gill net; YOY = young-of-the-year; JUV = juvenile; SA = subadult; REP = reproductively mature; TL = total length; TW = total carapace width; SPGNS = Spring gill net season; FGNS = Fall gill net season. Gill net seasons are defined in “Methods”.

Species	Gear Type	Life Stage	Size Range (mm)	Months
red drum	BS	YOY	20-39 TL	Oct.Nov. Dec.
	GN	SA	525-749 TL	SPGNS
spotted seatrout	BS	YOY	60-79 TL	Aug.Sep.Oct.
	GN	REP	300-449 TL	SPGNS
white shrimp	BS	YOY	40-59 TL	June July Aug.
	TR	Emigratory size	100-124 TL	Sep. Oct. Nov.
brown shrimp	BS	YOY	40-59 TL	Apr. May June
	TR	Emigratory size	100-124 TL	May June July
black drum	GN	SA (Corpus Christi and Aransas Bays)	375-449 TL	SPGNS
		REP (Upper Laguna Madre)		
blue crab	BS	YOY	20-39 TW	Mar. Apr. May
	TR	JUV	50-74 TW	Mar. Apr. May
	GN	REP	150-224 TW	FGNS
Atlantic croaker	BS	YOY	60-79 TL	Mar. Apr.
	GN	REP	225-299 TL	FGNS
pink shrimp	BS	YOY	40-59 TL	Sep. Oct. Nov.
	TR	REP	100-124 TL	Mar. Apr. May.
Southern flounder	BS	YOY	20-39 TL	Feb. Mar. Apr.
	GN	REP	300-375 TL	FGNS
Gulf menhaden	BS	YOY	20-39 TL	April May
	TR	SUBAD	100-124 TL	Sep.Oct. Nov. Dec.
	GN	REP	225-299 TL	FGNS

Table III.2. Salinity limits and preferences or optima for various features of the biology of the red drum.

Biological Feature	(ppt)	Range (ppt)	Preference or Optimum	Remarks/Citation
Field distribution in Texas Bays (adults and juveniles)	0->50	20-40		(most abundant at 30-35 ppt) Simmons and Breuer, 1962
Records for collection in coastal waters of Eastern Florida	-29.9			Springer and Woodburn, 1960; Tagatz, 1962
Records for collection in coastal waters of North Carolina	0-22.3			Tagatz and Dudley, 1961
Records for collection of larvae in the Florida Everglades	8-35			Rutherford et al., 1986
Buoyancy of eggs after acclimation to 26-36 ppt (laboratory study)	(eggs sink in <25 ppt)			Holt et al., 1981
Egg development and hatching at 25^{o}C (laboratory study)	10-40	30		Holt et al., 1981
Successful egg hatching at 25-27^{o}C (laboratory study)	5-60			Holt and Banks, 1989
Survival of Day 1 larvae (25-27^{o}C)	5-60		15-35 (30 at 25^{o}C)	Holt and Banks, 1989
Survival of Day 2 larvae (25-27^{o}C)	5-60			poorest conditions
Survival of Day 3 larvae (25-27^{o}C) (laboratory study)	5-50			at 15 ppt at 30^{o}C
Metabolism of adult fish laboratory study)	5-45		20-25 (at 20-28^{o}C)	Wohlschlag, 1977
Osmotic adaptation (after 24 h) after acclimation to 30 ppt at 24^{o}C	2-40		(isotonicity at 11 ppt)	Wakeman and Wohlschlag, 1983
Salinity at which diet has no influence on otolith elemental composition	30			Hoff and Fuiman, 1995

Table III.3. Salinity limits and preferences or optima for various features of the biology of the spotted seatrout.

Biological Feature	(ppt)	Range (ppt)	Preference or Optimum	Remarks/Citation
Field distribution in Copano and Aransas Bays		2.3-34.9		80% of individuals caught at 5-20; Gunter, 1945
Field distribution in Baffin and Alazan Bays	< 55	15-35		Breuer, 1957
Field distribution of juveniles in Laguna Madre	< 60	< 45		Simmons, 1957
Spawning in Laguna Madre	< 45			Simmons, 1957
Field distribution in Mesquite Bay, Texas	1.5-45.3			Hoese, 1960
Peak spawning in Florida estuaries and lagoons	30-35			Tabb, 1966
Field distribution in Texas Bays and lagoons of northwestern Gulf of Mexico	<5-77			Hedgpeth, 1967
Occurrence of spawning in Louisiana estuaries	> 30			Sabins and Truesdale,1974
Spawning site selection in Texas	20-37			Arnold et al., 1978
Collection of larvae in the Florida Everglades	8-40	mean 33.2 + 1.7		Rutherford et al., 1986
Spawning site selection in Florida	15.5-36			Rutherford et al., 1989 McMichael and Peters, 1989
Field distribution of larvae in Copano Bay	24			Banks et al., 1991
Spawning in the Laguna Madre	< 48			Holt et al., 1990
Field distribution of larvae in the Laguna Madre	> 40			
Detection of drumming sounds associated with spawning near Charleston, SC	16-32.5			Saucier and Baltz, 1992
Greatest abundance of recruits and spawners during spawning season (May-Aug.) in Louisiana estuaries	15-30			Helser et al., 1993; abundance positively correlated with salinity ($p < 0.0001$)
Significant ($p < 0.01$) abundance of recruits during Sep.-Dec.	0-9			Abundance of recruits negatively correlated with salinity ($p < 0.01$); spawners uniformly distributed over all salinity zones

Table III.3 continued. Salinity limits and preferences or optima for various features of the biology of the spotted seatrout.

Biological Feature	(ppt)	Range (ppt)	Preference or Optimum	Remarks/Citation
Operational metabolic limits at 20-28^{o}C (laboratory study)	10-45	20		Wohlschlag and Wakeman, 1978
Successful egg hatching and larval survival to developmen of eye pigmentation in laboratory at 28^{o}C	28.1			Taniguchi, 1978; 100% survival predicted between 23.1-32.9^{o}C at 8.6-37.5ppt
Successful fertilization	10-50	25-35		Thomas and Boyd, 1989
Successful egg hatching (laboratory study)	5-50	10-35		(35-50 ppt not investigated for hatching)
Survival of 1 Day larvae (laboratory study)	5-50	10-35		Thomas and Boyd, 1989
Range of no-salinity related mortality during the pelagic larval stage at 28^{o}C	10-40			Holt and Banks, 1989
Upper and lower limits for 50% survival (LD50) for larvae spawned at 32 ppt (Lydia Ann Channel, Texas) at 28^{o}C				Banks et al., 1991
Day 1	2 to3 - 45.4			
Day 3	6.4 - 42.5			
Day 5	3 to 4 - 44 to 45			
Day 7	3 to 4 - 44 to 45			
Day 9	1.9 - 49.8			
Median lethal (LC50) and near-total lethal (LC99) in terms of egg hatching success at various temperature regimes				Gray et al., 1991
20^{o}C LC50 = 37 LC99 = 50				
23^{o}C LC50 = 42 LC99 = 61				
26^{o}C LC50 = 52 LC99 = 69				
29^{o}C LC50 = 41 LC99 = 61				
32^{o}C LC50 = 44 LC99 = 59				

Table III.4. Salinity limits and preferences or optima for various features of the biology of the white shrimp.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Abundance center in 1987 and for 10 years prior to 1987 in marsh habitats in Galveston Bay		16.1	Zimmerman et al., 1990
Field distribution in Copano and Aransas bays (range of greatest abundance)	2.1-36.6	10.0-14.0	Gunter, 1950
Field distribution in the upper Laguna Madre, Texas	<45		Simmons, 1957
Field collection of size class 23-76 mm in Laguna Madre de Tamaulipas, Mexico	<48		Hildebrand, 1958
Lower distribution limit in Grand and White Lakes, Louisiana	0.42		young shrimp abundant at 0.7-0.8; Gunter and Shell, 1958
Preference based on apparent population distributions	<10		Gunter et al., 1964
Field distribution in Texas bays and lagoons of northwestern Gulf of Mexico	2-45		Hedgpeth, 1967
Optimum catch at 20-38^{o}C	0-38		Copeland and Bechtel, 1974
Field distribution of 91.1% of juveniles collected in Caminada Bay, Louisiana	1-34	1-20	Crowe, 1975
Distribution in a salt marsh on Galveston Island, Texas	16-37		Zimmerman and Minello, 1984
Range at which 80% of individuals in size class 8-50 mm survive after 48 h acclimation in laboratory	<2 - >40		Zein-Eldin and Griffith, 1969
Increased growth rates (>25^{o}C)	5-15		
Postlarval distribution in laboratory gradient tanks during May to July		28.0 (median)	Keiser and Aldrich, 1976
Postlarval distribution in laboratory gradient tanks during August to November		21.0 (median)	
Isosmotic point for individuals > 100 mm (subadults) held at 25.5-28.9^{o}C	27.6-28.3		McFarland and Lee, 1963

Table III.4 continued. Salinity limits and preferences or optima for various features of the biology of the white shrimp.

Biological Feature	(ppt)	Range (ppt)	Preference or Optimum	Remarks/Citation
Isosmotic point for juveniles at 23°C		23.3		Castille and Lawrence, 1981
Salinity at which thermal resistance of postlarvae is (< 30) optimal in laboratory studies		25		Wiesepape, 1975
Optimal laboratory acclimation salinity for preparation of larvae for thermal resistance tests		5		

Table III.5. Salinity limits and preferences or optima for various features of the biology of the brown shrimp.

Biological Feature	(ppt)	Range (ppt)	Preference or Optimum	Remarks/Citation
Field distribution in Copano and Aransas Bays, Texas	2.1-36.6	15.0-19.9		Gunter, 1950
Field collection in Laguna Madre, Texas	<69			Simmons, 1957
Lower limit for field distribution in Grand and White lakes, Louisiana	0.8			Gunter and Shell, 1958
Field distribution in Mesquite Bay, Texas	0.5-45.3			Hoese, 1960
Lower limit for field collection in St. Lucie estuary, Florida	0.22			Gunter and Hall, 1963
Range of juvenile abundance in the field	10-30	10-19.9		Gunter et al., 1964
Lower limit on the northern coast of the Gulf of Mexico		0.8		
Relatively large number of juveniles collected in estuaries of the Western Gulf	2.5-7.7			significantly less caught at 12.5-22.5 ppt; Chapman et al., 1966
Conditions apparently conducive to enhanced survival and growth of postlarvae in Barataria Bay, Louisiana	>15			St. Amant et al., 1966
Field distribution in Texas bays and lagoons	5-70			Hedgpeth, 1967
Lower limit for field collection in North Carolina estuaries	0.1			Williams and Deubler, 1968
Abundant field distribution of juveniles (70-100mm) in Galveston Bay	0.9-30.8			Parker, 1970
Occurrence of postlarvae in Vermilion Bay, Louisiana	<1			Caillouet et al., 1971
Higher commercial catch yields coincident with occurrence of postlarvae	>15			Gaidry and White, 1973
Field collections within 20-35oC range in six Gulf of Mexico estuaries	9-40			Copeland and Bechtel, 1974
Field distribution in Caminada Bay, Louisiana	0.2-30			Crowe, 1975
Range over which 92% of juveniles were collected	10-30			

Table III.5 continued. Salinity limits and preferences or optima for various features of the biology of the brown shrimp.

Biological Feature	(ppt)	Range (ppt)	Preference or Optimum	Remarks/Citation
High field densities in Louisiana waters	<5	1-3		White and Boudreaux, 1977
Ranges within which the following percentages of total catch for individuals ranging in size from 10-130 mm were recorded at Marsh Island, Louisiana				Herke et al., 1987 shrimp in every 5mm size class were caught within 3.00-3.99ppt
7.7%	0.57-0.99			
27.9%	1.0-1.99			
45.9%	2.0-2.99			
18.3%	3.0-6.99			
Isosmotic point for individuals >100 mm in length (laboratory study)	27.6-28.3			above 28.3 ppt, brown shrimp apparently osmoregulates more efficiently than white shrimp McFarland and Lee, 1963
Range for 90-100% postlarval survival at 23-25^{o}C in laboratory	2-40			Zein-Eldin, 1963
Range over which postlarvae and juveniles (12.1-50mm) exhibited poor tolerance at 7-15^{o}C in the laboratory	5-10			Zein-Eldin and Aldrich, 1965
Optimal laboratory conditions for growth and survival of young individuals at 20^{o}C	>15			St. Amant et al., 1966
Range for 80% survival of <25mm postlarvae at >33^{o}C in laboratory, after acclimation	<3->40			Zein-Eldin and Griffith, 1969; lower limits of tolerance are at 15^{o}C at
Optimal conditions for juvenile shrimp growth in mariculture ponds	15-25			Broom, 1970
Range for increased postlarval growth at >25^{o}C	15-35			
Acclimation salinity which provided optimal resistance to high temperatures and 2-25 ppt conditions in laboratory			5	Wiesepape et al., 1972
Optimal conditons for growth of postlarvae under laboratory conditions	8.5-17			Bidwell, 1975
Median value for postlarval distribution during March-April in an artificial gradient		29.9		Keiser and Aldrich, 1976

Table III.5 continued. Salinity limits and preferences or optima for various features of the biology of the brown shrimp.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Median value for postlarval distribution during May-July in an artificial gradient	20.6		
Apparent preference of juvenile (70 mm) individuals at >26°C in laboratory	<17		Venkataramiah et al., 1977a
Apparent optimal conditions for subadult (95 mm) individuals at <25oC in laboratory	15-25		
Apparent optimal conditions for juvenile growth on low (40%) protein diet in laboratory at 21-31°C	8.5-17		Venkataramiah et al., 1977b
Isosmotic point for juveniles (mean length 83mm) at 28°C in the laboratory	25.6		Castille and Lawrence, 1981
Salinity at which taurine was found to comprise the greater fraction of the free amino acid (FAA) pool	~13		Bishop and Burton, 1993
Salinity at which proline was found to comprise the greater fraction of the free amino acid (FAA) pool	~26		

Table III.6. Salinity limits and preferences or optima for various features of the biology of the black drum

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Field distribution in Laguna Madre (adults and juveniles)	0-80	25-50	Simmons and Breuer, 1962
Field distribution in Copano and Aransas Bays (adults and juveniles)	2.6-34.9	10-15	Gunter, 1945
Field distribution in Baffin Bay (larvae and juveniles)	50% of individuals found above 50		two juveniles caught in 134 ppt Gunter, 1945
Conditions for spawning	<45		Simmons, 1957
Field distribution of small larvae (< 3mm) in Laguna Madre	<45		Holt et al., 1990
Field distribution of large larvae (> 3mm)			high density of larvae at 54 ppt (highest salinity observed in study)
Egg development and hatching (laboratory study)	5-34		Garza et al., 1978
Metabolism of adult fish (laboratory study)	5-45	20-30 (at 20-28^{o}C)	Wohlschlag, 1977

Table III.7. Salinity limits and preferences or optima for various features of the biology of the blue crab.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Lower limit for occurrence in Louisiana	0		Gunter, 1938
Range for egg hatching in Virginia estuaries	23-38		Sandoz and Rogers, 1944
Collection of egg-bearing females near Aransas Pass, Texas	22.9-32.4	> 30.0	Gunter, 1950
Field distribution in Copano and Aransas Bays, Texas	2.0-37.210-20		
Collection in Laguna Madre de Tamaulipas, Mexico	<117		(evidence for toleration of extreme salinities) Hildebrand, 1958
Field distribution in Mesquite Bay, Texas	2.8-40.6		Hoese, 1960
Spawning activity near the Texas coast	>20		Daugherty, 1952 More, 1969
Salinity level associated with departure of crabs from the Upper Laguna Madre	>45		Hawley, 1963
Field distribution in Texas bays and lagoons of northwestern Gulf of Mexico	2-60		Hedgpeth, 1967
Spawning and early development in Texas Bays	>20		More, 1969
Optimal catches at 10-35^{o}C	0-40	0-27	Copeland and Bechtel, 1974
Collection of juveniles (< 20 mm) in the lower Trinity River and upper Trinity Bay	<1		Truesdale, 1970
Egg hatching in the field	23-30		Davis, 1965
Egg hatching in the field	23-30		Davis, 1965
Egg hatching in the laboratory	18-26		Davis, 1965
Egg hatching in the laboratory	none below 20.1		Costlow and Bookhout,1959

Table III.7 continued. Salinity limits and preferences or optima for various features of the biology of the blue crab.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Frequent occurrence of individuals in 3-10mm (carapace width) size class in Mississippi	15-20		
Frequent occurrence of individuals in 10-20 mm (carapace width) size class in Mississippi	<10		Perry and Stuck, 1982
Maximum number of individuals in 20-40 mm (carapace width) size class in Mississippi	<10		
Highest densities of individuals in megalops stage (ages 6-20 days) in South Carolina	>18		Mense and Wenner, 1989
Highest densities of juveniles in South Carolina	5-18		Mense and Wenner, 1989
Salinity at which the osmolarity of extra-cellular fluid is regulated by active transport of ions		26	Mantel, 1967
Salinity for widest range of thermal tolerance in adults		24.2	Mahood et al., 1970
Lethal conditions for larvae at 20^{o}C in the laboratory		5	100% mortality observed
Lethal conditions for larvae at 15^{o}C in the laboratory		10	100% mortality observed
Salinity at which 100% of megalops survived at 30^{o}C in the laboratory		35	Delayed metamorphosis was most apparent at low temperatures (i.e., 15^{o}C) and high salinities (~35-40 o/oo) Costlow, 1967
Salinity at which 50% of megalops survived at 15^{o}C in the laboratory		35	
Optimum for zoeal development at 25^{o}C in the laboratory		30	Costlow and Bookhout, 1959 Sulkin and Epifanio, 1975 Bookhout et al., 1976
Lethal limit for juvenile crabs held at 29^{o}C below 1o/oo in the laboratory		<1.0	mortality associated with molting < 1 o/oo not lethal at 15oC Holland et al., 1971
Range over which oxygen consumption is not affected	5-30		Laird and Haefner, 1976
Highest growth rate per ecdysis at 23^{o}C of juveniles in the laboratory		3	Cadman, 1990

Table III.7 continued. Salinity limits and preferences or optima for various features of the biology of the blue crab.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Upper limit of 21-day LC50 for juveniles collected from a normal salinity environment (ca. Grand Isle, Louisiana) Louisiana)	56		Individuals from the Texas population were found to have higher energy absorption and scope for growth at extreme salinities (i.e., 2.5, 35, and 50 o/oo) relative to individuals from Louisiana population Guerin and Stickle, 1990
Lower limit of 21-day LC50 for juveniles the collected from a normal salinity environment (ca. Grand Isle, Louisiana)	0		
Upper limit of 21-day LC50 for juveniles collected from a hypersaline environment (ca. Corpus Christi, Texas)	67		
Lower limit of 21-day LC50 for juveniles collected from a hypersaline environment (ca. Corpus Christi, Texas)	1		Guerin and Stickle, 1990

Table III.8. Salinity limits and preferences or optima for various features of the biology of the Atlantic croaker.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Field distribution in northwestern Gulf and Laguna Madre	2- >60		Hedgpeth, 1967
Greatest abundance in Texas Waters	<15		Gunter, 1945
Collections of larvae in waters of South Carolina		28-36	Powles and Stender, 1979
Field distribution in mesohaline region of South Carolina Estuaries	0.4-34.4	5-15	Miglarese and Shealy, 1982
Field distribution in Mississippi Sound	0-37	6-15	Overstreet and Heard, 1978
Range of common occurrence in Barataria Bay, Louisiana	0-15		Rogers, 1979
Lowest range of abundant catches in Grand and White Lakes, Louisiana	0.1 to 0.9		Gunter and Shell, 1958
Distribution of larvae between 0-16 m in Chesapeake Bay Mouth			
North Transect	32		
South Transect	30-32		
Inside Bay Mouth	25-31		Norcross, 1991
Limits for egg buoyancy (laboratory study)	15- >30		eggs tend to sink at <25 Thomas and Boyd, 1989
Limits for successful fertilization of eggs (laboratory study)	15-45	25-35	
Limits for successful hatching of eggs (laboratory study)	>5-<45	15-35	
Limits for 1 Day larvae survival (laboratory study)	15-20		
Limits for no salinity related mortality during the pelagic larval stage spawned in near full-strength seawater under optimum temperature conditions (laboratory study)	15-35		Holt and Banks, 1989

Table III.9. Salinity limits and preferences or optima for various features of the biology of the pink shrimp.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Apparent salinity preference of juveniles in the Gulf of Campeche	>20		Hildebrand, 1955
Field collections of individuals in 32-212 size range in Pamlico Sound, North Carolina at 6.0-32.2°C	6.3-18.8		Williams, 1955
Field distribution in the Upper Laguna Madre, Texas	3-69		Simmons, 1957
Field collections in Lake Pontchartrain, Louisiana at 10.5-28.8°C	3.9-10.3		Darnell and Williams, 1956
Field collections in Chandeleur Sound, Louisiana at 20.0-21.5°C	30.6-35.3		
Field collections in Mesquite Bay, Texas	2.7-35.7		Hoese, 1960
Field collections in the Dry Tortugas at 21.7-30.4°C	36.2-37.7		Iverson and Idyll, 1960
Field collections of individuals in 40-110mm size range in Lake Borgner-Breton Sound, Louisiana at 8.0-26.9°C	3.0-21.9		El-Sayed, 1961
Field collections in Tampa Bay, Florida at 15.8-33.0°C	20.44-35.18		Dragovich and Kelly, 1964
Field collections in Northern Gulf Coast waters	2.5-65		Gunter et al., 1964
Lower limit for field distribution in St. Lucie estuary, Florida	<1		Gunter and Hall, 1963
Field collections of individuals in 20-110mm size range in Caloosahatchee estuary, Florida	1.0-34.2		
Field collections of individuals in 15-145mm size range in the Northwest Florida coast at 7.6-34.7°C	0.64-40.4		Joyce, 1965
Field collections of individuals in 6.5-9.0mm size range in Aransas Pass, Texas at 12.6-30.6°C	29.7-37.4		Copeland and Truitt, 1966

Table III.9 continued. Salinity limits and preferences or optima for various features of the biology of the pink shrimp.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Field collections of individuals in various size classes in Florida waters			Sykes and Finucane, 1966; shrimp caught in <31.8 and <30.5 ppt in Old Tampa and Hillsborough bays, respectively
Lower Tampa Bay 4.3-28.7mm	21.9-37.2		
Central Tampa Bay 5.0-31.8mm	15.9-33.5		
Field disribution in the northwestern Gulf of Mexico	5.0-60.0		Hedgpeth, 1967
Field distribution in waters of the northern Gulf coast	2.7-60		Gunter, 1967
Field collections of individuals in Tampa Bay Florida at 13.0-31.0°C	20.44-35.18		Saloman, 1968
Field collections in Florida Bay at 16.6-32.2°C	27.8-49.6		Hudson et al., 1970
Field collections in Gulf coast estuaries	8-37	28-35	(highest catch ratio) virtually zero catch ratio below 8ppt; Copeland and Bechtel, 1974
Isosmotic point for individuals of mean length 84 mm at 28°C		26.3	Castille and Lawrence, 1981

Table III.10. Salinity limits and preferences or optima for various features of the biology of the Southern flounder.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Collection of adults in Aransas Bay, Texas	0-36		Stokes, 1977
Largest catches of juveniles and young adults in Mississippi		15-20	Christmas and Waller, 1973
No adverse effects on survival and growth of postlarvae	< 26		Deubler, 1960 (growth faster at higher salinities)

Table III.11. Salinity limits and preferences or optima for various features of the biology of the Gulf menhaden.

Biological Feature	Range (ppt)	Preference or Optimum (ppt)	Remarks/Citation
Catch ratio (successful catches divided by attempts) for gulf coast juveniles	1-20	0-12	catch diminishes with increasing salinity Copeland and Bechtel, 1974
Greatest abundance of all life stages	5-10		Christmas, 1982
Catch of gulf menhaden 20-34.9 mm SL in marshland routes of Southwestern Louisiana	0.2-32.5	9-28	Marotz et al. 1990

HISTORICAL DATA REVIEW

CF of TPWD has been monitoring biota of major Texas estuaries: Sabine, Galveston, San Antonio, Matagorda, East Matagorda, Aransas, and Corpus Christi Bays, upper Laguna Madre, and lower Laguna Madre, and nearshore habitat of the Gulf of Mexico with gill nets, bag seines, otter trawls, and oyster dredges (commencing in 1975, 1977, 1982, and 1992, respectively) for about two decades (Dailey et al., 1991). As a result of these sampling procedures, TPWD amassed a growing body of data on biological resources and history of enviromental conditions of major Texas estuaries. The data base consists of biological resource records noted for each specimen and environmental information typically obtained with each biological sample. The data base expands as field observations are transcribed into the TPWD mainframe data storage bank by CF personnel, after which data are routinely subjected to computerized and manual procedures designed to ensure quality control. Details of the data base are given in the ensuing chapter.

METHODS

Detailed description of the TPWD Coastal Fisheries data base

The following records (hereafter referred to as resource records) were noted for organisms collected during sampling: species name, species code, collection date, collection time, collection location (identified by a major code [bay system], minor zone code [zone within the bay], station [station within the zone], latitude, and longitude), length descriptor (total length, standard length, fork length [methods of measurement are specific for each invertebrate taxonomic group]), length, sex, and gear type used for collection (i.e., gill net, trawl, bag seine). Hydrologic and environmental data (hereafter referred to as hydrologic records), which are typically gathered in conjunction with a biological sampling procedure, include: location (major, minor, and station, as defined above), surface area, start date, start time, lighting conditions, latitude, longitude, wind speed, wind direction, cloud cover, barometric pressure, precipitation, fog, wave height, tide, water depth, water temperature, dissolved oxygen, salinity, turbidity, bottom type, completion date, completion time, lighting condition at end of sampling, and disposition of water samples if taken. Field notes are transcribed into the TPWD mainframe data bank by TPWD personnel. Data are subsequently assessed for quality with a computer program filter by an analyst affiliated with the TPWD Resource Protection Division. Irregularities in resource or hydrologic records are submitted to CF personnel for review and correction.

Description of sample collection sites according to Texas Parks and Wildlife Marine Resource Monitoring Manual (1995)

Aransas Bay system: All waters, including all saltwater bayous in the bay system, behind the surfline from the eastern edge of Mesquite Bay to the causeway between Port Aransas and Aransas Pass, including the ICWW (intracoastal waterway). TPWD recognizes 21 minor zones (Allyns Lake, Aransas Bay, Big Brundrett Lake, Little Brundrett Lake, Carlos Bay, Cedar Bayou, Lydia Ann Channel, Aransas Channel, Copano Bay, Dunham Bay, Long Lake, Little Bay, Mission Bay, Mesquite Bay, Port Bay, Redfish Bay, South Bay, Salt Lake, St. Charles Bay, Sundown Bay, Swan Lake) within the Aransas Bay system.

Corpus Christi Bay system: All waters, including all saltwater bayous, behind the surfline from the western edge of the causeway between Aransas Pass and Port Aransas to the powerline connecting Demit Island to Mustang Island, and the mouth of the Nueces River. TPWD recognizes eight minor zones (Port Aransas Pass, Corpus Christi Channel, Corpus Christi Bay, Nueces Bay, Oso Bay, Redfish Bay, Sunset Lake, Water Exchange Channel) within the Corpus Christi Bay system.

Upper Laguna Madre system: All waters, including all saltwater bayous, from the powerline connecting Demit Island to Mustang Island to the land cut (middle ground to Rincon de San Jose), including Baffin Bay and its tributaries. TPWD recognizes six minor zones (Alazan Bay, Baffin Bay, Cayo del Grullo, Laguna Salada, Upper Laguna Madre, Corpus Christi Pass) within the Upper Laguna Madre system.

Description of sampling techniques

Bag seine

Bag seines were 18.3 m in length, 1.8 m in depth, and had 19 mm stretched nylon #5 multifilament mesh wings (8.3 m in length) and a 13 mm stretched nylon #5 multifilament mesh bag (1.8 m in length). Bag seines were pulled in a direction parallel to the shoreline for a distance of 15.2-30.5 m. Estuaries were divided into grids (one minute latitude by one minute longitude) and only those grids containing a minimum of 15.2 m of shoreline were sampled. Grids were subdivided into 144 gridlets (five seconds latitude by five seconds longitude). Gridlets containing shoreline were chosen randomly. Shoreline within a gridlet was divided into 15.2 m sections, one of which was selected randomly as a starting point for the sample. Bag seines were not pulled more than once in a grid during a month. Catch per unit effort (CPUE) was defined as the number of individuals captured per unit area (18.3 m [bag seine length] x length of pull) and was therefore standardized as the number of individuals captured per 0.03 hectare (CATCH/0.03 hectare).

Trawl

Otter trawl nets were flat, 6.1 m in width, and constructed with 38 mm stretched #9 nylon. Samples were taken between dawn and dusk by pulling the net along the bay bottom at a speed of approximately 3 mph (4.8 km/h) in a circular pattern for ten minutes. Sample locations were selected randomly following the procedure described above for bag seines, under the additional conditions that at least 1/3 of the grid was at least one meter deep and free of obstructions. Trawling was not restricted to the vicinity of the shoreline and grids were not sampled more than once a month. CPUE was defined as the number of individuals captured per ten minutes of towing time (CATCH/10 min).

Gill net

Gill nets were 183 m in length, 1.2 m in depth, and were divided into four panels, each 45.75 m in length with increasing mesh size (76 mm, 102 mm, 127 mm, and 152 mm). The nets were situated in the vicinity of the shoreline and were oriented perpendicular to it, such that the smallest mesh panel was closest to shore: nets were suspended by hard plastic floats and weighted by a leadline. Sample grids and gridlets, which were selected randomly according to the parameters used for bag seine grid and gridlet selection, conformed to additional conditions: (1) each grid could contain no more than one set per night; (2) each grid could contain no more than three gill nets per season, and; (3) sets occurring on the same night had to be at least one kilometer apart. Nets were set within one hour of sunset and retrieved within four hours after sunrise. Thus, the length duration of net emplacements varied with daylength, with an average set duration of 12.5 h in the spring and 14 h in the fall.

Sampling schedule

For bag seine collections, ten sites were sampled per month during October 1981-March 1988. Twelve sites were sampled per month by bag seine during April 1988-December 1989. Sixteen sites were sampled per month by bag seine from January 1990-1992. Twenty sites have been sampled per month by bag seine from 1992-present, under the still existing condition that no more than five samples are taken per day. For trawl collections, 20 sites have been sampled per month from May 1982 to the present (in the Upper Laguna Madre only 10 sites per month have been sampled), under the condition that no more than five samples are taken per day. For gill net collections, eight to 12 samples were taken per three-month season during the Fall of 1975-1981. Since the Fall of 1982, sampling has been conducted during two ten-week periods, the first being a Spring season which commences the second full week of April, and the second being a Fall season which commences the second full week of September: 45 samples are collected per season under the condition that no more than three samples are taken per day.

Data Collection

All organisms captured were identified to species or to the lowest taxon possible. For most specimens, the total length (TL: tip of the snout to caudal fin of a fish; tip of rostrum to end of telson of a shrimp) or carapace width (CW: between carapace tips of a carb) was measured to the nearest millimeter. Whenever TL could not be measured directly, the standard length (SL: tip of the snout to caudal peduncle of a fish) was measured, and TL was estimated using conversion equations (Harrington et al. 1979). Commencing in 1980, only the first 19 individuals of the same species caught in the same mesh size were measured, and all remaining individuals were counted. In trawl samples up to 50 shrimp of each species and up to 35 blue crabs were measured. Unmeasured specimens were assumed to have a size frequency distribution identical to the measured individuals and were prorated accordingly into size groups for calculation of catch rates. The ratio of the number of measured individuals of a given size (N) to the total number of individuals measured (M), was multiplied by the total number of individuals not measured (X), to obtain the number of unmeasured individuals assigned to a length group (Y) such that $Y = X(N/M)$, and the total number of a given size $(T) = (N+Y)$. Field data were recorded on standardized TPWD data sheets. After initial editing by CF personnel, data sheets were submitted to the TPWD Data Processing Section at TPWD Headquarters for transcription into computer files. Error-detection computer programs were routinely applied to identify unlikely or impossible values for each variable, e.g., suspicious sizes, sample locations, and/or unusually high catches. Computer printouts of the original data, annotated with potential errors, and original field sheets were returned to field personnel for verification. Corrected data were resubmitted to TPWD Data Processing for file updates.

Data Analysis

Gill Net Saturation Effect and Modelled Trend Analyses

Preliminary Evaluation of “Saturation Effect” in Gill Net Data

The effect of set duration on the catch rate was evaluated. Results of the Galveston Bay Status and Trends analyses revealed that gill net CPUE of a number of species must be tested for “saturation effect.” Because gill net sampling takes place over a much longer time frame (12.5-14 hours) than bag seine and trawl sampling, it was necessary to test for a significant relationship between catch and net set time, owing to the possibility that gill nets become increasingly saturated with fish or macroinvertebrates with increased set time. Catch as related to set duration was analyzed using the equation:

$$\text{CATCH} = b_o + b_{(\text{Year})} * \text{Year} + b_1 * \text{GTIME} + b_{(\text{Year})} * \text{Year} * \text{GTIME}$$

where “CATCH” is the total number of individuals netted within a particular size class per net emplacement , “Year” is a categorical variable representing the year in which the sample was collected, “GTIME” (in hours) is a continuous variable representing the duration of each gill net emplacement, and “b_1” represents the rate of change in CATCH for a unit increase in GTIME for those years in which the rate of change was significantly different from zero. In cases where GTIME was not a significant factor in the model, the CPUE was simply defined as CATCH. In those cases where preliminary analysis of covariance (ANCOVA) revealed a significant effect of set duration, subsequent testing was performed to determine the best-fit relationship between CATCH and GTIME. These preliminary analyses of deviance (ANODE) were performed with the generalized linear model routine available in the software package S-PLUS (3.3). Results of these analyses are presented in Table V.1.

Table V.1. Specifications for CPUE by gill net, corrected for saturation effect, for the study species sampled in Corpus Christi and Aransas Bays and Upper Laguna Madre. COR=Corpus Christi, ARA=Aransas, ULM=Upper Laguna Madre

Species	Location	CPUE =
Sciaenops ocellatus (red drum)	COR	$CATCH/(GTIME/14)^{2}$
	ARA	$CATCH/(GTIME/14)^{2}$
	ULM	$CATCH/(GTIME/14)^{2}$
Cynoscion nebulosus (spotted seatrout)	COR	CATCH/(GTIME/12.5)
	ARA	CATCH/(GTIME/12.5)
	ULM	CATCH/(GTIME/12.5)
Pogonias cromis (black drum)	COR	$CATCH/(GTIME/12.5)^{3}$
	ARA	CATCH/(GTIME/12.5)
	ULM	$CATCH/(GTIME/12.5)^{1.5}$
Callinectes sapidus (blue crab)	COR	CATCH/(GTIME/14)
	ARA	CATCH/(GTIME/14)
	ULM	$CATCH/(GTIME/14)^{-1.5}$
Micropogonias undulatus (Atlantic croaker)	COR	$CATCH/(GTIME/14)^{-3.5}$
	ARA	$CATCH/(GTIME/14)^{-3.5}$
	ULM	CATCH/(GTIME/14)
Paralichthys lethostigma (Southern flounder)	COR	$CATCH/(GTIME/14)^{1.5}$
	ARA	$CATCH/(GTIME/14)^{3}$
	ULM	CATCH/(GTIME/14)
Brevoortia patronus (Gulf menhaden)	COR	$CATCH/(GTIME/14)^{-8}$
	ARA	$CATCH/(GTIME/14)^{-5}$
	ULM	$CATCH/(GTIME/14)^{-7}$

Trend Analysis for Gill Net Data

After correction for saturation effect, models relating gill net CPUE to time were tested by analysis of deviance (ANODE) according to expectations for non-normal error distributions with the S-PLUS (Version 3.3) software package. Gill net data were evaluated for conformance to the following models:

i. Log(mean CPUE) = b_o + Year
ii. Log(mean CPUE) = $b_o + b_1$*YEAR
iii. Log(mean CPUE) = $b_o + b_1$*YEAR + b_2*YEAR^2

where "b_o" is a constant and b_1 and b_2 are partial slope parameters related to yearly trends. Error deviance for gill net data was based on evaluation of models including Year, GTIME, and YEAR*GTIME interaction in those cases where set duration was determined to be significant. In those cases where set duration was not significant, error deviance was determined by a model based on the categorical variable Year.

Trend Analysis for Bag Seine Data

In all cases, CPUE = CATCH/0.03 hectare. Bag seine data were evaluated for conformance to the following models:

i. Log(mean CPUE) = b_o + Month + Year + Month*Year
ii. Log(mean CPUE) = b_o + Month + Year
iii. Log(mean CPUE) = b_o + Month + b_1*YEAR
iv. Log(mean CPUE) = b_o + Month + b_1*YEAR + b_2*YEAR^2,

where "b_o" is a constant and b_1 and b_2 were partial slope parameters related to yearly trends. Error deviance for bag seine data was based on evaluation of models including Month, Year, Month by Year interaction. The terms Month, Year, and Month*Year were categorical variables, whereas YEAR was a continuous variable. In models i and ii, the terms Month, Year, and Month*Year were included in order to evaluate variation in CPUE among months within individual years and among months from year to year. Models iii and iv were used to evaluate yearly trends.

Trend Analyses for Trawl Data

In all cases, CPUE = CATCH/10 min. Trawl data were evaluated for conformance to the following models:

i. Log(mean CPUE) = b_o + Month + Year + Month*Year
ii. Log(mean CPUE) = b_o + Month + Year
iii. Log(mean CPUE) = b_o + Month + b_1*YEAR
iv. Log(mean CPUE) = b_o + Month + b_1*YEAR + b_2*YEAR^2,

where the various terms were the same as in the bag seine model.

Data Summarization

The regression-fitted annual models were plotted as “actual” and “modelled” CPUE (ordinate) versus Year (abscissa) in order to provide a graphical representation of the predictive value of the models: 95% confidence limits were estimated and plotted on the same set of axes to demonstrate the degree of variation in the modelled CPUE. ANODE results were summarized in tabular form. Tables provide linear YEAR and/or quadratic YEAR effects and an error term which represents all other possible effects. For gill net analyses, ANODE tables do not include effects attributable to Monthly (MONTH) variation, because gill net data were collected seasonally.

Spatial Distribution

Data from selected months were plotted using Arcview-GIS (Version 3.0), which superimposes a circle, whose diameter represents a range of CPUE values, on a map of each bay. The position of the circle indicates the sampling location from which CPUE data were derived. Data used to create spatial distribution maps were different from data used in the trend analysis, because trend analysis examined changes in CPUE of a particular size or age group as a function of time, whereas spatial analysis examined where the species was distributed in terms of relative abundance. As such, data extracted for the purpose of spatial distribution analysis was not subject to temporal constraints imposed to avoid repetitive sampling as in the case of trend analysis; the information content of spatial distribution maps was greatly enhanced by including other months when study species were caught in large numbers. Based on the calculated mean (x), minimum (MIN), and maximum (MAX) CPUE values, the relative abundance of a species was divided into four categories, each represented by a different circle size. Circle sizes (smallest [1] to largest [4]) were set to represent relative abundance as follows:

Size 1: $\text{CPUE} < [\text{MIN} + 0.5(x - \text{MIN})]$
Size 2: $[\text{MIN} + 0.5(x - \text{MIN})] \leq \text{CPUE} < x$
Size 3: $x \leq \text{CPUE} < [x + 0.5(\text{MAX} - x)]$
Size 4: $\text{CPUE} \geq [x + 0.5(\text{MAX} - x)]$

Maps generated with this procedure depict the spatial distribution of catches according to relative size of the circle at each sampling location. One map was created for each species/gear type/bay combination.

RESULTS

Results of the trend analyses are summarized below (Table VI.1). Several model outcomes are possible, including no trend (NT), linear increasing (+LIN) or decreasing (-LIN), or curved (i.e., quadratic [Q]). In the latter case, the model will either curve upward after a predicted minimum (Q;MIN) or downward after a predicted maximum (Q;MAX). Results are arranged as species/gear type/bay combinations.

Table VI.1. Summary results of trend analyses. BS = bag seine; TR = trawl; GN = gill net. COR = Corpus Christi Bay; ARA = Aransas Bay; ULM = Upper Laguna Madre. Dates given are the years included in the analyses.

Species	Gear Type	COR	ARA	ULM
red drum	BS (79-93)	NT	NT	Q; MIN=85
	GN (79-93)	+LIN	+LIN	Q; MIN=82
spotted seatrout	BS (78-93)	NT	NT	Q; MIN=86
	GN (79-93)	+LIN	NT	Q; MIN=87
white shrimp	BS (79-93)	Q; MIN=88	Q: MAX=88	+LIN
	TR (82-93)	NT	MIN=88+LIN	
brown shrimp	BS (79-93)	Q; MIN=86	-LIN	Q; MAX=88
	TR (82-93)	Q; MAX=86	Q; MAX=89	Q; MIN=87
black drum	GN (79-93)	Q; MIN=85	Q; MIN=85	Q; MIN=84
blue crab	BS (79-93)	NT	NT	NT
	TR (83-93)	NT	NT (82-93)	Q; MIN=88
	GN (79-93)	Q; MAX=88	Q; MAX=86	Q; MAX=87
Atlantic croaker	BS (78-93)	NT	NT	NT
	GN (79-93)	NT	NT	Q; MAX=81
pink shrimp	BS (78-93)	NT	+LIN	+LIN
	TR (83-93)	Q; MAX=89	Q; MAX=87	+LIN
Southern flounder	BS (78-93)	Q; MAX=89	Q; MAX=85	-LIN
	GN (79-93)	NT	NT	Q; MAX=83
Gulf menhaden	BS (1978-1993)	Q; MAX=84	-LIN	-LIN
	TR (1982-1993)	Q; MAX=88	-LIN	-LIN
	GN (1979-1993)	Q; MAX=82	Q; MAX=84	-LIN

Results of the analyses are ordered according to the species priority system specified by the CCBNEP. Descriptions of the raw data for each species/gear type/bay combination and results of the analyses of deviance used to test the significance of linear and quadratic components of best-fit models are presented in the Appendix.

Analysis for red drum (*Sciaenops ocellatus*)
red drum/gill net/ Corpus Christi Bay

Modelled CPUE increased linearly during 1979-1993 (Table IX.1). Actual CPUE during 1986-1989 was lower than in 1985. There were very large increases in actual CPUE during 1990-1991, followed by a significant drop in actual CPUE in 1992. Actual CPUE then improved in 1993. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.2.

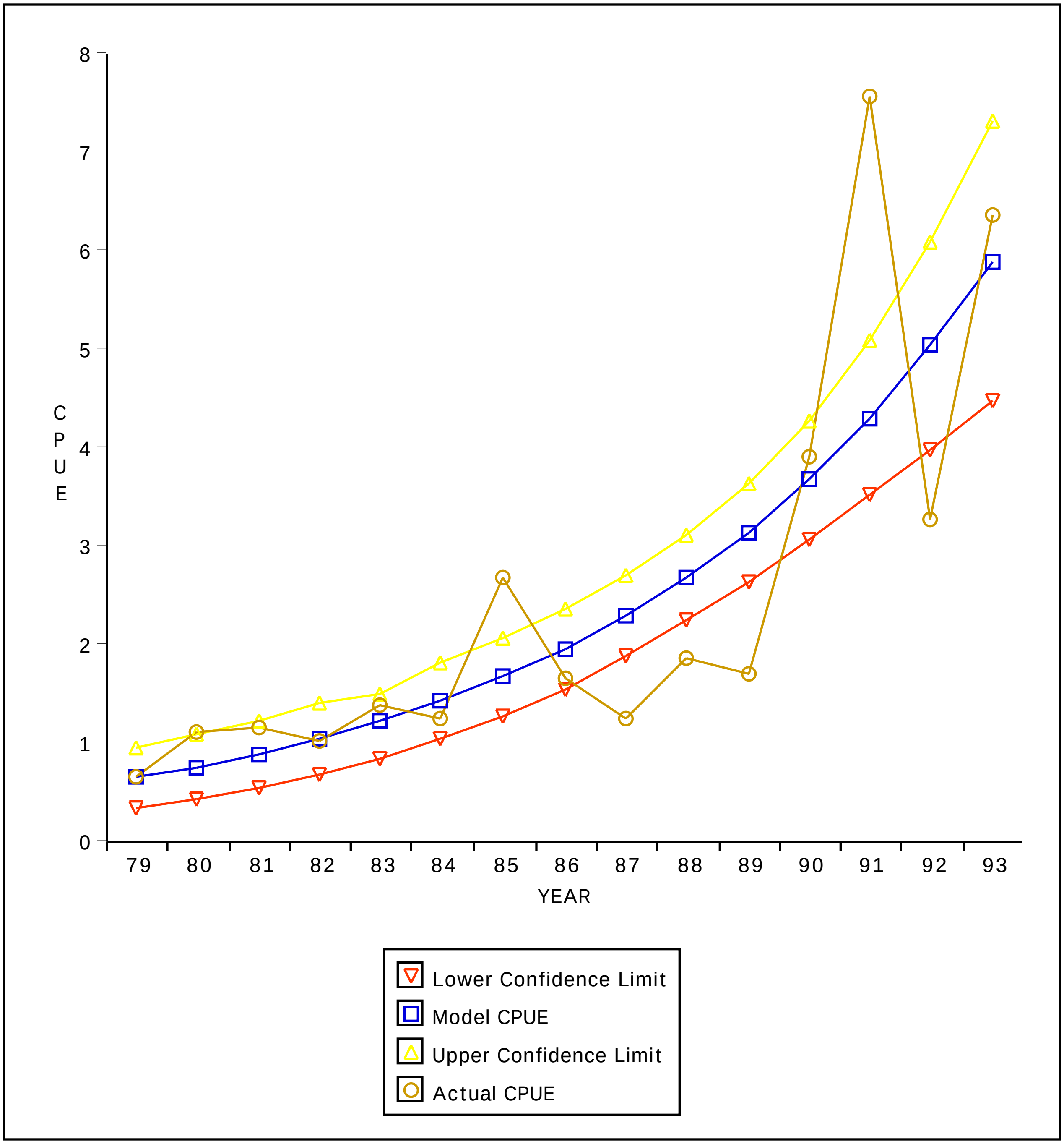

Figure VI.1. Actual catch per unit of effort and model with significant linear component (**CPUE**

$= b_0 + b_1$*YEAR, where CPUE = CATCH/(GTIME/14)^2) for subadult red drum (525-749 mm TL) caught by gill net in Corpus Christi Bay during the Spring netting season.

red drum/gill net/ Aransas Bay

Modelled CPUE increased linearly (Table IX.2). The two largest actual CPUE values were recorded in 1990 and 1993, whereas the lowest actual CPUE values were recorded in 1983 and 1984. Actual CPUE fluctuated substantially during the study. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.4.

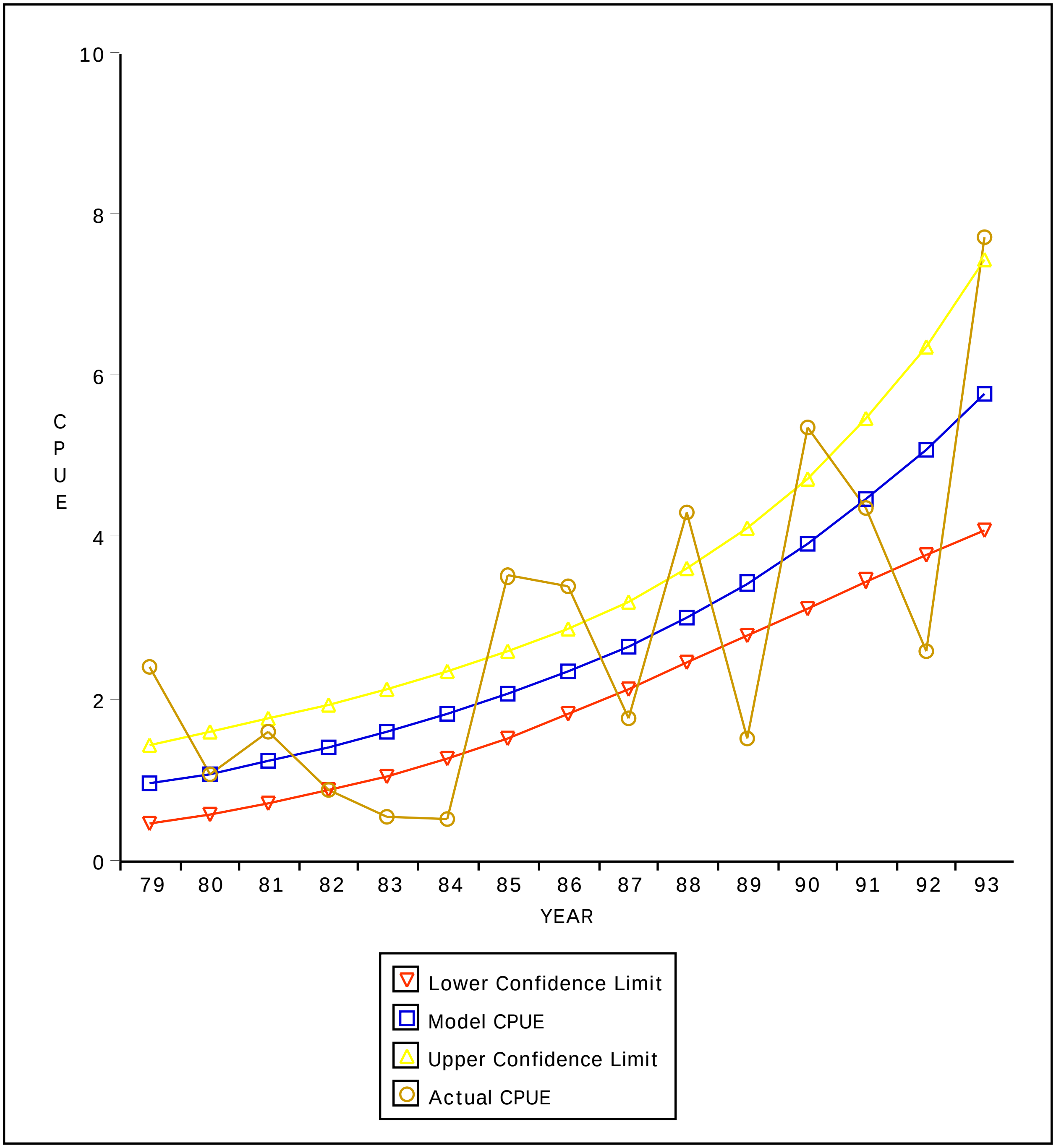

Figure VI.3. Actual catch per unit of effort and model with significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/(GTIME/14)^2) for subadult red drum (525-749 mm TL) caught by gill net in Aransas Bay during the Spring netting season.

red drum/gill net/Upper Laguna Madre

Modelled CPUE curved upward after 1982 (Table IX.3). Actual CPUE was generally poor prior to 1986, with very low CPUE recorded in 1979, 1982, 1983, and 1986. Improvements in CPUE were detected in 1990 and 1993. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.6.

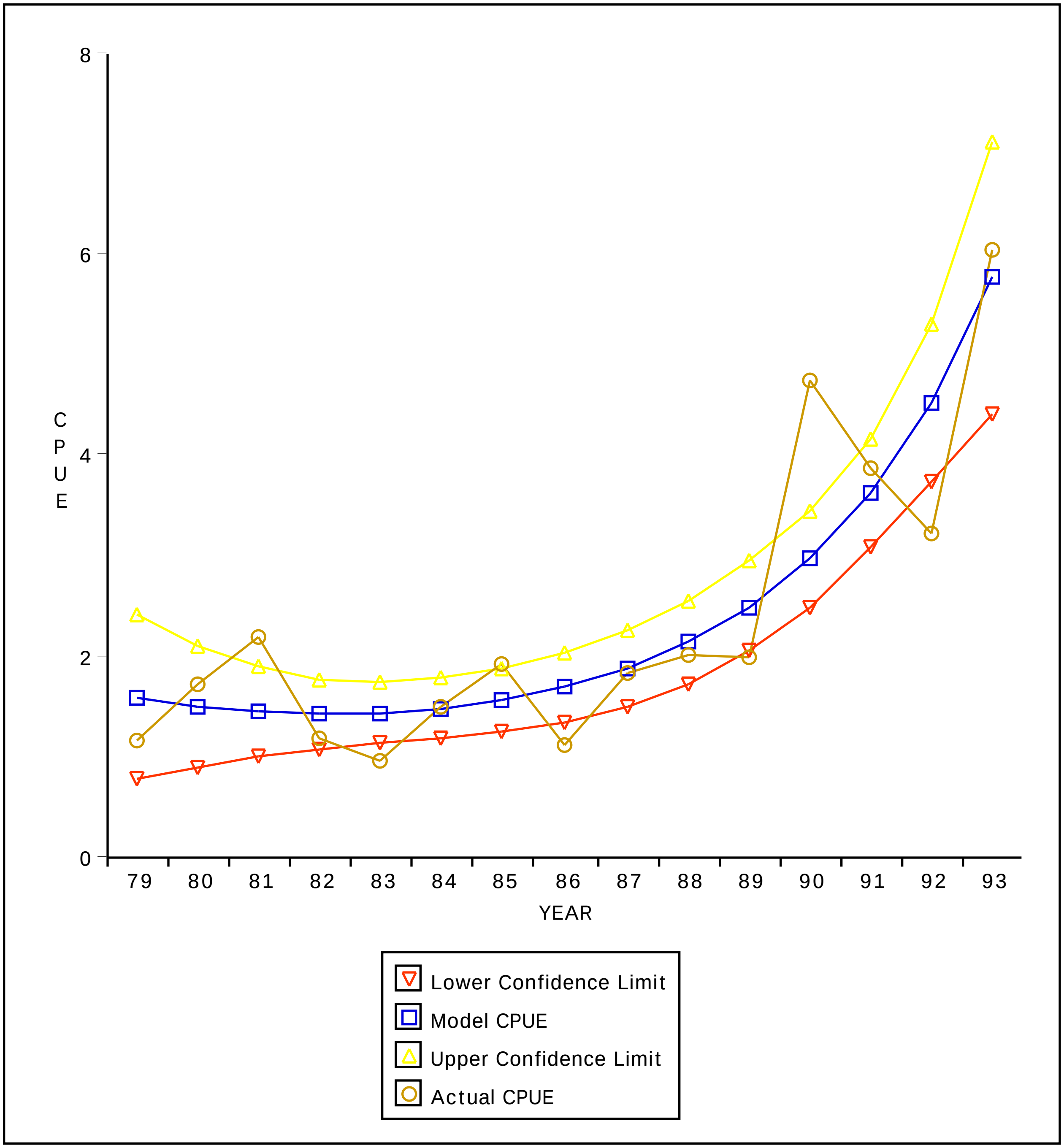

Figure VI.5. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR** + **b_2*YEAR^2,** where CPUE = CATCH/(GTIME/14)^2) for subadult red drum (525-749 mm TL) caught by gill net in Upper Laguna Madre during the Spring netting season.

red drum/gill net/model comparison

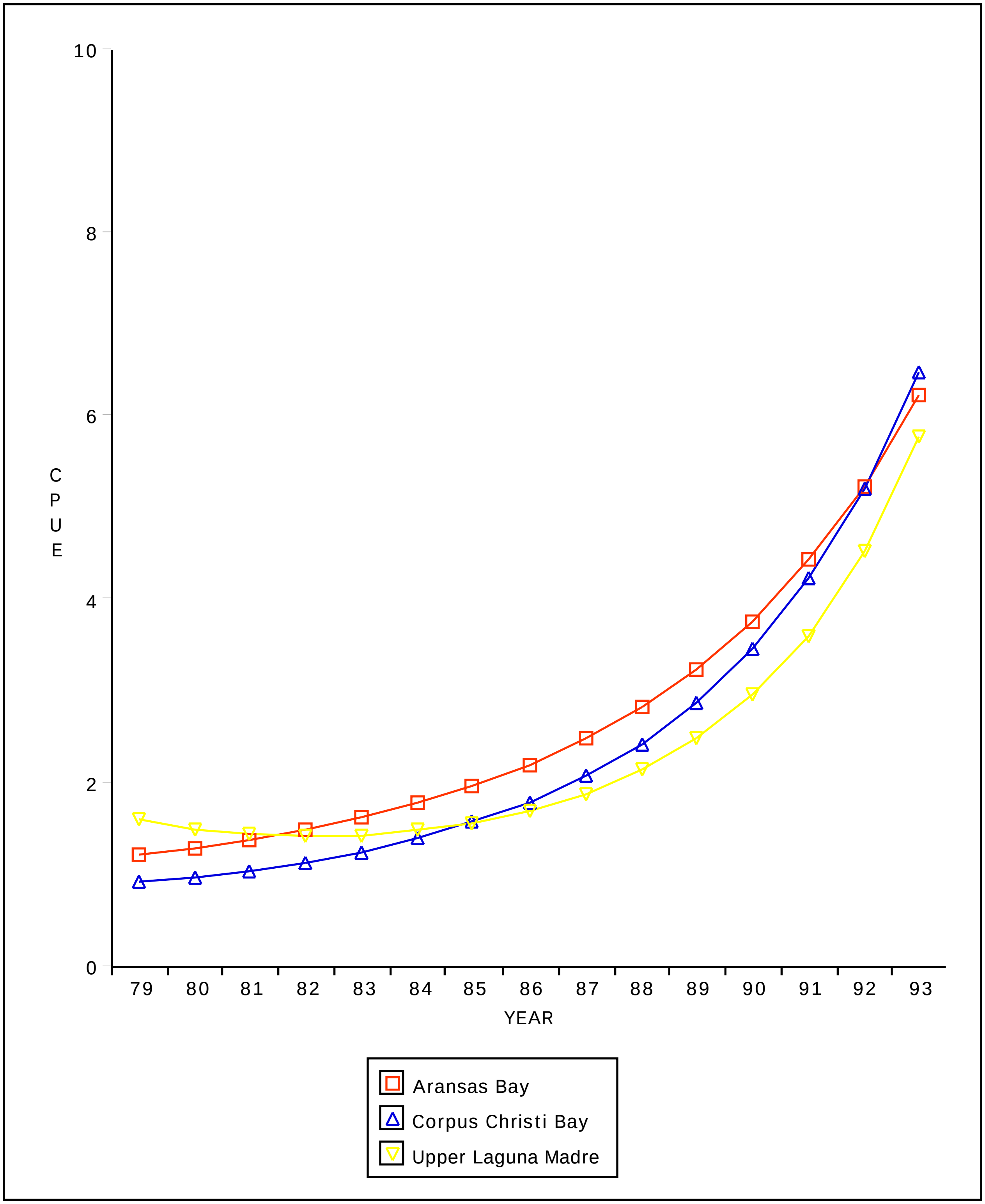

Figure V1.7. Comparison of best-fit models for subadult red drum (525-749 mm TL), caught by gill net in the CCBNEP (Table IX.4). CPUE = CATCH/(GTIME/14)^2 for all models.

red drum/bag seine/Corpus Christi Bay

There was no trend in modelled CPUE (Table IX.5). Virtually no red drum were caught by bag seine during 1984-1989. Yields were phenomenal in 1981 and 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.9.

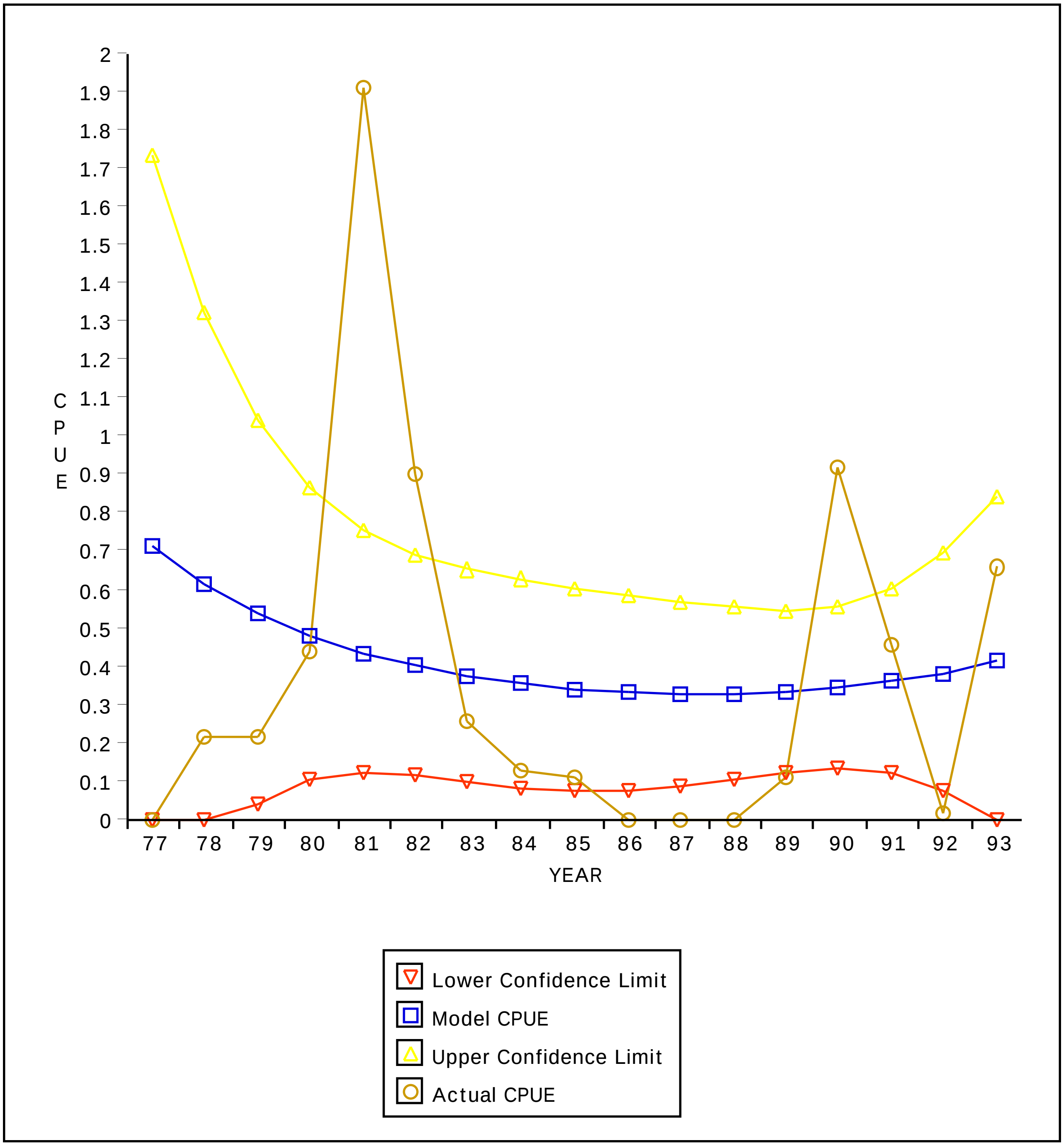

Figure VI.8. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year red drum (20-39 mm TL) caught by bag seine in Corpus Christi Bay during October, November, and December.

red drum/bag seine/ Aransas Bay

There was no trend in modelled CPUE (Table IX.6). Virtually no red drum were caught by bag seine during the years 1977-1980 and 1983-1989. Yields were phenomenal in 1981 and 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.11.

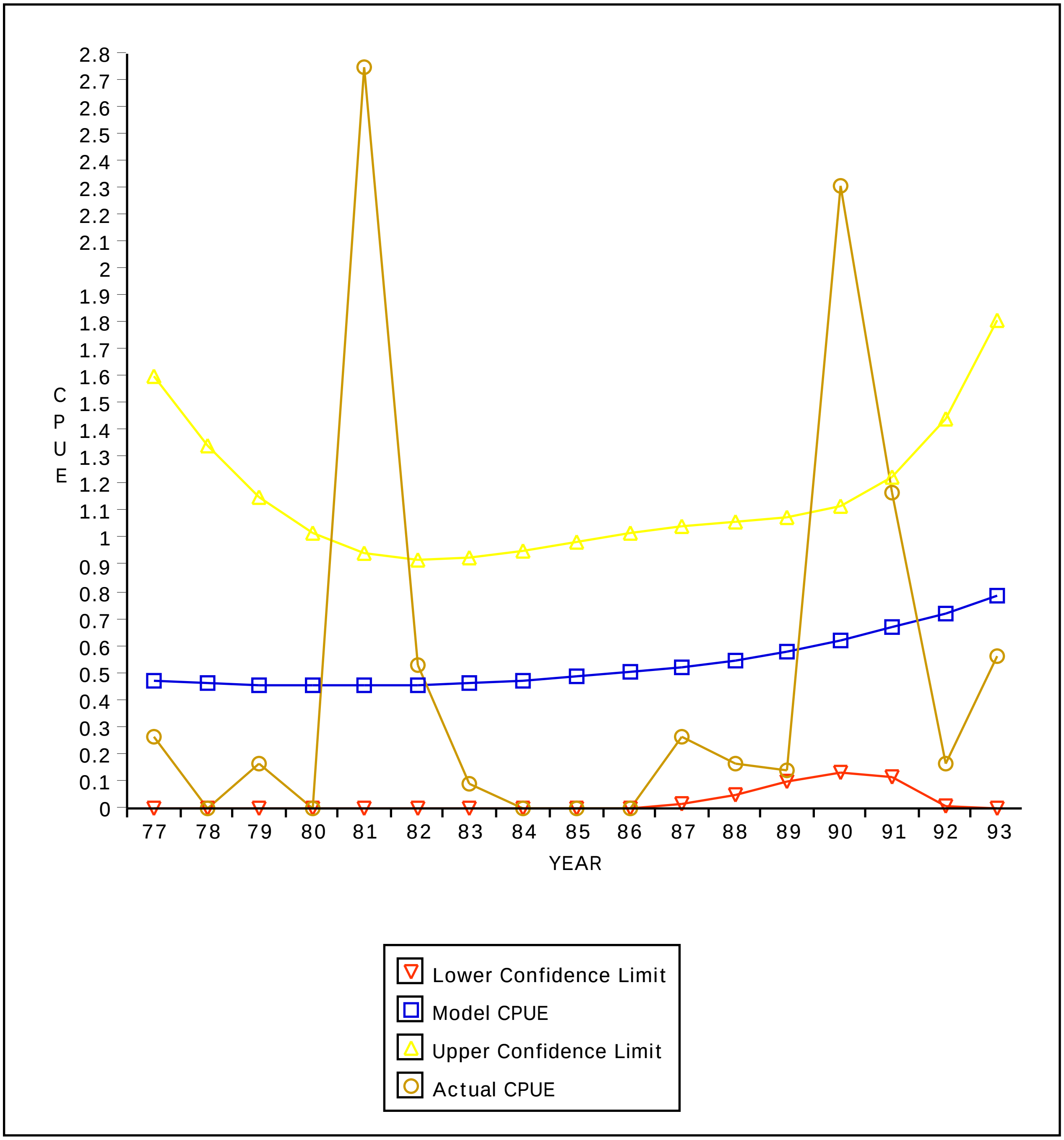

Figure VI.10. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year red drum (20-39 mm TL) caught by bag seine in Aransas Bay during October, November, and December.

red drum/bag seine/Upper Laguna Madre

Modelled CPUE curved upward after 1985 (Table IX.7). CPUE was phenomenal in 1979. Virtually no red drum were caught during 1982-1987. Improved yields in 1988, 1990, and 1992 strongly influenced the upward curvature of the quadratic model. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.13.

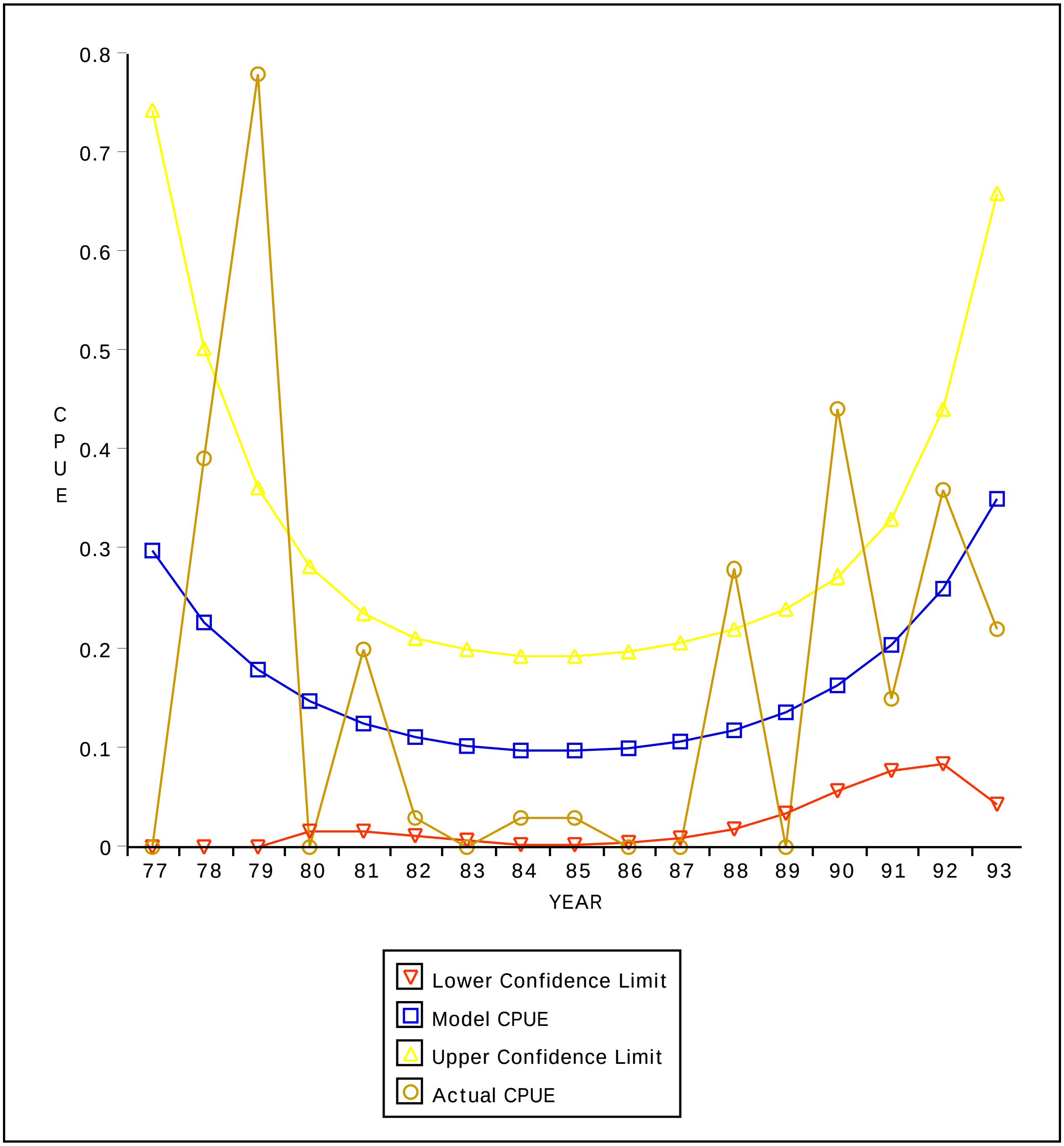

Figure VI.12. Actual catch per unit of effort and model with a significant quadratic component (**$CPUE = b_0 + b_1*YEAR + b_2*YEAR^2$**, where CPUE = CATCH/0.03 hectare) for young-of-the-year red drum (20-39 mm TL) caught by bag seine in Upper Laguna Madre during October, November, and December.

red drum/bag seine/model comparison

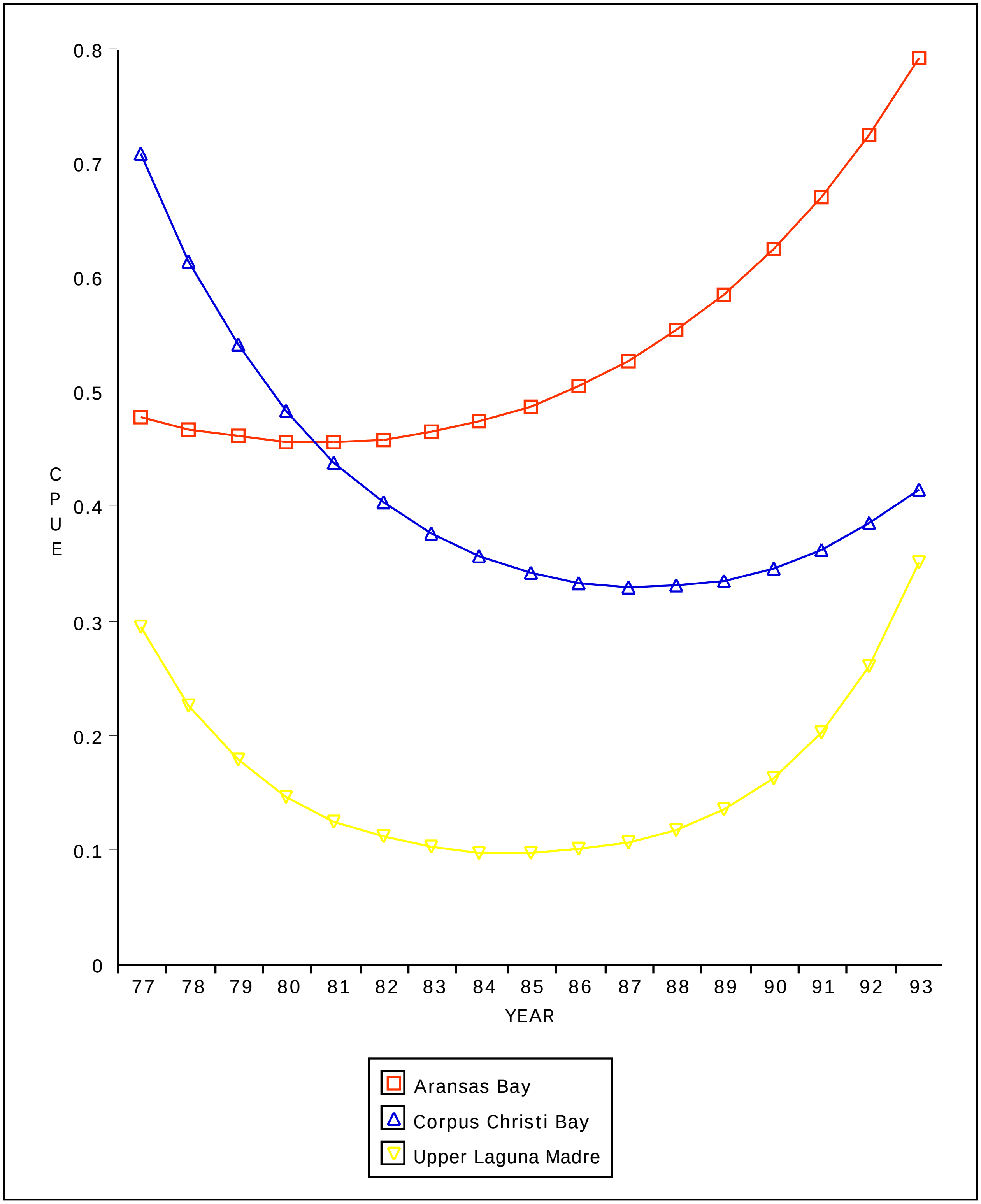

Figure VI.14. Comparison of best-fit models for young-of-the-year red drum (20-39 mm TL) caught by bag seine in the CCBNEP (Table IX.8). CPUE = CATCH/0.03 hectare for all models.

Results and Discussion for red drum

Results of red drum analyses indicate that the population dynamics of this species should be examined during more than one stage of its life, because substantial differences in YOY versus subadult CPUE were observed. In all three bays, modelled gill net CPUE of adults increased significantly. These increases were linear for Corpus Christi and Aransas Bays. For Upper Laguna Madre, the best-fit model curved upward after 1982. By contrast, no statistically significant trend was detected in modelled bag seine CPUE of YOY in both Corpus Christi and Aransas Bays. Red drum bag seine CPUE in Upper Laguna Madre curved upward after 1985. Examination of actual catch by bag seine revealed similarities between Corpus Christi and Aransas Bays. This was evident from peaks in actual catch seen in 1981 and 1990 and extremely poor CPUE in both bays during 1977-1980 and 1983-1989. Conversely, a major peak in red drum actual bag seine CPUE was detected in Upper Laguna Madre in 1979, whereas only a minor peak was evident in Upper Laguna Madre in 1981.

An interesting aspect of the results for red drum is that early year peaks in bag seine CPUE corresponded with peaks observed in gill net data a few years later. For example, relatively large numbers of YOY red drum were collected in both Corpus Christi and Aransas Bays in 1981 and, coincidentally, the first perceptible peaks in gill net catch were observed in 1985 in Corpus Christi Bay and 1985-1986 in Aransas Bay. It is predictable that YOY cohorts sampled by bag seine in 1981 would have reached large enough size to be caught by gill net in 1985-1986. During the latter years of the study period, actual CPUE by bag seine of red drum in Corpus Christi Bay exhibited a peak in 1990 which was followed by a peak in actual CPUE by gill net in 1993. Bag seine CPUE in Aransas Bay and Upper Laguna Madre also exhibited noticeable peaks in 1990.

It is clear that relatively few YOY red drum were caught during 1983-1986. This finding was expected given that a severe freeze occurred in Texas in 1983 and a red tide plagued Texas waters in 1986. Despite the 1983-1986 anomaly in bag seine catch, significant long-term increases in CPUE of subadult red drum in all three bays were probably due to concerted effects of the netting ban, increasingly protective bag and size limits (i.e., three red drum 20-28 inches can be kept), and the production and release of millions of red drum fry (1-2 mm TL) and fingerlings (25-25 mm TL) by TPWD. Since the inception of the TPWD Stocking Program in 1983, Aransas Bay (913,168,907 fry; 20,615,457 fingerlings), Corpus Christi Bay (146,075,488 fry; 25,150,438 fingerlings), and Upper Laguna Madre (618,693,859 fry; 34,013,663 fingerlings), have yielded significantly increasing numbers of subadult red drum. Results of this analysis suggest that, with regard to increased yields of subadult red drum, the effects of the Stocking Program were perceptible 3-4 years after the 1986 red tide.

Analysis for spotted seatrout (*Cynoscion nebulosus*)
spotted seatrout/gill net/Corpus Christi Bay

Modelled CPUE increased linearly (Table IX.9). CPUE was extremely poor during 1979-1980 and in 1984. Great improvement in CPUE was seen in 1990 and again during 1992-1993. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.16.

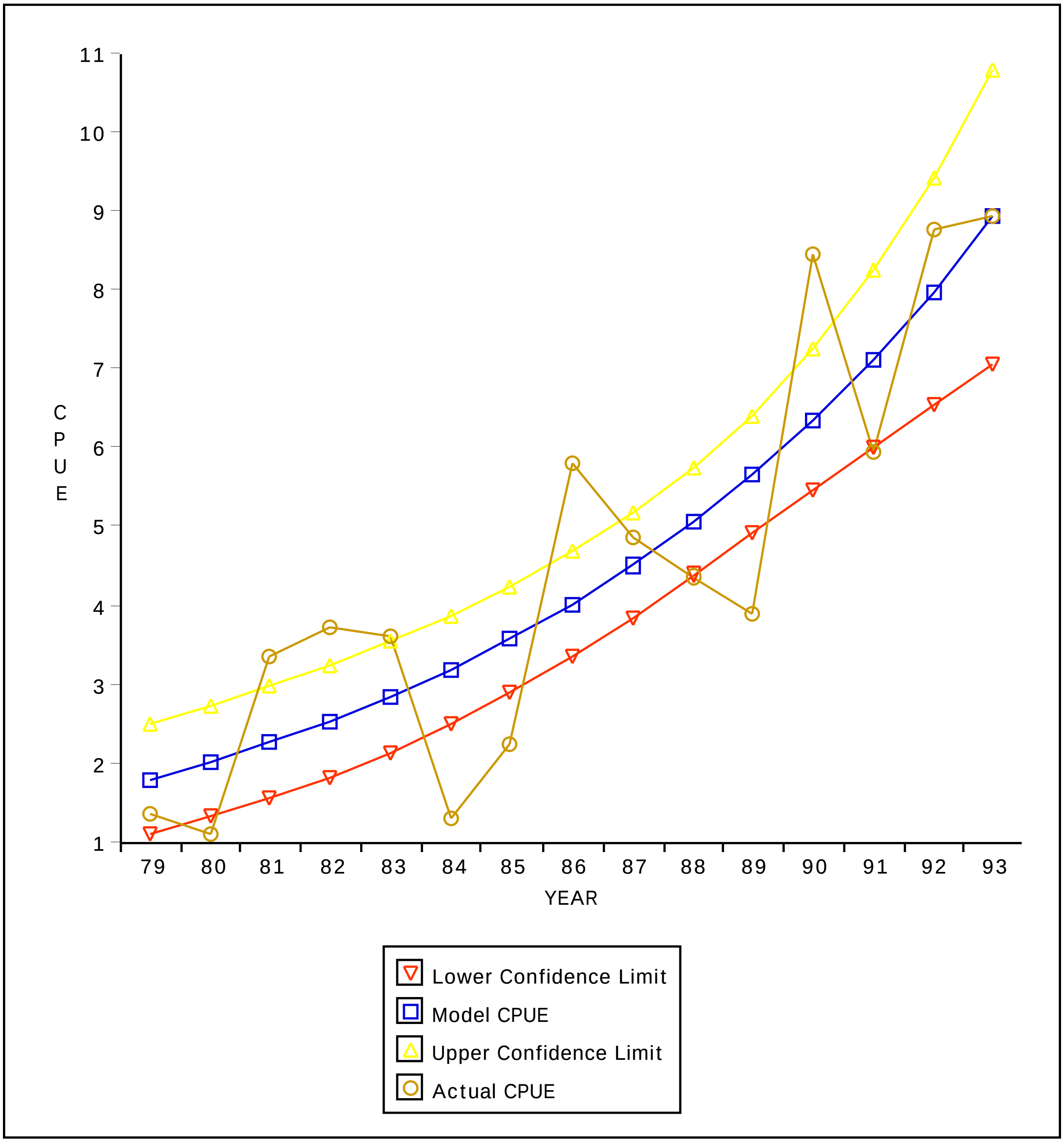

Figure VI.15. Actual catch per unit of effort and model with significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/(GTIME/12.5)) for reproductively mature spotted seatrout (300-449 mm TL) caught by gill net in Corpus Christi Bay during the Spring netting season.

spotted seatrout/gill net/Aransas Bay

There was no statistically significant trend in modelled CPUE (Table IX.10). Actual CPUE was high during the early years of the survey (1981-1983) then showed steady improvement after the extremely poor yield recorded in 1984. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.18.

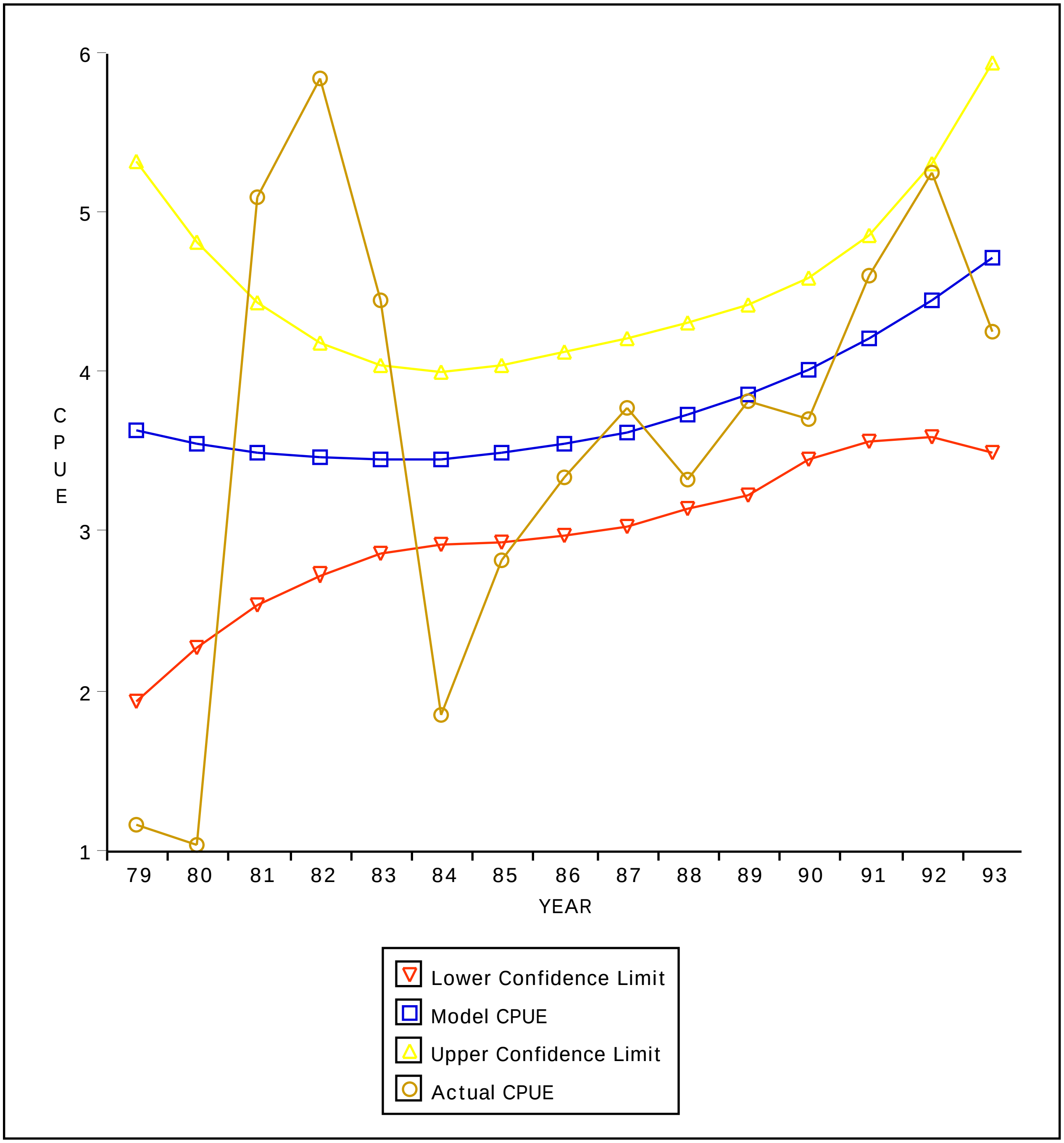

Figure VI.17. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = $\mathbf{b_0}$**, where CPUE = CATCH/(GTIME/12.5)) for reproductively mature spotted seatrout (300-449 mm TL) caught by gill net in Aransas Bay during the Spring netting season.

spotted seatrout/gill net/ Upper Laguna Madre

Modelled CPUE curved upward after 1987 (Table IX.11). Actual CPUE for spotted seatrout generally decreased during 1979-1984. CPUE showed some improvement in 1986 and 1991. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.20.

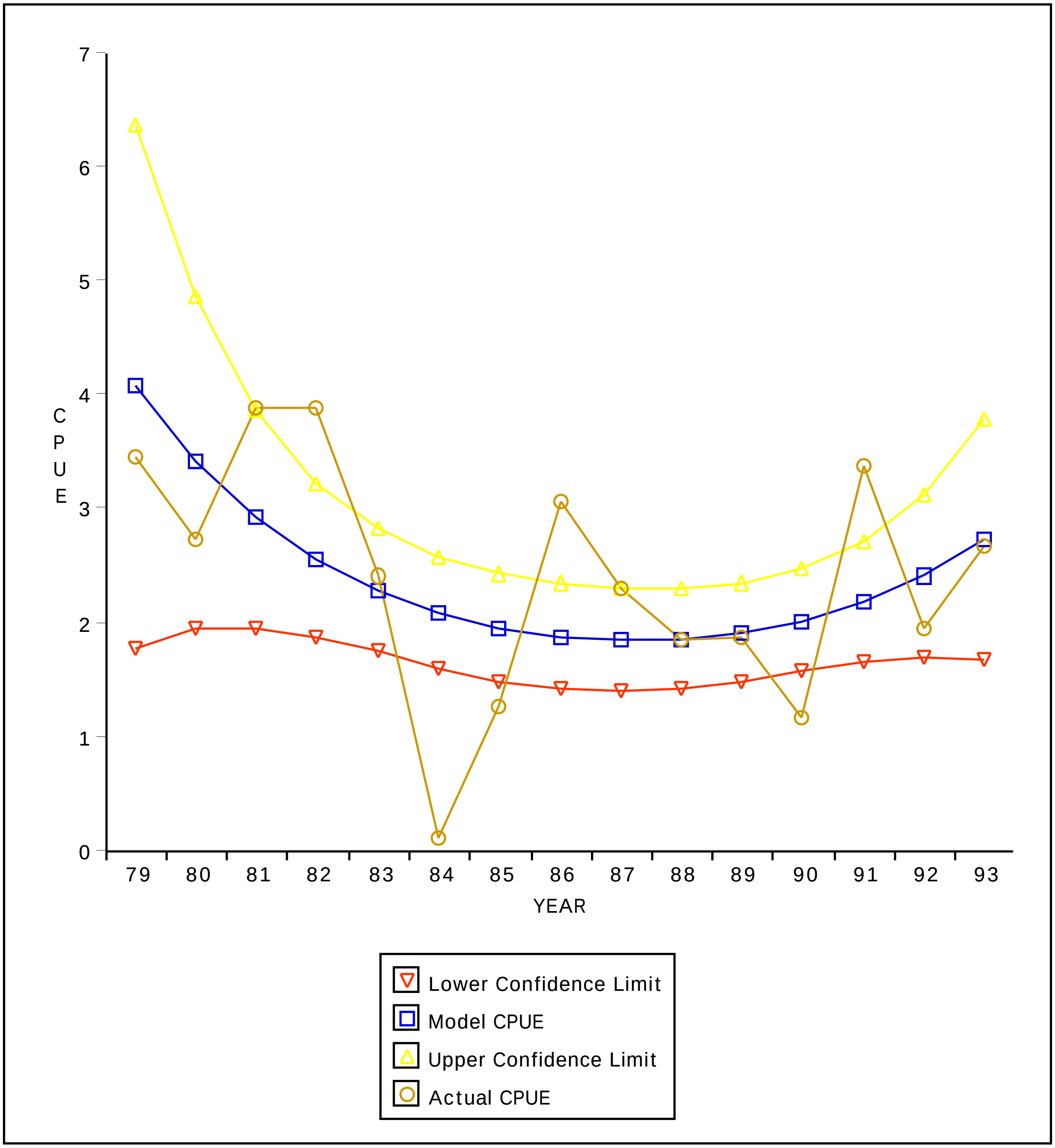

Figure VI.19. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_o + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/(GTIME/12.5)) for reproductively mature spotted seatrout (300-449 mm TL) caught by gill net in Upper Laguna Madre during the Spring netting season.

spotted seatrout/gill net/model comparison

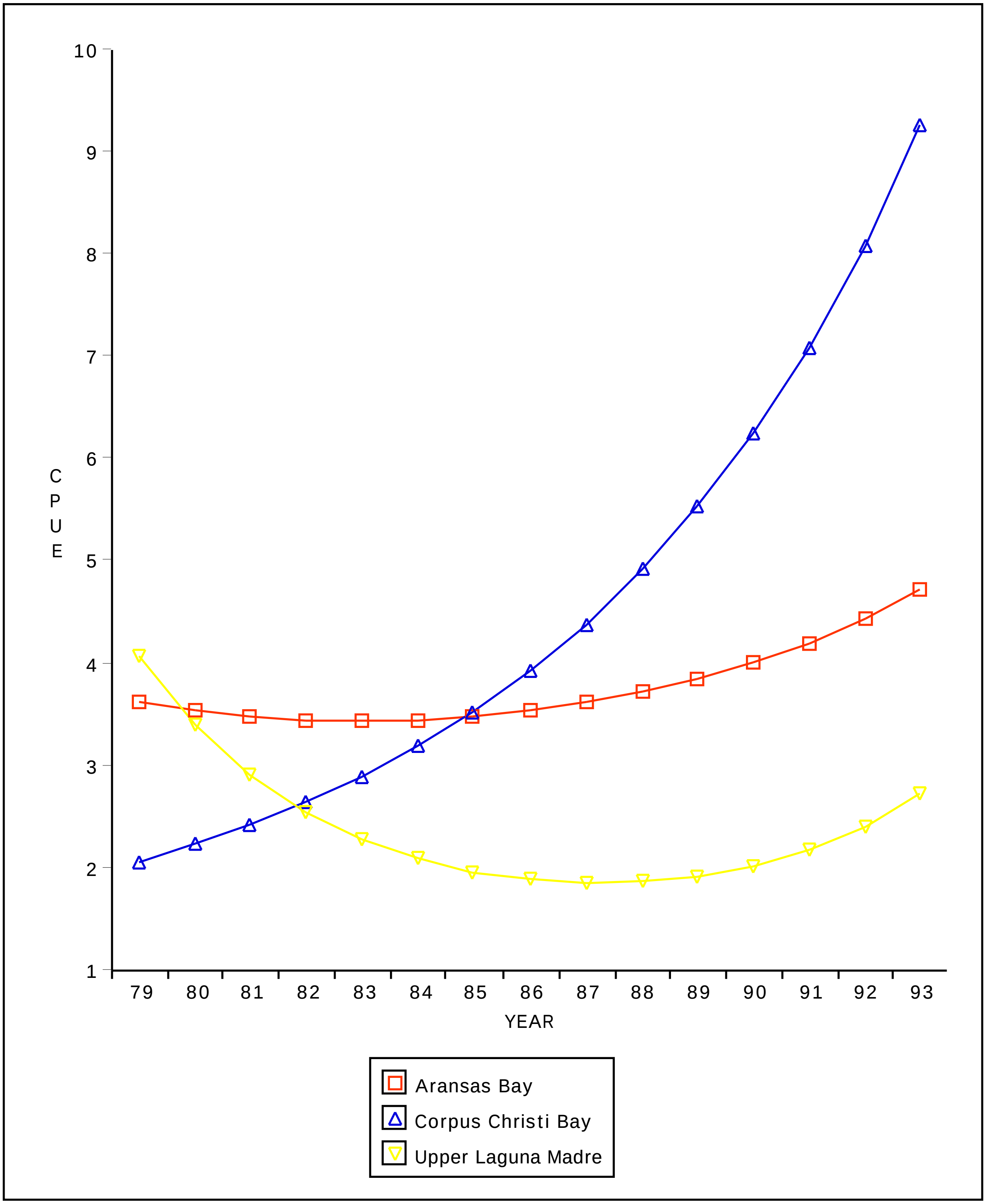

Figure VI.21. Comparison of best-fit models for reproductively mature spotted seatrout caught by gill net in the CCBNEP (Table IX.12). CPUE = CATCH/(GTIME/12.5) for all models.

spotted seatrout/bag seine/Corpus Christi Bay

There was no statistically significant trend in modelled CPUE (Table IX.13). Actual CPUE was poorest during 1982-1986 and virtually no spotted seatrout were caught in 1984. Phenomenal yields were recorded in 1981 and 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.23.

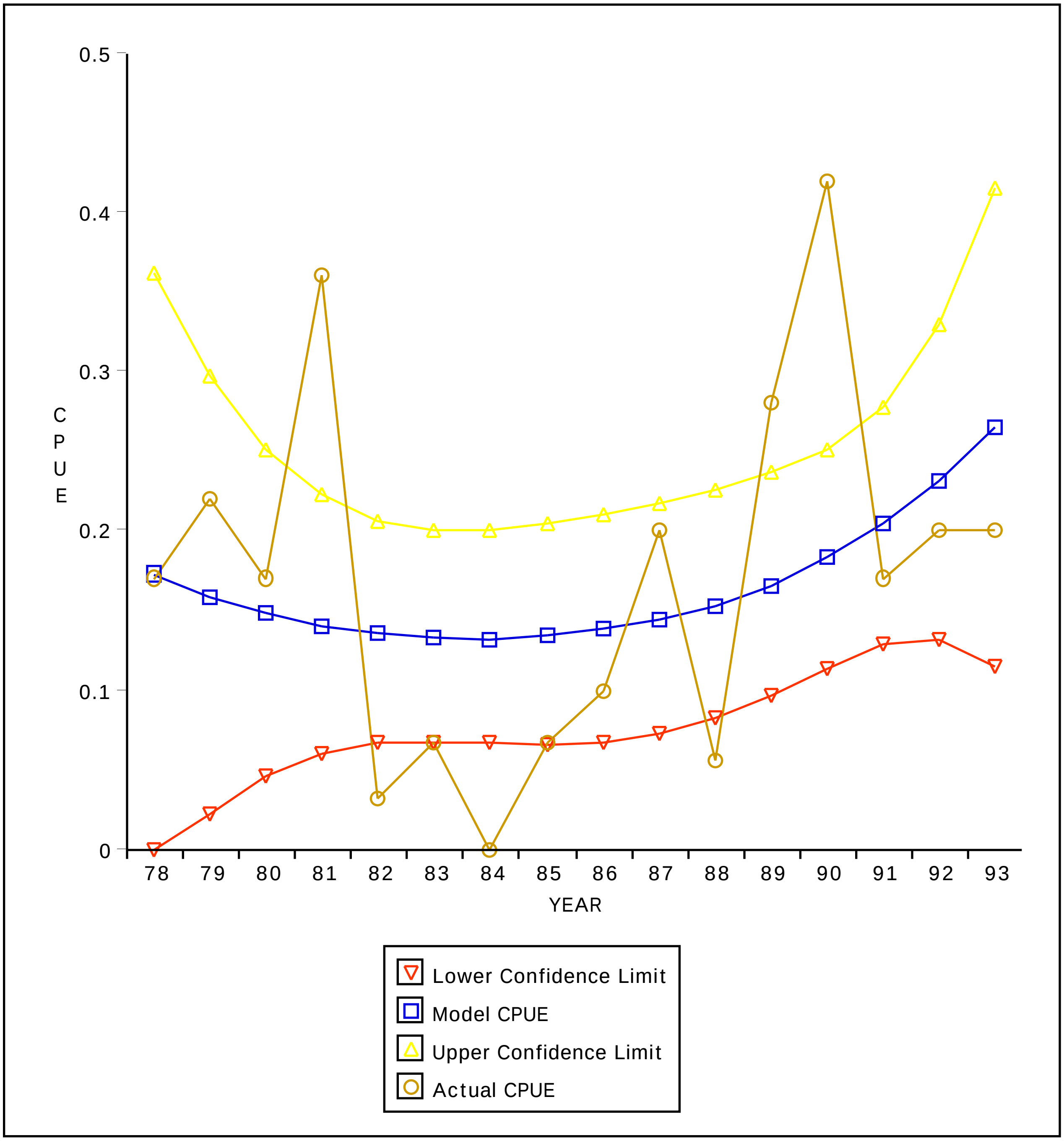

Figure VI.22. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year spotted seatrout (60-79 mm TL) caught by bag seine in Corpus Christi Bay during August, September, and October.

spotted seatrout/bag seine/Aransas Bay

There was no statistically significant trend in modelled CPUE (Table IX.14). Yields were generally poor during 1983-1987. A phenomenal yield was recorded in 1988. No sustained improvement in CPUE was seen after 1989. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.25.

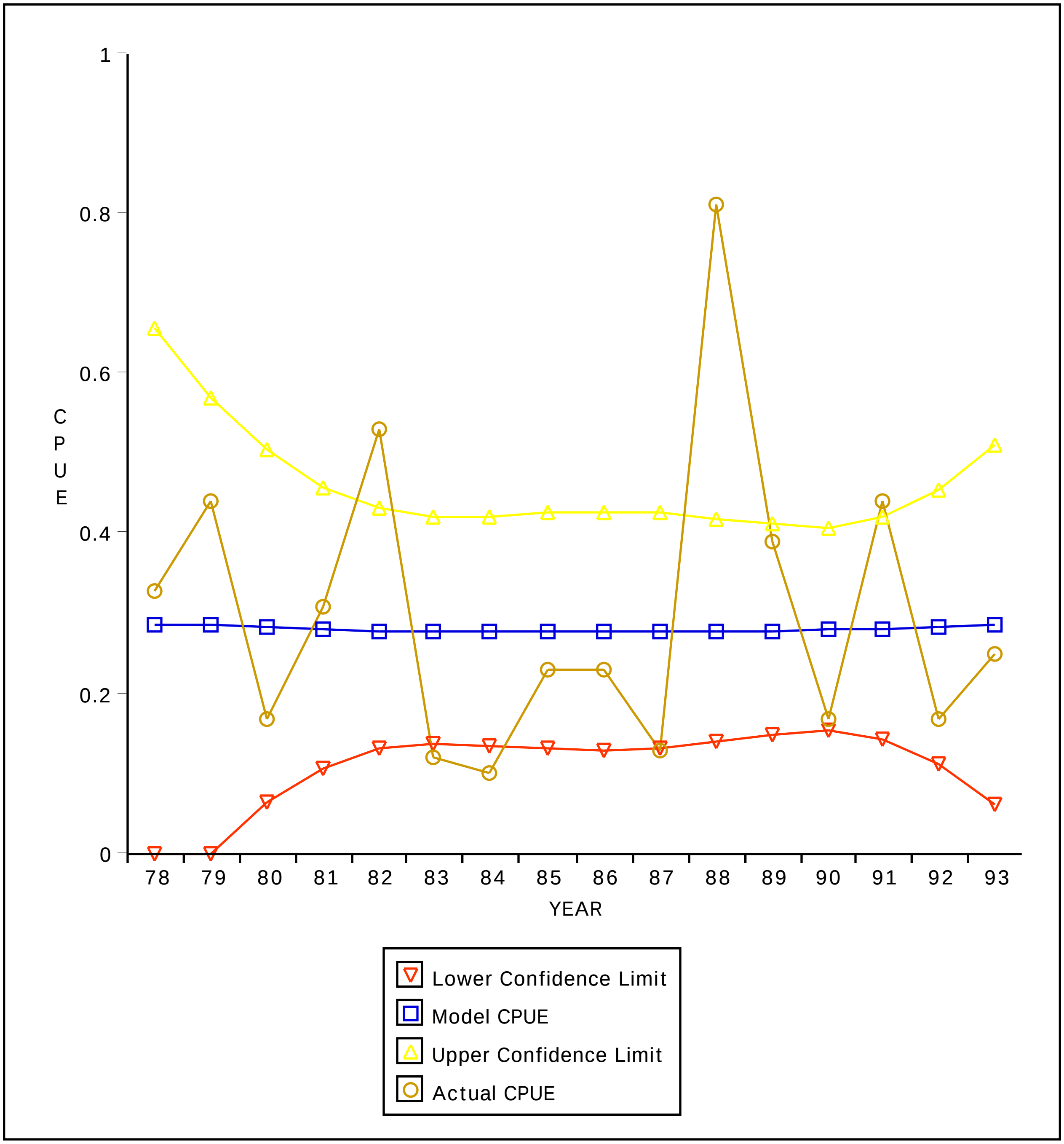

Figure VI. 24. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year spotted seatrout (60-79 mm TL) caught by bag seine in Aransas Bay during August, September, and October.

spotted seatrout/bag seine/Upper Laguna Madre

Modelled CPUE curved upward after 1986 (Table IX.15). Yields were phenomenal in 1982 and 1992 but they were generally very poor during 1983-1991. Virtually no spotted seatrout were caught during 1979-1980 and 1986-1990. Some improvement was seen after 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.27.

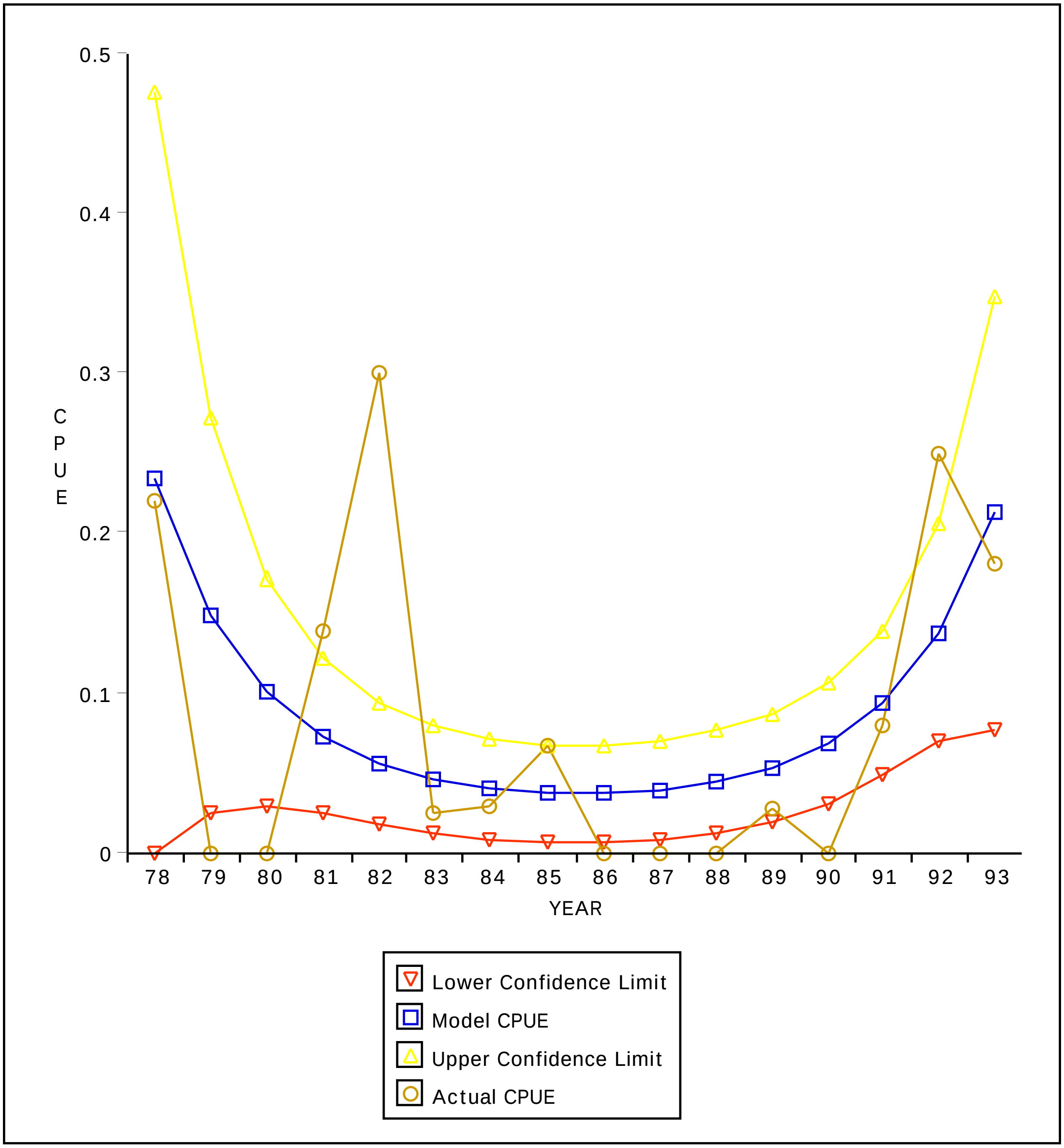

Figure VI.26. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/0.03 hectare) for young-of-the-year spotted seatrout (60-79 mm TL) caught by bag seine in Upper Laguna Madre during August, September, and October.

spotted seatrout/bag seine/model comparison

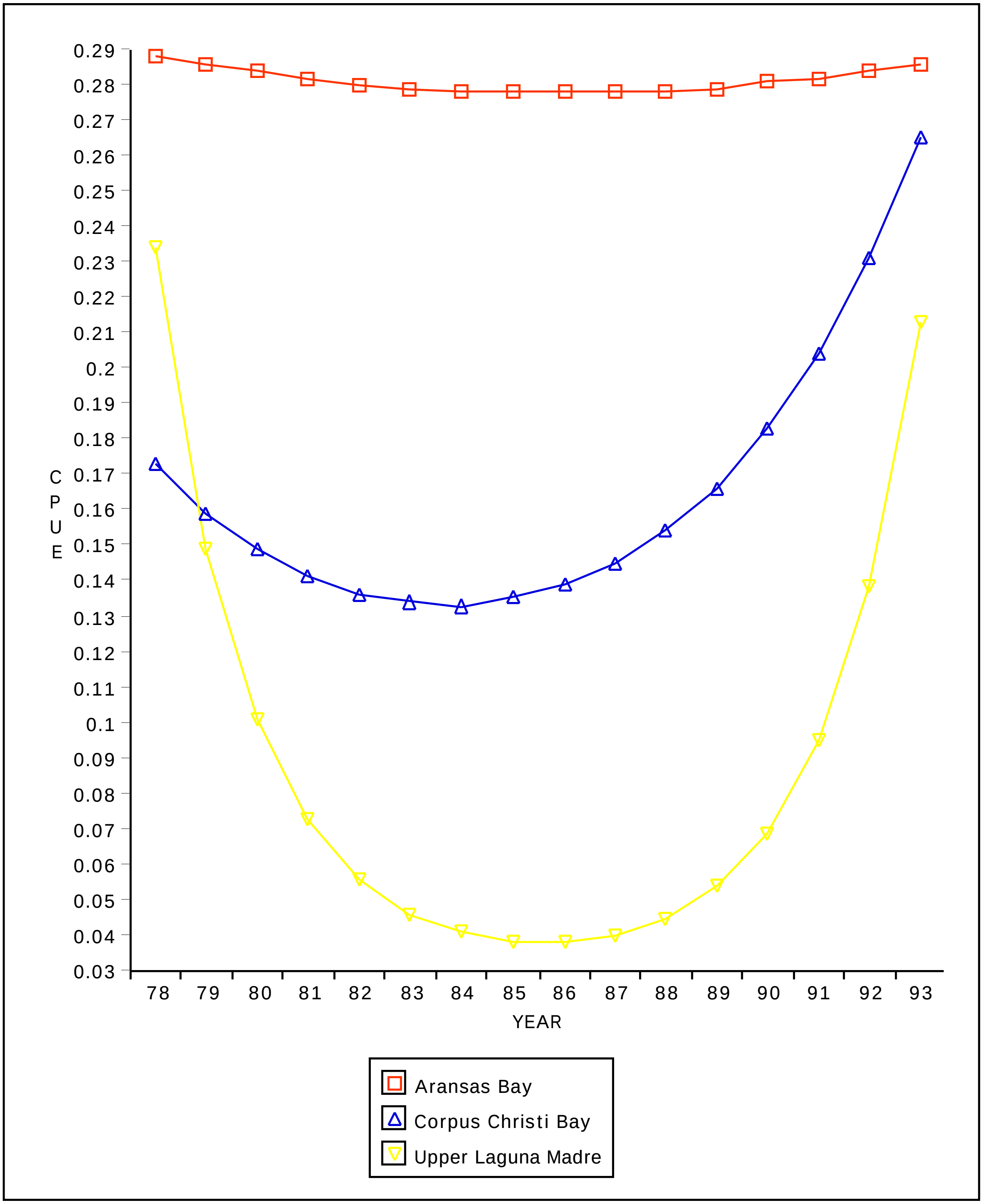

Figure VI.28. Comparison of best-fit models for young-of-the-year spotted seatrout (60-79 mm TL) caught by gill net in the CCBNEP (Table IX.16). CPUE = CATCH/0.03 hectare for all models.

Results and Discussion for spotted seatrout

Results of the trend analysis indicate actual and modelled bag seine and gill net catches within Upper Laguna Madre exhibited similar patterns: models for these gears both exhibited quadratic curvature, with minima only one year apart (1986 for bag seine and 1987 for gill net). An early year peak was detected in actual CPUE by both gears in 1982. A peak in actual bag seine CPUE was evident in 1992. Another latter year peak in actual gill net CPUE was detected in 1991. It is noteworthy that the interpolated minima for modelled gill net trend curves were not concordant with actual CPUE minima during the study. The poorest catch of spotted seatrout by gill net occurred in 1984, due to the effects of the 1983 freeze in Texas. Conversely, actual bag seine CPUE was at lowest levels in 1986 and 1987, thus the model minimum was in this case more concordant with the actual catch.

Despite the fact that modelled bag seine CPUE in Corpus Christi Bay was shown to have no significant linear or quadratic component, modelled gill net CPUE increased linearly. Interestingly, actual gill net CPUE peaked in 1990 and again during 1992-1993, whereas actual bag seine CPUE declined substantially after 1990. Bag seine and gill net actual CPUE minima evident in 1984 suggest that both YOY and reproductive spotted seatrout fared poorly in the year following the 1983 freeze. A noticeable peak was evident in actual gill net CPUE during 1986, but actual bag seine CPUE during 1986 was below the best-fit model minimum. This suggests that the 1986 red tide may have caused mortality of relatively more YOY than fish of reproductive size.

Modelled bag seine and gill net CPUE in Aransas Bay exhibited no significant linear or quadratic trends. Catches in both of these gears were relatively large in 1982, but below the best-fit model minima in 1984. Actual CPUE by bag seine was maximal in 1988, and a corresponding later-year peak was evident in 1991-1992 in gill net. Results of the analyses suggest no clear pattern of increase in spotted seatrout catches in Aransas Bay during the study. The analysis has shown the long-term spotted seatrout population growth in Aransas Bay to be static and thus clearly different from Corpus Christi Bay and Upper Laguna Madre populations. As noted for the increase in actual CPUE by bag seine of red drum seen in later years in the Upper Laguna Madre, increased catches of YOY spotted seatrout in the Upper Laguna Madre may have been due to increasingly protective management measures.

In summary, results of the trend analysis for spotted seatrout indicate stability or slight improvement of CPUE in Corpus Christi Bay and Upper Laguna Madre, particularly after the 1986 red tide, but no sustained population growth in Aransas Bay. A possible explanation is that TPWD has stocked substantially more fry (1-2 mm TL) or fingerlings (25-35 mm TL) in Upper Laguna Madre (183,486,303 fry; 9,762,613 fingerlings) and Corpus Christi Bay (40,858,750 fry; 4,407 fingerlings) than in Aransas Bay (231,170 fry; 236,422 fingerlings) between 1983 and the present. It should be noted that all except 4,438 fingerlings stocked into Upper Laguna Madre in 1984 have been stocked into the CCBNEP bays after 1990.

Analysis for white shrimp (*Penaeus setiferus*)
white shrimp/bag seine/Corpus Christi Bay

Modelled CPUE decreased curvilinearly after an interpolated model maximum in 1979 (Table IX.17). Actual CPUE was phenomenally high in 1979, but white shrimp catches were generally poor during 1980-1983, 1985-1990, and 1991-1993. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.30.

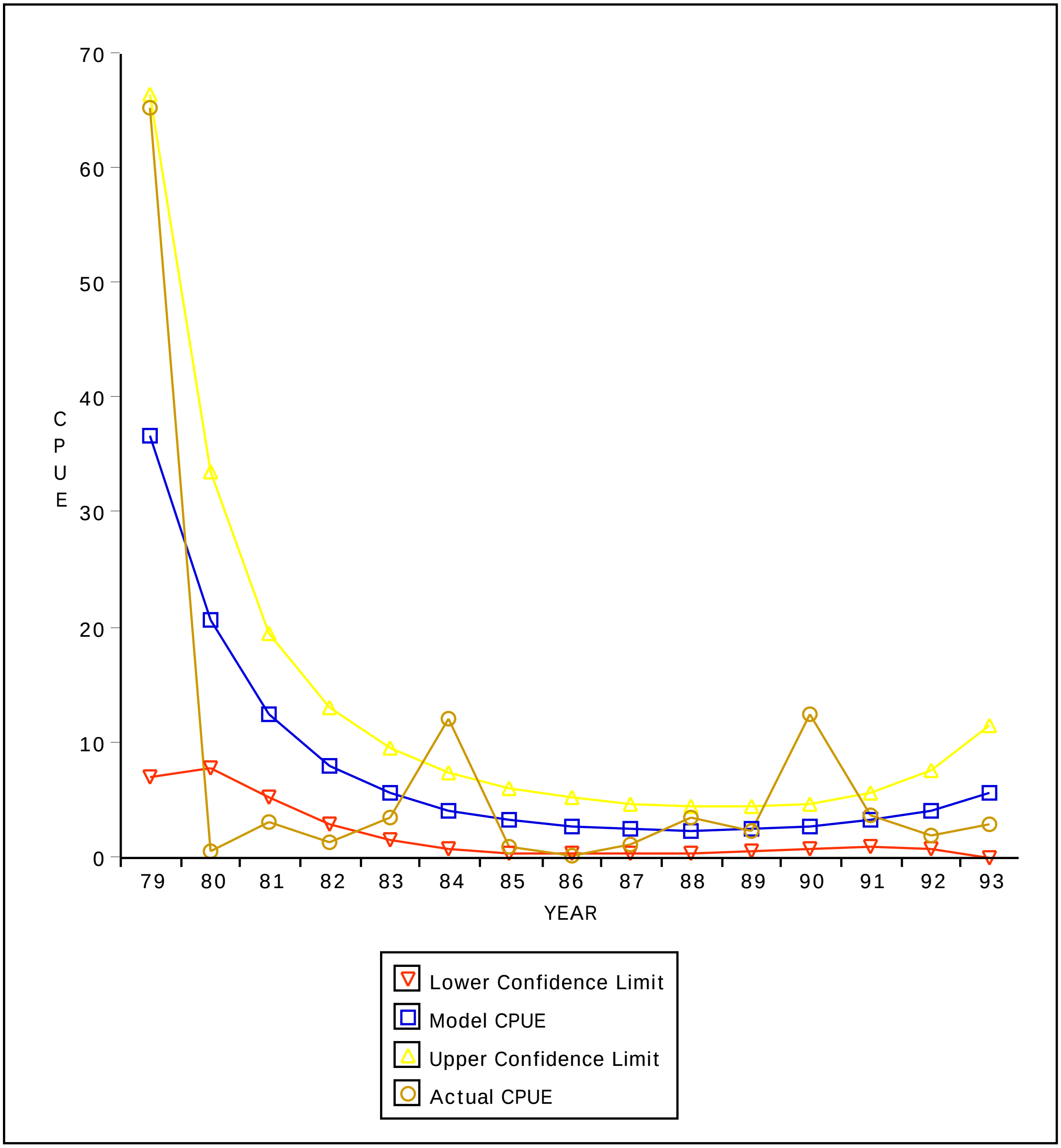

Figure VI.29. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year white shrimp (40-59 mm TL) caught by bag seine in Corpus Christi Bay during June, July, and August.

white shrimp/bag seine/Aransas Bay

Modelled CPUE reached a maximum in 1988. However, actual CPUE was generally poor during 1987-1989, so this quadratic model must be interpreted with caution (Table IX.18). A phenomenal peak in CPUE was recorded in 1990. After 1990 there was no sustained improvement in white shrimp yield. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.32.

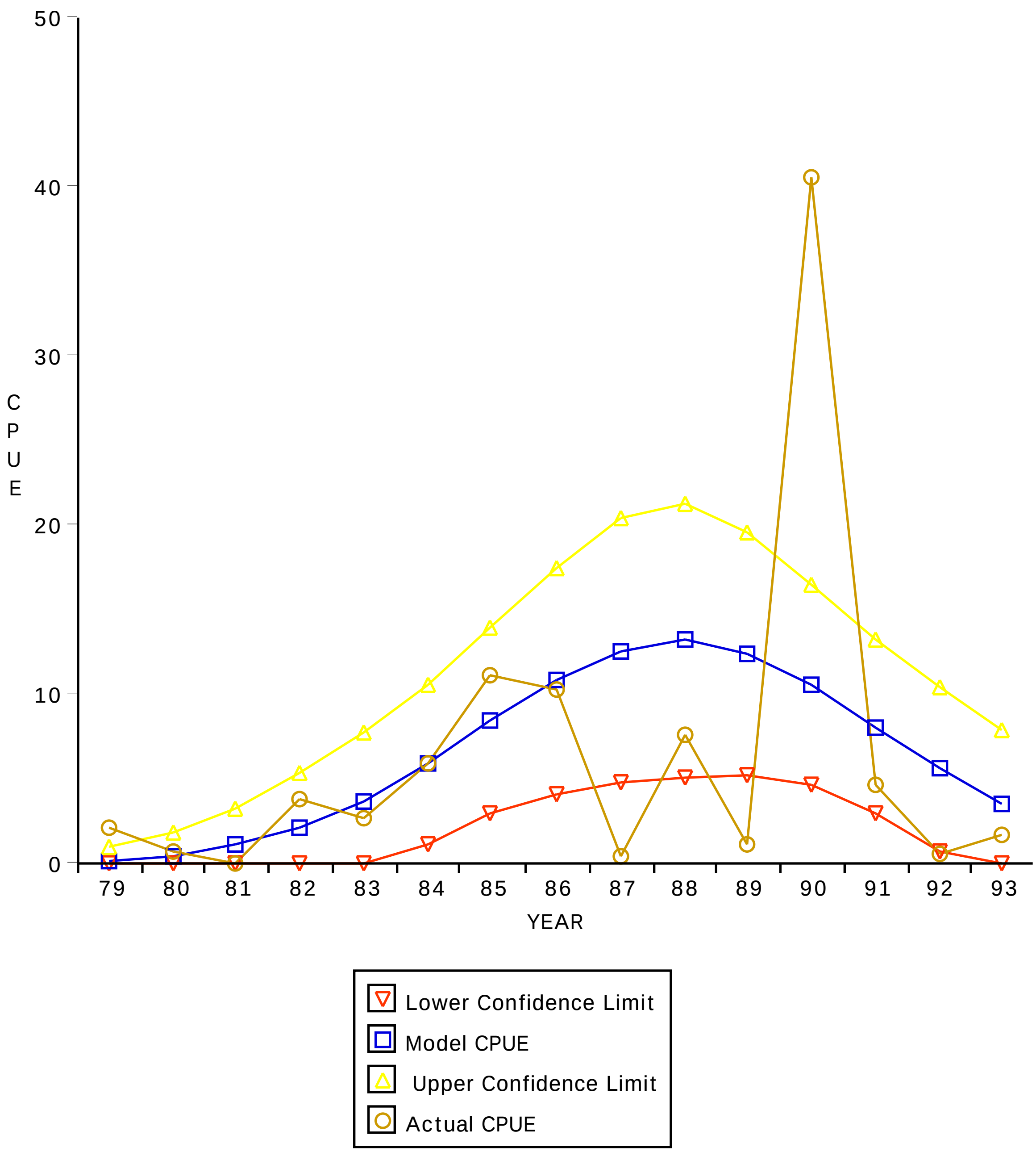

Figure VI.31. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year white shrimp (40-59 mm TL) caught by bag seine in Aransas Bay during June, July, and August.

white shrimp/bag seine/Upper Laguna Madre

Modelled CPUE increased linearly (Table IX.19). The positive slope was influenced strongly by an excellent yield in 1988, followed by better than average yields during 1990-1991 and 1993. Yields were negligible during 1982-1987. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.34.

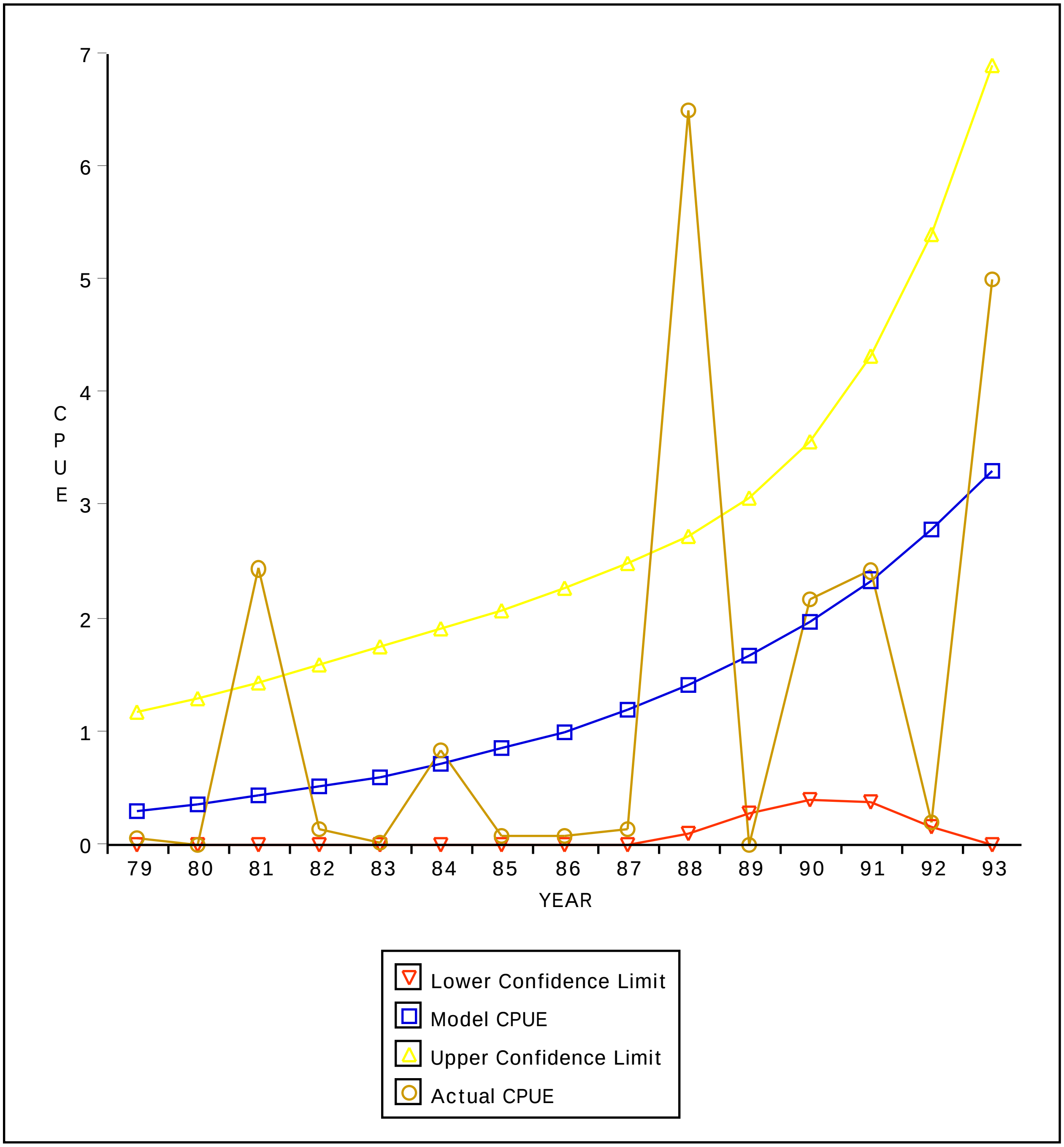

Figure VI.33. Actual catch per unit of effort and model with significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year white shrimp (40-59 mm TL) caught by bag seine in the Upper Laguna Madre during June, July, and August.

white shrimp/bag seine/model comparison

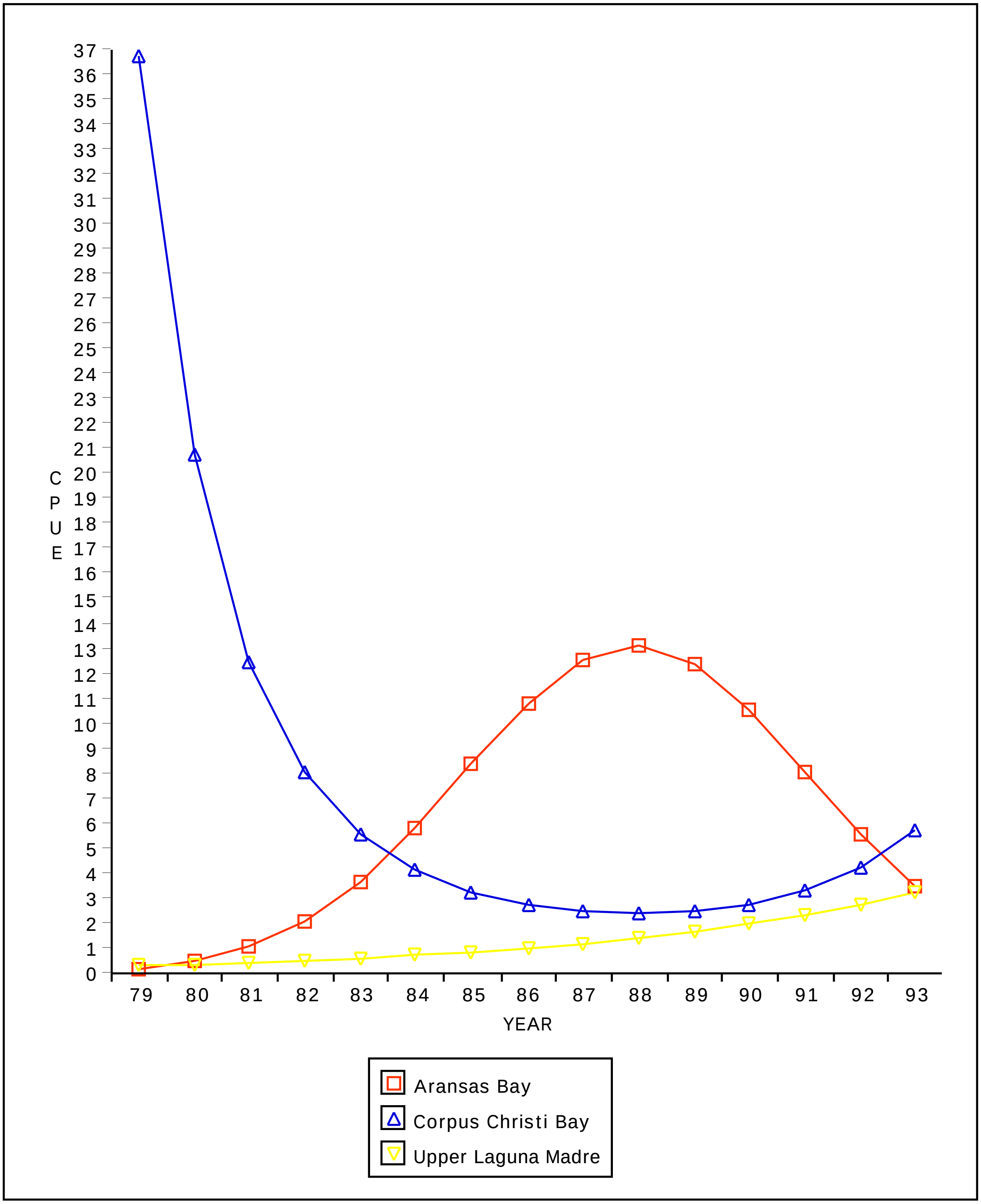

Figure VI.35. Comparison of best-fit models for young-of-the-year white shrimp (40-59 mm TL), caught by bag seine in the CCBNEP (Table IX.20). CPUE = CATCH/0.03 hectare for all models.

white shrimp/trawl/Corpus Christi Bay

Modelled CPUE exhibited no trend (Table IX.21). Actual CPUE values were relatively large during 1984-1985, but were generally poor during 1986-1989. Actual CPUE improved during 1990-91, but decreased thereafter. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.37.

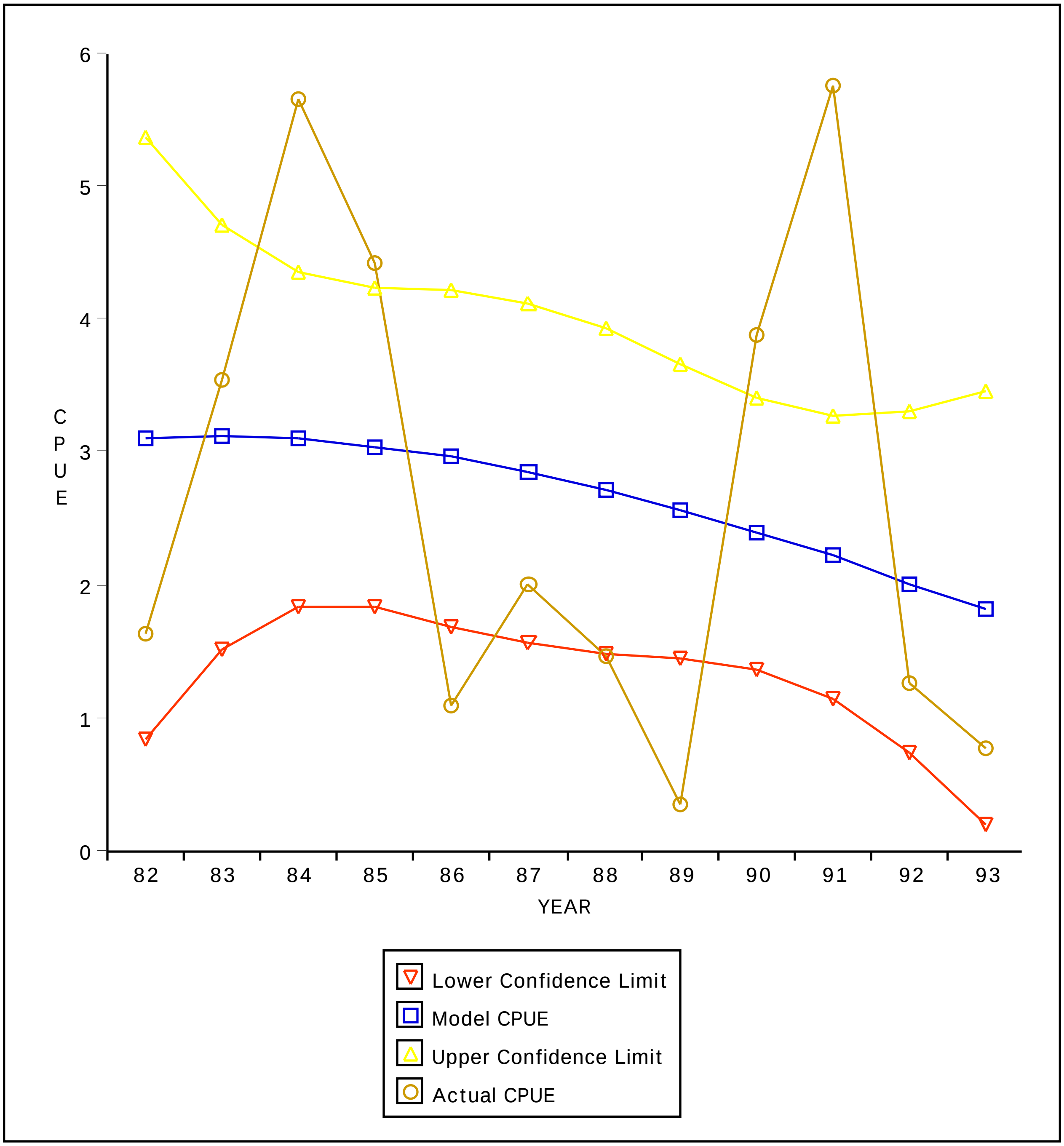

Figure VI.36. Actual catch per unit of effort and model with no statistically significant trend

(**CPUE = b_0**, where CPUE = CATCH/10 minutes) for white shrimp (100-124 mm TL) caught by trawl in Corpus Christi Bay during September, October, and November.

white shrimp/trawl/Aransas Bay

Modelled CPUE exhibited a slightly curvilinear trend, with an interpolated minimum in 1988 (Table IX.22). Actual CPUE was phenomenal in 1984 but generally poor during 1985-1989. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.39.

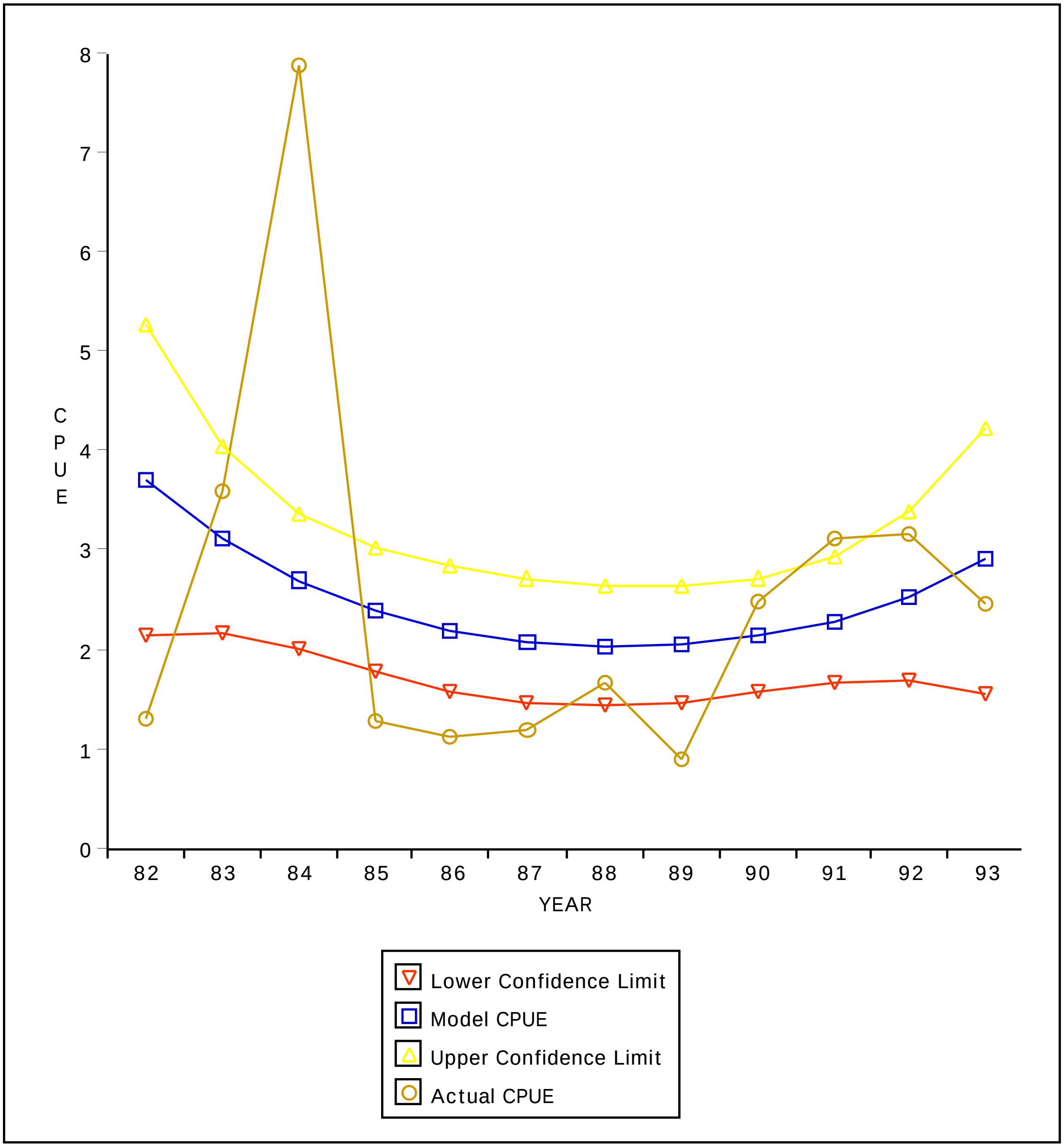

Figure VI.38. Actual catch per unit of effort and best-fit model with significant quadratic component (**CPUE =** $\mathbf{b_0}$ + $\mathbf{b_1}$***YEAR** + $\mathbf{b_2}$***YEAR**^{2}, where CPUE = CATCH/10 minutes) for white shrimp (100-124 mm TL) caught by trawl in Aransas Bay during September, October, and November.

white shrimp/trawl/Upper Laguna Madre

Modelled CPUE increased linearly (Table IX.23). Greatest actual CPUE values were recorded during 1990-1991. Actual CPUE was generally poor during 1985-1989. The positive slope of the model was influenced strongly by yields recorded in 1990, 1991, and 1993. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.41.

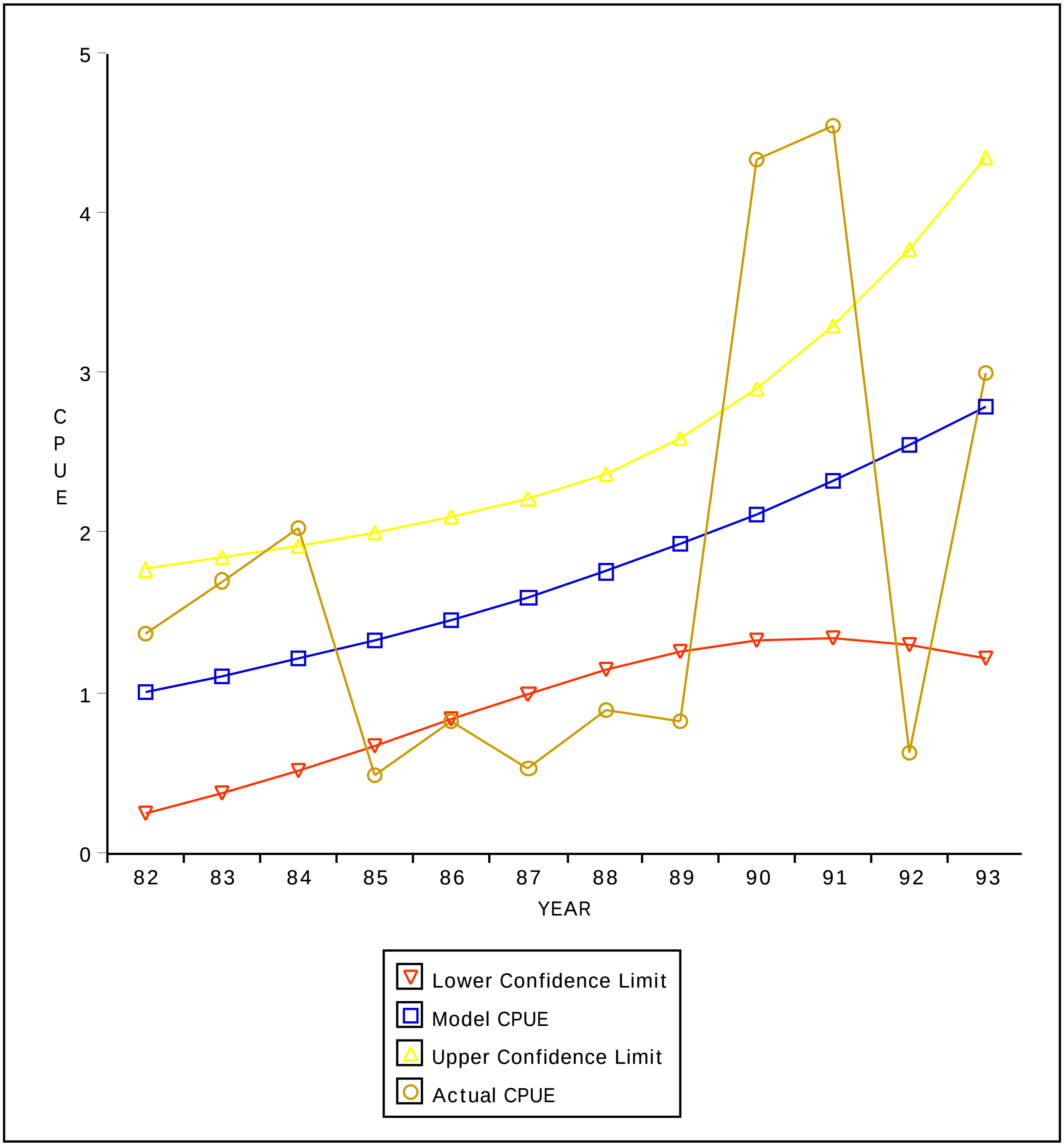

Figure VI.40. Actual catch per unit of effort and best-fit model with significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/10 minutes) for white shrimp (100-124 mm TL) caught by trawl in Upper Laguna Madre during September, October, and November.

white shrimp/trawl/model comparison

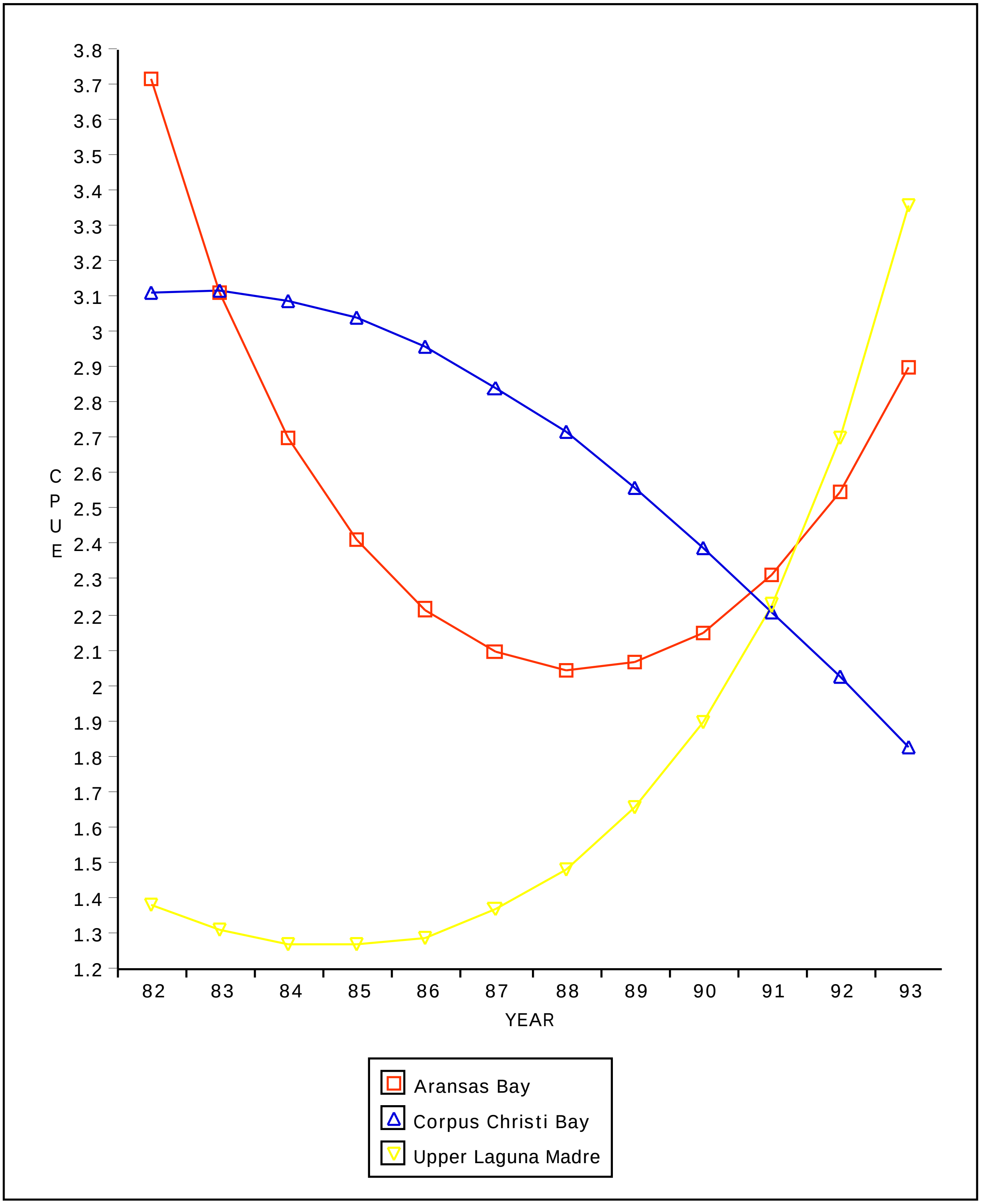

Figure VI.42. Comparison of best-fit models for white shrimp (100-124 mm TL) caught by trawl in the CCBNEP (Table IX.24). CPUE = CATCH/10 minutes.

Modelled bag seine and trawl CPUE for Upper Laguna Madre both exhibited significant increasing linear trends. Actual catches by bag seine and trawl were also consistent, except for a major peak in bag seine catch evident in 1988: no coincidental peak in CPUE by trawl of larger size white shrimp (100-124 mm TL) was detected. This suggests unusually large numbers of YOY white shrimp entering Upper Laguna Madre in that year. Minor peaks in bag seine and trawl actual catch in 1984 and 1990-1991 were detected. Actual catch by bag seine and trawl was minimal during 1985-1987. The latter year (1988 and 1990-1991 for bag seine catches and 1990-1991 for trawl catches) peaks in actual CPUE strongly influenced the positive slope of the linear model.

The probable cause for discrepancy between best-fit models for Corpus Christi Bay bag seine and trawl data sets was inclusion of bag seine data from 1979, the year during which highest catches of white shrimp were recorded. The 1979 bag seine data strongly influenced the model's quadratic curvature and its interpolated minimum in 1988. If the 1979 bag seine catch had been removed, it is likely that no significant trend in modelled bag seine CPUE would have been detected. Otherwise, there was consistency between actual catches by bag seine and trawl, with both data sets revealing high actual yields of white shrimp in 1984 and 1990 and relatively low yields during 1986-1989. Categorization of the bag seine model as quadratic with a minimum in 1988 must be interpreted with caution because it implies curved upward population growth in later years: this implication is not entirely supported by the raw actual catch data. Thus, there appears to be no sustained population growth of white shrimp in Corpus Christi Bay.

The most perplexing aspect of the analysis was the detection of opposing quadratic trends for bag seine and trawl data for Aransas Bay. Largely due to the highest recorded catch of white shrimp by bag seine in 1990 and a secondary peak observed in 1985, the best-fit model for bag seine CPUE displayed slight quadratic curvature with a maximum in 1988, even though actual CPUE in 1988 was well below the maximum predicted by the model. On the other hand, the primary peak in white shrimp caught by trawl (recorded in 1984) and relatively large average yields sustained through 1990, 1991, and 1992, influenced the curvature of the Aransas Bay trawl model in the opposite direction: in this latter case, actual CPUE was at a minimum in 1989 even though the best-fit model interpolated a minimum in 1988. Apart from high catches of white shrimp in both bag seine and trawl collections in 1990, peaks in actual catch differed substantially between the two gear types, indicating that catches of YOY white shrimp in Aransas Bay are not a reliable predictor of catches of emmigratory-sized white shrimp in the same year or in a subsequent year.

In summary, results of the trend analyses for white shrimp catches within the CCBNEP study area revealed substantial differences in population dynamics of white shrimp among Corpus Christi Bay, Aransas Bay, and Upper Laguna Madre. Of the three bays, Upper Laguna Madre has generally yielded the least white shrimp because high average salinity in Upper Laguna Madre precludes optimal recruitment of YOY. Nonetheless, only Upper Laguna Madre indicated sustained population growth of white shrimp of emmigratory size: there was a two-fold increase in modelled CPUE by trawl within Upper Laguna Madre by the end of the study. Numbers of white shrimp sampled by bag seine in Corpus Christi Bay have declined drastically since 1979. Additional research into the causes for this decline is warranted. Finally, the striking discrepancy between maxima and minima detected by bag seine and trawl collections in Aransas Bay provides yet another example of the need to sample representatives of more than one life stage of this estuarine macroinvertebrate.

Analysis for brown shrimp (*Penaeus aztecus*)
brown shrimp/bag seine/Corpus Christi Bay

Modelled CPUE curved upward after 1986 (Table IX.25). Actual CPUE was generally poor during 1983-1988, but showed sustained improvement during 1988-1993. Actual CPUE was phenomenally high in 1981. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.44.

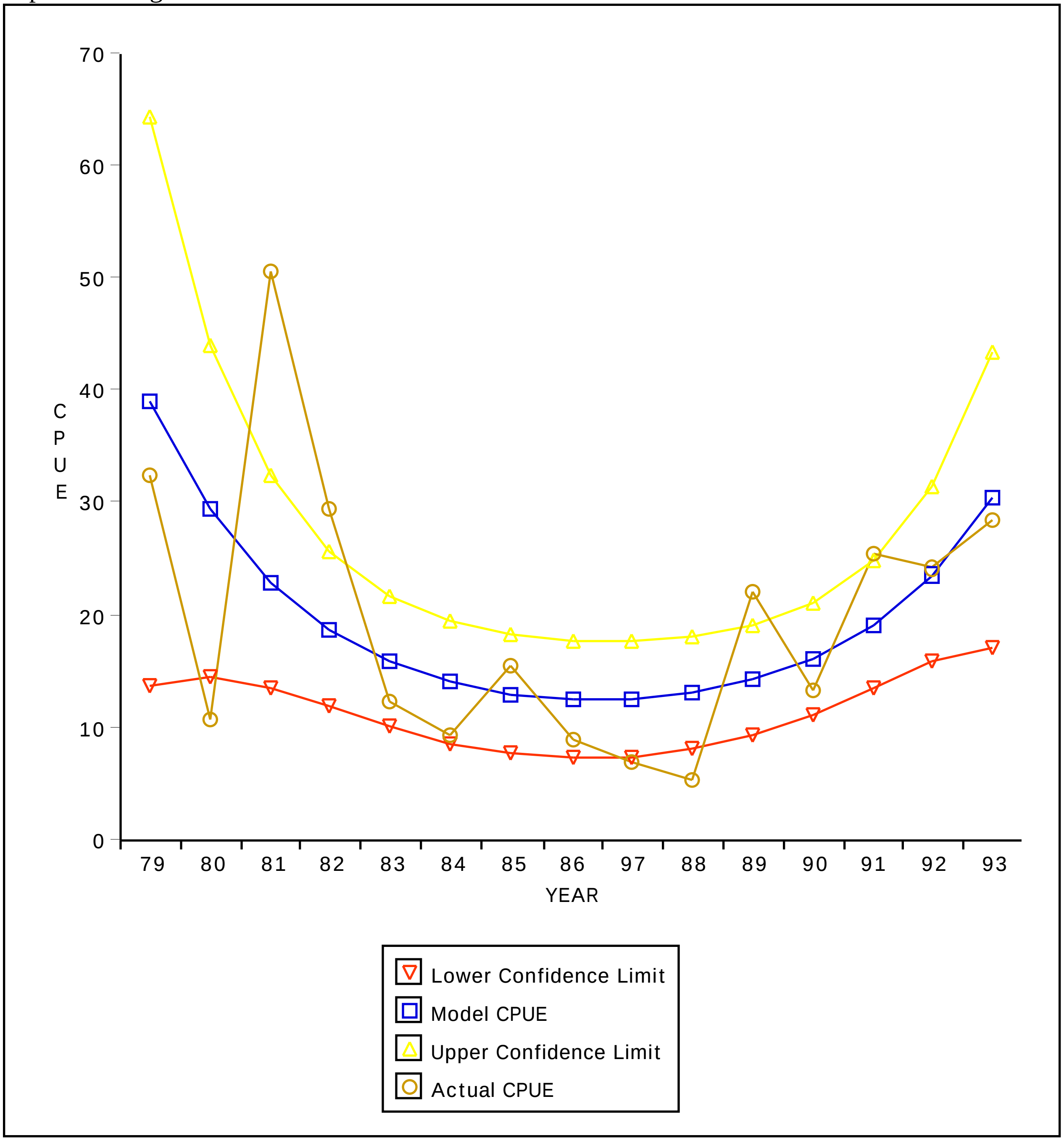

Figure VI.43. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_o + b_1*YEAR + b_2*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year brown shrimp (40-59 mm TL) caught by bag seine in Corpus Christi Bay during April, May, and June.

brown shrimp/bag seine/Aransas Bay

Modelled CPUE decreased linearly (Table IX.26). Peaks in CPUE were seen in 1982, 1985, and 1989-1990. Actual CPUE dropped sharply after 1990. Actual CPUE fluctuated substantially from year to year. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.46.

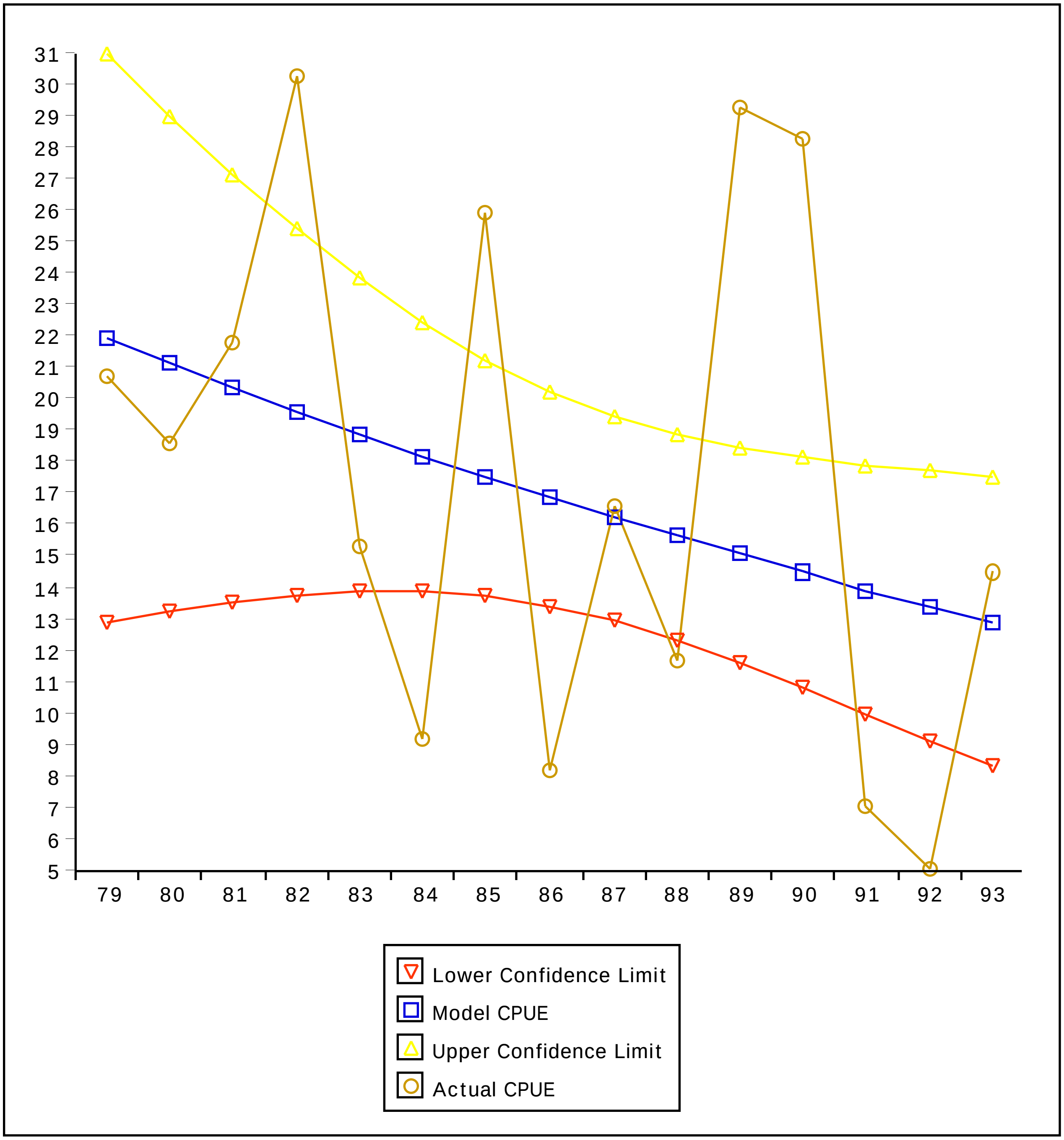

Figure VI.45. Actual catch per unit of effort and model with significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year brown shrimp (40-59 mm TL) caught by bag seine in Aransas Bay during April, May, and June.

brown shrimp/bag seine/Upper Laguna Madre

Modelled CPUE exhibited curvature with an interpolated maximum in 1988 (Table IX.27). The primary peak in actual CPUE was recorded in 1987, but actual CPUE declined sharply thereafter. Actual CPUE improved after 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.48.

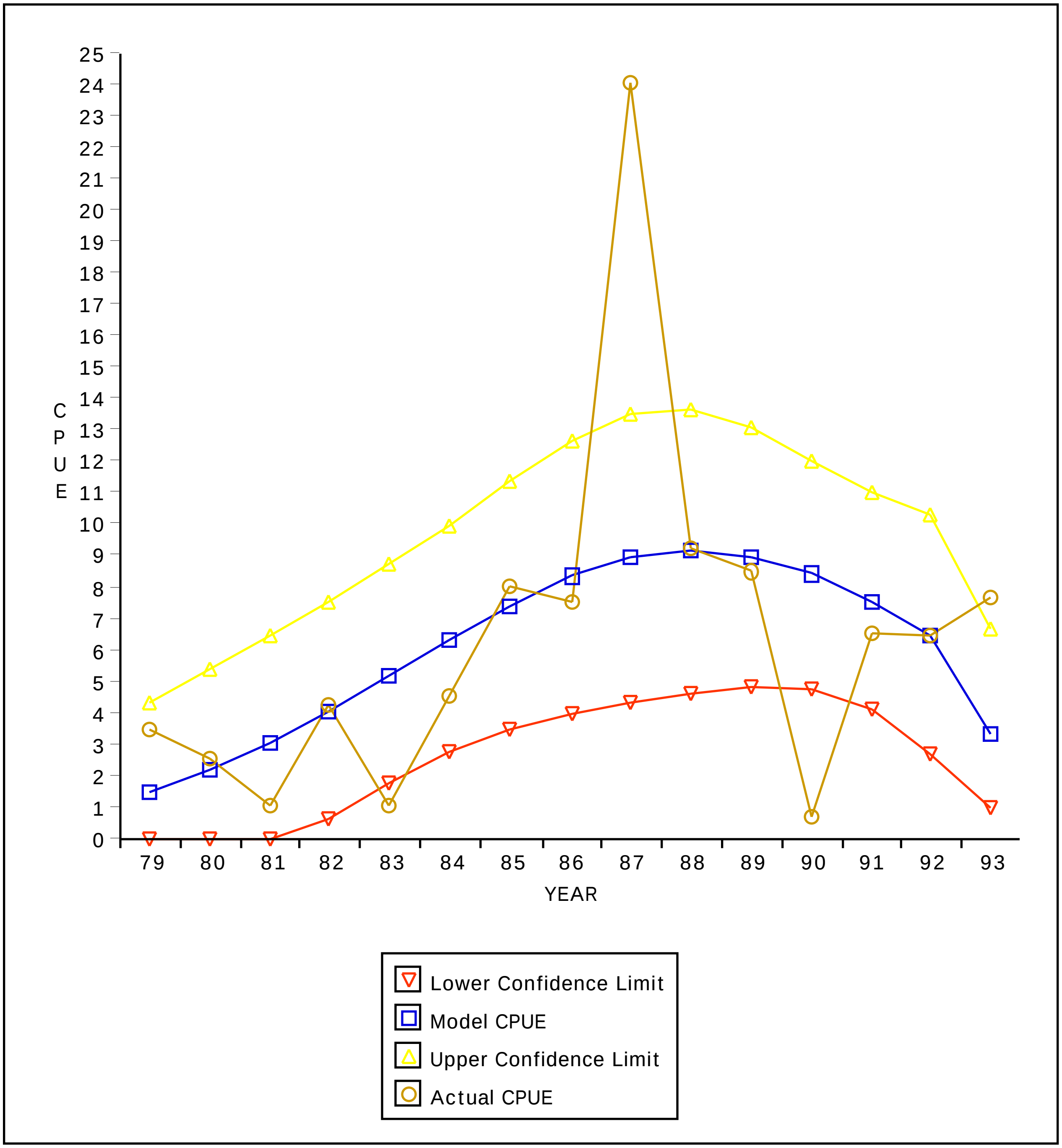

Figure VI.47. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/0.03 hectare) for young-of-the-year brown shrimp (40-59 mm TL) caught by bag seine in the Upper Laguna Madre during April, May, and June.

brown shrimp/bag seine/model comparison

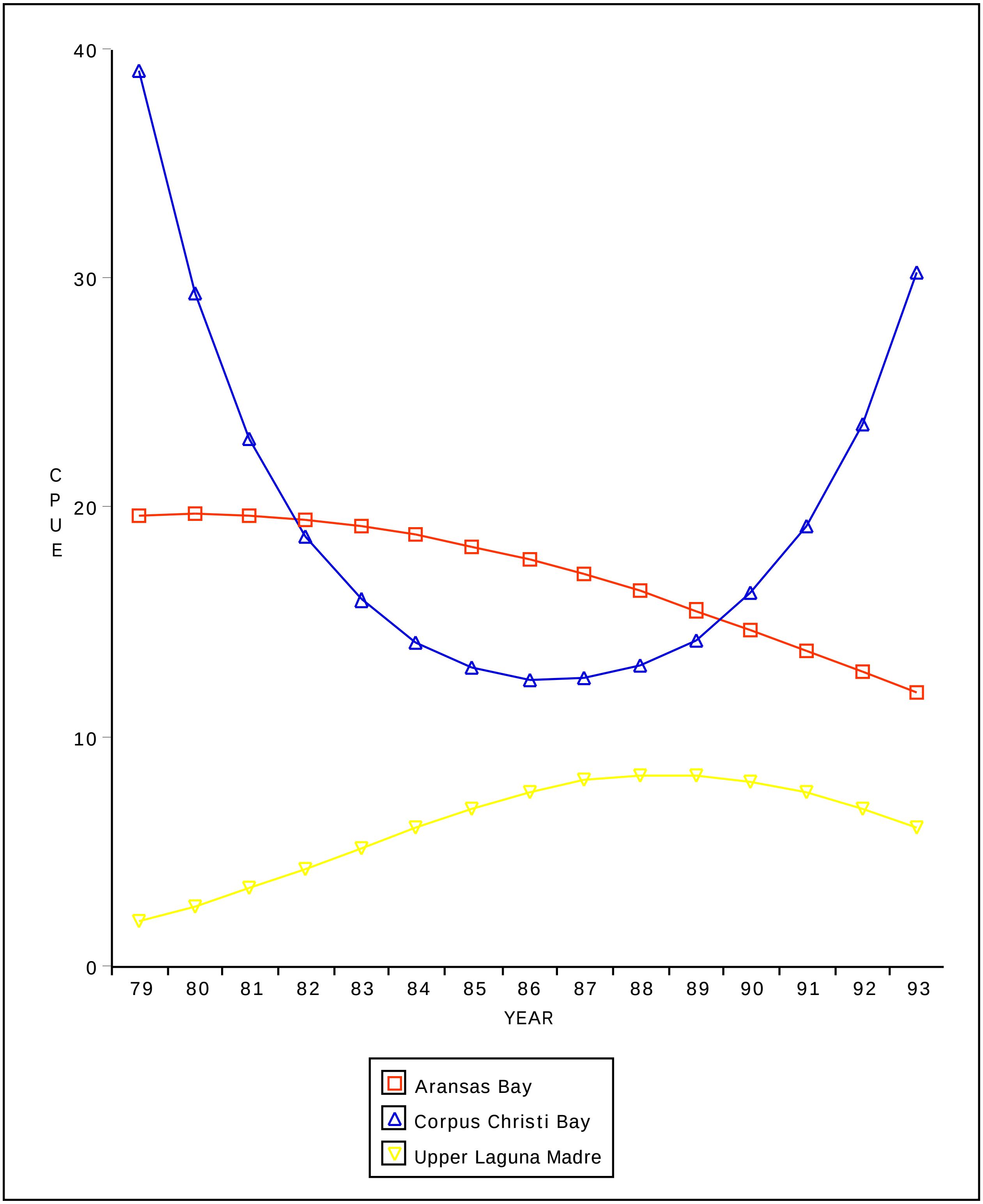

Figure VI.49. Comparison of best-fit models for young-of-the-year brown shrimp (40-59 mm TL) caught by bag seine in the CCBNEP (Table IX.28). CPUE = CATCH/0.03 hectare.

brown shrimp/trawl/Corpus Christi Bay

Modelled CPUE curved downward after 1986 (Table IX.29). Actual CPUE was greatest in 1984 and a secondary peak was observed in 1987. Actual CPUE was negligible during 1988-1989. Actual CPUE decreased again after 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.51.

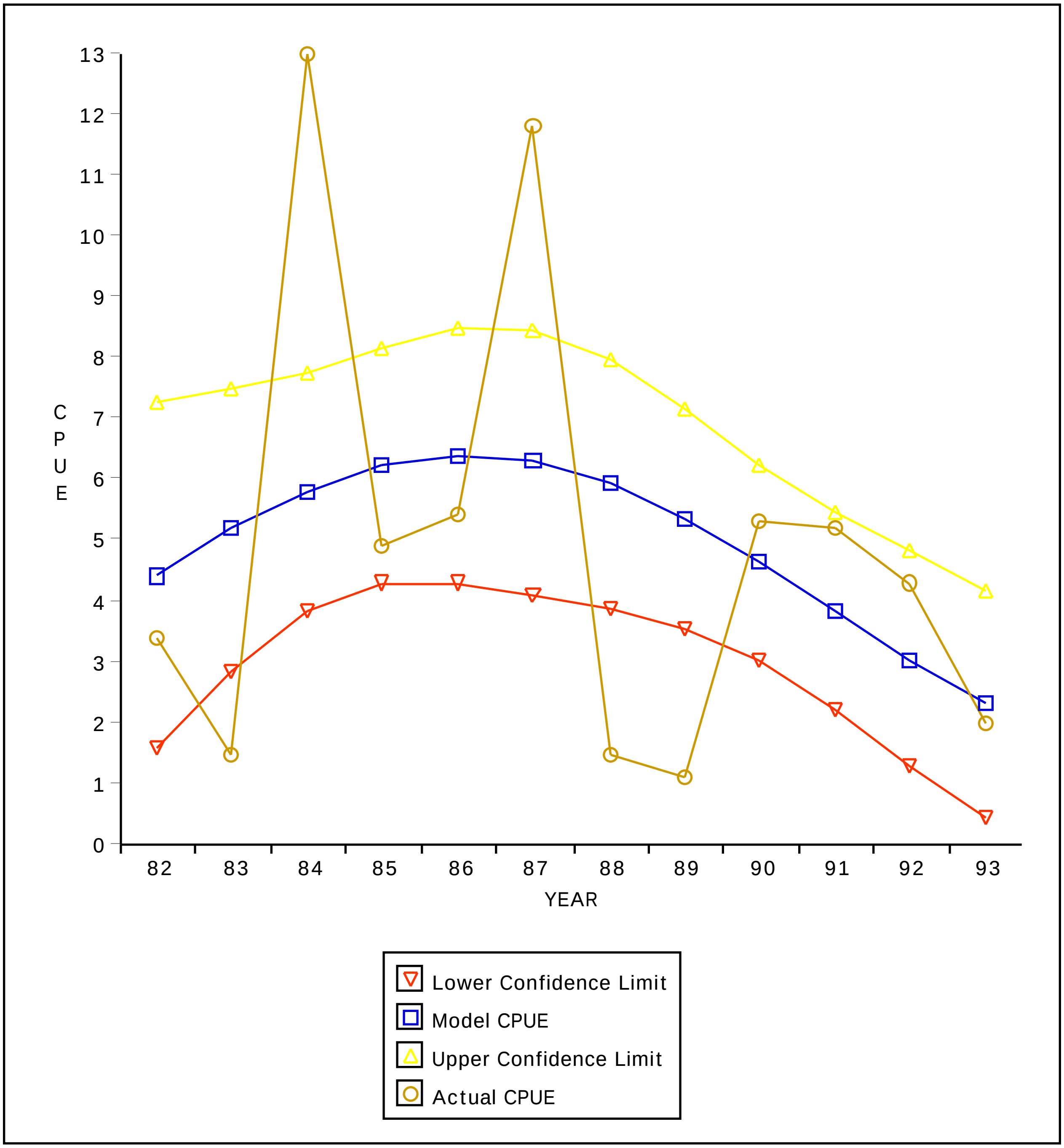

Figure VI.50. Actual catch per unit of effort and best-fit model with significant quadratic component (**CPUE = b_0** + **b_1*YEAR** + **b_2*YEAR^2**, where CPUE = CATCH/10 minutes) for brown shrimp (100-124 mm TL) caught by trawl in Corpus Christi Bay during May, June, and July.

brown shrimp/trawl/Aransas Bay

Modelled CPUE curved downward after 1989 (Table IX.30), even though actual CPUE was phenomenal in 1991. Actual CPUE was generally poor during 1982-1985. An improved yield in 1986 was temporary. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.53.

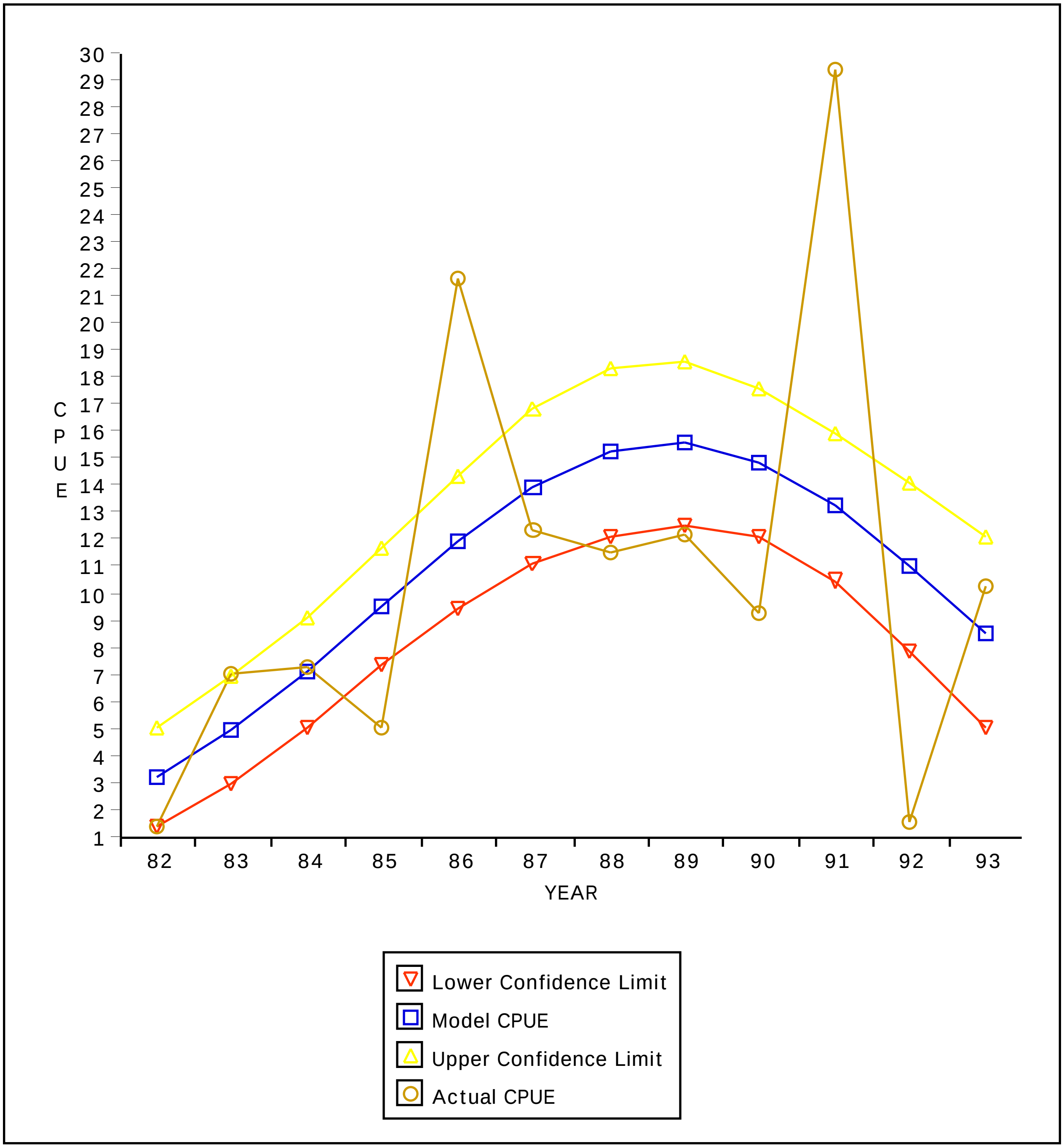

Figure VI.52. Actual catch per unit of effort and best-fit model with significant quadratic component (**CPUE = b_o** + **b_1*YEAR** + **b_2*YEAR^2**, where CPUE = CATCH/10 minutes) for brown shrimp (100-124 mm TL) caught by trawl in Aransas Bay during May, June, and July.

brown shrimp/trawl/Upper Laguna Madre

Modelled CPUE curved upward after 1987 (Table IX.31). Improved yields were recorded in 1984 and 1992, but yields were generally very poor during 1985-1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.55.

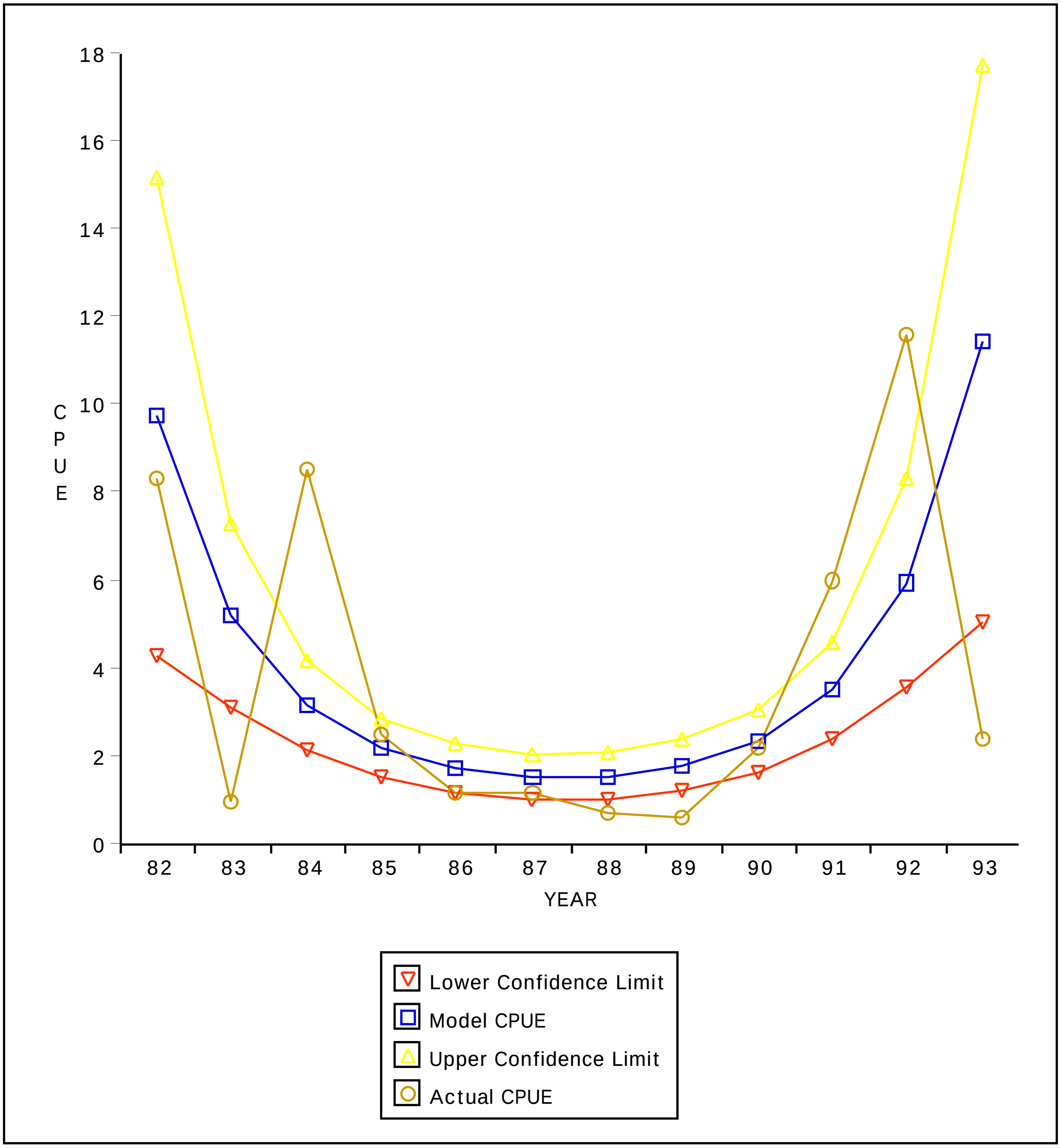

Figure VI.54. Actual catch per unit of effort and best-fit model with significant quadratic component (**CPUE =** $\mathbf{b_0}$ + $\mathbf{b_1}$***YEAR** + $\mathbf{b_2}$***YEAR**$^{\mathbf{2}}$, where CPUE = CATCH/10 minutes) for brown shrimp (100-124 mm TL) caught by trawl in Upper Laguna Madre during May, June, and July.

brown shrimp/trawl/model comparison

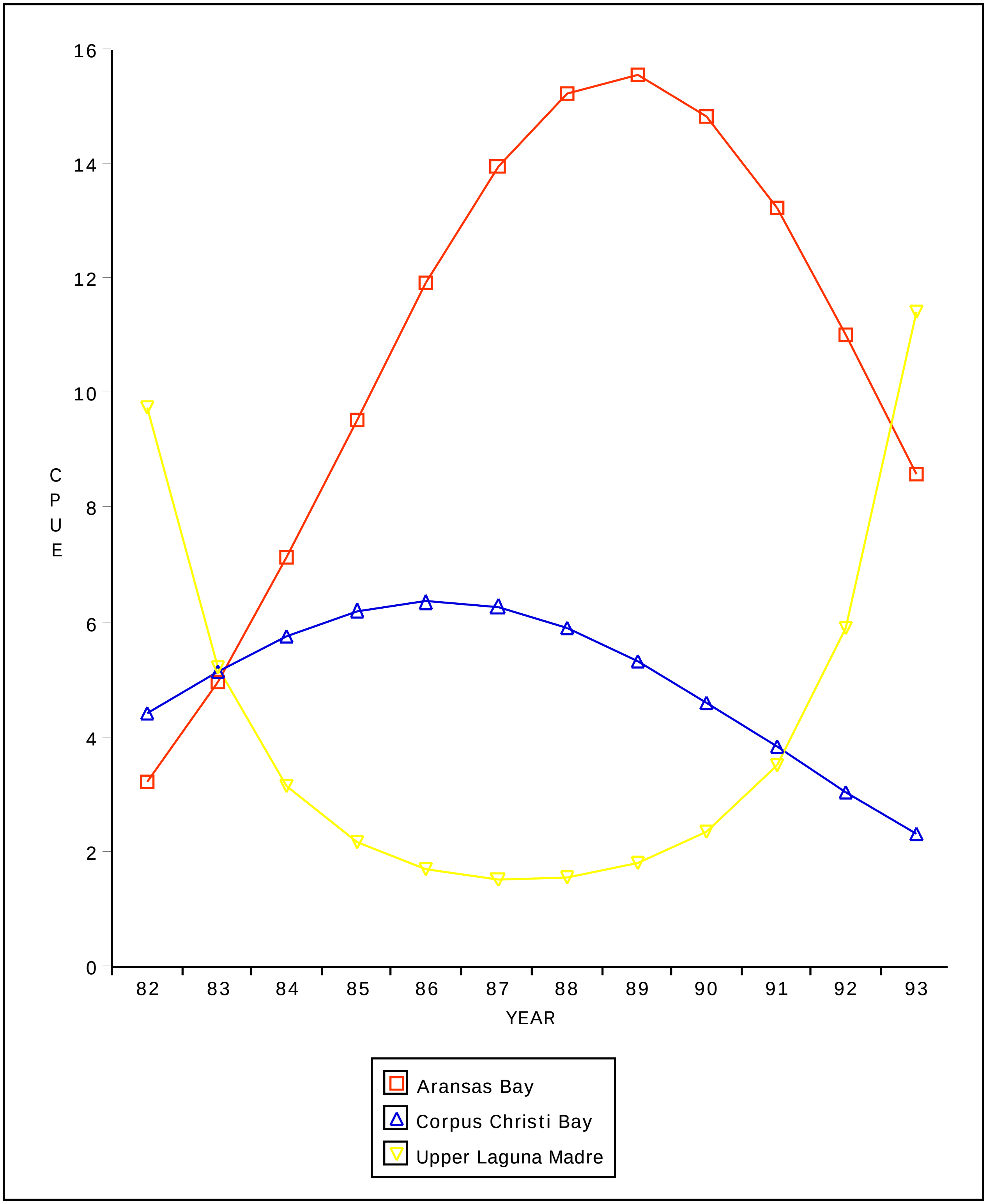

Figure VI.56. Comparison of best-fit models for brown shrimp (100-124 mm TL) caught by trawl in the CCBNEP (Table IX.32). CPUE = CATCH/10 minutes.

Significant results of the trend analysis were: (1) population dynamics of brown shrimp representing the three bay systems differed substantially and; (2) bag seine and trawl catches of brown shrimp did not correlate temporally, regardless of bay system examined. In Corpus Christi Bay, the discrepancy between models for bag seine and trawl catches was due in part to inclusion of bag seine data from 1981. Actual bag seine CPUE exhibited a major peak in 1981 which strongly influenced the quadratic curvature of the model. In addition to a basic difference in models, peaks in actual catches differed temporally between gear type. Obvious peaks in actual bag seine catch were evident in 1985, 1989, and 1991, whereas peaks in actual trawl catch were detected in 1984 and 1987. Actual trawl catch was also slightly elevated during 1990-1992. This was the only period when both bag seine and trawl actual catches were elevated simultaneously.

Results of the trend analysis for the Aransas Bay bag seine data set differed substantially from that of Corpus Christi Bay. In Aransas Bay, a significant peaks in actual bag seine CPUE were recorded in 1982, 1985 and 1989-1990. Two peaks were observed in trawl data, one in 1986 and the other in 1991.

The characteristic feature of bag seine data for Upper Laguna Madre was the sole peak in catch clearly evident in 1987: such a well-defined peak in bag seine actual catch was not evident in the northern two bays. Otherwise, actual bag seine CPUE in Upper Laguna Madre was routinely poor and reached lowest levels in 1981, 1983, and 1990. Actual trawl CPUE in Upper Laguna Madre was greater after the incurrence of brown tide in late spring/early summer of 1990. The late-year rise in actual CPUE by trawl contributed strongly toward the upward curvature of the model after 1987. Interestingly, white shrimp population growth also appeared favorable in the face of the brown tide. Thus, it is safe to conclude that brown tide has had no adverse effects upon the population growth of the two most commercially significant penaeid species harvested within the CCBNEP.

Analysis for black drum (*Pogonias cromis*)
black drum/gill net/Corpus Christi Bay

Modelled CPUE curved upward after 1984-1985 (Table IX.33). Actual CPUE improved substantially after 1991 and reached its greatest level by the end of the study. Actual CPUE was generally poor during 1979-1982, 1985-1988, and in 1991. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.58.

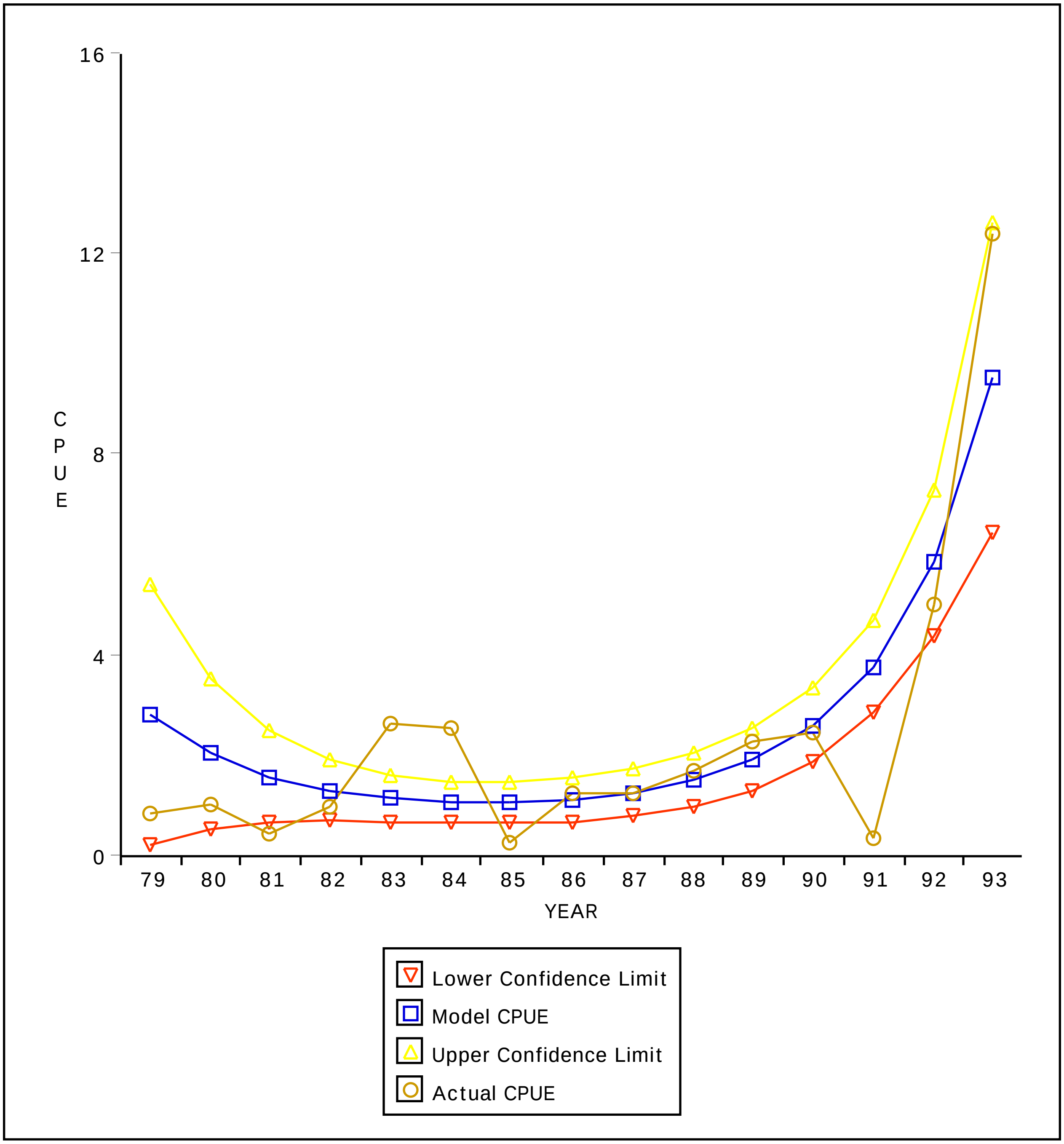

Figure VI.57. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR** + **b_2*YEAR^2,** where CPUE = CATCH/(GTIME/12.5)^3) for subadult black drum (375-449 mm TL) caught by gill net in Corpus Christi Bay during the Spring netting season.

black drum/gill net/Aransas Bay

Modelled CPUE curved upward after 1985 (Table IX.34). The interpolated model minimum was consistent with the low actual yield recorded during 1984-1985. Actual CPUE in 1993 was highest on record. Smaller peaks in actual CPUE were seen in 1983 and 1987. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.60.

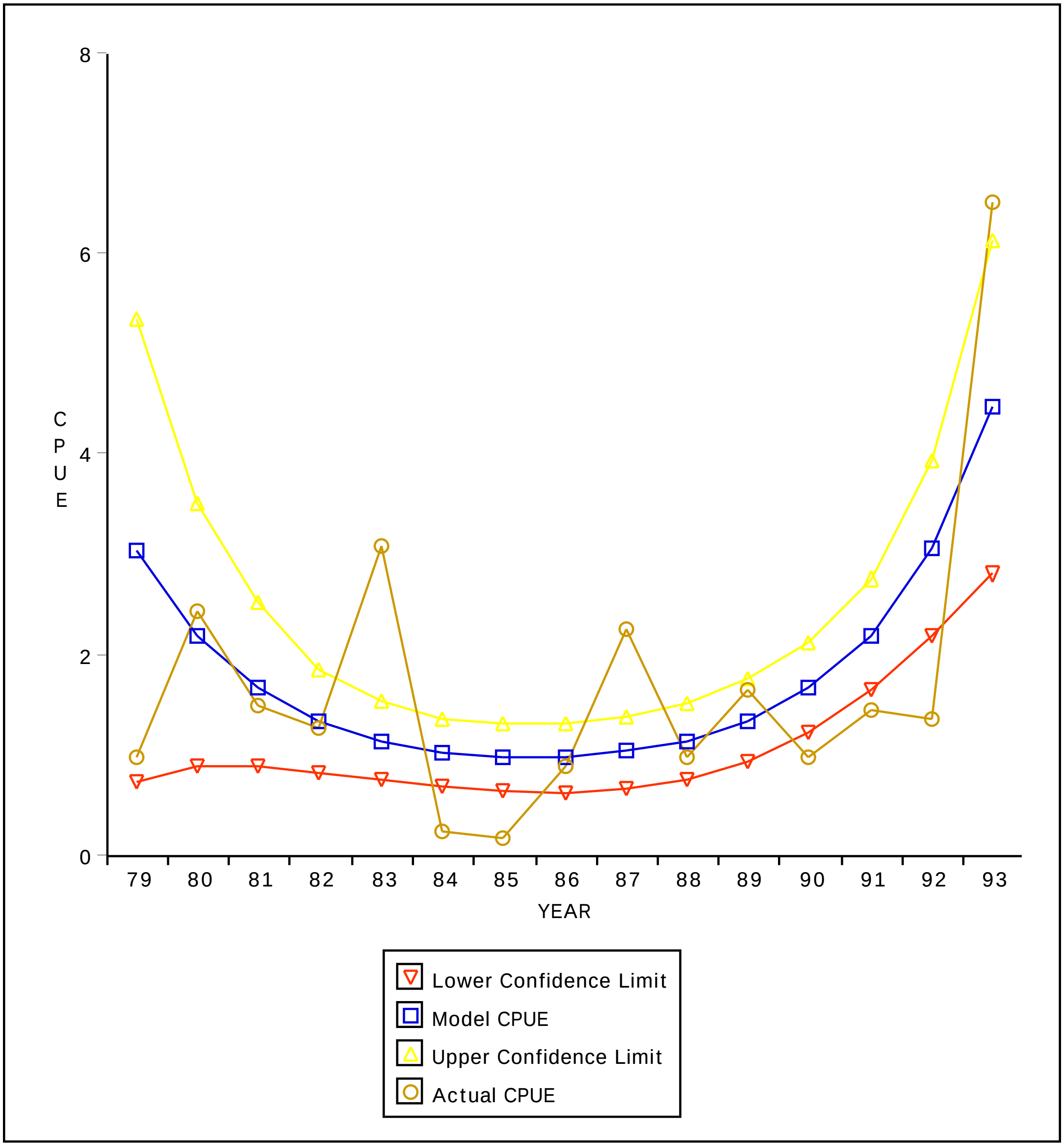

Figure VI.59. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR** + **b_2*YEAR^2,** where CPUE = CATCH/(GTIME/12.5)) for subadult black drum (375-449 mm TL) caught by gill net in Aransas Bay during the Spring netting season.

black drum/gill net/Upper Laguna Madre

Modelled CPUE curved upward after 1984 (Table IX.35). Actual CPUE was generally poor during 1984-1988 but thereafter improved steadily. Actual yields were greatest during the last two years of the survey. Secondary peaks were observed in 1981 and 1983. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.62.

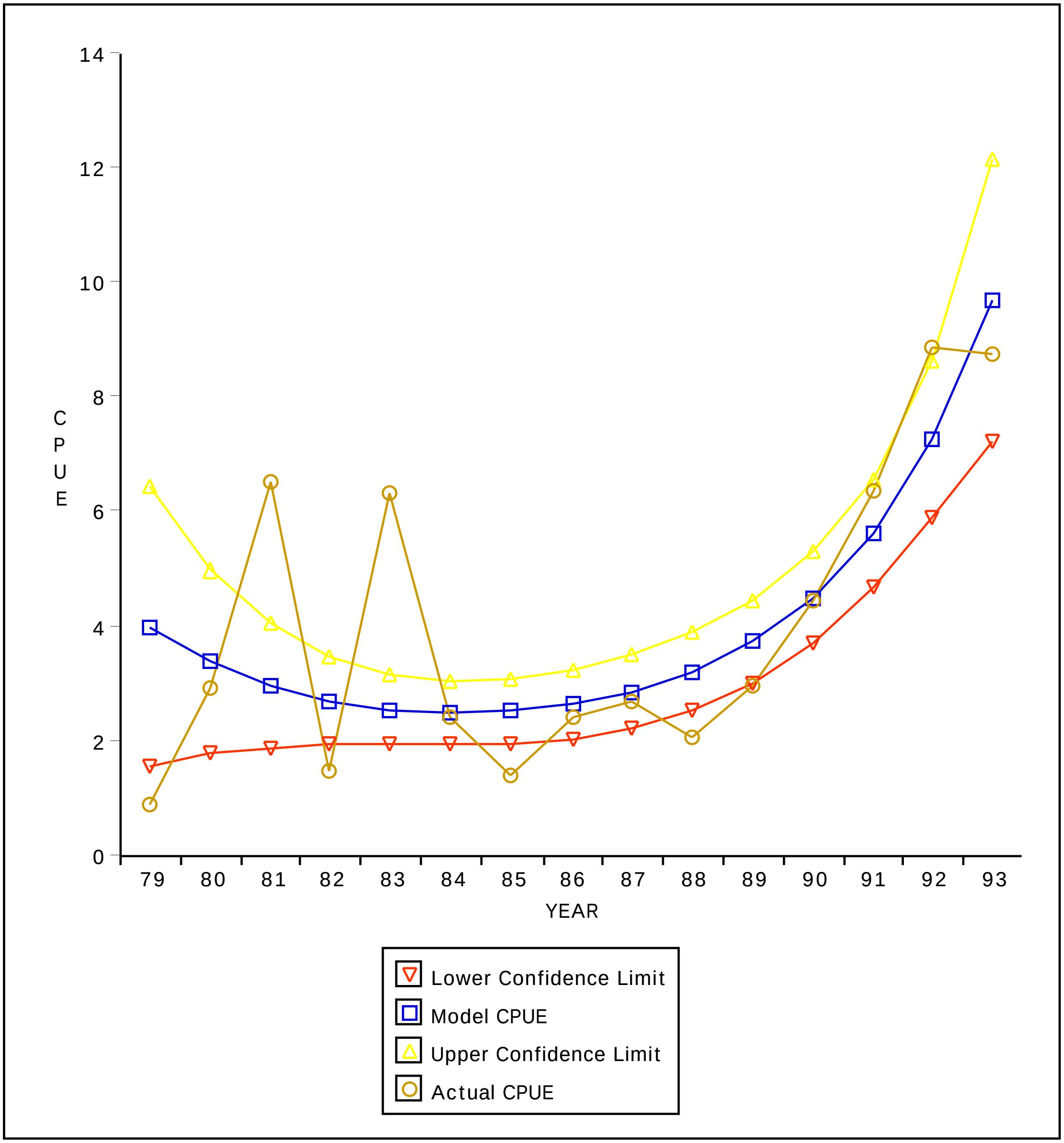

Figure VI.61. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2,** where CPUE = CATCH/(GTIME/12.5)$^{1.5}$) for reproductive black drum (375-449 mm TL) caught by gill net in the Upper Laguna Madre during the Spring netting season.

black drum/gill net/model comparison

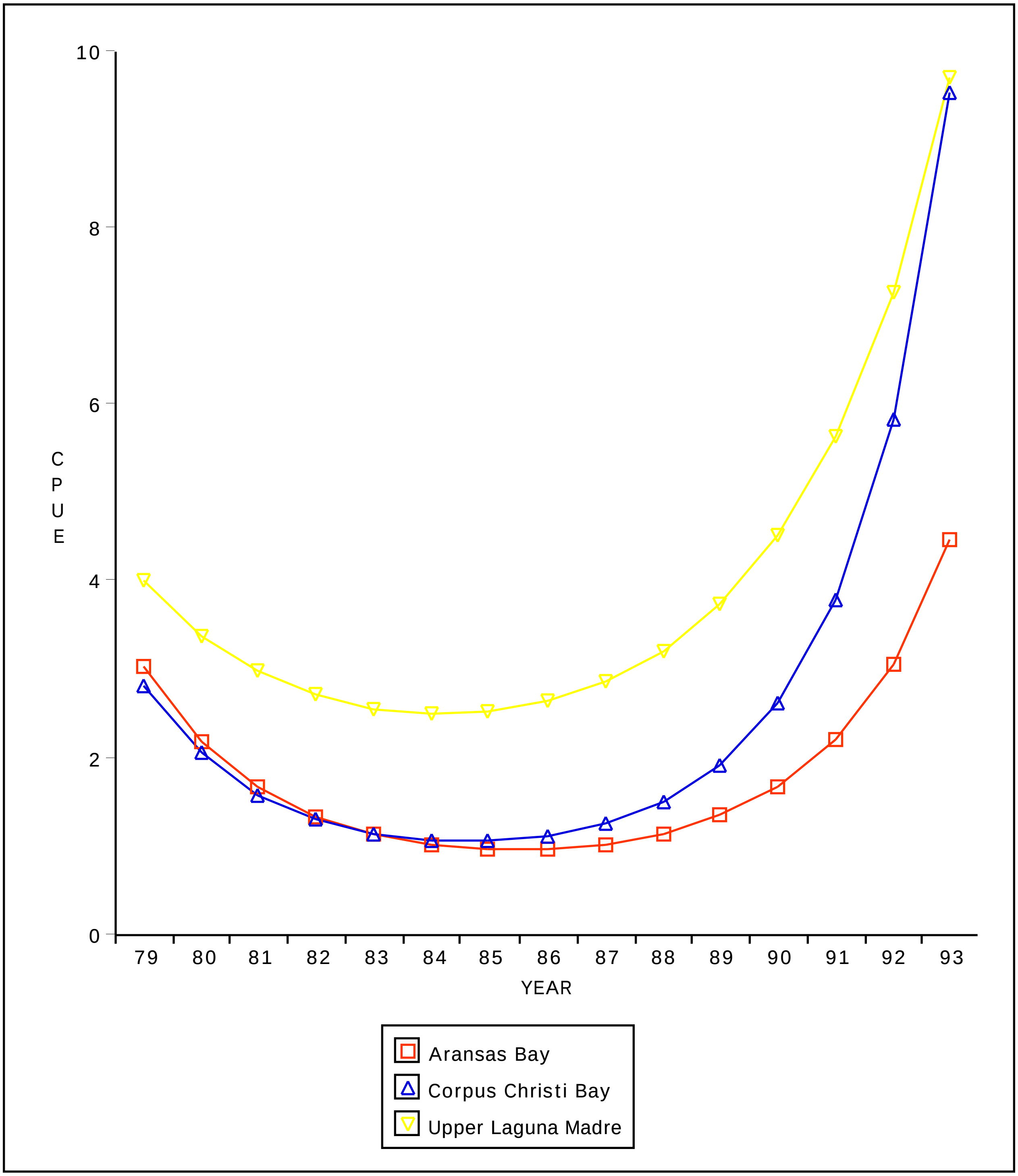

Figure VI.63. Comparison of best-fit models for reproductive black drum (375-449 mm TL) caught by gill net in the CCBNEP (Table IX.36). CPUE = CATCH/(GTIME/12.5)^3 for Corpus

Christi Bay, CPUE = CATCH/(GTIME/12.5) for Aransas Bay, and CPUE = CATCH/$(GTIME/12.5)^{1.5}$ for Upper Laguna Madre.

Results and Discussion for black drum

Only gill net CPUE was amenable to analysis because of extremely low catches of black drum by bag seine and trawl. Also, gill net CPUE in Corpus Christi Bay exhibited significant saturation effect (CPUE = CATCH/$(GTIME/12.5)^3$) as it also did in Upper Laguna Madre (CPUE = CATCH/$(GTIME/12.5)^{1.5}$). Thus, comparisons among data from the three bays must be considered in light of these differences. Black drum population growth in Corpus Christi Bay was phenomenal during 1991-1993. No other significant peaks in actual catch of black drum by gill net were evident during 1979-1991. The Corpus Christi Bay data set provided a rare example of concordance of actual and model minima, with both occurring in 1985. Actual CPUE was slightly elevated during 1983-1984, but then declined noticeably in 1985. Given the size range chosen to represent subadults in Corpus Christi and Aransas Bays (adults in Upper Laguna Madre [375-449 mm TL]), it is likely that the drop in 1985 was related to commercial fishing and to mortality of a large number of juvenile black drum during the freeze in 1983.

Actual catch of black drum by gill net in Aransas Bay increased significantly beginning in 1992, one year later than the surge detected in Corpus Christi Bay. Minor peaks in actual CPUE were evident in 1983 and 1987. As in Corpus Christi Bay, the steep decline in actual catch after the 1983 peak was most likely due to commercial fishing and to large-scale mortality of juvenile cohorts during the 1983 freeze. In Aransas Bay, actual and modelled CPUE minima coincided in 1985.

Sustained population growth, as evidenced by steadily increasing actual CPUE, was evident in Upper Laguna Madre commencing in 1988. Significant peaks in actual CPUE were detected in 1981 and 1983. Once again, a drop-off in actual catch was evident in 1984 and 1985, and it is likely that this was also due to commercial fishing and to relatively high mortality of juvenile black drum during the 1983 freeze. Actual CPUE was minimal in 1979, whereas the model interpolated a minimum in 1984. Upper Laguna Madre data differed from Corpus Christi and Aransas Bays; the steep increase in CPUE by gill net of black drum commenced several years earlier. It is also noteworthy that overall levels of modelled CPUE were greatest in Upper Laguna over the entire study, as evidenced by results of the three-bay comparison which indicated significantly different model intercepts between Upper Laguna Madre and the other two bays.

In summary, population growth of black drum within the CCBNEP study area was on the rise during the latter years of the survey. Generally, black drum of the selected size class have been caught in greater numbers in Upper Laguna Madre than in Aransas or Corpus Christi Bays. Incurrence of the brown tide did not seem to adversely affect the population of reproductive black drum in Upper Laguna Madre.

Analysis for blue crab (*Callinectes sapidus*)
blue crab/gill net/Corpus Christi Bay

Modelled CPUE curved downward after 1988 (Table IX.37). Prominent peaks in actual CPUE were seen in 1983, 1987, and 1991. Actual CPUE was negligible during 1979-1982. These low catches were influential in generating curvature in the model. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.65.

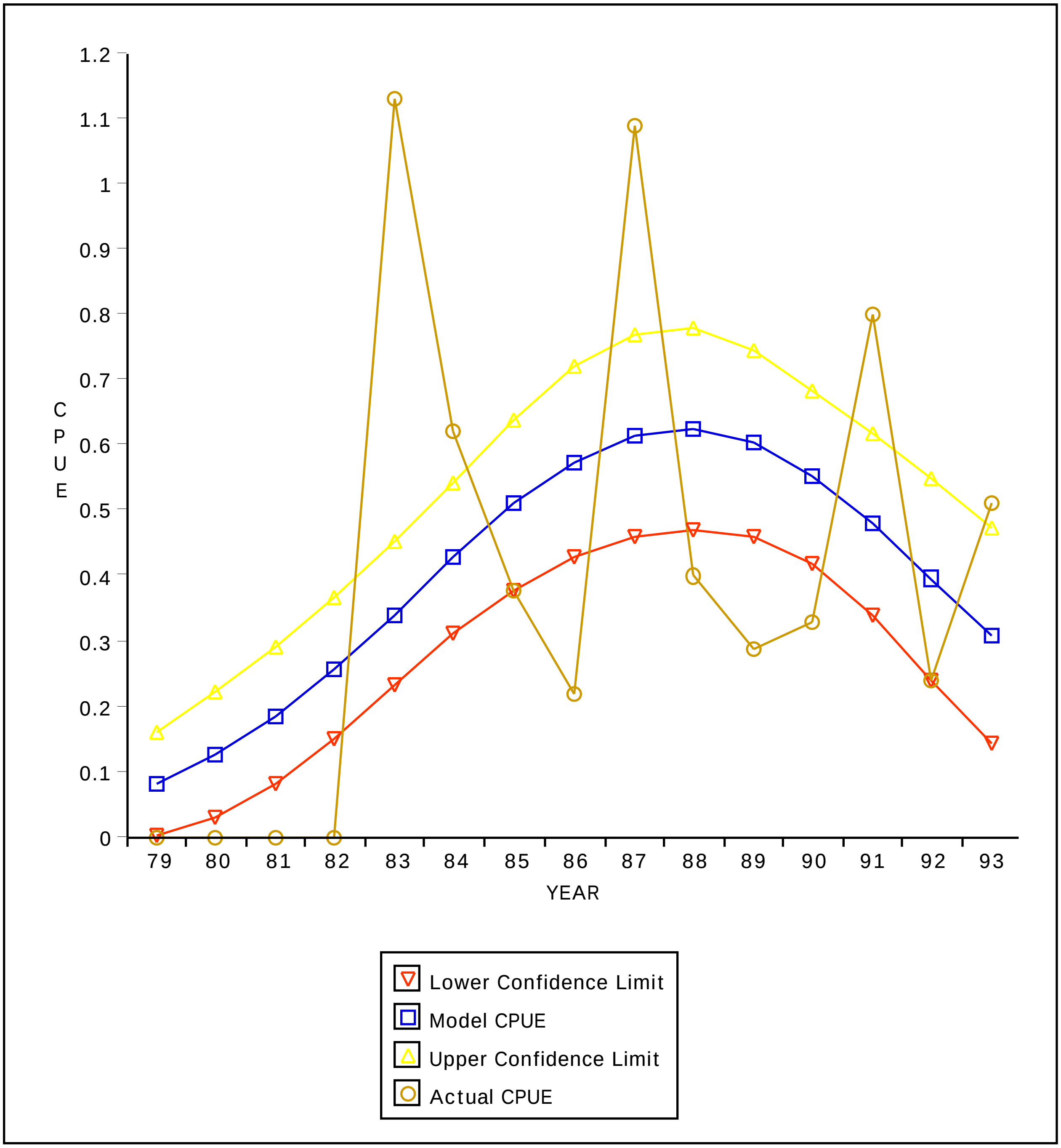

Figure VI.64. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/(GTIME/14)) for reproductively mature blue crab (150-224 mm TW[total width of carapace]) caught by gill net in Corpus Christi Bay during the Fall netting season.

blue crab/gill net/Aransas Bay

Modelled CPUE curved downward after 1986 (Table IX.38). As in Corpus Christi Bay, actual yield was negligible during 1979-1982. A phenomenal yield in 1983 influenced curvature of the quadratic model. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.67.

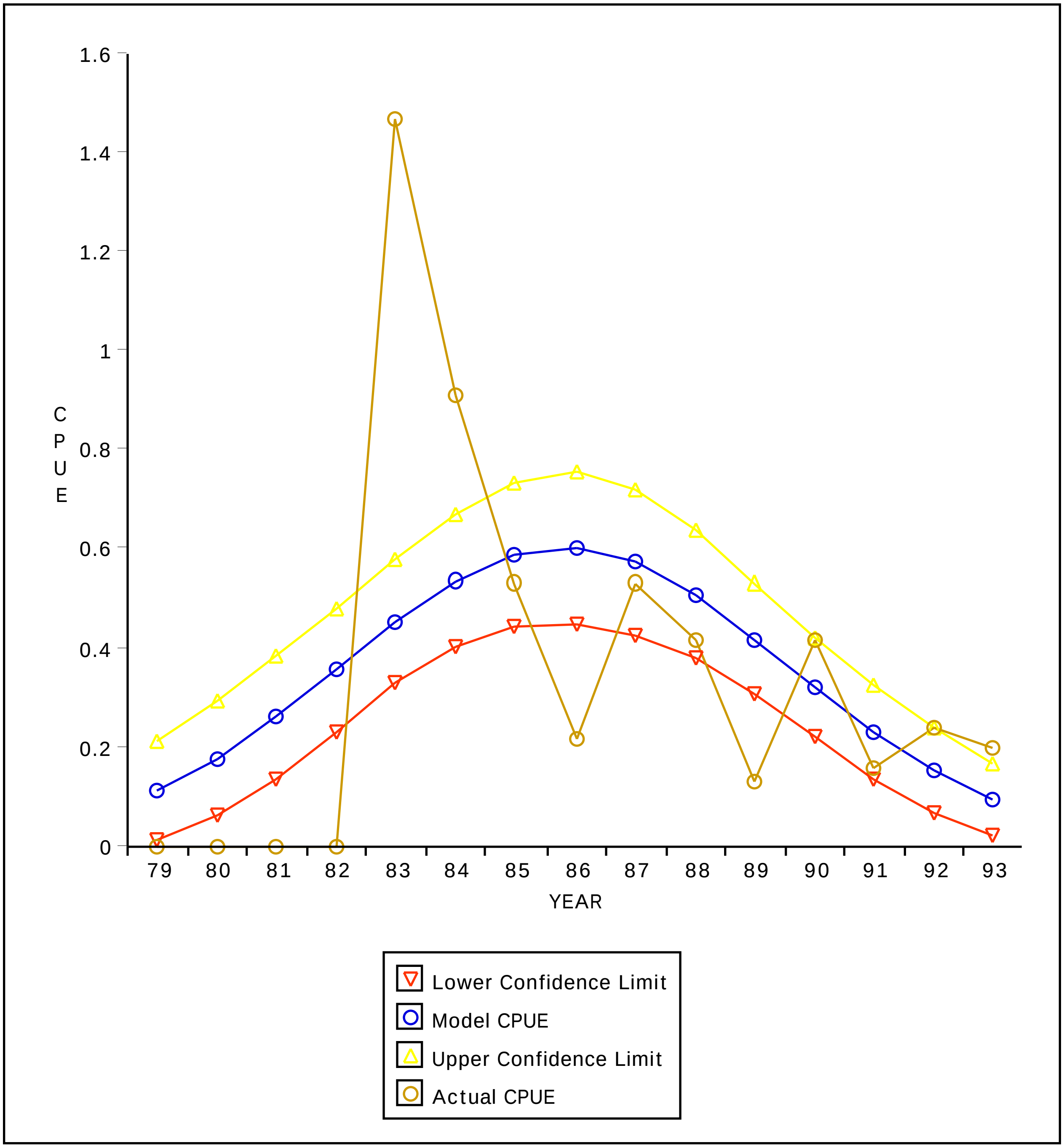

Figure VI.66. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/(GTIME/14)) for reproductively mature blue crab (150-224 mm TW[total width of carapace]), caught by gill net in Aransas Bay during the Fall netting season.

blue crab/gill net/Upper Laguna Madre

Modelled CPUE exhibited a significant quadratic trend with an interpolated maximum in 1987 (Table IX.39). Actual CPUE values during 1979-1982 and 1988-1990 were negligible. A phenomenal peak in actual CPUE was observed in 1987. This peak coincided with the interpolated model maximum. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.69.

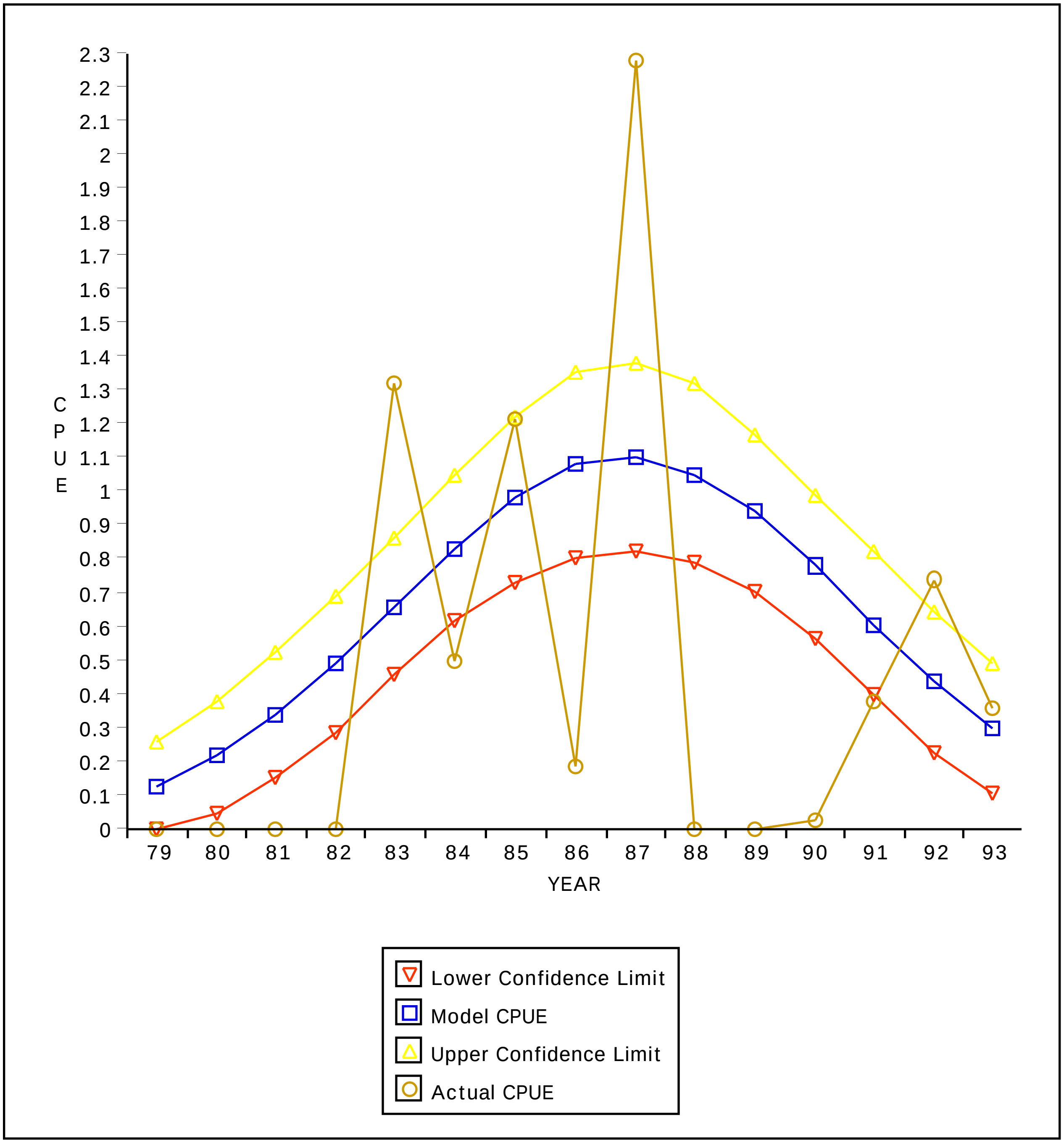

Figure VI.68. Actual catch per unit of effort and model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/(GTIME/14)$^{-1.5}$) for reproductively mature blue crab (150-224 mm TW[total width of carapace]), caught by gill net in the Upper Laguna Madre during the Fall netting season.

blue crab/gill net/model comparison

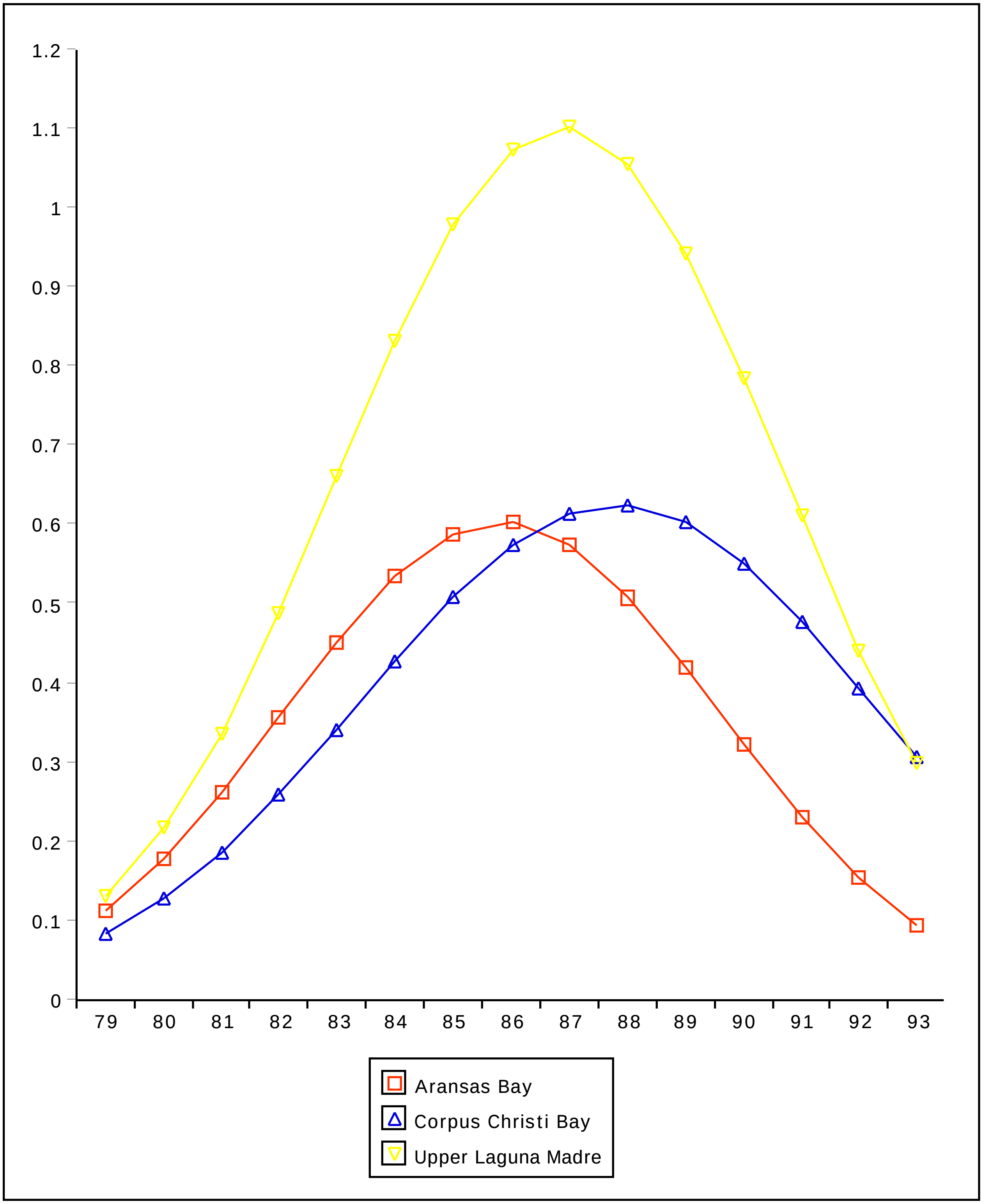

Figure VI.70. Comparison of best-fit models for reproductively mature blue crab caught by gill net in the CCBNEP (Table IX.40). CPUE = CATCH/(GTIME/14) for Corpus Christi and Aransas Bays. CPUE = $CATCH/(GTIME)^{-1.5}$ for the Upper Laguna Madre.
blue crab/bag seine/Corpus Christi Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.41). Actual CPUE values during 1979, 1981, and 1992 were high in comparison to most other years. A phenomenal yield was obtained in 1985. Actual CPUE improved steadily after 1987. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.72.

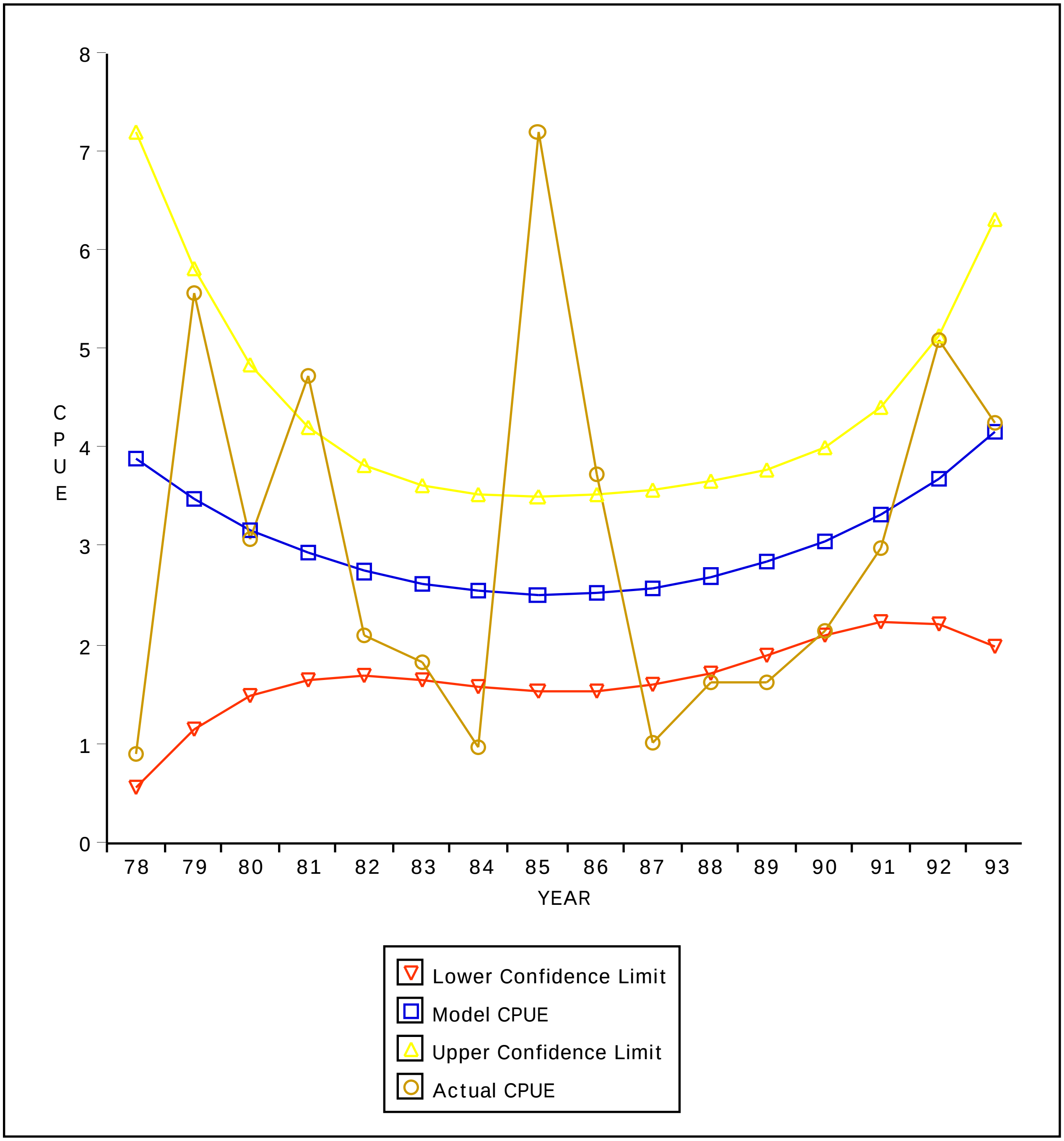

Figure VI.71. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year blue crab (20-39 mm

TW[total width of carapace]) caught by bag seine in Corpus Christi Bay during March, April, and May.

blue crab/bag seine/Aransas Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.42). Actual CPUE was greatest in 1982 and smaller peaks were observed in 1985 and 1991. Actual CPUE was negligible during 1978-1981 and 1986-1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.74.

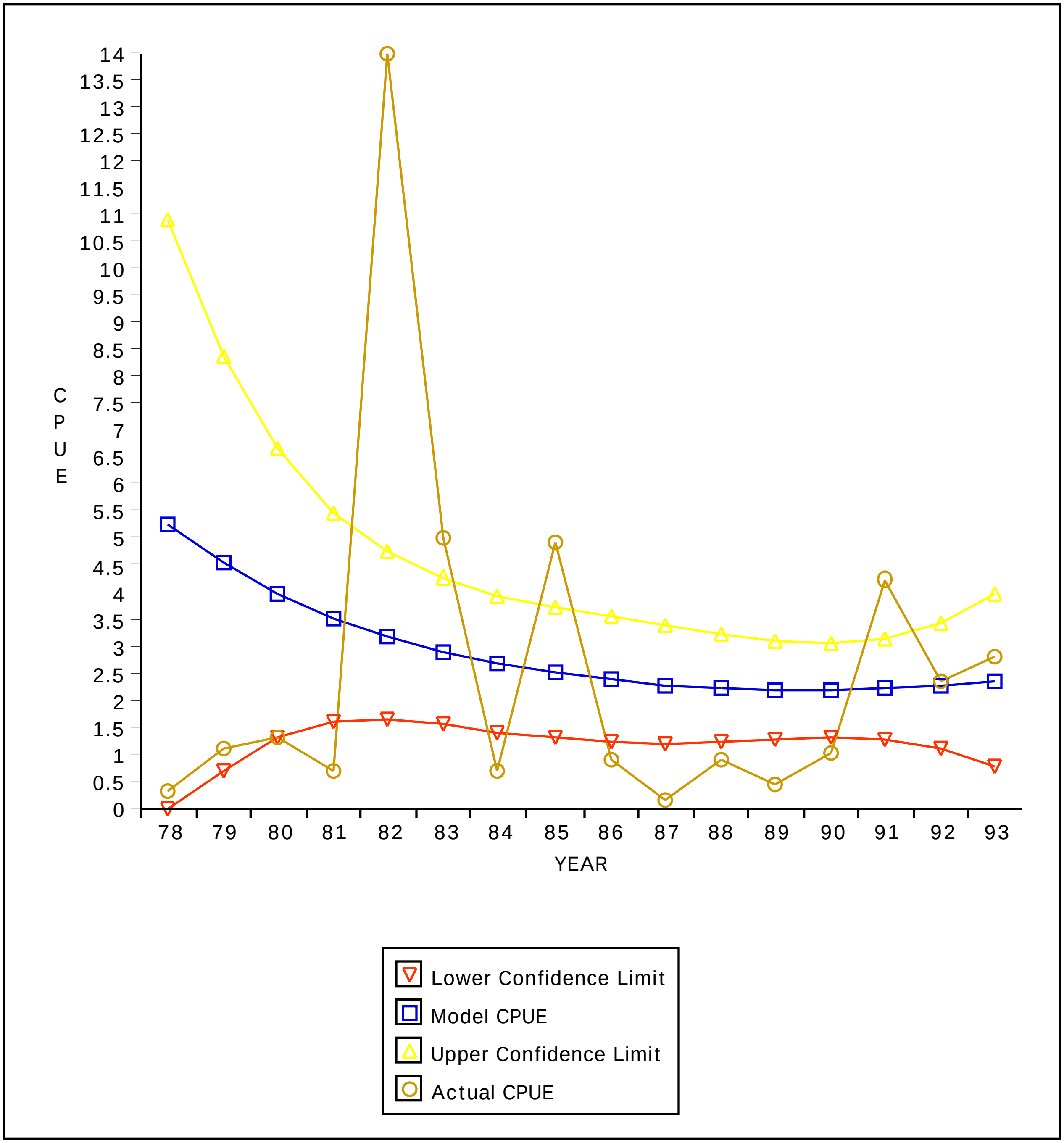

Figure VI.73. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year blue crab (20-39 mm TW[total width of carapace]) caught by bag seine in Aransas Bay during March, April, and May.

blue crab/bag seine/Upper Laguna Madre

Modelled CPUE exhibited no statistically significant trend (Table IX.43). Actual CPUE was greatest in 1985 and secondary peaks were observed in 1980 and 1992. Actual CPUE was negligible in 1981, 1984, 1989, and 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.76.

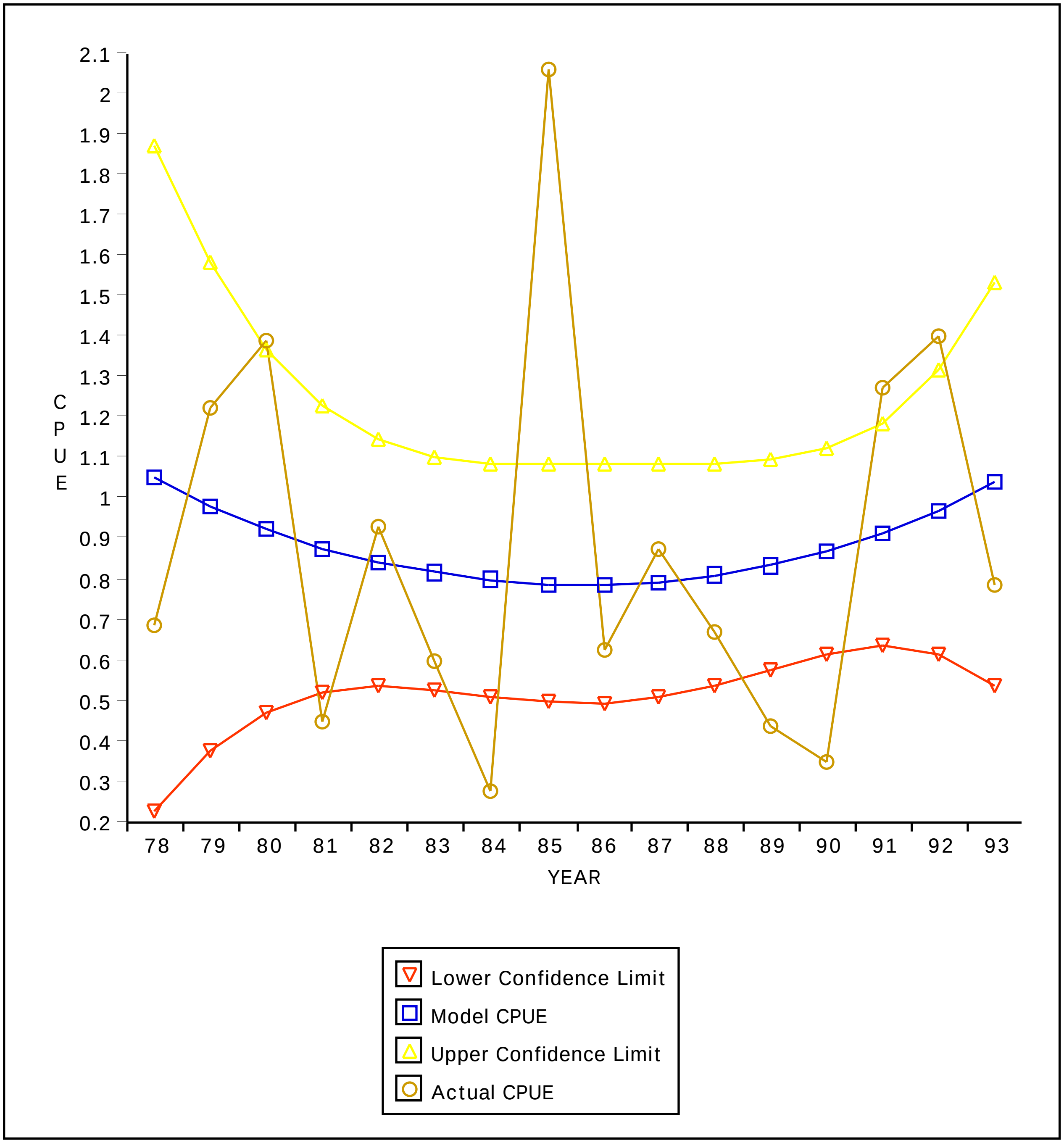

Figure VI.75. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year blue crab (20-39 mm TW[total width of carapace]) caught by bag seine in Upper Laguna Madre during March, April, and May.

blue crab/bag seine/model comparison

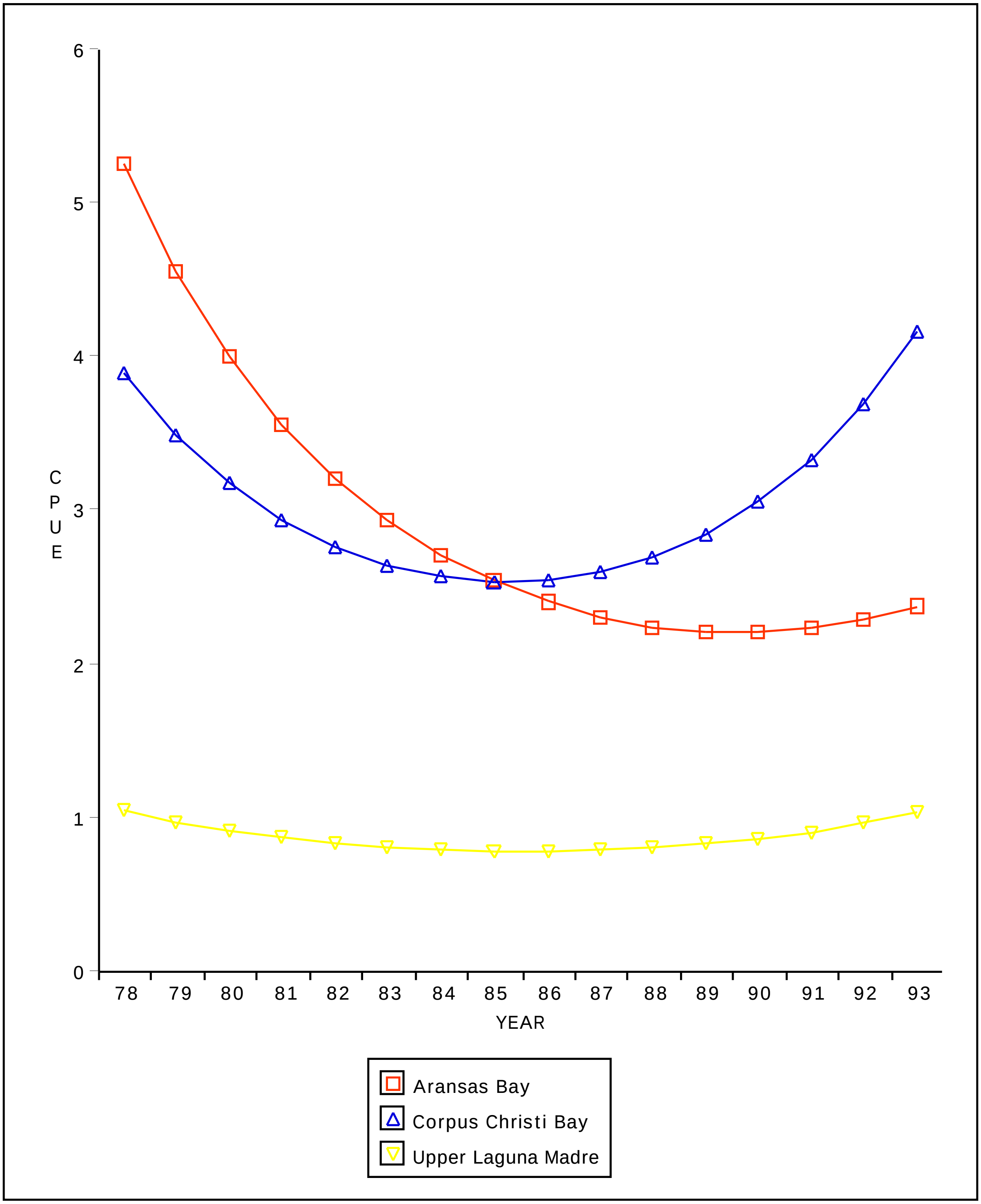

Figure VI.77. Comparison of best-fit models for young-of-year blue crab (20-39 mm TW[total width of carapace]) caught by bag seine in the CCBNEP (Table IX.44). CPUE = CATCH/0.03 hectare.
blue crab/trawl/Corpus Christi Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.45). Virtually no blue crab were caught in 1985 and 1989. Peaks in blue crab yield were observed in 1984, 1986, 1990, and 1992. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.79.

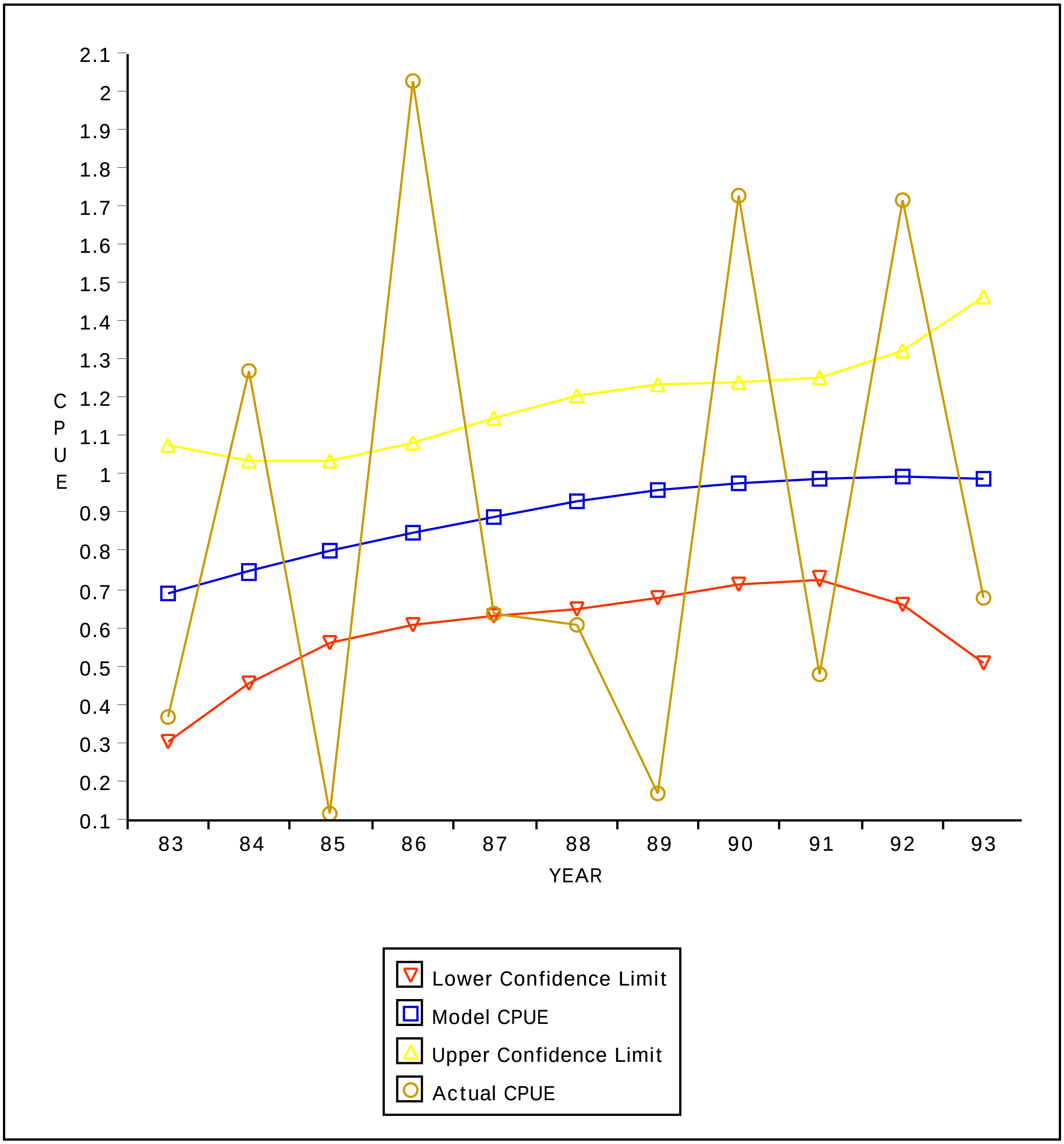

Figure VI.78. Actual catch per unit of effort and best-fit model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/10 minutes) for juvenile blue crab (50-74 mm TW[total width of carapace]) caught by trawl in Corpus Christi Bay during March, April, and May.

blue crab/trawl/Aransas Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.46). Actual CPUE was poorest on record in 1987. Actual CPUE fluctuated substantially around a mean of four blue crab per trawl. Peaks in actual catch were observed in 1984, 1986, 1988, and 1991. Since 1991, blue crab yield by trawl has declined. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.81.

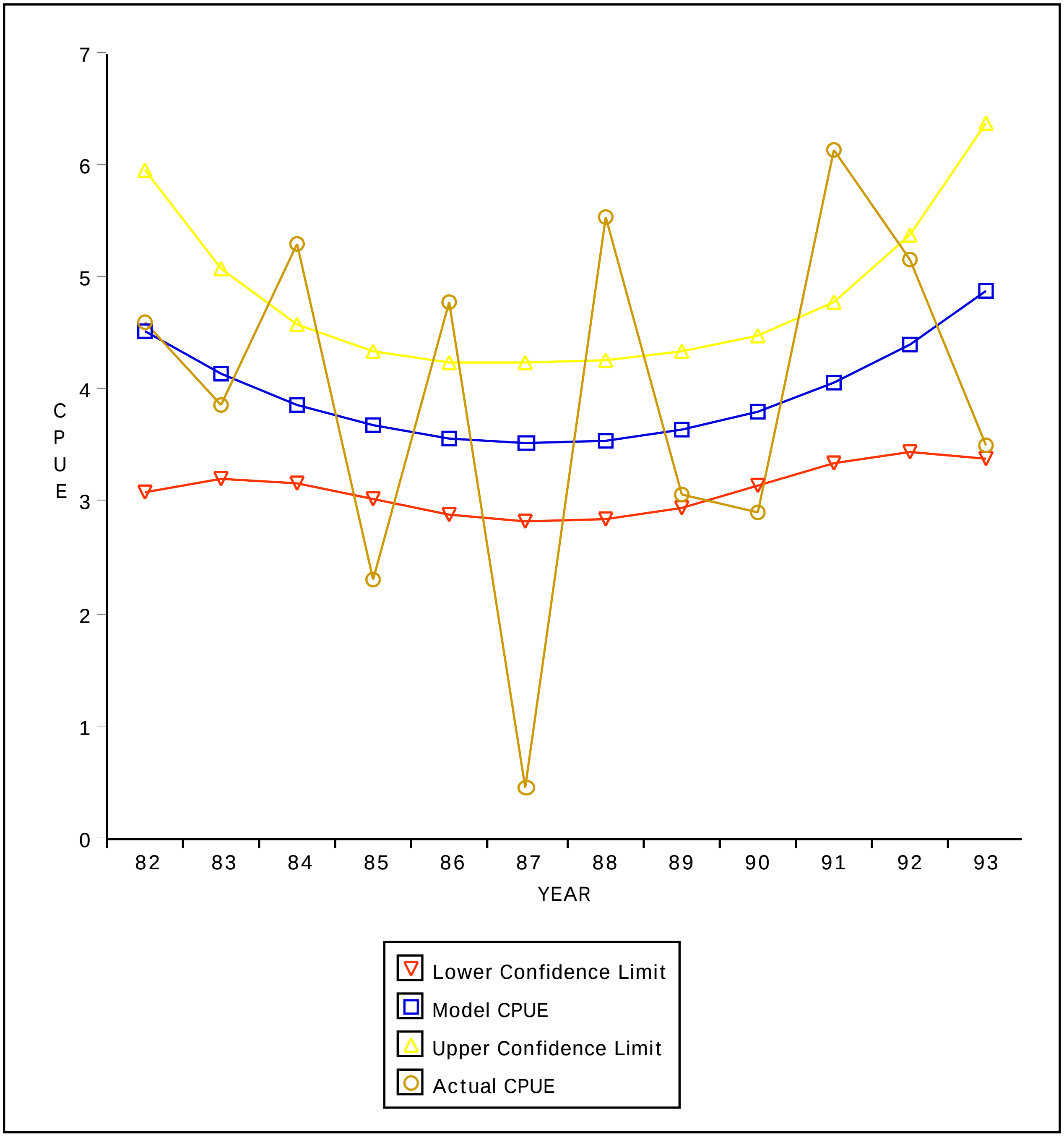

Figure VI.80. Actual catch per unit of effort and best-fit model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/10 minutes) for juvenile blue crab (50-74 mm TW[total width of carapace]) caught by trawl in Aransas Bay during March, April, and May.

blue crab/trawl/Upper Laguna Madre

Modelled CPUE curved upward after 1988 (Table IX.47). Actual CPUE was extremely poor in 1983, 1989, and 1991. Curvature of the model was influenced strongly by good yields during 1984-1985 and a phenomenally high yield in 1992. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.83.

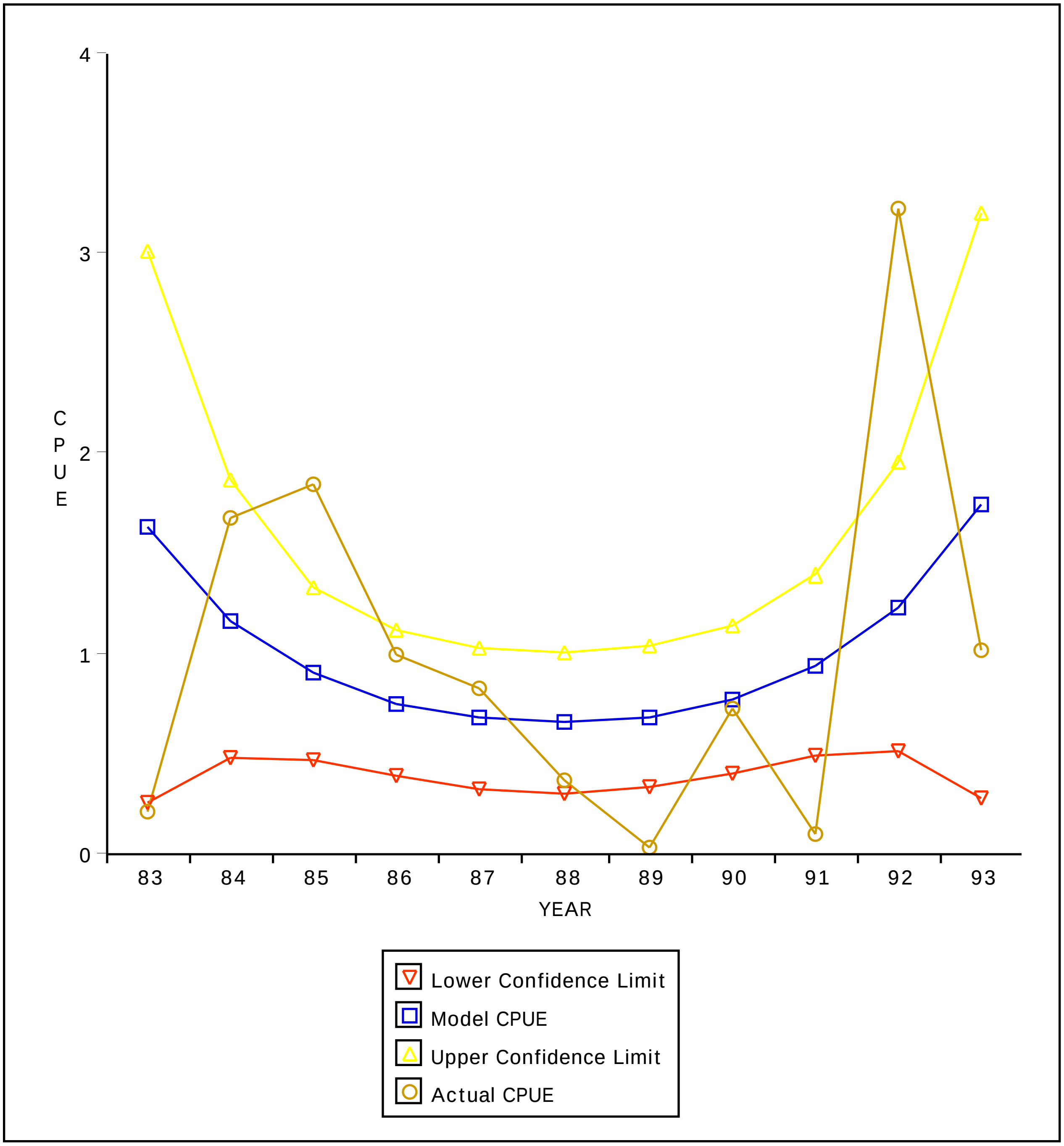

Figure VI.82. Actual catch per unit of effort and best-fit model with a significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/10 minutes) for juvenile blue crab (50-74 mm TW[total width of carapace]) caught by trawl in Upper Laguna Madre during March, April, and May.

blue crab/trawl/model comparison

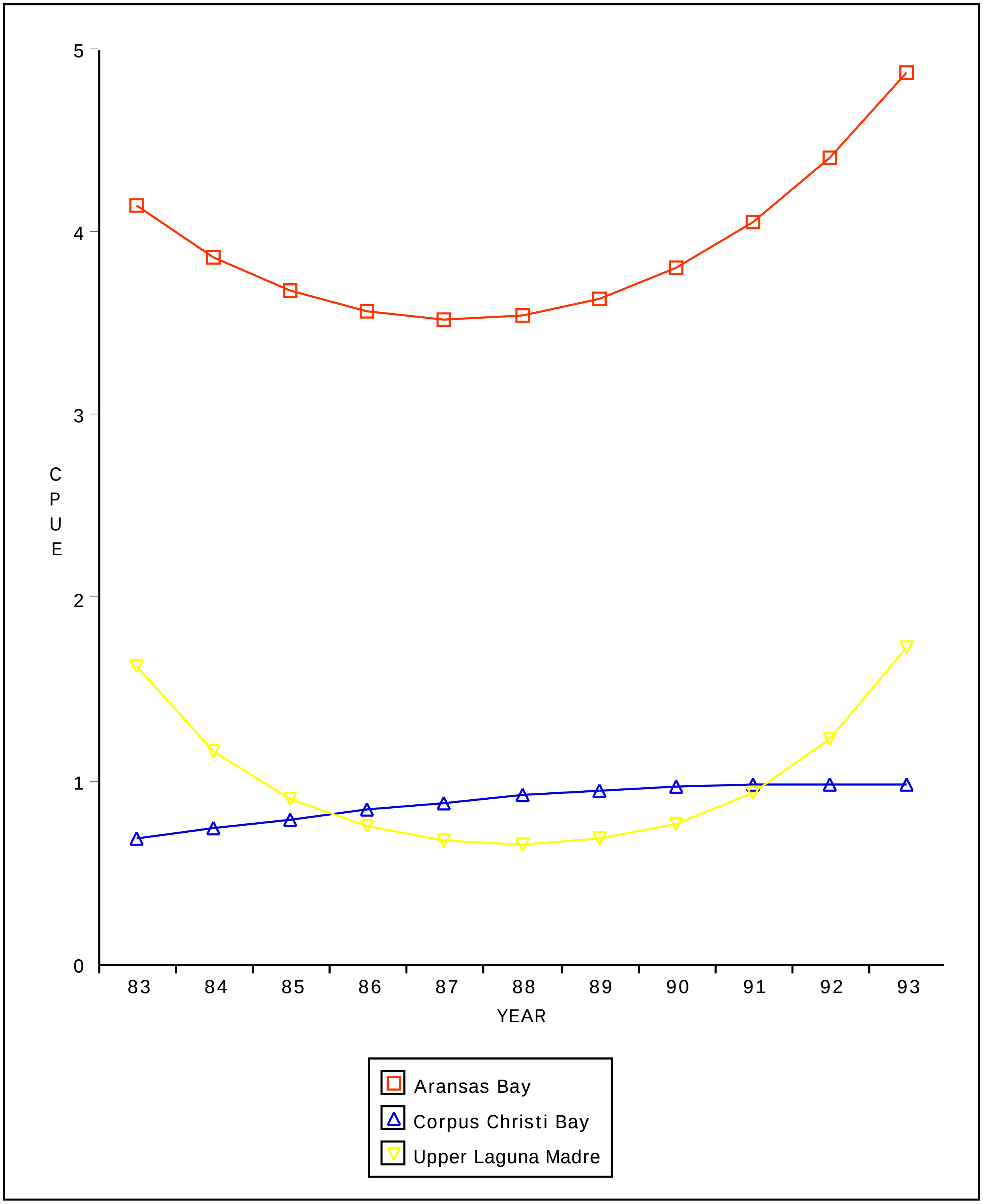

Figure VI.84. Comparison of best-fit models for juvenile blue crab (50-74 mm TW[total width of carapace]), caught by trawl in the CCBNEP (Table IX.48). CPUE = CATCH/10 minutes.

Actual gill net catch of adult blue crab (150-224 mm CW) peaked in 1983 and 1987 in all three bays, although mean number of blue crab caught in Corpus Christi Bay in 1987 was about twice the amount caught in Aransas Bay. Minor peaks in actual CPUE were seen in 1991, 1990, and 1992, in Corpus Christi Bay, Aransas Bay, and the Upper Laguna Madre, respectively. Synchronicity of peaks in actual catch by gill net resulted in similar models for the three bays: all exhibited significant quadratic curvature with maxima in 1986 (Aransas Bay), 1987 (Upper Laguna Madre), or 1988 (Corpus Christi Bay), respectively. When comparing the gill net models for the three bays, it is important to note that significant saturation effect was detected in Upper Laguna Madre catches.

Although analysis of bag seine catch revealed no significant linear or quadratic trend in any of the three bays surveyed, graphical representation of actual catch was similar. All three bays yielded low numbers of YOY in 1984 and the largest actual blue crab catches in Corpus Christi Bay and Upper Laguna Madre were recorded in 1985. All three bays exhibited increasing bag seine yields in the latter years of the survey. A gradual increase in bag seine actual catch in Corpus Christi Bay commenced in 1988 and peaked in 1992. A minor peak in bag seine actual catch was evident in 1991 in Aransas Bay , whereas Upper Laguna Madre exhibited a sustained secondary peak during 1991-1992. By contrast, the primary peak in actual bag seine catch in Aransas Bay was detected in 1982, whereas actual bag seine catch in Corpus Christi Bay declined from 1981 through 1984.

Actual blue crab trawl CPUE in Aransas Bay was generally fourfold greater than catches in either Corpus Christi Bay or Upper Laguna Madre. Although significant quadratic curvature was detected in the Upper Laguna Madre trawl model and no significant trend was detected in that of Corpus Christi Bay, these two data sets were more similar to each other with regard to timing of increases and decreases in actual catch than either was to Aransas Bay. Actual trawl catch within Aransas Bay was highly erratic, because noticeable peaks in 1984, 1986, 1988, and 1991 were followed by sharp decreases in subsequent years. Actual catch in Upper Laguna Madre and Corpus Christi Bay decreased commencing in 1986 and 1987, respectively, until negligible catches were obtained in 1989.

Interestingly, Upper Laguna Madre gill net catch conformed best to a quadratic model with a maximum in 1987, whereas trawl catches fit best to a quadratic model with a minimum in 1988. Moreover, bag seine data did not fit either a linear or quadratic model. These results further indicate the need to sample different life stages of this estuarine macroinvertebrate instead of relying on data from only one life stage. Because of similarities among gill net models, it is reasonable to conclude that blue crab of reproductive size were most plentiful within the CCBNEP study area during 1986-1988 and that the trend indicates blue crab numbers have declined since then, even though smaller peaks in actual yield were detected in later years. With regard to juvenile blue crab (50-74 mm TW) caught by trawl, the only bay demonstrating a modelled increase (after 1988) in catch was Upper Laguna Madre. Incurrence of brown tide in Upper Laguna Madre did not adversely affect the catch of YOY, juvenile, or adult blue crab during the latter years surveyed (1990-1993). In fact, the greatest trawl CPUE of blue crab in Upper Laguna Madre occurred in 1992.

Analysis for Atlantic croaker (*Micropogonias undulatus*)

Atlantic croaker/gill net/Corpus Christi Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.49). Actual CPUE fluctuated around a mean of four fish per gill net set. Actual CPUE was high during 1984-1986 and in 1993. Actual CPUE was minimal in 1989, after which it exhibited sustained improvement. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.86.

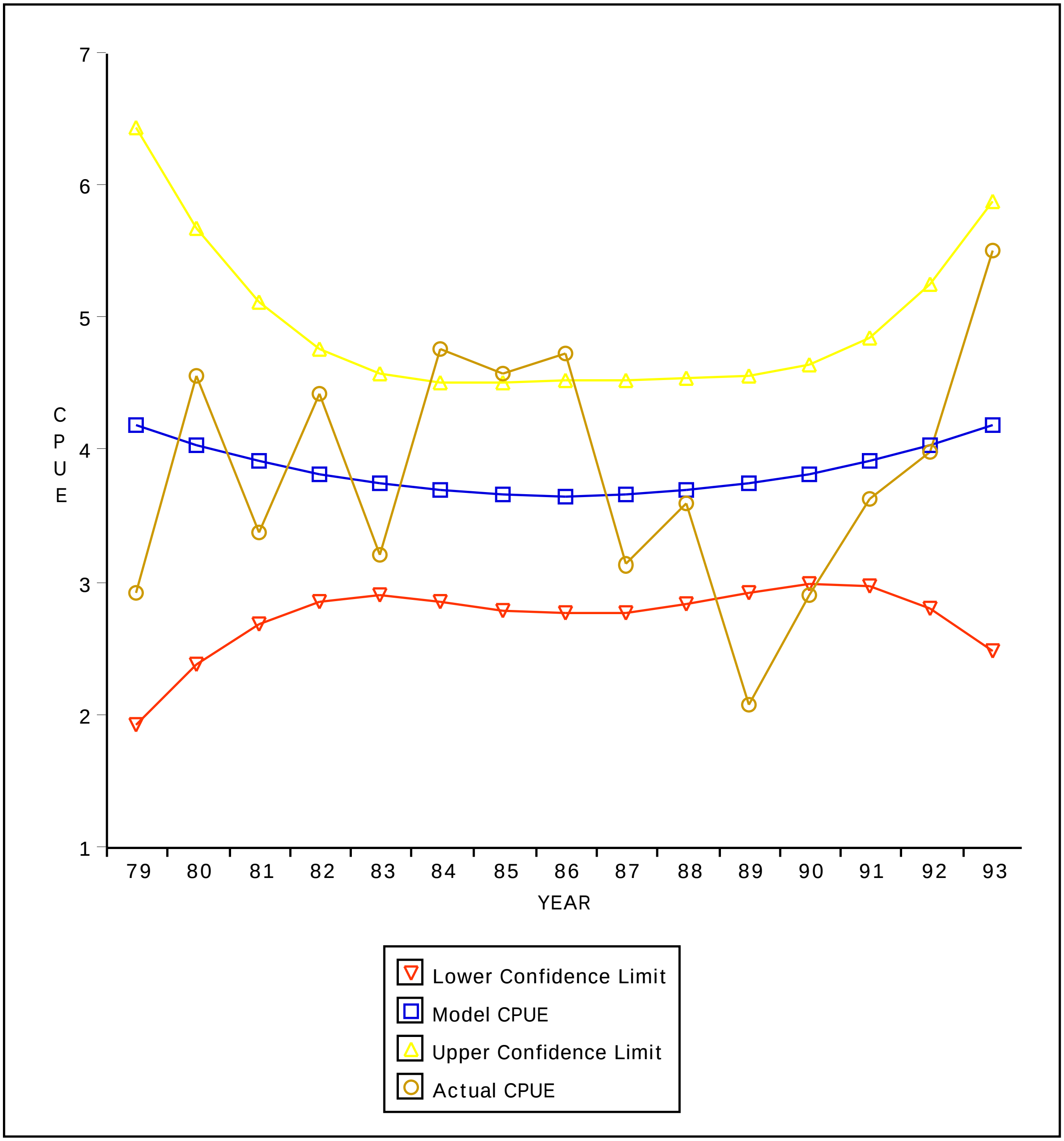

Figure VI.85. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/(GTIME/14)$^{-3.5}$) for reproductively mature Atlantic croaker (225-299 mm TL) caught by gill net in Corpus Christi Bay during the Fall netting season.

Atlantic croaker/gill net/Aransas Bay

Although the best-fit model exhibited slight curvature, no statistically significant trend in modelled CPUE was found (Table IX.50). Actual CPUE fluctuated around a mean of about 1.6 fish per gill net set. Actual CPUE was best during 1985-1986 and in 1992. Poorest actual CPUE was recorded during 1979-1980 and in 1984. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.88.

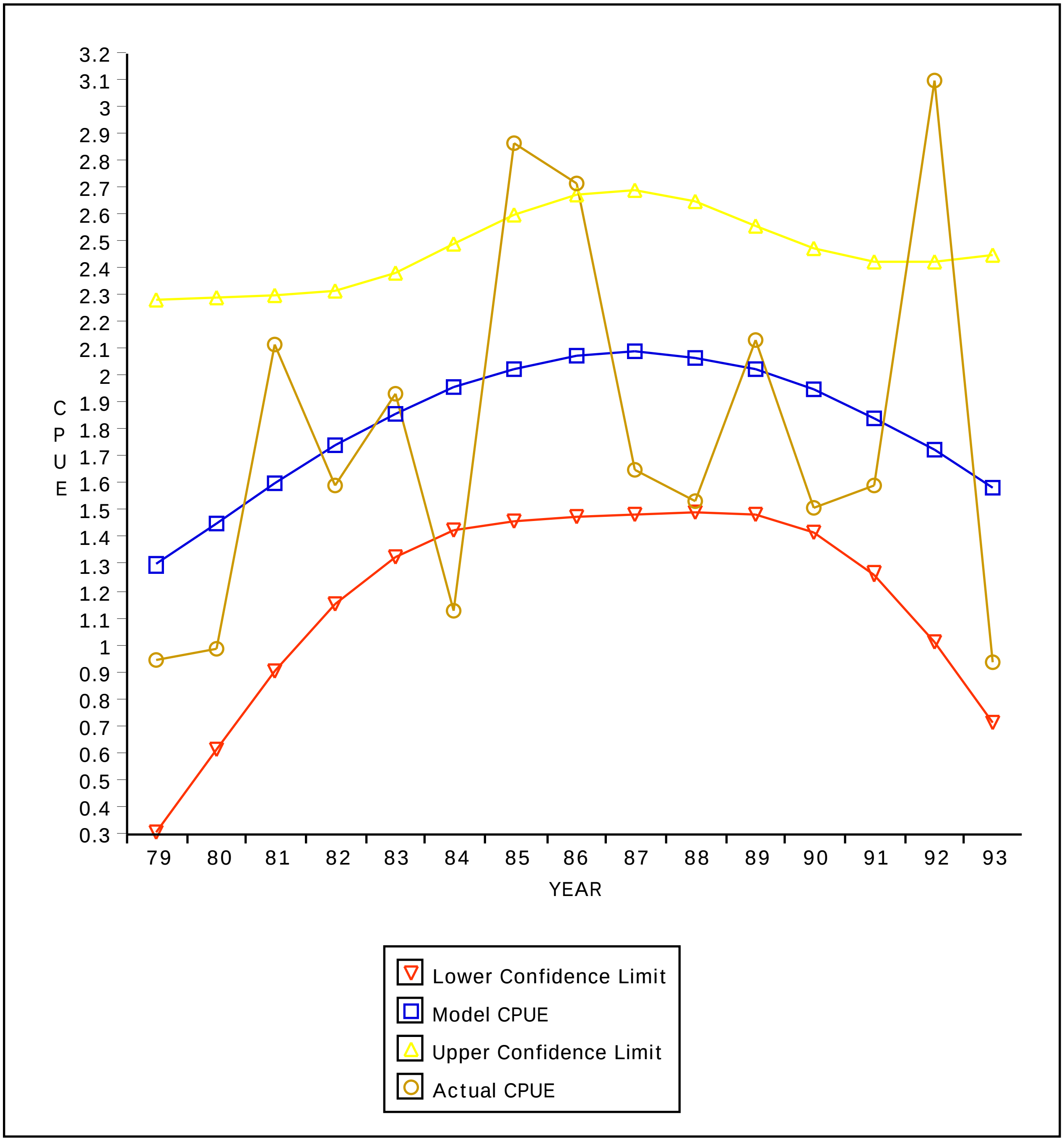

Figure VI.87. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/(GTIME/14)$^{-3.5}$) for reproductively mature Atlantic croaker (225-299 mm TL), caught by gill net in Aransas Bay during the Fall netting season.

Atlantic croaker/gill net/Upper Laguna Madre

Modelled CPUE curved downward after 1981 (Table IX.51). Actual CPUE peaked in 1982 and 1985. These high yields, along with generally declining yields after 1985, were influential in generating curvature in the model. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.90.

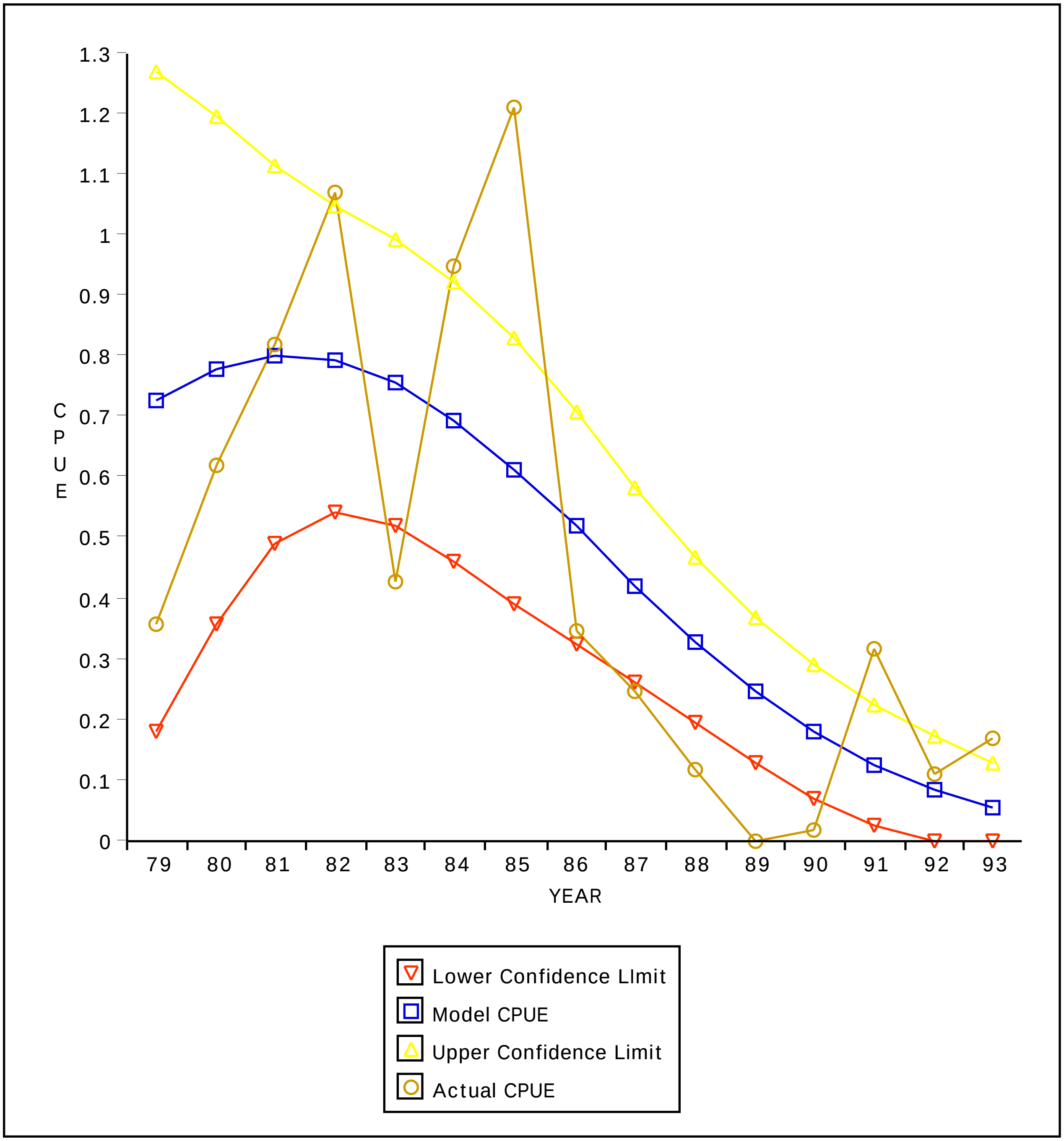

Figure VI.89. Actual catch per unit of effort and model with significant quadratic component (**CPUE = $\mathbf{b_0}$ + $\mathbf{b_1}$*YEAR + $\mathbf{b_2}$*YEAR$^{\mathbf{2}}$** where CPUE = CATCH/(GTIME/14)) for reproductively mature Atlantic croaker (225-299 mm TL), caught by gill net in the Upper Laguna Madre during the Fall netting season.

Atlantic croaker/gill net/model comparison

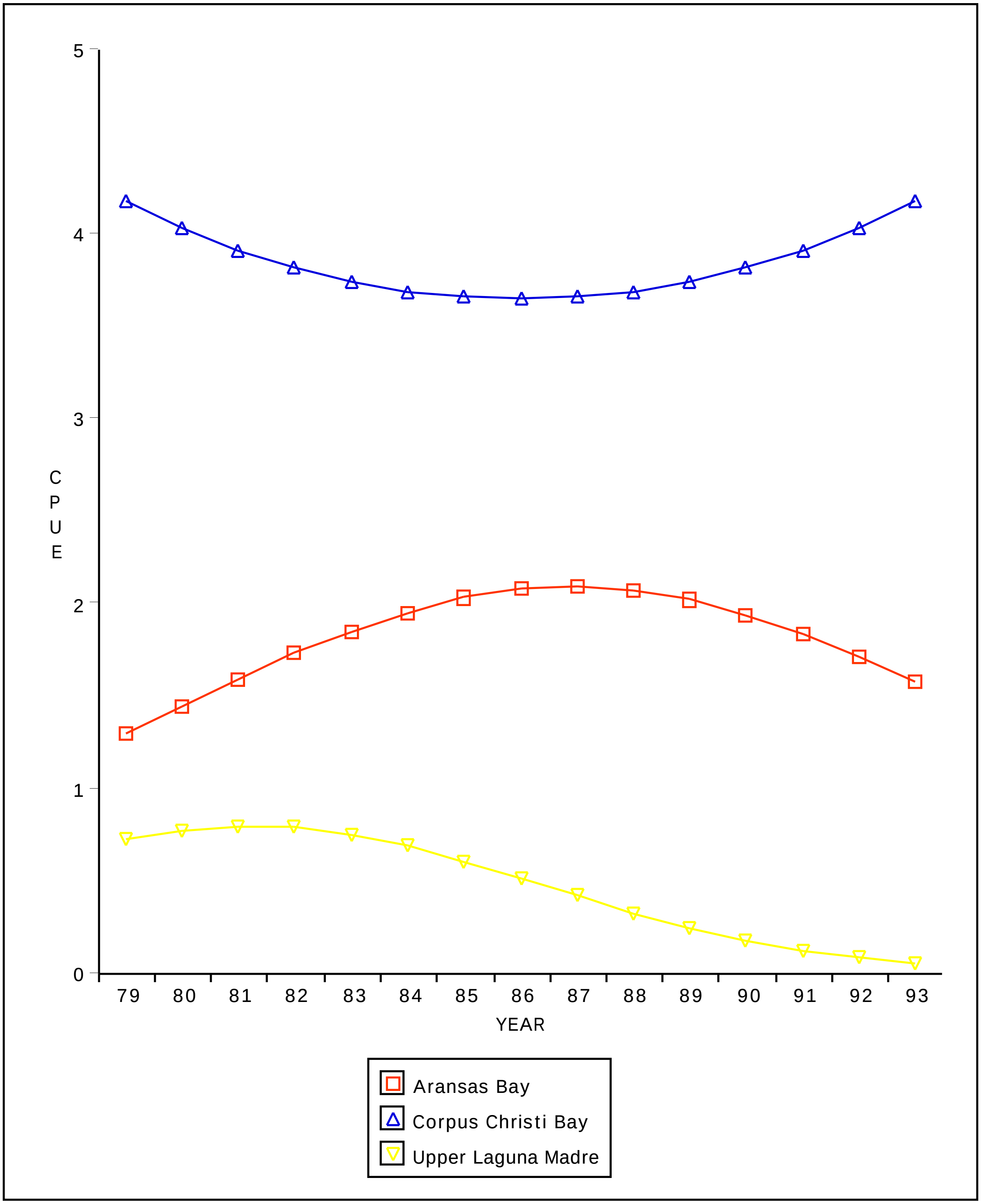

Figure VI.91. Comparison of best-fit models for reproductively mature Atlantic croaker caught by gill net in the CCBNEP (Table IX.52). CPUE = CATCH/(GTIME/14)$^{-3.5}$ for Corpus Christi Bay and Aransas Bay. CPUE = CATCH/(GTIME/14) for Upper Laguna Madre.
Atlantic croaker/bag seine/Corpus Christi Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.53). Slight curvature in the best-fit model was influenced strongly by extremely poor yields during 1985-1991. Actual CPUE peaked in 1984. Smaller peaks in 1979, 1981, and 1992 were also influential in generating curvature in the model. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.93.

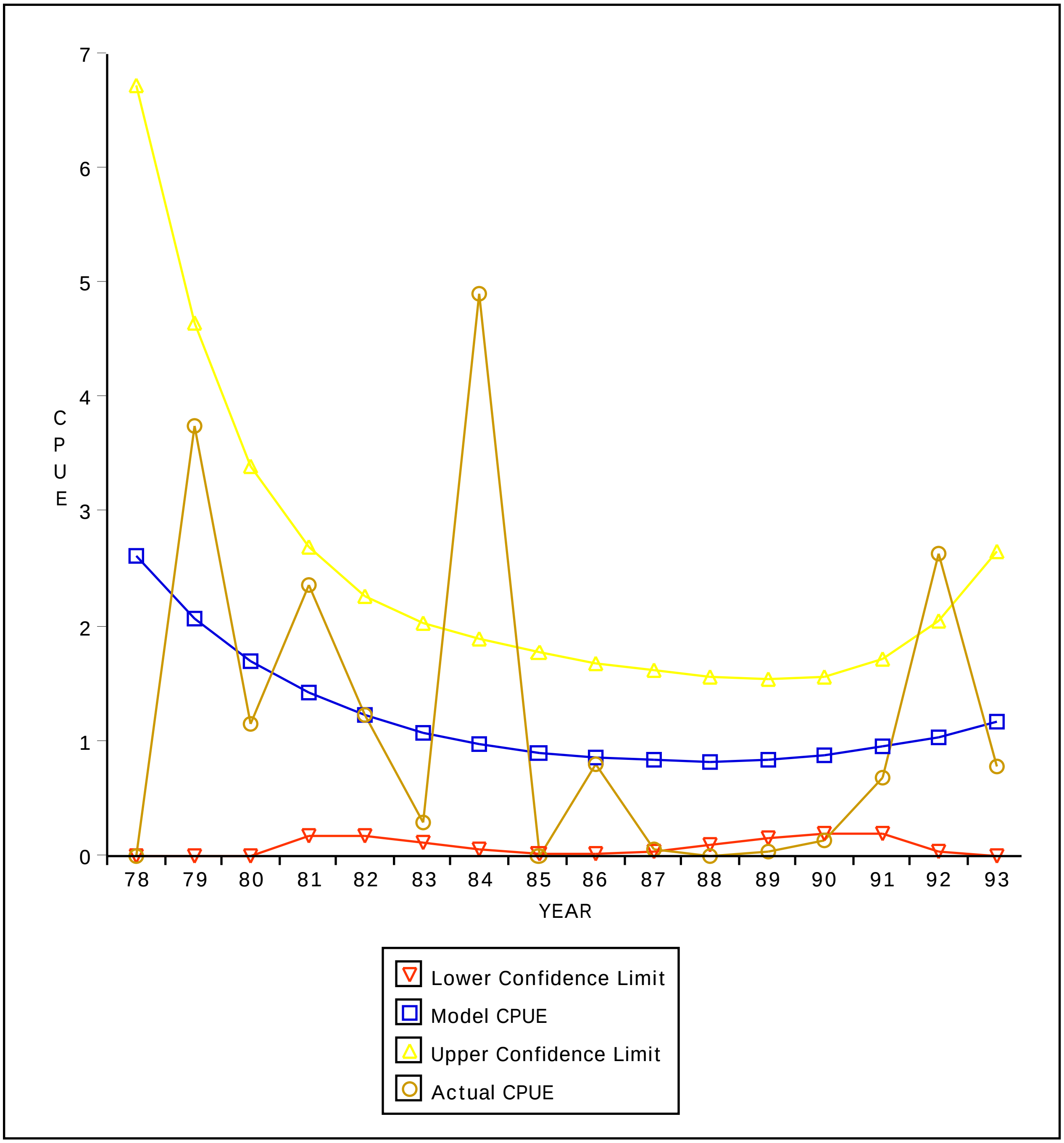

Figure VI.92. Actual catch per unit of effort and model with no statistically significant trend

(**CPUE = $\mathbf{b_o}$**, where CPUE = CATCH/0.03 hectare) for young-of-the-year Atlantic croaker (60-79 mm TL) caught by bag seine in Corpus Christi Bay during April and May.

Atlantic croaker/bag seine/Aransas Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.54). Actual CPUE was negligible during 1978-1981 and 1986-1988. Actual CPUE was highest on record in 1982. Smaller peaks were observed in 1984 and 1992. Actual CPUE improved steadily after 1988, but it declined steeply after 1992. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.95.

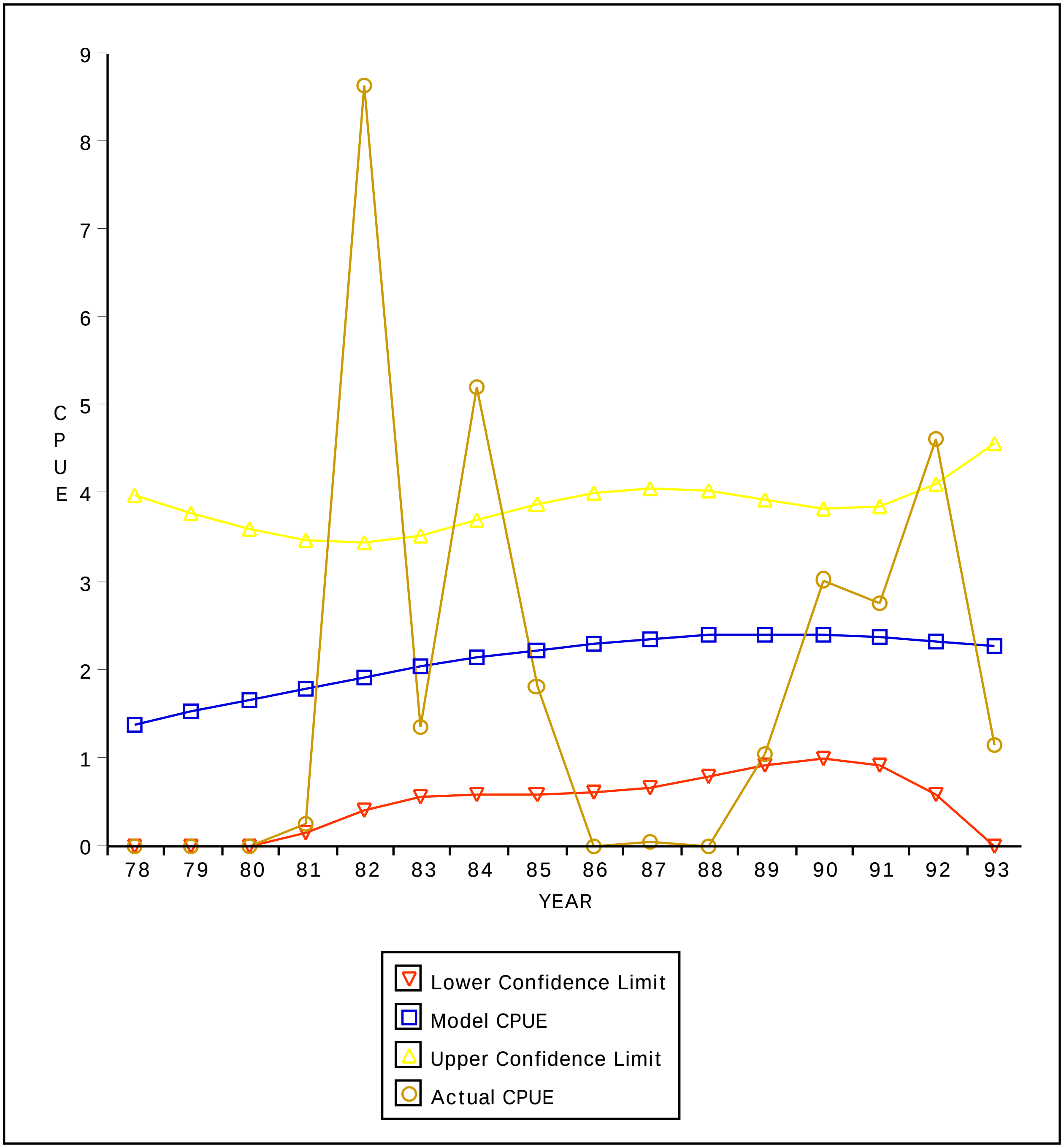

Figure VI.94. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year Atlantic croaker (60-79 mm TL) caught by bag seine in Aransas Bay during April and May.

Atlantic croaker/bag seine/Upper Laguna Madre

Modelled CPUE exhibited no statistically significant trend (Table IX.55). Actual CPUE was negligible during 1986-1991. Prominent peaks in actual CPUE were observed in 1979, 1985, and 1992. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.97.

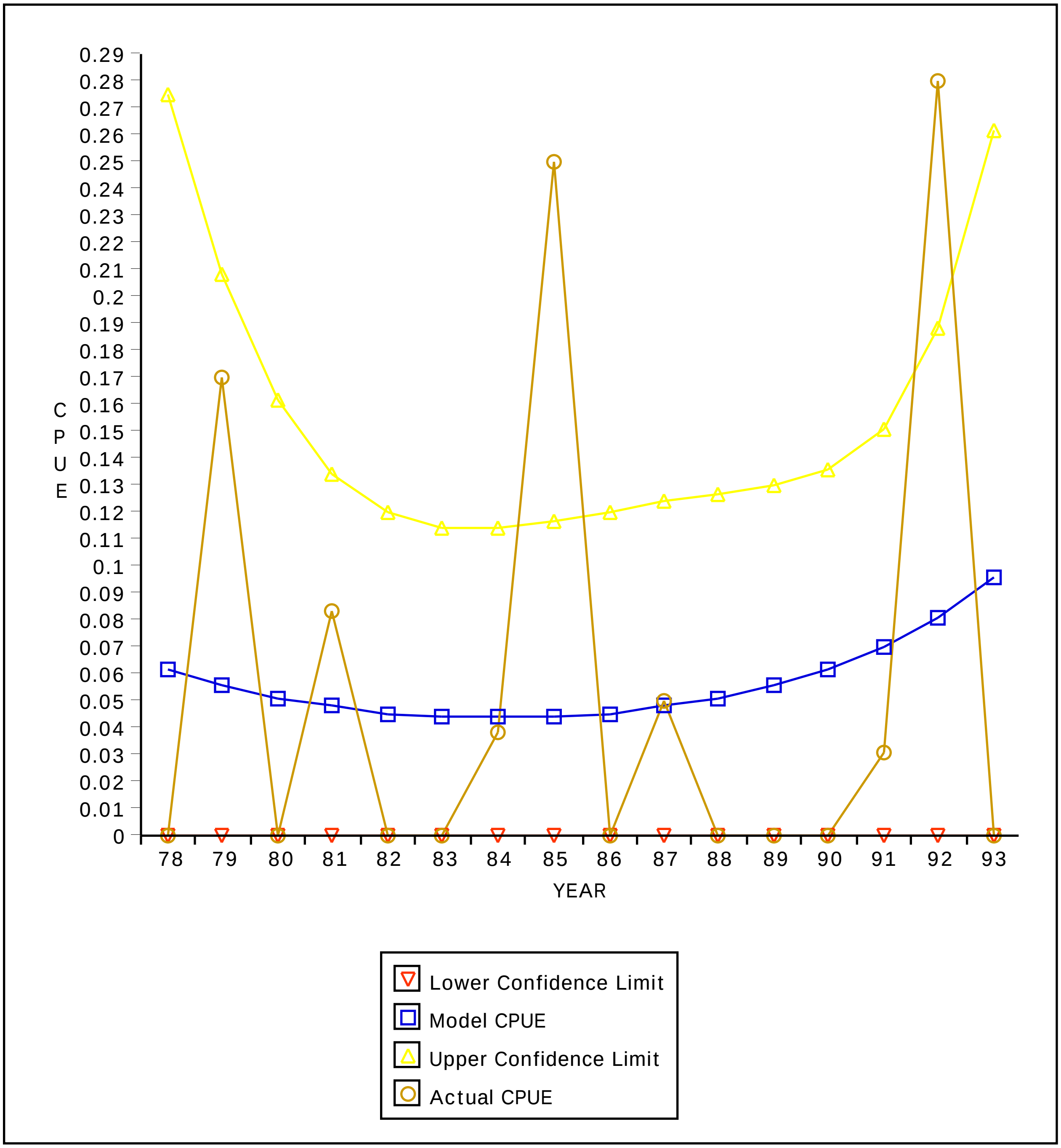

Figure VI.96. Actual catch per unit of effort and model with no statistically significant trend

(**CPUE = $\mathbf{b_o}$**, where CPUE = CATCH/0.03 hectare) for young-of-the-year Atlantic croaker (60-79 mm TL) caught by bag seine in Upper Laguna Madre during April and May.

Atlantic croaker/bag seine/model comparison

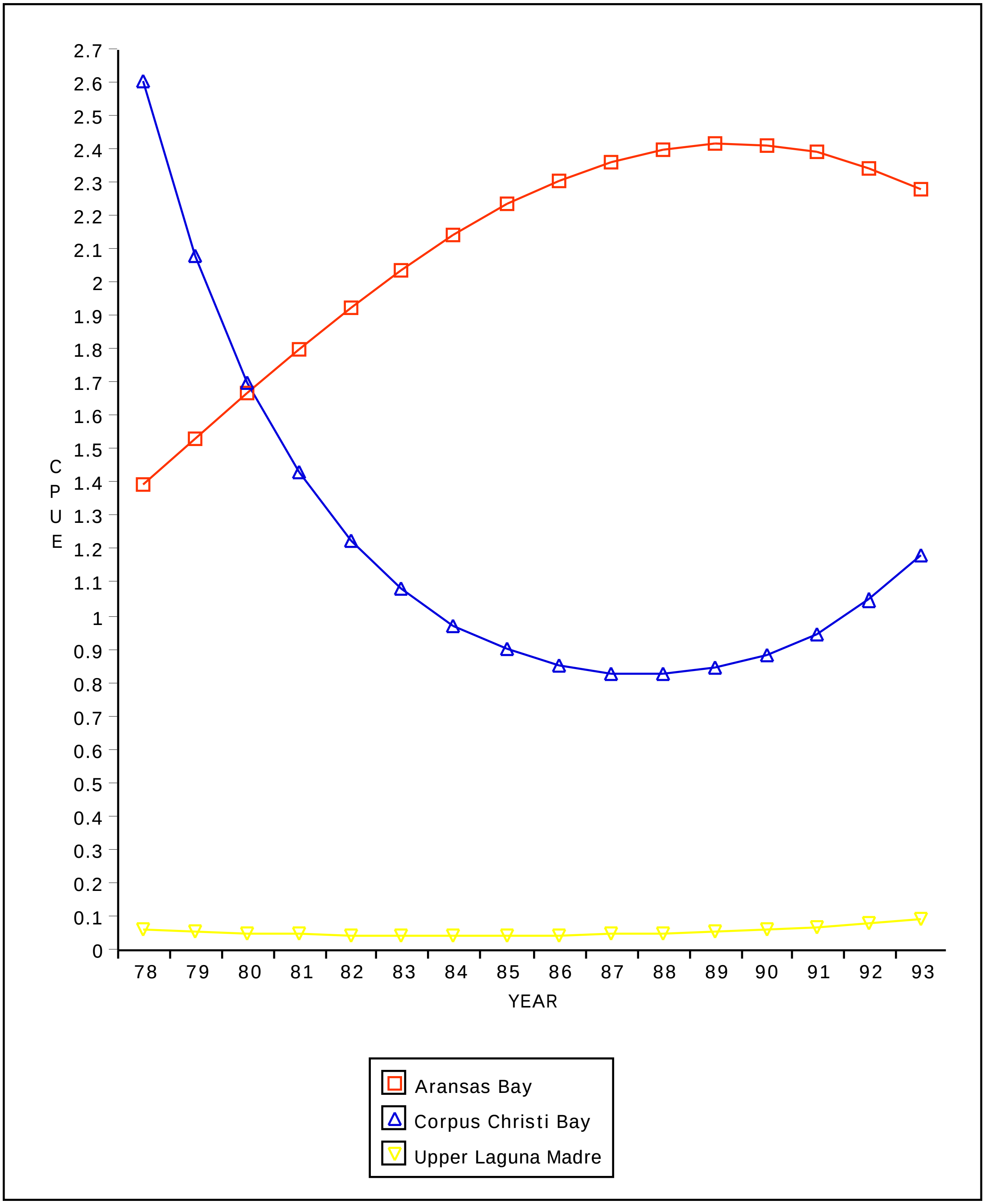

Figure VI.98. Comparison of best-fit models for young-of-year Atlantic croaker caught by bag seine in the CCBNEP (Table IX.56).

No significant quadratic or linear trends were detected for bag seine CPUE of YOY Atlantic croaker within the CCBNEP area. Nevertheless, timing of increases and decreases in actual catch was generally similar in Corpus Christi and Aransas Bays. YOY were caught in relatively large numbers in 1984 in Corpus Christi and Aransas Bays. In all three bays, YOY Atlantic croaker were caught infrequently in 1986 and 1987, possibly due to high mortality rates for YOY and juveniles during the red tide. In Upper Laguna Madre, very few young-of-year Atlantic Croaker were caught until 1992, whereas increased yields were evident in Aransas Bay as early as 1989: actual bag seine catch generally increased from 1989 to 1992 in Aransas Bay. Decreases in bag seine catches were evident in all three bays in 1993. A primary peak in actual CPUE was detected in Aransas Bay in 1982, but not in Corpus Christi Bay and Upper Laguna Madre.

Catch by gill net of adult (225-299 mm TL) Atlantic croaker in Corpus Christi Bay exhibited significant saturation effect ($CATCH/(GTIME/14)^{-3.5}$), thus comparisons with Aransas Bay and Upper Laguna Madre should be interpreted with caution. No trends were detected Corpus Christi and Aransas Bays, whereas modelled CPUE by gill net in Upper Laguna Madre curved downward after a maximum in 1981. Actual catch maximum in Upper Laguna Madre was detected in 1985. Poor actual catches of Atlantic croaker were recorded in 1983, and then again from 1986 until 1993. It is clear from the model and actual catches that the trend in Upper Laguna Madre should be a cause for concern, even though actual bag seine yields of YOY exhibited strong peaks in 1979, 1985, and 1992.

In Corpus Christi Bay, principal peaks in actual bag seine catch of Atlantic croaker were recorded in 1979, 1984, and 1992. The 1984 bag seine peak coincided with high gill net yields sustained during 1984-1986. Actual catch by gill net of reproductive Atlantic croaker in Corpus Christi Bay was low in 1989, but yields increased thereafter to an actual catch maximum in 1993. Actual bag seine catches also peaked in 1984 and 1992 in Aransas Bay, but as mentioned previously, a primary peak in 1982 was evident only in Aransas Bay. With regard to the relative timing of high catches in both bag seine and gill net collections, Corpus Christi Bay and Aransas Bay were more similar to each other than either was to Upper Laguna Madre. Bag seine catches of YOY Atlantic croaker were lowest during 1978-1981 and 1986-1989 in Aransas Bay.

In summary, five of the six models tested revealed no significant linear or quadratic trends. The decreasing curvilinear trend exhibited by the Upper Laguna Madre gill net model suggests that Atlantic croaker of reproductive size were becoming increasingly rare despite sporadic high catches in bag seines. On the basis of similar timing of peaks in actual yield by both gears, Corpus Christi Bay and Aransas Bay were more similar to one another than either was to Upper Laguna Madre during 1978-1993.

Analysis for pink shrimp (*Penaeus duorarum*)
Pink Shrimp/Bag Seine/Corpus Christi Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.57). Actual CPUE peaked in 1979 and 1988. Poorest yields were recorded in 1978, 1985, and 1993. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.100.

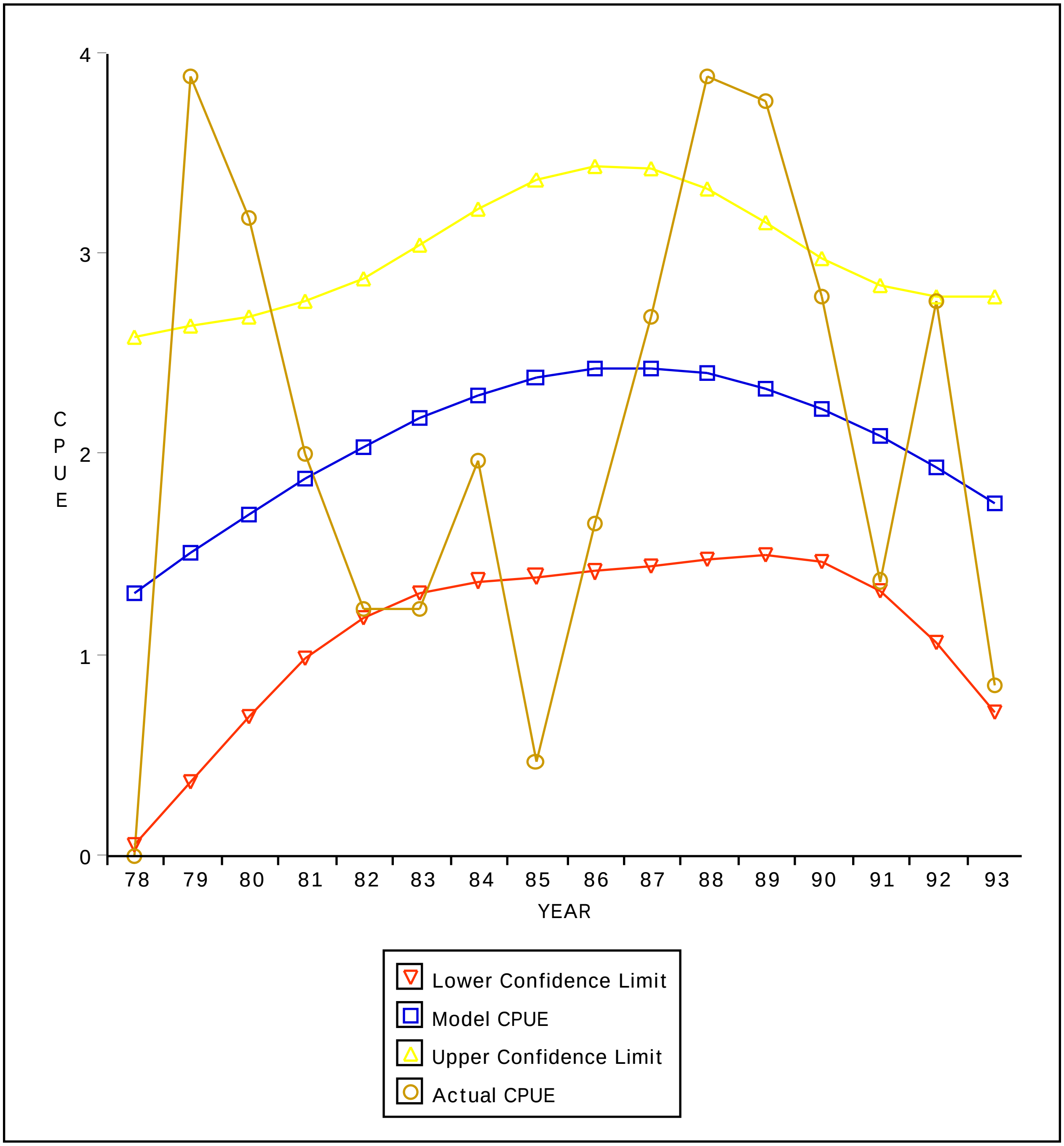

Figure VI.99. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/0.03 hectare) for young-of-the-year pink shrimp (40-59 mm TL) caught by bag seine in Corpus Christi Bay during September, October, and November.

pink shrimp/bag seine/Aransas Bay

Modelled CPUE increased linearly during the study (Table IX.58). Actual CPUE peaked in 1981, 1988, and 1990. Virtually no pink shrimp of the selected size class were caught during 1978-1979 and 1984-1986. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.102.

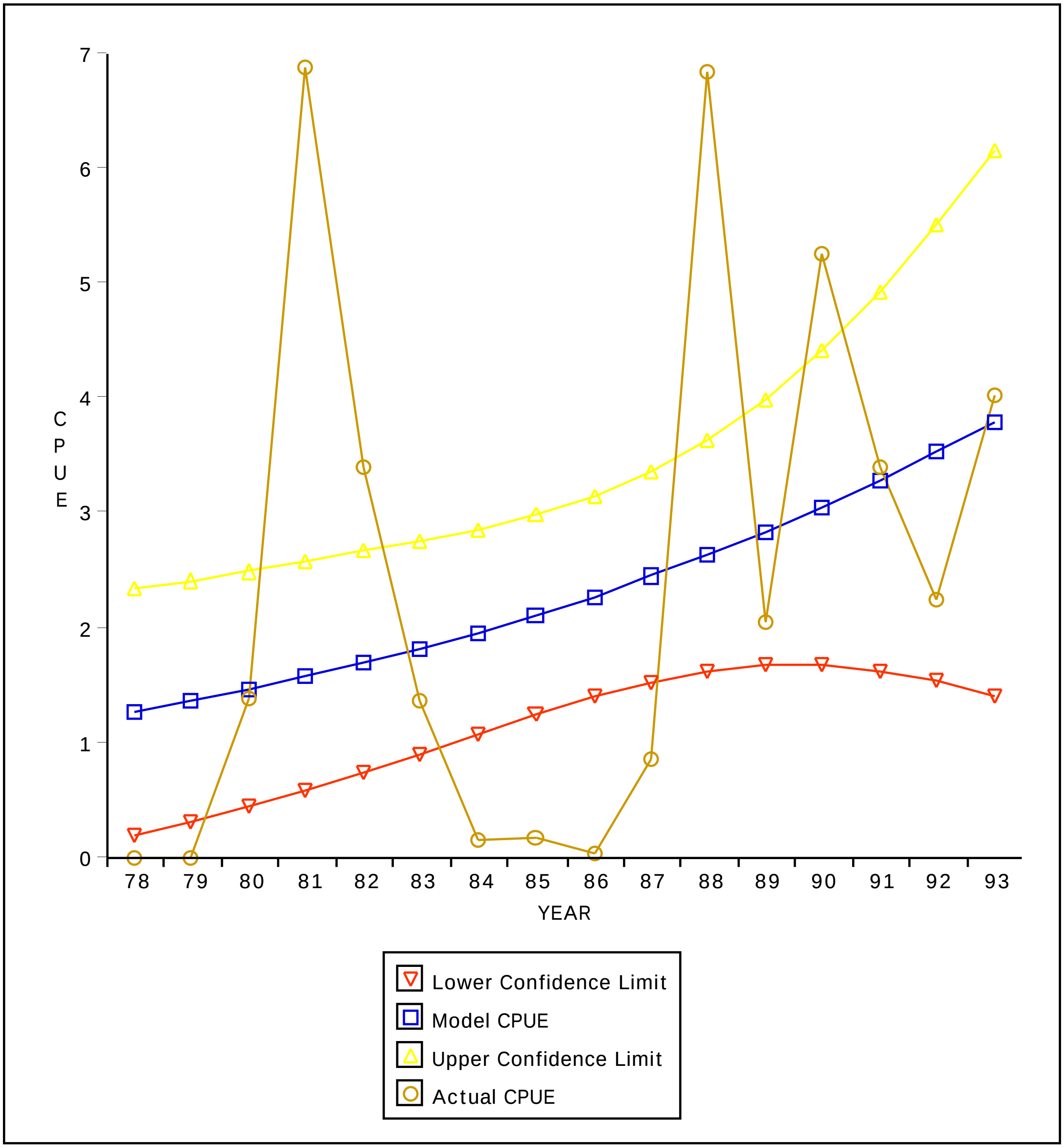

Figure VI.101. Actual catch per unit of effort and model with a significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year pink shrimp (40-59 mm TL) caught by bag seine in Aransas Bay during September, October, and November.

pink shrimp/bag seine/Upper Laguna Madre

Modelled CPUE increased linearly during the study (Table IX.59). Virtually no pink shrimp of the selected size class were caught during 1978-1980. After 1980, CPUE fluctuated dramatically, but the height of peaks observed in 1982, 1984, 1987, 1989, and 1991 increased gradually. Increasing peak height strongly influenced the positive slope of the model. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.104.

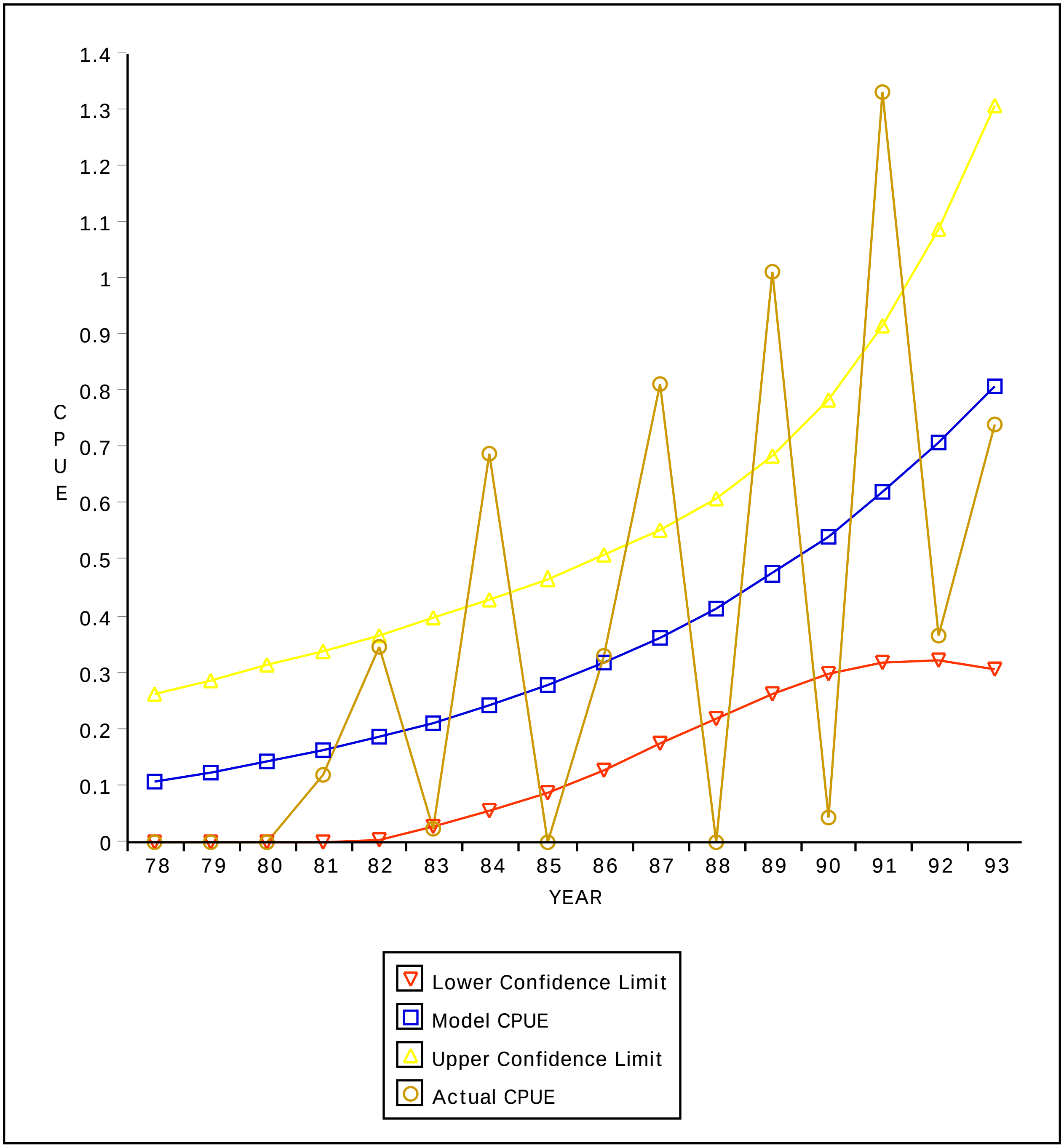

Figure VI.103. Actual catch per unit of effort and model with a significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year pink shrimp (40-59 mm TL) caught by bag seine in Upper Laguna Madre during September, October, and November.

pink shrimp/bag seine/model comparison

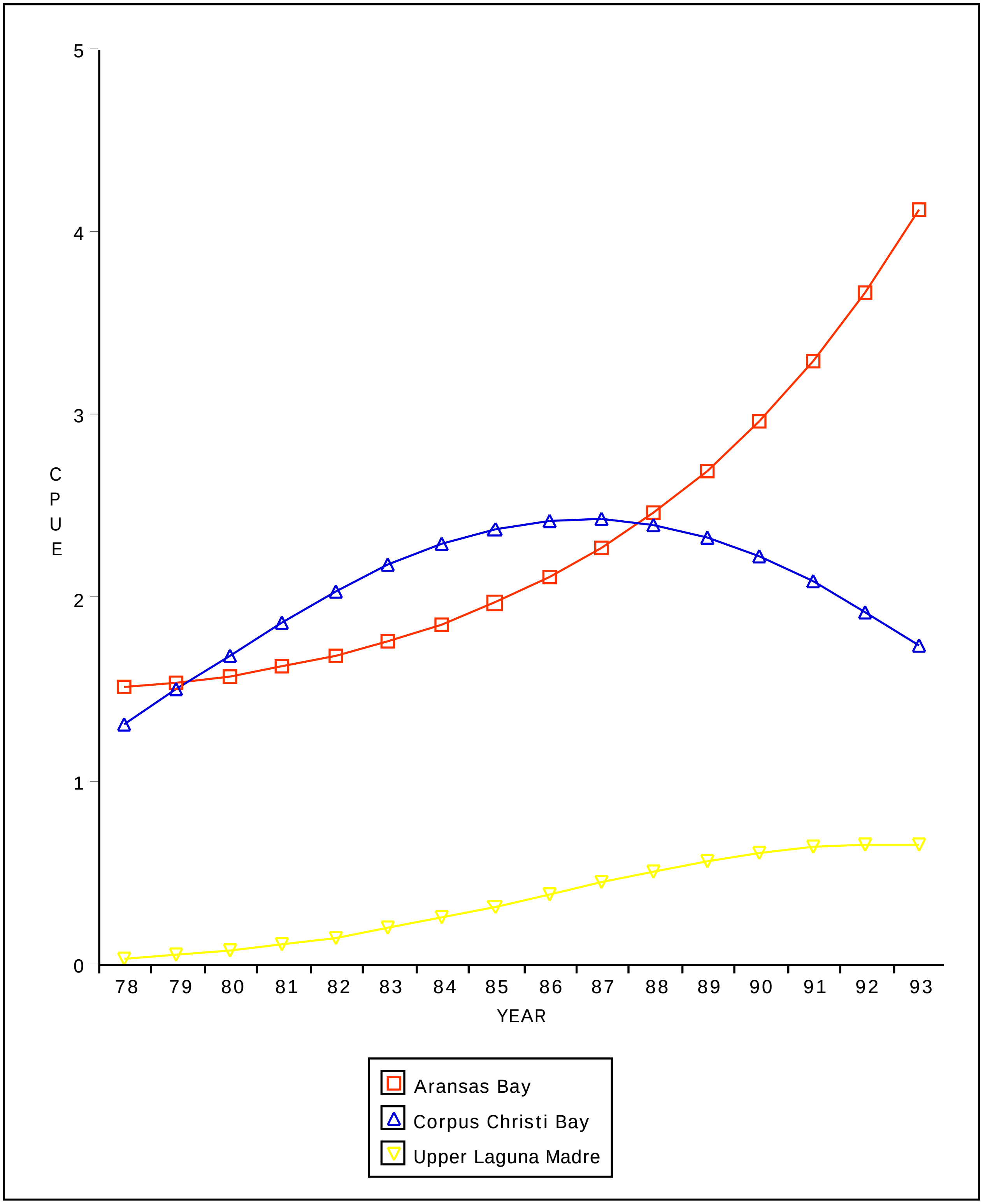

Figure VI.105. Comparison of best-fit models for young-of-the-year pink shrimp (40-59 mm TL), caught by bag seine in the CCBNEP (Table IX.60). CPUE = CATCH/0.03 hectare.

pink shrimp/trawl/Corpus Christi Bay

Modelled CPUE exhibited significant quadratic curvature with an interpolated maximum in 1989 (Table IX.61). Curvature of the model was influenced strongly by a primary peak in 1986 and secondary peaks observed in 1989 and 1992. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.107.

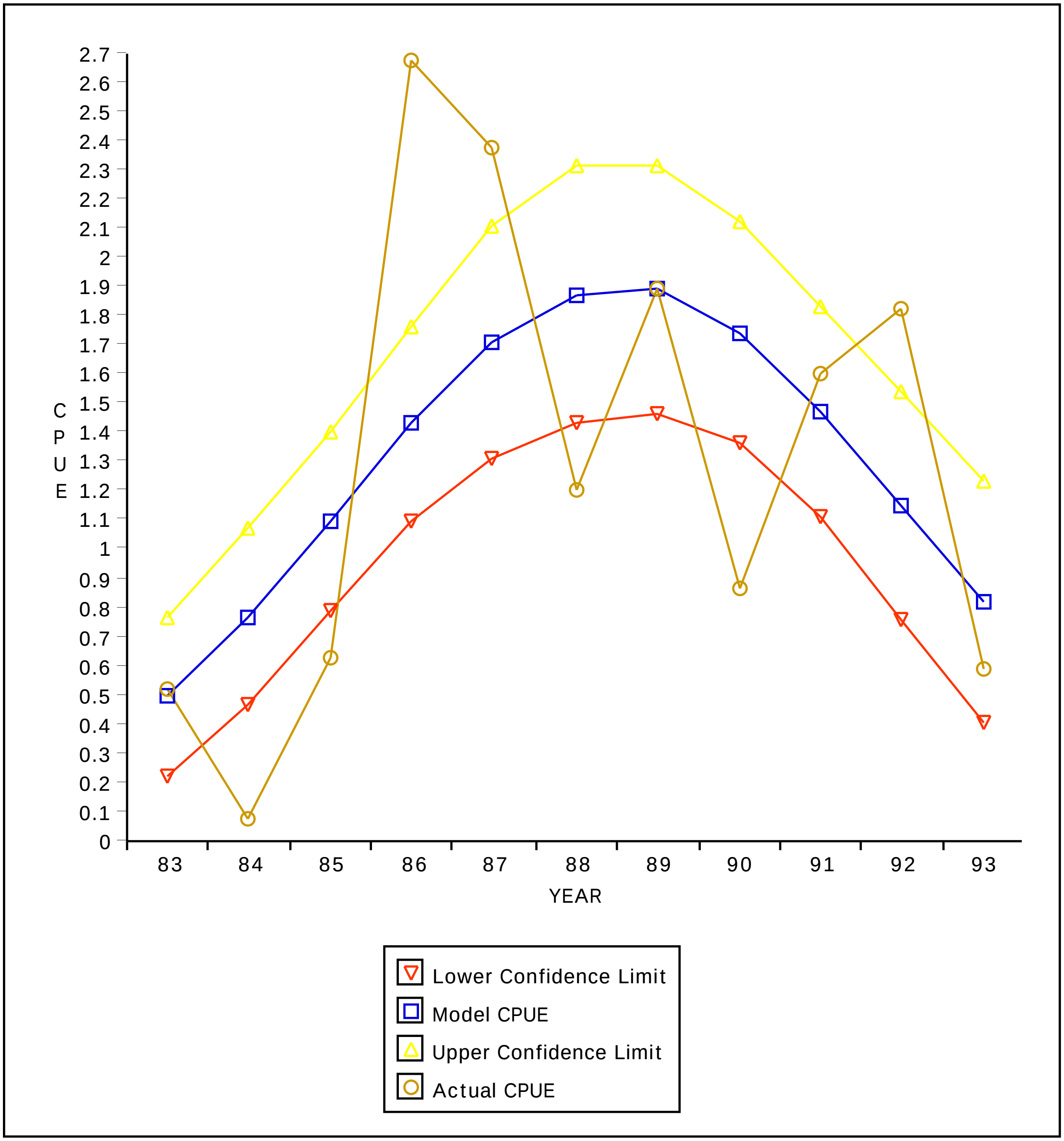

Figure VI.106. Actual catch per unit of effort and best-fit model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/10 minutes) for pink shrimp (100-124 mm TL) caught by trawl in Corpus Christi Bay during March, April, and May.

pink shrimp/trawl/Aransas Bay

Modelled CPUE exhibited significant quadratic curvature with an interpolated maximum in 1987 (Table IX.62). Although peaks in actual CPUE observed in 1986 and 1990 did not coincide with the model maximum, they were influential in generating model curvature. Since 1990, actual CPUE has declined alarmingly. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.109.

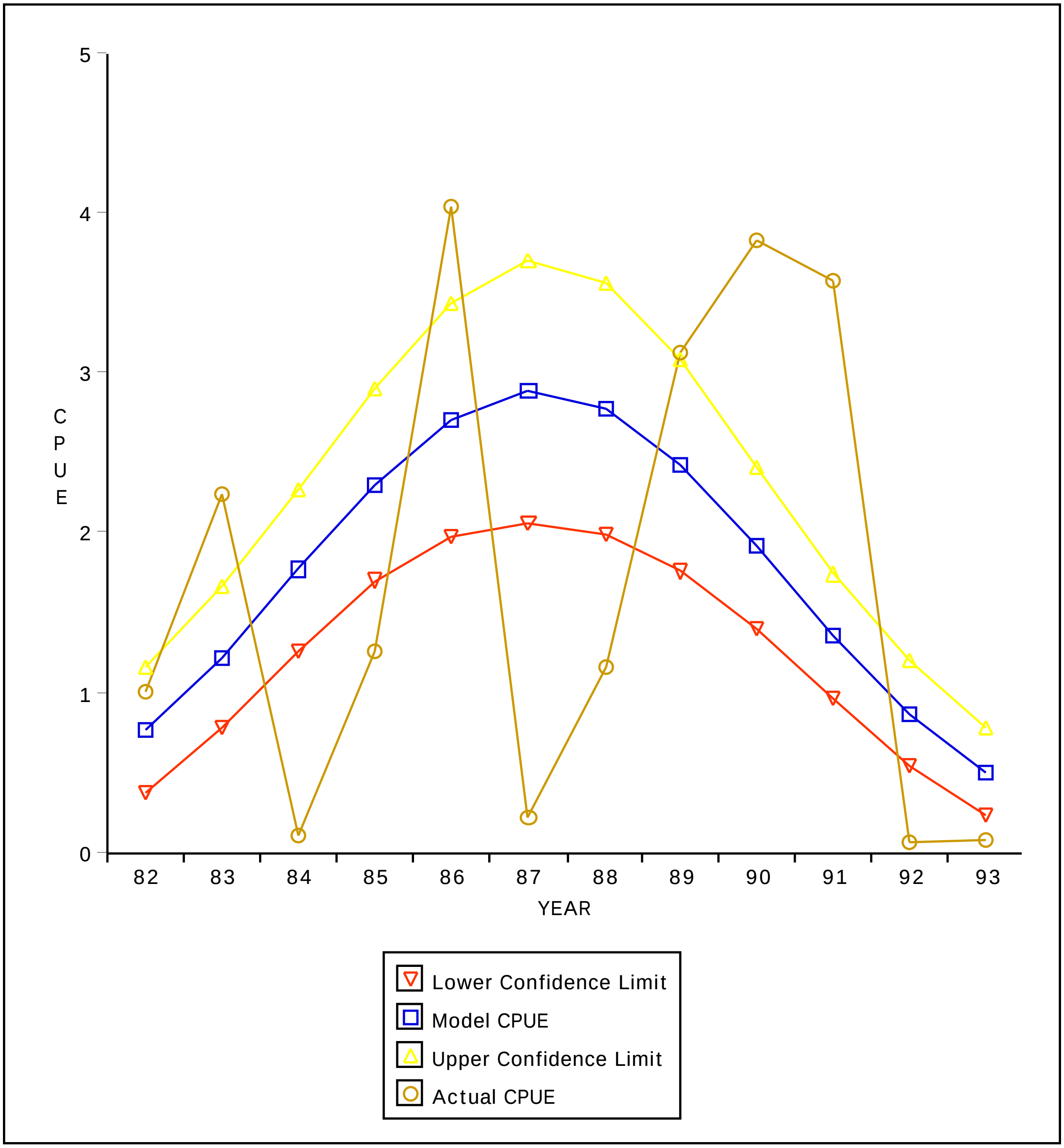

Figure VI.108. Actual catch per unit of effort and best-fit model with significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/10 minutes) for pink shrimp,(100-124 mm TL) caught by trawl in Aransas Bay during March, April, and May.

pink shrimp/trawl/Upper Laguna Madre

Modelled CPUE increased linearly (Table IX.63). Except for a slightly improved yield in 1985, actual CPUE was poor during 1983-1990. A phenomenal peak in actual catch observed in 1992 strongly influenced the positive slope of the model. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.111.

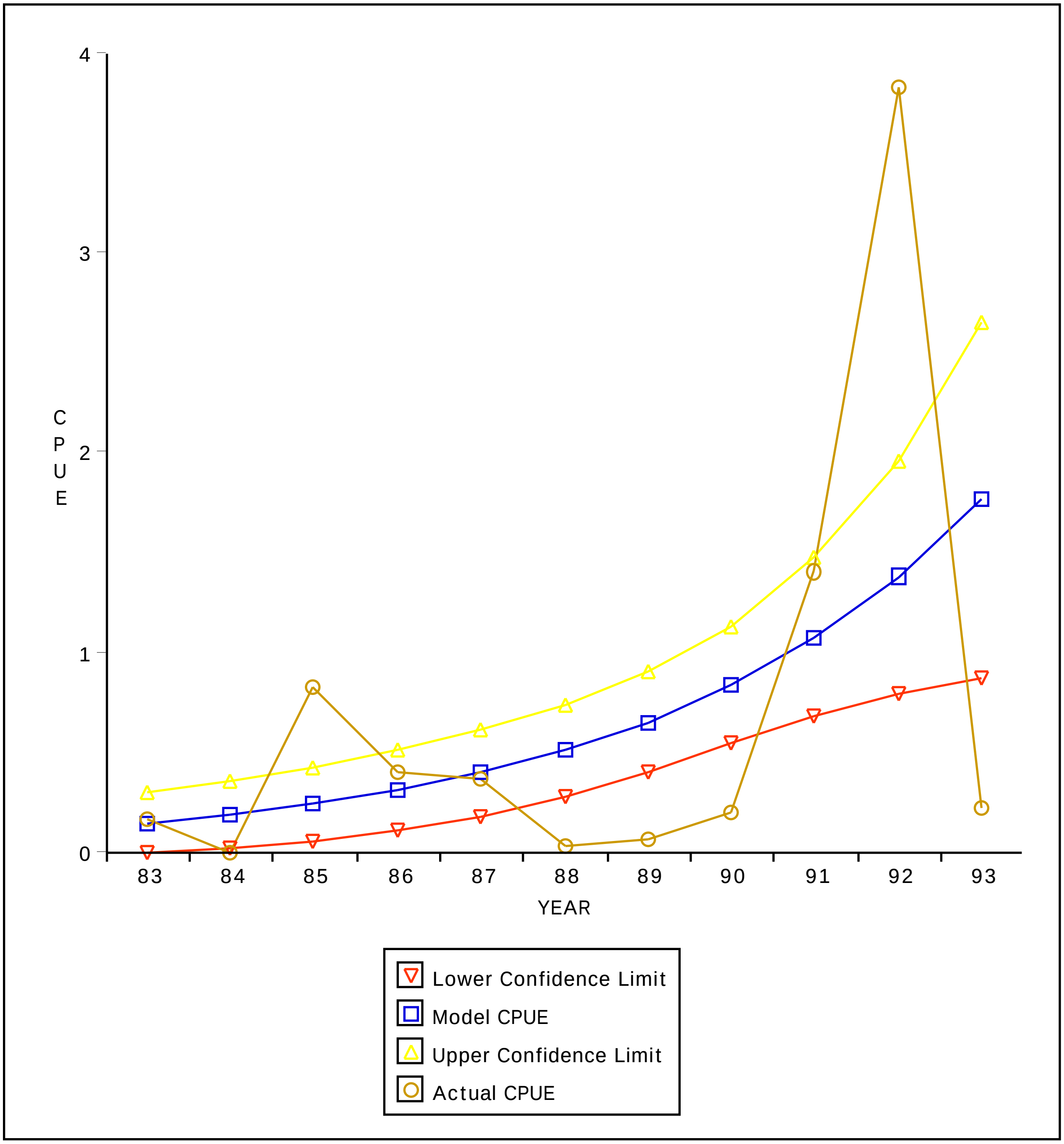

Figure VI.110. Actual catch per unit of effort and best-fit model with significant linear component (**CPUE =** $\mathbf{b_0}$ + $\mathbf{b_1}$***YEAR**, where CPUE = CATCH/10 minutes) for pink shrimp (100-124 mm TL) caught by trawl in Upper Laguna Madre during March, April, and May.

pink shrimp/trawl/model comparison

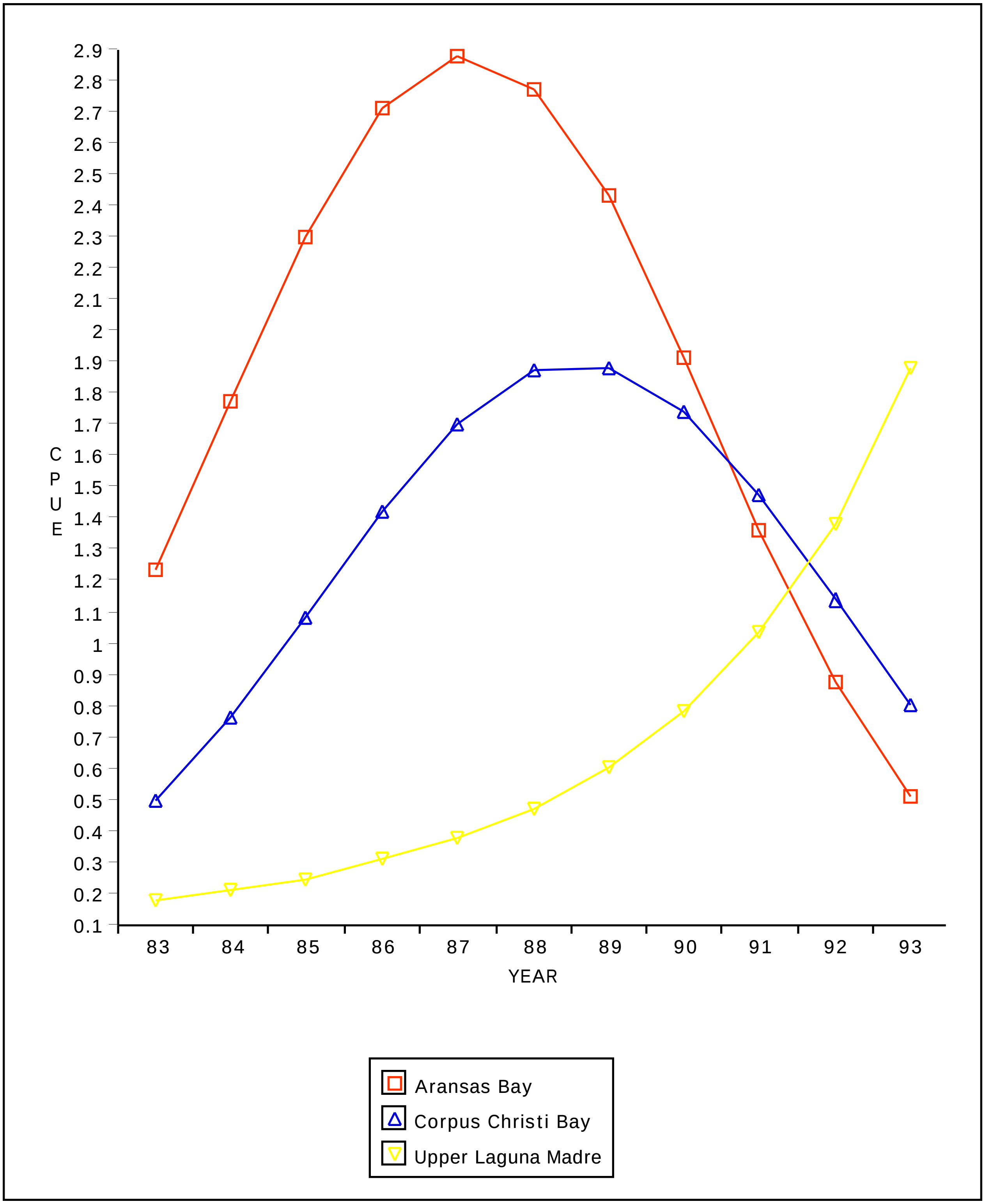

Figure VI.112. Comparison of best-fit models for pink shrimp (100-124 mm TL), caught by trawl in the CCBNEP (Table IX.64). CPUE = CATCH/10 minutes

Of the three bays examined, Upper Laguna Madre exhibited the most improvement in yield of YOY (40-59 mm TL) catch and emigratory-sized (100-124 mm TL) pink shrimp in latter years of the study. Bag seine catches were negligible during 1978-1983, but sporadic small peaks in actual catch were detected in 1987, 1989, and 1991. These elevated catches contributed strongly to the positive slope of the model. Actual trawl catch of pink shrimp was negligible throughout most of the survey, but strong increases in catch sustained during 1991-1992 were sufficiently large to generate a positive slope for the linear trend.

The large discrepancy between models derived for bag seine versus trawl CPUE of pink shrimp in Aransas Bay may have been due to different time frames: the trawl data included only 1983-1993, whereas the bag seine model was constructed with five more data points (1978-1993). Bag seine actual catch exhibited peaks in 1981, 1988, and 1990. Bag seine yields in Aransas Bay were lowest during 1978-1979 and 1984-1987. By contrast, actual trawl catches began to increase in 1985, then peaked in 1986 in Aransas Bay. By 1987, trawl catches were again minimal, but they increased thereafter to high levels sustained until 1991. Apart from elevated catches of YOY and reproductive-sized pink shrimp during latter years, the only example of temporal consistency between bag seine and trawl catch was a peak in actual catch by trawl during 1989-1990, which followed a peak in bag seine catch evident in 1988. Even though the modelled trend curve for Aransas Bay reached a maximum in 1987, actual CPUE by trawl was in fact minimal during 1987.

The resultant model for Corpus Christi Bay trawl catch resembled that of Aransas Bay except the derived model for Corpus Christi Bay achieved a maximum in 1989: the actual catch maximum occurred in 1986. Once again, the discrepancy between models derived for bag seine versus trawl CPUE in Corpus Christi Bay may have been due to different time frames. High actual catches of reproductive-sized pink shrimp were recorded in 1986-1987, 1989, and 1991-1992. High actual catches of YOY were recorded in 1979-1980, 1987-1990, and 1992. Latter year peaks were consistent between gears: the 1991 bag seine peak coincided with sustained high yield in trawl catch evident during 1991-1992. Thus, despite differences in models, bag seine and trawl data for Corpus Christi were generally consistent with regard to the timing of peaks.

In summary, modelled trends indicate trawl catches in Corpus Christi Bay and Aransas Bay were more similar in magnitude and timing to each other than either one was to Upper Laguna Madre. In Upper Laguna Madre, increasing catches of both YOY and reproductive-sized pink shrimp were evident in later years of the study, suggesting brown tide has not adversely affected the pink shrimp population.

Analysis for Southern flounder (*Paralichthys lethostigma*)

Southern flounder/gill net/Corpus Christi Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.65). Actual CPUE fluctuated without any discernible pattern and was poorest during 1986-1989. Actual CPUE declined after 1991. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.114.

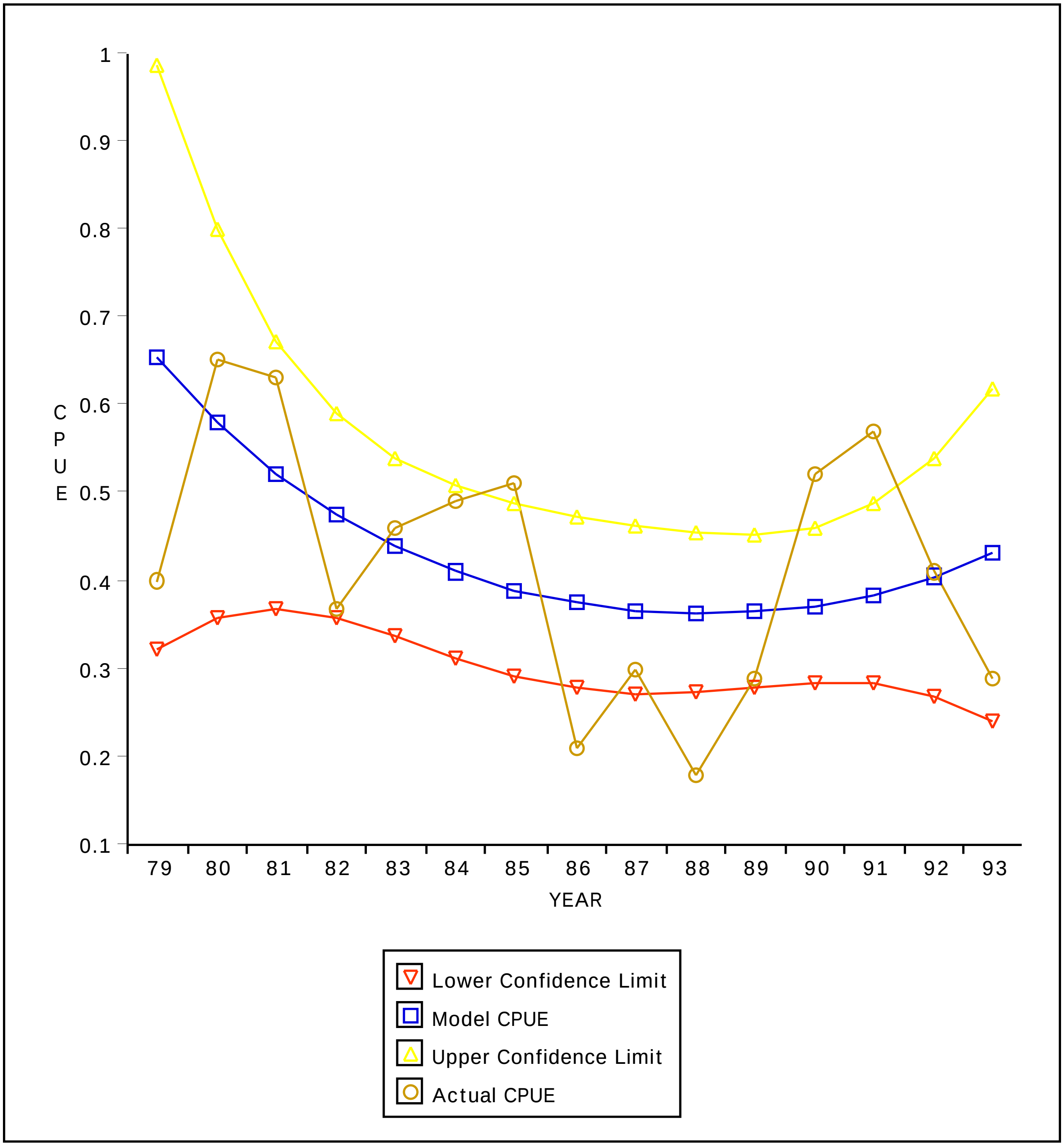

Figure VI.113. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/(GTIME/14)$^{1.5}$) for reproductively mature Southern flounder (300-375 mm TL) caught by gill net in Corpus Christi Bay during the Fall netting season.

Southern flounder/gill net/Aransas Bay

Modelled CPUE exhibited no statistically significant trend (Table IX.66). Yields were generally poor during 1983-1988. Actual CPUE peaks were seen in 1982 and 1990. After 1990, actual CPUE decreased to the lowest average yield on record during the study. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.116.

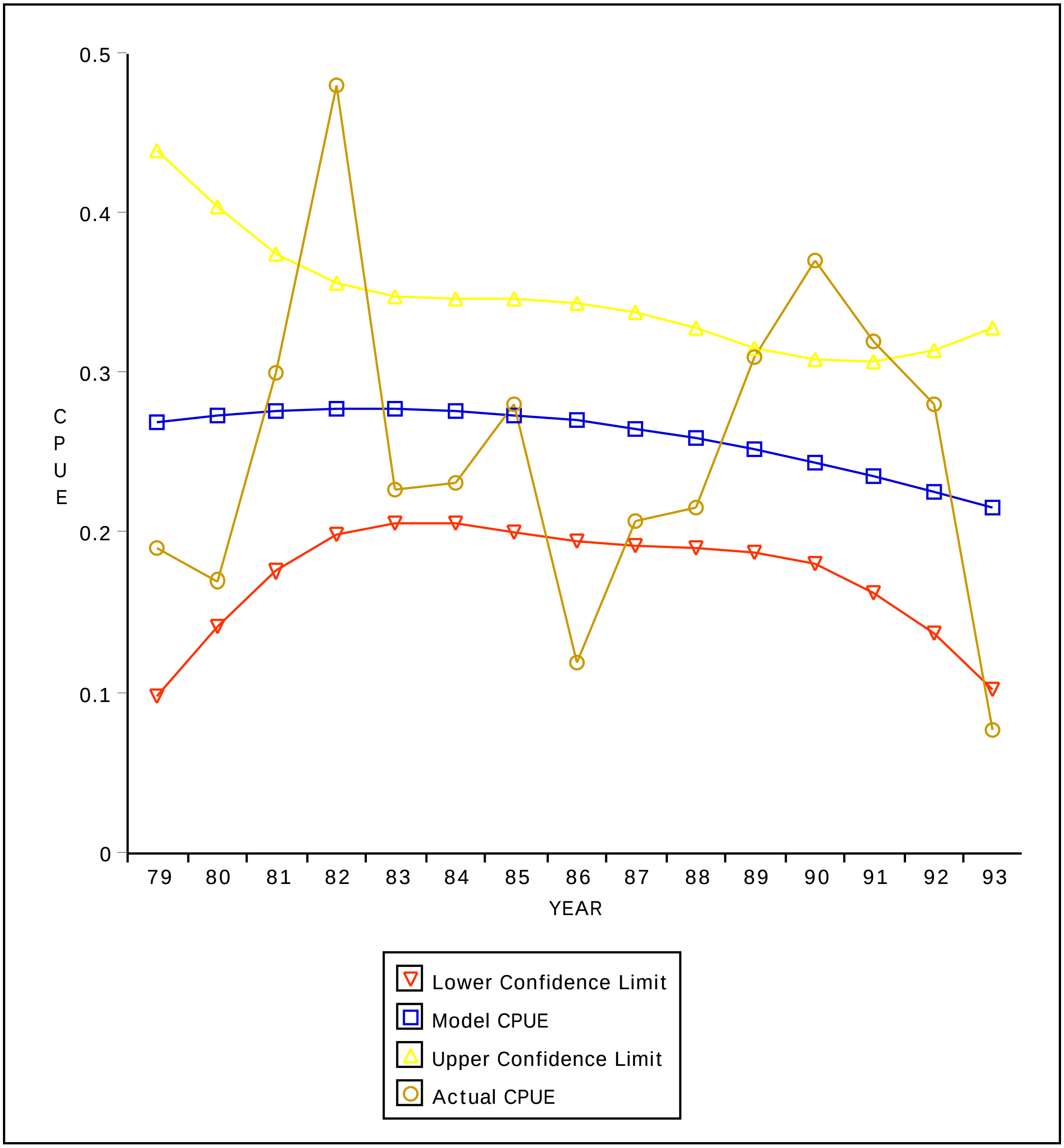

Figure VI.115. Actual catch per unit of effort and model with no statistically significant trend (**CPUE = b_0**, where CPUE = CATCH/(GTIME/14)^3) for reproductively mature Southern flounder (300-375 mm TL) caught by gill net in Aransas Bay during the Fall netting season.

Southern flounder/gill net/Upper Laguna Madre

Modelled CPUE curved downward after 1983 (Table IX.67). Curvature of the quadratic model was influenced by peaks in actual catch observed in 1982, 1985, and 1991. Poor yields recorded in 1987-1989 also influenced the model curvature. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.118.

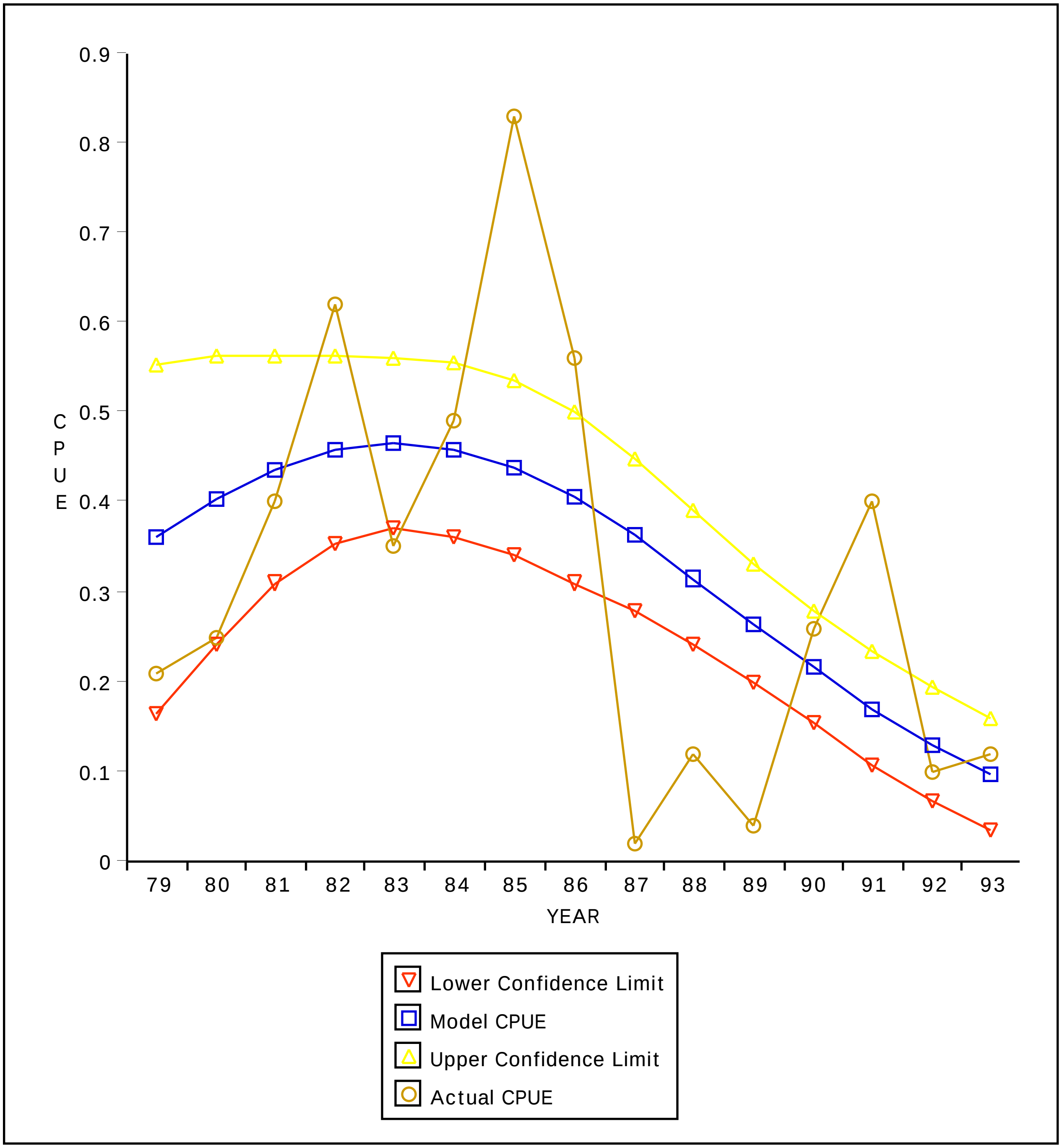

Figure VI.117. Actual catch per unit of effort and model with a significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/(GTIME/14)) for reproductively mature Southern flounder (300-375 mm TL) caught by gill net in Upper Laguna Madre during the Fall netting season.

Southern flounder/gill net/3 Bay Comparison

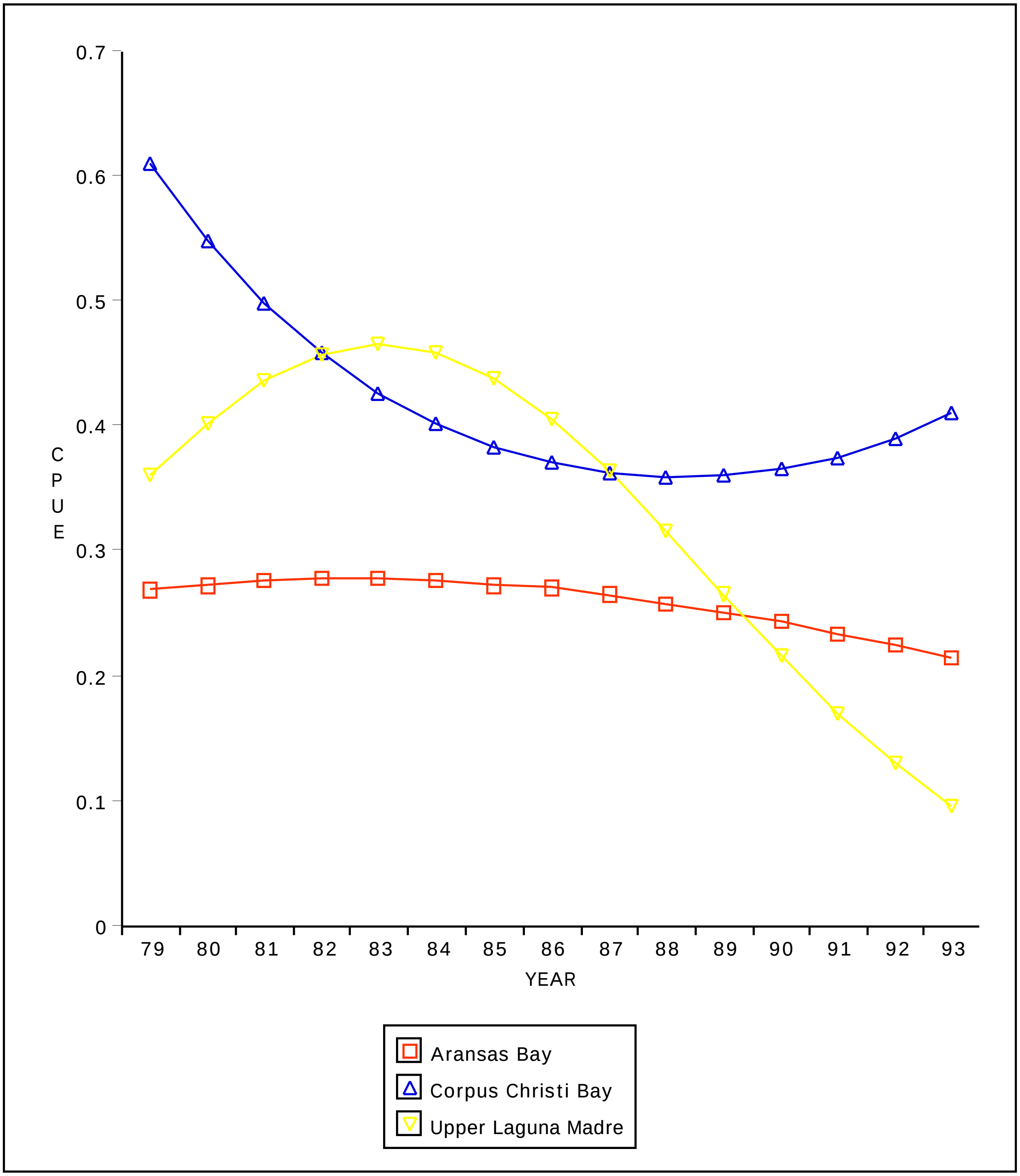

Figure VI.119. Comparison of best-fit models for reproductively mature Southern flounder caught by gill net in the CCBNEP (Table IX.68). CPUE = CATCH/(GTIME/14)$^{1.5}$ for Corpus

Christi Bay. CPUE = CATCH/(GTIME/14)^3 for Aransas Bay. CPUE = CATCH/(GTIME/14) for the Upper Laguna Madre.

Southern flounder/bag seine/Corpus Christi Bay

Modelled CPUE exhibited a significant quadratic trend with an interpolated maximum in 1989 (Table IX.69). Curvature of the model was influenced by relatively low actual CPUE during 1978-1983 and a phenomenal peak in 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.121.

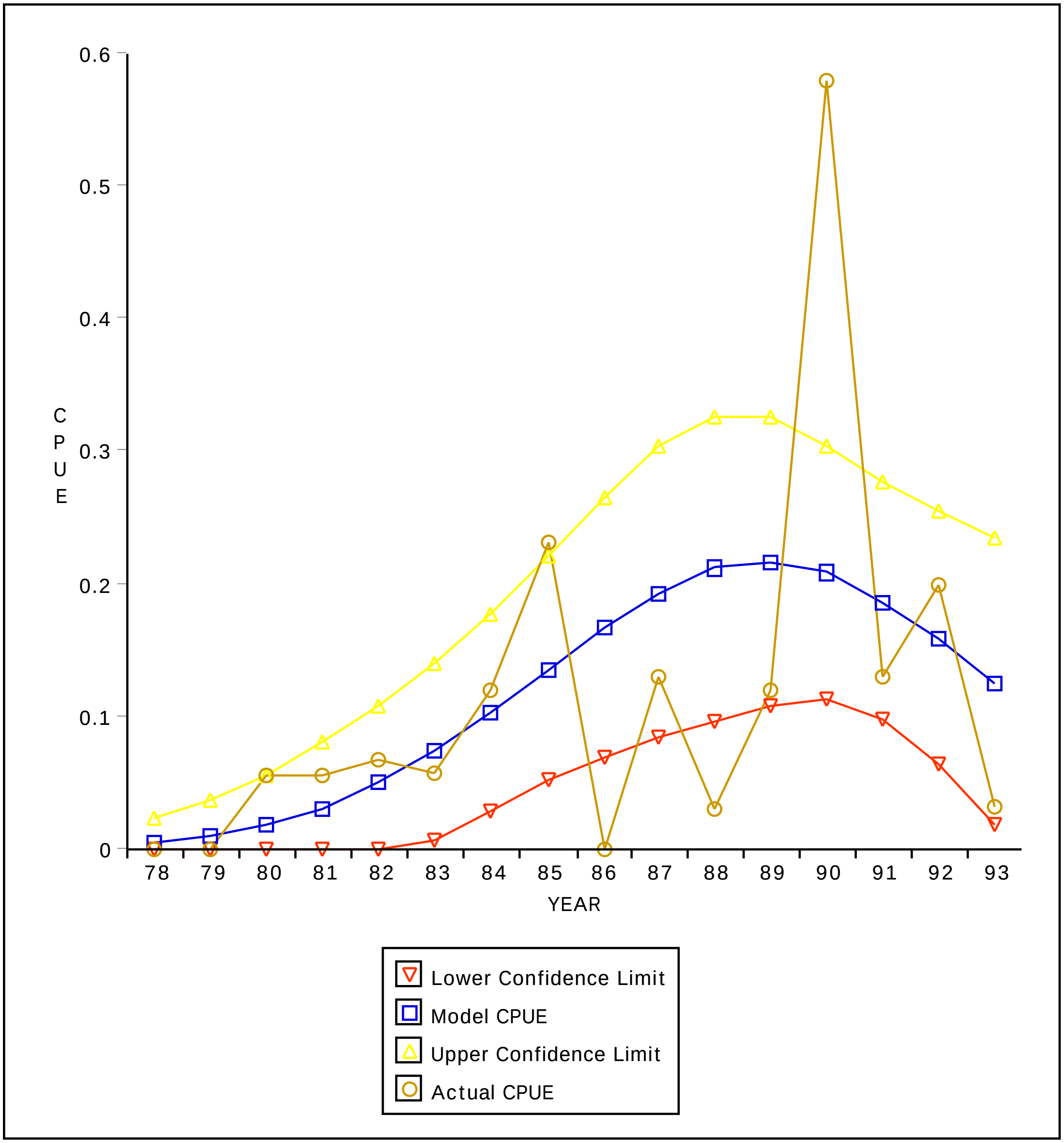

Figure VI.120. Actual catch per unit of effort and model with a significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/0.03 hectare) for young-of-the-year Southern flounder (20-39 mm TL), caught by bag seine in Corpus Christi Bay during February, March, and April.

Southern flounder/bag seine/Aransas Bay

Modelled CPUE exhibited a significant quadratic trend with an interpolated maximum in 1985 (Table IX.70). Actual CPUE peaked in 1982 and 1989. These two peaks, along with poor CPUE during 1978-1981 and 1990-1993, were influential in generating model curvature. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.123.

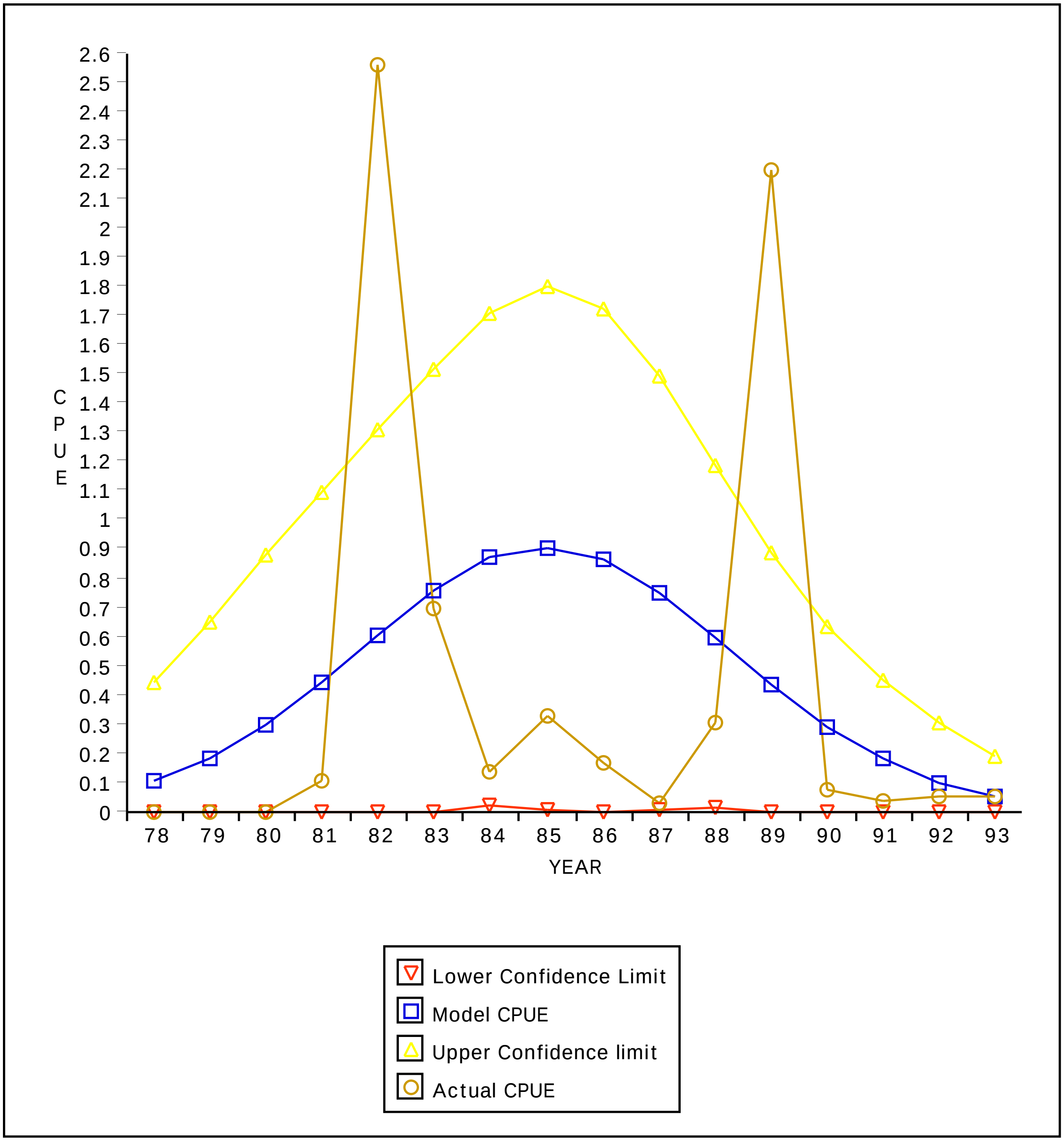

Figure VI.122. Actual catch per unit of effort and model with a significant quadratic component (**CPUE =** $\mathbf{b_0 + b_1{*}YEAR + b_2{*}YEAR^2}$, where CPUE = CATCH/0.03 hectare) for young-of-the-year Southern flounder (20-39 mm TL) caught by bag seine in Aransas Bay during February, March, and April.

Southern flounder/bag seine/Upper Laguna Madre

Although modelled CPUE decreased linearly during the study period (Table IX.71), the trend analysis was of limited interpretative value. Only 11 of the 536 bag seines yielded any southern flounder of the selected size class. Furthermore, no southern flounder were caught in nine of the 16 years surveyed. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.125.

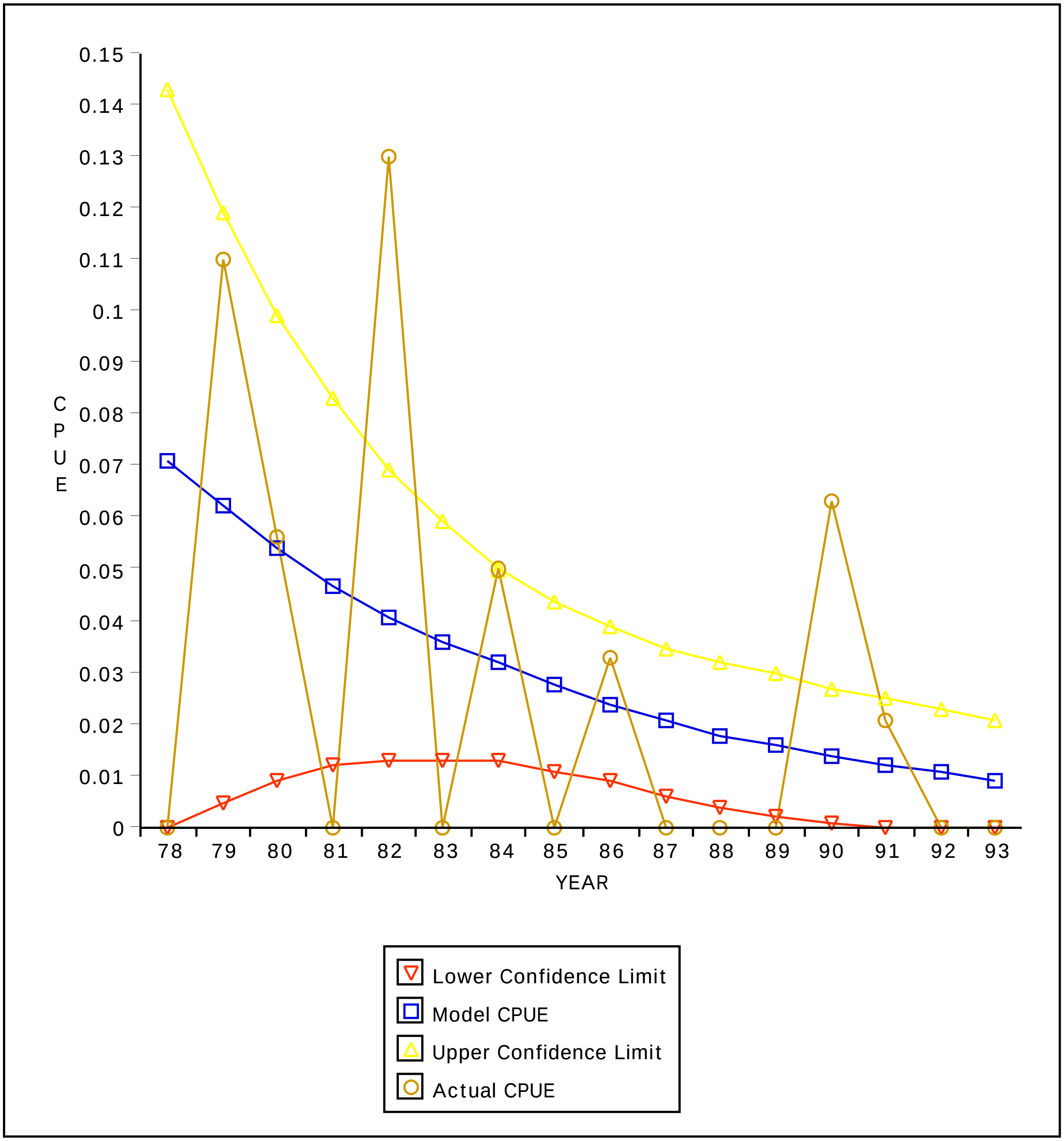

Figure VI.124. Actual catch per unit of effort and model with a significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/0.03 hectare) for young-of-the-year Southern flounder (20-39 mm TL) caught by bag seine in Upper Laguna Madre during February, March, and April.

southern flounder/bag seine/model comparison

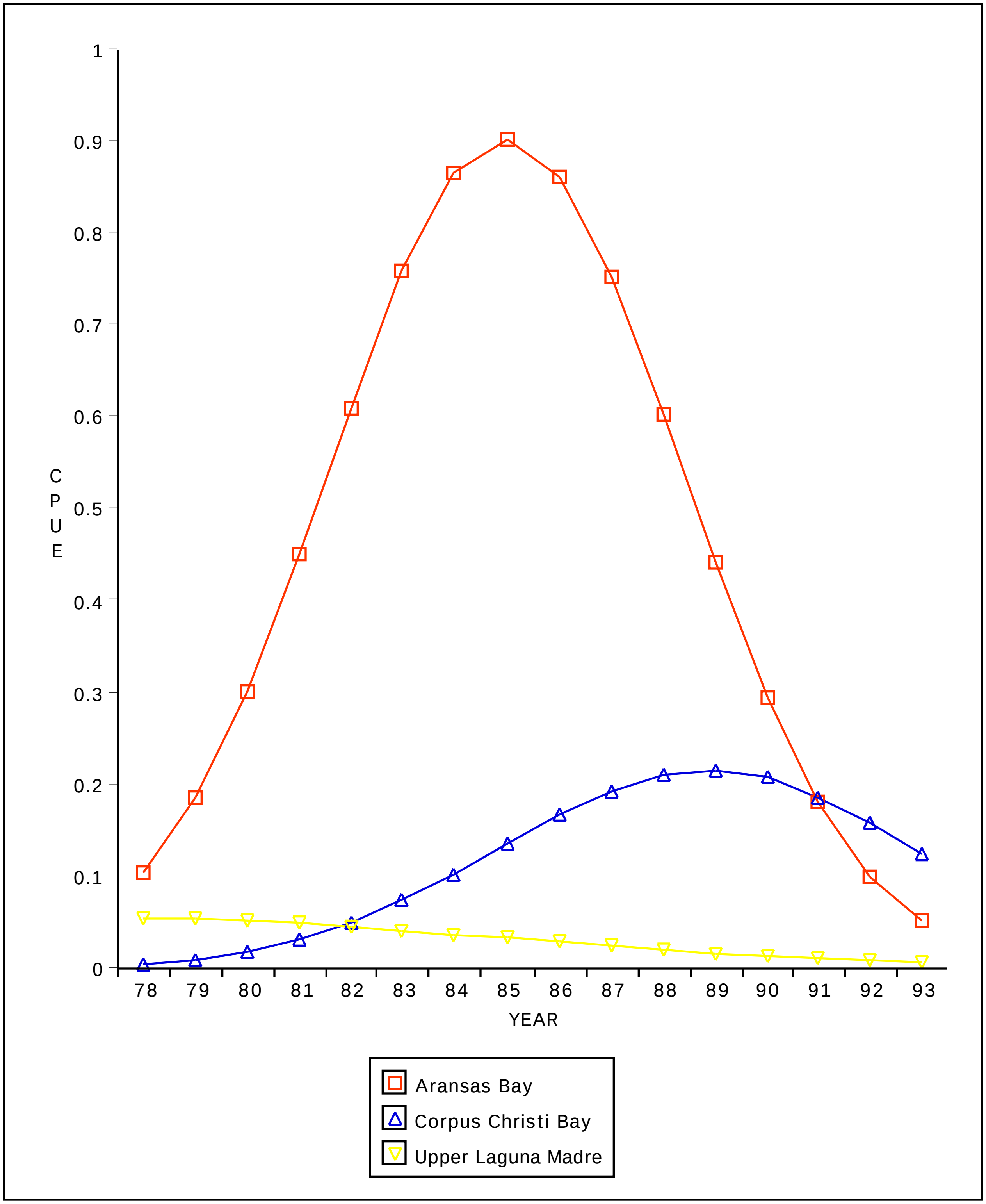

Figure VI.126. Comparison of best-fit models for young-of-year Southern flounder caught by bag seine in the CCBNEP (Table IX.72).

Modelled bag seine CPUE by bag seine of YOY (20-39 mm TL) in Corpus Christi Bay exhibited significant quadratic curvature with a maximum in 1989, whereas the actual maximum catch was recorded in 1990. A major peak in bag seine catch in 1990 preceded elevated yields of reproductive Southern flounder (300-375 mm TL) in 1990 and 1991. Although no significant trend was detected in gill net CPUE, the best fit model exhibited slight curvature with a minimum coinciding with the actual CPUE minimum (1988). Yields by both gears were poor during 1986-1989. Bag seine catch was very low during 1978-1984. Many more YOY were caught during the latter years of the study (1985-1993). Hence, a quadratic model with an interpolated maximum in 1989 adequately represented the actual pattern of bag seine yields.

In Aransas Bay, bag seine actual catch exhibited two significant peaks, one in 1982 and another in 1989. Similarly, actual gill net catch exhibited a primary peak in 1982 and elevated catches were sustained during 1989-1991. Poor catches of both size classes of Southern flounder were recorded during 1983-1988, and in earlier years (1978-1981 for bag seine and 1979-1980 for gill net). Thus, although the modelled trend for bag seine catches may suggest decreasing yields commencing in 1985, the model is a poor representation of the pattern of actual yields of YOY Southern flounder. First, the model estimates a maximum in 1985 even though actual catches were very low during 1984-1987. Second, the model was fitted to essentially two strong peaks in actual catch. A more accurate description of YOY catch in Aransas Bay is that peaks were sporadic.

CPUE of reproductive Southern flounder decreased sharply after 1985 in Upper Laguna Madre. Furthermore, gill net catches in 1987-1989 were the lowest recorded for that bay. Bag seine catches were also extremely poor during 1987-1989, suggesting that representatives of young-of-the-year and adult Southern flounder were significantly rarer in the years immediately after the 1986 red tide. The bag seine model exhibited a good fit to a negative linear trend, because substantially more young-of-year were caught during 1978-1987 versus 1987-1992.

In summary, the trends exhibited by bag seine and gill net yields of Southern flounder in the Upper Laguna Madre are unfavorable and suggest long-term decline in the relative abundance of this species. The model derived for bag seine catches of young-of-the-year Southern flounder in Aransas Bay should be interpreted with caution because the model was fitted around only two major peaks and the model maximum coincided with the actual catch minimum.

Analysis for Gulf menhaden (*Brevoortia patronus*)
Gulf menhaden/gill net/Corpus Christi Bay

Modelled CPUE exhibited a significant quadratic trend with an interpolated maximum in 1982 (Table IX.73). Actual CPUE peaked in 1982, 1985, and 1986, but was minimal in 1980 and during 1987-1993. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.128.

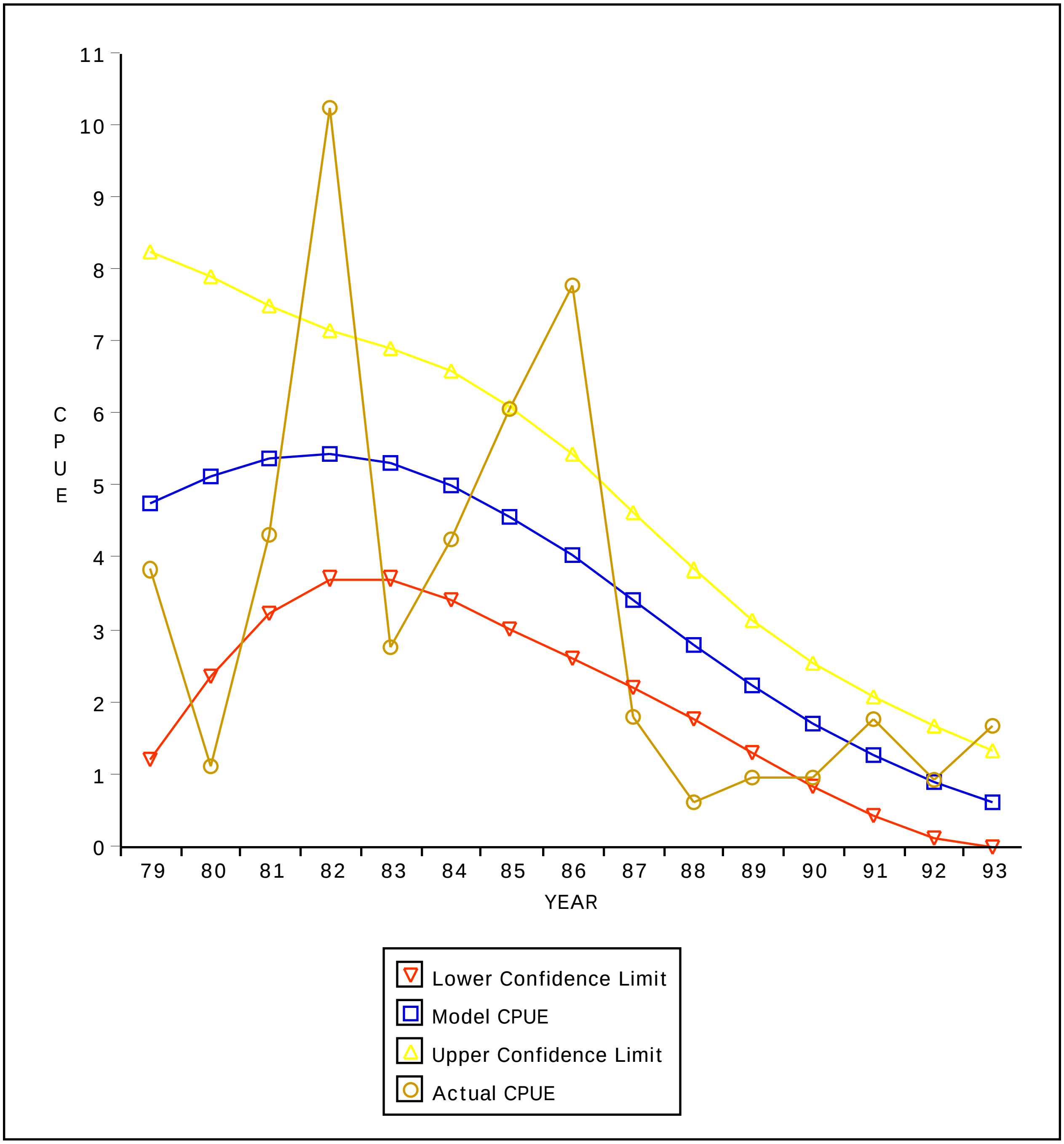

Figure VI.127. Actual catch per unit of effort and model with a significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/(GTIME/14)$^{-8}$) for reproductively mature Gulf menhaden (225-299 mm TL) caught by gill net in Corpus Christi Bay during the Fall netting season.

Gulf menhaden/gill net/Aransas Bay

Modelled CPUE exhibited a significant quadratic trend with an interpolated maximum in 1984 (Table IX.74). Actual CPUE peaked in 1984, providing a rare example within this survey of coincidence between model and actual maxima. Downward curvature of the model was influenced by a decrease in actual CPUE after 1986. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.130.

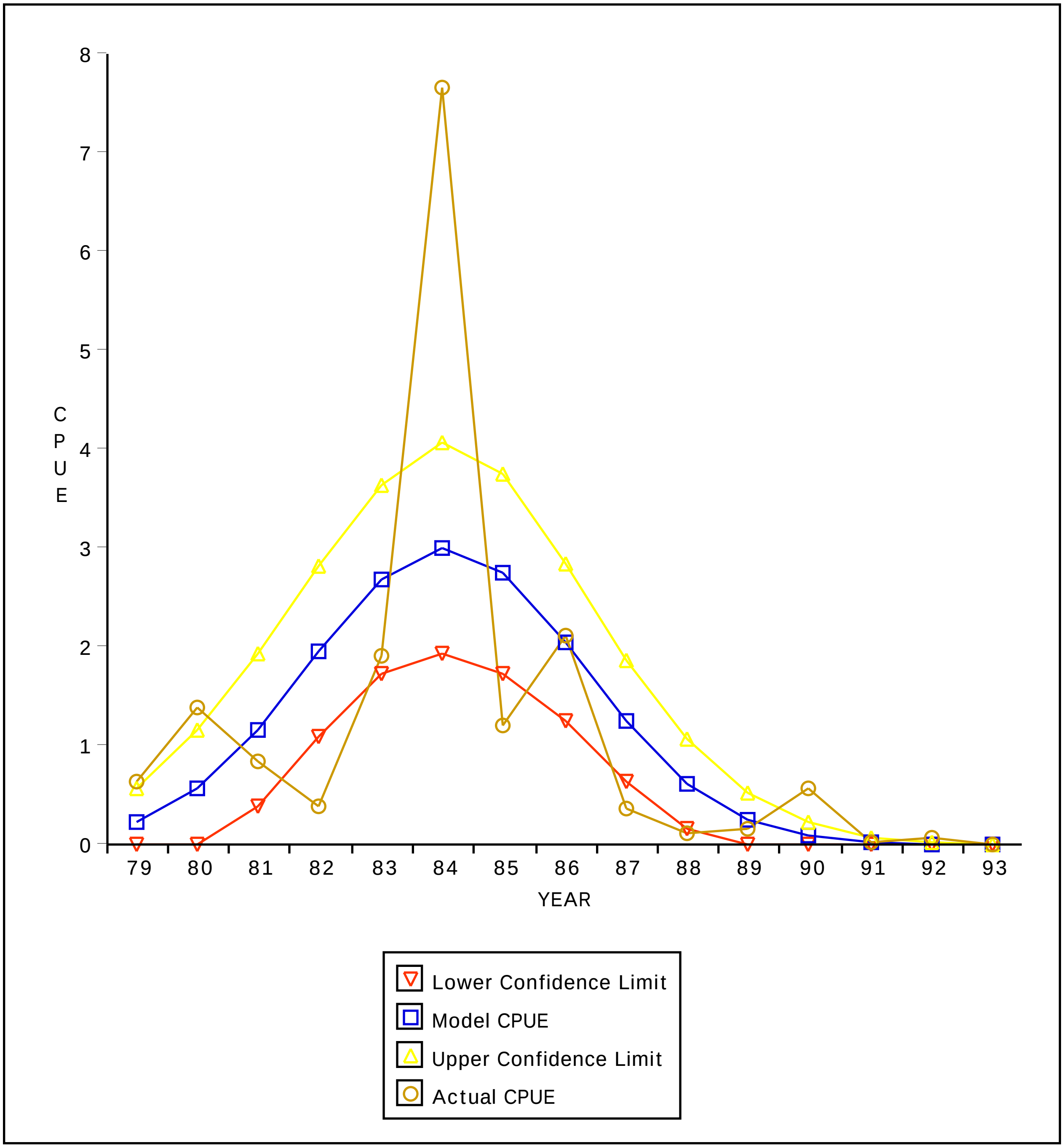

Figure VI.129. Actual catch per unit of effort and model with a significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2**, where CPUE = CATCH/(GTIME/14)$^{-5}$) for reproductively mature Gulf menhaden (225-299 mm TL) caught by gill net in Aransas Bay during the Fall netting season.

Gulf menhaden/gill net/Upper Laguna Madre

Modelled CPUE decreased linearly (Table IX.75). Actual CPUE peaked in 1981 and was generally much lower in the other years surveyed. Slight improvement was seen during 1984-1985. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.132.

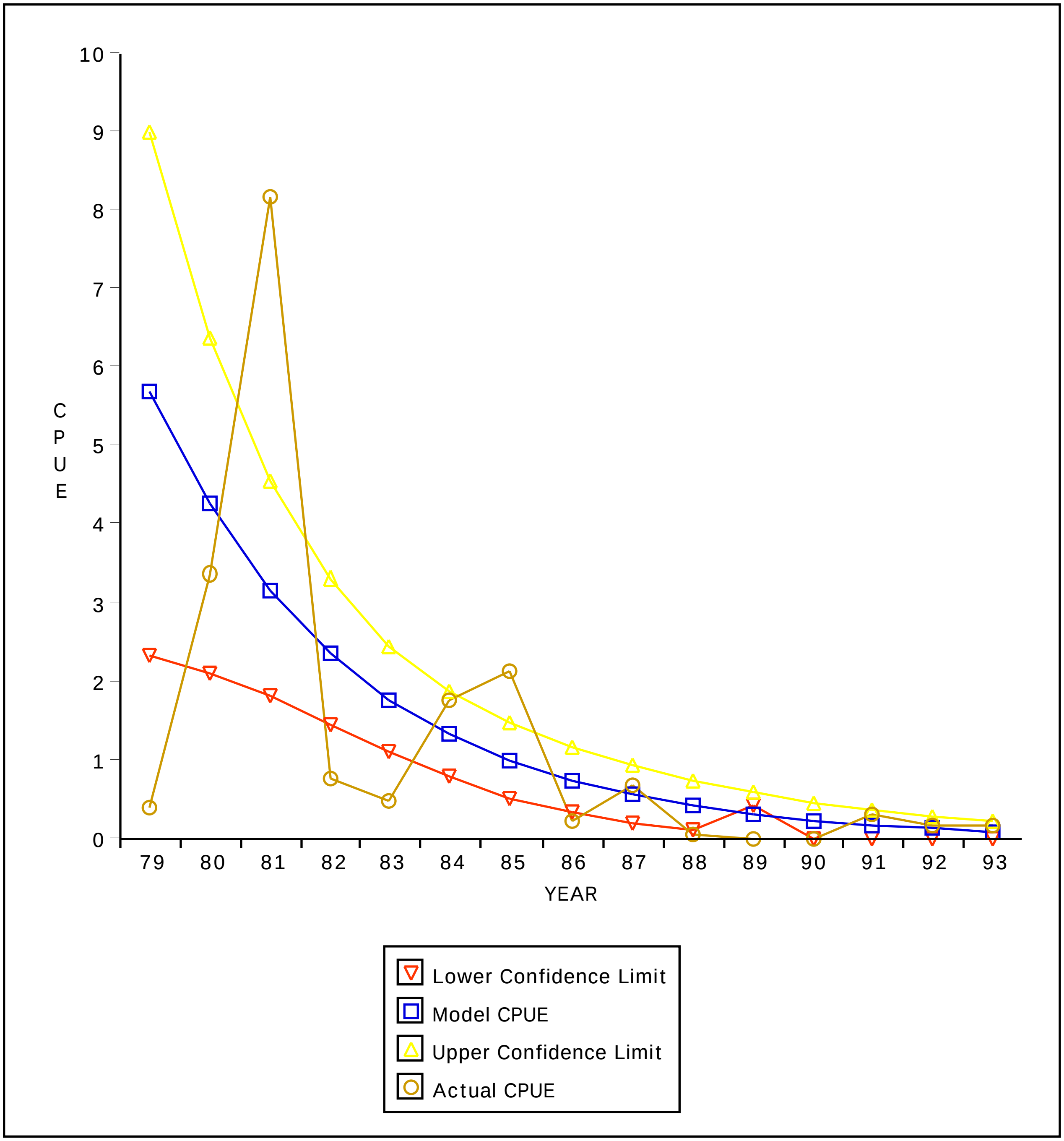

Figure VI.131. Actual catch per unit of effort and model with a significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/(GTIME/14)$^{-7}$) for reproductively mature Gulf menhaden (225-299 mm TL) caught by gill net in Upper Laguna Madre during the Fall netting season.

Gulf menhaden/gill net/model comparison

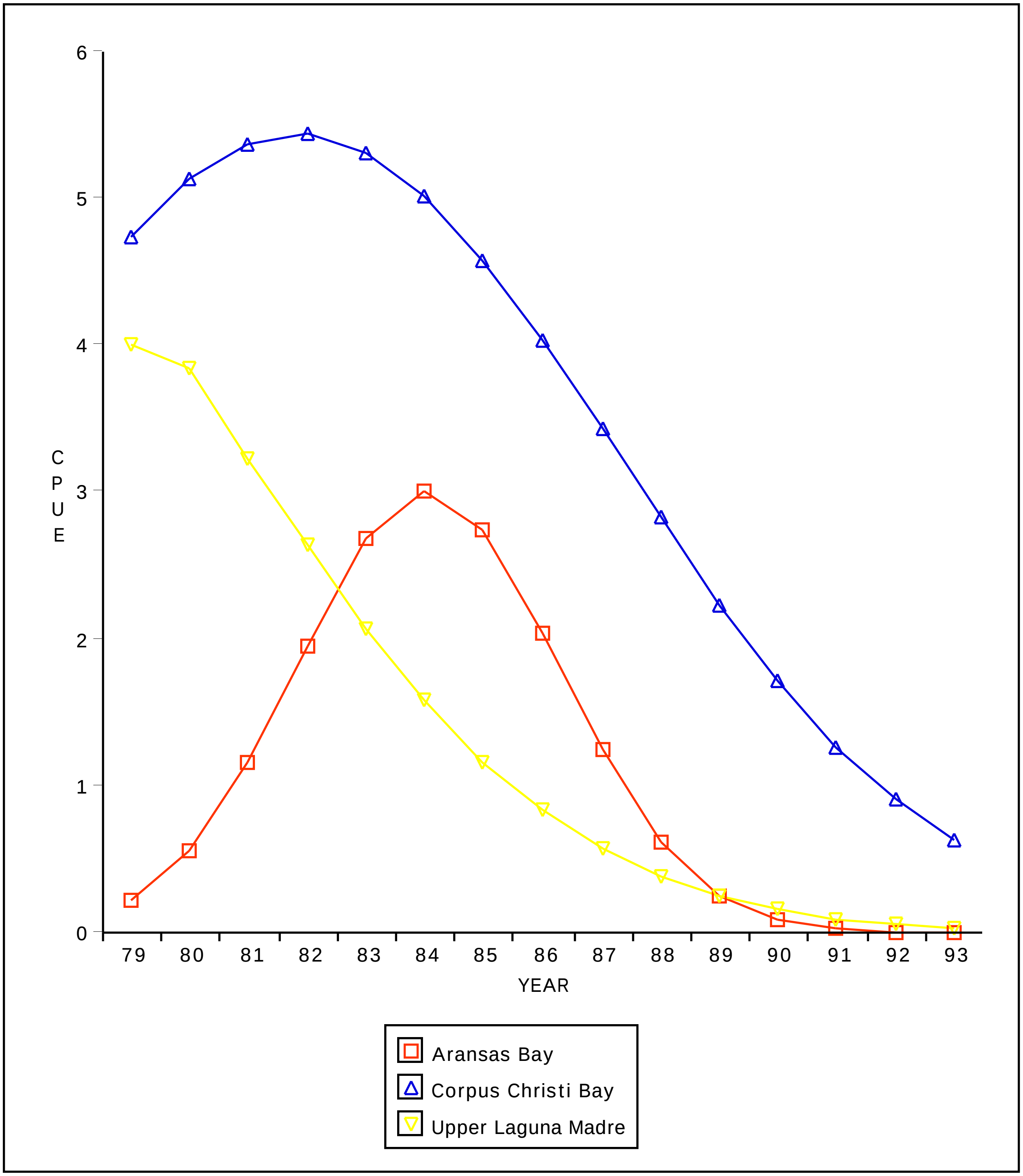

Figure VI.133. Comparison of best-fit models for reproductively mature Gulf menhaden caught by gill net in the CCBNEP (Table IX.76). $CPUE = CATCH/(GTIME/14)^{-8}$ for Corpus Christi Bay. $CPUE = CATCH/(GTIME/14)^{-5}$ for Aransas Bay. $CPUE = CATCH/(GTIME/14)^{-7}$ for Upper Laguna Madre.

Gulf menhaden/bag seine/Corpus Christi Bay

Modelled CPUE exhibited a slight but significant quadratic trend with an interpolated maximum in 1984 (Table IX.77). A phenomenal peak in actual CPUE was seen in 1983, but otherwise yields were extremely poor. Slight improvement in actual CPUE was evident during 1990-1991. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.135.

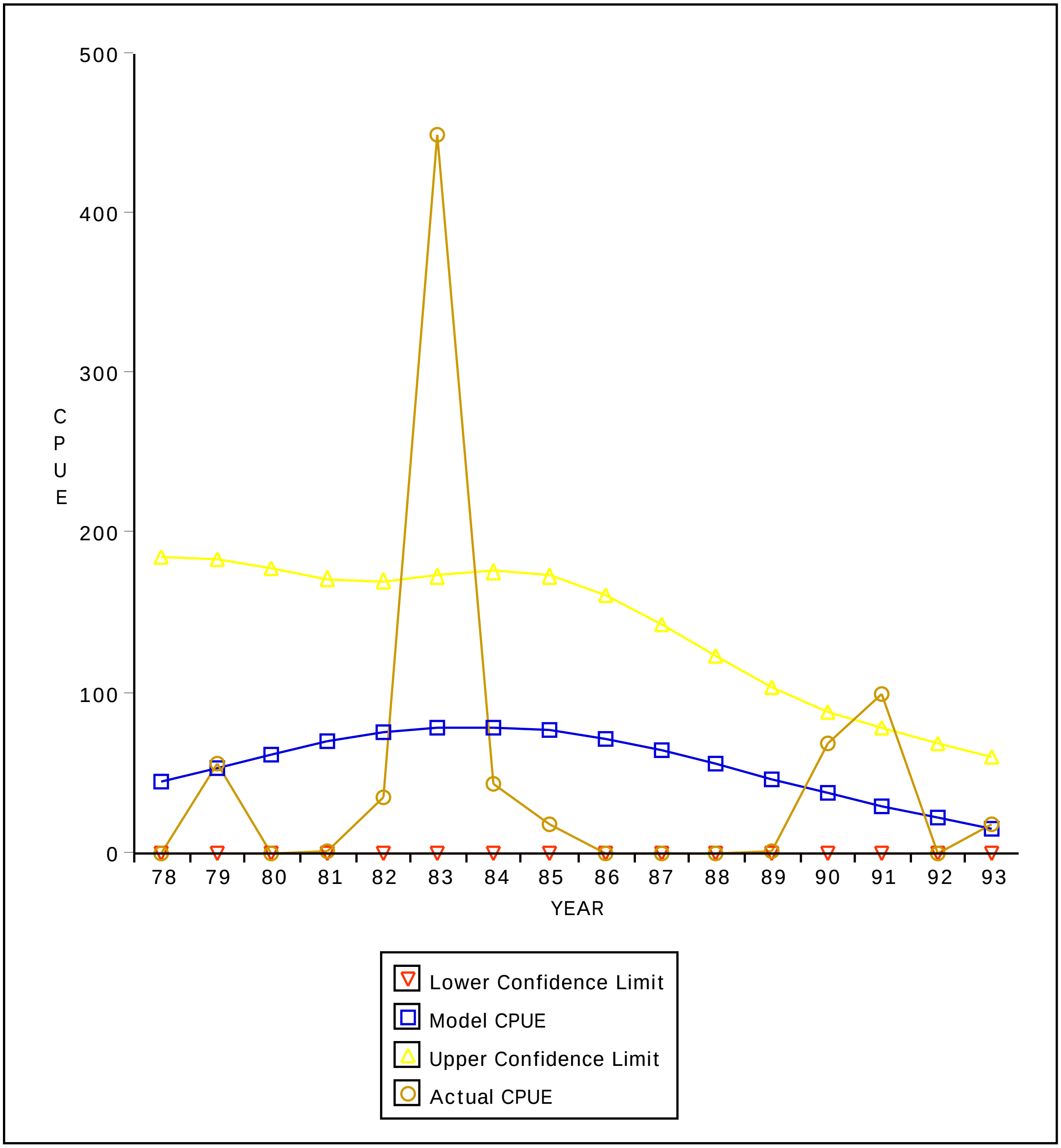

Figure VI.134. Actual catch per unit of effort and model with a significant quadratic component (**CPUE = b_0 + b_1*YEAR + b_2*YEAR^2,** where CPUE = CATCH/0.03 hectare) for young-of-the-year Gulf menhaden (20-39 mm TL) caught by bag seine in Corpus Christi Bay during April and May.

Gulf menhaden/bag seine/Aransas Bay

Modelled CPUE decreased linearly (Table IX.78). Actual CPUE was greatest during the first two years surveyed, then it was consistently poor until a phenomenal peak observed in 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.137.

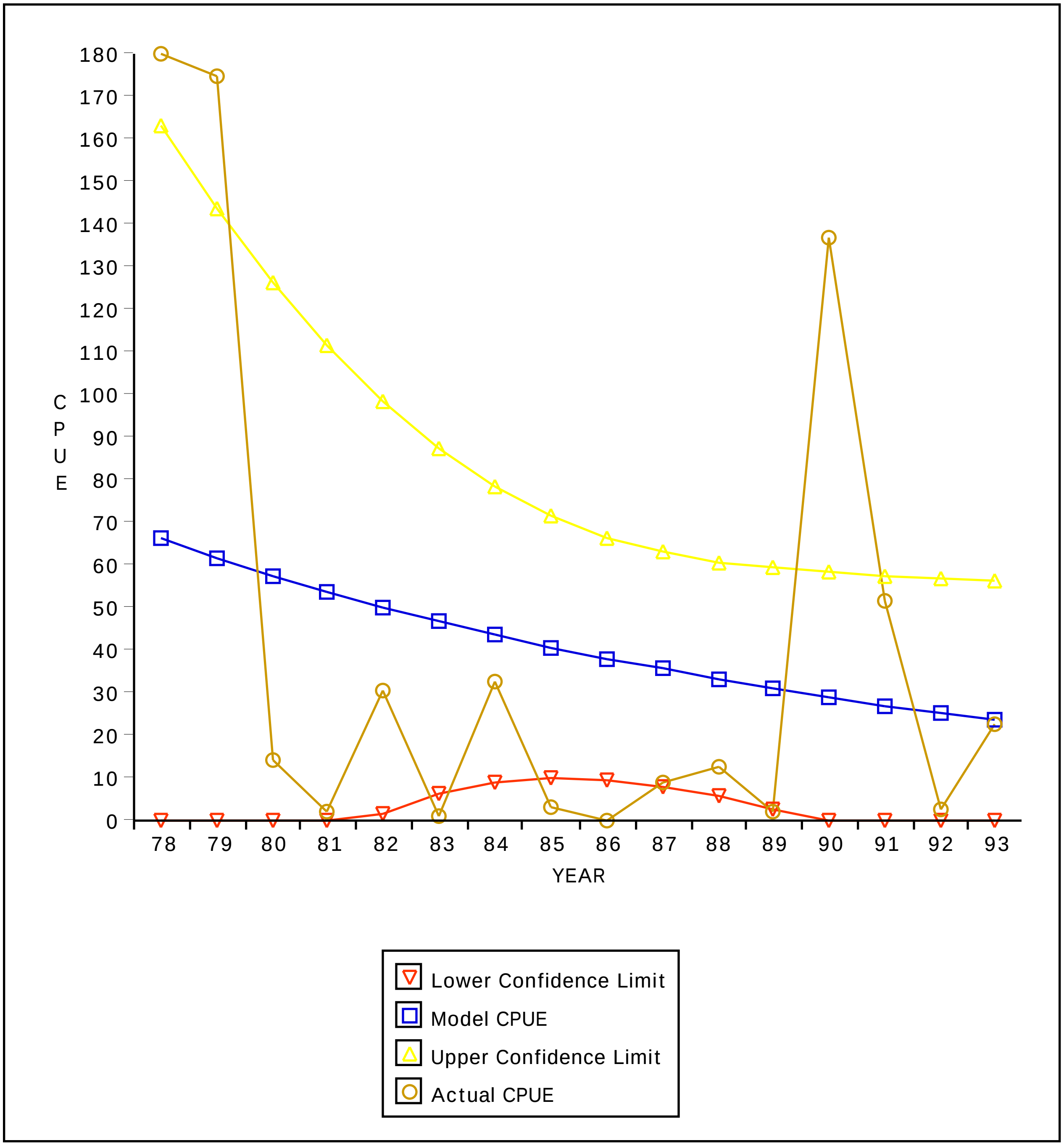

Figure VI.136. Actual catch per unit of effort and model with a significant linear component (**CPUE = b_0 + b_1*YEAR,** where CPUE = CATCH/0.03 hectare) for young-of-the-year Gulf menhaden (20-39 mm TL) caught by bag seine in Aransas Bay during April and May.

Gulf menhaden/bag seine/Upper Laguna Madre

Modelled CPUE decreased linearly (Table IX.79). A phenomenal peak in actual CPUE was seen in 1981. Otherwise, actual CPUE was negligible except for a small peak observed in 1991. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.139.

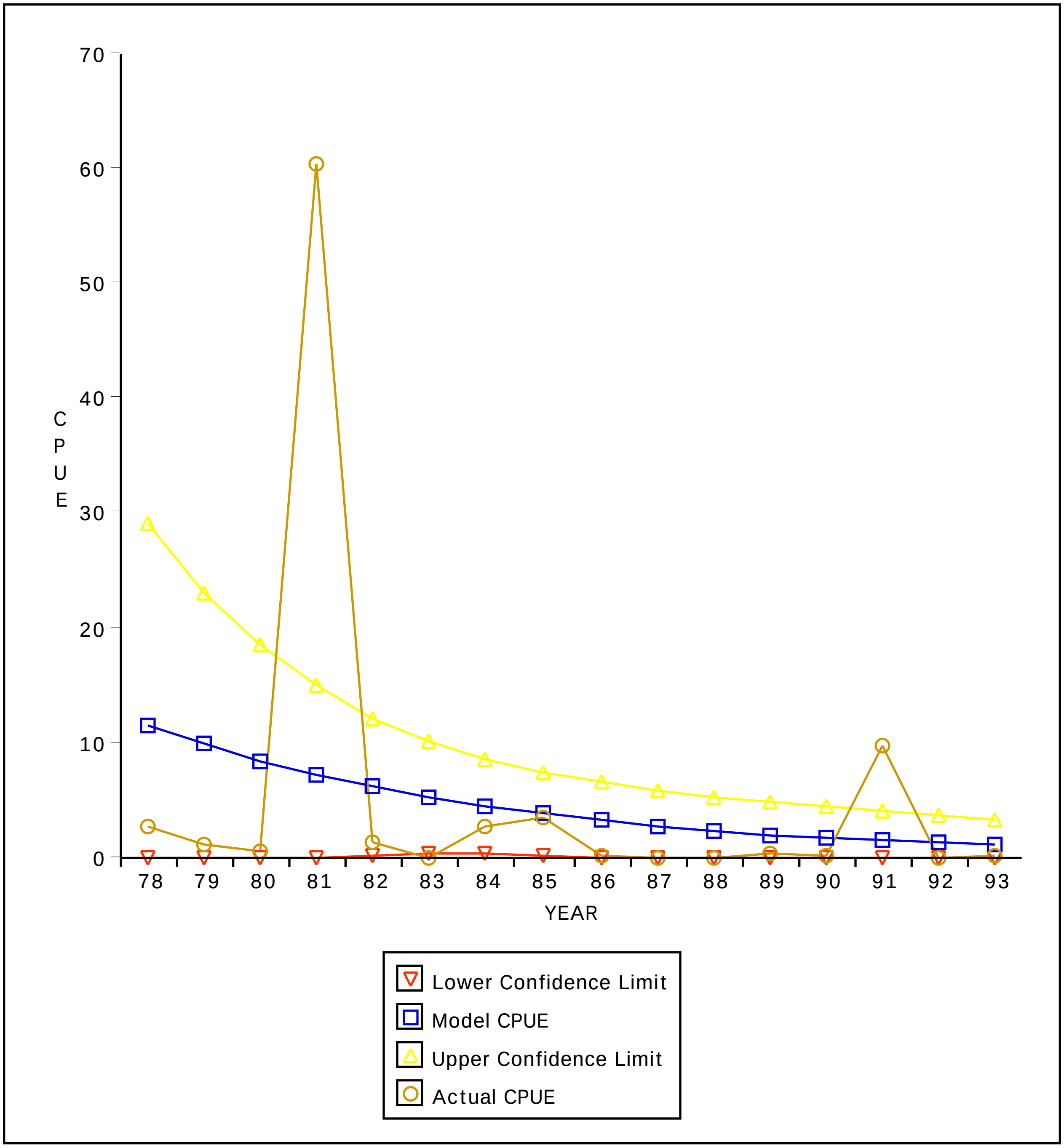

Figure VI.138. Actual catch per unit of effort and model with a significant linear component (**CPUE = b_0 + b_1*YEAR,** where CPUE = CATCH/0.03 hectare) for young-of-the-year Gulf menhaden (20-39 mm TL) caught by bag seine in Upper Laguna Madre during April and May.

Gulf menhaden/bag seine/model comparison

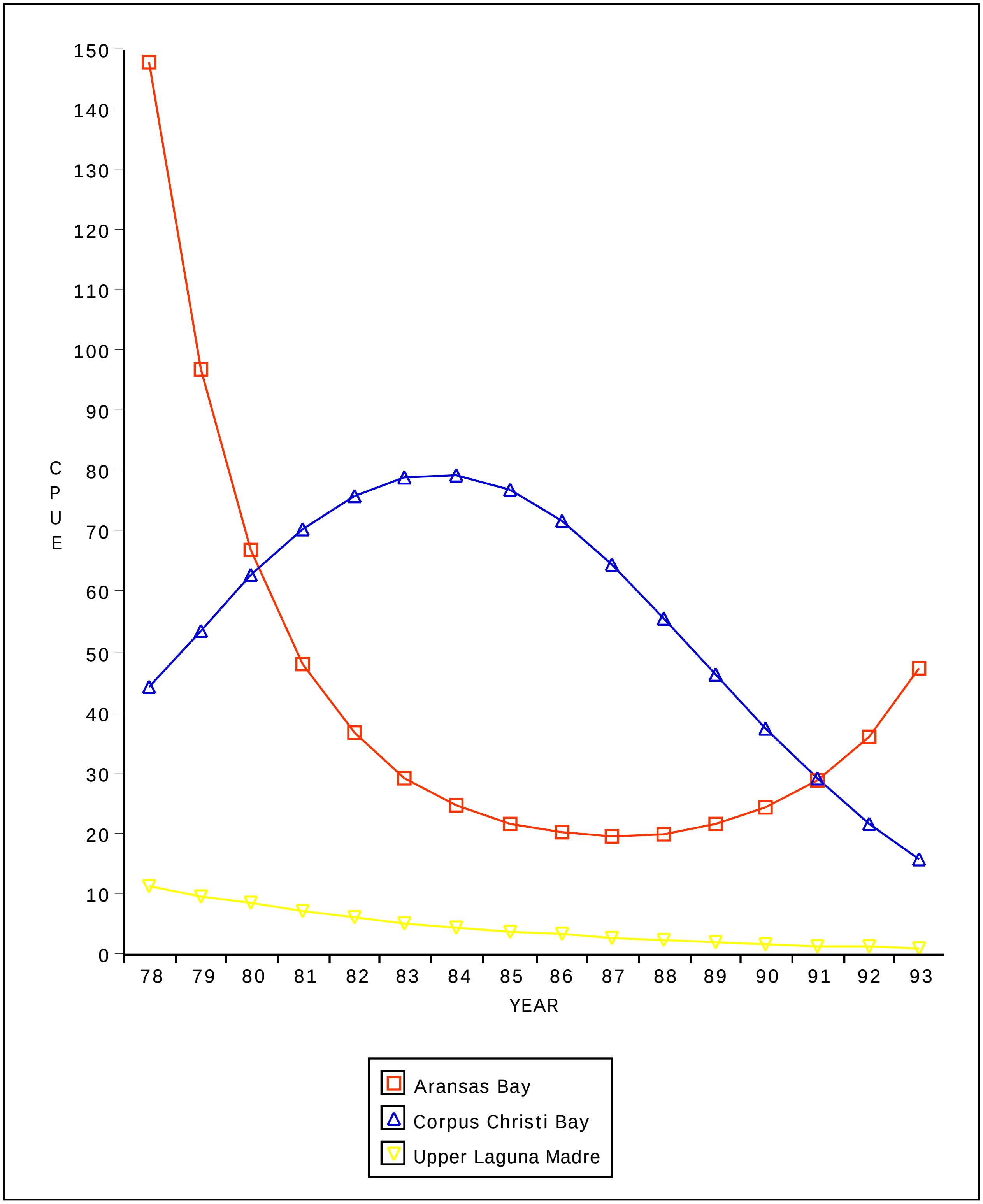

Figure VI.140. Comparison of best-fit models for young-of-the-year Gulf menhaden caught by bag seine in the CCBNEP (Table IX.80).

Gulf menhaden/trawl/Corpus Christi Bay

Modelled CPUE exhibited a significant quadratic trend with an interpolated maximum in 1988 (Table IX.81). Actual CPUE exhibited peaked in 1983 and 1989. These two peaks were influential in generating model curvature. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.142.

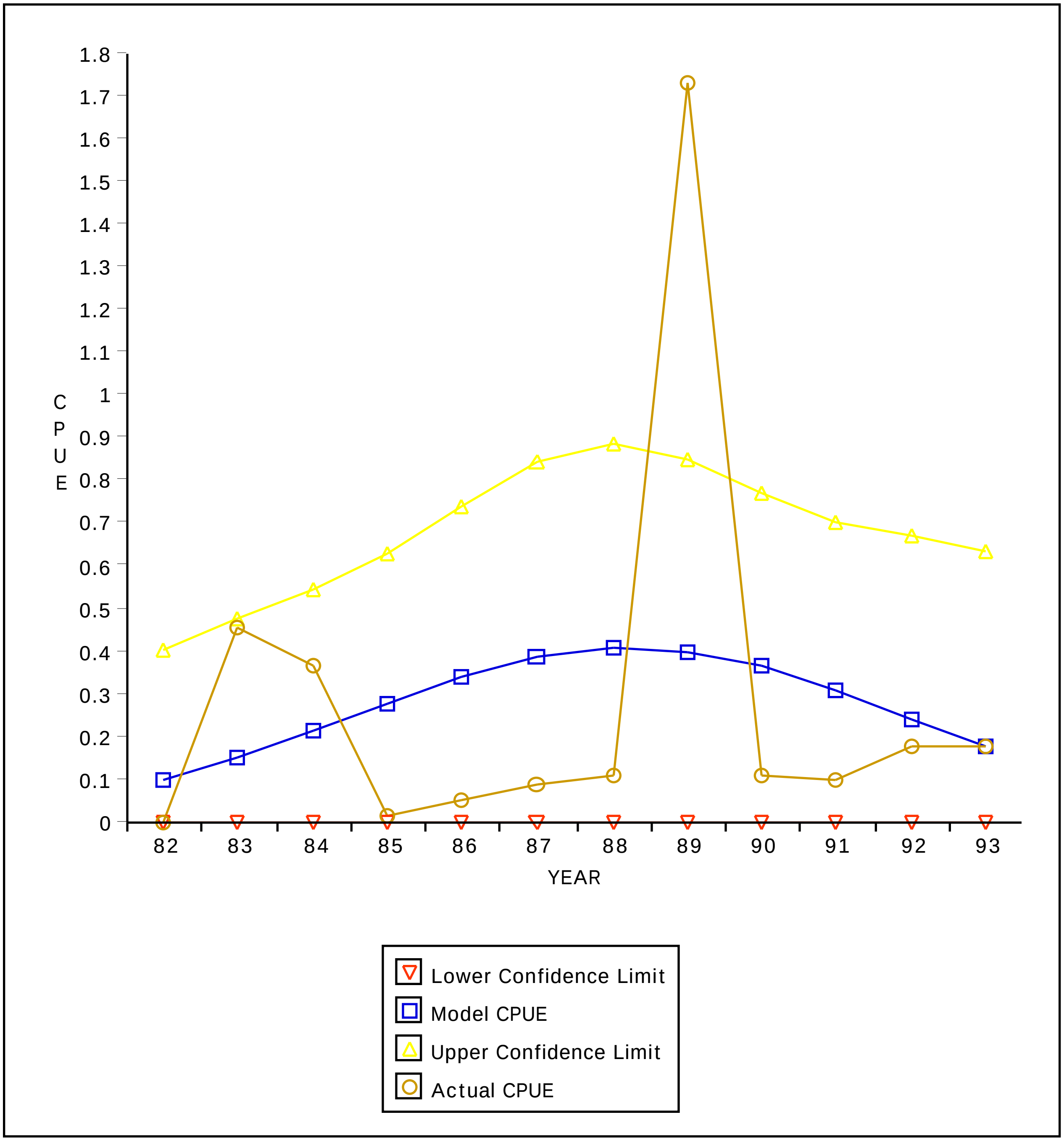

Figure VI.141. Actual catch per unit of effort and best-fit model with a significant quadratic component (**CPUE =** $\mathbf{b_o}$ + $\mathbf{b_1}$***YEAR +** $\mathbf{b_2}$***YEAR**$^{\mathbf{2}}$, where CPUE = CATCH/10 minutes) for subadult Gulf menhaden (100-124 mm TL) caught by trawl in Corpus Christi Bay during September, October, November, and December.

Gulf menhaden/trawl/Aransas Bay

Modelled CPUE decreased linearly (Table IX.82). Actual CPUE peaked in 1984 and 1992. These two peaks influenced the negative slope of the model. Otherwise, actual CPUE was negligible. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.144.

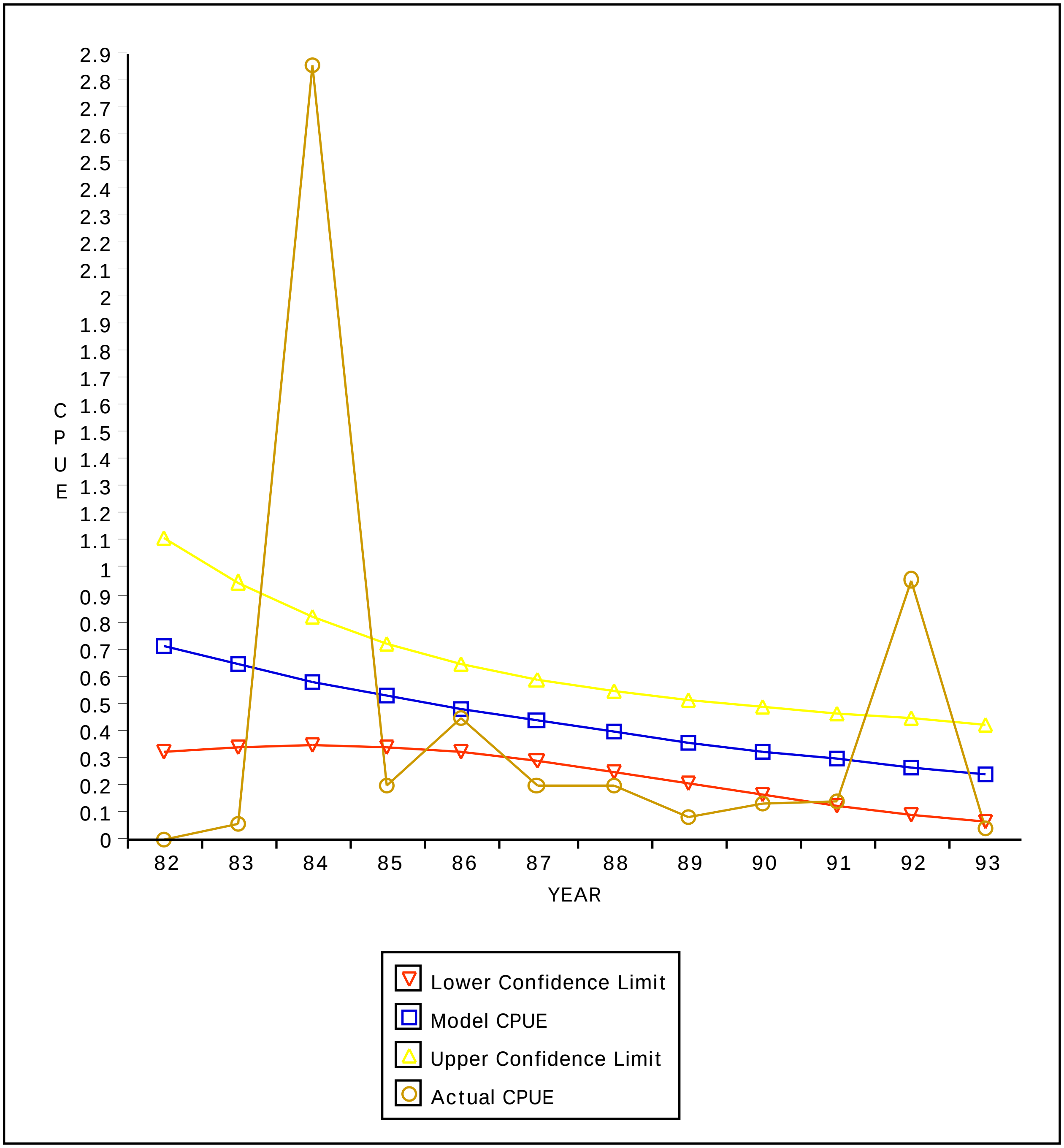

Figure VI.143. Actual catch per unit of effort and best-fit model with a significant linear component (**CPUE = b_0 + b_1*YEAR**, where CPUE = CATCH/10 minutes) for subadult Gulf menhaden (100-124 mm TL) caught by trawl in Aransas Bay during September, October, November, and December.

Gulf menhaden/trawl/Upper Laguna Madre

Modelled CPUE decreased linearly (Table IX.83). However, it should be noted that no gulf menhaden were caught in 460 of 480 trawls, thus this analysis should be interpreted with caution. Peaks in actual CPUE were detected in 1984 and 1990. Spatial distribution of mean CPUE during selected months is depicted in Figure VI.146.

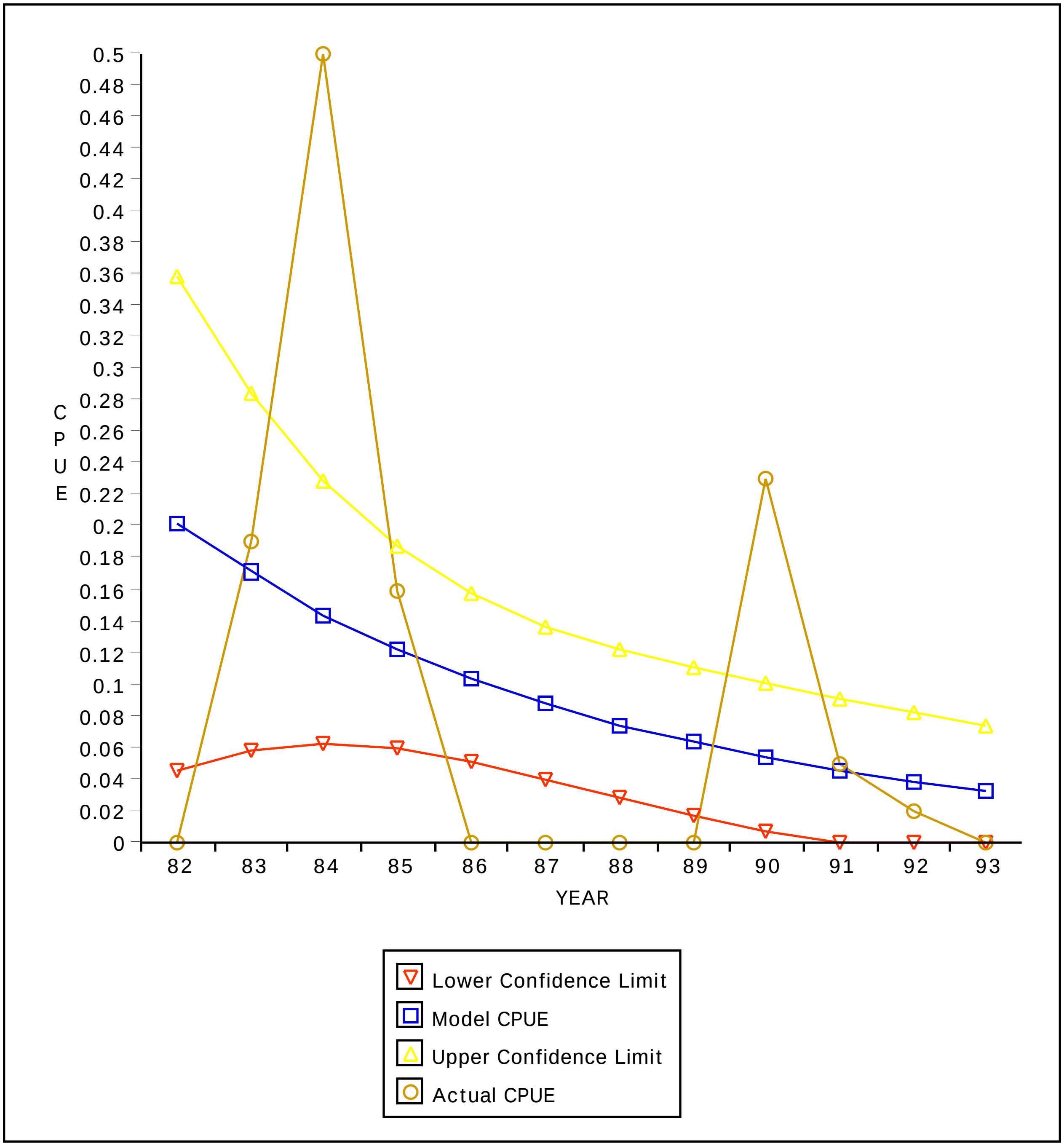

Figure VI.145. Actual catch per unit of effort and best-fit model with a significant linear component (**CPUE = b_0** + **b_1*YEAR**, where CPUE = CATCH/10 minutes) for subadult Gulf menhaden (100-124 mm TL) caught by trawl in Upper Laguna Madre during September, October, November, and December.

Gulf menhaden/trawl/model comparison

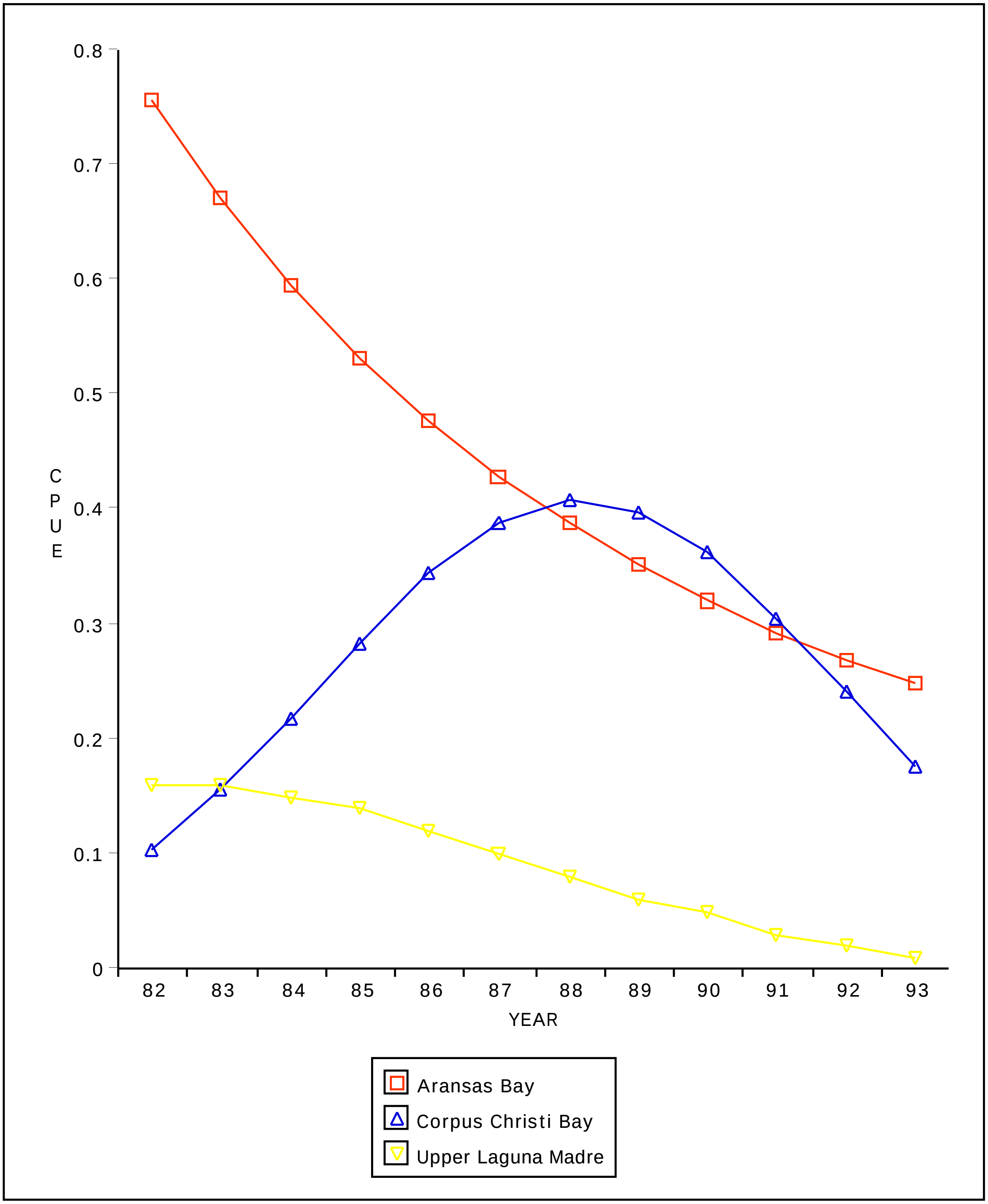

Figure VI.147. Comparison of best-fit models for subadult Gulf menhaden (100-124 mm TL), caught by trawl in the CCBNEP (Table IX.84). CPUE = CATCH/10 minutes

Modelled bag seine and trawl CPUE within Upper Laguna Madre exhibited significant decreasing linear trends. Similarly, the best fit model for gill net was suggestive of a slightly decreasing trend. Major peaks in actual catch of both YOY and reproductive-sized fish in collections by bag seine and gill net, respectively, were evident in 1981. A major peak in trawl actual catch of subadults evident in 1984 coincided with a secondary peak in actual gill net catch sustained during 1984-1985 and a minor elevation in bag seine yield during the same two years. All gears exhibited slight pulses in actual catch in latter years of the study (1990 for trawl, 1991 for gill net and bag seine).

In Aransas Bay, bag seine, trawl, and gill net catches decreased. For modelled bag seine and trawl catches, the decrease was linear with a negative slope, whereas modelled gill net catches decreased quadratically commencing from an estimated (and actual) maximum in 1984. Gill net and trawl actual catches exhibited coincident peaks in 1984 and a slight pulse in bag seine catch was also evident in 1984. All three gears yielded low numbers of Gulf menhaden in 1986 and yields decreased further until 1989: this suggested high mortality of one or more Aransas Bay cohorts during the 1986 red tide. Slight elevations in actual yield by bag seine and gill net were evident in 1990, but no such elevation was evident in trawl yield until 1992.

Models for bag seine and gill net catch in Corpus Christi Bay also exhibited quadratic decreases with interpolated maxima in 1984 and 1982, respectively. For gill net catches, the interpolated model maximum was coincident with the actual catch maximum. In bag seines, the actual maximum catch was recorded in 1983. By contrast, the modelled trend for trawl data exhibited an interpolated maximum in 1988, one year apart from the actual maximum yield recorded in 1989. Very few Gulf menhaden young-of-the-year were caught by bag seine and trawl during 1985-1988 in Corpus Christi Bay. A secondary peak in bag seine actual yield in 1983 coincided with mildly elevated trawl catches during 1983-1984. Substantially more reproductive-sized Gulf menhaden were caught by gill net during 1979-1987 versus 1987-1993. Thus, in all three water bodies examined there is evidence that Gulf menhaden representing three life stages have been caught in generally decreasing numbers.

CONCLUSIONS AND RECOMMENDATIONS

Finfish

In all three bays, modelled gill net CPUE of subadult red drum (545-749 mm TL) increased during the study. In Corpus Christi and Aransas Bays the increasing trend was linear, whereas in Upper Laguna Madre, the model curved upward after 1982. By contrast, no trend was detected in modelled CPUE of young-of-the-year ([YOY] 20-39 mm TL) red drum in Corpus Christi and Aransas Bays. The best fit model for red drum bag seine CPUE in Upper Laguna Madre exhibited upward curvature after 1985. Despite the relatively large number of YOY red drum collected in Corpus Christi and Aransas Bays in 1981, no associated peaks in 1984 or 1985 gill net CPUE were apparent. Red drum populations in the CCBNEP were low during 1983-1986. This finding was expected because of overfishing in the early 1980s, a severe freeze in Texas in 1983, and a red tide in 1986. Probable causes for the resurgence of red drum populations after the 1983-1986 bottleneck include changes in size and bag limits, the restocking program, and stricter management measures.

Modelled bag seine and gill net catches of spotted seatrout within Upper Laguna Madre exhibited upward curvature, with model minima occurring one year apart (1986 for bag seine and 1987 for gill net). In Upper Laguna Madre, the poorest gill net CPUE of reproductively mature (300-449 mm TL) spotted seatrout occurred in 1984, probably as an after-effect of the 1983 freeze. Bag seine CPUE of YOY (60-79 mm TL) in Corpus Christi Bay exhibited no trend, but modelled gill net CPUE increased linearly. In Aransas Bay, modelled bag seine and gill net CPUE exhibited no linear or curvilinear trends. Spotted seatrout in Upper Laguna Madre were apparently not affected by effects of brown tide and actual CPUE increased noticeably as of 1993. Based on these results, yields of spotted seatrout in Aransas Bay are not improving as vigorously as they are in Corpus Christi Bay and Upper Laguna Madre.

In Corpus Christi and Aransas Bays, modelled gill net CPUE of black drum curved upward after 1985. In Upper Laguna Madre, the upward curve of the model began one year earlier. Although the same size range of black drum (375-449 mm TL) was analyzed in all three bays, fish of this size in the Upper Laguna Madre are thought to be reproductively active, whereas Corpus Christi and Aransas Bay fish of this size are still considered subadults by TPWD researchers. This apparent difference in size at reproduction itself suggests that black drum inhabiting Upper Laguna Madre represent a unique fishery with distinctive population dynamics. In the CCBNEP, declines in actual catch centered around 1984 and 1985 were probably due to high mortality of cohorts of young black drum during the 1983 freeze. Actual black drum gill net CPUE in Corpus Christi Bay was phenomenal commencing in 1991. Clearly, yields of subadult black drum in Corpus Christi and Aransas Bays and of reproductively mature fish in Upper Laguna Madre were on the upswing during the latter years of the survey. Based on data through

1993, incurrence of the brown tide did not have an adverse effect on adult black drum within Upper Laguna Madre.

No trends were detected for YOY (60-79 mm TL) Atlantic croaker caught by bag seine within the CCBNEP, but they were caught in relatively large numbers in 1984 in Corpus Christi and Aransas Bays. In all three bays, YOY Atlantic croaker were caught infrequently in 1986 and 1987, possibly as a result of high mortality during the red tide. In Upper Laguna Madre, very few YOY Atlantic croaker were caught until 1992. Although actual bag seine CPUE generally increased from 1989 to 1992 in Aransas Bay, the increase was not sufficient to give the model a statistically positive slope. Declines in bag seine yields were evident in all three bays in 1993. No trends were detected in Corpus Christi Bay and Aransas Bay gill net CPUE of reproductively mature Atlantic croaker (225-299 mm TL). Modelled gill net CPUE within Upper Laguna Madre curved downward after a maximum in 1981. With regard to the relative timing of high CPUE in both bag seine and gill net collections, Corpus Christi Bay and Aransas Bay were more similar to each other than either one was to Upper Laguna Madre. Thus, of the four sciaenids (members of the drum family) examined in the CCBNEP, the Atlantic croaker shows the least improvement in population dynamics.

Modelled bag seine CPUE of YOY (20-39 mm TL) Southern flounder in Corpus Christi Bay curved downward after 1989, even though actual maximum CPUE was recorded in 1990. No significant trend was detected in gill net CPUE of reproductively mature (300-375 mm TL) Southern flounder in Corpus Christi Bay. Yields by both gear types were poor in Corpus Christi Bay during 1986-1989. Bag seine yield in Corpus Christi Bay was very poor during 1978-1984 and many more YOY Southern flounder were caught during the latter half of the survey period (1985-1993). Modelled bag seine CPUE of Southern flounder in Aransas Bay also exhibited downward curvature after 1985, whereas no significant trend was detected in gill net CPUE. Poor actual yields of both size classes of Southern flounder were recorded during 1983-1988, and in earlier years of the study period (1978-1981 for bag seine and 1979-1980 for gill net) in Aransas Bay. In Upper Laguna Madre, actual yield of reproductive Southern flounder decreased sharply after 1985. Furthermore, gill net yields in Upper Laguna Madre during 1987-1989 were poorest on-record during the survey. These data resulted in a gill net model for Upper Laguna Madre with downward curvature after 1983. Bag seine yields in Upper Laguna Madre were also extremely poor during 1987-1989, leading to a linear model with negative slope.

Modelled bag seine, trawl, and gill net CPUE of Gulf menhaden within Upper Laguna Madre exhibited decreasing linear trends. In Aransas Bay, Gulf menhaden bag seine, trawl, and gill net CPUE decreased: for modelled bag seine and trawl catches, the decrease was linear, whereas gill net catch curved downward after 1984. Models for bag seine, trawl, and gill net catch in Corpus Christi Bay also exhibited downward curving trends with interpolated maxima in 1984, 1988, and 1982, respectively. In Aransas Bay, all three gears yielded low numbers of Gulf menhaden in 1986 and yields decreased further until 1989. Very few YOY Gulf menhaden were caught by bag seine and trawl during 1986-1988 in Corpus Christi Bay. This suggests high mortality during the 1986 red tide. In general, substantially more reproductive-sized Gulf menhaden were caught within the CCBNEP during 1979-1987 versus 1987-1993. Thus, in all three bays there was evidence that Gulf menhaden representing three life stages were caught in generally decreasing numbers during the survey.

Macroinvertebrates

In Upper Laguna Madre, bag seine CPUE of juvenile white shrimp (40-59 mm TL) and trawl CPUE of emigratory-sized (100-124 mm TL) shrimp increased linearly, despite minimal actual bag seine and trawl CPUE values recorded during 1985-1987. The best-fit model for bag seine in Aransas Bay curved downward after 1988. This contrasted with the trawl model for Aransas Bay, which curved upward after 1988. In Corpus Christi Bay, there was no trend in trawl catch, but the model for bag seine catch curved upward slightly after 1988. Of the three bays, Upper Laguna Madre has generally yielded the least white shrimp. This was the expected result because of high salinity in Upper Laguna Madre compared to other Texas estuaries. However, white shrimp yield of both size classes increased linearly by almost two-fold during the study in Upper Laguna Madre.

Whereas bag seine CPUE of juvenile brown shrimp increased curvilinearly after 1986 in Corpus Christi Bay, trawl catch of emigratory-sized brown shrimp decreased gradually after the same year. This was a curious result similar to that found in the case of white shrimp caught in Aransas Bay. Opposing trends were also seen in Upper Laguna Madre, where bag seine yield of juvenile brown shrimp (40-59 mm TL) curved downward after 1988, whereas trawl catch curved upward after 1987. Bag seine CPUE of brown shrimp in Upper Laguna Madre was routinely poor and reached lowest levels in 1981, 1983, and 1990. The characteristic feature of bag seine data for Upper Laguna Madre was the sole peak in catch clearly evident in 1987: such a well-defined peak in bag seine actual catch was not evident in the other two bays. Actual trawl CPUE of brown shrimp in Upper Laguna Madre was obviously much greater after the incurrence of brown tide in late spring/early summer of 1990. In Aransas Bay, the model derived for bag seine catch was linear with a decreasing slope, whereas the model derived for trawl catch of emigratory-sized shrimp (100-124 mm TL) was curvilinear with an estimated maximum in 1989; there was also a major peak in actual catch by trawl in 1991.

Upper Laguna Madre exhibited the most improvement in CPUE of YOY (40-59 mm TL) and emigratory-sized (100-124 mm TL) pink shrimp. Bag seine CPUE in Upper Laguna Madre was negligible during 1978-1983, but sporadic small peaks in actual catch were detected in 1987, 1989, and 1991; improved yields in these latter years influenced the positive linear component of the bag seine model. In Aransas Bay, the bag seine model increased linearly whereas the trawl model curved downward after 1987; actual trawl yields began to increase in 1985, then peaked in 1986 in Aransas Bay. It is important to note that even though the modelled curve for Aransas Bay trawl CPUE reached a maximum in 1987, actual trawl CPUE was minimal during 1987. The resultant model for Corpus Christi Bay trawl catch resembled that of Aransas Bay except that downward curvature was evident after 1989. Modelled bag seine CPUE of pink shrimp in Corpus Christi Bay exhibited no trend. In general, the modelled trends indicate that catches in Corpus Christi Bay and Aransas Bay were more similar in magnitude and timing to each other than either one was to Upper Laguna Madre.

Analysis of bag seine CPUE of blue crab revealed no significant linear or curved trend in any of the bays; all three bays yielded low numbers of YOY (20-39 mm TW [total width]) blue crab in 1984. The same result was obtained for trawl catches of juveniles (50-74 mm TW) in Corpus

Christi and Aransas Bays. Of all the models tested, only Upper Laguna Madre trawl CPUE curved upward (after 1988). Actual trawl CPUE in Aransas Bay was generally greater than catches in either Corpus Christi Bay or Upper Laguna Madre. Actual catch by gill net of adult blue crab (150-224 mm TW [total carapace width]) peaked in 1983 and 1987 in all three bays, although mean number of blue crab caught in Corpus Christi Bay in 1987 was about twice that caught in Aransas Bay. Synchronicity of peaks in actual gill net catch resulted in similar models for the three bays: all exhibited significant curvature with interpolated maxima in 1986 (Aransas Bay), 1987 (Upper Laguna Madre), and 1988 (Corpus Christi Bay). These results confirm that blue crab of reproductive size were most plentiful within the CCBNEP sometime within 1986-1988. Catches of blue crab have declined since then, even though some peaks in actual CPUE were recorded in latter years.

Results of this study indicate that it is often possible to: 1) discern significant mathematical trends in CPUE and; 2) detect differences in species trends among water bodies, which in turn may confirm ecological variation among estuarine systems. It is likely that future studies designed to detect trends in biological collections of these ecologically and commercially valuable species will generate much needed information for resource managers. We recommend a more comprehensive evaluation of biodiversity and community dynamics of Texas estuaries be undertaken, one which would utilize the TPWD Coastal Fisheries data set to measure an index of biotic integrity (IBI) for Texas estuaries. Such a study should attempt to correlate salinity patterns with levels of biodiversity and biotic integrity, in order to conclusively demonstrate differences between high salinity areas, e.g. Baffin Bay, Upper Laguna Madre, and areas with more typical salinity regimes, e.g., Aransas Bay.Numerous researchers have proposed methods for arriving at an IBI for various trophic levels within aquatic ecosystems (reviewed by Miller et al. 1988, Engle et al. 1994). Of these, the method proposed by Thompson and Fitzhugh (1986) is directly applicable to the TPWD Coastal Fisheries data: these investigators identified several metrics which could be used in a prototypic assessment of estuarine environmental condition.

For the purpose of evaluating species composition, at least the following metrics could be evaluated from the CF data base: 1) total number of fish species, 2) number of freshwater species, 3) number of estuarine species, 4) number of estuarine-marine species, 5) number of marine species, 6) proportion of individuals that are bay anchovies, 7) proportion of individuals which are Atlantic croaker, and 8) number of species required to make up 90% of a collection. Categorization of fish species as freshwater (FW), estuarine (ES), estuarine-marine (EM), or marine (MA) could follow the system of Thompson and Fitzhugh (1986). Rationale for quantifying the proportion of individuals as bay anchovy is that prolonged dominance over several seasons or years by this species is indicative of poor estuarine condition. Bay anchovy is a generalized feeder because it may consume microbenthos and detritus in addition to its typical diet of zooplankton: according to Bechtel and Copeland (1970), prolonged dominance by this species indicates a disproportionate flow of energy through a relatively short foodchain. Atlantic croaker is considered to be a generalized benthic omnivore during all stages of its life history (Levine 1980) and has been implicated as a second indicator species by Thompson and colleagues (Thompson and Verret 1980, Thompson and Fitzhugh 1985, 1986) and Sheridan (1983). Increases in energy directed disproportionately to such dominant species are thought to be indicative of a decline in ecosystem complexity (McErlean et al. 1973).

In prime estuarine condition, a substantial number of species should be found in 90% of a biological collection: the converse situation would indicate low diversity. It may also be helpful to evaluate metrics indicative of trophic composition including: 1) the proportion of individuals which are benthic feeders, 2) the proportion of individuals which are planktonic grazers, and 3) the proportion of individuals which are top carnivores. Moreover, it would certainly be of great interest to evaluate a metric indicative of population dynamics, such as the proportion of YOY in a biological collection.

In conclusion, it is safe to say that studies designed to quantify populations of estuarine fishes and macroinvertebrates over time can be used comprehensively as an indicator of estuarine condition. Studies which examine one species at a time are necessary as baseline research. Examination of community dynamics becomes the logical next step. These are worthwhile research endeavors deserving of continued funding.

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APPENDIX

red drum/gill net/Corpus Christi Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary analysis of deviance (ANODE) revealed a significant relationship between catch per set and set duration (*P* < 0.0001). CPUE was evaluated as CATCH/(GTIME/14)^2. The linear term in year was highly significant (*P* < 0.0001), but the quadratic term was not significant (*P* = 0.2708). The fitted model displays a gradual linear increase in CPUE from 1979 through 1993. Studentized residuals for the individual CPUE values ranged from -1.27 to 3.88. Fourteen of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the size of the 14 largest yields (20-57 red drum caught). Approximately half (307 of 617) of the gill net sets yielded no red drum.

Table IX.1. ANODE for red drum/gill net/Corpus Christi Bay (CPUE = CATCH/(GTIME/14)^2)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	564.55	564.55	60.38	3.4×10^{-14}
Quadratic	1	11.36	11.36	1.21	0.2708
Other	12	218.27	18.19	1.95	0.0269
Error	602	5628.45	9.35		

red drum/gill net/Aransas Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration ($P < 0.0001$). CPUE was evaluated as CATCH/(GTIME/14)^2. The linear term in year was highly significant ($P < 0.0001$), but the quadratic term was not significant ($P = 0.4620$). The fitted model displays a gradual increase in CPUE from 1979 through 1993. Deviation from the model was due to substantial fluctuation in CPUE values during 1984-1993. Studentized residuals for the individual CPUE values ranged from -1.07 to 5.19. Eleven of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no individuals (342 of 617 gill net sets) in combination with the effects of relatively few large yields (the 11 largest catches yielded 28-93 red drum).

Table IX.2. ANODE for red drum/gill net/Aransas Bay (CPUE = CATCH/(GTIME/14)^2)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	430.14	430.14	31.86	2.6×10^{-8}
Quadratic	1	7.31	7.31	0.54	0.4620
Other	12	404.09	33.67	2.49	0.0034
Error	602	8127.33	13.50		

red drum/gill net/Upper Laguna Madre

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration (P = 0.0213). CPUE was evaluated as CATCH/(GTIME/14)^2. Both the linear and quadratic term in year were highly significant (P < 0.0001 and P = 0.0055, respectively). The fitted model displays curvature with a minimum in 1982. Actual CPUE increased substantially in 1987 and levels remained relatively high during 1990-1993. Studentized residuals for the individual CPUE values ranged from -1.46 to 5.24. Eleven of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no individuals (224 of the 617 gill net sets) in combination with the effects of relatively few large yields (the 11 largest catches yielded 19-54 red drum).

Table IX.3. ANODE for red drum/gill net/Upper Laguna Madre (CPUE = CATCH/(GTIME/14)^2)

Source of Variation	D.F.	Deviance	Mean Deviance	F	P
YEAR					
Linear	1	323.28	323.28	57.02	$1.6x10^{-13}$
Quadratic	1	44.08	44.08	7.78	0.0055
Other	12	106.80	8.90	1.57	0.0960
Error	602	3413.06	5.67		

red drum/gill net/model comparison

Corpus Christi Bay: CPUE = exp(34.812 - 0.935*Y + 0.00624*Y^2)
Aransas Bay: CPUE = exp(24.907 - 0.677*Y + 0.00461*Y^2)
Upper Laguna Madre: CPUE = exp(79.853 - 1.936*Y + 0.0118*Y^2)

Modelled CPUE intercepts were not significantly different (P =0.3520). Among the three water bodies, neither the linear (P = 0.5109) nor quadratic terms (P = 0.6499) were significant.

Table IX.4. ANODE for red drum/gill net/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	22.97	11.49	1.04	0.3520
YEAR					
Linear	1	1301.76	1301.76	118.41	0.0000
Quadratic	1	54.88	54.88	4.99	0.0256
Bay-Linear	2	14.77	7.39	0.67	0.5109
Bay-Quadratic	2	9.48	4.74	0.43	0.6499
Error	1842	20249.93	10.99		

red drum/bag seine/Corpus Christi Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. Results of the ANODE indicated a significant difference ($P < 0.0001$) in mean CPUE values among October, November, and December. In addition, there was significant month by year interaction ($P = 0.0226$) indicating that the observed overall difference in mean CPUE among the three months varied from year to year. There were four years during which no red drum were caught. The highest mean CPUE value was recorded in November in seven of the 17 years, whereas highest values were recorded in December in five of the remaining years. The highest value was recorded in October in only one of the 17 years. The linear ($P = 0.4285$) and quadratic ($P = 0.4369$) terms in YEAR were not significant. Higher order terms were significant ($P < 0.0001$) indicating significant fluctuation in mean CPUE over the 17 years of the study. Mean CPUE was less than 0.5 red drum/0.03 hectare in nine of the 17 years. In the remaining four years during which some red drum were caught, mean CPUE was 0.66, 0.90, 0.92, and 1.91 red drum/0.03 hectare. There was no trend in CPUE values over the 17 years. Studentized residuals for the individual CPUE values ranged from -1.84 to 6.41. Nine of the 574 residuals values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of bag seines which yielded no red drum (518 of the 574 seines) in combination with the effects of a few large yields (the 9 largest catches yielded 7-44 red drum).

Table IX.5. ANODE for red drum/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	92.76	44.38	16.22	1.5×10^{-7}
YEAR					
Linear	1	1.79	1.79	0.63	0.4285
Quadratic	1	1.73	1.73	0.61	0.4369
Other	14	299.99	21.43	7.50	2.0×10^{-14}
Month x Year	32	145.48	4.55	1.59	0.0226
Error	523	1495.14	2.86		

red drum/bag seine/Aransas Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. Results of the ANODE indicated a significant difference (*P* < 0.0001) in the mean CPUE values among October, November, and December. There was significant month by year interaction (*P* = 0.0015) indicating that observed overall differences in mean CPUE over the three months varied from year to year. There were five years during which no red drum were caught. The highest mean CPUE value was recorded in November in six of the 17 years, whereas six of the remaining years had highest yields recorded in October or December. The linear (*P* = 0.1133) and quadratic (*P* = 0.6549) terms in YEAR were not significant. The higher order terms were significant (*P* < 0.0001), indicating significant fluctuation in mean CPUE values over the 17 years of the study. Mean CPUE was less than 0.5 red drum/0.03 hectare in nine of the 17 years, and the remaining mean CPUE values were 1.17, 2.31, and 2.75 red drum/0.03 hectare. Studentized residuals ranged from -1.73 to 7.14. Three of the 591 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the extremely large number of bag seines which yielded no red drum (536 of the 594 values bag seines) in combination with the effects of large numbers of red drum caught in three bag seines (30, 66, and 78 red drum, respectively).

Table IX.6. ANODE for red drum/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	99.03	49.52	10.24	4.3×10^{-5}
YEAR					
Linear	1	12.17	12.17	2.51	0.1133
Quadratic	1	0.97	0.97	0.20	0.6549
Other	14	543.38	38.81	8.02	1.2×10^{-15}
Month x Year	32	303.26	9.48	1.96	0.0015
Error	543	2626.50	4.84		

red drum/bag seine/Upper Laguna Madre

There was a linear relation between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. Results of the ANODE indicated a significant difference ($P < 0.0001$) in mean CPUE values among October, November, and December. There was significant month by year interaction ($P < 0.0001$) indicating that observed overall differences in mean CPUE over the three months varied from year to year. There were six years during which no red drum were caught. The highest mean CPUE value was recorded in December in seven of the 17 years. Highest yields were recorded in either October or November in the four remaining years during which red drum were caught. The linear term in YEAR was not significant ($P = 0.1393$). The quadratic term in YEAR was significant ($P = 0.00223$). Higher order terms were significant ($P < 0.000001$), indicating significant fluctuation in mean CPUE values over the 17 years. Modelled CPUE displays a significant quadratic trend, with an estimated minimum in 1985. Actual CPUE was less than 0.25 red drum/0.03 hectare in six of the 17 years. Mean CPUE values in the remaining five years during which red drum were caught ranged between 0.25 and 1.00 red drum/0.03 hectare. Studentized residuals ranged from -1.62 to 6.37. Six of the 591 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to a large number of bag seines which yielded no red drum (546 of the 574 bag seines) in combination with the effects of a few large yields (the six largest catches yielded 7-19 red drum).

Table IX.7. ANODE for red drum/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	38.39	19.20	10.81	0.0000251
YEAR					
Linear	1	3.89	3.89	2.19	0.1393
Quadratic	1	16.77	16.77	9.44	0.00223
Other	14	100.79	7.20	4.05	0.0000011
Month x Year	32	134.44	4.20	2.37	0.0000528
Error	523	928.67	1.78		

red drum/bag seine/model comparison

Corpus Bay: CPUE = exp(53.923 - 1.261*Y + 0.00722*Y^2)
Aransas Bay: CPUE = exp(22.849 - 0.586*Y + 0.00363*Y^2)
Upper Laguna Madre: CPUE = exp(131.682 - 3.164*Y + 0.0187*Y^2)

Model intercepts differed significantly (*P* = 0.0288) indicating differences in the overall level of CPUE across the years 1977-1993. Mean CPUE was highest in Aransas Bay (0.573 red drum/0.03 hectare), intermediate in Corpus Christi (0.395 red drum/hectare), and lowest in the Upper Laguna Madre (0.179 red drum/hectare). Only the quadratic trend for Upper Laguna Madre was significant and depicted models for Corpus Christi Bay and Aransas Bay represent only nonsignificant best fits. Neither the linear (*P* = 0.6239) nor quadratic (*P* = 0.3346) terms in YEAR were significant.

Table IX.8. ANODE for red drum/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	86.27	43.14	3.55	0.0288
YEAR					
Linear	1	2.92	2.92	0.24	0.6239
Quadratic	1	11.31	11.31	0.93	0.3346
Bay-Linear	2	8.25	4.13	0.34	0.7119
Bay-Quadratic	2	6.32	3.16	0.26	0.7708
Error	1733	21039.62	12.14		

spotted seatrout/gill net/Corpus Christi Bay

There was a nonlinear relation between the mean and variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. Results of the preliminary ANODE indicated no significant relationship between catch per set and set duration (P = 0.5658). CPUE was defined as CPUE = CATCH/(GTIME/12.5). The linear term in YEAR was highly significant (P < 0.0001), but the quadratic term was not significant (P = 0.5475). The higher order terms in YEAR were significant (P = 0.00068), indicating substantial fluctuation in CPUE over the years. Modelled CPUE diplayed a linear increase during 1979-1993. Studentized residuals for the fitted model ranged from -1.9 to 2.9. Five of the 572 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to a large number of gill net sets which yielded no spotted seatrout (183 of 572 gill net sets) in combination with the effects of high yields in relatively few gill net sets (the five largest catches yielded 46-108 spotted seatrout).

Table IX.9. ANODE for spotted seatrout/gill net/Corpus Christi Bay (CPUE = CATCH/(GTIME/12.5)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	0.35	0.35	0.33	0.5658
YEAR					
Linear	1	53.50	53.50	50.34	4.1×10^{-12}
Quadratic	1	0.39	0.39	0.36	0.5475
Other	12	36.91	3.08	2.89	0.000681
GTIME*YEAR	14	19.16	1.37	1.29	0.2101
Error	542	576.04	1.06		

spotted seatrout/gill net/Aransas Bay

There was a nonlinear relation between the mean and variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. Results of the preliminary ANODE indicated no significant relationship between catch per set and set duration (*P* = 0.4123). CPUE was defined as CPUE = CATCH/(GTIME/12.5). Neither the linear (*P* = 0.0918) nor quadratic (*P* = 0.4181) terms in YEAR were significant. The higher order terms in YEAR were significant (*P* = 0.000556). This is attributed to the three years in which CPUE was significantly lower. The fitted model depicts essentially constant CPUE from 1979 through 1993. Studentized residuals for the fitted model ranged from -1.9 to 2.9. Five of the 572 residual values were less than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no spotted seatrout (171 of 572 gill net sets) in combination with the effects of high yields in relatively few net sets (the five largest catches yielded 28-41 spotted seatrout).

YTable IX.10. ANODE for spotted seatrout/gill net/Aransas Bay (CPUE = CATCH/(GTIME/12.5)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	0.72	0.72	0.67	0.4123
YEAR					
Linear	1	3.05	3.05	2.85	0.0918
Quadratic	1	0.70	0.70	0.66	0.4181
Other	12	37.80	3.15	2.94	0.000556
GTIME*YEAR	14	12.53	0.90	0.84	0.6294
Error	542	580.06	1.07		

spotted seatrout/gill net/Upper Laguna Madre

There was a nonlinear relation between the mean and variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. Results of the preliminary ANODE indicated no significant relationship between catch per set and set duration (*P* = 0.3499). CPUE was defined as CPUE = CATCH/(GTIME/12.5). The linear term in YEAR was not significant (*P* = 0.9280), but the quadratic term was significant (*P* = 0.0303). The higher order terms in YEAR were significant (*P* < 0.0001). Modelled CPUE decreased from 1979 to a minimum value in 1987, then increased in remaining years. Studentized residuals for the fitted model ranged from -1.2 to 2.9. Two of the 572 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to a large number of gill net sets which yielded no spotted seatrout (266 of 572 gill net sets) in combination with the effects of high yields in two gill net sets (these yielded 39 and 62 spotted seatrout, respectively).

Table IX.11. ANODE for spotted seatrout/gill net/Upper Laguna Madre (CPUE = CATCH/(GTIME/12.5)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	1.18	1.18	0.88	0.3499
YEAR					
Linear	1	0.01	0.01	0.01	0.9280
Quadratic	1	6.36	6.36	4.72	0.0303
Other	12	70.12	5.84	4.33	0.0000013
GTIME*YEAR	14	25.11	1.79	1.33	0.1837
Error	542	730.19	1.35		

spotted seatrout/gill net/model comparison

Corpus Bay: CPUE = exp(8.568-0.274*Y +0.00222*Y^2)
Aransas Bay: CPUE = exp(23.137-0.527*Y + 0.00318*Y^2)
Upper Laguna Madre: CPUE = exp(89.246-2.032*Y+0.0116Y^2)

Modelled CPUE from 1979 to 1993 in Corpus Christi Bay increased linearly, whereas for Aransas Bay there was no trend. Modelled CPUE in the Upper Laguna Madre decreased quadratically from 1979 to 1987 and then increased in subsequent years. Results of the ANODE revealed significant differences among the water bodies ($P < 0.0001$) indicating substantial variation among modelled intercepts. Among the three water bodies, linear terms were significantly different ($P = 0.0000113$), whereas the quadratic terms were not ($P = 0.3806$).

Table IX.12. ANODE for spotted seatrout/gill net/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	621.34	310.67	32.21	1.9×10^{-14}
YEAR					
Linear	1	272.85	272.85	28.29	1.18×10^{-7}
Quadratic	1	45.37	45.37	4.70	0.0302
Bay-Linear	2	221.20	110.60	11.47	0.0000113
Bay-Quadratic	2	18.65	1.70	0.97	0.3806
Error	1707	16465.76	9.65		

spotted seatrout/bag seine/Corpus Christi Bay

Since there was very little variation in catch per seine, and the greatest yield was seven spotted seatrout, the Poisson distribution was selected as the most appropriate for evaluating the significance of model components. Results of the ANODE indicated no significant difference (*P* = 0.0925) in mean CPUE values among August, September, and October. However, there was significant month by year interaction (*P* < 0.0001), indicating that the observed overall difference in mean CPUE over the three months varied from year to year. The highest mean CPUE value was recorded in August in six of the 16 years. Highest mean CPUE values were recorded in October in five years. Highest mean CPUE values were recorded in September in three years. In 17 of the 48 months in the study, there were no spotted seatrout of the selected size caught. Neither the linear (*P* = 0.0791) nor quadratic (*P* = 0.1960) terms in YEAR were significant. The higher order terms were significant (*P* = 0.0022), indicating substantial fluctuation in mean CPUE values over the 16 years of the study. The three largest mean CPUE values were recorded in 1981, 1989, and 1990 (0.364, 0.285, and 0.417 spotted seatrout/0.03 hectare, respectively). In the remaining 13 years, mean CPUE values were less than 0.22 spotted seatrout/0.03 hectare. Studentized residuals for the individual CPUE values ranged from -0.88 to 3.18. Twelve of the 544 values were greater than 2.0 in absolute value. Deviation from the model was attributed to a large number of bag seines which yielded no spotted seatrout (492 of 544 bag seines) in combination with infrequent large yields (the 11 largest catches yielded 3-7 spotted seatrout).

Table IX.13. ANODE for spotted seatrout/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	5.58	2.79	2.39	0.0925
YEAR					
Linear	1	3.61	3.61	3.10	0.0791
Quadratic	1	1.95	1.95	1.68	0.1960
Other	13	38.35	2.95	2.53	0.0022
Month x Year	30	87.94	2.93	2.51	0.0000248
Error	496	578.32	1.17		

spotted seatrout/bag seine/Aransas Bay

Since there was very little variation in catch per seine, and there was only a single bag seine which yielded more than seven spotted seatrout, the Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE indicated a significant difference ($P < 0.0001$) in mean CPUE values among August, September, and October. There was a significant month by year interaction ($P = 0.0013$) indicating that the observed overall difference in mean CPUE over the three months varied from year to year. The highest mean CPUE value was recorded in October in nine of the 16 years. The highest mean CPUE value was recorded in August in five of the 16 years. The highest mean CPUE value was recorded in September in two of the 16 years. There were no spotted seatrout of the selected size caught in 11 of the 48 months in the study. Neither the linear ($P = 0.9684$) nor quadratic ($P = 0.9680$) terms in YEAR were significant. The higher order terms were significant ($P = 0.0031$) indicating significant fluctuation in mean yearly CPUE values over the 16 years of the study. The two largest CPUE values were recorded in 1982 and 1988 (0.533 and 0.810 spotted seatrout/0.03 hectare, respectively). Mean CPUE was less than 0.45 spotted seatrout/0.03 hectare in the remaining 14 years. There was no trend in the CPUE values during the years 1978 to 1993. Studentized residuals for the individual CPUE values ranged from -1.11 to 4.39. Deviation from the model was attributed to a large number of bag seines which yielded no spotted seatrout (505 of 591 bag seines) in combination with infrequent large yields (the 11 largest catches yielded 4-24 spotted seatrout).

Table IX.14. ANODE for spotted seatrout/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	37.68	18.84	9.90	0.0000599
YEAR					
Linear	1	0.01	0.01	0.00	0.9684
Quadratic	1	0.01	0.01	0.00	0.9680
Other	13	60.62	4.66	2.45	0.00309
Month x Year	30	115.08	3.84	2.01	0.00129
Error	543	1033.45	1.90		

spotted seatrout/bag seine/Upper Laguna Madre

Since there was very little variation in catch per seine, and the largest number of spotted seatrout caught by bag seine was five individuals, the Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE indicated a significant difference (P < 0.0001) in mean CPUE values among August, September, and October. There was significant month by year interaction (P = 0.0117) indicating that observed overall differences in mean CPUE over the three months varied from year to year. Actual mean CPUE values varied considerably from year to year, ranging from a high of 0.80 spotted seatrout/0.03 hectare in October, 1982, to a CPUE value of 0.0 spotted seatrout/0.03 hectare in 30 of the 48 months in the study. The linear term in YEAR was not significant (P = 0.1029), whereas the quadratic term in YEAR was highly significant (P < 0.0001). The higher order terms were also highly significant (P < 0.0001). There was a significant quadratic trend in the CPUE values over the years 1978-1993. Modelled CPUE values decreased from 1978 through 1986 then increased during the remaining years of the study. Studentized residuals for the individual CPUE values ranged from -1.55 to 4.78. Ten of the 544 studentized residuals were greater than 2.0 in absolute value. Deviation from the model was attributed to a large number of bag seines which yielded no spotted seatrout (511 of 544 bag seines) in combination with a a rarity of large yields (the 11 largest catches yielded 2-5 spotted seatrout).

Table IX.15. ANODE for spotted seatrout/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*	
Month	2	13.19	6.60	10.09	0.0000508	
YEAR						
Linear	1	1.74	1.74	2.67	0.1029	
Quadratic	1	17.92	17.92	27.41 2.4x10^{-7}		Other
13 45.75		3.52	5.38	4.07x10^{-9}		
Month x Year	30	33.60	1.12	1.71	0.0117	
Error	496	324.41	0.65			

spotted seatrout/bag seine/model comparison

Corpus Christi Bay: CPUE = exp(54.117-1.341*Y + 0.00801*Y^2)
Aransas Bay: CPUE = exp(3.106-0.102*Y + 0.000594*Y^2)
Upper Laguna Madre: CPUE = exp(229.611 - 5.442*Y + 0.0318*Y^2)

The ANODE revealed significantly different model intercepts (*P* = 0.000498), indicating differences in overall levels of CPUE among the three water bodies during 1978-1993. Spotted seatrout yield within the Upper Laguna Madre was consistently lower than that of Corpus Christi and Aransas Bays. Among the three water bodies, the linear terms were not significantly different (*P* = 0.8767) but the quadratic terms were significantly different (*P* = 0.0373).

Table IX.16. ANODE for spotted seatrout/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*	
Bay	2	50.65	25.33	7.64	0.000498	YEAR
Linear	1	1.16	1.16	0.35	0.5536	
Quadratic	1	10.36	10.36	3.12	0.0773	
Bay-Linear	2	0.87	0.44	0.13	0.8767	
Bay-Quadratic	2	21.86	10.93	3.30	0.0373	
Error	1688	5596.19	3.32			

white shrimp/bag seine/Corpus Christi Bay

There was a linear relation between the mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE indicated no significant difference in mean CPUE values among June, July and August ($P = 0.2675$). There was significant month by year interaction ($P < 0.0001$) indicating that the observed overall difference in mean CPUE among June, July, and, August varied from year to year. The highest mean CPUE value was recorded in August in seven of the 15 years, whereas six of the remaining years had highest values recorded in July. Highest values were recorded in June in only two of the 15 years. The largest monthly mean CPUE value was recorded in June, 1979. There were seven months during which no white shrimp were caught. Both the linear and quadratic terms in YEAR were significant ($P < 0.0001$). Higher order terms were also significant ($P < 0.0001$) indicating substantial fluctuation in mean yearly CPUE values over the 15 years. The three largest CPUE values were recorded in 1979, 1984, and 1990. There was a significant quadratic trend in modelled CPUE values over the years 1979-1993, with an estimated minimum in 1988. Studentized residuals corresponding to individual CPUE values ranged from -3.46 to 6.30. Ten of the 522 residual values were larger than 2.0 in absolute value.

Table IX.17. ANODE for white shrimp/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	81.86	40.93	1.32	0.2675
YEAR					
Linear	1	1349.78	1349.78	43.60	1.1×10^{-10}
Quadratic	1	1059.57	1059.57	34.23	9.11×10^{-9}
Other	12	3028.10	252.34	8.15	5.2×10^{-14}
Month x Year	28	4083.62	145.84	4.71	2.80×10^{-13}
Error	477	14766.25	30.96		

white shrimp/bag Seine/Aransas Bay

There was a linear relation between the mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE indicated no significant difference in the mean CPUE values among June, July, and August (P = 0.0969). There was significant month by year interaction (P = 0.0029) indicating that the observed overall difference in mean CPUE among the three months varied from year to year. In eight of the 15 years, the highest mean CPUE value was recorded in August, whereas 5 of the remaining years had highest values recorded in July. In only 2 of the 15 years was the highest value recorded in June. The largest monthly mean CPUE value was recorded in June, 1990. There were seven months during which no white shrimp were caught. The linear term in YEAR was not significant (P = 0.0815) but the quadratic term in YEAR was significant (P < 0.0001). The higher order terms were also significant (P < 0.0001), indicating substantial fluctuation in mean yearly CPUE values over the 15 years of the study. The three largest mean CPUE values were recorded in 1985, 1986, and 1990. There was a significant quadratic trend in the CPUE values over the years 1979-1993, with an estimated maximum in 1988. The studentized residuals corresponding to individual CPUE values ranged from -1.6 to 6.2. Nine of the 562 residual values were larger than 2.0 in absolute value.

Table IX.18. ANODE for white shrimp/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	P
Month	2	243.33	121.67	2.34	0.0969
YEAR					
Linear	1	158.07	158.07	3.05	0.0815
Quadratic	1	1284.19	1284.19	24.75	8.9×10^{-7}
Other	12	4530.79	377.57	7.28	2.15×10^{-12}
Month x Year	28	2822.01	100.79	1.94	0.0029
Error	517	26830.60	51.90		

white shrimp/bag seine/Upper Laguna Madre

There was a linear relation between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE indicated a significant difference in the mean CPUE values among June, July, and August ($P < 0.0001$). Month by year interaction was not significant ($P = 0.9615$). Most of the extremely large CPUE values were recorded in August and the largest monthly mean CPUE value was recorded in August, 1988. No individuals were caught in 23 of the 45 months included in the analysis. The linear term in YEAR was significant ($P = 0.0003$) but the quadratic term in YEAR was not significant ($P = 0.9620$). The higher order terms were significant ($P < 0.0001$), indicating substantial fluctuation in mean yearly CPUE values over the 15 years of the study. The two largest CPUE values were recorded in 1988 and 1993. Modelled CPUE exhibited a significant increasing linear trend in the CPUE values over the years 1979-1993. Studentized residuals corresponding to individual CPUE values ranged from -1.3 to 6.8. Four of the 522 residual values were larger than 2.0 in absolute value.

Table IX.19. ANODE for white shrimp/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	1251.25	625.63	26.23	$1.6x10^{-11}$
YEAR					
Linear	1	315.94	315.94	13.25	0.000303
Quadratic	1	0.05	0.05	0.01	0.9620
Other	12	1029.79	85.82	3.60	0.0000365
Month x Year	28	384.37	13.73	0.58	0.9615
Error	477	11376.05	23.85		

white shrimp/bag seine/model comparison

Corpus Bay: CPUE = exp(262.126 - 5.939*Y + 0.0338*Y^2)
Aransas Bay: CPUE = exp(-401.410 + 9.188*Y - 0.0522*Y^2)
Upper Laguna Madre: CPUE = exp(-1.960 + 2.846*Y - 6.564*Y^2)

The model for Upper Laguna Madre exhibited an increasing linear trend, whereas the models for Corpus Christi and Aransas Bays were quadratic but with opposing trends. The ANODE revealed significant differences among the intercepts (*P* = 0.00208), indicating different overall CPUE levels among the three water bodies during 1979-1993. CPUE within the Upper Laguna Madre Bay was consistently lower than in the other two bays. Among the three water bodies, both the linear (*P* = 0.00816) and the quadratic (*P* = 0.00102) terms were significant.

Table IX.20. ANODE for white shrimp/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	2098.51	1049.26	6.20	0.00208
YEAR					
Linear	1	88.14	88.14	0.52	0.4707
Quadratic	1	106.13	106.13	0.63	0.4286
Bay-Linear	2	1633.28	816.64	4.82	0.00816
Bay-Quadratic	2	2342.11	1171.06	6.92	0.00102
Error	1597	270394.40	169.31		

white shrimp/trawl/Corpus Christi Bay

No white shrimp were caught in 454 of the 720 trawls, whereas 12 trawls contained more than 50 white shrimp. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed significant month by year interaction (P = 0.00702) indicating that the observed overall difference in mean CPUE among September, October, and November varied from year to year. The highest CPUE value was recorded in September in only one of the 12 years. The highest mean CPUE value was recorded in in November in six of the 12 years, whereas five of the remaining years had highest CPUE values recorded in October. The linear (P = 0.1091) and quadratic (P = 0.5916) terms in YEAR were not significant. The higher order terms were significant (P < 0.0001), indicating substantial fluctuation in mean yearly CPUE values over the 12 years of the study. Studentized residuals for the fitted model ranged from -1.33 to 5.76.

Table IX.21. ANODE for white shrimp/trawl/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	165.13	82.57	4.51	0.0114
YEAR					
Linear	1	47.18	47.18	2.57	0.1091
Quadratic	1	5.28	5.28	0.29	0.5916
Other	9	867.64	96.40	5.26	6.01×10^{-7}
Month x Year	22	774.01	35.18	1.92	0.00702
Error	684	12534.91	18.33		

white shrimp/trawl/Aransas Bay

No white shrimp were caught in 392 of the 720 trawls, whereas four trawls contained more than 50 white shrimp. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE indicated a significant difference in mean CPUE values among September, October, and November (*P* < 0.0001). There was significant month by year interaction (*P* = 0.0237) indicating that the observed overall difference in mean CPUE among September, October, and November varied from year to year. The highest mean CPUE value was recorded in November in nine of the 12 years. The linear term in YEAR was not significant (*P* = 0.1847) but the quadratic term was significant (*P* = 0.0142). The higher order terms were significant (*P* < 0.0001), indicating substantial fluctuation in mean yearly CPUE values over the 12 years. Modelled CPUE exhibited a slight quadratic trend from 1982-1993, with larger values recorded in the earlier and later years in the study and a minimum in 1988. Studentized residuals for the individual CPUE values ranged from -1.76 to 5.37. Seven of the 720 residual values were larger than 2.0 in absolute value.

Table IX.22. ANODE for white shrimp/trawl/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	318.13	159.07	19.48	5.92×10^{-9}
YEAR					
Linear	1	14.40	14.40	1.76	0.1847
Quadratic	1	49.38	49.38	6.05	0.0142
Other	9	708.09	78.67	9.63	6.42×10^{-14}
Month x Year	22	305.78	13.90	1.70	0.0237
Error	684	5585.36	8.17		

white shrimp/trawl/Upper Laguna Madre

No white shrimp were caught in 239 of the 360 trawls, whereas the six largest catches contained 22-73 white shrimp of the specified size. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed significant month by year interaction (*P* < 0.0001), indicating that the observed overall difference in mean CPUE among September, October and November varied from year to year. The linear term in YEAR was significant (*P* = 0.0023) whereas the quadratic term in YEAR was not significant (*P* = 0.1521). The higher order terms were also significant (*P* < 0.0001). Modelled CPUE exhibited a significant increasing linear trend from 1982-1993. Studentized residuals for the individual CPUE values ranged from -1.86 to 4.77. Six of the 544 residual values were greater than 2.0 in absolute value.

Table IX.23. ANODE for white shrimp/trawl/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	15.33	7.67	1.17	0.3109
YEAR					
Linear	1	61.81	61.81	9.46	0.00228
Quadratic	1	13.47	13.47	2.06	0.1521
Other	9	276.31	30.70	4.70	0.00000704
Month x Year	22	435.83	19.81	3.03	0.00000963
Error	324	2117.42	6.54		

white shrimp/trawl/model comparison

Corpus Bay: CPUE = exp(-33.805 + 0.844*Y - 0.00510*Y^2)
Aransas Bay: CPUE = exp(119.5 - 2.692*Y + 0.0153*Y^2)
Upper Laguna Madre: CPUE = exp(98.8 - 2.331*Y + 0.0138*Y^2)

Modelled CPUE for Upper Laguna Madre exhibited a slightly increasing linear trend, whereas no trend was observed for Corpus Christi Bay. The trend line for Aransas Bay was slightly curved, with a minimum in 1988. The ANODE indicated that the intercepts (*P* = 0.2096), linear terms (*P* = 0.1708), and quadratic trerms (*P* = 0.4300) were not significantly different among the three water bodies.

Table IX.24. ANODE for white shrimp/trawl/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	89.12	44.56	1.56	0.2096
YEAR					
Linear	1	16.01	16.01	0.56	0.4536
Quadratic	1	26.59	26.59	0.93	0.3341
Bay-Linear	2	100.82	50.41	1.77	0.1708
Bay-Quadratic	2	48.12	24.06	0.84	0.4300
Error	1791	51032.43	28.49		

brown shrimp/bag seine/Corpus Christi Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. No individuals were caught in 211 of 522 trawls, whereas 49 trawls yielded more than 50 brown shrimp. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among April, May, and June (*P* = 0.0039). There was no significant month by year interaction (*P* < 0.0513), indicating that the difference in mean CPUE among April, May, and June was consistent from year to year. The highest mean CPUE value was recorded in May in nine of the 15 years, and the largest monthly mean CPUE value was recorded in May, 1981. The linear term in YEAR was not significant (*P* = 0.7645), but the quadratic term was significant, (*P* = 0.0002). The higher order terms were not significant (*P* = 0.1044) indicating a close fit of the mean yearly CPUE values to the estimated quadratic line. The six largest CPUE values were recorded during the initial or final years in the study. Thus, modelled CPUE exhibited a significant quadratic trend from 1979-1993, with an estimated minimum in 1986. The studentized residuals for the individual CPUE values ranged from -1.34 to 5.21. Seven of the 522 residual values were larger than 2.0 in absolute value.

Table IX.25. ANODE for brown shrimp/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	953.00	476.50	5.63	0.00385
YEAR					
Linear	1	7.61	7.61	0.09	0.7645
Quadratic	1	1185.44	1185.44	14.00	0.000205
Other	12	1570.97	130.91	1.55	0.1044
Month x Year	28	3546.07	126.65	1.50	0.0513
Error	477	40398.83	84.69		

brown shrimp/bag seine/Aransas Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. This was attributed to a large number of bag seines which yielded no brown shrimp (195 of 545 bag seines) in combination with the effect of including 55 bag seines which each yielded more than 50 brown shrimp. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among April, May, and June (P = 0.00013). There was significant month by year interaction (P < 0.0001), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. The highest mean CPUE value occurred in May in eight of the 15 years. Four of the remaining years had highest CPUE values recorded in April. Three of the 15 years had highest CPUE values recorded in June. The largest monthly mean CPUE value, 59.3 brown shrimp/0.03 hectare, was recorded in May, 1990. No brown shrimp of the selected size range were caught in April, 1979 and April, 1980. The linear term in YEAR was significant (P = 0.0383) but the quadratic term in YEAR was not significant (P = 0.5590). The higher order terms were significant (P < 0.0001), indicating substantial fluctuation in actual CPUE during the 15 years included in the study. Studentized residuals for the individual CPUE values ranged from -1.51 to 4.30. Eighteen of the 545 values were larger than 2.0 in absolute value. Deviation from the model was attributed to the the large number of bag seines which yielded no brown shrimp, in combination with the effect of several bag seines with extremely high yields (the 18 largest catches yielded 130-386 brown shrimp).

Table IX.26. ANODE for brown shrimp/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	694.36	347.18	6.72	0.00132
YEAR					
Linear	1	222.90	222.90	4.32	0.0383
Quadratic	1	17.66	17.66	0.34	0.5590
Other	12	2258.86	188.24	3.64	0.0000292
Month x Year	28	3523.79	125.85	2.44	0.0000750
Error	500	25824.45	51.65		

brown shrimp/bag seine/Upper Laguna Madre

There was a linear relation between mean CPUE and the variance around mean CPUE. The Poisson model was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among April, May and June (P < 0.0001). The month by year interaction was significant (P = 0.0283). Maximum CPUE values were recorded in May in ten of the 15 years. The largest monthly mean CPUE value, 60.1 brown shrimp/0.03 hectare, was recorded in May, 1987. No brown shrimp of the selected size were caught in five of the 45 months surveyed. The linear term in YEAR was not significant (P = 0.1454) but the quadratic term in YEAR was significant (P = 0.0081). The higher order terms were also significant (P = 0.0016), indicating substantial fluctuation in mean CPUE values over the 15 years surveyed. The largest yields were recorded in 1987, with a three-month mean CPUE of 24.1 brown shrimp/0.03 hectare. Large actual yields were also recorded in 1986 and 1988. Thus, modelled CPUE exhibited a significant quadratic trend over the years 1979-1993, with an estimated maximum occurring in 1988. Studentized residuals for individual CPUE values ranged from -1.68 to 4.79. Eleven of the 522 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number of bag seines which yielded no brown shrimp (75.5% of the 522 bag seines), in combination with the effect of a few very large yields (the 11 largest catches yielded 96 -442 brown shrimp).

Table IX.27. ANODE for brown shrimp/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	P
Month	2	1644.93	822.47	19.05	1.10×10^{-8}
YEAR					
Linear	1	91.83	91.83	2.13	0.1454
Quadratic	1	304.89	304.89	7.06	0.00813
Other	12	1392.64	116.05	2.69	0.00163
Month x Year	28	1931.68	68.99	1.60	0.0283
Error	477	20590.97	43.17		

brown shrimp/bag seine/model comparison

Corpus Bay: CPUE = exp(156.2 - 3.554*Y + 0.0206*Y^2)
Aransas Bay: CPUE = exp(-15.5 + 0.462*Y - 0.00289*Y^2)
Upper Laguna Madre: CPUE = exp(-167.0 + 3.843*Y - 0.0218*Y^2)

The modelled trend for Aransas Bay was linear and slightly decreasing. The trend lines for Corpus Bay and Upper Laguna Madre Bas exhibited curvature but in opposite directions. The ANODE (Table VI.29) detected significantly different intercepts ($P < 0.0001$), indicating that CPUE values from Upper Laguna Madre Bay were consistently smaller than values recorded for the other two water bodies. The quadratic terms were also significantly different ($P = 0.0043$) among the three water bodies.

Table IX.28. ANODE for white shrimp/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	3696.68	1848.34	15.61	1.94×10^{-7}
YEAR					
Linear	1	14.80	14.80	0.12	0.7238
Quadratic	1	235.57	235.57	1.99	0.1587
Bay-Linear	2	290.16	145.08	1.22	0.29416
Bay-Quadratic	2	1292.96	646.48	5.46	0.00434
Error	1580	187141.90	118.44		

brown shrimp/trawl/Corpus Christi Bay

No brown shrimp of the selected size class were caught in 342 of the 720 trawls, whereas 17 trawls yielded more than 50 brown shrimp. The negative binomial model was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed significant month by year interaction ($P < 0.0001$), indicating that the observed overall difference in mean CPUE among May, June, and July varied from year to year. Highest actual mean CPUE values were recorded in May in seven of the 12 years, in June in two of the 12 years, and in July in three of the 12 years. The largest actual monthly mean CPUE was`recorded in May, 1987 (31.9 brown shrimp/10 minutes) and the smallest in June, 1983 (0.3 brown shrimp/10 minutes). The linear ($P = 0.0273$) and quadratic ($P = 0.0042$) terms in YEAR were both significant. Higher order terms were significant ($P < 0.0001$), indicating substantial fluctuation in actual CPUE during the 12 years of the study. Actual mean CPUE in 1984 and 1987 was large (> 10.0 brown shrimp/10 minutes) relative to the range of other years' mean CPUE values (1.1-5.4 brown shrimp/10 minutes). There was a significant quadratic trend in the CPUE values over the years 1982-1993. Estimated CPUE was maximal in 1986, then decreased during the remaining years in the study. Studentized residuals for the fitted model ranged from -1.81 to 5.94, with 13 residual values larger than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no brown shrimp (47.5%) in combination with the effect of a few trawls which yielded very large numbers of brown shrimp (the 13 largest catches yielded 68-389 brown shrimp.

TAble IX.29. ANODE for brown shrimp/trawlCorpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	800.16	400.08	20.44	2.4×10^{-9}
YEAR					
Linear	1	95.78	95.78	4.89	0.0273
Quadratic	1	161.91	161.91	8.27	0.00415
Other	9	1521.35	169.04	8.64	2.46×10^{-12}
Month x Year	22	1886.15	85.73	4.38	1.94×10^{-10}
Error	684	13387.15	19.57		

brown shrimp/trawl/Aransas Bay

No brown shrimp were caught in 249 of the 720 trawls, whereas 40 trawls yielded more than 50 brown shrimp. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among May, June, and July ($P < 0.0001$). There was a significant month by year interaction ($P < 0.0001$), indicating that the observed overall difference in mean CPUE over the three months varied from year to year. Monthly mean CPUE values ranged from 50.2 brown shrimp/10 minutes in May of 1991 to a low of 0.6 brown shrimp/trawl in July of 1982. Mean CPUE was > 10 brown shrimp/10 minutes in six of the 12 years. By contrast, CPUE was < 1.0 in two years. Linear ($P = 0.00011$) and quadratic ($P < 0.0001$) terms in YEAR were significant. Higher order terms were significant (P < 0.0001), indicating substantial fluctuation in CPUE during the study period. There was a significant quadratic trend in estimated CPUE values over the years 1982-1993, with an estimated maximum in 1989. Studentized residuals for the individual CPUE values ranged from -2.02 to 4.60. Sixteen of the 720 residuals were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no shrimp (33.6% of the 720 trawls), in combination with the effect of a few very large catches (the 16 largest catches yielded 88- 231 brown shrimp of the selected size).

Table IX.30. ANODE for brown shrimp/trawl/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	652.76	326.38	13.31	2.14×10^{-6}
YEAR					
Linear	1	369.38	369.38	15.06	0.000114
Quadratic	1	802.36	802.36	32.71	1.60×10^{-8}
Other	9	2586.08	287.34	11.71	0.0000
Month x Year	22	2553.59	116.08	4.73	1.30×10^{-11}
Error	684	16777.57	24.53		

brown shrimp/trawl/Upper Laguna Madre

No brown shrimp were caught in 206 of the 360 trawls. By contrast, the largest yield for a particular trawl was 54 brown shrimp of the selected size. The negative binomial distribution was selected as the most appropriate model for evaluating the significance of model components. The ANODE revealed significant month by year interaction ($P < 0.0001$), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. The difference in monthly mean CPUE values varied considerably from year to year, ranging from a high of 20.6 brown shrimp/10 minutes in May, 1982 to 0.0 in May, 1989 and July, 1989. The linear term in YEAR was not significant ($P = 0.7031$). The quadratic term in YEAR was highly significant ($P < 0.0001$). Higher order terms were also significant ($P < 0.0001$). Large actual CPUE values in the early and latter years of the study period resulted in a model with a significant quadratic component with an estimated minimum in 1987. Studentized residuals for the individual CPUE values ranged from -2.23 to 2.83. Ten of the 360 residuals were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no brown shrimp (64.4% of the 360 trawls yielded no brown shrimp of the selected size) in combination with the effect of a few very large yields (the 10 largest catches yielded 30-54 brown shrimp of the selected size class).

Table IX.31. ANODE for brown shrimp/trawl/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	182.85	91.43	11.03	0.0000232
YEAR					
Linear	1	1.21	1.21	0.15	0.7031
Quadratic	1	314.13	314.13	37.90	2.20×10^{-9}
Other	9	803.73	89.30	10.77	1.2×10^{-14}
Month x Year	22	538.19	24.46	2.95	0.0000161
Error	324	2685.67	8.29		

brown shrimp/trawl/model comparison

Corpus Bay: CPUE = $\exp(-157.45 + 3.699*Y - 0.0215*Y^2)$
Aransas Bay: CPUE = $\exp(-264.1 + 6.009*Y - 0.0338*Y^2)$
Upper Laguna Madre: CPUE = $\exp(488.3 - 11.167*Y + 0.0639*Y^2)$

The trend for the Upper Laguna Madre exhibited curvature with a minimum in 1987, whereas the trend for Corpus Christi Bay exhibited opposite curvature, with a maximum in 1986. The trend for Aransas Bay exhibited the most curvature and a maximum in 1989. The ANODE revealed significantly different intercepts ($P < 0.0001$), indicating that CPUE was generally greatest in Aransas Bay trawls and least in Upper Laguna Madre trawls. Both the linear ($P = 0.0067$) and quadratic ($P = 0.00011$) terms were significantly different among the three water bodies.

Table IX.32. ANODE for brown shrimp/trawl/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	2347.84	1173.92	27.11	2.5×10^{-12}
YEAR					
Linear	1	103.63	103.63	2.39	0.1220
Quadratic	1	420.60	420.60	9.71	0.00186
Bay-Linear	2	435.01	217.51	5.02	0.00668
Bay-Quadratic	2	787.16	393.58	9.09	0.000118
Error	1791	77550.10	43.30		

black drum/gill net/Corpus Christi Bay

There was a nonlinear relationship between the mean and variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant relationship between catch per set and set duration (*P* = 0.0064). CPUE was defined as CPUE = CATCH/(GTIME/12.5)^3. The linear term in YEAR was highly significant (*P* < 0.0001), as was the quadratic term (*P* < 0.0001). The higher order terms were also significant (*P* = 0.00047). Modelled CPUE exhibited a slightly decreasing trend from 1979 through 1985, followed by increasing values up until 1993. Studentized residuals for the fitted model ranged from -1.35 to 7.08. Seven of the 572 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no black drum (56.6% of the 572 gill net sets) in combination with the effect of the seven largest catches in the study (which yielded 33-513 black drum per gill net set).

Table IX.33. ANODE for black drum/gill net/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	686.28	686.28	50.20	$4.2\text{x}10^{-12}$
Quadratic	1	266.96	266.96	19.53	0.000012
Other	12	489.23	40.77	2.98	0.00047
Error	557	7614.86	13.67		

black drum/gill net/Aransas Bay

There was a nonlinear relationship between the mean and variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed no significant relationship between catch per set and set duration (*P* = 0.3307). CPUE was defined as CPUE = CATCH/(GTIME/12.5). Both the linear (*P* = 0.00032) and quadratic (*P* < 0.0001) terms in YEAR were significant. Higher order terms were also significant (*P* < 0.0001). Modelled CPUE decreased slightly to a minimum value in 1985, then increased quadratically during the remaining years. Studentized residuals for the fitted model ranged from -1.38 to 2.92. Three of the 572 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no black drum (58.0% of the 572 gill net sets) in combination with the effect of the three largest catches in the study. These large catches yielded 28-58 black drum of the selected size class.

Table IX.34. ANODE for black drum/gill net/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	1.16	1.16	0.95	0.3307
YEAR					
Linear	1	16.04	16.04	13.12	0.000320
Quadratic	1	23.56	23.56	19.26	1.37×10^{-6}
Other	12	82.60	6.88	5.63	3.75×10^{-9}
GTIME*YEAR	14	17.60	1.26	1.03	0.4233
Error	542	662.87	1.22		

black drum/gill net/Upper Laguna Madre

There was a nonlinear relationship between the mean and variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration (*P* = 0.0273). Average catch increased with length of set duration. CPUE was defined as CPUE = CATCH/(GTIME/12.5)$^{1.5}$. The linear (*P* < 0.0001) and quadratic (*P* = 0.0002) terms in YEAR were highly significant. The higher order terms were significant (*P* < 0.0001). Studentized residuals for the fitted model ranged from -1.33 to 4.42. Sixteen of the 572 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no black drum (39.0% of the 572 gill net sets) in combination with the effect of the 16 largest yields. These gill net sets yielded 28-77 black drum of the selected size class.

TAble IX.35. ANODE for black drum/gill net/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	396.87	396.87	39.78	$5.8x10^{-10}$
Quadratic	1	139.68	139.68	14.00	0.000202
Other	12	353.18	29.43	2.95	0.000537
Error	557	5557.24	9.98		

black drum/gill net/model comparison

Corpus Bay: CPUE = exp(223.34 - 5.278*Y + 0.0312*Y^2)
Aransas Bay: CPUE = exp(197.58 - 4.623*Y + 0.0270*Y^2)
Upper Laguna Madre: CPUE = exp(124.36 -2.933*Y + 0.0174*Y^2)

CPUE in relation to gill net set duration was different for the three water bodies, therefore the three bay comparison should be interpreted with caution. The models for Corpus Christi and Aransas Bays were similar from 1979 to 1987. From 1988 to 1993, the trend line for Corpus Christi Bay increased much more steeply than the trend line for Aransas Bay. The curve representing CPUE in the Upper Laguna Madre was situated above the curves for the other two water bodies. The ANODE revealed significantly different intercepts among the three models ($P < 0.0001$) indicating a detectable difference among mean yearly CPUE values for the three water bodies. The linear terms were significantly different ($P = 0.0226$) but the quadratic terms were not significantly different ($P = 0.1006$) among the three water bodies .

Table IX.36. ANODE for black drum/gill net/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	685.55 342.78	19.40	$4.7x10^{-9}$	
YEAR					
Linear	1	1459.66	1459.66	82.61	0.000
Quadratic	1	704.16	704.16	39.85 $3.5x10^{-10}$	
Bay-Linear	2	134.41 67.21	3.80	0.0226	
Bay-Quadratic2	81.22	40.61	2.30	0.1006	
Error	1707 30161.47		17.67		

blue crab/gill net/Corpus Christi Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed no significant relationship between catch per set and set duration (P = 0.3688). CPUE was defined as CATCH/(GTIME/14). Both the linear (P = 0.0135) and quadratic (P < 0.0001) terms in year were significant. Higher order terms were also significant (P < 0.0001). Modelled CPUE exhibited a significant quadratic trend with an estimated maximum in 1988. Studentized residuals for the individual CPUE values ranged from -1.48 to 3.71. Eleven of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no blue crab (468 of the 617 gill net sets). The 11 largest catches yielded 5-9 blue crab of the selected size class.

Table IX.37. ANODE for blue crab/gill net/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	1.23	1.23	0.81	0.3688
YEAR					
Linear	1	9.31	9.31	6.14	0.0135
Quadratic	1	29.45	29.45	19.42	0.0000125
Other	12	162.20	13.52	8.92	7.77×10^{-16}
GTIME*YEAR	14	28.86	2.06	1.36	0.1679
Error	587	889.97	1.52		

blue crab/gill net/Aransas Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed no significant relationship between catch per set and set duration (P = 0.9819). CPUE is defined as CATCH/(GTIME/14). The linear term in YEAR was not significant (P = 0.0902) but the quadratic term was significant (P < 0.0001). Higher order terms were also significant (P < 0.0001). The fitted model was influenced by relatively large actual CPUE values recorded in 1983 and 1984. Modelled CPUE exhibited a significant quadratic trend with an estimated maximum in 1986. Studentized residuals for the individual CPUE values ranged from -0.74 to 4.52. A total of 33 of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no blue crab (491 of the 617 gill net sets).

Table IX.38. ANODE for blue crab/gill net/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	0.01	0.01	0.01	0.9819
YEAR					
Linear	1	4.21	4.21	2.88	0.0902
Quadratic	1	52.27	52.27	35.78	3.84×10^{-9}
Other	12	173.91	14.49	9.92	0.00
GTIME*YEAR	14	22.42	1.60	1.10	0.3577
Error	587	857.51	1.46		

blue crab/gill net/Upper Laguna Madre

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration (*P* = 0.0396). CPUE was defined as CATCH/(GTIME/14)$^{-1.5}$. The linear term in YEAR was not significant (*P* = 0.4157) but the quadratic term was significant, (*P* < 0.0001). Higher order terms were also significant (*P* < 0.0001), indicating substantial fluctuation in CPUE during 1979-1993. Modelled CPUE exhibited a significant quadratic trend with an estimated maximum in 1987. Studentized residuals for the individual CPUE values ranged from -2.44 to 4.09. Thirteen of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no blue crab (470 of the 617 gill net sets).

Table IX.39. ANODE for blue crab/gill net/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	1.23	1.23	0.66	0.4157
Quadratic	1	83.29	83.29	44.9	4.89x10^{-11}
Other	12	572.31	47.69	25.68	
Error	602	1118.01	1.86		

blue crab/gill net/model comparison

Corpus Bay: CPUE = exp(-201.31 + 4.575*Y - 0.0261*Y^2)
Aransas Bay: CPUE = exp(-264.31 + 6.148*Y - 0.0358*Y^2)
Upper Laguna Madre: CPUE = exp(-260.04 + 5.990*Y - 0.0345*Y^2)

Modelled CPUE in all three water bodies exhibited quadratic trends. The trend for Upper Laguna Madre Bay was more peaked than the trends for Corpus Christi and Aransas Bays. The ANODE revealed significantly different intercepts ($P < 0.0011$), indicating that overall CPUE in Upper Laguna Madre was greater than in Corpus Christi and Aransas Bays. The linear terms in YEAR were significantly different ($P = 0.0385$) but the quadratic terms were not significantly different ($P = 0.6327$).

Table IX.40. ANODE for blue crab/gill net/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	39.82	19.91	6.87	0.00106
YEAR					
Linear	1	1.17	1.17	0.40	0.5251
Quadratic	1	149.36 149.36	51.55	1.01×10^{-12}	
Bay-Linear	2	18.91	9.46	3.26	0.0385
Bay-Quadratic2	2.65	1.33	0.46	0.6327	
Error	1842	5336.40	2.90		

blue crab/bag seine/Corpus Christi Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in the mean CPUE values among March, April, and May (*P* = 0.0107). There was no significant month by year interaction (*P* = 0.1845), indicating that the difference in mean CPUE among the three months was fairly consistent from year to year. The highest mean CPUE value was recorded in April in 11 of the 16 years. The largest monthly mean CPUE, 13.1 blue crab/0.03 hectare, was recorded in March, 1985. Both the linear (*P* = 0.2459) and quadratic (P = 0.0789) terms in YEAR were not significant. Higher order terms were significant (*P* = 0.0007), indicating substantial fluctuation in CPUE during the study period. There was no detectable trend in the CPUE values during 1978-1993. Studentized residuals for the individual CPUE values ranged from -1.46 to 5.10. Eleven of the 538 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of bag seines which yielded no blue crab (278 of the 538 bag seines), in combination with the effect of a few large yields (the 11 largest catches yielded 29-122 blue crab of the selected size class).

Table IX.41. ANODE for blue crab/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	112.91	56.46	4.58	0.0107
YEAR					
Linear	1	16.64	16.64	1.35	0.2459
Quadratic	1	38.22	38.22	3.10	0.0789
Other	13	451.93	34.76	2.82	0.000650
Month x Year	30	457.11	15.24	1.24	0.1845
Error	490	6041.08	12.33		

blue crab/bag seine/Aransas Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among March, April, and May (P = 0.0024). There was no significant month by year interaction (P = 0.2941). The maximum mean monthly CPUE was recorded in April, 1982 (24.1 blue crab/0.03 hectare). The greatest yearly mean CPUE was recorded during 1982 (14 blue crab/0.03 hectare). Neither the linear (P = 0.0623) nor quadratic (P = 0.9086) terms in YEAR were significant. Higher order terms were significant (P < 0.0001). This reflects the variations in mean yearly CPUE values over the16 years of the study. There was detectable trend in CPUE during 1978-1993. Studentized residuals for the individual CPUE values ranged from -2.12 to 6.93. Ten of the 548 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number of bag seines which yielded no blue crab (314 of the 548 bag seines) in combination with the effect of a few large catches (the 10 largest catches yielded 31-206 individuals).

Table IX.42. ANODE for blue crab/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	130.49	65.25	6.09	0.00244
YEAR					
Linear	1	37.44	37.44	3.49	0.0623
Quadratic	1	0.14	0.14	0.01	0.9086
Other	13	1394.84	107.30	10.01	0.0000
Month x Year	30	363.05	12.10	1.13	0.2941
Error	500	5360.71	10.72		

blue crab/bag Seine/Upper Laguna Madre

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed no significant difference in mean CPUE values among March, April, and May (P = 0.2409). Month by year interaction was significant (P = 0.0003). The largest mean monthly CPUE was recorded during April in seven of the 16 years. The maximum monthly mean CPUE was recorded in April, 1980 (3.5 blue crab/0.03 hectare). Neither the linear (P = 0.8262) nor quadratic (P = 0.2301) terms in YEAR were significant. Higher order terms were significant (P = 0.0012), indicating substantial fluctuation in CPUE during 1978-1993. There was no detectable trend in CPUE during 1978-1993. Studentized residuals for the individual CPUE values ranged from -1.30 to 2.31. Four of the 538 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of bag seines which yierlded no blue crab (389 of the 538 bag seines) in combination with the effect of a few large catches (the four largest catches yielded 14, 16, 20, and 21 blue crab, respectively).

Table IX.43. ANODE for blue crab/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	5.62	2.81	1.43	0.24091
YEAR					
Linear	1	0.10	0.10	0.05	0.8262
Quadratic	1	2.84	2.84	1.44	0.2301
Other	13	68.87	5.30	2.69	0.00115
Month x Year	30	130.13	4.34	2.20	0.000319
Error	490	965.12	1.97		

blue crab/bag seine/model comparison

Corpus Bay: CPUE = exp(60.94 - 1.408*Y + 0.00826*Y^2)
Aransas Bay: CPUE = exp(52.55 - 1.155*Y + 0.00645*Y^2)
Upper Laguna Madre Bay: CPUE = exp(36.27 - 0.853*Y + 0.00498*Y^2)

Modelled CPUE for the three bodies of water are essentially horizontal lines. The trend lines for Aransas and Corpus Christi Bays are essentially the same, and both are elevated above the trend line for the Upper Laguna Madre. The ANODE revealed significantly different intercepts ($P < 0.0001$), confirming. the apparent difference in overall CPUE among the three water bodies during 1978-1993. Neither the linear ($P = 0.3703$) nor quadratic ($P = 0.6776$) terms were significantly different among trhe three water bodies.

Table IX.44. ANODE for blue crab/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	780.29	390.15	15.97	1.36×10^{-7}
YEAR					
Linear	1	0.60	0.60	0.02	0.8755
Quadratic	1	26.64	26.64	1.09	0.2966
Bay-Linear	2	48.57	24.29	0.99	0.3703
Bay-Quadratic	2	19.02	9.51	0.39	0.6776
Error	1615	39462.48	24.44		

blue crab/trawl/Corpus Christi Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in CPUE among March, April, and May (P = 0.0006) and significant month by year interaction (P < 0.0001), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. The highest mean CPUE value was recorded in May in 5 of the 11 years. The greatest mean monthly CPUE was recorded in April, 1986 (4.2 blue carb/10 minutes). Neither the linear (P = 0.1334) nor quadratic (P = 0..5775) terms YEAR were significant. Higher order terms were significant (P < 0.0001) indicating substantial fluctuation in CPUE during 1983-1993. There was no significant trend in CPUE values during 1983-1993. Studentized residuals for the fitted model range from -1.64 to 4.20. Fifteen of the 660 residualvalues were greater than 2.0 in absolute value. As reflected by the large positive residuals, deviation from the model was attributed to the large number of trawls which yielded no blue crab (444 of the 660 trawls) in combination with the effect of a few large yields. The 15 largest catches yielded 8-29 blue crab of the selected size class.

Table IX.45. ANODE for blue crab/trawlCorpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	P
Month	2	46.24	23.12	7.54	0.000581
YEAR					
Linear	1	6.93	6.93	2.26	0.1334
Quadratic	1	0.95	0.95	0.31	0.5775
Other	8	304.92	38.12	12.43	1.1×10^{-16}
Month x Year	20	171.21	8.56	2.79	0.0000532
Error	627	1922.78	3.07		

blue crab/trawl/Aransas Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in the mean CPUE values among March, April, and May ($P < 0.0001$). There was significant month by year interaction ($P = 0.0004$), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. The highest mean CPUE value was recorded in April in 7 of the 12 years. The greatest monthly mean CPUE value was recorded in April, 1992 (11.9 blue crab/10 minutes). Neither the linear ($P = 0.6473$) nor quadratic ($P = 0.0680$) terms in YEAR were significant. Higher order terms were significant ($P < 0.0001$), indicating substantial fluctuation in CPUE during 1982-1993. There was no significant trend in CPUE during 1982-1993. Studentized residuals for the individual CPUE values ranged from -1.64 to 4.27. Fourteen of the 720 residual values were greater than 2.0 in absolute value. As reflected by the large positive residuals, deviation from the model was attributed to the large number of trawls which yielded no blue crab (223 of 720 trawls) in combination with the effect of a few large yields. The 14 largest catches yielded 33-80 blue crab of the selected size class.

Table IX.46. ANODE for blue crab/trawl/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	203.12	101.56	11.45	0.0000129
YEAR					
Linear	1	1.86	1.86	0.21	0.6473
Quadratic	1	29.64	29.64	3.34	0.0680
Other	9	506.46	56.27	6.34	1.17×10^{-8}
Month x Year	22	462.27	21.01	2.37	0.000436
Error	684	6068.15	8.87		

blue crab/trawl/Upper Laguna Madre

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. TheA NODE revealed a significant difference in the mean CPUE values among March, April, and May (*P* < 0.0001). There was significant month by year interaction (*P* = 0.0003), indicates that the observed overall difference in mean CPUE among the three months varied from year to year. Actual CPUE was greatest in April in five of the 11 years in the study. Monthly mean CPUE values ranged from 7.5 blue crab/10 minutes in April, 1992, to 0.0 in seven of the 33 months surveyed. The linear term in YEAR was not significant (*P* = 0.2967), but the quadratic term in YEAR was significant (*P* = 0.0208). Higher order terms were significant (*P* < 0.0001). There was a significant quadratic trend in CPUE during 1983-1993, with an estimated minimum CPUE in 1988. Studentized residuals for the individual CPUE values ranged from -2.08 to 4.57. Seven of the 330 residual values were greater than 2.0 in absolute value. As reflected by the large positive residuals, deviation from the model was attributed to the large number of trawls which yielded no blue crab (249 of 330 trawls) in combination with the effect of a few large yields. The seven largest catches yielded 10-27 blue crab of the selected size class.

Table IX.47. ANODE for blue crab/trawl/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	87.12	43.56	12.69	$5.15x10^{-6}$
YEAR					
Linear	1	3.75	3.75	1.09	0.2967
Quadratic	1	18.52	18.52	5.40	0.0208
Other	8	236.78	29.60	8.62	$1.42x10^{-10}$
Month x Year	20	178.84	8.94	2.61	0.000266
Error	297	1019.23	3.43		

blue crab/trawl/3 Bay Comparison

Corpus Bay: $CPUE = \exp(-38.87+0.846*Y - 0.00461*Y^2)$
Aransas Bay: $CPUE = \exp(73.35-1.655*Y + 0.00949*Y^2)$
Upper Laguna Madre: $CPUE = \exp(288.77-6.579*Y + 0.0374*Y^2)$

Modelled CPUE for Aransas and Corpus Christi Bays were essentially flat lines, with Aransas Bay exhibiting higher overall CPUE levels than Corpus Christi Bay. The trend for Upper Laguna Madre was quadratic with a minimum in 1988. The ANODE revealed significantly different intercepts ($P < 0.0001$), indicating that overall CPUE values for Aransas Bay were significantly larger than values for Corpus Christi Bay and the Upper Laguna Madre. Neither the linear (P = 0.9227) nor quadratic (P = 0.4262) terms were significantly different among the water bodies.

Table IX.48. ANODE for blue crab/trawl/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	1642.10	821.05	85.81	0
YEAR					
Linear	1	17.89	17.89	1.87	0.1717
Quadratic	1	19.82	19.82	2.07	0.1503
Bay-Linear	2	1.54	0.77	0.08	0.9227
Bay-Quadratic2		16.33	8.17	0.85	0.4262
Error	1641	15702.27	9.57		

Atlantic croaker/gill net/Corpus Christi Bay

There was a nonlinear relationship between mean CPUE and the variance around CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration ($P < 0.0010$). CPUE was defined as CATCH/(GTIME/14)$^{-3.5}$. Neither the linear ($P = 0.8908$) nor the quadratic ($P = 0.6007$) term in year were significant. Higher order terms were not significant ($P = 0.7738$). The fitted model exhibited no trend during 1979-1993. Studentized residuals for the individual CPUE values ranged from -1.66 to 2.43. Six of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no Atlantic croaker (310 of the 617 gill net sets) in combination with the effect of the six largest catches (38-60 individuals) in the study .

Table IX.49. ANODE for Atlantic croaker/gill net/Corpus Christi Bay (CPUE = CATCH/(GTIME/14)$^{-3.5}$)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	0.30	0.30	0.02	0.8908
Quadratic	1	4.30	4.30	0.27	0.6007
Other	12	127.50	10.63	0.68	0.7738
Error	602	9438.96	15.68		

Atlantic croaker/gill net/Aransas Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration ($P < 0.0030$). CPUE was defined as CATCH/(GTIME/14)$^{-3.5}$. Neither the linear ($P = 0.8015$) nor the quadratic ($P = 0.2556$) terms in YEAR were significant. Higher order terms were not significant ($P = 0.4701$). The fitted model exhibited no trend during 1979-1993. Studentized residuals for the individual CPUE values ranged from -1.14 to 2.54. Four of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no Atlantic croaker (376 of the 617 gill net sets) in combination with the effect of the four largest catches (25-50 individuals) in the study .

Table IX.50. ANODE for Atlantic croaker/gill net/Aransas Bay (CPUE = CATCH/(GTIME/14)$^{-3.5}$)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	0.67	0.67	0.06	0.8015
Quadratic	1	13.73	13.73	1.29	0.2556
Other	12	124.24	10.35	0.98	0.4701
Error	602	6383.24	10.60		

Atlantic croaker/gill net/Upper Laguna Madre

There was a nonlinear relationship between mean CPUE and the variance around CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed no significant relationship between catch per set and set duration (*P*=0.7730). CPUE was defined as CATCH/(GTIME/14). Both the linear (*P* < 0.0001) and quadratic (*P* = 0.0148) term in year were highly significant. Higher order terms were also significant (*P* = 0.0004), indicating substantial fluctuation in actual CPUE during the study period. Modelled CPUE exhibited a quadratic decline with a maximum in 1981. Studentized residuals for the individual CPUE values ranged from -1.39 to 5.02. Ten of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no Atlantic croaker (515 of the 617 gill net sets) in combination with the effect of the ten largest catches (5-24 individuals) in the study .

Table IX.51. ANODE for Atlantic croaker/gill net/Upper Laguna Madre (CPUE = CATCH/(GTIME/14).

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	0.27	0.27	0.08	0.7730
YEAR					
Linear	1	95.79	95.79	29.78	$7.15x10^{-8}$
Quadratic	1	19.23	19.23	5.98	0.0148
Other	12	115.57	9.63	2.99	0.000441
GTIME*YEAR	14	64.03	4.57	1.42	0.1375
Error	587	1888.47	3.22		

Atlantic croaker/gill net/model comparison

Corpus Bay: CPUE = exp(21.97-0.481*Y + 0.00280*Y^2)
Aransas Bay: CPUE = exp(-56.065+1.307*Y-0.00751*Y^2)
Upper Laguna Madre: CPUE = exp(-128.60 + 3.160*Y - 0.0194*Y^2)

Whereas modelled CPUE declined significantly in the Upper Laguna Madre after 1981, there was no significant trend observed in Corpus Christi and Aransas Bays. The ANODE revealed significantly different intercepts ($P < 0.0001$), indicating that CPUE in Corpus Christi Bay was generally greater than iin Aransas Bay. Among the three water bodies, the linear terms were significantly different ($P = 0.0101$), but the quadratic terms were not significantly different ($P = 0.3172$).

Table IX.52. ANODE for Atlantic croaker/gill net/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	1794.05	897.03 83.32	0	
YEAR					
Linear	1	4.81	4.81	0.45	0.5040
Quadratic	1	0.71	0.71	0.06	0.7994
Bay-Linear	2	99.27	49.64	4.61	0.0101
Bay-Quadratic2	24.74	12.37	1.15	0.3172	
Error	1842 19830.56		10.77		

Atlantic croaker/bag seine/Corpus Christi Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial model was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values between March and April (P = 0.0097). There was significant month by year interaction (P = 0.0002), indicating that the difference in mean CPUE between the two months varied from year to year. The largest monthly mean CPUE value was recorded in April in seven of the 16 years. The largest monthly mean CPUE value, 9.8 Atlantic croaker/0.03 hectare, was recorded in April, 1984. No atlantic croaker of the selected size were caught in 14 of the 32 months in the study. Neither the linear (P = 0.1837) nor the quadratic terms (P = 0.0530) in YEAR were significant. Higher order terms were significant (P < 0.0001), indicating substantial fluctuation in CPUE during the study period. Studentized residuals for the individual CPUE values ranged from -1.48 to 3.56. Ten of the 358 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no Atlantic croaker (87%, or 314 of the 358 bag seines).

Table IX.53. ANODE for Atlantic croaker/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	1	37.50	37.50	6.78	0.00965
YEAR					
Linear	1	9.82	9.82	1.78	0.1837
Quadratic	1	20.86	20.86	3.77	0.0530
Other	13	406.96	31.30	5.66	2.37×10^{-9}
Month x Year	15	248.59	16.57	3.00	0.000162
Error	326	1803.69	5.535		

Atlantic croaker/bag seine/Aransas Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE . The negative binomial model was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values between March and April ($P < 0.0001$). There was no significant month by year interaction ($P = 0.1064$), indicating that the mean monthly CPUE was consistently larger in one month during the study period. Highest mean CPUE was recorded in April in nine of the 16 years and the largest monthly mean CPUE value, 17.1 Atlantic Croaker/0.03 hectare, was recorded in April, 1982. No Atlantic croaker were caught in 14 of the 32 months surveyed. Neither the linear ($P = 0.4269$) nor quadratic ($P = 0.6852$) terms in YEAR were significant. Higher order terms were highly significant ($P < 0.0001$), indicating substantial variation in CPUE during the study period. No significant trend in modelled CPUE was detected. Studentized residuals for the individual CPUE values ranged from -1.62 to 4.88. Six of the 358 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no Atlantic croaker (77.9% or 279 of 358 bag seines) in combination with the effect of the six largest catches (29-132 Atlantic croaker/0.03 hectare) in the study.

Table IX.54. ANODE for Atlantic croaker/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	1	258.49 258.49	19.92	0.0000111	YEAR
Linear	1	8.21	8.21	0.63	0.4269
Quadratic	1	2.13	2.13	0.16	0.6852
Other	13	867.23 66.71	5.14	$2.51x10^{-8}$	
Month x Year	15	290.16 19.34	1.49	0.1064	
Error	326	4230.70	12.98		

Atlantic croaker/bag seine/Upper Laguna Madre

Since there were only eight nonzero values (ranging from 1-11 individuals caught), the Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE between March and April (*P* = 0.0032). The month by year interaction was significant (*P* = 0.0336). No Atlantic croaker were caught in 25 of the 32 months (and none in nine of the 16 years) surveyed. The maximum monthly mean CPUE was 0.55 Atlantic croaker/0.03 hectare, recorded in March, 1992. Neither the linear (*P* = 0.2843) nor the quadratic (*P* = 0.3901) terms were significant. Higher order terms were significant (*P* < 0.0001).

Table IX.55. ANODE for Atlantic croaker/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	1	7.46	7.46	8.82	0.00321
YEAR					
Linear	1	0.97	0.97	1.15	0.2843
Quadratic	1	0.63	0.63	0.74	0.3901
Other	13	47.85	3.68	4.35	8.99×10^{-7}
Month x Year	15	22.83	1.52	1.80	0.0336
Error	326	275.75 0.85			

Atlantic croaker/bag seine/model comparison

Corpus Bay: CPUE = exp(94.13-2.152*Y+0.0123*Y^2)
Aransas Bay: CPUE = exp(-33.42+0.768*Y-0.00430*Y^2)
Upper Laguna Madre: CPUE = exp(65.34-1.630*Y+0.00970*Y^2)

The nonsignificant best-fit line for Aransas Bay was elevated above that of Corpus Christi Bay, and actual and modelled CPUE for both of these bays was significantly greater than that of the Upper Laguna Madre. The ANODE confirmed that model intercepts were significantly different (*P* < 0.0001), indicating clear differences in overall CPUE levels among the three bays (*P* < 0.0001).

Table IX.56. ANODE for Atlantic croaker/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	658.66	329.33	18.92	8.43×10^{-9}
YEAR					
Linear	1	0.08	0.08	0.005	0.9456
Quadratic	1	5.09	5.09	0.29	0.5888
Bay-Linear	2	12.26	6.13	0.35	0.7033
Bay-Quadratic	2	17.46	8.73	0.50	0.6058
Error	1065	18537.60	17.41		

pink shrimp/bag seine/Corpus Christi Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed no significant difference in mean CPUE among September, October, and November (*P* = 0.9501). There was significant month by year interaction (*P* = 0.0351), indicating that the difference in mean CPUE among the three months varied from year to year. Highest mean CPUE was recorded in November in six of the 16 years surveyed, but the largest monthly mean CPUE value, 7.8 pink shrimp/0.03 hectare, was recorded in October, 1979. No pink shrimp of the selected size were caught in four of the 48 months surveyed: 392 of 557 bag seines yielded no pnk shrimp. Neither the linear (*P* = 0.6477) nor quadratic (*P* = 0.1889) terms in YEAR were significant. Higher order terms were significant (*P* = 0.0069), indicating substantial fluctuation in CPUE. No significant trend was detected in modelled CPUE during 1978-1993. Studentized residuals for the individual CPUE values ranged from -1.15 to 5.00. Thirteen of the 557 values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no pink shrimp (70.4% of the 557 bag seines) in combination with the effect of the 13 largest catches (27-84 pink shrimp/0.03 hectare) in the study.

Table IX.57. ANODE for pink shrimp/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	1.22	0.61	0.05	0.9501
YEAR					
Linear	1	2.49	2.49	0.21	0.6477
Quadratic	1	20.62	20.62	1.73	0.1889
Other	13	349.79	26.91	2.26	0.00687
Month x Year	30	550.60	18.35	1.54	0.0351
Error	509	6064.01	11.91		

pink shrimp/bag seine/Aransas Bay

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. No pink shrimp were caught in 431 of 586 bag seines. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed no significant difference in mean CPUE among September, October, and November (P = 0.3584). There was a significant month by year interaction (P = 0.0098), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. Highest mean CPUE was recorded in September in seven years and in October in four years. No pink shrimp were caught in 10 of the 48 months surveyed. The largest monthly mean CPUE value, 14.6 pink shrimp/0.03 hectare, was recorded in October, 1988. The linear term in YEAR was significant (P = 0.0034), but the quadratic term was not significant (P = 0.7431). Higher order terms were significant (P < 0.0001), indicating substantial fluctuation in CPUE during the study period. With the exception of a peak in actual CPUE in 1981, CPUE in 1988 and later was generally greater. Modelled CPUE exhibited a significant linear increasing trend. Studentized residuals for the individual CPUE values ranged from -1.28 to 5.52. Twelve of the 586 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no pink shrimp (73.5% of the 586 bag seines) in combination with the effect of the 12 largest catches (30-152 pink shrimp/0.03 hectare) in the study.

Table IX.58. ANODE for pink shrimp/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	36.67	18.34	1.03	0.3584
YEAR					
Linear	1	153.96	153.96	8.63	0.00344
Quadratic	1	1.92	1.92	0.11	0.7431
Other	13	1125.64	86.59	4.85	4.79×10^{-8}
Month x Year	30	928.86	30.96	1.74	0.00977
Error	538	9595.51	17.84		

pink shrimp/bag seine/Upper Laguna Madre

There was a nonlinear relation between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE among September, October, and November ($P < 0.0001$). There was significant month by year interaction ($P = 0.0019$), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. No pink shrimp were caught in 26 of the 48 months surveyed. The largest monthly mean CPUE, 3.0 pink shrimp/0.03 hectare, was recorded in October, 1991. The linear term in YEAR was significant ($P < 0.0001$) but the quadratic term was not significant ($P = 0.1055$). Higher order terms were significant ($P < 0.0001$). Modelled CPUE exhibited a significant increasing trend during the years 1978-1993. Studentized residuals for the individual CPUE values ranged from -1.28 to 3.66. Twelve of the 548 values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no pink shrimp (92.3% or 506 of the 548 bag seines) in combination with the effect of the 12 largest catches (8-28 pink shrimp/0.03 hectare) in the study.

Table IX. 59. ANODE for pink shrimp/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	68.57	34.29	10.48	0.0000349
YEAR					
Linear	1	63.08	63.08	19.28	0.0000138
Quadratic	1	8.61	8.61	2.63	0.1055
Other	13	178.68	13.74	4.20	1.15×10^{-6}
Month x Year	30	193.08	6.46	1.97	0.00192
Error	500	1636.00	3.27		

pink shrimp/bag seine/model comparison

Corpus Bay: CPUE = exp(-60.50 + .147*Y - 0.00817*Y^2)
Aransas Bay: CPUE = exp(21.58 - 0.555*Y + 0.00363*Y^2)
Upper Laguna Madre: CPUE = exp(-118.98 + 2.571*Y - 0.0139*Y^2)

CPUE increased linearly in the Aransas Bay and Upper Laguna Madre models, whereas no significant trend was detectable in the Corpus Christi Bay data. The ANODE revealed significantly different intercepts among the models for the three water bodies ($P < 0.0001$), confirming that CPUE values for Corpus Christi and Aransas Bays were significantly larger than those recorded in the Upper Laguna Madre.

Table IX.60. ANODE for pink shrimp/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	138.39	69.20	22.37	2.6×10^{-10}
YEAR					
Linear	1	23.01	23.01	7.44	0.00644
Quadratic	1	0.55	0.55	0.18	0.6743
Bay-Linear	2	15.65	7.83	2.53	0.0800
Bay-Quadratic	2	4.21	2.11	0.68	0.5061
Error	1682	5202.85	3.09		

pink shrimp/trawl/Corpus Christi Bay

There was a linear relationship between mean CPUE and the variance around CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in CPUE among March, April, and May (*P* < 0.0001). There was significant month by year interaction (*P* < 0.0001), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. The highest mean CPUE was recorded in April in six of the 11 years surveyed. The largest monthly mean, 6.2 pink shrimp/10 minutes was recorded in April, 1986. Linear (*P* = 0.0369) and quadratic (*P* < 0.0001) terms in YEAR were significant. Higher order terms were highly significant (*P* < 0.0001), indicating substantial fluctuation in CPUE during the study period. Despite such fluctuation, modelled CPUE exhibited a significant quadratic trend during 1983-1993, with an estimated maximum in 1989. Studentized residuals for the fitted model range from -1.87 to 4.75. Eleven of the 660 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no pink shrimp (421 of the 660 trawls) in combination with the effect of the 11 largest catches (13-28 pink shrimp/10 minutes) in the study.

Table IX.61. ANODE for pink shrimp/trawl/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	162.26	81.13	22.81	2.7×10^{-10}
YEAR					
Linear	1	15.56	15.56	4.38	0.0369
Quadratic	1	132.05 132.05	37.12	1.94×10^{-9}	
Other	8	212.57 26.57		7.47	1.54×10^{-9}
Month x Year	20	362.55 18.13		5.10	6.94x10-12
Error	627	2230.22	3.56		

pink shrimp/trawl/Aransas Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in CPUE among March, April, and May ($P < 0.0001$). There was significant month by year interaction ($P < 0.0001$), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. The highest mean CPUE was recorded in April in nine of the 12 years surveyed. The largest monthly mean, 9.7 pink shrimp/10 minutes was recorded in April, 1986. The linear term in YEAR was not significant ($P = 0.5364$) but the quadratic term was significant ($P < 0.0001$). Higher order terms were highly significant ($P < 0.0001$), indicating substantial fluctuation in CPUE during the study period. Despite such fluctuation, modelled CPUE exhibited a significant quadratic trend during 1982-1993, with an estimated maximum in 1987. Studentized residuals for the fitted model range from -2.01 to 5.25. Fifteen of the 720 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no pink shrimp (499 of the 720 trawls) in combination with the effect of the 15 largest catches (22-41 pink shrimp/10 minutes) in the study.

Table IX.62. ANODE for pink shrimp/trawl/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	504.62	252.31	52.76	0.00
YEAR					
Linear	1	1.83	1.83	0.38	0.5364
Quadratic	1	155.48	155.48	32.51	1.76×10^{-8}
Other	9	905.58	100.62	21.04	0.00
Month x Year	22	498.60	22.66	4.74	1.2×10^{-11}
Error	684	3271.17	4.78		

pink shrimp/trawl/Upper Laguna Madre

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in CPUE among March, April, and May (*P* < 0.0001). There was significant month by year interaction (*P* < 0.0001), indicating that the observed overall difference in mean CPUE among the three months varied from year to year. The highest mean CPUE was recorded in April in six of the 11 years surveyed. The largest monthly mean, 7.9 pink shrimp/10 minutes was recorded in April, 1992. No pink shrimp were caught in 11 of the 33 months surveyed. The linear term in YEAR was significant (*P* < 0.0001) but the quadratic term was not significant (*P* = 0.4903). Higher order terms were highly significant (*P* < 0.0001), indicating substantial fluctuation in CPUE during the study period. Despite such fluctuation, modelled CPUE exhibited a significant linear increasing trend during 1983-1993. Studentized residuals for the fitted model range from -2.88 to 5.58. Six of the 330 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no pink shrimp (260 of the 330 trawls) in combination with the effect of the six largest catches (8-38 pink shrimp/10 minutes) in the study.

Table IX.63. ANODE for pink shrimp/trawl/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	126.62	63.31	33.25	9.3x10-14
YEAR					
Linear	1	116.79	116.79	61.34	8.6×10^{-14}
Quadratic	1	0.91	0.91	0.48	0.4903
Other	8	262.30	32.79	17.22	0.00
Month x Year	20	50.48	2.52	1.33	0.1608
Error	297	565.49	1.90		

pink shrimp/trawl/model comparison

Corpus Bay: CPUE = $\exp(-338.27 + 7.652*Y - 0.0432*Y^2)$
Aransas Bay: CPUE = $\exp(-378.63 + 8.716*Y - 0.0500*Y^2)$
Upper Laguna Madre: CPUE = $\exp(42.40 - 1.212*Y + 0.00821*Y^2)$

Corpus Christi and Aransas Bay models exhibited quadratic curvature with maxima shifted two years apart . By contrast, modelled CPUE for the Upper Laguna Madre exhibited a significant linear increasing trend. The ANODE revealed significantly different intercepts ($P < 0.0001$), confirming that overall CPUE values for Corpus Christi and Aransas Bays were generally larger than for the Upper Laguna Madre.

Table IX.64. ANODE for Pink shrimp/Trawl/3 Bay Comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	220.49	110.25	12.35	4.75×10^{-6}
YEAR					
Linear	1	26.21	26.21	2.93	0.0869
Quadratic	1	202.78	202.78	22.71	2.05×10^{-6}
Bay-Linear	2	146.16	73.08	8.18	0.000291
Bay-Quadratic	2	33.34	16.67	1.87	0.1550
Error	1641	14654.26	8.93		

Southern flounder/gill net/Corpus Christi Bay

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration (*P* = 0.0413). CPUE was defined as CATCH/(GTIME/14)$^{1.5}$. Neither the linear (*P* = 0.2128) nor the quadratic (*P* = 0.1907) terms in YEAR were significant. Higher order terms were not significant (*P* = 0.5011). The fitted model is a flat line for 1979-1993. There was no trend in modelled CPUE. Studentized residuals for the individual CPUE values ranged from -1.54 to 4.51. Seven of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no southern flounder (436 of the 617 gill net sets).

Table IX.65. ANODE for Southern flounder/gill net/Corpus Christi Bay (CPUE = CATCH/(GTIME/14)$^{1.5}$)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	2.84	2.84	1.56	0.2128
Quadratic	1	3.13	3.13	1.72	0.1907
Other	12	20.69	1.72	0.94	0.5011
Error	602	1098.48	1.82		

Southern flounder/gill Net/Aransas Bay

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration (P = 0.0042). CPUE was defined as CATCH/(GTIME/14)^3. Neither the linear (P = 0.4667) nor the quadratic (P = 0.7211) terms in YEAR were significant. Higher order terms were not significant (P = 0.2130). The fitted model is a flat line for 1979-1993. There was no trend in modelled CPUE. Studentized residuals for the individual CPUE values ranged from -1.16 to 3.65. Nine of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no southern flounder (497 of the 617 gill net sets).

Table IX.66. ANODE for Southern flounder/gill net/Aransas Bay(CPUE = CATCH/(GTIME/14)^3)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	0.80	0.80	0.53	0.4667
Quadratic	1	0.19	0.19	0.13	0.7211
Other	12	23.45	1.95	1.30	0.2130
Error	602	903.79 1.50			

Southern flounder/gill net/Upper Laguna Madre

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed no significant relationship between catch per set and set duration (*P* = 0.1298). CPUE was defined as CATCH/(GTIME/14). The linear (*P* <0.0001) and the quadratic (*P* = 0.0027) terms in YEAR were significant. Higher order terms were significant (*P* < 0.0001). Modelled CPUE exhibited a significant quadratic trend during 1979-1993, with an estimated maximum in 1983. Studentized residuals for the individual CPUE values ranged from -1.62 to 3.21. Thirteen of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no southern flounder (472 of the 617 gill net sets).

Table IX.67. ANODE for Southern flounder/gill net/Upper Laguna Madre (CPUE = CATCH/(GTIME/14))

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
GTIME	1	2.94	2.94	2.30	0.1298
YEAR					
Linear	1	22.34	22.34	17.51	0.0000330
Quadratic	1	11.61	11.61	9.09	0.00268
Other	12	83.75	6.98	5.47	7.09×10^{-9}
GTIME*YEAR	14	21.10	1.51	1.18	0.2857
Error	587	749.18	1.28		

Southern flounder/gill net/model comparison

Corpus Bay: CPUE = exp(53.62 - 1.240*Y + 0.00703*Y^2)

Aransas Bay: CPUE = exp(-17.00 + 0.381*Y - 0.00231*Y^2)

Upper Laguna Madre: CPUE = exp(-109.37 + 2.616*Y - 0.0158*Y^2)

Modelled CPUE for Corpus Christi and Aransas Bays displayed no significant trends. Modelled CPUE for the Upper Laguna Madre exhibited curvature with a maximum in 1983. The ANODE revealed significantly different intercepts for the three models (*P* < 0.0001), confirming that overall CPUE was greater in Corpus Christi Bay than in Aransas Bay.

Table IX.68. ANODE for Southern flounder/gill net/model comparison (CPUE = CATCH/(GTIME/14))

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	22.05	11.03	6.65	0.00132
YEAR					
Linear	1	19.49	19.49	11.76	0.000619
Quadratic	1	0.42	0.42	0.25	0.6165
Bay-Linear	2	9.09	4.55	2.74	0.0645
Bay-Quadratic	2	12.95	6.48	3.91	0.0203
Error	1842	3052.38	1.66		

Southern flounder/bag seine/Corpus Christi Bay

Modelled CPUE exhibited a significant quadratic trend, with an estimated maximum in 1989. There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among February, March, and April ($P = 0.0044$). There was significant month by year interaction ($P < 0.0001$), indicating that the difference in mean CPUE among the three months varied from year to year. The largest monthly mean CPUE value was recorded in March in seven of the 16 years. The largest monthly mean CPUE value, 1.3 southern flounder/0.03 hectare, was recorded in February, 1990. No southern flounder of the selected size class were caught in 25 of the 48 months in the study. The linear ($P = 0.0014$) and the quadratic terms ($P = 0.0006$) in YEAR were significant. Higher order terms were significant ($P < 0.0001$), indicating substantial fluctuation in CPUE during the study period. Modelled CPUE exhibited a significant quadratic trend, with an estimated maximum in 1989. Studentized residuals for the individual CPUE values ranged from -1.62 to 4.82. Eleven of the 536 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no southern flounder (92.7%, or 497 of the 536 bag seines).

Table IX.69. ANODE for Southern flounder/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	10.92	5.46	5.49	0.00441
YEAR					
Linear	1	10.33	10.33	10.37	0.00136
Quadratic	1	12.02	12.02	12.07	0.000557
Other	13	53.22	4.09	4.11	1.78×10^{-6}
Month x Year	30	72.40	2.41	2.42	0.0000531
Error	488	485.76	0.995		

Southern flounder/bag seine/Aransas Bay

There was a nonlinear relationship between mean CPUE and the variance around mean CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among February, March, and April ($P < 0.0001$). There was significant month by year interaction ($P = 0.0005$), indicating that the difference in mean CPUE among the three months varied from year to year. The largest monthly mean CPUE value was recorded in March in 11 of the 15 years. The largest monthly mean CPUE value was recorded in February in 4 of the 15 years. The largest monthly mean CPUE value, 6.8 southern flounder/0.03 hectare, was recorded in March, 1982. No southern flounder of the selected size class were caught in 25 of the 48 months in the study. The linear ($P = 0.0068$) and the quadratic terms ($P < 0.0001$) in YEAR were significant. Higher order terms were significant ($P < 0.0001$), indicating substantial fluctuation in CPUE during the study period. Modelled CPUE exhibited a significant quadratic trend, with an estimated maximum in 1985. Studentized residuals for the individual CPUE values ranged from -1.99 to 7.80. Four of the 536 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no southern flounder (91.2%, or 489 of the 536 bag seines), in combination with the effect of the four largest yields. These four largest catches yielded 7, 10, 61, and 67 southern flounder/0.03 hectare, respectively.

Table IX.70. ANODE for Southern flounder/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	81.31	40.66	11.87	9.23×10^{-6}
YEAR					
Linear	1	25.33	25.33	7.40	0.00677
Quadratic	1	70.67	70.67	20.64	6.99×10^{-6}
Other	13	385.94	29.69	8.67	5.6×10^{-16}
Month x Year	30	220.58	7.35	2.15	0.000492
Error	488	1670.92	3.42		

Southern flounder/bag seine/Upper Laguna Madre

Because only 11 of the 536 bag seines yielded souther flounder, and those seines yielded only 1-3 individuals, the Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE values among February, March, and April (*P* < 0.0001). There was significant month by year interaction (*P* < 0.0001), indicating that the difference in mean CPUE among the three months varied from year to year. The largest monthly mean CPUE value, 0.4 southern flounder/0.03 hectare, was recorded in March, 1982. No southern flounder of the selected size class were caught in 38 of the 48 months in the study. The linear term in YEAR was significant (P < 0.0001). The quadratic term in year was not significant (*P* < 0.2547). Higher order terms were significant (*P* < 0.0001), indicating substantial fluctuation in CPUE during the study period. Modelled CPUE exhibited a slightly decreasing trend.

Table IX.71. ANODE for Southern flounder/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	2	7.77	3.89	15.99	1.88×10^{-7}
YEAR					
Linear	1	5.12	5.12	21.07	5.64×10^{-6}
Quadratic	1	0.32	0.32	1.30	0.2547
Other	13	23.05	1.77	7.30	3.9×10^{-13}
Month x Year	30	12.58	0.42	1.73	0.0106
Error	488	118.50 0.24			

Southern flounder/bag seine/model comparison

Corpus Bay: CPUE = exp(-248.99 + 5.570*Y - 0.0313*Y^2)
Aransas Bay: CPUE = exp(-319.91 + 7.527*Y - 0.0443*Y^2)
Upper Laguna Madre: CPUE = exp(-52.27 + 1.282*Y - 0.00831*Y^2)

Modelled CPUE for Corpus Christi and Aransas Bays both exhibited quadratic curvature but with maxima shifted four years apart. The model for Upper Laguna Madre exhibited a decreasing linear trend, but this should be interpreted with caution because of the extremely small number of bag seines which yielded southern flounder in the Upper Laguna Madre. The ANODE revealed significantly different intercepts ($P < 0.0001$), confirming that overall CPUE in Aransas Bay was greater than that of Corpus Christi Bay and of the Upper Laguna Madre. This was atrributed to the large yearly mean CPUE values recorded in Aransas Bay in 1982 and 1989.

TAble IX.72. ANODE for Southern flounder/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	235.19	117.60	9.89	0.0000536
YEAR					
Linear	1	10.70	10.70	0.90	0.3428
Quadratic	1	60.93	60.93	5.13	0.0237
Bay-Linear	2	49.39	24.70	2.08	0.1256
Bay-Quadratic	2	2.69	1.35	0.11	0.8931
Error	1599	19004.44	11.89		

Gulf menhaden/gill net/Corpus Christi Bay

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration ($P < 0.0001$). CPUE was defined as CATCH/(GTIME/14)$^{-8}$. Both the linear ($P < 0.0001$) and quadratic ($P = 0.0238$) terms in YEAR were significant. Higher order terms were also significant ($P = 0.0017$), indicating substantial fluctuation in actual CPUE during the study period. Modelled CPUE exhibited a quadratic trend with a maximum in 1982. Studentized residuals for the individual CPUE values ranged from -1.78 to 4.80. Twelve of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no Atlantic croaker (418 of the 617 gill net sets) in combination with the effect of the 12 largest catches (45-148 gulf menhaden) in the study .

Table IX. 73. ANODE for Gulf menhaden/gill net/Corpus Christi Bay(CPUE = CATCH/(GTIME/14)$^{-8}$)

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
YEAR					
Linear	1	507.73	507.73	22.98	0.00000207
Quadratic	1	113.43	113.43	5.13	0.0238
Other	12	708.61	59.05	2.67	0.00165
Error	602	13302.48	22.10		

Gulf menhaden/gill net/Aransas Bay

There was a nonlinear relationship between mean CPUE and the variance around CPUE. The negative binomial distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration (P = 0.0004). CPUE was defined as CATCH/(GTIME/14)$^{-5}$. Both the linear and quadratic terms in YEAR were highly significant (P < 0.0001). Higher order terms were also significant (P < 0.0001), indicating substantial fluctuation in actual CPUE during the study period. Modelled CPUE exhibited a quadratic trend with a maximum in 1984. Studentized residuals for the individual CPUE values ranged from -1.94 to 4.88. Nine of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no Atlantic croaker (499 of the 617 gill net sets) in combination with the effect of the nine largest catches (15-64 gulf menhaden) in the study .

Table IX.74. ANODE for Gulf menhaden/gill net/Aransas Bay(CPUE = CATCH/(GTIME/14)$^{-5}$)

Source of Variation		D.F.	Deviance	Mean Deviance	F	P
YEAR						
	Linear	1	255.92	255.92	33.73	1.03×10^{-8}
	Quadratic	1	480.26	480.26	63.29	1.00×10^{-14}
	Other	12	531.96	44.33	5.84	1.23×10^{-9}
Error		602	4567.93	7.59		

Gulf menhaden/gill net/Upper Laguna Madre

There was a linear relationship between mean CPUE and the variance around CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The preliminary ANODE revealed a significant relationship between catch per set and set duration (*P* = 0.0004). CPUE was defined as CATCH/(GTIME/14)$^{-7}$. The linear term in YEAR was highly significant (*P* < 0.0001). The quadratic term in YEAR was not significant (P=0.2054) . Higher order terms were highly significant (*P* < 0.0001), indicating substantial fluctuation in actual CPUE during the study period. Modelled CPUE exhibited a decreasing linear trend. Studentized residuals for the individual CPUE values ranged from -1.95 to 4.97. Nine of the 617 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of gill net sets which yielded no Atlantic croaker (549 of the 617 gill net sets) in combination with the effect of the nine largest catches (25-165 gulf menhaden) in the study .

Table IX.75. ANODE for Gulf menhaden/gill net/Upper Laguna Madre (CPUE = CATCH/(GTIME/14)$^{-7}$)

Source of Variation		D.F.	Deviance	Mean Deviance	F	*P*
YEAR						
	Linear	1	744.09	744.09	51.90	0.0000
	Quadratic	1	23.04	23.04	1.60	0.2054
	Other	12	664.16	55.35	3.86	0.0000103
Error		602	8630.40	14.34		

Gulf menhaden/gill net/model comparison

Corpus Bay : CPUE = $\exp(-151.03 + 3.711*Y - 0.0225*Y^2)$

Aransas Bay : CPUE = $\exp(-715.86 + 17.0589*Y - 0.1015*Y^2)$

Upper Laguna Madre Bay : CPUE = $\exp(-91.63 + 2.479*Y - 0.0165*Y^2)$

Modelled CPUE for Corpus Christi and Aransas Bays exhibited quadratic curvature but with maxima shifted two years apart (1982 and 1984, respectively). By contrast, modelled CPUE in the Upper Laguna Madre exhibited a decreasing linear trend. The ANODE revealed significantly different intercepts ($P < 0.0001$), indicating larger overall CPUE in Corpus Christi Bay than in Aransas Bay and the Upper Laguna Madre.

Table IX.76. ANODE for Gulf menhaden/gill net/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	908.94	454.47	17.34	$3.46x10^{-8}$
YEAR					
Linear	1	1565.57	1565.57	59.74	$1.77x10^{-14}$
Quadratic	1	407.41	407.41	15.55	0.0000835
Bay-Linear	2	391.43	195.72	7.47	0.000588
Bay-Quadratic	2	116.46	58.23	2.22	0.1087
Error	1842	48269.04	26.20		

Gulf menhaden/bag seine/Corpus Christi Bay

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE between April and May (*P* < 0.0001). There was no significant month by year interaction (*P* = 0.2314), indicating that mean monthly CPUE in April was generally higher than in May. Highest mean CPUE was recorded in April in 11 of the 16 years surveyed. The largest monthly mean CPUE value, 891.4 gulf menhaden/0.03 hectare, was recorded in April, 1983. No gulf menhaden of the selected size class were caught in six of the 32 months surveyed. The linear term in YEAR was not significant, (*P* = 0.0582) whereas the quadratic term was significant (*P* = 0.0013). Higher order terms were significant (*P* < 0.0001), indicating substantial fluctuation in CPUE. Modelled CPUE exhibited a significant quadratic trend during 1978-1993, with an estimated maximum in 1984. Studentized residuals for the individual CPUE values ranged from -1.90 to 7.10. Three of the 360 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no gulf menhaden (80.8 % of the 360 bag seines) in combination with the effect of the 3 largest catches (these yielded 1612, 3030, and 11,884 gulf menhaden/0.03 hectare) in the study.

Table IX.77. ANODE for Gulf menhaden/bag seine/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	1	6799.39	6799.39	19.49	0.0000136
YEAR					
Linear	1	1259.84	1259.84	3.61	0.0582
Quadratic	1	3669.49	3669.49	10.52	0.00130
Other	13	16658.76	1281.44	3.67	0.0000180
Month x Year	15	6548.92	436.59	1.25	0.2314
Error	338	117894.70	348.80		

Gulf menhaden/bag seine/Aransas Bay

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE between April and May (*P* = 0.0016). There was significant month by year interaction (*P* = 0.0192), indicating that mean monthly CPUE was not consistently larger in one month than in the other from year to year. Highest mean CPUE was recorded in May in 11 of the 16 years surveyed. The largest monthly mean CPUE value, 359 gulf menhaden/0.03 hectare, was recorded in May, 1978. No gulf menhaden of the selected size class were caught in five of the 32 months surveyed. The linear term in YEAR was significant (*P* = 0.0386) whereas the quadratic term was not significant (*P* = 0.0560). Higher order terms were significant (*P* < 0.0001), indicating substantial fluctuation in CPUE. Modelled CPUE exhibited a significant decreasing linear trend during 1978-1993. Studentized residuals for the individual CPUE values ranged from -1.44 to 6.48. Six of the 370 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no gulf menhaden (72.2 % of the 370 bag seines) in combination with the effect of the six largest catches (these ranged from 679-4035 gulf menhaden/0.03 hectare) in the study.

Table IX.78. ANODE for Gulf menhaden/bag seine/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	1	5018.46	5018.46	10.12	0.00160
YEAR					
Linear	1	2137.67	2137.67	4.31	0.0386
Quadratic	1	1822.72	1822.72	3.68	0.0560
Other	13	38463.18	2958.71	5.97	5.71×10^{-10}
Month x Year	15	14394.85	959.66	1.94	0.0194
Error	328	162604.60	495.75		

Gulf menhaden/bag seine/Upper Laguna Madre

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference in mean CPUE between April and May (P = 0.0026). There was significant month by year interaction (P = 0.0001), indicating that mean monthly CPUE was not consistently larger in one month than in the other from year to year. No gulf menhaden of the selected size class were caught in 12 of the 32 months surveyed. The linear term in YEAR was significant (P < 0.0001) whereas the quadratic term was not significant (P = 0.9347). Higher order terms were significant (P < 0.0001), indicating substantial fluctuation in CPUE. Modelled CPUE exhibited a significant decreasing linear trend during 1978-1993. Studentized residuals for the individual CPUE values ranged from -3.20 to 7.67. Four of the 360 residual values were larger than 2.0 in absolute value. Deviation from the model was attributed to the large number bag seines which yielded no gulf menhaden (88.9 % of the 360 bag seines) in combination with the effect of the four largest catches (these yielded 54, 56, 177, and 725 gulf menhaden/0.03 hectare, respectively) in the study.

Table IX.79. ANODE for Gulf menhaden/bag seine/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	1	216.99 216.99	9.19	0.00262	
YEAR					
Linear	1	660.55 660.55	27.99	2.23x10^{-7}	
Quadratic	1	0.16	0.16	0.01	0.9347
Other	13	3793.31	291.79	12.36	0.0000
Month x Year	15	1070.73	71.38	3.02	0.000140
Error	328	7741.40	23.60		

Gulf menhaden/bag seine/model comparison

Corpus Bay : CPUE = $\exp(-123.80 + 3.066*Y - 0.01833*Y^2)$
Aransas Bay : CPUE = $\exp(190.50 - 4.309*Y + 0.02476*Y^2)$
Upper Laguna Madre: CPUE = $\exp(10.43 - 0.0558*Y - 0.000599*Y^2)$

Modelled CPUE for Corpus Christi Bay exhibited curvature with a maximum in 1984. By contrast, modelled CPUE within Aransas Bay and the Upper Laguna Madre decreased linearly. The ANODE revealed significantly different intercepts (P = 0.0143), confirming that overall CPUE within Corpus Christi and Aransas Bays was generally greater than in the Upper Laguna Madre.

Table IX.80. ANODE for Gulf menhaden/bag seine/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	17986.34	8993.17	4.26	0.0143
YEAR					
Linear	1	3957.95	3957.95	1.88	0.1710
Quadratic	1	84.55	84.55	0.04	0.8413
Bay-Linear	2	180.43	90.22	0.043	0.9581
Bay-Quadratic	2	5157.58	2578.79	1.22	0.2948
Error	1081	2279854.00	2109.02		

Gulf menhaden/trawl/Corpus Christi Bay

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. There was significant month by year interaction ($P < 0.0001$), indicating that the observed overall difference in mean CPUE among September, October, November, and December varied from year to year. The highest mean CPUE was recorded in September in seven of the 12 years surveyed. The highest mean CPUE was recorded in December in three of the 12 years surveyed. The largest monthly mean, 6.9 gulf menhaden/10 minutes was recorded in December, 1989. No gulf menhaden of the selected size class were caught in 21 of the 48 months surveyed. The linear term in YEAR was not significant ($P = 0.3128$), whereas the quadratic term was significant ($P = 0.0066$). Higher order terms were highly significant ($P < 0.0001$), indicating substantial fluctuation in CPUE during the study period. Modelled CPUE exhibited a significant quadratic trend during 1982-1993, with an estimated maximum in 1988. Studentized residuals for the fitted model range from -1.76 to 11.22. Ten of the 960 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no gulf menhaden (898 of the 960 trawls) in combination with the effect of the 10 largest catches (5-136 gulf menhaden/10 minutes) in the study.

Table IX.81. ANODE for Gulf menhaden/trawl/Corpus Christi Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	3	180.73	60.24	13.63	1.05x10-8
YEAR					
Linear	1	4.51	4.51	1.02	0.3128
Quadratic	1	32.79	32.79	7.42	0.00659
Other	9	401.60	44.62	10.09	6.77×10^{-15}
Month x Year	33	338.00	10.24	2.32	0.0000457
Error	912	4031.46	4.42		

Gulf menhaden/trawl/Aransas Bay

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. The ANODE revealed a significant difference ($P < 0.0001$) in mean CPUE among September, October, November, and December. There was significant month by year interaction ($P = 0.0002$), indicating that the observed overall difference in mean CPUE among September, October, November, and December varied from year to year. The highest mean CPUE was recorded in September in 11 of the 12 years surveyed. The highest mean CPUE was recorded in December in three of the 12 years surveyed. The largest monthly mean, 5.3 gulf menhaden/10 minutes was recorded in September, 1984. No gulf menhaden of the selected size class were caught in 27 of the 48 months surveyed. The linear term in YEAR was significant ($P < 0.001$), whereas the quadratic term was not significant ($P = 0.2466$). Higher order terms were highly significant ($P < 0.0001$), indicating substantial fluctuation in CPUE during the study period. Modelled CPUE exhibited a significant decreasing linear trend during 1982-1993. Studentized residuals for the fitted model range from -2.37 to 9.91. Eighteen of the 960 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no gulf menhaden (841 of the 960 trawls) in combination with the effect of the 18 largest catches (9-86 gulf menhaden/10 minutes) in the study.

Table IX.82. ANODE for Gulf menhaden/trawl/Aransas Bay

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	3	435.39	145.13	76.46	0
YEAR					
Linear	1	46.28	46.28	24.38	9.40×10^{-7}
Quadratic	1	2.55	2.55	1.34	0.2466
Other	9	741.43	82.38	43.40	0
Month x Year	33	135.15	4.10	2.16	0.000196
Error	912	1731.16	1.90		

Gulf menhaden/trawl/Upper Laguna Madre

There was a linear relationship between mean CPUE and the variance around mean CPUE. The Poisson distribution was selected as the most appropriate for evaluating the significance of model components. There was significant month by year interaction ($P < 0.0001$), indicating that the observed overall difference in mean CPUE among September, October, November, and December varied from year to year. The largest monthly mean, 1.0 gulf menhaden/10 minutes was recorded in October, 1984. No gulf menhaden of the selected size class were caught in 36 of the 48 months surveyed. The linear term in YEAR was significant ($P < 0.001$), whereas the quadratic term was not significant ($P = 0.1562$). Higher order terms were highly significant ($P < 0.0001$), indicating substantial fluctuation in CPUE during the study period. Modelled CPUE exhibited a significant decreasing linear trend during 1982-1993. Studentized residuals for the fitted model range from -1.77 to 5.75. Nine of the 480 residual values were greater than 2.0 in absolute value. Deviation from the model was attributed to the large number of trawls which yielded no gulf menhaden (460 of the 480 trawls) in combination with the effect of the nine largest catches (2-6 gulf menhaden/10 minutes) in the study.

Table IX.83. ANODE for Gulf menhaden/trawl/Upper Laguna Madre

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Month	3	4.17	1.39	2.18	0.0896
YEAR					
Linear	1	13.42	13.42	21.02	0.00000596
Quadratic	1	1.29	1.29	2.02	0.1562
Other	9	78.69	8.74	13.70	0
Month x Year	33	54.74	1.66	2.60	0.00000646
Error	432	275.68	0.64		

Gulf menhaden/trawl/model comparison

Corpus Bay : CPUE = exp(-284.89 + 6.438*Y - 0.0365*Y^2)
Aransas Bay : CPUE = exp(-50.64 + 1.244*Y - 0.00771*Y^2)
Upper Laguna Madre: CPUE = exp(-124.33 + 2.983*Y - 0.0182*Y^2)

There was no statistical difference revealed in CPUE among the three water bodies. This is because so few gulf menhaden were caught in Aransas Bay and the Upper Laguna Madre. The analysis was thus of limited interpretative value. The ANODE confirmed that the model intercepts were not significantly different (*P* = 0.0604), although actual CPUE in Corpus Christi and Aransas Bays seemed larger than in the Upper Laguna Madre.

Table IX.84. ANODE for Gulf menhaden/trawl/model comparison

Source of Variation	D.F.	Deviance	Mean Deviance	F	*P*
Bay	2	147.62	73.81	2.81	0.0604
YEAR					
Linear	1	22.50	22.50	0.86	0.3548
Quadratic	1	17.15	17.15	0.65	0.4192
Bay-Linear	2	48.93	24.47	0.93	0.3941
Bay-Quadratic	2	12.26	6.13	0.23	0.7918
Error	2391	62790.25	26.26		