

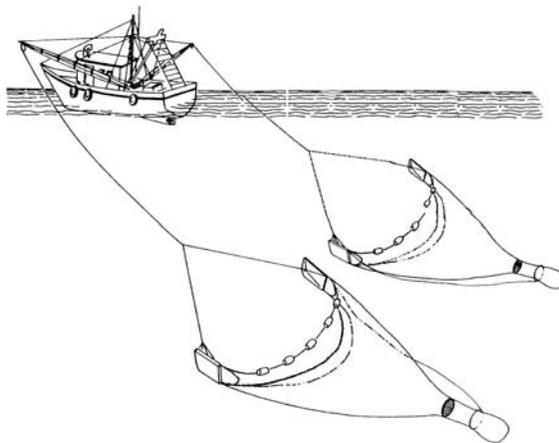


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A Biological Review of the Tortugas Pink Shrimp Fishery 1960 through 2007

By

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Introduction

This document outlines the commercial catch history of the Florida Tortugas grounds pink shrimp fishery, summarizing records dating from 1960 through 2007. These fishing grounds are habitats located off of the western coast of the state of Florida and consist of a small group of islands and reefs around which are habitats favorable for pink shrimp survival and conducive to commercial fishing operations (Fig. 1) (Iversen *et. al.* 1960). This fishery has been studied extensively after the discovery of commercially harvestable populations of pink shrimp (*Penaeus duorarum*) in the late 1940's (Iversen *et. al.* 1960). Subsequent to this discovery, during the 1950's concerns over the potential for overfishing were expressed by Florida researchers as well as legislatures (Iversen *et. al.* 1960). These concerns were mitigated in part by the establishment of sanctuary habitats which were set aside and closed to fishing for specified periods, thus allowing for not only the protection of pink shrimp stocks, but also increased fishery production upon resumption of fishing operations (see Klima *et. al.* 1986, Klima and Patella 1985, and references contained therein for a synopsis of the fishery's management history).

The collection of commercial fishing statistics was also initiated in the 1950s during the fishery's development (Iversen *et. al.* 1960). These statistics have been used to elucidate trends and changes in the fishery. While the currently available statistics are fishery dependent, they do illustrate a population's behavior when data sets are viewed in conjunction with one another. For example, catch and effort data can be used to develop catch per unit effort (CPUE) trends, which not only show the fishing efficiency of the fleet, but also the availability of the shrimp to harvest, and hence may be used as an index of the population's abundance. These catch statistics are used by National Marine Fisheries Service (NMFS) scientists in the development of stock assessment models, estimating parent stock size and annual recruitment, which are then used as indices to gauge the "health" of a population.

While the use of fishery independent data would be useful for tuning the assessment of a given stock, no independent data are currently available for the Tortugas pink shrimp fishery. However, the availability of almost 50 years of catch data have led to the development of several robust stock assessment models which have

successfully measured the performance and “health” of the fishery (Iversen *et al.* 1960, Klima *et al.* 1986, Nance and Patella 1989, Nance *et al.* 2008). Upon completion of the annual pink shrimp stock assessments, NMFS scientists present the Gulf of Mexico Fisheries Management Council with stock assessments results and reports. The Council uses these assessment reports to evaluate the health and status of this fishery stock as well as to determine if any management measures need to be implemented. The results of these assessments are summarized in this report in an attempt to describe and explain recent trends and changes in the Florida and Tortugas pink shrimp fishery.

Methods

As noted, records of the commercial harvest of pink shrimp have been collected for several decades, beginning in the 1950’s (Iversen *et al.* 1960). Commercial fishery statistics of pink shrimp catch (both annual and biological years), shrimp size distributions, monthly shrimp catch, fishing effort, and catch per unit effort (CPUE) for annual and biological years are collected using a variety of methods.

National Marine Fisheries Service and state port agents record the daily operations and shrimp production of the commercial fisheries fleet operating within the boundaries of the East coast of Florida and the Tortugas fishing grounds. To assist in the assignment of fishing locations, scientists have subdivided the U.S. Gulf of Mexico into 21 statistical sub-areas. These subdivisions are used by the port agents to assign the location of catches and fishing effort expended by the shrimp fleet on a trip by trip basis. The East coast of Florida consists of sub-areas 1-9, while the Tortugas fishing grounds are located within sub-areas 1-3 (Fig. 1). Port agents randomly visit fishing ports with the goal of interviewing fishing captains and/or crews to record data pertaining to the number of days fished (effort); the location and depth fished, by statistical sub-area; the species specific pounds and sizes of shrimp landed; as well as the commercial value of the catch for each individual trip that a vessel has completed (Nance *et al.* 1989). These data are entered into a data base maintained and managed by fisheries staff under the direction of the NMFS Southeast Fisheries Science Center, located in Miami, Florida.

Upon the completion of the collection of annual fishing data, the data are then used in shrimp stock assessment models. The primary model used in our pink shrimp assessments is a virtual population analysis (VPA) (Ricker 1975). This analysis is used to calculate the number of parents, i.e., parent stock, which in turn is used as an index of the populations "health." See Nichols (1984) for a complete description of the parameters and the VPA model used in the gulf shrimp assessments and Nance *et. al.* (2008) for a detailed description of the shrimp fishery effort calculations used in stock assessments.

Results and Discussion

Fishing Effort

Fishing effort in the Tortugas, as measured in thousands of 24 hour days fished, was at constant level from 1960 through the mid-1980's. This stable period of fishing effort has been used as long term average, against which other later years are compared. Effort values started to decline during the late 1980's to the 1990's, especially during biological years 1988-1992 (July-June). Fishing effort in the Tortugas during 1994 was about 13 thousand days fished (Fig. 2). While effort in the Tortugas increased in 1993 and 1994, it still remained below the 1960-1985 long term average (16.3 thousand days \pm 2.13 thousand days fished). Fishing effort spiked during 1995 to about 25 thousand days fished. However, effort decreased during 1996, to around 17 thousand days of fishing and remained there during 1997. Fishing effort in the Tortugas has been below the 1996 level of 17 thousand days fished ever since. The effort levels reached during the mid-1990s are all above the historical average for the area. But in 1998 effort declined to about 14 thousand days of fishing, and declined again in 1999 to 11 thousand days of fishing. Effort increased in 2000 and 2001 to approximately 13 and 14 thousand days fished respectively; in 2002 and 2003 effort was about 13 thousand days fished. The decline in effort accelerated through 2004 and 2005 when only 9 and 7 thousand days respectively were fished. Effort during 2006 continued to decline to only 6.0 and 3.0 thousand days fished for the western coast of Florida, and the Tortugas, respectively (Fig. 2). These declining effort levels are most likely due to adverse economic conditions the fishery community is experiencing during this time

period (Travis and Griffin 2004). Several factors have been attributed to the decline in effort, including the devastation caused by hurricanes Katrina and Rita in 2005, an increase in low cost shrimp imports onto the American market (Haby *et. al.* 2003), and an increase in fuel prices (Haby *et. al.* 2003).

Annual Shrimp Catch

From calendar year 1960 through 2007, the Florida pink shrimp catch averaged 11.2 million pounds (\pm 921 thousand pounds, 95% confidence interval) (Fig. 3). Record numbers of pink shrimp were landed in 1996 (18.9 million pounds), yet catch subsequently declined in 1997, and have remained below or near the long term mean (Fig. 3). Until the year 2004 there was a slight trend of increasing pink shrimp catch. However, since 2004 catch has declined to 8 million, 7.8 million, and 3.4 million pounds of tails in 2005, 2006 and 2007 respectively.

When pink shrimp catch is plotted for the nine statistical sub-areas off the Western coast of Florida, we can see that the Tortugas grounds (sub-areas 1-3) account for the majority of the shrimp caught from this region of the Gulf (Fig. 4). While the volume of shrimp harvested from sub-areas 4-5 and 6-9 is less than the Tortugas grounds, the general patterns in catch are comparable. Similar to the catch of pink shrimp of the entire Western portion of Florida, the catch from the Tortugas has remained steady through the mid-1980s to the late-1990s. However, Tortugas catch for calendar year 2005, 2006, and 2007 decreased to about 5.4, 5.0, and 2.0 million pounds respectively (Fig. 4).

Annual catch (*i.e.*, calendar year) on the Tortugas grounds (sub-areas 1-3) remained quite stable for 4 years (1989-1992), while catch from the other sub-areas off of Florida decreased during this same period. During 1993, catch from sub-areas 1-3 increased, while catch from the other sub-areas remained stable. In 1994 the catch from sub-areas 1-3 remained near the 1993 level, but an increase was noted in sub-areas 6-9 (Fig. 4). In 1995 catch increased in all of the statistical sub-areas. Catch from Western Florida equaled 13.7 million pounds in 1995; slightly above the historical average for this statistical zone combination. In 1996 the total Florida catch was 18.9 million pounds, which is the largest harvest recorded since 1960. Similar to 1995, all statistical-areas off the Florida coast showed increases in catch during 1996. In 1997

the overall Florida catch declined to 12.2 million pounds. This decrease was due to a decline in the Tortugas catch, while sub-areas 4-5 and 6-9 remained stationary. In 1998, total Florida catch was 16.6 million pounds, with increased catches in all areas. The most notable increase in catch for this year was from the Tortugas ground, while the other sub-areas increased slightly. In 1999 the total Florida catch was only 7.7 million pounds. This represented a dramatic decline in catch for the Florida area, with major decreases being noted in all statistical areas in Florida. The decrease of catch for Florida continued into 2000 with only 6.9 million pounds reported for the year. Prior to that year, only the catch levels experienced in 1991 and 1992 were lower. The decrease in catch was experienced in all the statistical areas in Florida. The catch for Florida in 2001 increased to 9.2 million pounds, with most sub-areas off Florida remaining stable or recording a slight increase. However, total Florida catch decreased again beginning in 2005 and 2006 to 8.0 and 7.8 million pounds respectively, continuing to decline in 2007 to 3.4 million pounds when compared to the 2004 catch of 9.4 million pounds. As noted earlier, catch from the Tortugas fishing grounds was approximately 5.4 million pounds in 2005 and 5.0 million pounds in 2006, decreasing to only 2.0 million pounds of tails in recorded in 2007.

Biological Year Shrimp Catch

During biological year 1986 (July 1986-June 1987) a 30% decrease in catch from the long term average was observed on the Tortugas grounds, with 25% less catch from the long-term average of 12.2 million pounds observed for the entire pink shrimp fishery off of the west coast of Florida (Fig. 5). Although an increase in catch from the Tortugas grounds was noted in biological year 1987 (7.40 million pounds), the next several fishing seasons produced very poor pink shrimp yield. Biological year 1989 produced the second lowest yield of Tortugas pink shrimp (4.3 million pounds) since current records began in 1960, with biological year 1990 having the third lowest level (4.6 million pounds). From 1986 through 1991, catch averaged only 5.30 million pounds \pm 1.15 million pounds; a 46% decrease in yield compared to pre-1985 conditions. Although still below the pre-1985 average, catches during 1992 (6.3 million pounds), 1993 (8.3 million pounds), and 1994 (8.0 million pounds) were greater than they had been for several years. The catch of 13.2 million pounds in biological year 1995 represented the first

year since the decrease in biological year 1986 in which catch was above average. The Tortugas catch in biological year 1996 was 8.7 million pounds, while the catch in biological year 1997 was 7.9 million pounds. Both of these values were slightly below the historical average for the Tortugas area. The catch in biological year 1998 was 7.3 million pounds, with biological year 1999 producing the lowest yield since 1960 with 4.0 million pounds caught. This was the fourth straight year recording a decrease in catch for this area. Although still below average, for biological years 2000, 2001, and 2002 catches increased to 6.4, 6.8, and 6.7 million pounds, respectively. However, catch from the Tortugas for biological year 2003 declined to 6.1 million pounds. Catch in the Tortugas fishing grounds declined again in 2004 to 6.0 million pounds, yet catch for the entire Western coast of Florida (statistical areas 1-9) increased to 8.9 million pounds. Tortugas pink shrimp catch in biological year 2005 remained near the 2004 level, with 5.6 million pounds being caught, while catch from statistical areas 1-9 increased slightly to 9.0 million pounds (Fig. 5). Catch in biological year 2006 is the lowest level on record. The west coast of Florida, recorded a catch of only 4.1 million pounds, while Tortugas fishermen caught about 2.4 million pounds of tails during biological year 2006.

Catches have been below the long term average in the last two decades; with the past suspected reasons being due to habitat degradation in Florida Bay (Robblee *et. al.* 1991) and increased freshwater influxes (Sheridan 1996). The decline in Florida Bay habitat's conducive to pink shrimp survival and growth could have devastating consequences to Gulf of Mexico pink shrimp populations as this habitat serves as the primary nursery area for this gulf shrimp species (Sheridan 1996). However, in recent years the primary suspected reason for lower harvests is the low level of effort being expended on this fishery. This level of effort and catch is the lowest on record (Fig. 6) and it is intuitive that the low catch is the result of the low effort.

Size Distributions during Calendar Years

The size distributions of shrimp caught from the Tortugas grounds have been variable over the recorded time period. Small shrimp, *i.e.*, those greater than 67 count/pound were increasingly represented in the catch from 1994-1995 and 1998 when compared to earlier and more recent catch records (Fig. 7). The increases in the 1994 and 1995 catch were primarily due to the increase in catch of the smaller size category

of shrimp (Fig. 8). In 1997 a general decline in shrimp harvest was noted, with the decrease in catch coming from all of the shrimp size categories (Figs. 7 and 8). A small percentage of the shrimp landed in 1997 were represented by the smallest size category. The increase in shrimp catch in 1998 was primarily due to an increase in the numbers of smaller sized shrimp in the 51-67 and >67 count/pound categories. Declines in catch for the years 1999-2000 was primarily due to fewer small category sized shrimp being caught (Figs. 7 and 8). An increase in calendar year catch was noted in 2001-04 relative to the previous two years. However, as mentioned previously, catches in 2005, 2006, and 2007 have declined. The decrease in Tortugas pink shrimp catch during 2005 was due to a lower yield of the 41-50 and >67 count shrimp and a lower catch of 51-67 and >67 sized shrimp in 2006 (Figs. 7 and 8). In 2007 there was a decrease in all of the sizes of shrimp caught from the Tortugas grounds. However, within the catch, sizes 15-20 and 41-50 increased relative to the other sizes when compared to 2006 (Figs. 7 and 8).

Monthly Shrimp Catch during Calendar Years

The monthly patterns of shrimp catch for sub-areas 1-3 from January 1989 through December 2007 were compared with historical monthly averages derived from the 1960-1985 catch (Fig. 9). During the time period from 1989-1992 monthly catch was below the long-term average (Fig. 9). Beginning in 1996 and continuing through 2005, catch fluctuated from near to slightly below the long-term average. In 1997, monthly catch was below the historical average for most of the time, while during 1998 monthly catch was usually above the historical averages. In both 1999 and 2000 catch fell to below historical average during all months. In the years 2001-04 only a small number of monthly catches were above the historical average. In 2005, catch in all months, except for June, were below the historical average, while the catch for all months of 2006 was below the historical average (Fig. 9). This pattern was again evident in 2007, when all of the months recorded catches were below the historical average (Fig. 9).

While decreases in both catch and effort during the later years is evident, disproportional changes in these parameters have actually resulted in an increase in

catch per unit effort (CPUE) for the fishermen working Florida and the Tortugas grounds.

Catch Per Unit Effort (CPUE)

Catch per unit effort is reported as pounds of shrimp caught during a 24 hour fishing day (pounds per nominal day fished). Catch per unit effort averaged 598 pounds per day fished \pm 81 pounds per day fished in the Tortugas area from 1960-1985. During the years between 1986 and 1994, annual CPUE was below average (Fig. 10, Table 1). The CPUE of 507 pounds per day fished during 1995 was still below the historical average for the area, while CPUE for 1996 decreased to 484 pounds per day fished. Catch per unit effort in 1998 increased to 492 pounds per day fished despite the low catch levels during that year. Disproportional decreases in both catch and effort caused the resulting increase in CPUE during 1998. However, this CPUE was still below the long term average. The CPUE experienced in biological year 1999 equaled 349 pounds per day fished, the lowest value recorded over the entire data set, resulting in about a 40% decrease in CPUE from 1994 to 1999 on the Tortugas fishing grounds. An increase in CPUE was observed in biological year 2000, increasing to 467 pounds per day fished. Catch per unit effort also increased during 2001 (482 pounds/day fished) and 2002 (511 pounds/day fished), followed by a slight decline in 2003 (460 pounds/day fished) (Fig. 10, Table 1). While catch and effort were down from previous years, CPUE increased in 2004 for both the entire Western coast of Florida and the Tortugas fishing grounds to 599 and 639 pounds per day fished respectively. Catch per unit effort for Florida increased in 2005 to 691 pounds per day fished, while CPUE for the Tortugas grounds increased to 736 pounds per day fished (Table 1). Like the previous years, an increased CPUE for 2005 was the result of disproportional decreases in both catch and effort. Catch per unit effort declined again in 2006 to 627 and 615 days fished for Florida and the Tortugas respectively. While CPUE did decline in 2006, its level for both the west coast of Florida and the Tortugas grounds is still one of the highest levels that have ever been measured over the last 20 years of records (Fig. 10 and Table 1). While as noted, catch and effort have declined, yet CPUE has remained high. Thus, relative abundance of pink shrimp in the Tortugas grounds as measured by CPUE has been stable over this long term data set (Table 1). This is an indication that the fishery

is most likely not in decline and the primary reasons for the recent spate of low harvest levels is due to economic and not biological conditions.

Recruitment

Low and high periods of recruitment have been experienced throughout the 46 year history of the fishery (Fig. 11). A three-year period of low recruitment occurred from 1988 through 1990, while an increase in recruitment was noted for the 1991-1995 time period. Although the 1996 value dropped from the 1995 level, it was only slightly below the long-term average of 1.07 billion recruits. A slight increase in recruitment was noted in 1997, declining in 1998 and 1999. The 1998 level was slightly below average for the area, with the 1999 recruitment being the lowest on record. Recruitment increased in 2000-2002 to about the 1998 level. Similar to the 2003 recruitment, recruitment in both 2004 and 2005 declined to approximately 0.7 billion recruits. Our assessment models indicate that recruitment continued to decline through 2006 to about 0.3 billion recruits.

Spring recruitment (January-June) on the Tortugas fishing grounds has undergone fluctuations during the 46 year period (Fig. 12). Spring recruitment showed a steady increase from 1991 through 1996, but declined sharply in 1997. Spring recruits increased during 1998, but fell again in 1999. The 2000 value was similar to the number of recruits estimated in 1999, with the 2001 value increasing to between the 1997 and 1998 levels. An increase in recruitment continued through the spring of 2003 but declined in 2004 and 2005 to 0.41 and 0.26 billion recruits respectively. Spring recruitment in 2006 declined to about 0.2 billion recruits. A general decreasing trend is visible for fall recruitment (July-December) from 1960 through about 1992. Fall recruitment was good in both 1995 and 1996, however these levels were still not above the average experienced during the early years of the fishery (Figure 12). There was a decrease in recruitment in 1997, increasing in 1998 to levels similar to those experienced in 1995 and 1996. Recruitment fell sharply in 1999, but increased slightly in 2000. A trend of increasing fall recruitment of pink shrimp has also continued through 2005. Our model estimates fall recruitment for 2004 and 2005 to be 0.47 and 0.49 billion young shrimp respectively.

From the first period of low catch in the Florida pink shrimp population (late 1980's to early 1990's), an increase in pink shrimp parent numbers was noted from 1990 through 1992 (Fig. 13 and Table 2). During 1992, an increase in the number of recruits also occurred. Although the 1993 parent level was below the 1992 value, the recruitment level was above the 1992 value (Fig. 13 and Table 2). In 1994 an increase in recruitment above the 1993 level occurred with only a slight increase in parent stock. In 1995 both the number of parents and the number of recruits increased above the 1994 values. This continued increase in recruitment, with an increase in parent stock levels, is an indication that improvements were beginning to occur in the pink shrimp nursery habitats in Florida. In 1996, the parent level was higher than the 1995 value, but fewer recruits were produced in the fishery. However, recruitment was still above the historical average for 1996. In 1997 a decrease in parents was again noted, but recruitment levels, although lower than 1996, were still above average. In 1998 an increase in parents was noted, but this increase produced fewer recruits than in any of the previous four years. This apparent lack of a strong relationship between the number of parents and resulting recruits indicate problems such as sea grass die-offs (Robblee *et. al.* 1991) and freshwater influxes (Sheridan 1996) were again possibly occurring in the pink shrimp habitat. The 1999 parent values and recruitment were similar to those experienced in the early 1990's. The total pink shrimp parent stock level in 1999 was at 108 million shrimp, which is near the over-fishing index level of 100 million shrimp. In 2000, 2001, and 2002 both parent stock and recruitment showed an increase above the 1999 levels (Fig. 13 and Table 2). Parent stocks for 2003 off of the Western coast of Florida declined to numbers last observed in 1991, while recruits are estimated to be at levels last noted in 1992. However, for 2004 and 2005 we have estimated an increase in parents compared to the 2003 levels (Fig. 13 and Table 2). Our assessment model estimates the parent number index in 2006 to be at about one-half of that estimated in 2005.

Figure 13 shows a lack of the parent-recruit stock relationship. This lack of relationship has been “measured” for other shrimp fisheries, and was first noted for this fishery in 1989 (Nance *et. al.* 1989). The addition of about 20 years of additional stock-recruit data, since Nance *et. al.* (1989) first noted the lack of relationship, has not strengthened this association.

As noted, pink shrimp parent numbers and recruitment are used as one measure of the health of the population and have been useful tool for management in the past. However, it appears that our models are not able to adequately reflect the changes in this population, primarily because our models use landings to assign ages and numbers of shrimp within the VPA. Unfortunately, with the low effort levels, and resulting low numbers of shrimp being landed, our models seem unable to adjust to these low numbers, and are generating a parent stock level that is most likely underestimated. New assessment models will be explored in the future which can adjust for these possibly continuing low levels of effort and catches.

From the currently available biological data, no causes for the recent declines in pink shrimp catches along the Florida coast have been documented. Previously, problems within the habitat; *e.g.*, freshwater flow pattern alteration (Sheridan 1996); sea grass die-off (Robblee *et. al.* 1991); high temperatures and/or salinity in Florida Bay, etc., have been suspected as potential reasons for declines in shrimp populations (Sheridan 1996). However, recent declines in catches over the last several years are most likely purely economical, resulting in lower fishing effort, and may be attributed to the financial hardships currently experienced throughout the Gulf of Mexico commercial shrimp fishery. These hardships have been documented to include an increase in low-cost imported shrimp on the domestic market, and most notable a dramatic rise in fuel costs. These non-biological factors are substantiated by the decline in effort and hence lower yields. If biological factors were a large factor in these recent downturns in shrimp catch, we would be documenting a decline in catch with stable or even increasing fishing effort. This is not occurring in this, as well as the entire Gulf of Mexico shrimp fishery, as we have recorded some of the highest CPUE levels in recent years. This measured increase in CPUE indicates that the shrimp are available for harvest for the fishermen who are financially able to target them. Therefore, the currently low yields and effort levels being seen in the Tortugas pink shrimp fishery can be attributed to economical and not biological conditions.

References

- Haby, M. G., R. J. Miget, L. L. Falconer, and G. L. Graham. 2003. A review of current conditions in the Texas shrimp industry, an examination of contributing factors, and suggestions for remaining competitive in the global shrimp market. Texas Cooperative Extension Sea Grant College Program, TAMU-SG-03-701. 26 p.
- Iversen, E.S., A.E. Jones, and C.P. Idyll. 1960. Size distribution of pink shrimp, *Penaeus duorarum*, and fleet concentrations on the Tortugas fishing grounds. U.S. Fish and Wildlife Service Special Scientific Report. Fisheries No. 356, 62 p.
- Klima, E.F., G.A. Matthews, and F.J. Patella. 1986. Synopsis of the Tortugas pink shrimp fishery, 1960-1983, and the impact of the Tortugas sanctuary. North American Journal of Fisheries Management 6:301-310.
- Klima, E.F., and F.J. Patella. 1985. A synopsis of the Tortugas pink shrimp, *Penaeus duorarum*, fishery, 1981-84, and the impact of the Tortugas Sanctuary. Marine Fisheries Review. 47 (4):11-18.
- Nance, J., W. Keithly Jr., C. Caillouet Jr., J. Cole, W. Gaidry, B. Gallaway, W. Griffin, R. Hart, and M. Travis. 2008. Estimation of effort, maximum sustainable yield, and maximum economic yield in the shrimp fishery of the Gulf of Mexico. NOAA Technical Memorandum NMFS-SEFSC-570, 71 p.
- Nance, J.M., E.F. Klima, and T.E. Czaplá. 1989. Gulf of Mexico shrimp stock assessment workshop. NOAA Technical Memorandum NMFS-SEFSC-239, 41p.
- Nance, J.M., and F.J. Patella. 1989. Review of the Tortugas pink shrimp fishery from May 1987 to January 1989. NOAA Technical Memorandum NMFS-SEFSC-238, 23 p.
- Nichols, S. 1984. Updated assessments of brown, white, and pink shrimp in the U.S. Gulf of Mexico. Paper presented at the SEFC Stock Assessment Workshop. Miami, Florida, May 1984.
- Ricker, W.E. 1975. Handbook of Computations for Biological Statistics of Fish Populations. Bulletin of Fisheries Research Board of Canada. 119:1-300.

- Robblee, M.B., T.R. Barber, P.R. Carlson Jr., M.J. Durako, J.W. Fourqurean, L.K. Muehlstein, D. Porter, L.A. Yarbro, R.T. Zieman, and J.C. Zieman. 1991. Mass mortality of the tropical seagrass *Thalassia testudinum* in Florida Bay (USA). *Marine Ecology Progress Series*. 71:297-299.
- Sheridan, P. 1996. Forecasting the fishery for pink shrimp, *Penaeus duorarum*, on the Tortugas Grounds, Florida. *Fishery Bulletin*. 94:743-755.
- Travis, M.D., and W.L. Griffin. 2004. Update on the Economic Status of the Gulf of Mexico Commercial Shrimp Fishery. SERO-ECON-04-01. 10 p.

Table 1. Biological year pink shrimp catch statistics for the Tortugas fishing grounds from 1960-2006.

Year	Catch (million Lbs.)	Effort (k days fish)	CPUE	CPUE	CPUE
1960	13.2	18	725	-	725
1961	8.5	16	523	-	523
1962	8.9	15	560	-	560
1963	10.3	17	595	-	595
1964	10.4	16	620	-	620
1965	13.0	17	730	-	730
1966	10.9	18	597	-	597
1967	8.5	16	506	-	506
1968	9.1	15	602	-	602
1969	11.2	15	704	-	704
1970	9.1	15	593	-	593
1971	7.7	12	599	-	599
1972	8.5	14	596	-	596
1973	10.0	17	565	-	565
1974	8.9	15	559	-	559
1975	8.4	15	524	-	524
1976	9.7	14	656	-	656
1977	13.0	20	629	-	629
1978	9.5	16	569	-	569
1979	8.8	18	489	-	489
1980	13.6	20	677	-	677
1981	8.7	11	786	-	786
1982	7.5	16	462	-	462
1983	7.6	15	474	-	474
1984	10.2	17	592	-	592
1985	7.9	12	614	-	614
1986	5.8	13	-	417	417
1987	7.4	16	-	459	459
1988	4.9	11	-	416	416
1989	4.3	10	-	390	390
1990	4.6	10	-	428	428
1991	4.8	10	-	460	460
1992	6.3	11	-	566	566
1993	8.3	15	-	544	544
1994	8.0	13	-	579	579
1995	13.2	25	-	507	507
1996	8.7	17	-	484	484
1997	7.9	17	-	464	464
1998	7.3	14	-	492	492
1999	4.0	11	-	349	349
2000	6.4	13	-	467	467
2001	6.8	14	-	482	482
2002	6.7	13	,	511	511
2003	6.1	13	,	460	460
2004	6.0	9.0	,	639	639
2005	5.6	7.0		736	736
2006	2.4	3.0		615	615
Mean CPUE (± 1 Standard Error) =			598 (±15.8)	498(±21.5)	553 (±14.3)

Table 2. Tortugas pink shrimp parents and recruits estimated from VPA stock assessment model.

Year	Parents	Recruits (billions of individuals)
1960	92370565.7	1.8
1961	76066230.7	1.2
1962	52346831.4	1.4
1963	64888524.7	1.6
1964	81029252.5	1.5
1965	83597051.8	1.8
1966	50866238.7	1.5
1967	75700263.9	1.2
1968	77341128.6	1.3
1969	72416930.8	1.6
1970	130037651.7	1.2
1971	170439409.8	1.4
1972	131613339.8	1.4
1973	145624471.8	1.8
1974	153591078.0	1.8
1975	156931947.7	1.5
1976	139545210.0	1.9
1977	203972649.7	2.2
1978	163779848.4	1.5
1979	107243283.8	1.5
1980	145674906.1	2.5
1981	164021725.6	1.4
1982	126635345.3	1.7
1983	135947796.6	1.9
1984	308447307.9	2.2
1985	530901207.9	1.7
1986	152957161.2	1.2
1987	152779904.9	1.4
1988	218096528.1	1.2
1989	132166822.8	1.0
1990	113931050.2	0.9
1991	135536056.1	0.9
1992	178619460.8	1.1
1993	124984518.6	1.4
1994	127825077.8	1.6
1995	166360654.5	2.5
1996	223641846.7	2.0
1997	169939119.4	2.2
1998	218418113.1	1.4
1999	108465747.0	1.0
2000	132785387.7	1.2
2001	113263672.9	1.4
2002	167058792.3	1.3
2003	132347993.9	1.1
2004	160174194.3	1.1
2005	140737836.6	1.1
2006	77938612.4	0.5

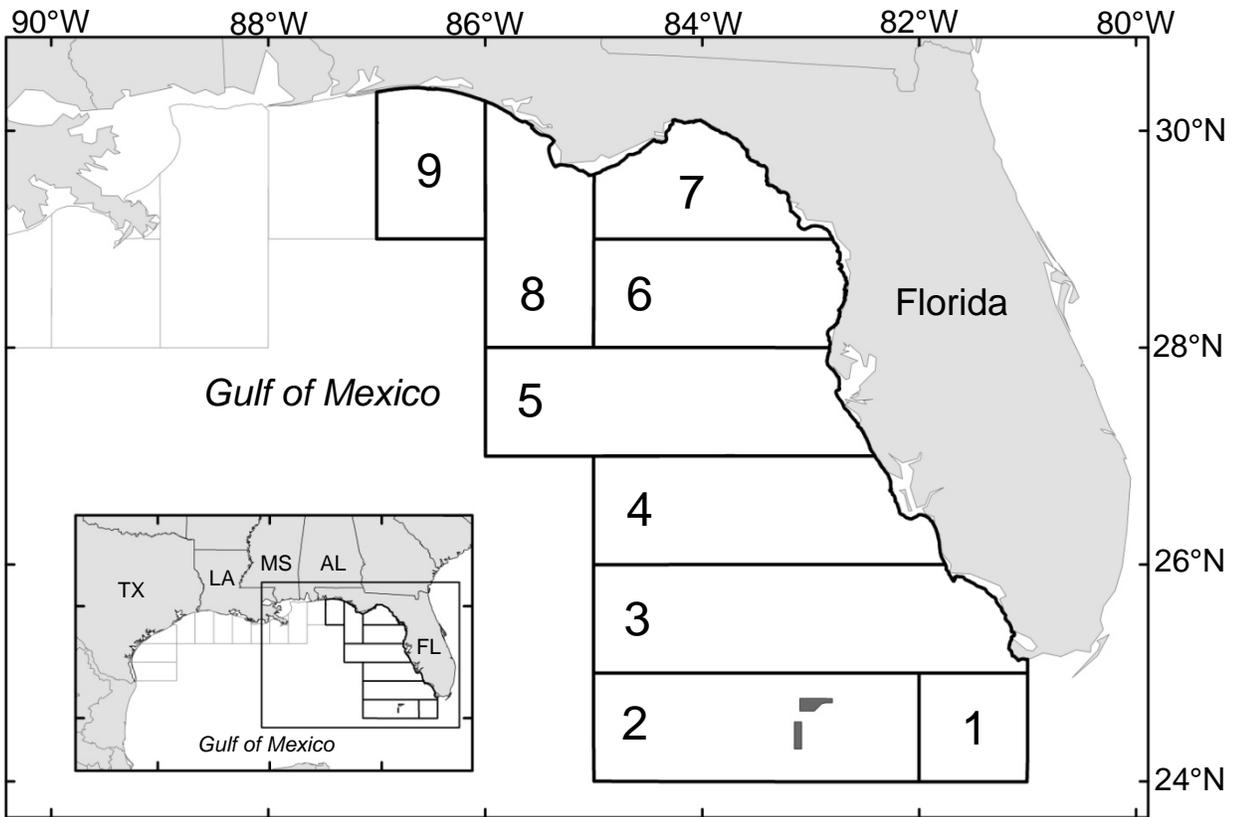


Figure 1. Tortugas fishing grounds (subareas 1-3) and the west coast of Florida (subareas 1-9).

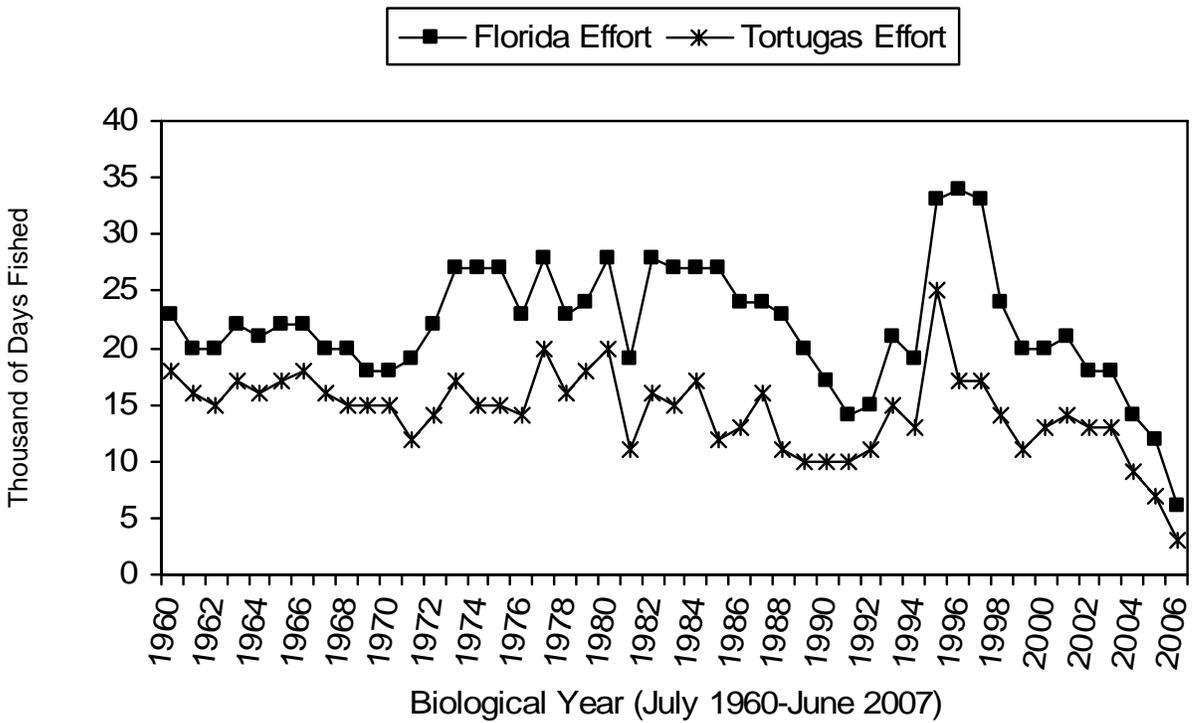


Figure 2. Pink shrimp fishing effort on the Tortugas grounds (subareas 1-3) and the west coast of Florida (subareas 1-9) for biological years 1960-2006.

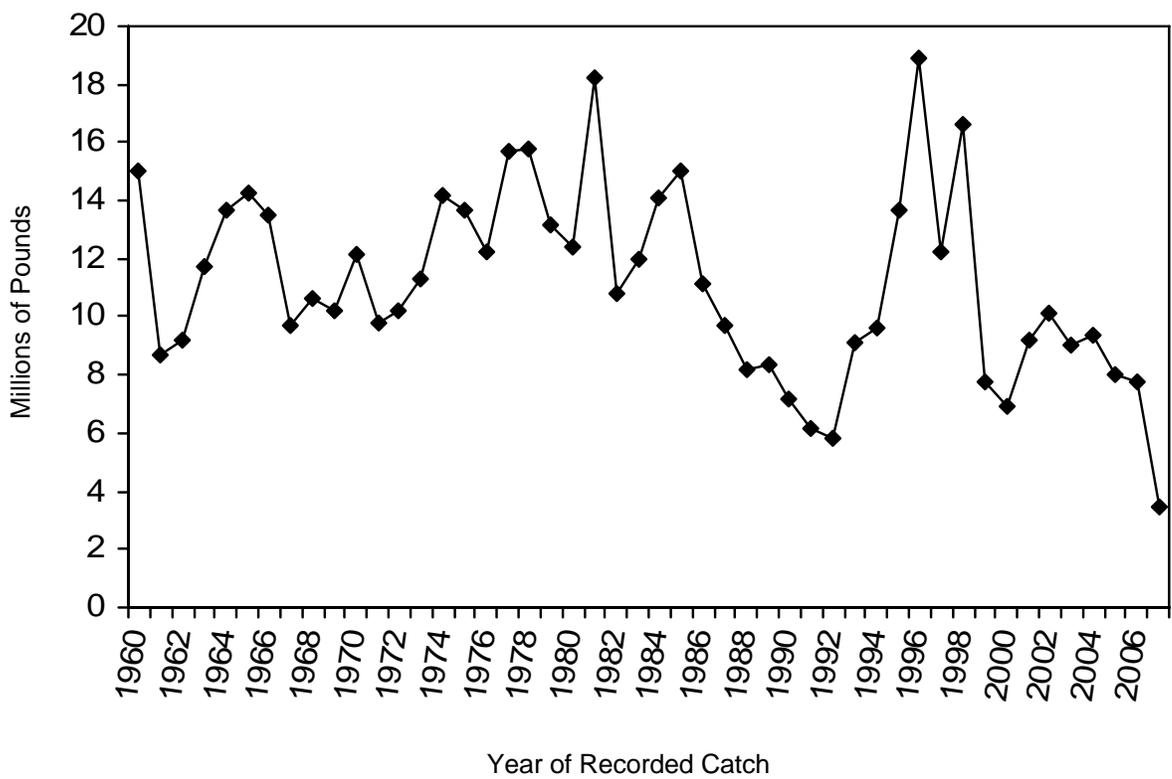


Figure 3. Annual pink shrimp catch for the West coast of Florida (1960-2007).

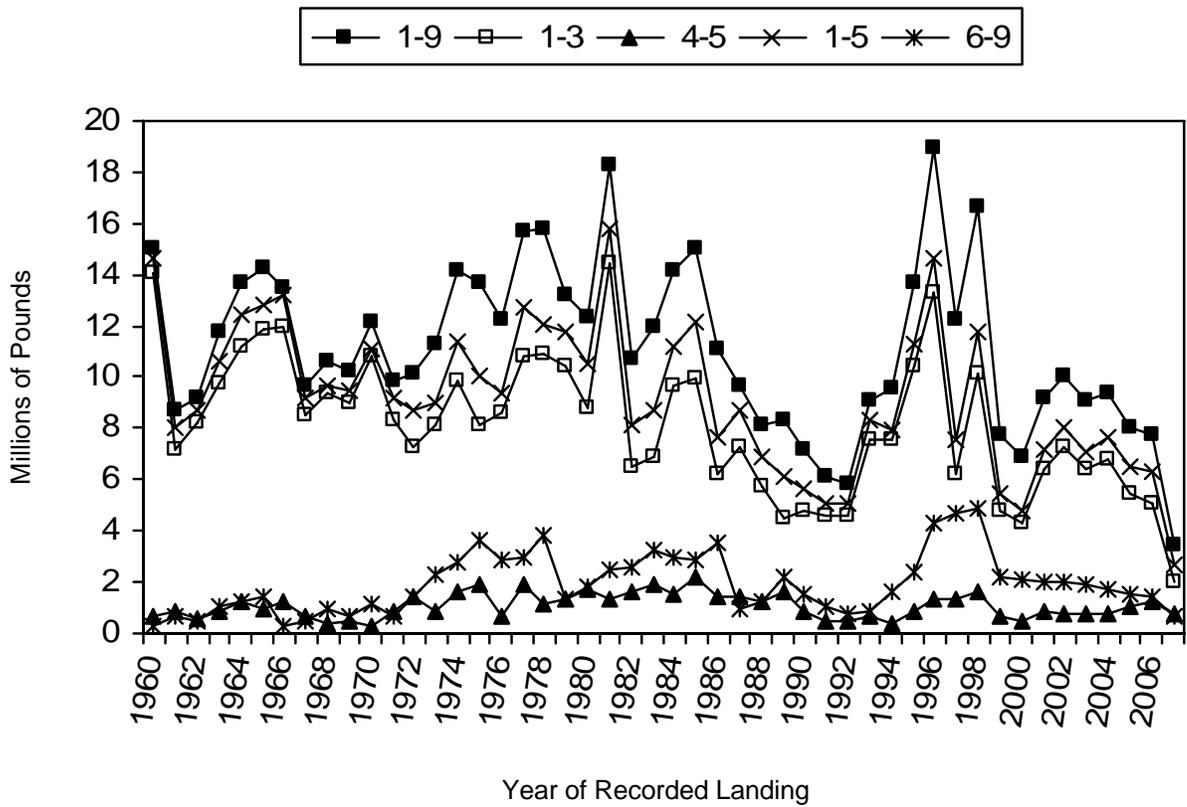


Figure 4. Annual pink shrimp catch (1960-2007) for the West Coast of Florida illustrating all of the sub-areas.

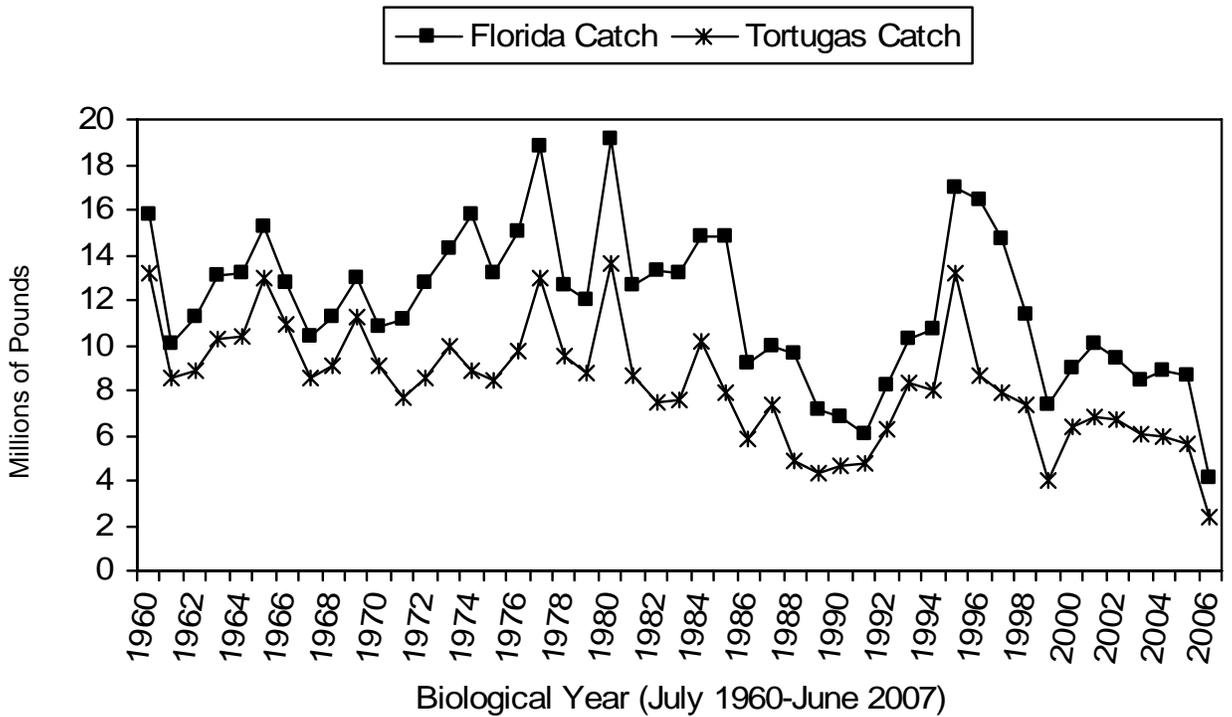


Figure 5. Pink shrimp catch for the Tortugas grounds (sub-areas 1-3) and the West coast of Florida (sub-areas 1-9) for biological years 1960-2006.

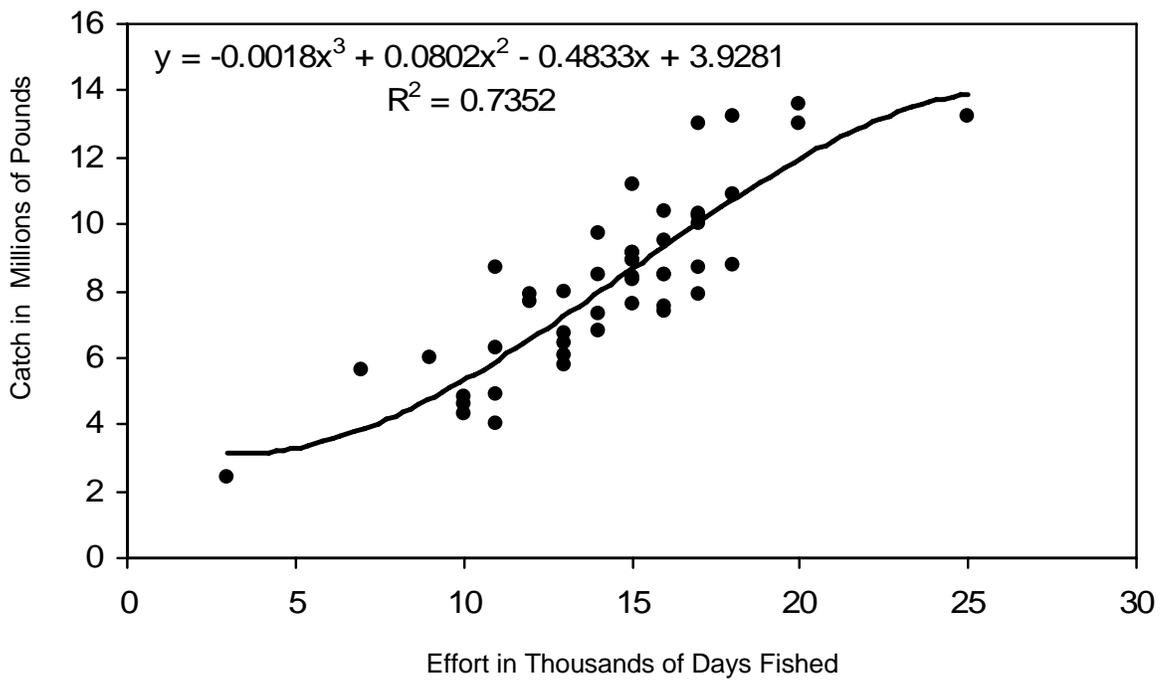


Figure 6. Relationship between effort and catch statistics for the Tortugas Pink Shrimp Fishery (1960-2006).

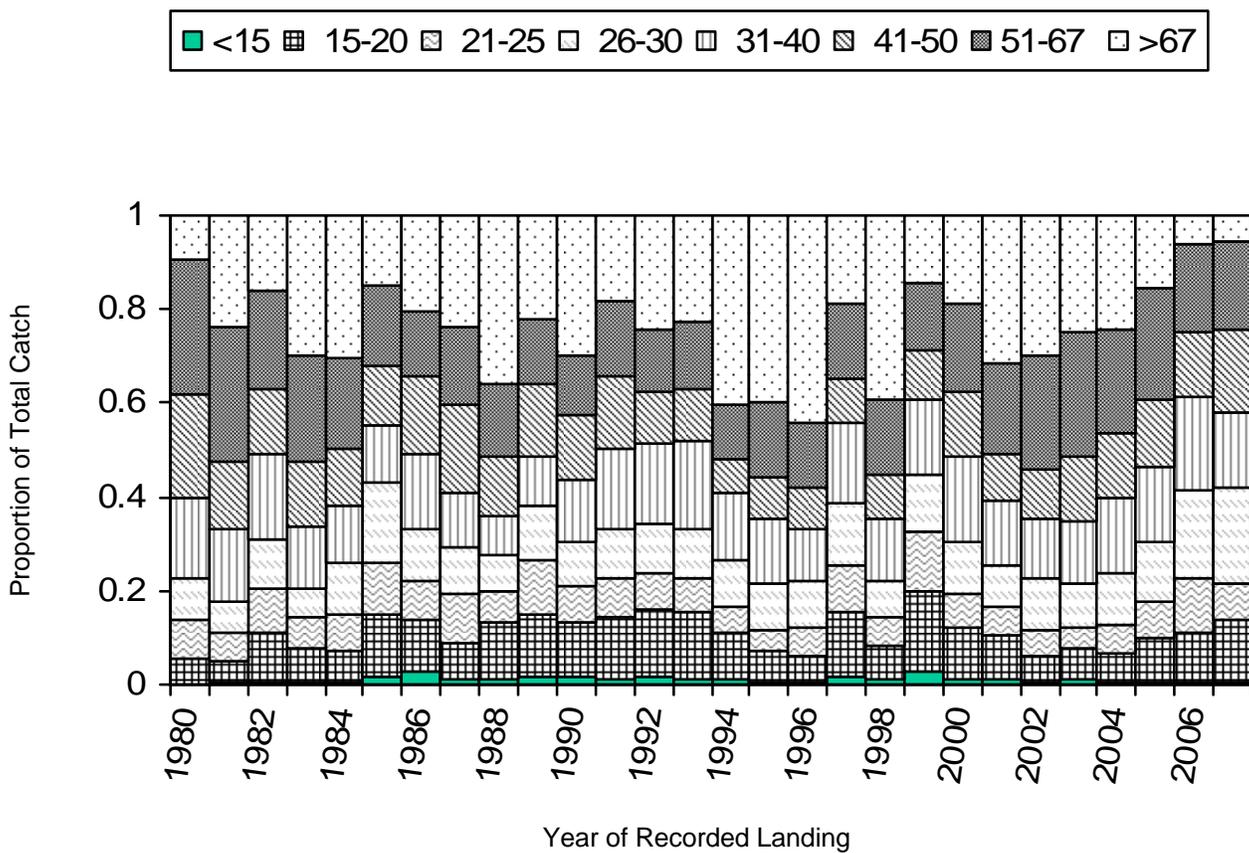


Figure 7. Size distribution of shrimp landed from the Tortugas grounds 1980 – 2007, expressed as a percentage of the total catch.

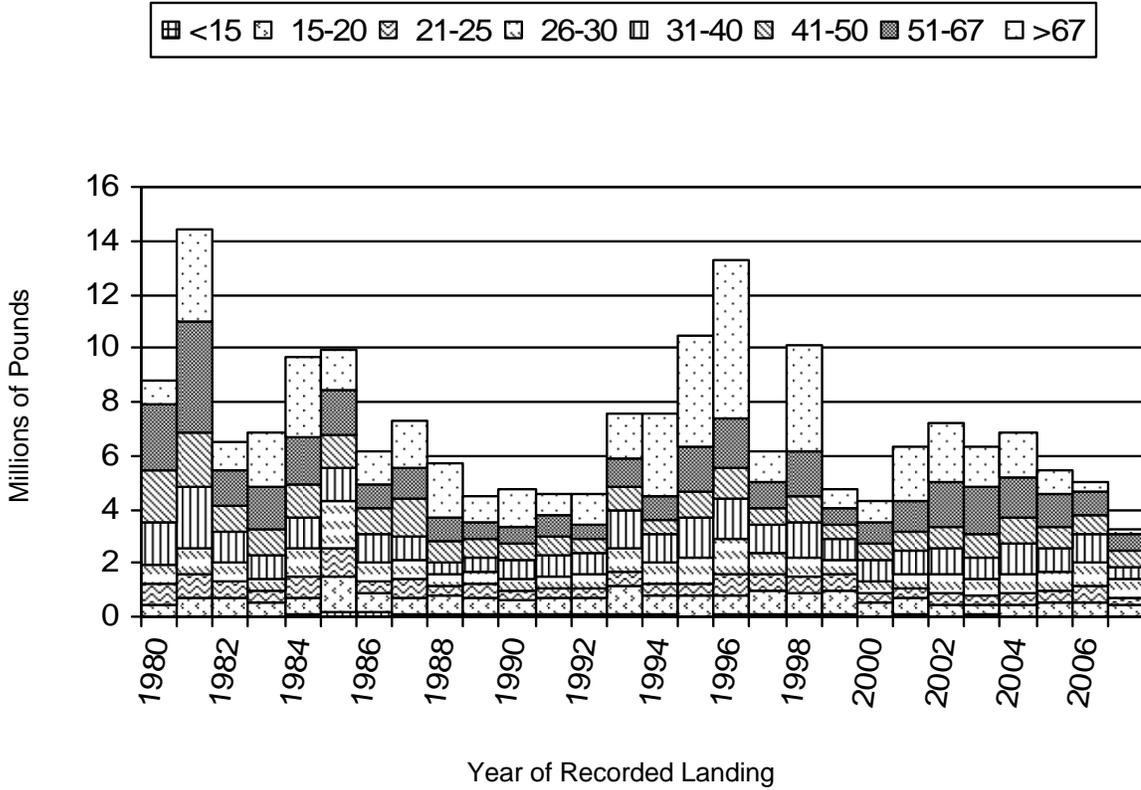


Figure 8. Size distribution of shrimp landed from the Tortugas grounds 1980-2007.

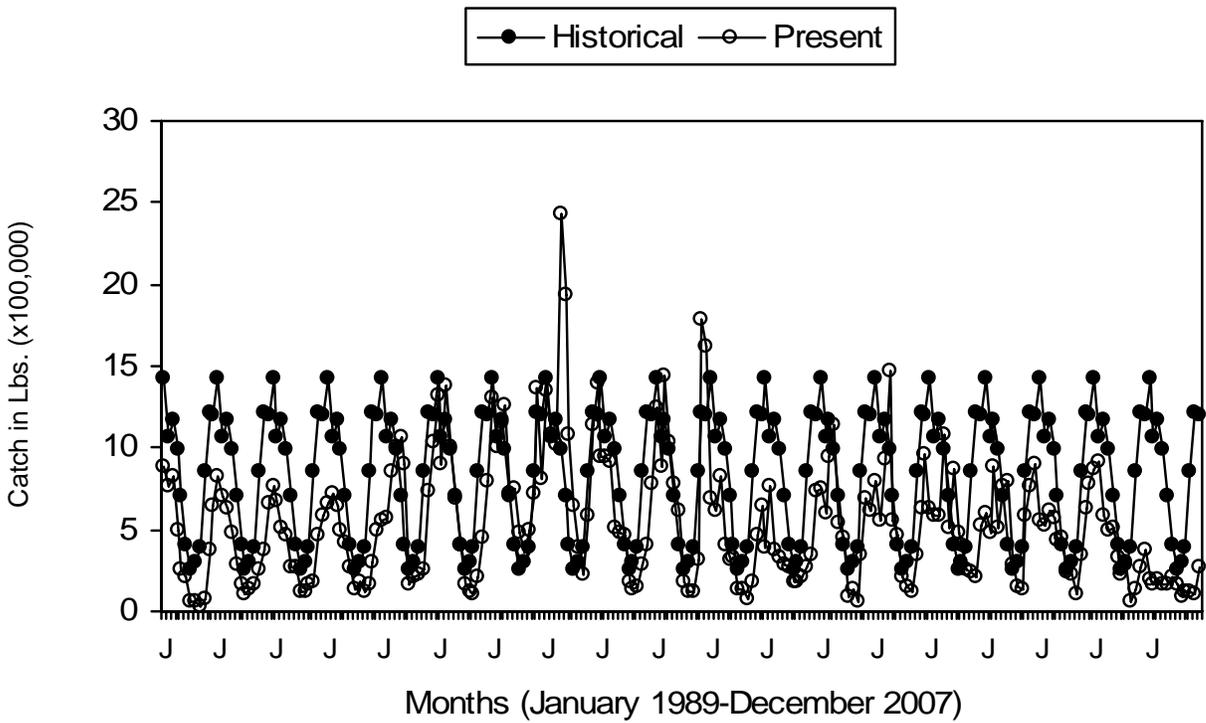


Figure 9. Average monthly historical catch (1960-1985) compared to recent catch (January 1988-December 2007) landed from the Tortugas grounds.

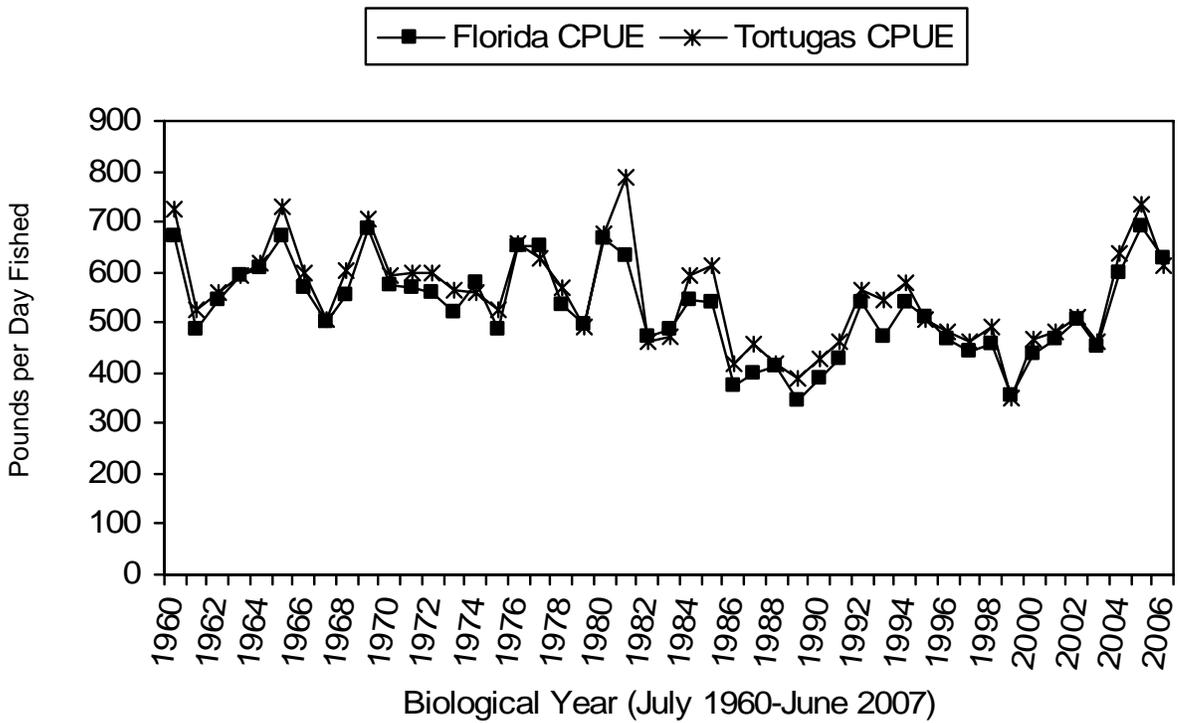


Figure 10. Pink shrimp catch per unit effort (CPUE) for the Tortugas grounds subareas 1-3) and the west coast of Florida (subareas 1-9) for biological years 1960-2006.

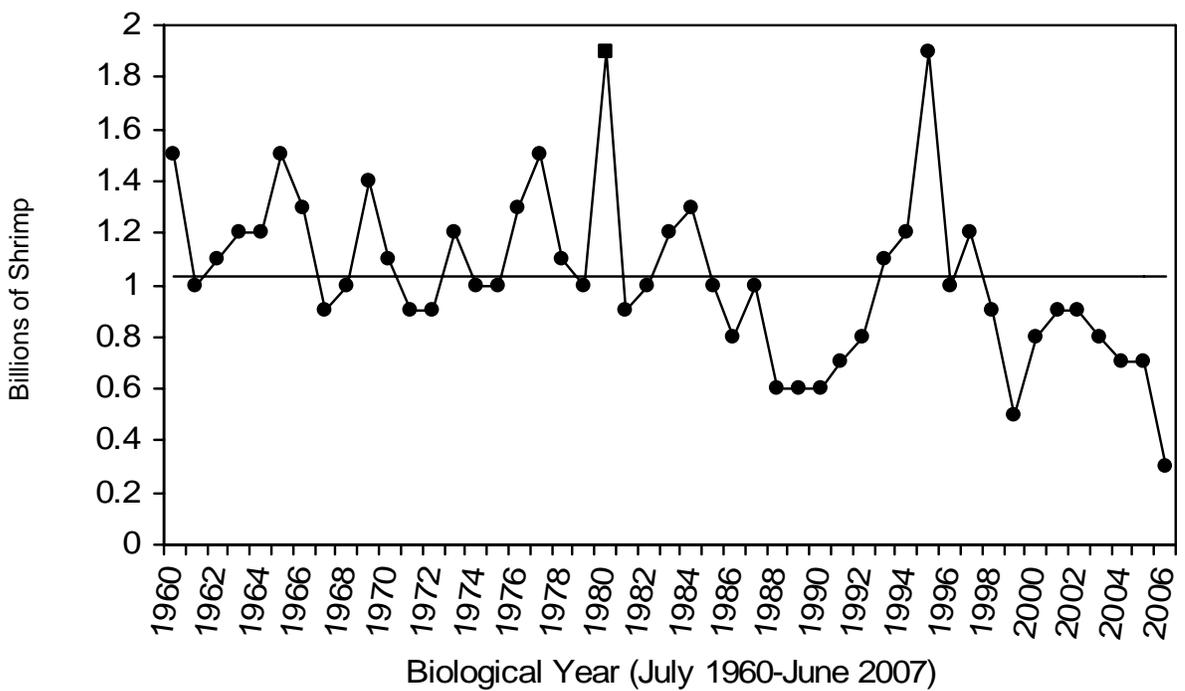


Figure 11. Estimates of pink shrimp recruitment on the Tortugas grounds for biological years 1960-2006. Horizontal line illustrates long term mean recruitment.

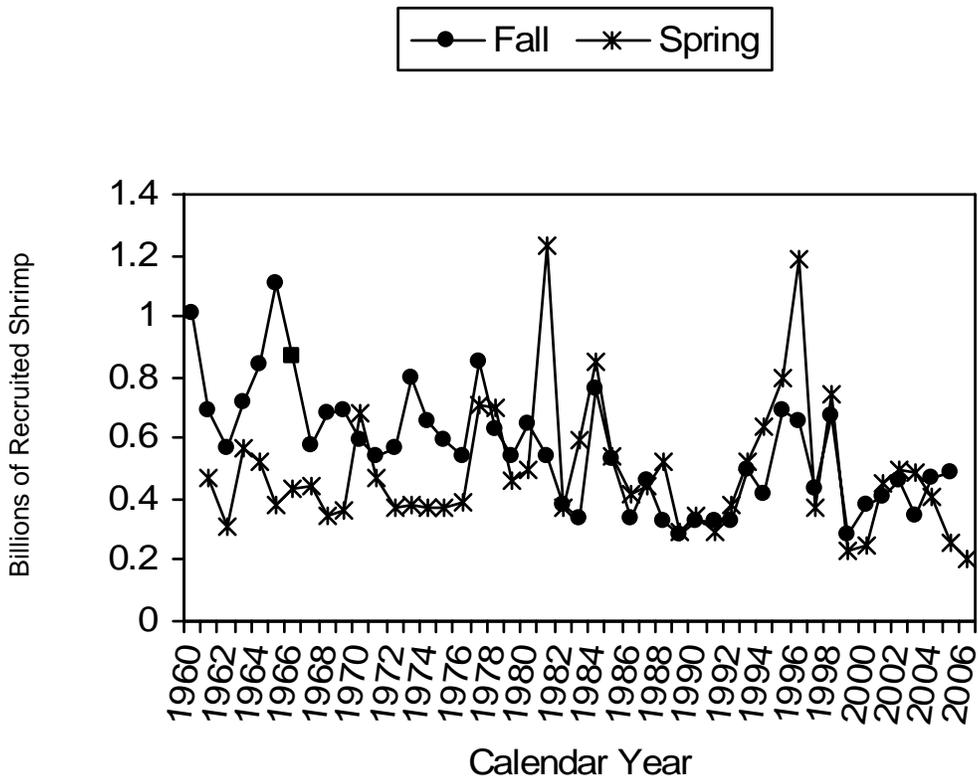


Figure 12. Estimate of seasonal pink shrimp recruitment on the Tortugas grounds for calendar year 1960-2007.

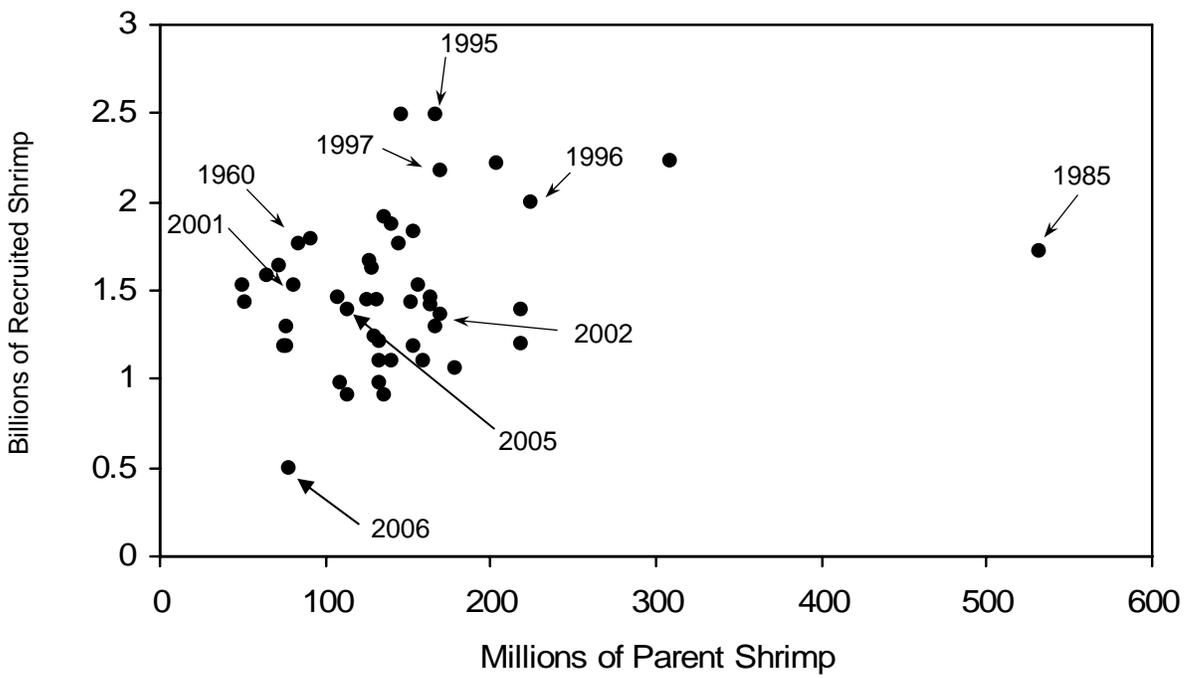


Figure 13. Relationship of pink shrimp parent stocks (age 5+ month shrimp) and recruitment, 1960-2006.