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GULF OF MEXICO SHRIMP STOCK ASSESSEMNT WORKSHOP

BY

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Gulf of Mexico
Shrimp Stock Assessment Workshop
June 19-22, 1989

OVERVIEW

A technical review of the biological status of the brown, pink and white shrimp fisheries was recommended by the Gulf of Mexico Fishery Management Council. This workshop was convened to assess the present status of the fisheries, review stock assessment techniques and make recommendations about areas of focus for research. The workshop panel was comprised of national experts, state and federal officials, and the scientific support staff from the National Marine Fisheries Service, NMFS, Galveston Laboratory (Appendix 1).

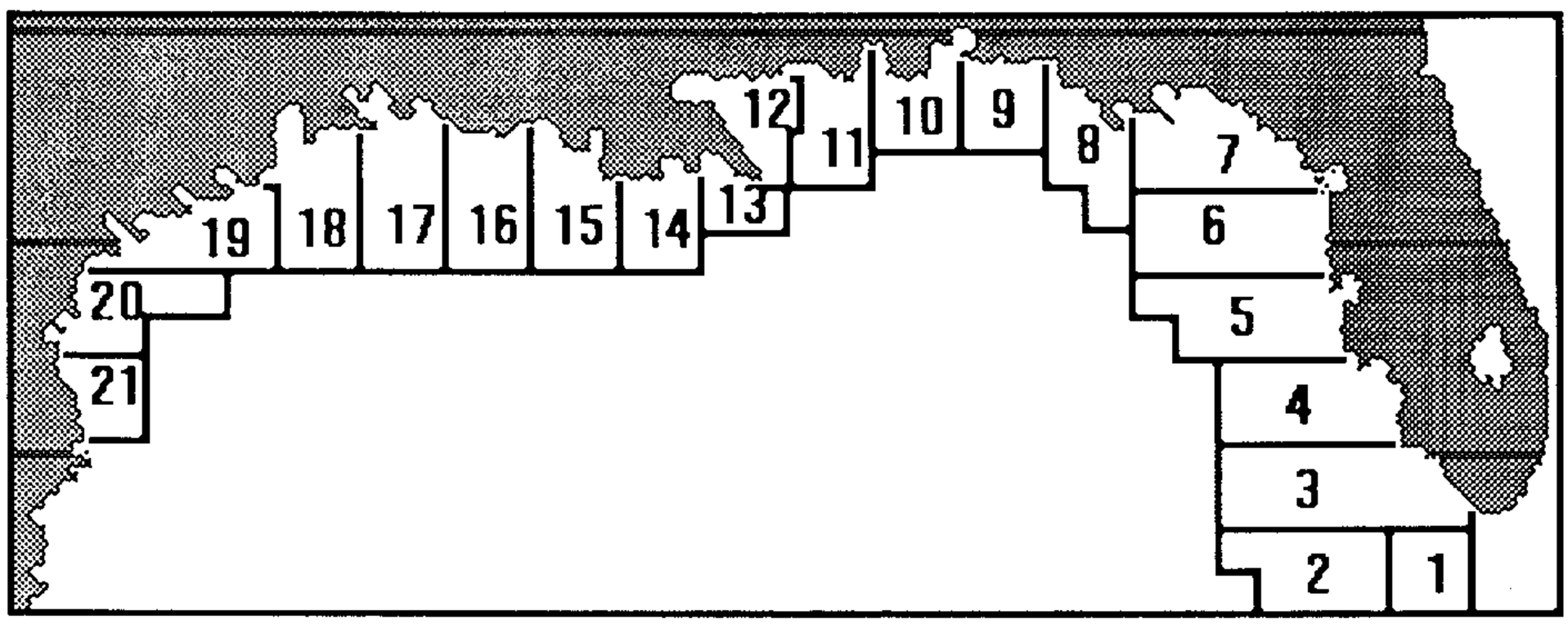
FISHERY DEPENDENT COLLECTION

Statistics of U.S. shrimp trawling operations and production in the Gulf of Mexico have been collected by NMFS since 1956. NMFS and state port agents record the day-to-day operations and production of the U.S. commercial shrimp fleet. These agents are located at strategically selected at landing ports around the Gulf in each of the respective states. They canvass both fishermen and processors for detailed information on location and amount of fishing, weight, size and species composition of shrimp landed, and current market prices and conditions.

The present statistical survey attempts to account for all commercial landings through a daily to weekly canvass of processing plants. From dealers' receipts, port agents transcribe the details of landings for each vessel trip. Most dealers are familiar with the species compositions of shrimp landed since shrimp are sold as white, brown, or pink (i.e., Penaeus setiferus, P. aztecus and P. duorarum respectively). A breakdown by species for each landing is then obtained automatically when transcribing landing data from dealer records. Size composition of the landings is recorded as number of tails per pound (count). Before 1984, values greater than 67 count were considered as a single category. Since that time, specific size information has been detailed into whatever market categories were recorded by the dealers.

Fishermen are interviewed by port agents to determine effort expended and location of specific catches. To facilitate geographical assignment of commercial trawling effort and shrimp catch, the U.S. continental shelf of the Gulf of Mexico has been subdivided coastwide into 21 statistical subareas (Figure 1). These areas have been further subdivided into five fathom increments of depth from the shoreline out to the edge of the continental shelf. Fishery statistics information is reported by these areal divisions hereafter termed "location cells".

Figure 1. Statistical Subareas in U.S. Gulf of Mexico.



Total monthly effort for each species is estimated from the interview records. To estimate effort directed at a single species, only interviews in which at least 95% of the catch was a single shrimp species are used for calculation of catch per unit of effort (CPUE). An average CPUE directed at a single species is calculated for each location cell. Most cells (about 85-95%) have a CPUE based upon interview data. Nichols (1984) outlines the methodologies used to calculate CPUE values for cells that have catch but no estimate of effort. Once a CPUE is calculated for each cell for each month on a species by species basis, effort can be calculated for the cell-month-species array. Directed effort in a given location is simply calculated by dividing the catch by the CPUE. It must be remembered that the values for directed effort are not necessarily additive across species.

FISHERY INDEPENDENT DATA COLLECTION

There is a recognized need within state and federal management agencies for fishery independent data collection. SEAMAP (Southeast Area Monitoring and Assessment Program) was designed to encompass and coordinate both state and federal fishery independent data collection activities in the U.S. southeast region (i.e., Gulf of Mexico, South Atlantic and Caribbean Sea). The goal of the program is to maximize the efficiency of data collection and processing, and to share and minimize costs among management agencies (Eldridge, 1988).

SEAMAP cruises are used to collect data about several species groups (i.e., shrimp and groundfish, reef fish, coastal pelagics, estuarine pelagics, menhaden, squid and butterfish, etc.). Each individual cruise is designed to collect data about a specific group. During the semi-annual shrimp and groundfish cruises, state vessels sample nearshore stations while a NOAA vessel surveys offshore stations. Data on abundance, size composition, sex ratio and distribution of shrimp species are obtained from these cruises.

SHRIMP SPECIES REVIEW

STOCKS

Brown shrimp, white shrimp, and pink shrimp are all assessed and managed as unit stocks in the Gulf of Mexico. Each species is widely distributed around the Gulf and, although there are characteristic centers of abundance, there are no distinct spawning grounds nor any separation of sexes (Osburn, et al., 1969). No genetic differences have been detected from any species throughout its distribution. Mark-recapture studies have indicated that each species is capable

of moving several hundred miles while remaining at large several hundred days, thus giving these shrimp the capability for traversing state and international boundaries (Klima, 1964; Klima, 1974; Gitschlag, 1986; Sheridan, et al., 1986).

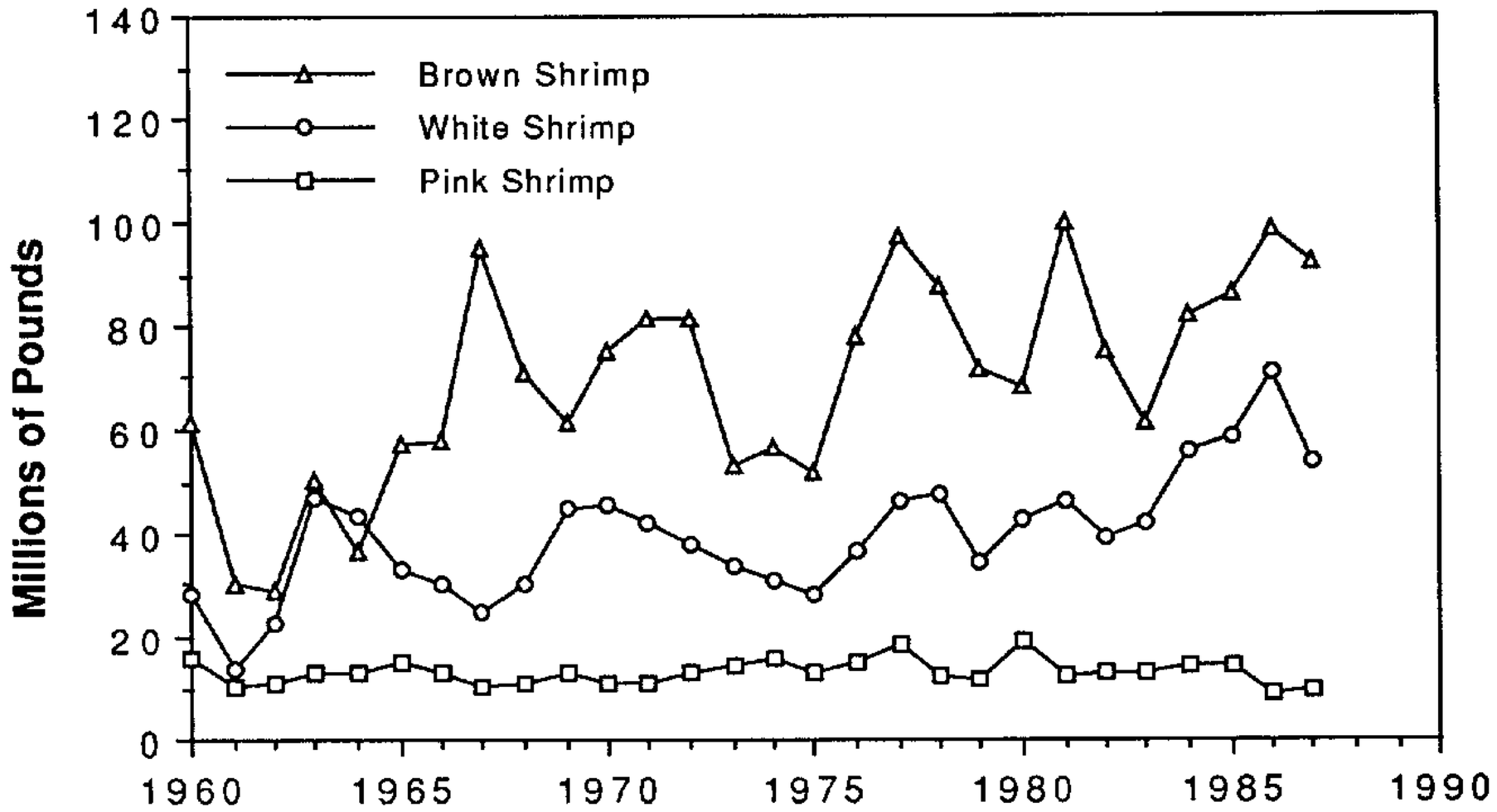
Each species has a definite center of abundance in the Gulf of Mexico. The white shrimp stock is most abundant from the Florida panhandle to the coastal bend of Texas. The brown shrimp stock is primarily distributed from west of the Mississippi River through Tamaulipas, Mexico. The pink shrimp stock is distributed primarily in south and west Florida, north and west of the Yucatan Peninsula, with a less abundant group off south Texas.

GENERAL FISHERY TRENDS

Catch

The annual U.S. Gulf of Mexico catch of brown, white and pink shrimp from 1960 to 1987 are illustrated in Figure 2 (Note: all values are for heads-off shrimp). Brown shrimp landings have generally increased by about 70 million pounds from a low in the early 1960's. The majority of the brown shrimp catch is taken during the months of May through September. White shrimp landings have trended upwards since the mid 1970's. White shrimp catch is highest during the months of August through December. Pink shrimp landings have been stable around 14 million pounds from 1960 to 1985, but, since 1985, there has been a decline noted in the fishery. Pink shrimp catch is greatest from December through May.

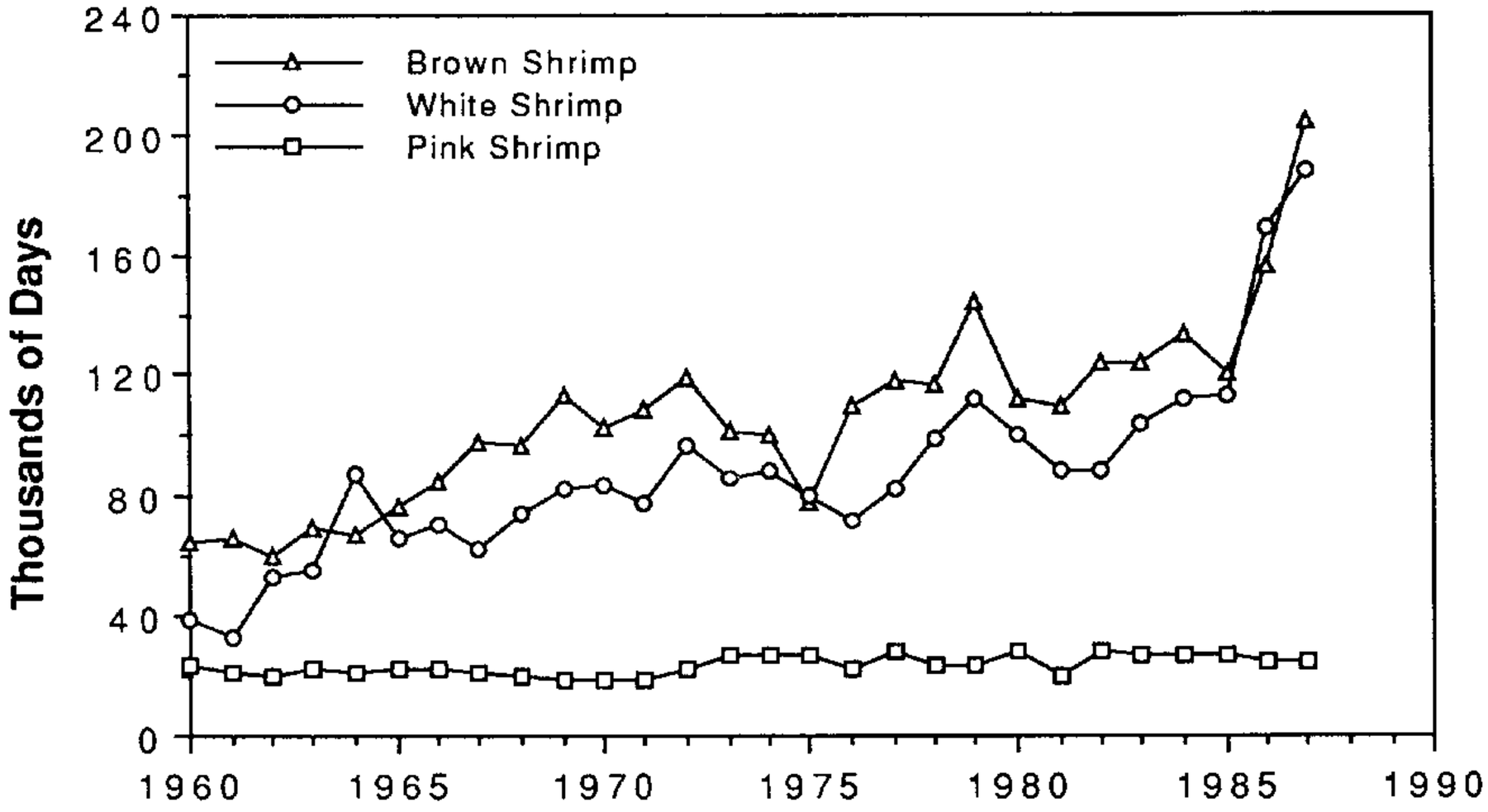
Figure 2. Gulf of Mexico Shrimp Catches from 1960-1987.



Effort

Nominal d irected effort for both brown and white shrimp has increased dramatically since the 1960's (Figure 3). Brown shrimp directed effort has nearly tripled coinciding with increased landings. Effort for the brown shrimp fishery occurs mostly from May through September. Annual white shrimp directed effort has also increased to a record high of 170,000 fishing days in 1986 and 190,000 fishing days in 1987. White shrimp directed effort usually has an initial peak in June, a decline in July, and its major peak from August through November. Pink shrimp directed effort has been low in comparison to the other two fisheries. An apparent transition occurred in the early 1970's from a mean of 21,000 fishing days prior to 1972 to a mean of 26,000 thousand days after 1972. Pink shrimp fishing effort peaks from December to May and then declines rapidly and remains low until the next December.

Figure 3. Directed Effort in Combined Inshore and Offshore Areas.



CPUE

The annual catch per unit of effort (annual CPUE = annual landings/annual effort) for each of the three species has fluctuated greatly with no consistent trends (Figures 4 and 5). Declines in CPUE have been observed for all three

Figure 4. CPUE for Brown and White Shrimp in Gulf of Mexico.

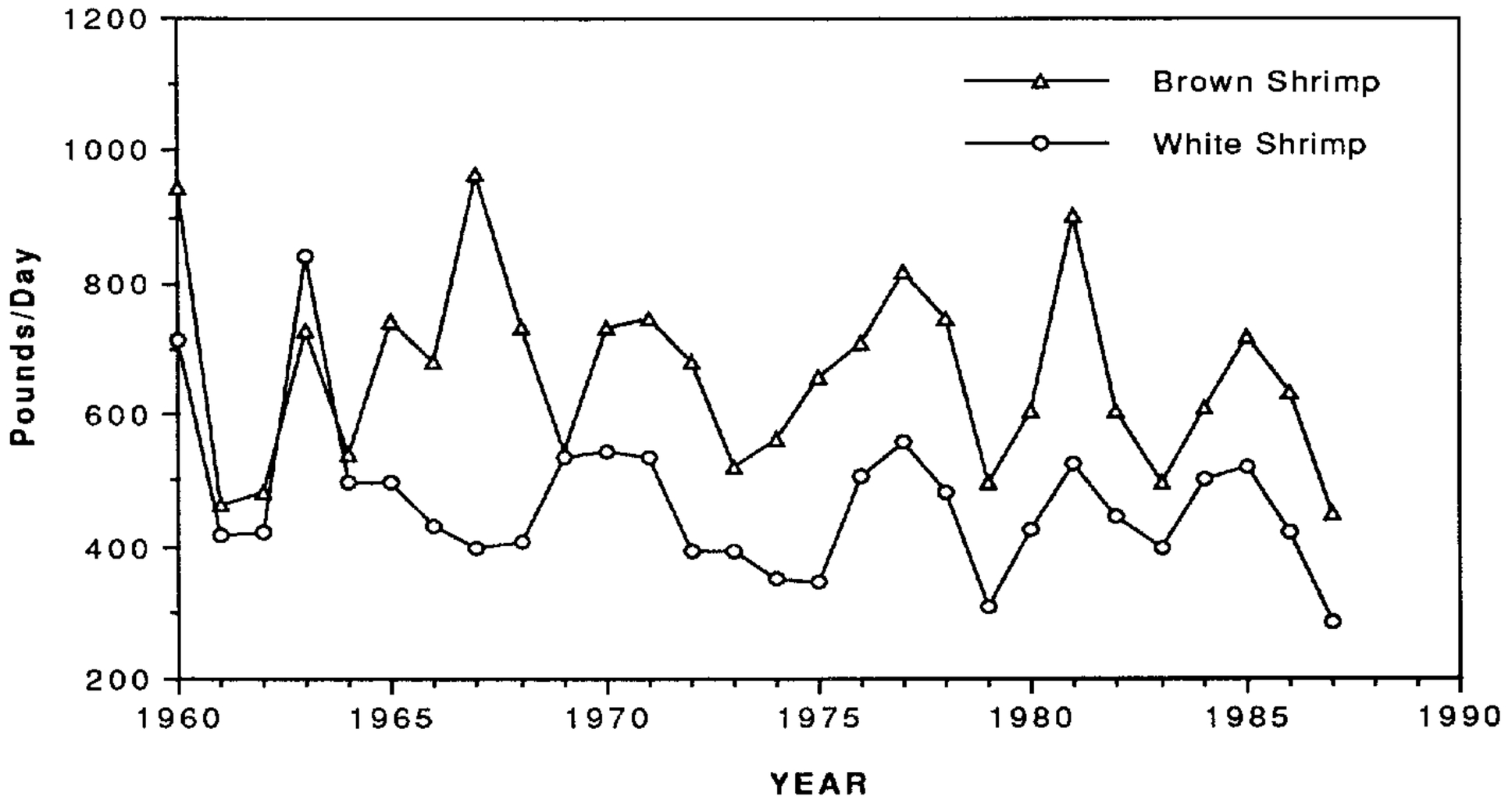
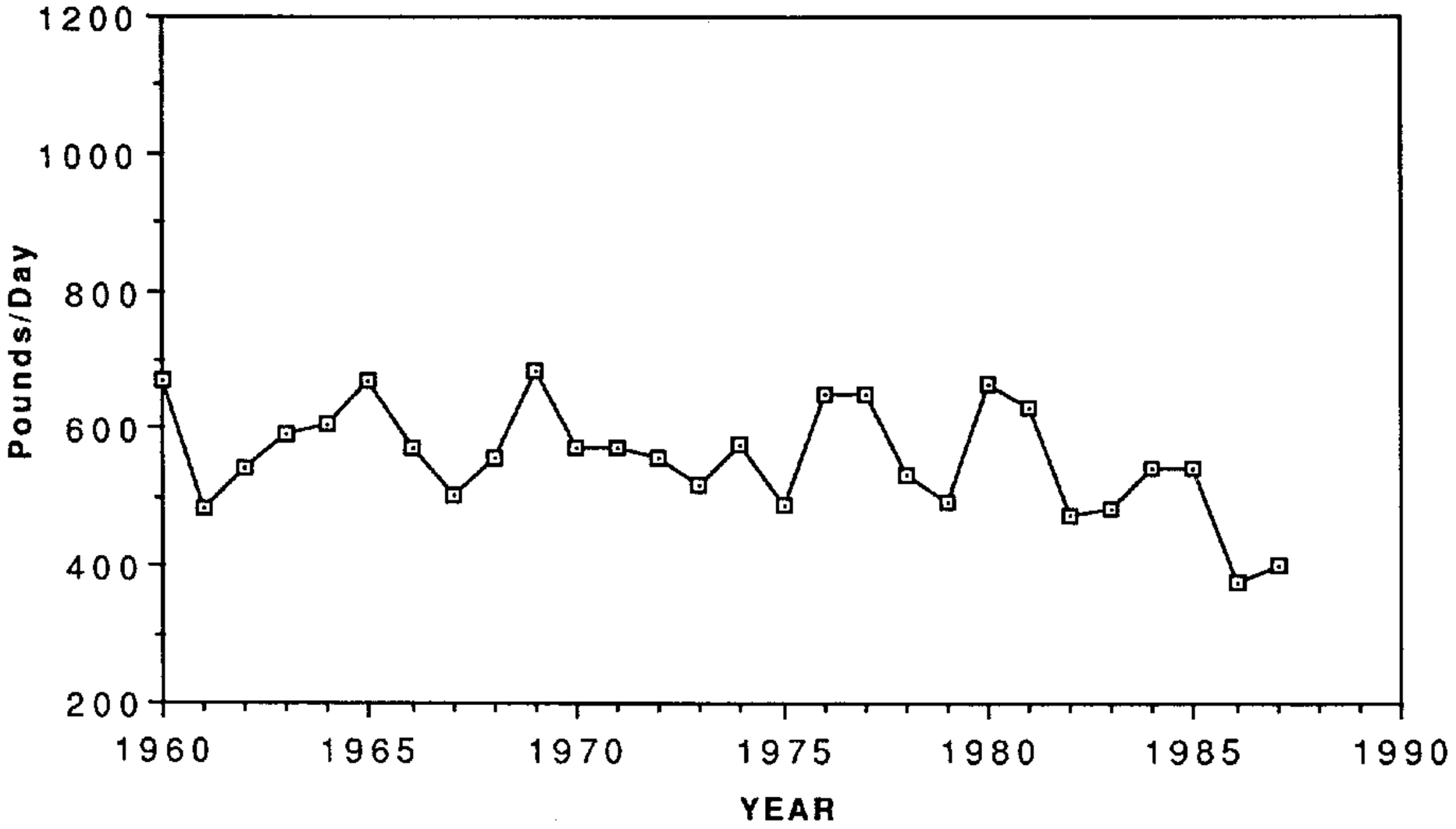


Figure 5. CPUE for Pink Shrimp in the Gulf of Mexico.

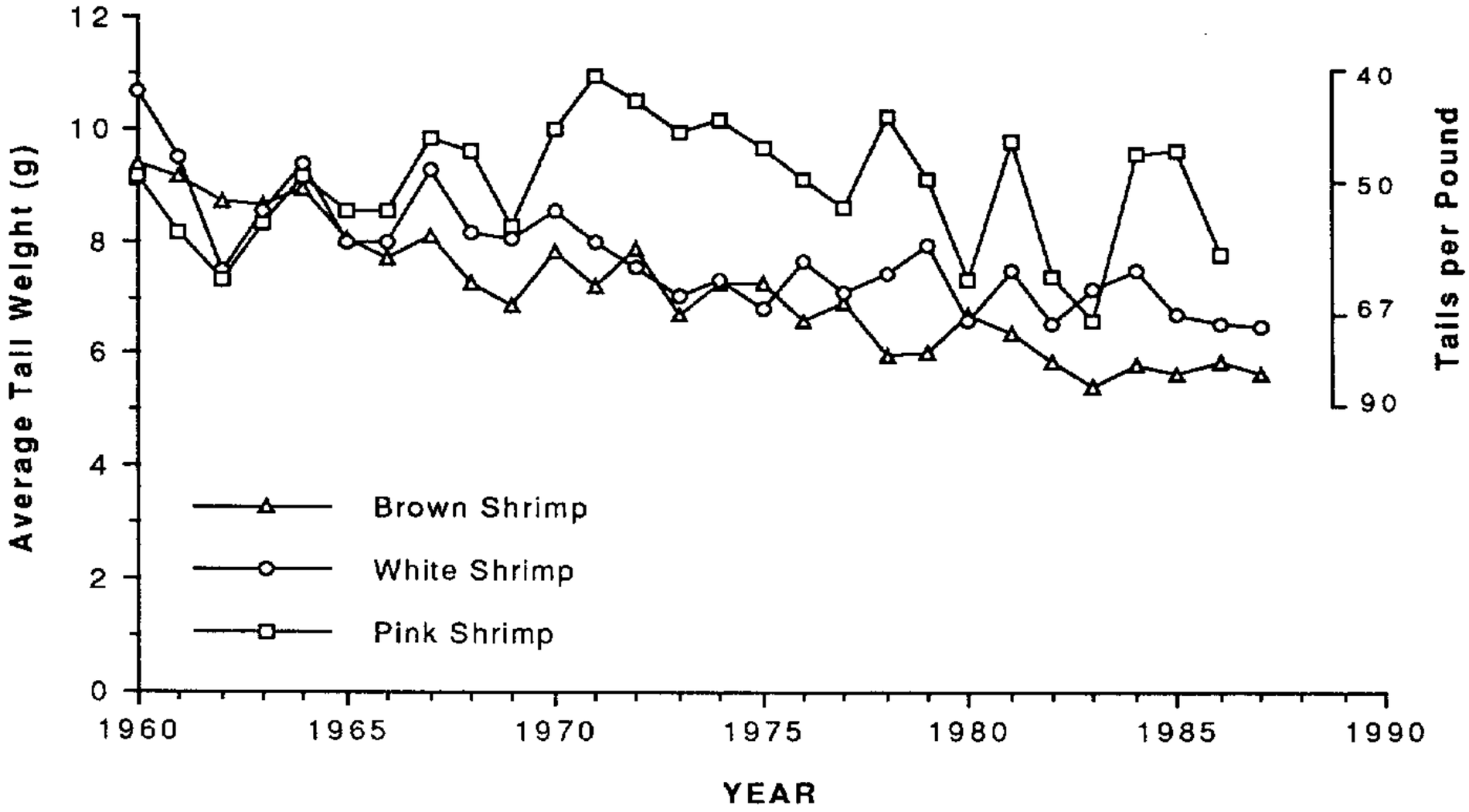


species since 1985; for the brown and white shrimp fisheries, the declines are within ranges seen in years past, but in the pink shrimp fishery, the 1986 value is the lowest ever observed.

Size

The size of shrimp (i.e., weight) is measured as either average weight per tail (in grams) or in number of tails per pound (termed count). Average size of brown and white shrimp landed has decreased since the 1960's (Figure 6). Brown shrimp count size has decreased from 50 count in 1960 to around 80 count in 1988, while white shrimp size has decreased from 45 count in 1960 to 70 count in 1988. Pink shrimp size has fluctuated considerably, showing no apparent trend over the past 27 years. Average count size has been around 50 tails per pound.

Figure 6. Average Size of Shrimp Landed.



VIRTUAL POPULATION ANALYSIS

Age specific estimates of fishing mortality rates (F) and stock sizes for each shrimp species can be made using virtual population analysis (Ricker, 1975). This method requires:

(1) a complete and accurate catch by age table exist,

(2) a known instantaneous rate of natural mortality (M), and

(3) a known instantaneous rate of fishing mortality (F) for at least one age in each cohort.

Although these three items are not "known," estimates are available. Description of how the estimates of catch by age, M and starting F were calculated are discussed briefly below. Detailed discussion about the techniques used for the estimates can be found in Nichols (1984).

Growth and Aging

Species specific growth curves were used to determine length-age relationships so a catch by age table could be created from the landing by size data. Growth curves developed by Parrack (1981) were used for brown shrimp, while curves derived by Phares (reported by Nichols, 1984) were used for pink shrimp. White shrimp catches by age were determined using a seasonally-varying growth model developed by Nichols (1981). Necessary conversions between lengths, weight and tail measurements were made using conversion factors reported by Brunenmeister (1980), Parrack (1981) and Phares (1980). All ages were calculated to the nearest whole month beginning with recruitment to the fishery.

Natural Mortality Rates

Estimation of the instantaneous rate of natural mortality (M) may be the most difficult technical problem in fishery stock assessment. Two "families" of techniques are generally available:

(1) Use catch and effort statistics to determine a relationship between instantaneous total mortality rate (Z) and fishing effort (f). Use the relationship to predict Z at zero effort. This allows M to be estimated, because Z=M when f=0.

(2) Use mark/recapture experiments to estimate the rate of disappearance of marked shrimp from a time series of catches. Estimate rates of losses from all causes, other than natural mortality, and ascribe to natural mortality any loss rate remaining.

Both techniques require postulating a model of the form:

$$Z = qf + M$$

where, Z = instantaneous rate of total mortality

q = catchability value (fraction of population taken by one unit of effective effort)

f = directed fishing effort

M = instantaneous rate of natural mortality.

The procedures used give a reasonable picture of the probable limits of M for brown and white shrimp. Ample evidence exists that M for adults of both species is between 0.2 and 0.35 per month, but there is little justification for narrowing the range further. Thus, the best estimate of M for both brown and white shrimp is taken as 0.275 per month, the mid-point of the range for probable values of natural mortality (Nichols, 1984). Associated q values were estimated to be 0.25 per 10,000 days effort for brown shrimp and 0.75 per 10,000 days effort for white shrimp (Nichols 1984).

Pink shrimp catch and effort data, when analyzed as above, did not provide reliable estimates of M. Thus, the M of 0.3 per month, derived from mark/recapture data developed by Berry (1967), was used as the best available alternative. A q value of 3.0 per 10,000 days fished was estimated by Nichols (1982).

Current Investigation of Natural Mortality

Studies of natural mortality of juvenile brown shrimp in estuaries indicated that mortalities ranged between 23% and 61% over a two week period. Comparable mortality in predator-exclusion cages was less than 3%. These data and published information on physical tolerances, food requirements, and

diseases suggest that predation is usually the major direct cause of brown shrimp mortality in estuarine nurseries of the Gulf of Mexico (Minello, et al., in press). In laboratory experiments, the presence of Spartina alterniflora reduced predation rates of fish predators. Predation rates in general decreased in proportion to decreased prey densities. Thus, high water levels in the marsh, which increase access to intertidal vegetation and decrease densities on nonvegetated bottom, probably result in decreased brown shrimp mortality. Mortality in the marsh also appeared to decline as brown shrimp size increased.

Systematic studies of predation on shrimp in offshore waters have been conducted only for brown shrimp (Divita, et al., 1983; Sheridan, et al., 1984b; NMFS, unpubl. data). Intensive summer SEAMAP surveys of over 150 species of fishes have identified few trawl- susceptible species that prey on brown shrimp as the shrimp move offshore from the estuaries. Although predation rates have not been calculated, they appear low relative to rates in estuaries. Seasonal SEAMAP surveys of selected shrimp predators identified in summer surveys have also indicated low predation on brown shrimp during spring through fall.

Population dynamics and energy flow models indicate that discards by the offshore shrimp fleet (of undersized shrimp and unwanted fish bycatch) could affect brown shrimp production (Sheridan, et al., 1984a). Elimination of discards either by utilizing the bycatch or by modifying the nets to reduce bycatch deprives the shrimp of potential food sources and increases predation. However, these variations are not likely to be detected due to low predation and a masking by wide variations in landings due to environmental effects.

Recruitment

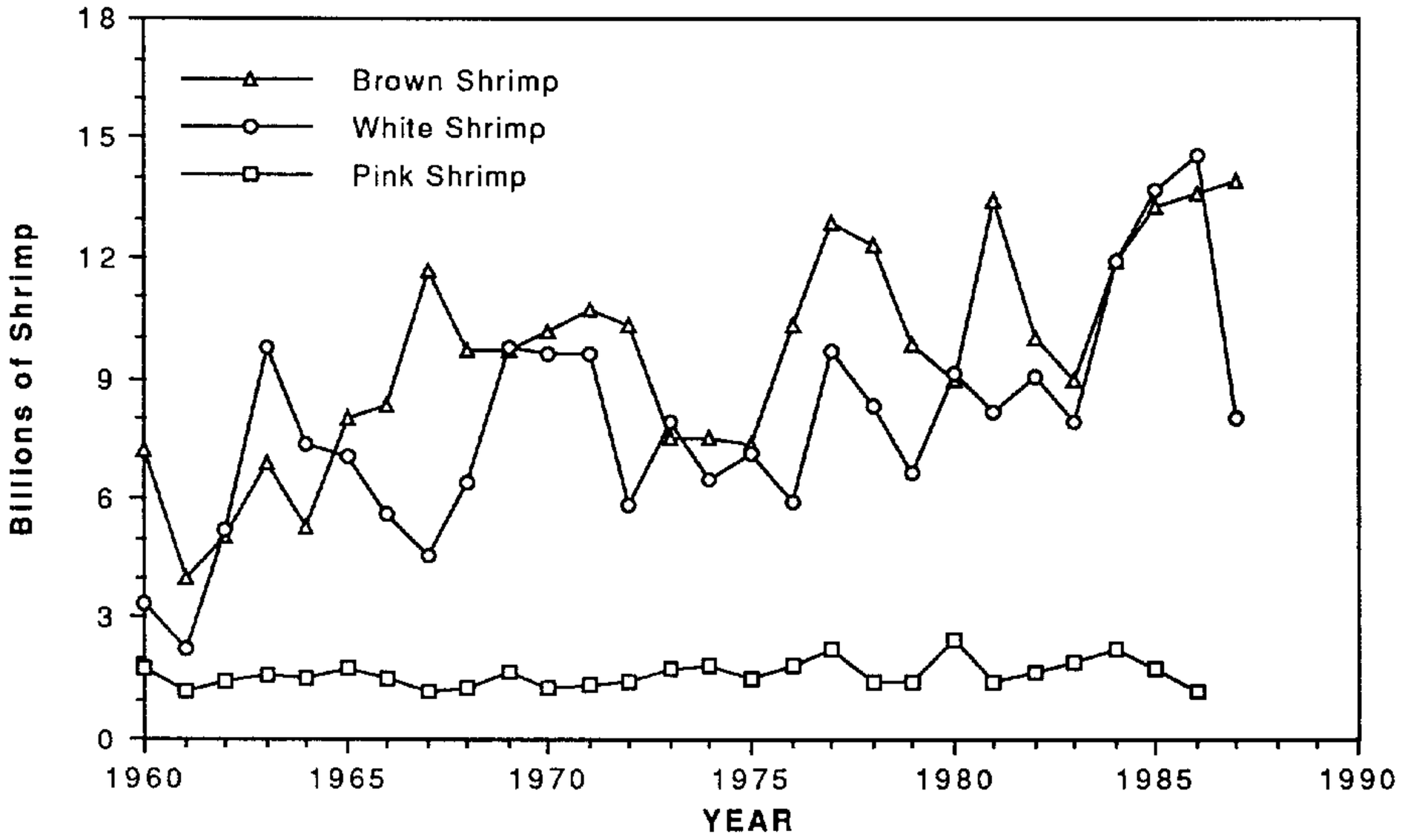
For this report, the recruitment period is defined as the period when juvenile shrimp migrate into the deeper waters of the bays and become

accessible to the shrimp fishery. This usually occurs at about 45 mm tail length (approx. 2 g tail weight).

All three species have prolonged spawning seasons; from April to September for whites and possibly year-round for browns and pinks. For brown and white shrimp the main periods of recruitment extend over several months, but both species show a single annual peak (May through June for brown shrimp and August through September for white shrimp).

Brown and white recruitment in the Gulf of Mexico have both fluctuated, but have generally increased over the 28-year period (Figure 7). White shrimp showed record levels from 1984 through 1986. Even though a substantial decrease in recruitment occurred in 1987, levels were still well within the 1960-1987 range.

Figure 7. Recruitment of Shrimp since 1960.



Pink shrimp recruitment is a year-round phenomenon. In any given year, timing of peaks in recruitment can be quite variable. There is usually a major

peak in the fall and a substantial recruitment may also occur during spring. Pink shrimp recruitment has been quite stable over the past 27 years, with a decline in 1986 and 1987.

Parent Stock-Recruitment Relationships

Parent stock is defined as the number of shrimp older than a given age that are available to spawn in a particular month. A range of possible parent stock age-month combinations can be selected for a given species and then compared with total annual recruitment. Parent stock-recruitment relationships that show high correlation are selected for further analysis.

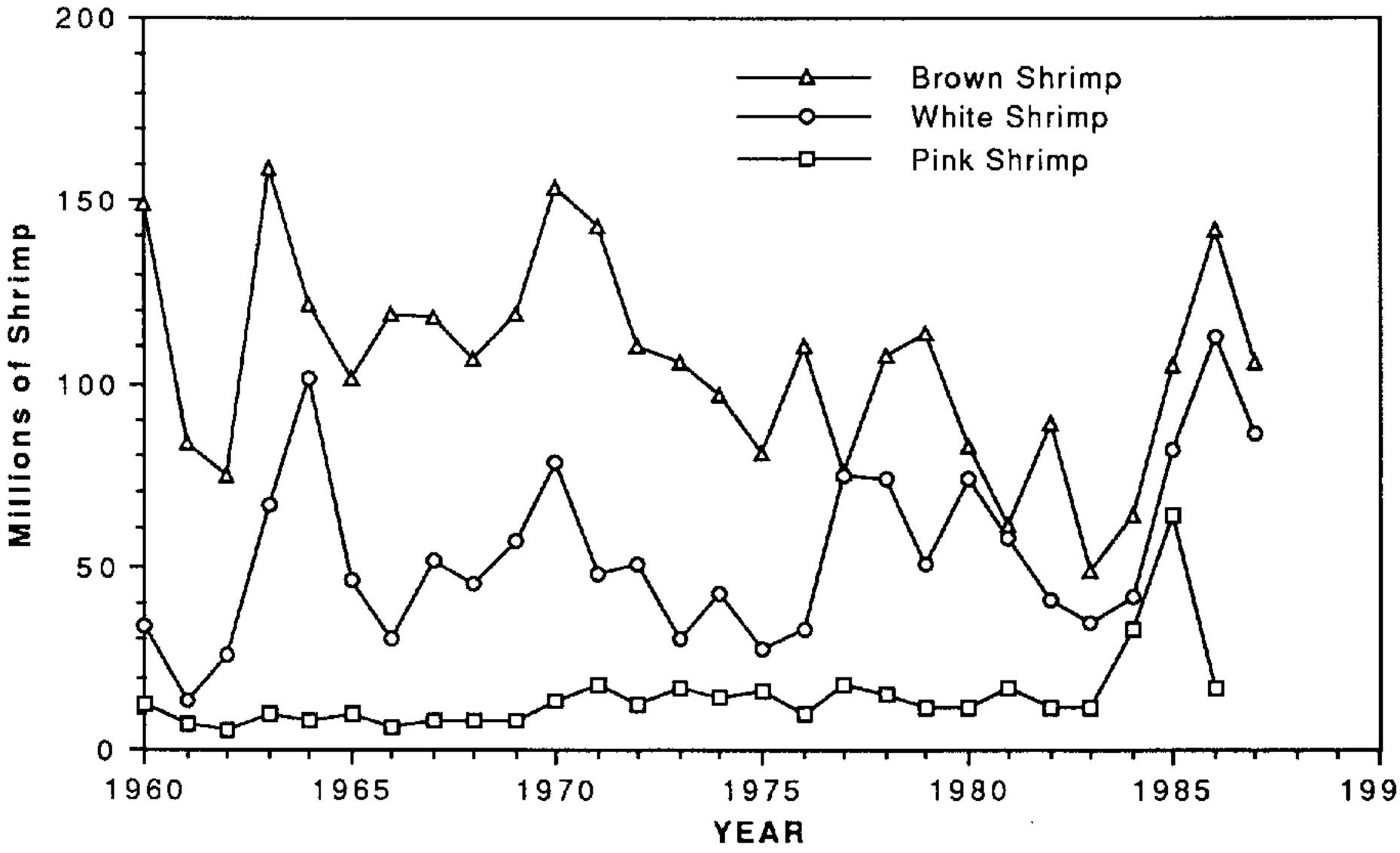
It is best to examine the stock-recruitment relationship between total annual recruitment and parent stock size for each month during the main spawning season for each species. This allows many possible combinations to be addressed during the analysis. The months of October through March were considered for brown shrimp and April through August for white shrimp. A range of possible minimum ages for parenthood (4 to 8 months) was considered for brown shrimp, while for white shrimp survivors left from the previous season were treated as possible parents (no age sensitivity). Thus, for brown shrimp, a total of 30 parent age-month parent combinations were compared to recruitment, while a total of only 5 parent age-month combinations were used for white shrimp.

Pink shrimp parents are, as with brown shrimp, examined from various age-month combinations. Since there are two recruitment periods in a given year, two months are selected together in the analysis. The months selected are 6 months apart (i.e., January and July, February and August, etc.). Thus, six possible month combinations are utilized in the analysis. The first month is compared to the spring recruitment, while the second month is compared to the

fall recruitment. Age sensitivity is also considered, with minimum ages from 4 to 8 months after recruitment used as potential parents.

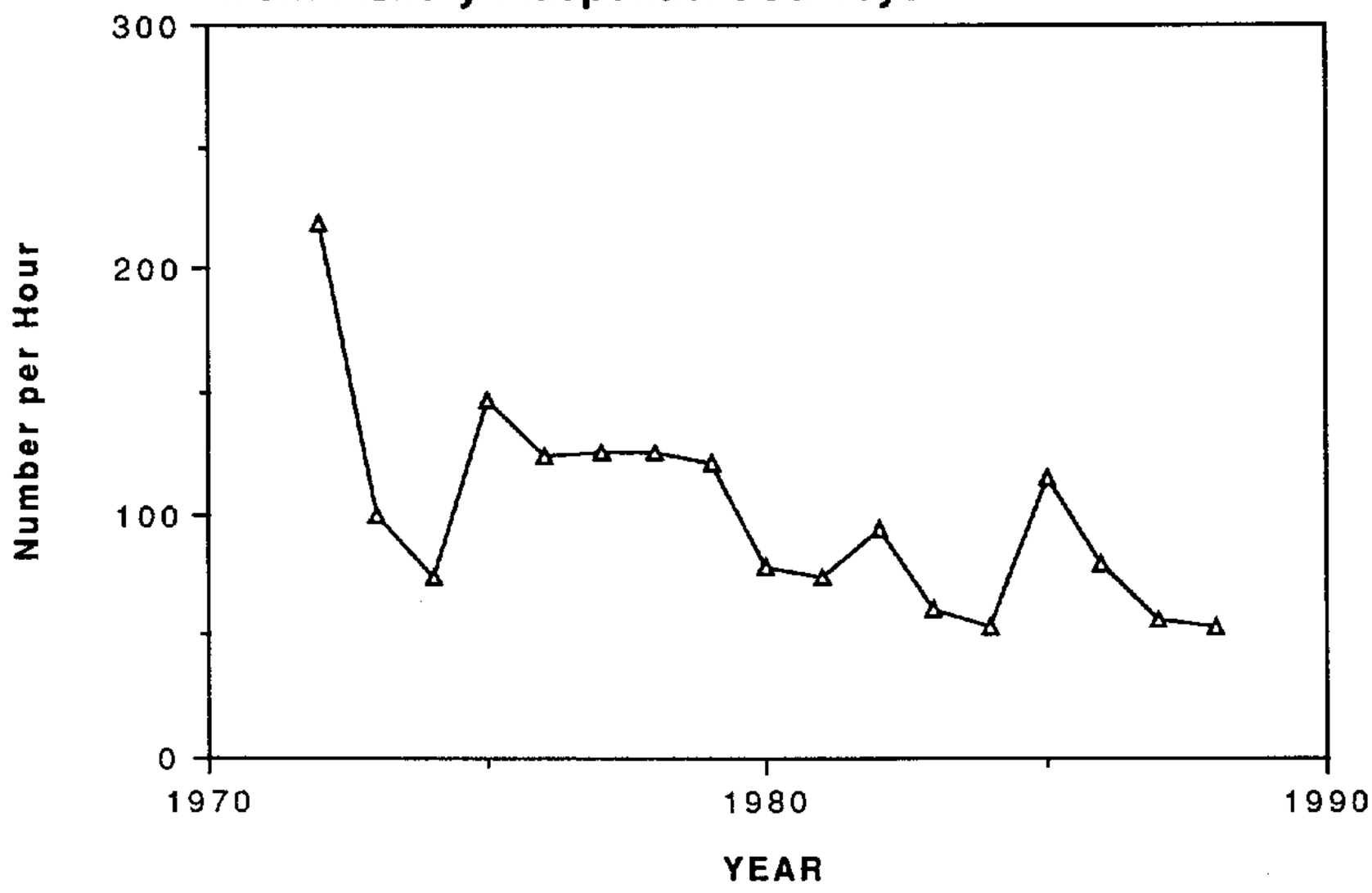
Estimates of parent stock values for a selected month/age combination are shown in Figure 8 for the 3 species. No trends are evident in these examples, nor in most other month/age combinations. Thus, no change in parent stock over the last three decades is apparent for the shrimp stocks in the Gulf of Mexico. Estimates of brown shrimp parent stocks from fishery independent SEAMAP cruise data are similar to those obtained from most VPA analysis (Figure 9). However, a slight downward trend is apparent in the SEAMAP data set.

Figure 8. Estimates of Shrimp Parent Stocks since 1960.



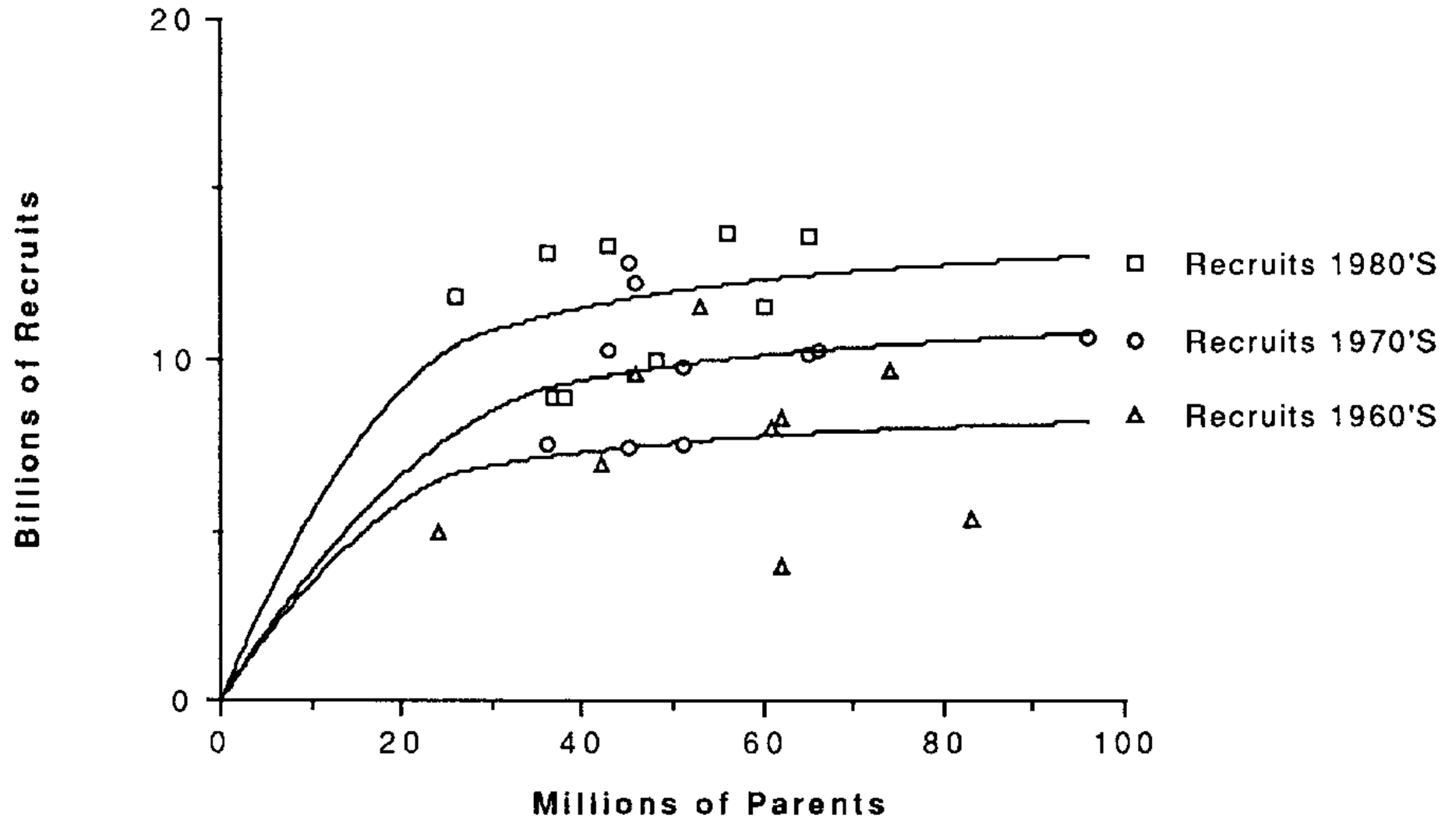
The Beverton-Holt stock recruitment model was used in the analysis because no decrease in recruitment was anticipated at high levels of parent stock. Data points were analyzed in 10-year increments to look for possible changes in the stock-recruitment relationship through time for each species.

Figure 9. Estimates of Brown Shrimp Parent Stocks from Fishery Independent Surveys.



It is likely that the stock-recruitment relationship for brown shrimp has changed through time (Figure 10). When all 28 data points are used in the model, a very poor fit ($r^2 = 0.02$) is the result. Yet, when the model is run for each decade

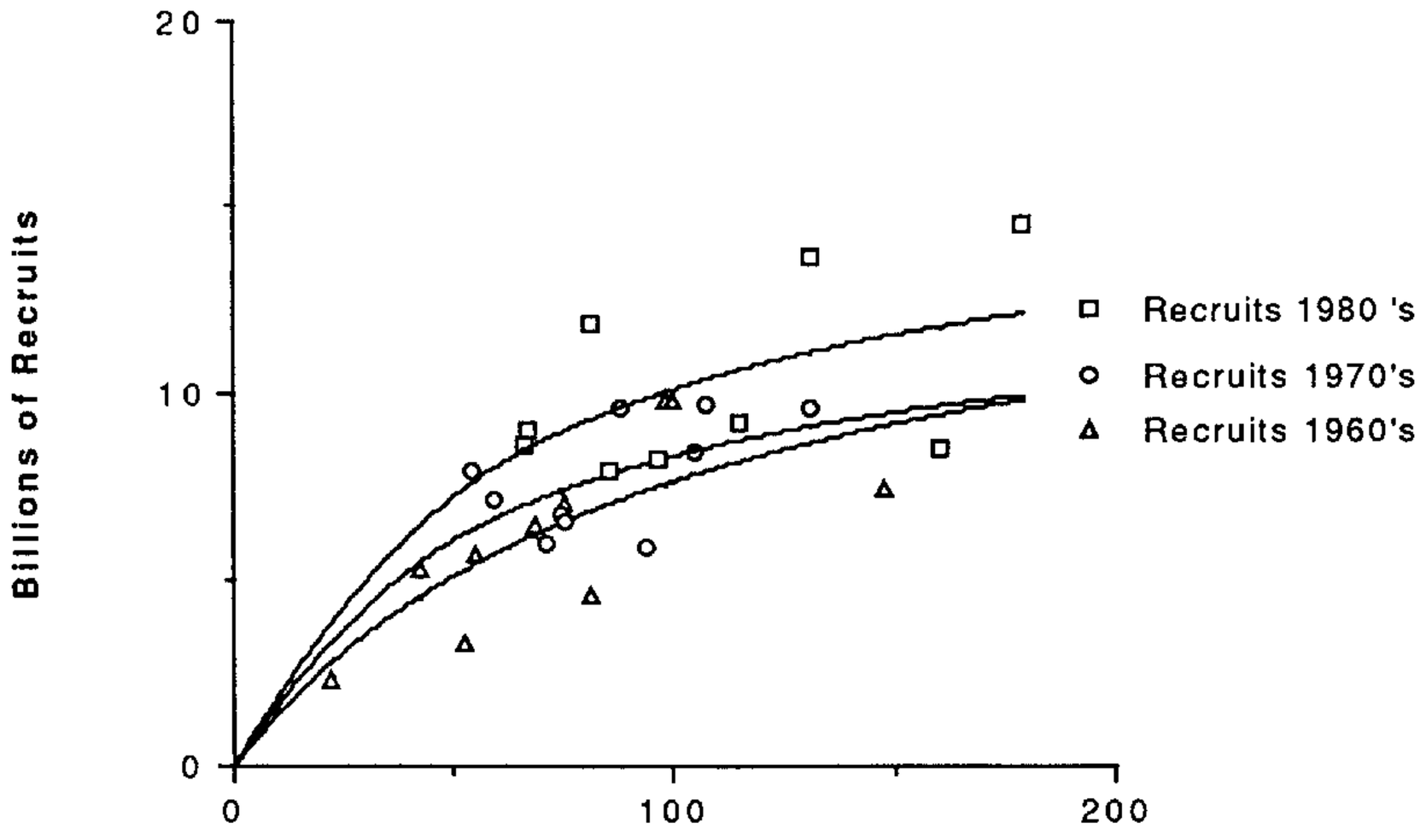
Figure 10. Beverton-Holt Recruitment Function for Brown Shrimp (October).



of data, better fits (r^2 = 0.25 - 0.29) are produced. However, none of the curve fits are significant. Thus, a stock-recruitment relationship for brown shrimp cannot be demonstrated with the data currently available.

White shrimp data also show that changes have occurred in the stock-recruitment relationship through time (Figure 11). Significant curve fits were obtained for each decade of data, as well as the overall set (r^2 = 0.53). However, even though an apparent stock-recruitment relationship was observed, factors unrelated to fishing could be generating the relationship.

Figure 11. Beverton-Holt Recruitment Function for White Shrimp (November).



Both pink shrimp stock-recruitment curves (Figures 12 and 13) indicate that no relationship is apparent with the data currently available. This was true for both the decade data sets and the overall composite set.

Figure 12. Beverton-Holt Recruitment Function for Pink Shrimp (Fall Months).

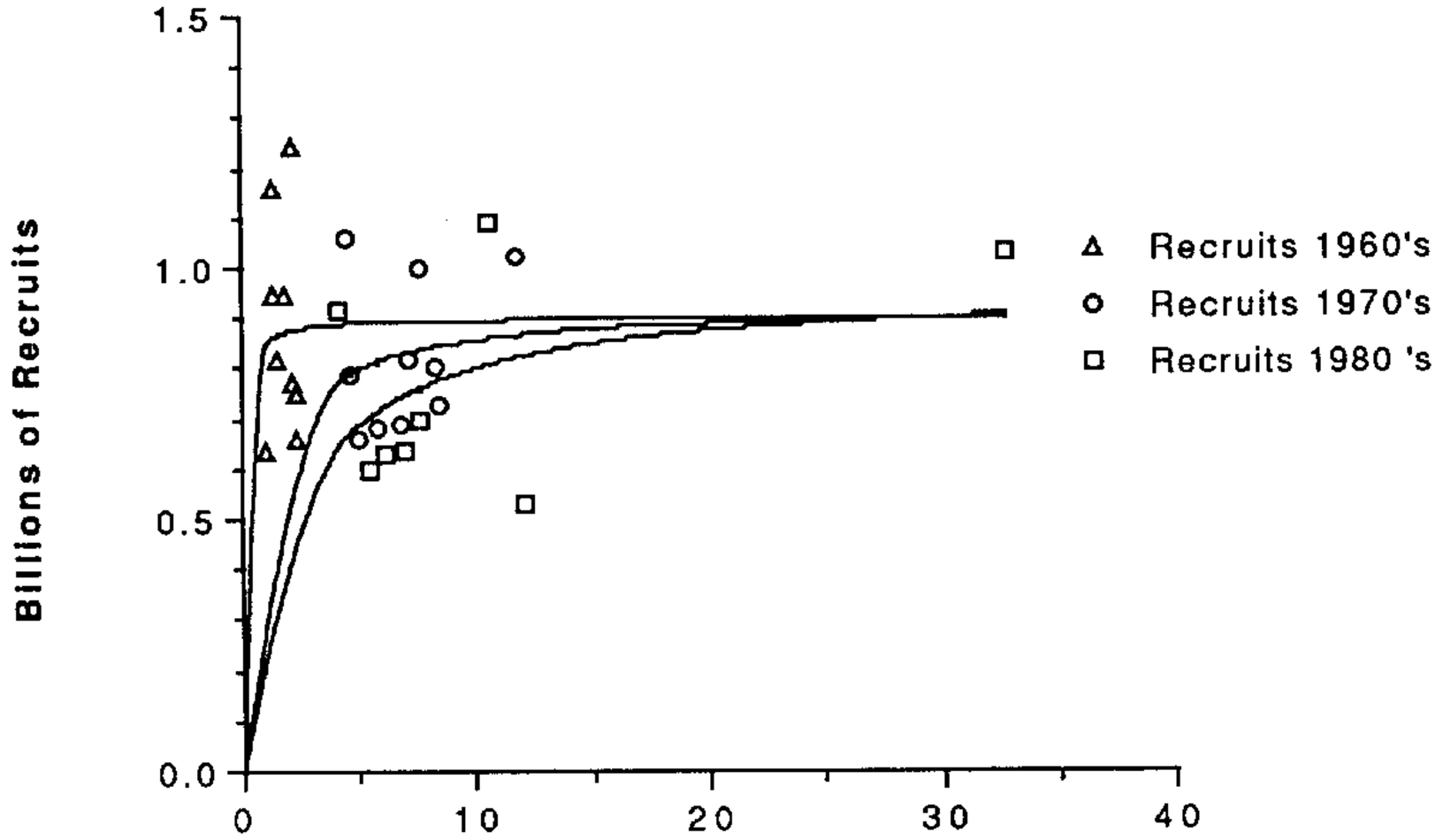
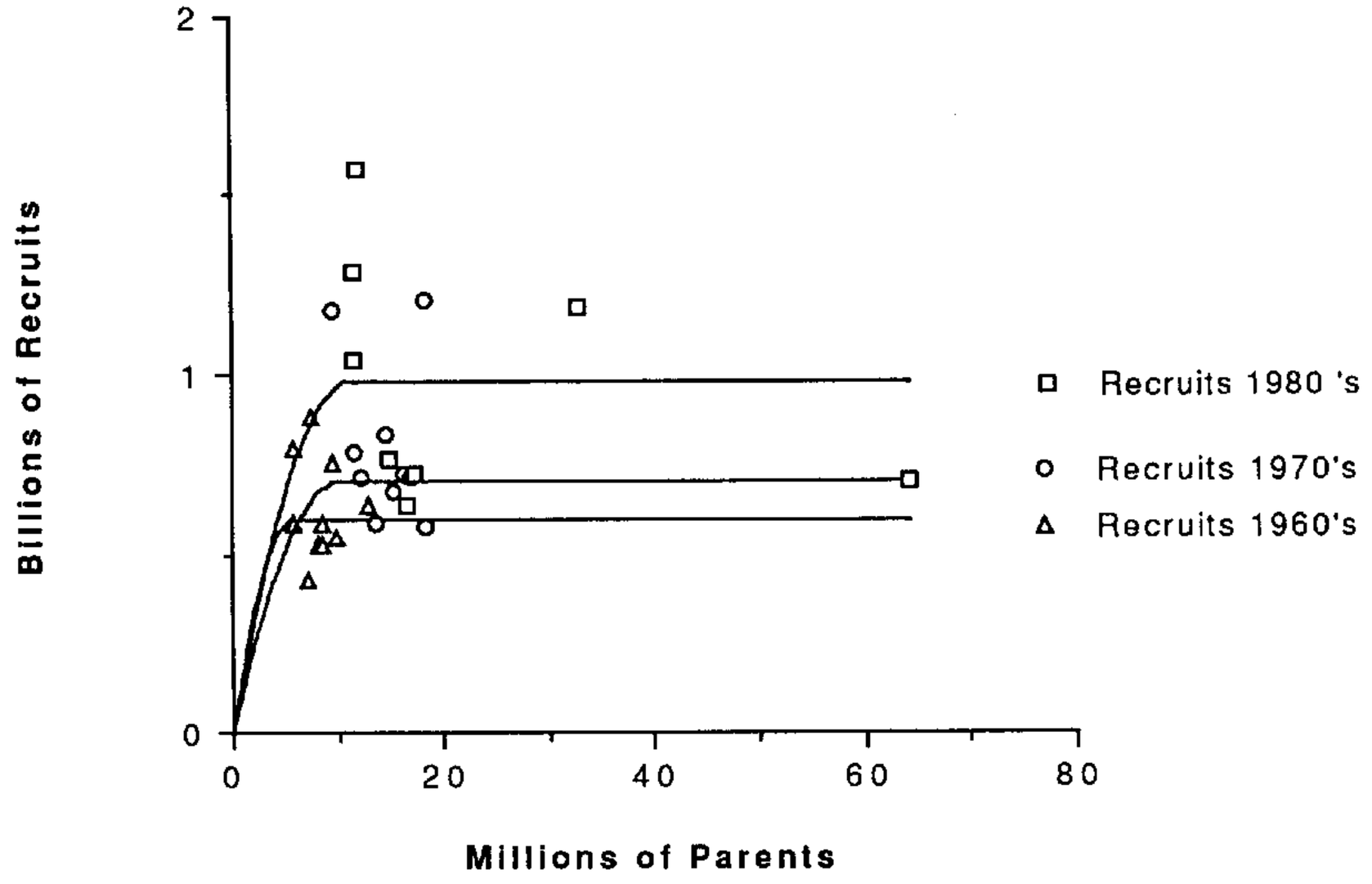


Figure 13. Beverton-Holt Recruitment Function for Pink Shrimp (Spring Months).



Yield Models

Ricker-type yield models were applied to the three shrimp species. All three models show the same basic trends, a flat curve with fishing mortality (F) values greater than 0.5 times the current value (Figures 14, 15, and 16). No further gain in yield will occur with further increases in fishing mortality under existing seasonal fishing levels (F at current value). The greatest potential exists for increasing yield by delaying fishing for two months on new recruits to the brown shrimp fishery.

Figure 14. Ricker Yield for Brown Shrimp.

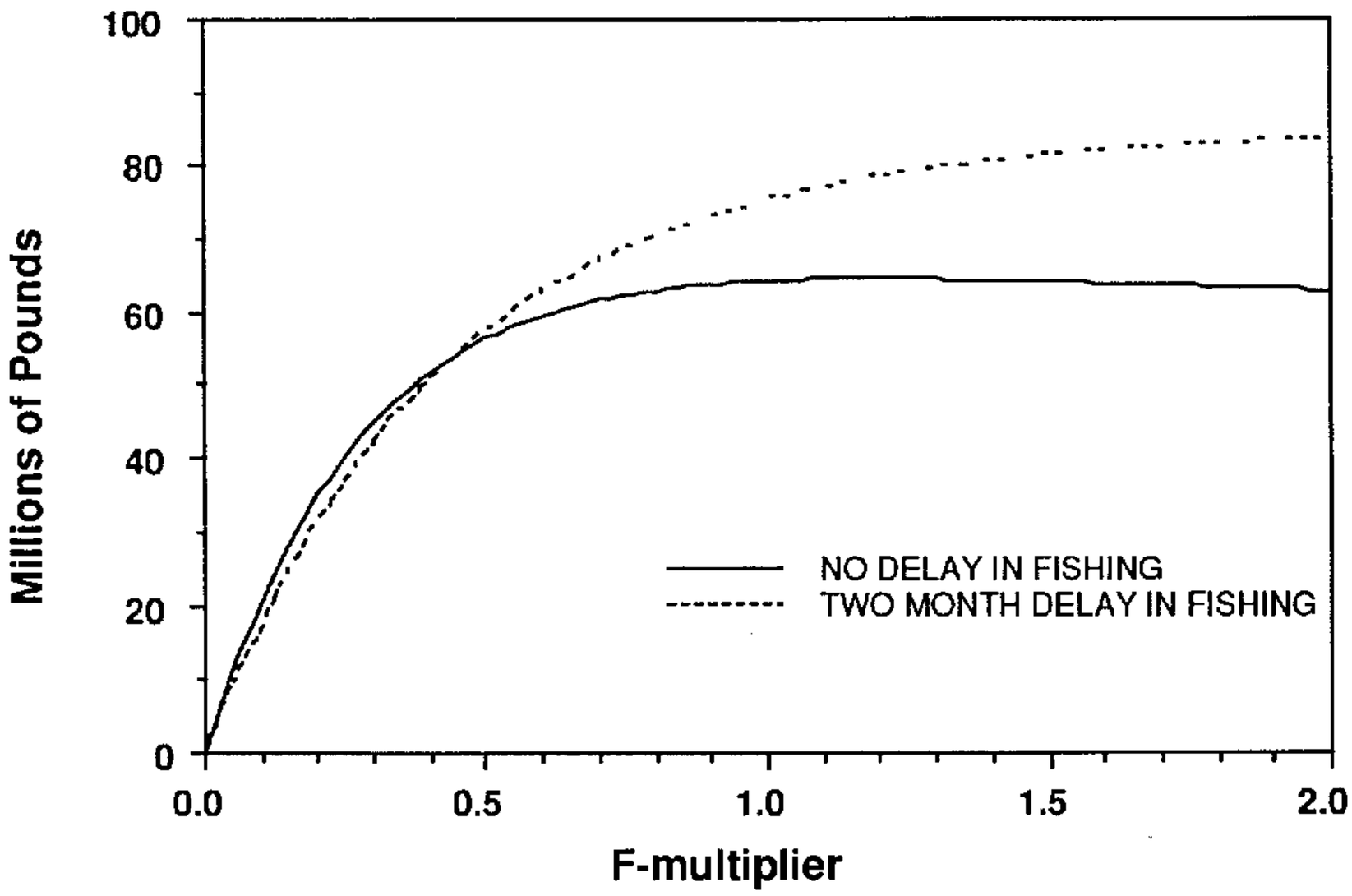


Figure 15. Ricker Yield for White Shrimp.

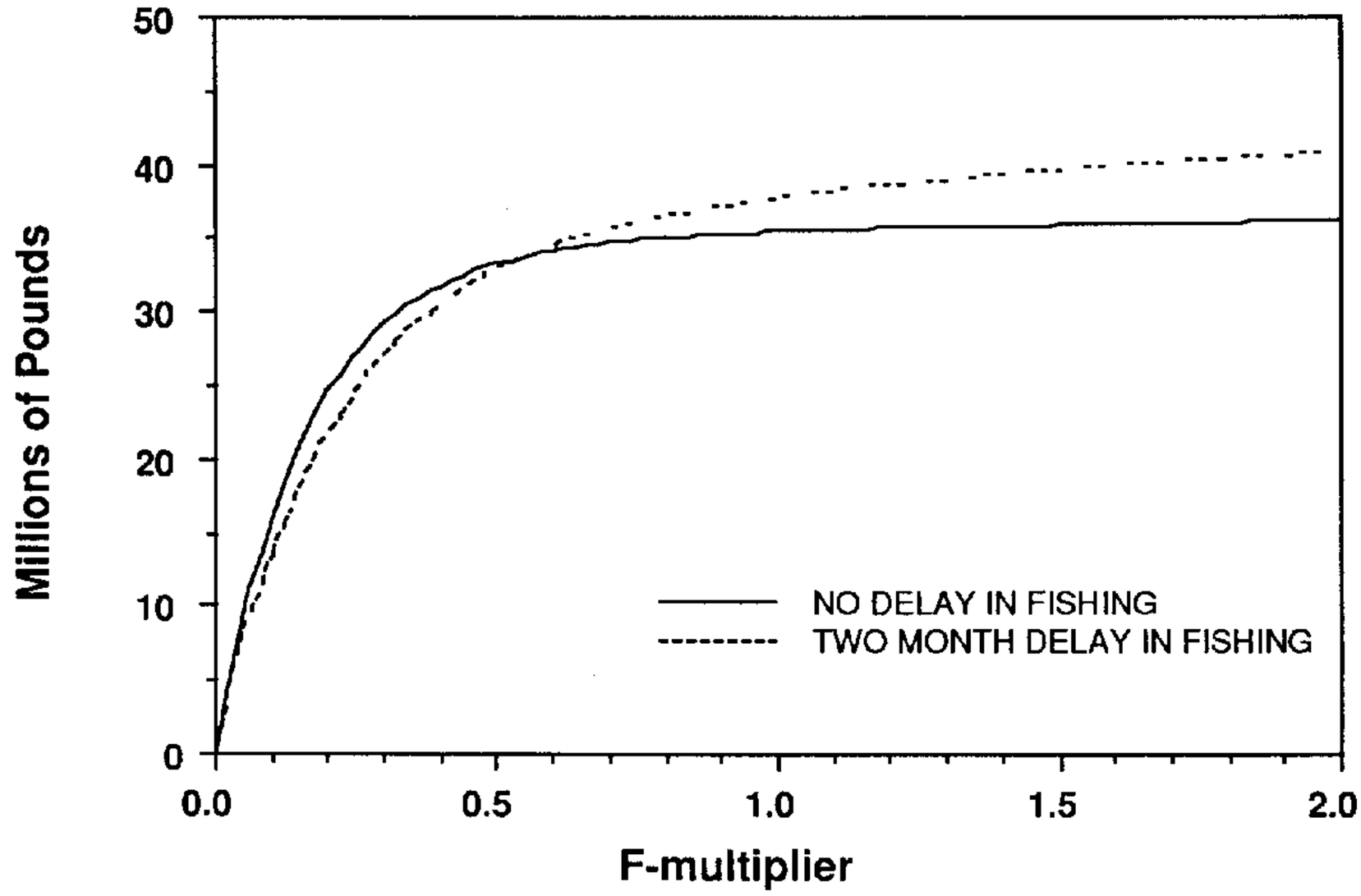
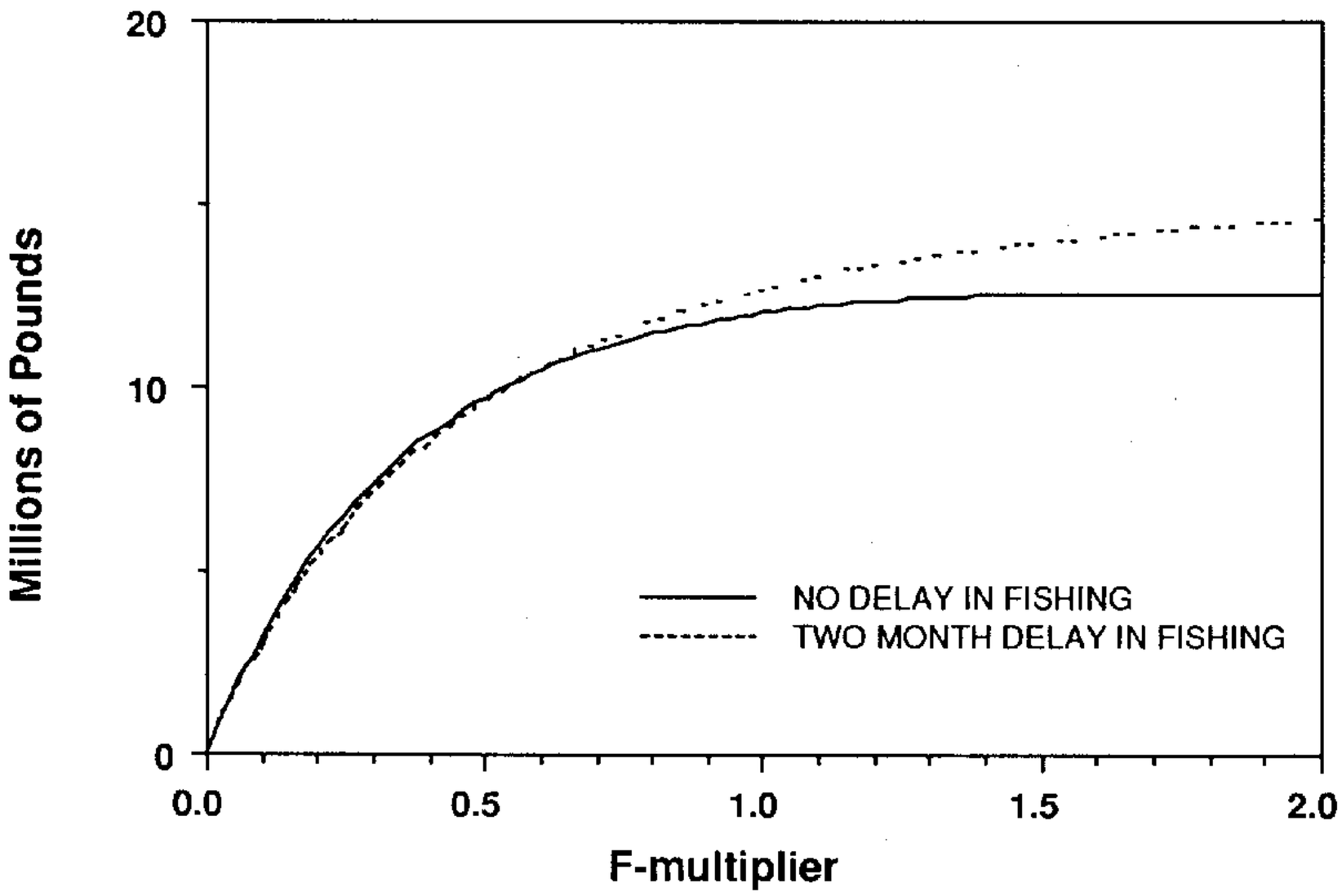


Figure 16. Ricker Yield for Pink Shrimp.



Forecast of Year-Class Strength

Currently, three prediction models are utilized to forecast shrimp catch from various areas in the Gulf of Mexico. Two brown shrimp predictions (one for offshore Texas and one for inshore/offshore Louisiana) are made each spring to serve the shrimpers in the areas. The Texas model utilizes mid April - mid June bait catch rate data from Galveston Bay to predict the catch off Texas for the June-May period of the upcoming season. The forecast has been quite dependable through the years (Table 1). The Louisiana model uses combined inshore and

Table 1. Galveston Bay Bait Shrimp Index values from 1960-1989 used to predict annual (July-June) Texas offshore brown shrimp catches. Average catch from 1960-1987 = 27.0 million pounds.

Year	Bait Index	Predicted catch in millions of pounds	Actual Catch in millions of pounds	Difference in millions of pounds
1960	53.6	29.1	34.5	+5.4
1961	20.8	20.0	13.2	-6.8
1962	26.1	21.5	17.3	-4.2
1963	53.0	29.0	24.6	-4.4
1964	30.2	22.6	18.6	-3.9
1965	41.0	25.6	26.5	+0.9
1966	-	-	31.5	-
1967	89.4	39.0	42.7	+3.7
1968	28.0	22.0	27.9	+5.9
1969	43.5	26.3	24.7	-1.6
1970	70.0	33.7	30.7	-3.0
1971	82.3	37.1	34.4	-2.6
1972	85.6	38.0	35.5	-2.5
1973	18.7	19.4	23.3	+3.9
1974	34.3	23.8	26.4	+2.6
1975	-	-	23.7	-
1976	34.2	23.8	25.7	+1.9
1977	58.5	30.5	34.4	+3.9
1978	40.5	25.5	27.7	+2.2
1979	-	-	16.5	-
1980	45.0	26.7	26.2	-0.5
1981	54.3	29.3	41.5	+12.2
1982	26.3	21.5	21.8	+0.3
1983	12.7	17.8	18.2	+0.4
1984	31.2	22.9	24.1	+1.2
1985	44.9*	29.0	30.4	+1.4
1986	37.2	25.3	27.1	+1.8
1987	38.7	25.7	27.2	+1.5
1988	41.9	25.9	27.2**	+1.3
1989	31.8	23.1	NA	NA

* Modified Bait Index Model used.
** Preliminary Data.

offshore catch in Louisiana (west of the Mississippi River) to predict the catch for the upcoming May through April period from the same area. It has also been quite dependable for the past 5 years that it has been used.

The third predictive model is used to forecast the catch of pink shrimp from the Tortugas grounds during the November through October period of a given year. It is different from the other two models in that it uses both catch and environmental data in the predictive process. Although it has been used the past two seasons, it has not been a very accurate estimator to date. A possible explanation is the apparent decline in the Tortugas fishery in the last few years.

SHRIMP HABITAT RESEARCH

FUNCTIONAL RELATIONSHIPS

Estuarine habitats, especially marshes, serve three major functions for developing shrimp: food, protection and space. The spatial function concerns density-dependent relationships of adjacent microhabitats (small scale) and large areas in the estuary (broad scale). Habitat use patterns of brown, white and pink shrimp between marsh and open water and along the salinity gradient differ in both spatial and seasonal distribution. Brown shrimp use the nursery mainly in the spring and are nearly always significantly more abundant in marsh than open water. But brown shrimp do not use areas where salinities are low (less than 2 ppt) for long periods (a month or longer), despite their ability to tolerate salinities near 0 ppt. Summer recruiting white shrimp are less affected by salinity or habitat differences than brown shrimp and their nursery habitat preferences are not well defined. The pink shrimp occurring as fall recruits

throughout the estuary are highly attracted to marsh habitat. Pink shrimp seem to use inundated marshes much the same as they do preferred seagrass habitats.

Shrimp distributions are related to salinity regimes and food abundance in estuaries. Higher abundances of foods, attracting higher numbers of shrimp, are associated with marshes and seagrasses and with mesohaline areas. Since food distributions are controlled to a great extent by salinity, an indirect relationship between shrimp abundance and salinity appears evident. In feeding experiments brown shrimp are extremely carnivorous, depleting infaunal animal foods at significantly higher rates than do white shrimp. Their preferred foods (amphipod and tanaid crustaceans) are most numerous in mesohaline and polyhaline areas. White shrimp, although readily feeding on infauna, are more herbivorous-detritivorous than brown shrimp. Small white shrimp are capable of attaining up to one-half of their growth on plant materials, whereas brown shrimp do not grow on plant diets alone. This difference may, in large degree, account for the ecological separation between the two species. Pink shrimp are typically associated with seagrasses and restricting food factors may be involved, but at this time they are unknown.

TORTUGAS PINK SHRIMP FISHERY DECLINE

Annual landings of pink shrimp from the Tortugas (Florida) fishery have declined from a long-term average of 10 million pounds to the current levels of 6-7 million pounds landed in 1986-1988. Catches have been below the long term average in almost every year since 1981. This may have resulted from habitat alterations to south Florida and Florida Bay nursery areas may, which have impacted on postlarval and juvenile pink shrimp populations. Freshwater inflow patterns have recently been altered and now include bursts of high freshwater

discharge that radically alter salinity regimes over short periods of time. Seagrass beds, the preferred habitat of postlarval and juvenile pink shrimp, have been undergoing an unprecedented die-off in western Florida Bay. There is also some concern that pesticide applications and runoff may have increased recently, and pink shrimp are sensitive to approved field application levels. Several production models have indicated that fresh water levels within, and thus flowing through, Everglades National Park are correlated with shrimp landings; these levels are controlled by water management structures. The individual and cumulative impacts of these habitat alterations on pink shrimp productivity need to be assessed, particularly since there is no present research on pink shrimp habitat use in Florida Bay.

HYPOTHESIS ON RECRUITMENT

Coastal subsidence and sea level rise in the northwestern Gulf is causing intertidal marshes to inundate longer and become more favorable for production of food for shrimp. It has also increased accessibility (more marsh edge), expanded estuarine area due to salt water intrusion, and provided more protection from predation. As a result, the nursery function of marshes has been greatly magnified, resulting in an expansion in recruitment to the fishery. Since continued subsidence will lead to marsh deterioration and ultimate loss of supporting wetlands, current high fishery yields may not be indefinitely sustainable.

SUMMARY OF RESULTS

BROWN SHRIMP FISHERY

1) Total annual Gulf of Mexico catch has increased from 40 million pounds in the early 1960's to almost 100 million pounds in the late 1980's.

2) The brown shrimp catch data are subject to some error due to occasional reporting of pink shrimp as brown shrimp. This error is not considered to be a significant source of bias in assessment analyses because of the relatively minor amounts of pink shrimp caught with brown shrimp.

3) Nominal fishing effort has tripled since 1960. It has increased from around 125 thousand days in 1985 to over 200 thousand days in 1987 and 1988.

4) Nominal inshore fishing effort increased from 13.8 thousand days in 1960 to 60.3 thousand days in 1987, while nominal offshore fishing effort has increased from 50.9 to 144.1 thousand days during the same period.

5) Annual CPUE has fluctuated around 600 pounds per day for the past 25 years. The decline since 1985 is similar to other declines in the 1960's and 1970's.

6) The average size of landed brown shrimp has decreased from 50 count in 1960 to 80 count in 1988.

7) Best estimates of instantaneous natural mortality rates range from 0.20-0.35 on a monthly basis, and the midpoint of 0.275 was selected for use in VPA analysis.

8) There is growth overfishing in the brown shrimp fishery. (Growth overfishing is defined as the condition which exists when the age at entry into the fishery is less than that which will support maximum yield.)

9) An increase in fishing effort will not increase long-term yield. However, increased age at entry, with or without a change in fishing effort, will increase yield.

10) Recruitment to the fishery has increased since 1960, and was at or near historic highs for 1985-1987, based on VPA analysis.

11) Changes in recruitment have varied geographically. There has been a continuous increase in recruitment in Louisiana west of the Mississippi River. East of the Mississippi River and in Texas the recruitment appears to have increased to a lesser extent.

12) Estuarine habitat is critical to survival and recruitment of brown shrimp juveniles. There appears to have been a temporary gain, during the last several years, in shrimp nursery habitats associated with coastal subsidence and sea level rise. This could have contributed to recent increases in recruitment.

13) It was the consensus of the working group that there appears to be an increasing trend in brown shrimp recruitment during the 28-year period. This increase appears related to an overall increase in nursery areas due, at least in part, to subsidence and sea level rise in the west-central Gulf of Mexico.

14) Concern was expressed that declines in productivity and recruitment could occur if an unspecified threshold level in the coastal subsidence and sea level rise is exceeded. This, coupled with continued high fishing mortality rates, could reduce spawning stock size to a level where recruitment overfishing could occur.

15) Percentage of recruits captured has increased from about 35 to 50 since 1960, based on VPA analysis.

16) Parent stock size is unchanged or has decreased slightly over time, based on VPA analysis and SEAMAP surveys.

17) The increase in percentage recruits captured with an unchanging stock size is not contradictory and is a result of the increase in recruitment.

18) Unreported catch, in most cases, affects the results of VPA and other models.

19) We cannot demonstrate a stock-recruitment relationship for brown shrimp with the data currently available; and there is no evidence to suggest a decline in recruitment due to insufficient parent stock.

1) Total annual Gulf of Mexico catch has increased from 20 million pounds in the early 1960's to over 60 million pounds in the late 1980's.

2) Nominal fishing effort has increased from 40 thousand days in 1960 to 200 thousand days in 1987. From 1985 to 1987, effort has almost doubled.

3) Nominal inshore fishing effort increased from 14.8 thousand days in 1960 to 78.9 thousand days in 1987, while nominal offshore fishing effort has increased from 24.3 to 109.2 thousand days during the same period.

4) Annual CPUE has fluctuated around 400 pounds per day. The decline since 1985 is similar to other declines in the 1960's and 1970's.

5) The average size of landed white shrimp has decreased from 45 count in 1960 to 70 count in 1988.

6) Growth rates are temperature dependent. Growth rates appear to be low during wintertime, although growth data are sparse for November to February. A dramatic increase in growth of overwintering juveniles occurs with spring warming.

7) Best estimates of instantaneous natural mortality rates range from 0.20-0.35 on a monthly basis, and the midpoint of 0.275 was selected

for use in VPA analysis. Due to a shortage of the necessary data, the estimates for the winter months are poor.

8) There is growth overfishing in the white shrimp fishery. (Growth overfishing is defined as the condition which exists when the age at entry into the fishery is less than that which will support maximum yield.)

9) An increase in fishing effort will not increase long-term yield. Delaying the start of the fishing season from August until October would result in a 5% increase in yield.

10) Recruitment to the fishery has increased since 1960. The greatest recruitment occurred during 1984, 1985 and 1986. Recruitment declined in 1987, but was still within the historical range.

11) Changes in recruitment have varied geographically. There has been a continuous increase in Louisiana west of the Mississippi River. East of the Mississippi River and in Texas, recruitment appears to have been stable.

12) Estuarine habitat is critical to survival and recruitment of white shrimp juveniles. There appears to have been a temporary gain, during the last several years, in shrimp nursery habitats associated with coastal subsidence and sea level rise. This could have contributed to recent increases in recruitment. If critical habitat is not maintained, gradual or precipitous declines in recruitment and yields may be anticipated.

13) Percentage of recruits captured has increased from 35 to 50 since 1960. The percentage for Texas has shown a steady increase since 1960, whereas for Louisiana it has been relatively stable.

14) Parent stock size is unchanged over time based on VPA analysis.

15) The increase in percentage recruits captured coupled with an unchanging stock size is not contradictory and is a result of the increase in recruitment.

16) An apparent stock-recruitment relationship was observed, indicating that exploitation levels are now within a range at which recruitment overfishing could occur. It was noted, however, that factors unrelated to fishing could be creating the relationship, and accordingly firm conclusions could not be reached.

PINK SHRIMP FISHERY

1) Total annual Gulf of Mexico catch has been stable at around 14 million pounds since early 1960's. The Tortugas catch was stable at around 10 million pounds until gradual decline began around 1981. Lowest catch for the Tortugas grounds (6 million pounds) occurred in 1986.

2) The average catch of 14 million pounds has been maintained through 1985 by an expansion of the fishery to waters off west Florida, north of the Tortugas grounds. From 1986 to the present, landings have declined in the entire Gulf of Mexico.

3) Pink shrimp catches for the northern Gulf of Mexico are under-reported due to misreporting as brown shrimp.

4) Nominal fishing effort has been relatively stable at about 20 thousand days since 1960.

5) Annual CPUE has been relatively stable from 1960 through 1985, but declined to an all-time low below 400 pounds per day in 1986 and 1987. The Tortugas CPUE was also at an all-time low of between 435 and 500 pounds per day in 1986-1987.

6) Historically, monthly Gulf of Mexico CPUE has shown a peak during the winter, but no peak was evident in either 1986-1987 or 1987-1988.

7) The best estimate of the monthly instantaneous natural mortality rates, derived from tagging data, is 0.3.

8) Recruitment occurs year round with two peaks each year, one in fall and one in spring.

9) Annual recruitment to the fishery was relatively stable from 1960 to the mid 1970's, with considerable variation in subsequent years. The lowest recruitment occurred in 1986, and the 1987 value was also low. Both fall and spring recruitment periods have experienced below average recruitment since the spring of 1986.

10) Percentage of recruits captured has averaged around 45.

11) An increase in fishing effort will not increase the long-term yield. However, increase age at entry will increase yield.

12) We cannot demonstrate a stock recruitment relationship for pink shrimp with the data currently available; there is no evidence to suggest a decline in recruitment due to insufficient parent stock.

13) The number of shrimp per pound has varied over time. When the "toe of boot area" has been opened in the 1980's, the number of shrimp per pound has increased; when the area has been closed the number of shrimp per pound has decreased.

14) Pink shrimp are estuarine dependent and are affected by acreage of seagrass beds and freshwater flow patterns. Florida Bay, the principal Tortugas pink shrimp nursery, is experiencing seagrass die-off, freshwater inflow manipulations, and possibly increased pesticide usage, all of which may have influenced the decline of the Tortugas pink shrimp landings during the 1980's.

RECOMMENDATIONS

Following are lists of recommendations. The first list is applicable to each of the shrimp species and is arranged in order of highest priority. Although members of the workshop were asked to rate each recommendation as high, medium or low priority, none were rated low; the rating is given after each recommendation in parentheses. It should also be noted that many of these recommendations will require additional funding.

GENERIC RECOMMENDATIONS

1) Further research which quantifies the relationship between shrimp recruitment and habitat should be conducted, specifically in the northern Gulf of Mexico. This research would include, but not be restricted to, studies of the effect of subsidence on marshland in all nursery areas and studies of the effects of reduced seagrass acreage, increased freshwater discharges, and increased use of pesticides near the Tortugas Grounds. This task would require the development of a major issue paper and a new funding initiative. (High Priority)

2) Fishery statistics data should be made available to managers within 3 months, so that they can make decisions in a timely manner. This would cost an additional 2 man years. (High Priority)

3) A greater proportion of the catch should be reported and the remainder should be statistically estimated, especially for peak seasons and areas, on a continuing basis. The costs associated with this task would

be extremely expensive and judgements should be based on potential value of changing the status quo. (High Priority)

4) Effort should be standardized for brown, white and pink shrimp. SEFC must update the vessel operating units file from 1981 to present. (High Priority)

5) State and Federal efforts to control freshwater introduction into marsh habitats should be supported to develop appropriate legislation. This task would have a minimal cost associated with it. (Medium Priority)

6) After standardizing effort, the instantaneous natural mortality rates of brown, white and pink shrimp should be re-estimated. The cost of this task would be minimal. (Medium Priority)

7) Work should continue on the stock-recruitment relationships incorporating environmental factors. The cost of this task would be minimal. (Medium Priority)

RECOMMENDATIONS FOR BROWN SHRIMP FISHERY

1) The possibility that current recruitment of brown shrimp is linked to expansion of shrimp nursery habitats due to sea level rise, subsidence and marsh deterioration, and that this process has stimulated a short-term increase in recruitment from 1960 to the present, should be recognized. If this link exists, and if critical habitat is not maintained, gradual or precipitous declines in recruitment and yields should be

anticipated. Highest priority should be given to research which quantifies these relationships. This task is part of the generic recommendation #1 and would require a new funding initiative. (High Priority)

2) Data on good, normal and poor years of climatic conditions for Louisiana should be compared with CPUE and habitat data. The costs associated with this task would be minimal. (Medium Priority).

3) Evaluation of present postlarval and juvenile data catch methodologies should be undertaken to determine variability of methods so a postlarval index can be developed and used to compare with parent stock values. Costs and benefits for this task are unknown. (Medium Priority)

RECOMMENDATIONS FOR WHITE SHRIMP FISHERY

1) The possibility that current recruitment of white shrimp is linked to expansion of shrimp nursery habitats due to sea level rise, subsidence and marsh deterioration, and that this process has stimulated a short-term increase in recruitment from 1960 to the present, should be recognized. If this link exists, and if critical habitat is not maintained, gradual or precipitous declines in recruitment and yields should be anticipated. Studies should be conducted to delineate critical shrimp habitat and the relationship between this habitat and recruitment. This task is part of the generic recommendation #1 and would require a new funding initiative. (High Priority)

2) Evidence was presented indicating the potential for a stronger stock-recruitment relationship for white shrimp than for brown or pink

shrimp. If the stock-recruitment relationship suggested by the data is genuine, recruitment overfishing is now occurring. However, it was emphasized that trends in the data unrelated to fishing could be biasing this interpretation. For example, environmental changes resulting in a general increase in recruitment and spawning stock size throughout the time series could be contributing to the shape of the curve. The lowest parent stocks occurred early in the 1960's, when fishing effort was considerably lower than it is now. On balance, the group believes that recruitment has not been reduced due to insufficient parent stock. Studies should be undertaken to clarify the nature of the stock-recruitment relationship. The costs for this task would be minimal. (High Priority)

RECOMMENDATIONS FOR PINK SHRIMP

1) Pink shrimp production in the Dry Tortugas is correlated with freshwater discharge into the Everglades and with seagrass bed acreage in that area. Recently, pink shrimp landings have undergone an unpredicted 5-year decline in the Tortugas fishery from a previously stable average of 10 million pounds (1960-1980) to low of 6 million pounds (1986). During this same time period, there have been non-traditional manipulations of the patterns of freshwater discharge and wide-scale, and apparently unprecedented, seagrass bed die backs in the Everglades. If these modifications of the nursery area are causal and uncorrected, further reductions can be anticipated in the Tortugas fishery. Field and habitat studies should be conducted to determine causative factors of the apparent decline in the Tortugas pink shrimp stock. The recruitment to the Tortugas Grounds should be compared to water discharges

in the nursery areas near these grounds. Other environmental factors, such as seagrass bed acreage and use of pesticides, should also be evaluated. This task is part of the generic recommendation #1 and would require a new funding initiative. (High Priority)

2) Pink shrimp should be identified in the catches, rather than reported as other species. This task would be very expensive and benefits would depend on results. (Medium Priority)

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APPENDIX

ATTENDEES OF THE SHRIMP STOCK ASSESSMENT WORKSHOP

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Dr. William Bayliff, Inter-American Tropical Tuna Com. LaJolla, CA

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