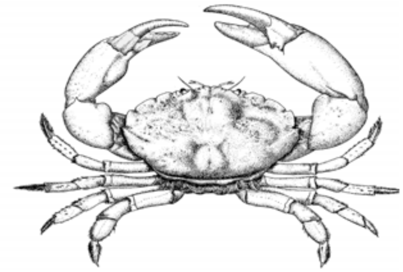

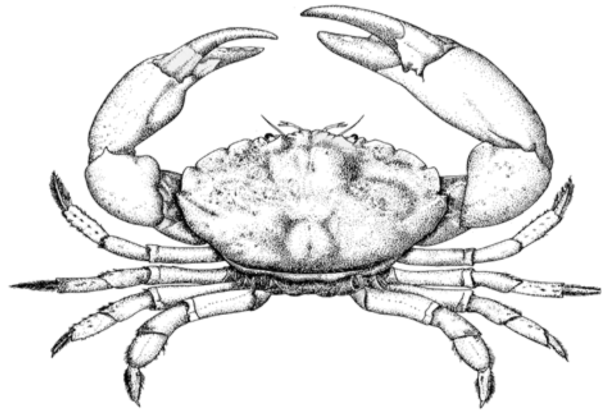

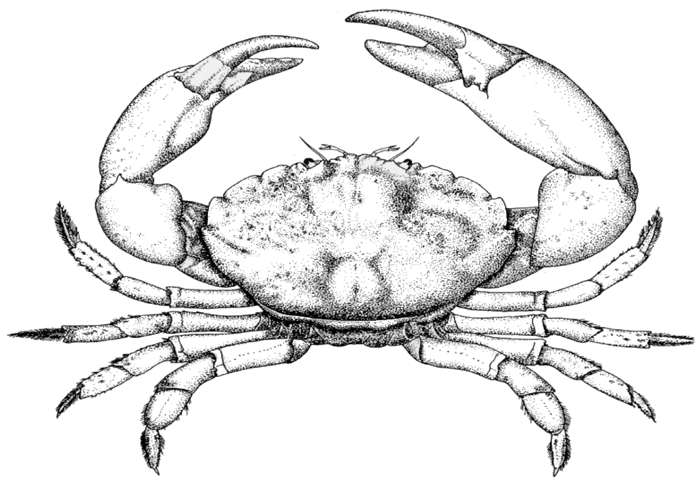

# The 2006 Stock Assessment Update for the Stone Crab, *Menippe* spp., Fishery in Florida

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# The 2006 Stock Assessment Update for the Stone Crab, *Menippe* spp., Fishery in Florida

## Executive Summary

- The stone crab fishery is unique in that fishers do not harvest the crabs; but, rather, the fishers remove legal-sized claws from the animals and then return the crabs alive to the water. Most female crabs have already spawned one or more seasons by the time their claws reach legal size.

- The stone crab fishery is managed with a seven-month fishing season (15 October through 15 May), a claw (propodus) minimum harvest size of 2-3/4 in (70 mm), trap specifications, and a passive trap limitation program.

- An average of 34% of the claws (weighted by regional landings) observed by FWC samplers in fish houses statewide showed evidence of forced breaks. Approximately 13% of the claws were regenerated claws, providing evidence that some declawed crabs survive the loss of their claws.

- Historical landings, in pounds of claws on a calendar-year basis, were extended back to 1902 to provide a context for evaluating the more recent landings for which we have information on effort. Landings generally increased until 1998.

- This update includes commercial landings through the 2004-05 fishing season because the information from the 2005-06 season is not yet available. Landings, in pounds of claws on a fishing-season basis, have varied without trend since 1989-90. Peak landings were 3.5 million lb statewide in the 1997-98 fishing season. Statewide landings for 2004-05 were 3.0 million lb of claws.

- The landings in October are good predictors of the landings for the entire season. However, the October 2005 landings are not expected to be a good indicator of the 2005-06 fishing season landings due the effects of Hurricane Wilma, which reached the Florida Keys on 24 October 2005. Both the number of trips and the pounds of claws landed in October 2005 were 56% of the 1985-2004 October averages.

- Since the 1962-63 fishing season (the first year with an estimate of the number of traps in the fishery), the number of traps in the fishery has increased more than a hundred-fold -- from 15,000 traps in the 1962-63 season to 1.6 million traps in the 2001-02 season. In a physical count of traps conducted in the 1998-99 fishing season, FWC employees found 1.4 million traps, which was twice the number that was estimated in 1992-93. As a response to the rapidly increasing number of traps in the fishery, the legislature in 2000 approved the stone crab trap limitation program, which was implemented in October 2002. The number of commercial trips also increased from 19,000 in the 1985-86 season (the first season with trip information available) to a maximum of 38,000 trips in the 1996-97 season and then declined afterwards.

- Catch-per-trap has fluctuated widely, but it has shown a generally decreasing trend over time. Catch rates dropped rapidly from more than 20 pounds per trap in the 1960s to less than 10 pounds per trap by 1971 to less than 5 pounds per trap by 1983. Catch rates continued to decline as the number of traps increased. The catch-per-trap since 1983 has been so low that it declined only slightly with the further doubling of traps.

- Catch-per-trip was standardized using a generalized linear model to remove confounding effects such as differences in location or time of the year. Most of the stone crab landings come from Florida's gulf coast and the Florida Keys. As would be expected in a fishery with a closed season, the stone crab fishery has a strong pattern of declining catch-per-trip during each season. The catch-per-trip data, available only since the 1985-86 season, also showed that the catch-per-trip has been declining over the same time period.

- We used two models to evaluate the condition of the stock. First, we used the landings, in pounds of claws, and the estimated numbers of traps in the fishery from the 1962-63 through 2004-05 fishing seasons in a surplus production model. As expected, the fishing mortality rate compared to its benchmark was too high. Because of the nature of this fishery, biomass of claws is not directly relevant. Second, in a modified DeLury model, we used the monthly landings, expressed as numbers of claws, and the commercial trips from the 1985-86 through 2004-05 fishing seasons to estimate the October recruitment that would be necessary to account for harvest and natural mortality (the DeLury continuity model). We found that recruitment has varied without trend during this period.

- The status of the stock is best indicated by the stable landings after 1989-90. The three-fold increase in the number of traps since then suggests that the current level of landings is all that can be harvested under current environmental conditions, regulations, and fishery practices and that the fishery is overfishing. Recruitment does not show any decline over the time series. These conclusions were the same as those from the 1997 and 2001 assessments. The stone crab fishery may be resilient because most female stone crabs spawn one or more times before their claws reach legal size, because some crabs survive declawing, and because the fishing season is closed during the principal spawning season. However, the fishery continues to have too many traps in the water. Further evidence of excess traps is the low catch-per-trap level over a very wide range of numbers of traps.

- In earlier assessments, we concentrated only on the harvested claws; but in this assessment, we began to investigate the biological basis of the fishery, i.e., the number of crabs affected by the fishery. There is no direct measure of this number. Therefore, we used the average weight of claws in the commercial claw-size categories to estimate the number of claws harvested and the monthly estimates of the average number of legal-sized claws per crab from a fishery-independent trapping study in Tampa Bay to estimate the number of crabs with legal-sized claws. Fishery-independent sampling has been conducted in the Tampa Bay region since 1988. To add some credence to applying information from Tampa Bay to the entire gulf coast of Florida, we compared the claws per crab from Tampa Bay from February through May 2005 with those from the Florida Keys (the only other area and time with comparable information). There was no significant difference between the number of claws per crab (1.21 claws per crab in the Keys and 1.23 claws per crab in Tampa Bay).

- For the past decade (1995-96 to 2004-05 fishing seasons), the gulf coast fishers have declawed approximately 10.5 million crabs during each seven-month fishing season.

# The 2006 Stock Assessment Update for the Stone Crab, *Menippe* spp., Fishery in Florida

## Background

Fishers in Florida harvest two species of stone crab and their hybrids, *Menippe adina and M. mercenaria*. *Menippe adina* and *M. adina*-like hybrid forms occur westward from Cape San Blas. Principally, *Menippe mercenaria*, intermediate hybrids, and *M. mercenaria*-like hybrids occur in varying proportions throughout the Big Bend and west-central Florida waters. Stone crabs in southwest, southeast, and east-central Florida, and in North Carolina are principally pure *M. mercenaria*. A relict hybrid zone, composed of pure *M. mercenaria* and *M. mercenaria*-like backcross hybrids exists from northeastern Florida through South Carolina (Bert and Harrison, 1988).

Initially, stone crabs were landed as by-catch in spiny lobster traps in the Florida Keys. Eventually, markets were developed and the harvesting of stone crab claws became a fishery in its own right.

The stone crab fishery is atypical in that stone crabs are not killed but, rather, the legal-sized claws are removed and the crabs are returned to the water alive. The crabs regenerate claws by molting, and regenerated claws can be subsequently harvested. Regenerated claws can be identified distinguished from original claws by their different stridulatory patterns (Savage et al. 1975). Prior to the 1973-74 fishing season, fishers were only allowed to take the claws from male crabs. After that season, fishers were allowed to harvest both claws from both sexes of stone crabs, if both claws were legal-sized and provided that the female crabs were not carrying eggs. Female crabs have been mature for one or more spawning seasons by the time they have developed legal-sized claws. In addition, the fishery is closed during the principal part of the spawning season. The stone crab spawning season varies with latitude. It extends from April to October in the north of Florida and from March to November in the south.

Early studies of the stone crab fishery were conducted by either the precursors to the Florida Fish and Wildlife Conservation Commission (FWC) (Savage et al. 1975, Sullivan 1979) or Florida Sea Grant (Bert et al. 1978) until the Gulf of Mexico Fishery Management Council (GMFMC) developed a fishery management plan in 1982. After that, National Marine Fisheries Service (NMFS) staff analyzed the fishery for the GMFMC (Powers 1982, Phares 1985, Phares 1989, Bolden and Harper 1992, Bolden 1993) and the FWC and its precursors analyzed the fishery within state territorial waters (Muller and Bert 1997, 2001).

## Regulations

Stone crabs are regulated under Florida Administrative Code, Chapter 68B-13. The statute covers *Menippe mercenaria, M. adina* and their hybrid forms. Only claws 2-3/4 inches (or 70 mm) propodus length can be removed. Propodus length is measured as a straight line from the junction of the elbow and "hand" (the crushing part of the claw) to the tip of the lower immovable finger of the hand. It is unlawful to remove claws from egg-bearing female stone crabs or to possess any egg-bearing female stone crabs on board a vessel. The open season is from 15 October to 15 May. Additional regulations include type of trap design, when the traps can be deployed, how the harvested crabs are to be treated onboard crabbers' vessels, Division of Law Enforcement notification of post-season trap retrieval, prohibition on the use of spears or hooks, buoy and vessel marking requirements, and the requirement of a Saltwater Products License (SPL) with a restricted species endorsement. The recreational harvest of stone crabs is restricted to a daily bag limit of 1 gallon of claws per person or 2 gallons of claws per vessel, a maximum of five traps that meet all of the commercial trap design criteria, a buoy marked with the letter "R" together with the name and address of the fisher unless the trap is fished from a dock, and the requirement that recreational traps be pulled manually and during daylight hours only.

The Florida Legislature authorized the stone crab trap limitation program during its 2000 session. When stone crab trap certificates are transferred, the number of certificates received by the purchaser is reduced by a percentage that depends upon the statewide total number of trap certificates available to harvesters until the number of available trap certificates reaches 600,000. This report will provide the FWC with the first assessment update since the trap limitation program was implemented in the 2002-03 fishing season.

## Landings

### Historical landings

Although some people capture stone crabs for recreation by diving or using up to five traps, stone crab landings data are only available from the commercial sector of the fishery.

Savage et al. (1975) said that the Florida stone crab landings in 1973 came from Franklin County through Brevard County; most (73%) of those landings were from Collier and Monroe counties (Figure 1). In the last five fishing seasons (2000-01 through 2004-05), landings from Collier and Monroe landings have averaged 58% of the statewide landings and landings from Franklin through Monroe counties have averaged 98.7% (Coefficient of variation [CV] = 0.27%). Therefore, our assessment update will focus principally on the Florida gulf stone crab fishery from Franklin to Monroe counties.

To provide a context for understanding today's fishery, we retrieved commercial landings by calendar year, beginning in 1902 (Reports of U.S. Fish Commissioner, various years 1896-1924; U. S. Bureau of Fisheries, 1925-37; State Board of Conservation Biennial Reports, 1941-50; National Marine Fisheries Service's website: http://www.st.nmfs.gov/st1/, 1950-2004). The landings of stone crab claws increased until 1998, after which landings decreased slightly (Figure 2).

Because the fishing season begins in October, landings are more informative when summarized by fishing season. Monthly landings of stone crab claws came from the NMFS General Canvass and Florida's Marine Resources Information System (trip ticket) program. The National Marine Fisheries Service collected monthly landings and value from wholesale seafood dealers for their General Canvass program. These data are available in digital form from 1978. In late 1984, FWC began collecting landings information on an individual-trip basis. After comparing the 1985 and 1986 monthly landings from NMFS General Canvass with those from FWC trip tickets monthly landings, the trip ticket program became the official source of Florida's landings on 1 January 1986. In the case of stone crabs, for every commercial trip, the dealer is required to report the crabber's SPL number, the dealer's wholesale number, the date purchased, the county where the claws were landed, the trip duration, the area fished, the depth fished, the market category (claw sizes), the pounds of claws, and the price per pound. The commercial landings data used in this assessment update are a composite of data from NMFS's General Canvass and Florida's trip tickets, and include all trip tickets that had been received by FWC through 26 January 2006 (Batch 910). These landings are considered final even though a few tickets invariably will show up later.

Earlier landings by fishing season came from the GMFMC Stone Crab Fishery Management Plan Amendment 1, which presented revised landings from Florida's gulf coast from 1962-63 through 1979-80 (Table 5-2, GMFMC 1981). Thus, we were able to piece together a time series of commercial landings of claws and numbers of traps in the fishery, by fishing season, from 1962-63 through 2004-05.

Seasonal landings of stone crab claws were less than 0.5 million lb until 1967-68 (Table 1, Figure 3). Florida's gulf coast landings increased to 1.0 million lbs by 1973-74; recent landings have exceeded 3.0 million lb.

The FWC fishery-dependent samplers noted that approximately 13% of the claws that they observed in fish houses had the broken stridulatory pattern indicative of claws that were regenerated (Simonson and Hochberg 1992). Our samplers noted that 66% of the claws had good breaks, similar to the 70% that Simonson and Hochberg observed in the 1983-84 and 1984-85 fishing seasons. Improper breakage of claws frequently causes death or severely disrupts growth (Savage and Sullivan 1978). The presence of regenerated claws indicates that some crabs do survive the 18-24 months that it takes for a regenerated claw to grow to legal size.

As with the spiny lobster fishery, the beginning of the fishing season is a good predictor of the season's total landings (Figure 4). The significance of the regression of the season's total landings on October landings was tested with an F-test of the variance explained by the model versus the variance not explained by the model (Zar 1996; $F = 108.6$, $df = 1, 25$, $P < 0.05$). However, the October 2005 landings will not be a good predictor for the 2005-06 season because Hurricane Wilma seriously affected the traps in the water. Fishers stopped fishing and began preparing for Hurricane Wilma beginning on 21 October (Figure 5). The strongest impact in the Florida Keys occurred on 24 October 2005. Fishing effort and landings were affected for at least the rest of the month. The October 2005 trips and landings were only 56% of the 1985-2004 averages.

Geographical Distribution

We divided the fishery for *Menippe* spp. stone crabs in Florida into six regions based on the extent and pattern of species distributions and hybridization, patterns of fishing activity, and landings (Figure 1, Table 2). The Panhandle region (Escambia through Gulf counties) is outside the main fishery and has only minute landings (an average of 534 pounds of claws per fishing season). The Big Bend region has the highest proportion of *M. adina*-like hybrids and extends from Franklin through Levy counties. The Crystal River region has a high proportion of intermediate and *M. mercenaria*-like hybrids, a high level of fishing activity, and evidence of overharvesting. It extends from Citrus through Pasco counties. The Tampa Bay region has intermediate hybrids, *M. mercenaria*-like hybrids, and pure *M. mercenaria*; and a moderate level of fishing activity and variable landings. It extends from Pinellas through Sarasota counties. The Southwest region has principally pure *M. mercenaria*, a very high level of fishing activity and most of the entire state's landings. It extends from Charlotte through Monroe counties. The Atlantic coast region consists of all of Florida's east coast counties, from Miami-Dade County northward. In the highly productive Southwest region, most of the stone crab claws are harvested in Collier and Monroe counties (Figure 6). The average depth of trap placement also differed among regions (Figure 7). The median depths of traps set by fishers in the Southwest and Tampa Bay regions were the deepest. and the shallowest median depth fished was on the Atlantic coast.

Numbers of Participants

When the trip ticket program was implemented in October 1984, SPL numbers could not be retained as part of the data record in the landings file. However, the Legislature removed that restriction during their 1986 session and by the 1987-88 fishing season, there were very few landings without associated SPL numbers. Statewide, the number of license holders that landed stone crab claws in a given season increased to more than 1,899 by 1993-94, varied around that level until 1996-97 and then declined afterward (Table 2c, Figure 8). The number of license holders with landings in the 2004-05 fishing season was 1,139. Similarly to the numbers of participants statewide, the numbers of SPL holders regionally have been decreasing in recent fishing seasons, especially after the mid-1990s (Table 2c).

**Effort**

The measures of effort available in this fishery are the estimated number of traps by fishing season (available since the 1962-63 fishing season), the number of commercial trips (available beginning with the 1985-86 fishing season), and the estimated number of traps pulled (also from 1985-86).

Numbers of Traps and Catch-per-Trap

Before the stone crab trap limitation program was implemented in 2002-03, the measure of effort used in this fishery was the number of traps in the fishery by fishing season, which was based on numbers provided by wholesale dealers to the NMFS General Canvass. After 2002-03, we used the number of stone crab trap tags purchased by fishers per fishing season. For those fishing seasons without trap estimates, we used the estimates that were generated for the last assessment (Muller and Bert 2001). These were based on the total number of traps claimed by fishers on their annual SPL applications. By comparing the two types of data from the fishing seasons that overlapped both data sources, we estimated that the number of traps from the NMFS General Canvass averaged 40% (CV = 11%) of the total number of traps claimed on the SPL applications. Therefore, for our analysis here, we multiplied the numbers of traps given on the applications by 0.40 to get comparable numbers for the seasons lacking estimates of the numbers of traps.

The number of traps in the stone crab fishery has increased dramatically from less than 15,000 in the 1962-63 season to approximately 1.57 million at the beginning of the trap limitation program in the 2002-03 season (Table 1, Figure 2). The number of traps doubled during the 1990s, partly in anticipation of the trap limitation program that was being discussed (Tom Matthews, FWC; personal communication). A physical count of stone crab traps conducted by FWC during the 1998-99 season confirmed that, collectively and statewide, fishers had 1.4 million stone crab traps. Since about 1980, landings have not continued to increase at the same rate as the numbers of traps (Figure 9). The pattern between landings and the numbers of traps can be summarized simply by

$$L = \frac{3.73T}{269 + T} \qquad (1)$$

where *L* is landings in millions of pounds and *T* is the number of traps in thousands. The relationship was significant ($F = 181.4$; $df = 2, 40$; $r^2 = 0.90$, $P < 0.05$) and it indicates that a statewide landings maximum of 3.73 million lb could be harvested with an unlimited number of traps.

As mentioned above, the historical pounds-per-trap was calculated simply as the landings from the fishing season divided by number of traps in the fishery that season. Although this measure is coarse, it provides some insight into the historical development of the fishery. The catch-per-trap fluctuated markedly in the early years (Figure 10a) possibly reflecting differences among the early fishers. By 1972, the catch-per-trap had decreased to approximately 7-8 lb per trap during a season and then continued to decline except for a couple of higher seasons (1981-82 and 1982-83). The lowest catch-per-trap in the time series was in the 2003-04 fishing season. When the pounds-per-trap is plotted against the number of traps in the fishery instead of by fishing season (Figure 10b), the pattern is similar because the number of traps in the fishery did not begin to decline until the 2003-04 fishing season. Dividing Equation 1 by the number of traps, *T*, provides an estimate of the predicted pounds of claws per trap (Figure 10b) or

$$\frac{L}{T} = \frac{3.73}{269 + T} \qquad (2)$$

The catch-per-trap has shown little variability over the past decade considering the potential effects of fluctuations in juvenile survival, predation, and other environmental perturbations. This stability may have been sustained because the fishers incorporated better navigation equipment, used trap haulers, and explored alternative fishing areas.

Numbers of Trips and Catch-per-Trip

The number of commercial stone crab trips peaked statewide in 1996-97 and then declined (Table 2b). To evaluate catch-per-trip, the pounds-per-trip by fishing season were standardized using generalized linear models (GLIM) with a log-normal distribution and adjusted for seasonal effects (month), geographical differences (region or county), the number of traps by 100-trap categories, and the soak time in number of days. All soak times greater than 15 days were lumped into the 15-day category because the pounds-per-trip increased with soak time up to 15 days and then leveled off (data not included). As in the 2001 stock assessment, we also used only directed trips, which were defined as trips where stone crabs accounted for at least half of the total landings on the trip. Goodness-of-fit for a generalized linear model was evaluated with the deviance, which was twice the difference between the maximum likelihood with an exact fit of the fitted values to the observations and the likelihood of a particular model (McCullagh and Nelder 1989). We used a stepwise approach in identifying which variables to include in the model and we only included variables that reduced the mean deviance (deviance/df) by at least 0.5% (R.I.C.C. Francis; National Institute of Water and Atmospheric Research Ltd, New Zealand; personal communication); trip duration only accounted for 0.32% and was not included in the final model. We estimated the variability in the seasonal catch-per-trip estimates with a Monte Carlo approach that used the least-squares means and their standard errors estimated from the GLIM and randomly drew 1000 values per fishing season from the log-normal distribution.

On the Atlantic coast, the standardized catch rates were variable in the seasons early in the development of the fishery (Figure 11a). On the gulf coast, the catch-per-trip fluctuated without trend and then dropped in the 1995-96 season. It has varied at a lower level since that season (Figure 11b). The overall decrease in catch rates on the gulf coast was significant (t-test that the slope of the line fitted to the points differed significantly from zero, $t$ = -4.49, $df$ = 18, $P < 0.05$). The volatility of catch rates on the Atlantic coast was illustrated by the highest catch rate in 1988-89 and lowest only two years later. A regression on the seasonal median catch rates showed that the apparent decrease was not significant (t-test for the slope being equal to zero, as above, $t$ = -0.33, $df$ = 18, $P$ = 0.75).

Traps pulled per season

Powers (1982) and Phares (1985, 1989) noted that the number of traps in the fishery would provide a useful measure of effort if all of the traps were fished the same way and were pulled the same number of times per fishing season. Fishers deploy traps differently. Therefore, to estimate the total number of traps pulled per fishing season, we calculated the average numbers of traps pulled by month and region from those individual trip tickets that provided numbers of traps pulled. Then we multiplied the average number of traps pulled per trip by the total number of trips to obtain the total number of traps pulled by month and region. The percentage of tickets that included numbers of traps pulled since 1992-93 ranged from 34% in the Crystal River region to 83% in the Southwest region; the statewide percentage was 75%.

The estimated number of traps pulled showed a slight increase over time but with singular sharp increases in 1989-90, 2003-04, and 2004-05 (Figure 12). This pattern is different from the number of trips per season, which increased until 1996-97 and then decreased afterwards (Figure 13).

## Population Analyses

Models are used to synthesize information and to identify and summarize patterns. Many fishery models attempt to estimate fishing mortality rates by age and fishing season; however, these models are inappropriate for stone crabs because the crabs are released after their legal-sized claws are removed and some percentage of crabs regenerates claws that can be harvested again. Length-based approaches also are not suitable because the size of claws is not closely correlated to crab size (carapace width). Therefore, we applied two empirical models to Florida's gulf coast data to identify whether 1) landings will continue to increase with increasing effort (surplus production model) and 2) there is a trend in recruitment based on monthly landings within fishing seasons (DeLury Depletion Model, for example see Basson et al. 1996 or Rosenberg et al. 1990).

Catch versus Effort

Hilborn and Walters (1992) do not recommend using equilibrium models because fisheries rarely attain equilibrium, but landings from 1962-63 and later were plotted on effort without assuming equilibrium (Figure 9). Landings from the developing fishery tracked the increasing number of traps quite closely up to about 600,000 traps. With higher numbers of traps, the landings were more variable and did not continue to track effort. Landings since the 1989-90 season have been stable. They averaged 3.07 million lb (t-test for the slope being equal to zero, $t = -0.51$, $df = 14$, $P = 0.62$) although the number of traps has more than doubled. A possible explanation is that there are so many traps that the crabbing grounds have become saturated. Increases in numbers of traps do not produce corresponding increases in landings.

A surplus production model is very straight-forward -- the biomass next year is a function of the biomass this year plus a combination of growth, recruitment and natural mortality minus deaths due to fishing; or:

$$B_{t+1} = B_t + rB_t(1 - \frac{B_t}{K}) - C_t \tag{3}$$

where $B_{t+1}$ is the biomass of claws at time, $t+1$; $B_t$ is the biomass of claws at time, $t$; $r$ is the intrinsic rate of increase combining growth, recruitment, and natural mortality; $K$ is the population carrying capacity; and $C_t$ is the catch in time, $t$. The predicted catch-per-unit-effort at time, $t$ , $\frac{\hat{C}}{E}t$ , is

$$\frac{\hat{C}}{E}t = qB_t \tag{4}$$

and the predicted catch, $\hat{C}_t$ , is

$$\hat{C}_t = qE_tB_t \tag{5}$$

where $q$ is the catchability coefficient and $E_t$ is the effort at time, $t$. If the second term in Equation (3) is greater than the landings then the population biomass will increase. We used the NMFS Stock Assessment Toolbox surplus production model, ASPIC 5.08 (Prager 1994) to fit the historical data set beginning with the 1962-63 fishing season (the first fishing season for which effort data are available) and the claimed numbers of traps by fishing season (Table 1). This version of ASPIC solves for the maximum sustainable yield (MSY); *K,* the carrying capacity of the environment to support stone crabs; *q*; and the ratio of the initial biomass to the carrying capacity, $B_1/K$. Because of a regulatory change in 1973, we used one catchability coefficient ($q1$) for the 1962-63 to 1972-73 fishing seasons and a different catchability coefficient ($q2$) for the later fishing seasons; thus, the model solved for five parameters. A problem that we had in the Excel version of the surplus production model is that the $B_1/K$ ratio tended to go much higher than 1.0; but ASPIC has a penalty, which we invoked, to curb that tendency.

The surplus production model fit the pounds of claws-per-trap especially after the 1972-73 season ($F$ = 33.3, $df$ = 5,37, $P$ < 0.05; Figure 14a). The catch-per-trap residuals (observed - predicted values) were balanced but larger in the earlier seasons (Figure 14b). For evaluating stock status, Prager (1994) recommends using the ratios of fishing mortality or biomass to their benchmarks rather than the actual values. Because the crabs are released alive, we have no direct link to the stone crab biomass and so the biomass benchmark is not applicable. The fishing mortality benchmark from this model is the fishing mortality rate that would, over time, produce the maximum sustainable yield, $F_{msy}$ = 2*MSY/K. The criterion for evaluating whether the fishery is overfishing the stock is if the fishing mortality ratio ($F/F_{msy}$) is greater than 1.0; i.e. the fishing mortality rate exceeds the benchmark. ASPIC uses a Monte Carlo technique with the covariance matrix to estimate uncertainty in the model. The median fishing mortality ratio of $F_{2004}/F_{msy}$ was 3.82 (Figure 15) indicating that the fishing mortality rate is too high (more traps are deployed than are needed to catch the available crabs).

Surplus production models have a difficult time when the catch-per-unit-effort continues to decline throughout the time series because the model needs some contrast to arrive at realistic solutions. In the case of stone crabs, the model estimated large stock sizes and very small fishing mortality rates. For example, the fishing mortality rate associated with MSY was 0.048 per year which is very low. However, the conclusion that the fishery is overfishing is consistent with the stable landings even though the number of traps more than doubled since 1989-90.

## Recruitment Trends

Although the surplus production model indicated that the fishery is overfishing, we nevertheless wanted to see whether recruitment is lower because of the overfishing (i.e., the stock is overfished). We used a modified DeLury model, developed in an Excel spreadsheet, to search for any trend in recruitment. Estimates of recruitment into the stone crab fishery are not as straightforward as in other fisheries because recruits come from two sources: crabs whose claws have reached legal size and crabs that have been declawed in the fishery or due to natural causes, survived, and undergone sufficient molts for their regenerated claws to attain legal size.

As a continuity model, we used the same DeLury Depletion model that was used in the previous two stone crab assessments and merely updated the data through the 2004-05 fishing season. This model estimated how many legal-sized claws would be required each October to mimic the monthly dynamics of landings, effort, and catch rates for the period from October 1985 through May 2005. The equations in the DeLury Depletion model are:

$$\overline{N}_t = (R_t + N_t)e^{-\frac{M}{2}} - \frac{C_t}{2} \qquad (6)$$

and

$$\hat{C}_t = qE_t\overline{N}_t \qquad (7)$$

where $\overline{N}_t$ is the average number of claws at time, $t$; $R_t$ is the recruitment in number of claws at time, $t$; $N_t$ is the number of claws in the population at the beginning of time, $t$; $M$ is the natural mortality rate; $\hat{C}_t$ is the predicted catch during time, $t$; $q$ is the catchability coefficient that relates the mortality expended by one unit of effort; and $E_t$ is the effort expended during time, $t$. Based on estimates of a maximum age of eight years for stone crabs (Bert 1985, Bert et al. 1986, and Restrepo 1989), we continue to use the same natural mortality rate of 0.35 per year that was used in the previous assessments. The predicted catch-per-unit-effort is obtained by dividing equation (7) by $E_t$. To estimate recruitment, we used monthly landings, trips, and standardized catch rates from 15 October 1985 through 15 May 2005 in the model.

The model captured the monthly pattern of landings (Figure 16a) reasonably well ($F$ = 36.9, $df$ = 21, 138, $P$ < 0.05) with well balanced residuals (Figure 16b). The resulting pattern in recruitment was similar to the recruitment trends estimated in the 1997 and 2001 stock assessments but with increased variability in recent seasons (including the highest value in the 2000-01 fishing season and the lowest in the 2002-03 fishing season, Figure 17). Recruitment varied without trend (t-test for the slope being equal to zero, $t$ = 0.74, $df$ = 17, $P$ = 0.47).

The natural mortality rate that we used was lower than Ehrhardt's et al. (1990) estimate of 0.939 per year (equivalent to a maximum age of approximately 3.2 years). When the model was rerun using a natural mortality rate of 0.939 per year, the model converged to an unrealistic population in billions of claws and with a very minute catchability coefficient (4.9 e -09) such that the fishing mortality was less than 0.001 per year. Also, recent research is showing that stone crabs with legal-sized claws may only molt once or twice per year such that growth may be slower than Ehrhardt et al. thought, further arguing against the higher natural mortality rate (Susan Gerhart, FWC; unpublished data).

For another look at the fishery, we developed another DeLury model that used the number of declawed crabs per month instead of just the claws. This is an initial attempt to examine the biological basis of the fishery. For the DeLury continuity model, we converted landings in pounds of claws to the number of claws harvested using the average weight by size class of claws. When we extended the analysis period back to October 1978, we had to convert the monthly landings in pounds of claws from NMFS's General Canvass to numbers of claws. Those monthly landings were converted to numbers of claws using the monthly average weight of the ungraded category of claws calculated from the 1985-86 through 1987-88 period. The General Canvass data lack any measure of effort, so we divided the monthly landings by the average trip ticket catch-rates (pounds per trip) from the same period, 1985-86 through 1987-88, to produce estimates of the number of trips each month that would be necessary to produce the landings.

Next, to convert landings in numbers of claws to the number of crabs that were declawed per month, we used data from four stations in the Tampa Bay fishery-independent trapping study: Anna Maria Island, Bean Point, Passage Key, and Rattlesnake Key. In the Tampa Bay trapping study, researchers measure the claws of every stone crab that they collect and they record which trap caught the crab. From those data, we used a GLIM to remove any station effect and estimated the average number of legal-sized claws per crab that were harvested per month. The average number of legal-sized claws has declined over time (t-test for the slope being equal to zero, $t$ = -3.54, $df$ = 15, $P$ < 0.05; Figure 18). For months prior to the time when the trapping study began in May 1988, we used the monthly average number of legal-sized claws from all years of the trapping study. The number of crabs declawed each month was the number of claws harvested in a month divided by the corresponding number of legal-sized claws per crab.

To provide guidance to the biological DeLury model on monthly recruitment, we developed a recruitment index from the trapping study that was the number of crabs per month with claws between 70 and 81 mm per trap haul across years using a GLIM with a Poisson distribution and log link (Figure 19). The upper end of the size range for recruiting claws, 81 mm, was one molt above legal size (Savage and Sullivan 1978). Due to a limitation in Excel's Solver routine, we were unable to solve for recruitment in every month individually, so we approximated the within-season pattern of recruitment by grouping months with similar levels of recruitment based on non-overlapping inter-quartile ranges. The groups of months were: June through August and October; September; November through January; February, March, and May; and April. By grouping the months, we reduced the number of recruitment estimates from 324 to 134.

In the DeLury continuity model, the model's fit was based on the predicted numbers of claws; however, the goodness-of-fit in the biological model was based on the monthly numbers of declawed crabs, the standardized commercial pounds of claws per trip, and the monthly recruitment index. The significance of these three components (whether the predicted values differed from the observed values) was evaluated by chi-square tests.

The inputs to the biological DeLury model are summarized in Table 3. For the past decade (1995-96 through 2004-05), crabbers have declawed an average of 10.5 million crabs per fishing season (Table 3). The biological DeLury model fit all three components well (Figure 20, landings $r^2$ = 0.90, $X^2$ = 0.63, $df$ = 215, $P$ = 1.00; commercial catch rate $r^2$ = 0.53, $X^2$ = 1.72, $df$ = 159, $P$ = 1.00; and recruitment index $r^2$ = 0.63, $X^2$ = 12.79, $df$ = 199, $P$ = 1.00). Note that the degrees of freedom are different among the components because we only included actual observations in determining the goodness-of-fit. For example, the model estimated recruitment values for every month but, since the trapping study began in 1988, only estimates from the 1988-89 and later fishing seasons were used to calculate the chi-square value.

The recruitment pattern from the biological model is similar to the pattern from the continuity model ($r$ = 0.56, $df$ = 17, $P$ < 0.05) except that the actual recruitment estimates were lower because the biological model estimated crabs, not claws, and there was less inter-season variability (Figure 21). The reduction in variability most likely stemmed from using the recruitment index. According to the biological DeLury model, recruitment since the 1986-87 fishing season, the same period that the continuity model covered, has been variable and without trend (t-test for the slope being equal to zero, $t$ = -0.61, $df$ = 17, $P$ = 0.55).

The biological model illustrates the importance of fishery-independent sampling. As the sampling extends to more areas along Florida's gulf coast, we will gain higher resolution in our understanding of stone crab dynamics.

## Condition of the Stock

The surplus production model demonstrated that the fishery is undergoing overfishing, as evidenced by the stable landings with increased numbers of traps in the fishery. Even with the overfishing, the lack of recruitment trends from the DeLury models indicate that the compensation by the stock seems to be sufficient to maintain current recruitment levels. We need to reiterate that landings have been level for more than a decade while the number of traps in the fishery has doubled. Simply put, there appears to be a certain number of claws that can be harvested each season and fishers compete with each other for those claws. Thus, the fishery is fully exploited and any further gains in landings, most likely, will come from expanding the fishing grounds. The number of traps is excessive and, even though a trap limitation program has been developed, the passive method of reducing numbers of traps means that the number of traps in the fishery will remain high for some time.

## Research Needs

The principal research need for stone crab management and assessment is the expansion of the fishery-independent monitoring project; this type of program provides information on future recruitment, sex ratios of the crabs, detailed catch-per-trap, carapace width, claw size, and number of legal-sized claws per crab. As noted above, our assessment relied heavily on the fishery-independent trapping program in Tampa Bay, initiated in 1988. Fishery-independent monitoring began in the Southwest region in 2005 and in the Big Bend region in 2006. Another possibility for collecting these data, albeit expensive, is an observer program.

Stone crab fishermen, including those on the FWC's Stone Crab Fishery Advisory Board, have expressed interest in research on other aspects of the stone crab fishery, such as mortality rate of recently molted, declawed crabs; habitat usage by sex and different life stages; effects of soak time (some research has been done on this topic; T.M. Bert, unpublished data); stone crab movement patterns; and effects of red tide on stone crabs. Funding to support basic and fishery-related research on stone crabs could come from the stone crab endorsement fees and associated fees.

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LIST OF TABLES

**Table 1.** Historical landings, number of traps, and pounds per trap for the gulf coast stone crab fishery by fishing season.

| Fishing Year | Landings Claw Weight (x1000 Lbs) | Number of traps (x1000) | Pounds per trap |
|---|---|---|---|
| 62-63 | 300 | 14.6 | 20.5 |
| 63-64 | 350 | 15.0 | 23.3 |
| 64-65 | 310 | 21.0 | 14.8 |
| 65-66 | 450 | 19.7 | 22.8 |
| 66-67 | 390 | 43.2 | 9.0 |
| 67-68 | 560 | 39.3 | 14.2 |
| 68-69 | 610 | 55.9 | 10.9 |
| 69-70 | 700 | 36.0 | 19.4 |
| 70-71 | 870 | 60.8 | 14.3 |
| 71-72 | 960 | 73.7 | 13.0 |
| 72-73 | 920 | 113.3 | 8.1 |
| 73-74 | 1,260 | 143.0 | 8.8 |
| 74-75 | 990 | 159.1 | 6.2 |
| 75-76 | 1,140 | 193.2 | 5.9 |
| 76-77 | 1,430 | 224.4 | 6.4 |
| 77-78 | 1,870 | 267.0 | 7.0 |
| 78-79 | 1,900 | 312.2 | 6.1 |
| 79-80 | 2,000 | 294.7 | 6.8 |
| 80-81 | 1,700 | 275.7 | 6.2 |
| 81-82 | 2,670 | 277.6 | 9.6 |
| 82-83 | 2,700 | 353.5 | 7.6 |
| 83-84 | 1,950 | 432.8 | 4.5 |
| 84-85 | 1,750 | 421.4 | 4.2 |
| 85-86 | 2,172 | 567.1 | 3.8 |
| 86-87 | 2,188 | 577.6 | 3.8 |
| 87-88 | 2,202 | 624.0 | 3.6 |
| 88-89 | 2,583 | 567.1 | 4.6 |
| 89-90 | 2,682 | 565.6 | 4.8 |
| 90-91 | 3,105 | 611.3 | 5.2 |
| 91-92 | 3,161 | 617.3 | 5.2 |
| 92-93 | 3,102 | 777.0 | 4.0 |
| 93-94 | 3,352 | 918.2 | 3.7 |
| 94-95 | 3,263 | 1,107.3 | 3.0 |
| 95-96 | 2,770 | 1,075.4 | 2.7 |
| 96-97 | 3,135 | 1,188.3 | 2.7 |
| 97-98 | 3,440 | 1,246.8 | 2.9 |
| 98-99 | 3,169 | 1,385.8 | 2.3 |
| 99-00 | 2,811 | 1,324.6 | 2.2 |
| 00-01 | 3,459 | 1,370.6 | 2.6 |
| 01-02 | 3,386 | 1,568.5 | 2.2 |
| 02-03 | 2,665 | 1,568.5 | 1.8 |
| 03-04 | 2,552 | 1,534.4 | 1.7 |
| 04-05 | 2,979 | 1,458.7 | 2.1 |

**Table 2.** Stone crab landings in pounds of claws (a), number of commercial trips (b), and number of Saltwater Products Licenses (c) by region and fishing season. These landings are a composite of *Menippe mercenaria*, *M.* adina, and their hybrids.

a. Pounds of claws

| Fishing Year | Escambia - Gulf | Franklin-Levy | Citrus-Pasco | Pinellas-Sarasota | Charlotte-Monroe | Gulf Coast | Atlantic Coast | Statewide |
|---|---|---|---|---|---|---|---|---|
| 85-86 | 3,881 | 111,306 | 385,281 | 35,436 | 1,636,228 | 2,172,132 | 2,919 | 2,175,051 |
| 86-87 | 374 | 139,320 | 459,594 | 40,517 | 1,548,006 | 2,187,811 | 8,724 | 2,196,535 |
| 87-88 | 362 | 230,479 | 381,795 | 63,446 | 1,526,321 | 2,202,403 | 34,096 | 2,236,499 |
| 88-89 | 1,520 | 147,636 | 334,071 | 99,870 | 1,999,620 | 2,582,717 | 19,780 | 2,602,497 |
| 89-90 | 268 | 99,744 | 396,665 | 116,041 | 2,069,104 | 2,681,822 | 27,204 | 2,709,026 |
| 90-91 | 484 | 188,992 | 613,060 | 139,250 | 2,163,360 | 3,105,146 | 30,737 | 3,135,883 |
| 91-92 | 123 | 240,179 | 620,835 | 132,270 | 2,168,045 | 3,161,452 | 40,803 | 3,202,255 |
| 92-93 | 298 | 137,784 | 559,464 | 219,461 | 2,185,338 | 3,102,345 | 29,070 | 3,131,415 |
| 93-94 | 342 | 203,180 | 534,762 | 316,043 | 2,297,404 | 3,351,731 | 57,229 | 3,408,960 |
| 94-95 | 642 | 223,376 | 430,317 | 191,477 | 2,417,576 | 3,263,388 | 54,268 | 3,317,656 |
| 95-96 | 12,637 | 182,180 | 391,937 | 136,401 | 2,047,101 | 2,770,256 | 38,754 | 2,809,010 |
| 96-97 | 46 | 248,818 | 483,196 | 394,498 | 2,008,305 | 3,134,863 | 44,739 | 3,179,602 |
| 97-98 | 80 | 263,350 | 616,434 | 172,038 | 2,388,579 | 3,440,481 | 78,206 | 3,518,687 |
| 98-99 | 39 | 255,880 | 691,154 | 242,517 | 1,979,663 | 3,169,253 | 37,474 | 3,206,727 |
| 99-00 | 120 | 214,644 | 421,733 | 150,992 | 2,023,416 | 2,810,905 | 45,621 | 2,856,526 |
| 00-01 | 277 | 183,980 | 681,225 | 356,500 | 2,236,568 | 3,458,550 | 53,202 | 3,511,752 |
| 01-02 | 707 | 261,417 | 698,128 | 193,893 | 2,232,151 | 3,386,296 | 39,341 | 3,425,637 |
| 02-03 | 561 | 284,061 | 626,208 | 260,211 | 1,494,059 | 2,665,100 | 46,158 | 2,711,258 |
| 03-04 | 77 | 195,078 | 425,531 | 143,770 | 1,787,486 | 2,551,942 | 28,658 | 2,580,600 |
| 04-05 | 361 | 233,303 | 478,220 | 273,459 | 1,993,995 | 2,979,338 | 35,526 | 3,014,864 |

b. Numbers of commercial trips

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 85-86 | 21 | 1,858 | 2,640 | 569 | 14,007 | 19,095 | 54 | 19,149 |
| 86-87 | 5 | 2,122 | 3,015 | 558 | 15,727 | 21,427 | 198 | 21,625 |
| 87-88 | 9 | 3,112 | 3,400 | 935 | 18,354 | 25,810 | 391 | 26,201 |
| 88-89 | 27 | 2,309 | 2,618 | 1,135 | 18,774 | 24,863 | 474 | 25,337 |
| 89-90 | 10 | 2,204 | 3,024 | 1,305 | 21,236 | 27,779 | 715 | 28,494 |
| 90-91 | 17 | 2,416 | 3,373 | 1,832 | 19,718 | 27,356 | 1,273 | 28,629 |
| 91-92 | 7 | 2,408 | 4,072 | 1,598 | 20,775 | 28,860 | 1,065 | 29,925 |
| 92-93 | 4 | 1,913 | 3,965 | 2,274 | 21,261 | 29,417 | 979 | 30,396 |
| 93-94 | 25 | 3,063 | 3,379 | 2,961 | 20,523 | 29,951 | 1,621 | 31,572 |
| 94-95 | 25 | 2,465 | 2,950 | 2,624 | 22,756 | 30,820 | 1,769 | 32,589 |
| 95-96 | 127 | 2,121 | 3,300 | 2,120 | 24,773 | 32,441 | 1,541 | 33,982 |
| 96-97 | 6 | 3,014 | 3,854 | 3,587 | 26,663 | 37,124 | 1,320 | 38,444 |
| 97-98 | 7 | 2,469 | 4,130 | 2,451 | 25,474 | 34,531 | 1,525 | 36,056 |
| 98-99 | * | 2,803 | 5,101 | 2,499 | 22,350 | 32,753 | 1,228 | 33,981 |
| 99-00 | 3 | 2,714 | 4,347 | 2,348 | 24,004 | 33,416 | 1,383 | 34,799 |
| 00-01 | 18 | 2,063 | 4,233 | 2,853 | 20,407 | 29,574 | 1,640 | 31,214 |
| 01-02 | 78 | 2,093 | 4,054 | 2,199 | 18,811 | 27,235 | 1,518 | 28,753 |
| 02-03 | 81 | 2,987 | 4,258 | 3,064 | 18,474 | 28,864 | 1,628 | 30,492 |
| 03-04 | 11 | 2,790 | 3,600 | 2,387 | 18,500 | 27,288 | 1,161 | 28,449 |
| 04-05 | 15 | 2,457 | 3,277 | 2,517 | 18,043 | 26,309 | 1,077 | 27,386 |

**Table 2 continued.** Stone crab landings in pounds of claws (a), number of commercial trips (b), and number of Saltwater Products Licenses (c) by region and fishing season. These landings are a composite of *Menippe mercenaria*, *M.* adina, and their hybrids.

c. Numbers of Saltwater Products Licenses

| Fishing Year | Escambia - Gulf | Franklin-Levy | Citrus-Pasco | Pinellas-Sarasota | Charlotte-Monroe | Gulf Coast | Atlantic Coast | Statewide |
|---|---|---|---|---|---|---|---|---|
| 85-86 | Saltwater Products License numbers were not allowed in the database. | | | | | | | |
| 86-87 | | | | | | | | |
| 87-88 | 4 | 166 | 148 | 89 | 1,011 | 1,418 | 75 | 1,493 |
| 88-89 | 13 | 171 | 145 | 114 | 1,137 | 1,580 | 87 | 1,667 |
| 89-90 | 6 | 158 | 169 | 165 | 1,269 | 1,767 | 99 | 1,866 |
| 90-91 | 13 | 134 | 171 | 196 | 1,194 | 1,708 | 129 | 1,837 |
| 91-92 | 6 | 153 | 176 | 150 | 1,019 | 1,504 | 119 | 1,623 |
| 92-93 | 4 | 139 | 154 | 174 | 914 | 1,385 | 117 | 1,502 |
| 93-94 | 5 | 190 | 191 | 267 | 1,049 | 1,702 | 197 | 1,899 |
| 94-95 | 6 | 176 | 197 | 244 | 1,048 | 1,671 | 206 | 1,877 |
| 95-96 | 26 | 174 | 170 | 173 | 1,053 | 1,596 | 135 | 1,731 |
| 96-97 | 4 | 166 | 211 | 266 | 1,098 | 1,745 | 124 | 1,869 |
| 97-98 | 3 | 148 | 192 | 202 | 987 | 1,532 | 141 | 1,673 |
| 98-99 | * | 161 | 207 | 205 | 907 | 1,480 | 121 | 1,601 |
| 99-00 | * | 154 | 182 | 170 | 918 | 1,424 | 114 | 1,538 |
| 00-01 | * | 140 | 172 | 208 | 867 | 1,387 | 130 | 1,517 |
| 01-02 | 15 | 120 | 155 | 161 | 771 | 1,222 | 115 | 1,337 |
| 02-03 | 16 | 130 | 151 | 172 | 714 | 1,183 | 126 | 1,309 |
| 03-04 | 6 | 114 | 138 | 154 | 658 | 1,070 | 98 | 1,168 |
| 04-05 | 5 | 118 | 127 | 162 | 637 | 1,049 | 90 | 1,139 |

* Less than three Saltwater Products Licenses

**Table 3**. Landings in pounds and numbers of claws, the average number of claws per crab, the number of crabs affected by the fishery, and number of traps pulled by fishing season.

| Fishing | Landings in claws | | | Affected Crabs | |
|---|---|---|---|---|---|
| Season | Pounds | Number | Claws/Crab | Number | Traps pulled |
| 78-79 | 1,894,531 | 5,995,168 | 1.34 | 4,460,274 | 5,562,506 |
| 79-80 | 2,010,919 | 6,263,324 | 1.36 | 4,613,456 | 5,783,054 |
| 80-81 | 1,695,805 | 5,291,828 | 1.35 | 3,907,149 | 4,990,734 |
| 81-82 | 2,668,079 | 8,298,017 | 1.36 | 6,098,563 | 7,489,177 |
| 82-83 | 2,698,314 | 8,322,858 | 1.37 | 6,075,123 | 7,300,385 |
| 83-84 | 1,952,096 | 5,990,739 | 1.37 | 4,363,468 | 5,333,055 |
| 84-85 | 1,761,077 | 5,309,017 | 1.39 | 3,811,355 | 4,634,415 |
| 85-86 | 2,166,587 | 9,914,778 | 1.39 | 7,137,260 | 5,842,102 |
| 86-87 | 2,187,281 | 10,123,767 | 1.37 | 7,375,711 | 6,950,005 |
| 87-88 | 2,206,257 | 10,323,774 | 1.38 | 7,480,238 | 7,733,480 |
| 88-89 | 2,590,202 | 12,116,340 | 1.42 | 8,503,094 | 7,737,142 |
| 89-90 | 2,672,034 | 12,303,287 | 1.39 | 8,830,683 | 11,847,503 |
| 90-91 | 3,121,734 | 14,208,726 | 1.49 | 9,529,080 | 9,956,860 |
| 91-92 | 3,164,594 | 14,547,400 | 1.49 | 9,745,908 | 9,389,730 |
| 92-93 | 3,111,351 | 14,542,085 | 1.48 | 9,804,996 | 9,354,801 |
| 93-94 | 3,365,764 | 15,836,234 | 1.37 | 11,521,930 | 9,695,959 |
| 94-95 | 3,267,611 | 14,898,322 | 1.31 | 11,380,735 | 10,881,154 |
| 95-96 | 2,827,729 | 12,974,022 | 1.30 | 9,953,272 | 10,057,220 |
| 96-97 | 3,181,597 | 14,337,244 | 1.43 | 10,020,477 | 10,511,054 |
| 97-98 | 3,478,893 | 15,464,890 | 1.39 | 11,136,402 | 10,289,322 |
| 98-99 | 3,213,166 | 14,581,134 | 1.32 | 11,035,926 | 10,259,740 |
| 99-00 | 2,857,758 | 13,140,112 | 1.33 | 9,876,308 | 10,177,531 |
| 00-01 | 3,535,026 | 15,862,825 | 1.41 | 11,256,979 | 10,407,742 |
| 01-02 | 3,445,668 | 15,967,484 | 1.30 | 12,242,736 | 10,569,762 |
| 02-03 | 2,701,260 | 12,360,243 | 1.32 | 9,384,932 | 10,533,762 |
| 03-04 | 2,594,702 | 11,988,397 | 1.24 | 9,648,806 | 13,167,889 |
| 04-05 | 3,036,456 | 13,815,678 | 1.26 | 10,938,480 | 13,072,108 |

LIST OF FIGURES

LIST OF FIGURES Continued.

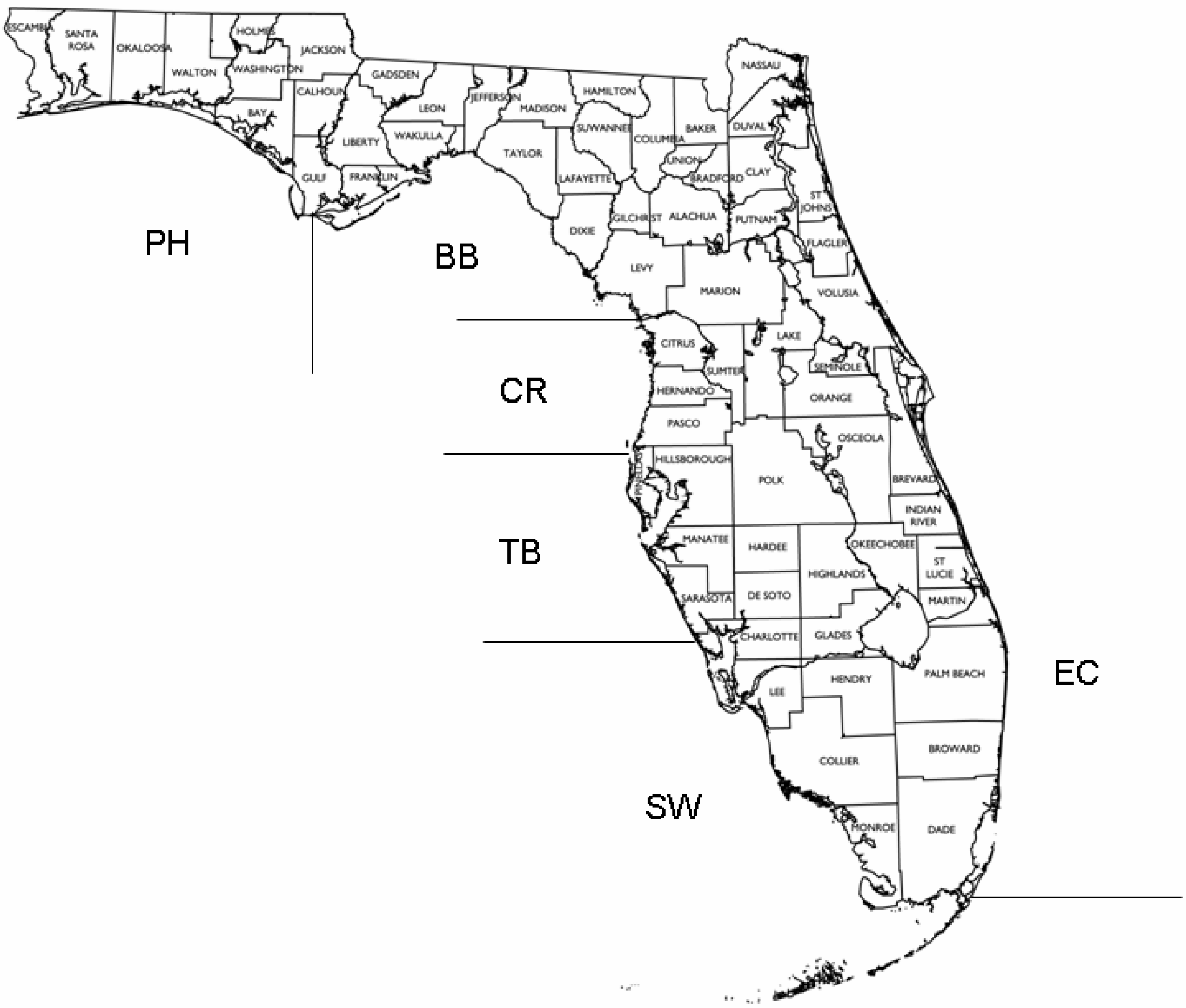



**Figure 1.** Geographic regions for stone crab landings and effort: PH - Panhandle (Escambia-Gulf counties), BB - Big Bend (Franklin-Levy counties, CR - Crystal River (Citrus-Pasco counties), TB - Tampa Bay (Pinellas-Sarasota counties). SW - Southwest (Charlotte - Monroe counties), and EC- Atlantic Coast (Nassau - Miami-Dade counties).

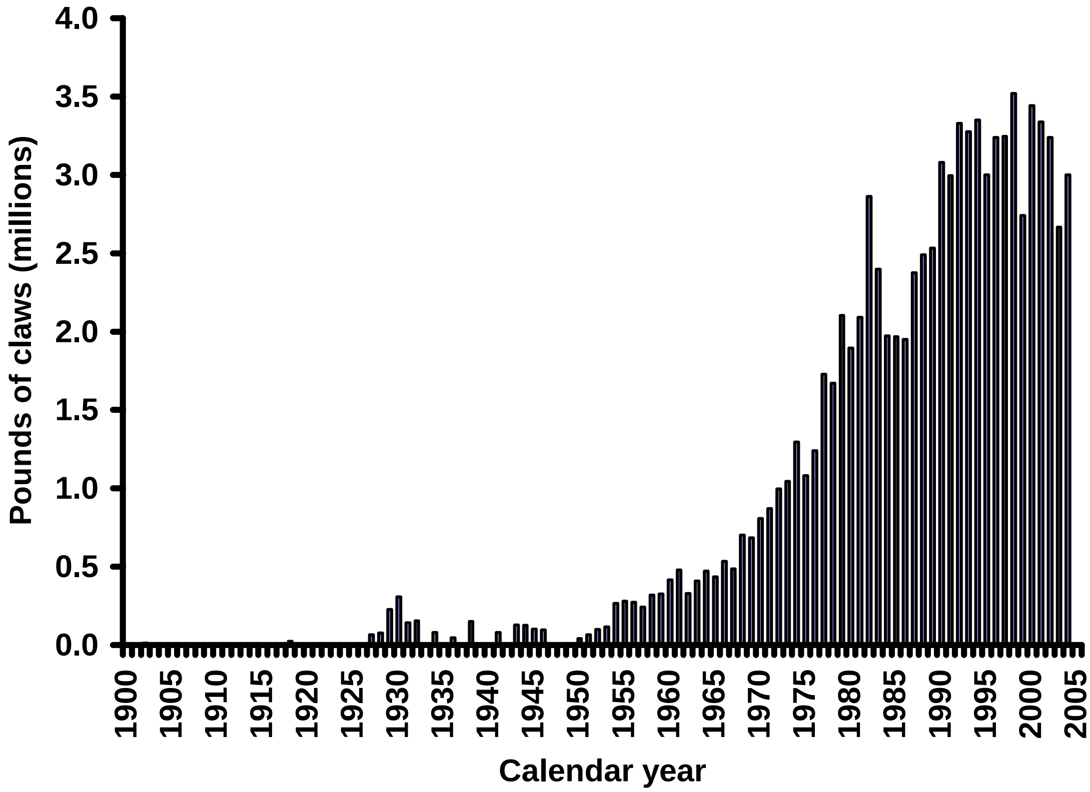



**Figure 2.** Historical landings of stone crabs statewide, in pounds of claws, on a calendar-year basis.

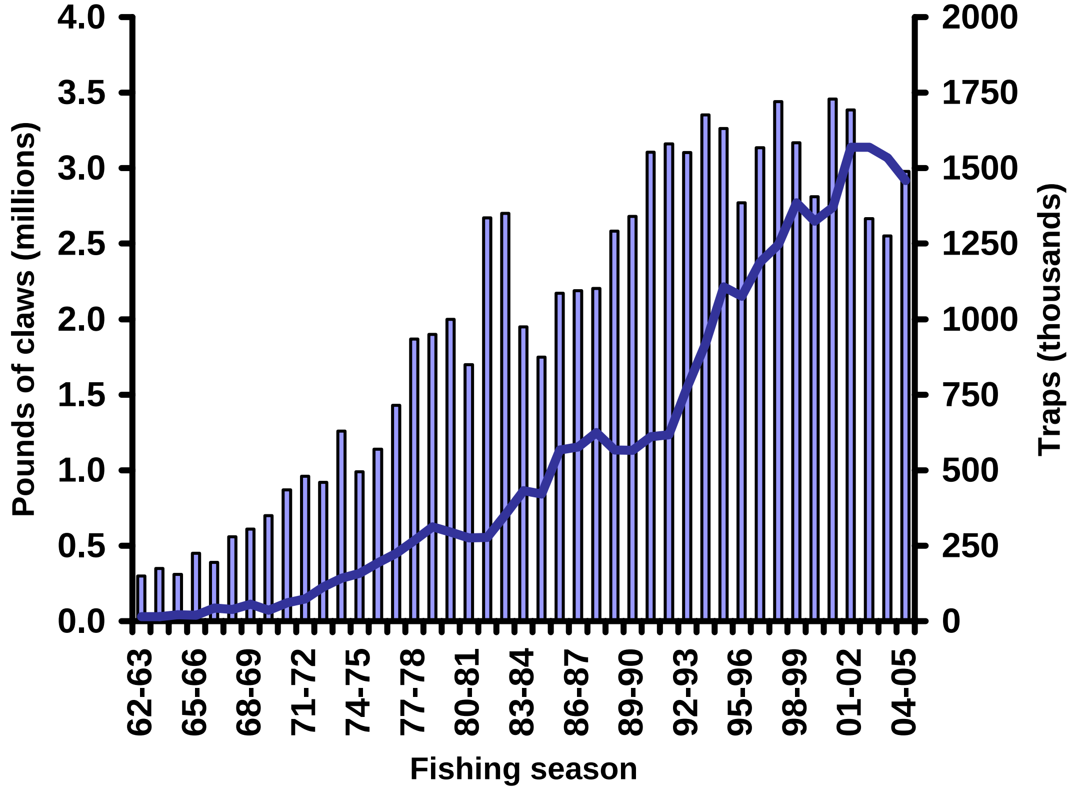



**Figure 3.** Gulf coast stone crab landings, in pounds of claws, and the numbers of traps by fishing season. Bars are landings and the line is the number of traps.

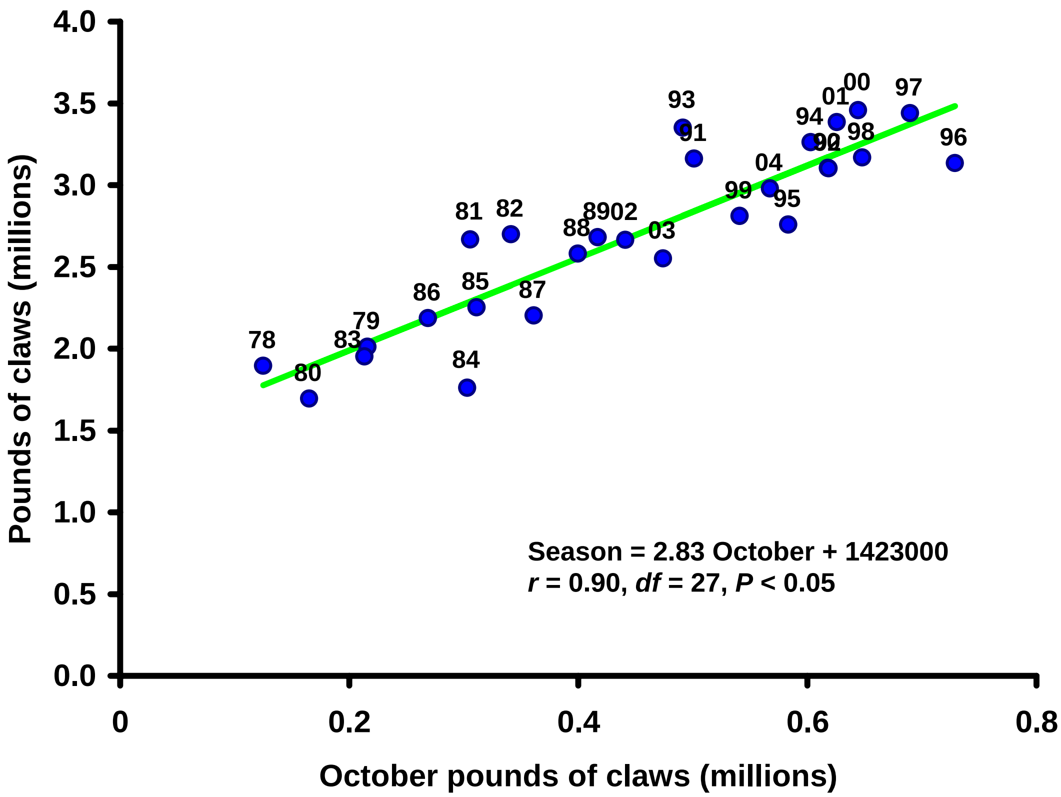
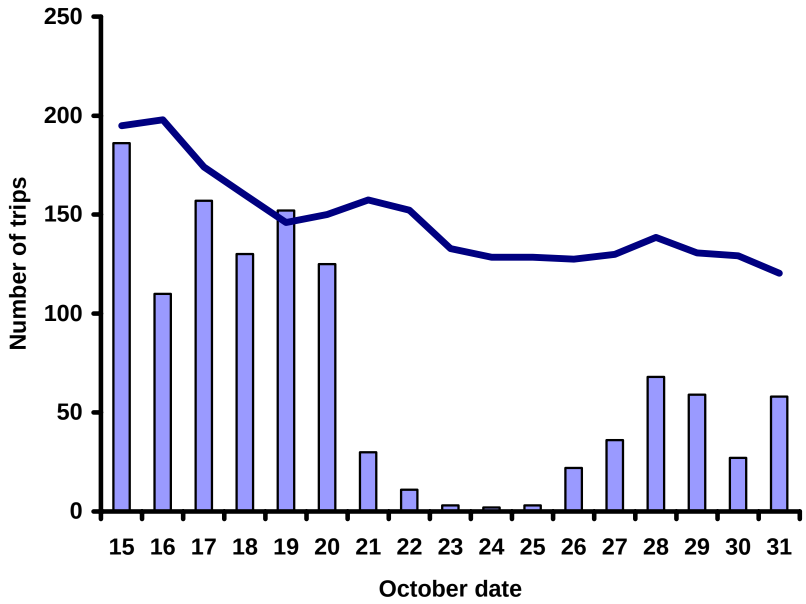



**Figure 4.** October landings and the season's total landings by fishing season, in pounds of claws.

**a.**




**b.**

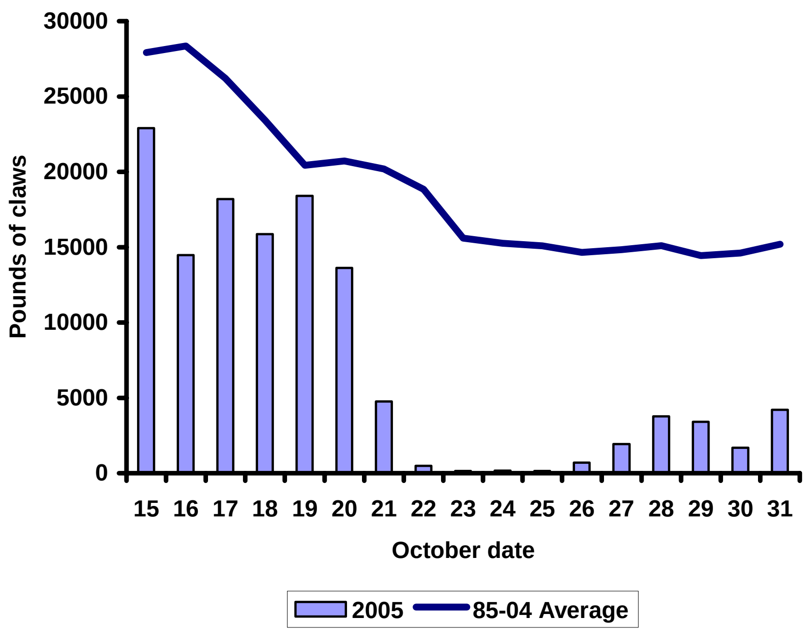



**Figure 5.** Daily trips and landings during October 2005 as compared to the 1985-2004 October daily averages, indicating the impact of Hurricane Wilma which reached the Florida Keys on 24 October 2005.

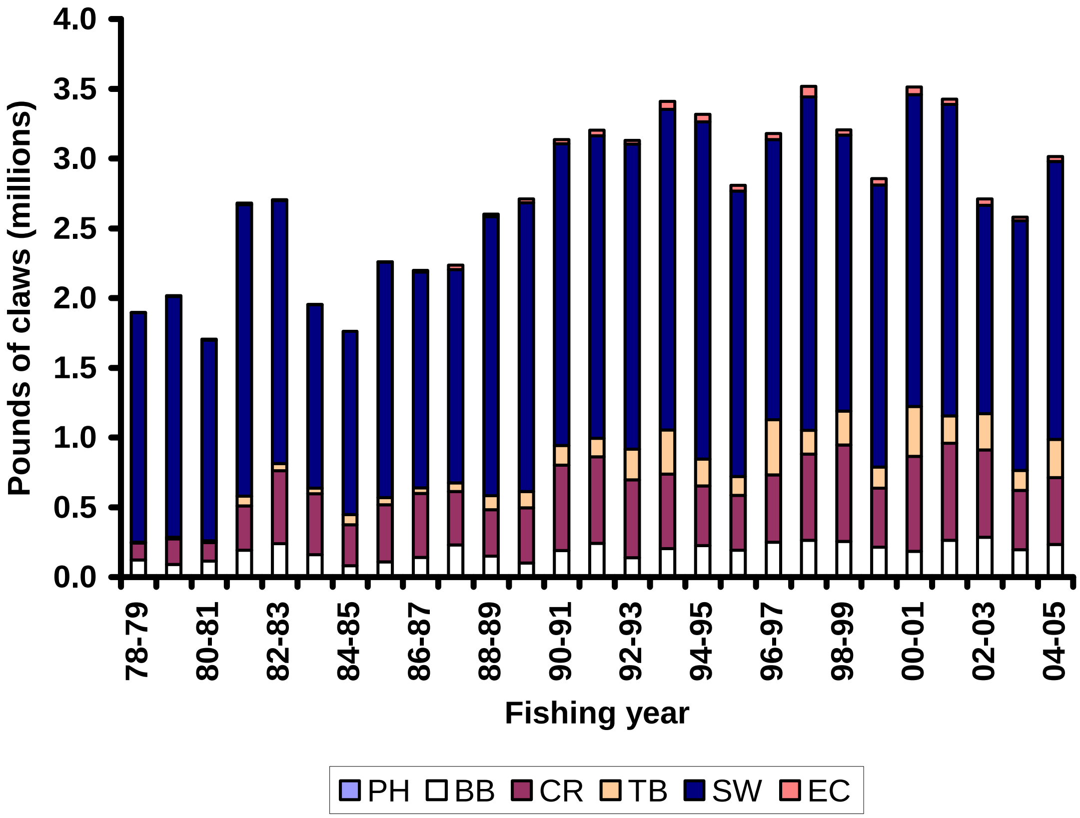



**Figure 6.** Landings, in pounds of claws, by region and fishing season. Regions: PH - Panhandle, BB - Big Bend, CR - Crystal River, TB - Tampa Bay. SW - Southwest, and EC- Atlantic Coast.

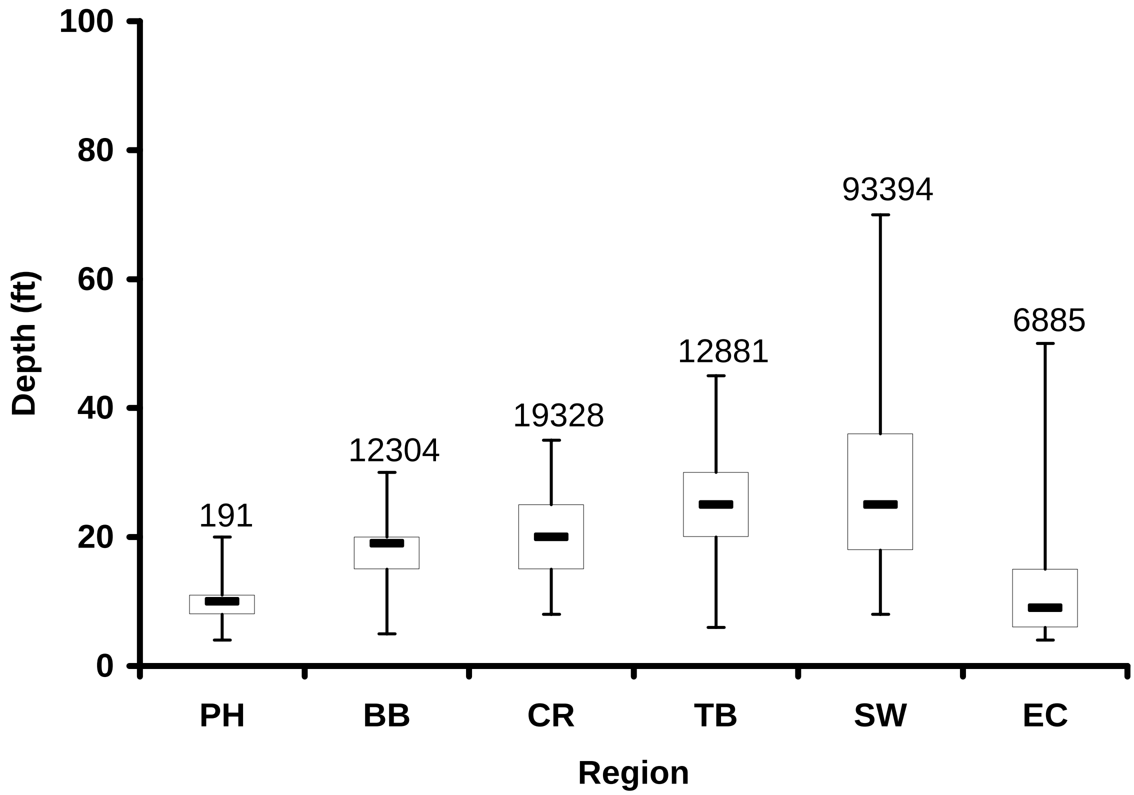



**Figure 7.** Distribution of depths fished by region based on trip tickets. Regions: PH - Panhandle, BB - Big Bend, CR - Crystal River, TB - Tampa Bay, SW - Southwest and EC- Atlantic coast. Number above the points - number of trips, vertical bar - 95% confidence interval, box - inter-quartile range, and horizontal line - median.

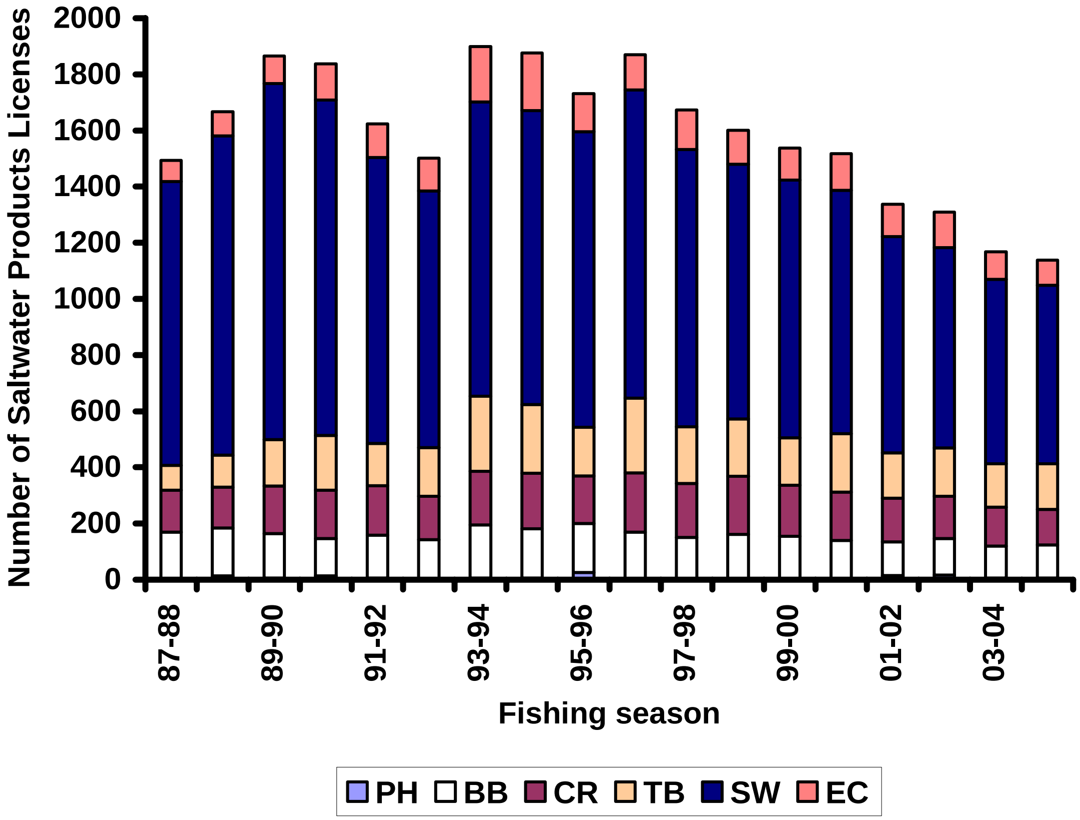



**Figure 8.** Regional participation by fishing season. Regions: PH - Panhandle, BB - Big Bend, CR - Crystal River, TB - Tampa Bay, SW - Southwest and EC- Atlantic coast.

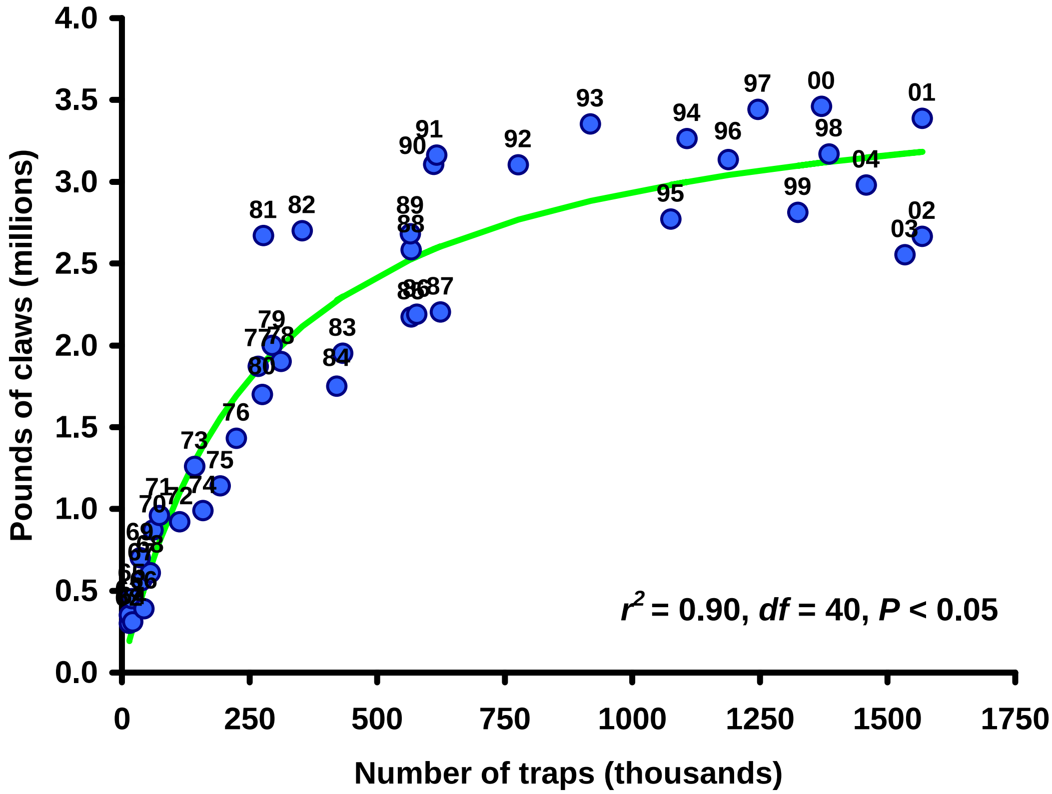
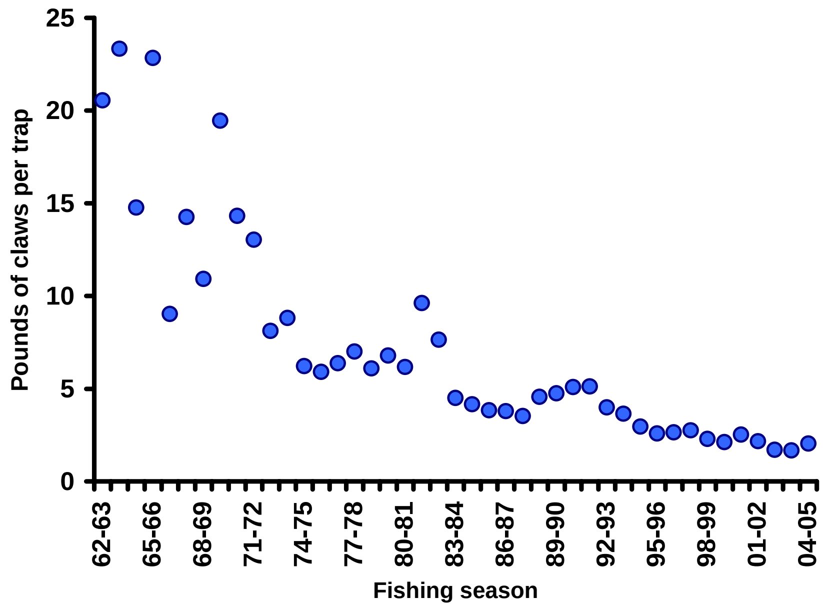



**Figure 9.** Historical landings, in pounds of claws, and the numbers of traps by fishing season. The fitted line summarizes the relationship between landings and traps.

a.




b.

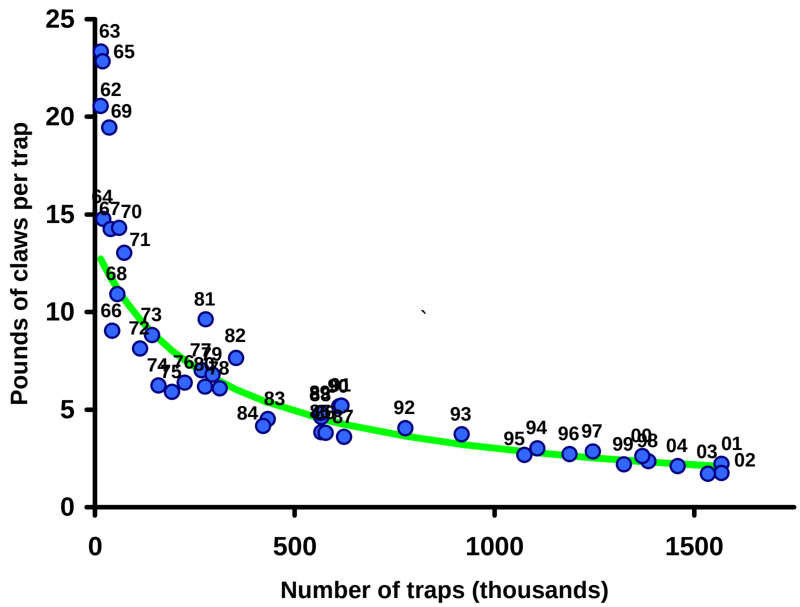
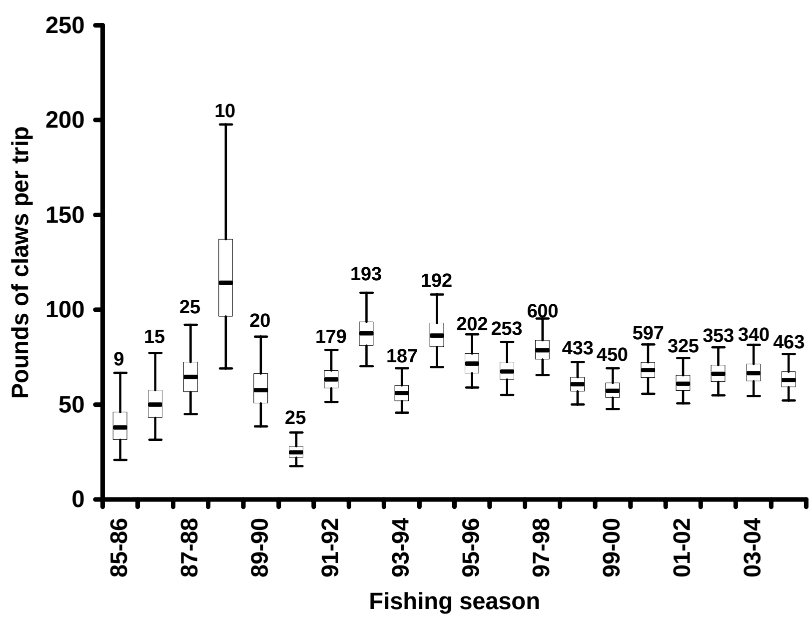



**Figure 10.** Historical pounds of claws per trap by fishing season (a) and number of traps (b). The fishing season is indicated above the points in Figure 7b and the line is the predicted pounds per trap from Equation 2.

a.




b.

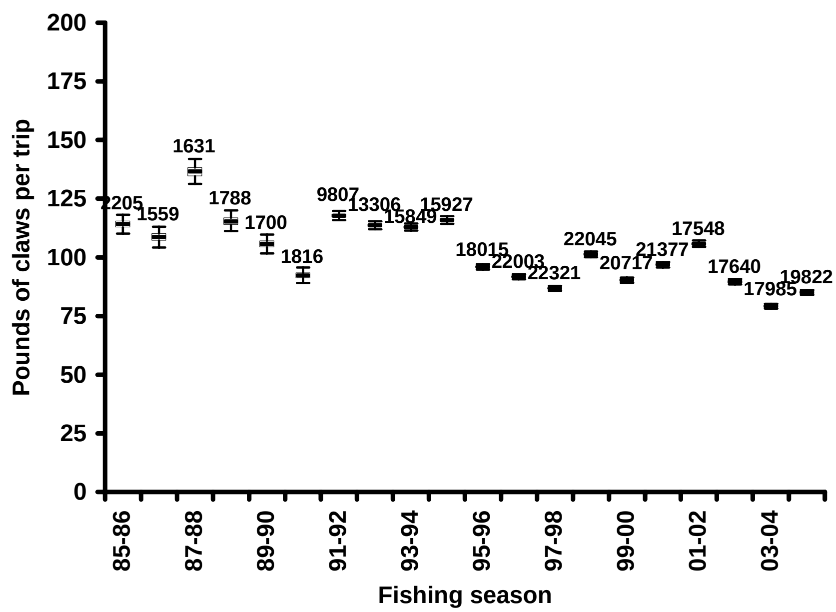



**Figure 11.** Standardized catch-per-trip for the Atlantic (a) and gulf (b) coasts. Number above the plot - number of trips, vertical bar - 95% confidence interval, box - inter-quartile range, and horizontal line - median.

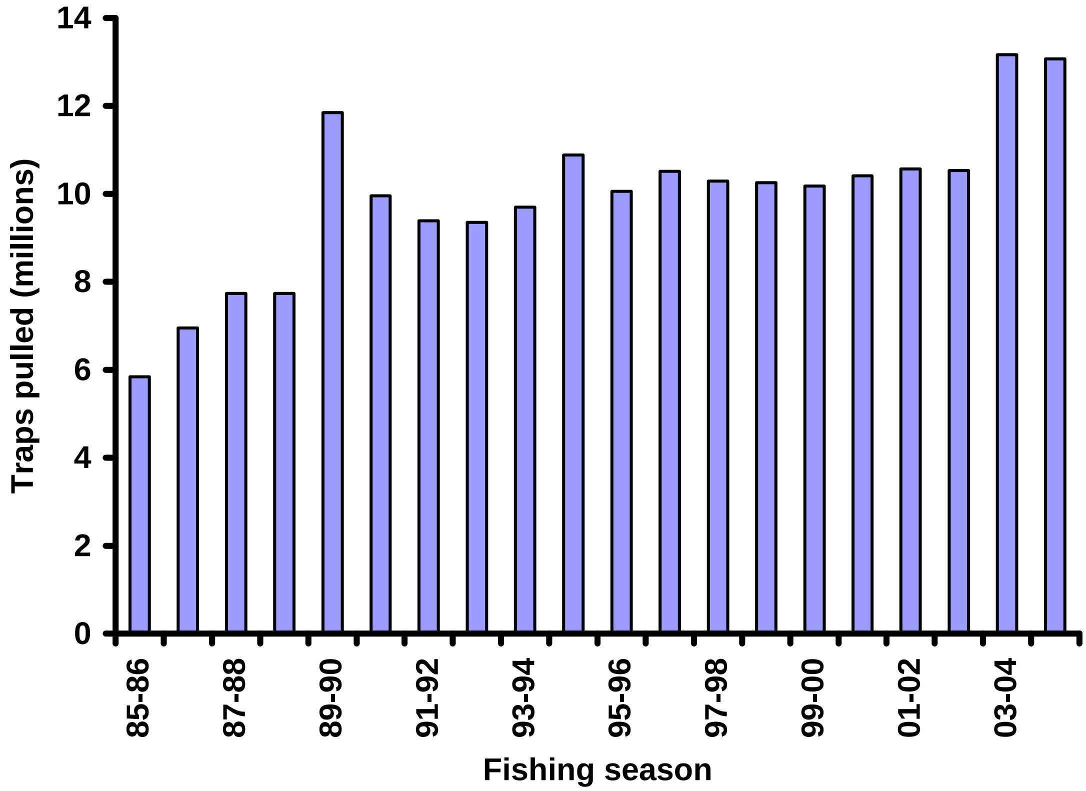



**Figure 12.** Estimated number of traps pulled per fishing season.

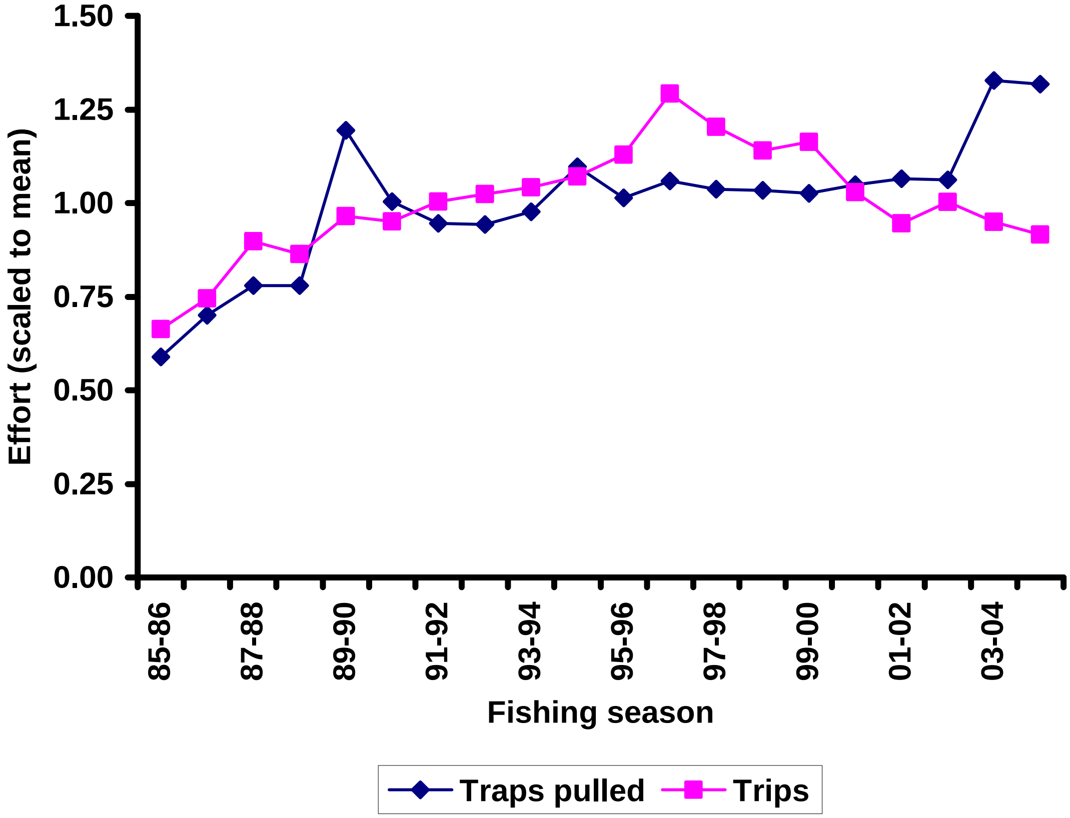
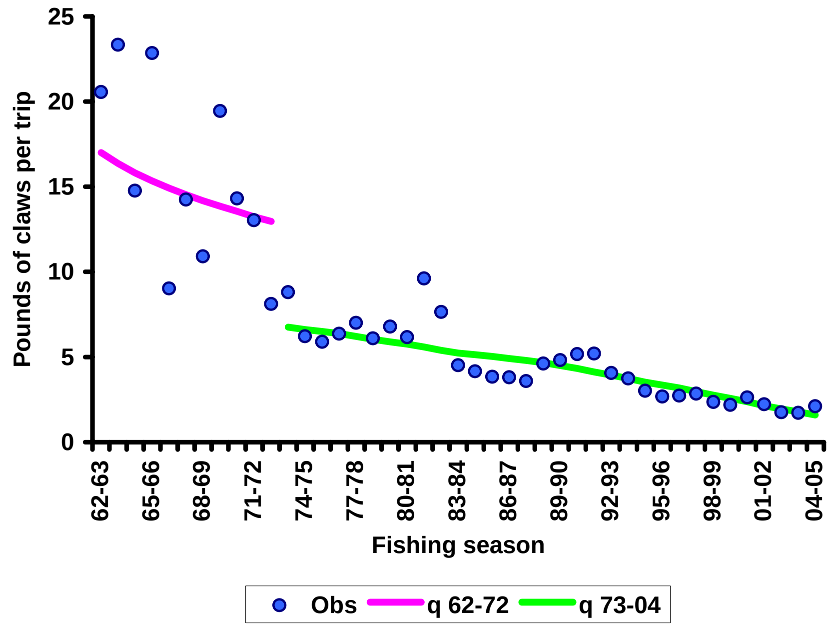



**Figure 13.** Comparison of the number of traps pulled per fishing season with the number of trips. Both series of effort have been scaled to their means to facilitate comparison.

a.




b.

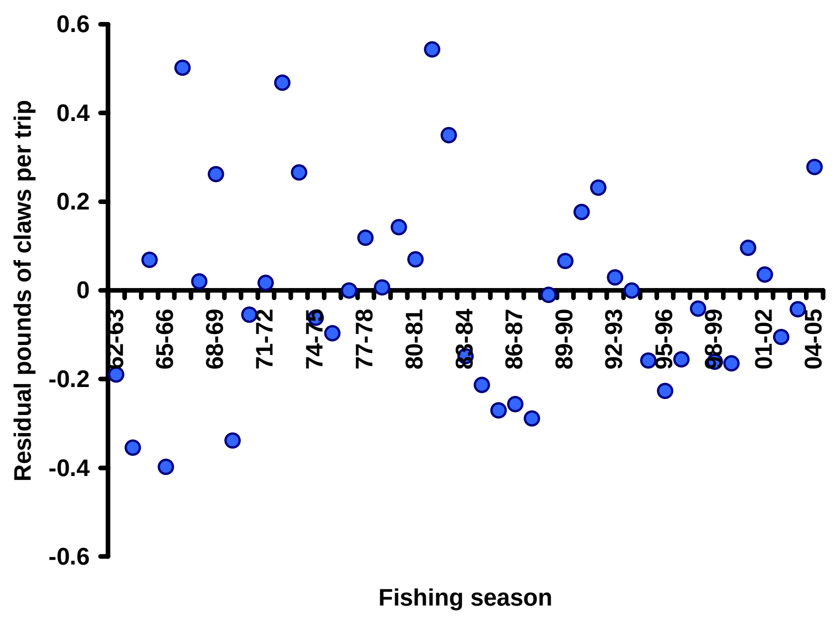



**Figure 14.** Fit of surplus production model (ASPIC) to catch-per-trap data (a) and catch-per-trap residuals (b). The model used two catchability coefficients, q 62-72, for the 1962-63 through 1972-73 fishing seasons and q 73-04 for the later fishing seasons.

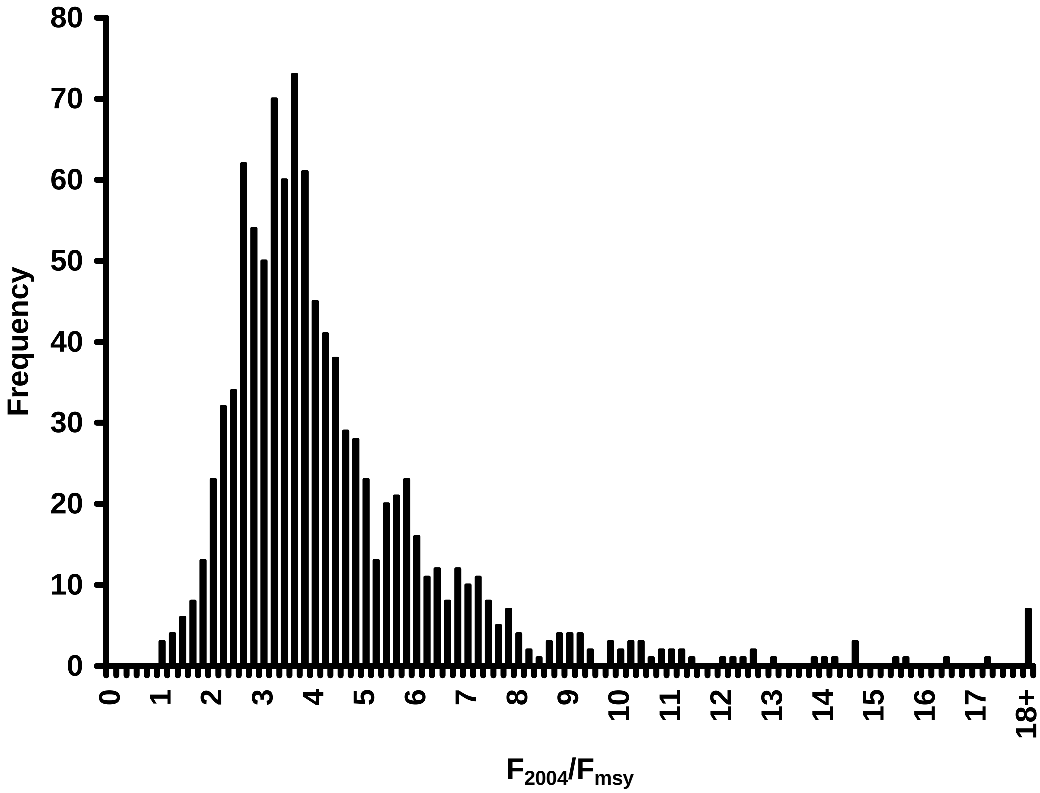
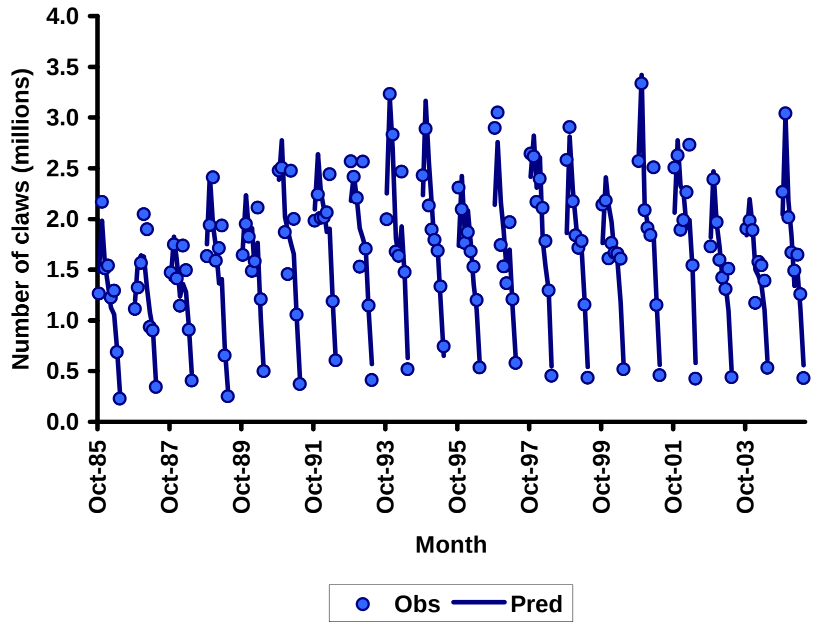



**Figure 15.** Frequencies of fishery mortality benchmark ratios from surplus production model (ASPIC) for fishing mortality rate, $F_{2004}/F_{msy}$ based on 1000 Monte Carlo iterations.

a.




b.

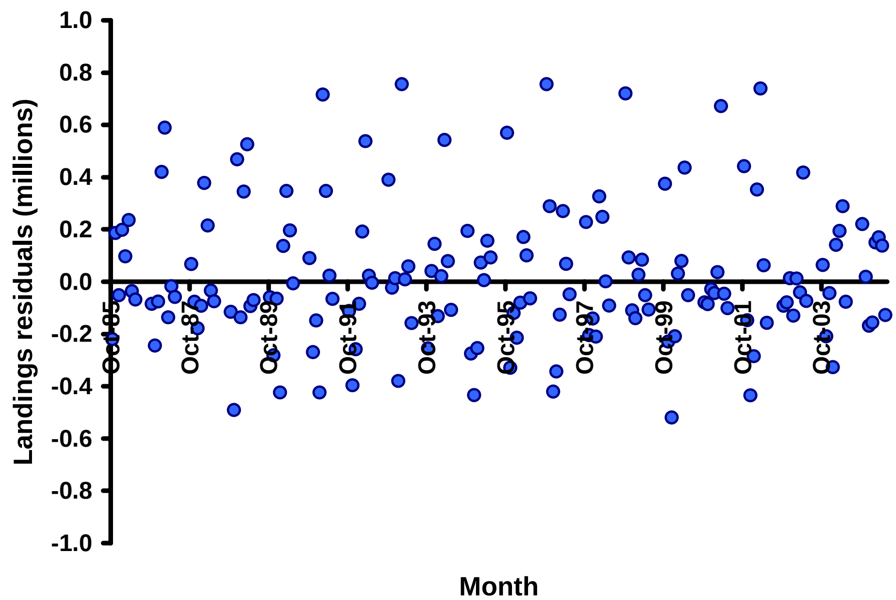



**Figure 16.** Observed (points) and predicted monthly landings (line), in numbers of claws, from the DeLury continuity model (a) and the landings residuals (observed - predicted, b).

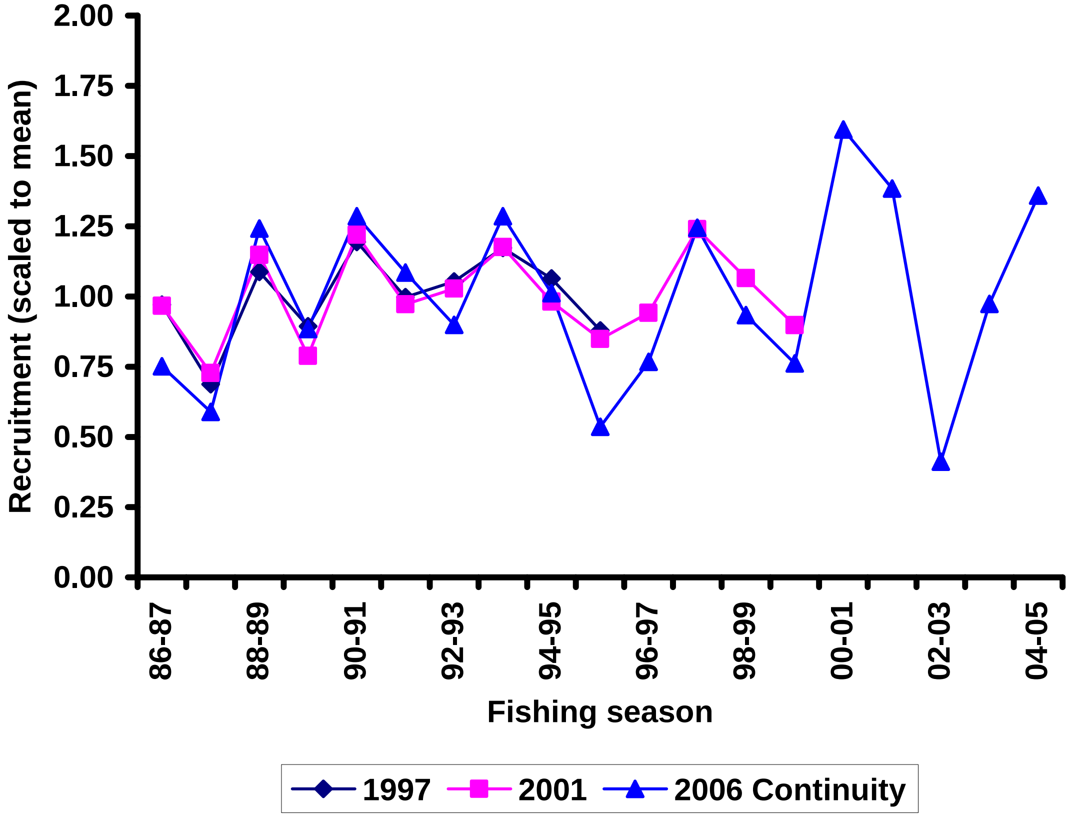



**Figure 17.** Recruitment, in numbers of claws, by fishing season estimated from the DeLury continuity model together with recruitment estimates from the 1997 and 2001 assessments. The recruitment series have been scaled to their means to facilitate comparison.

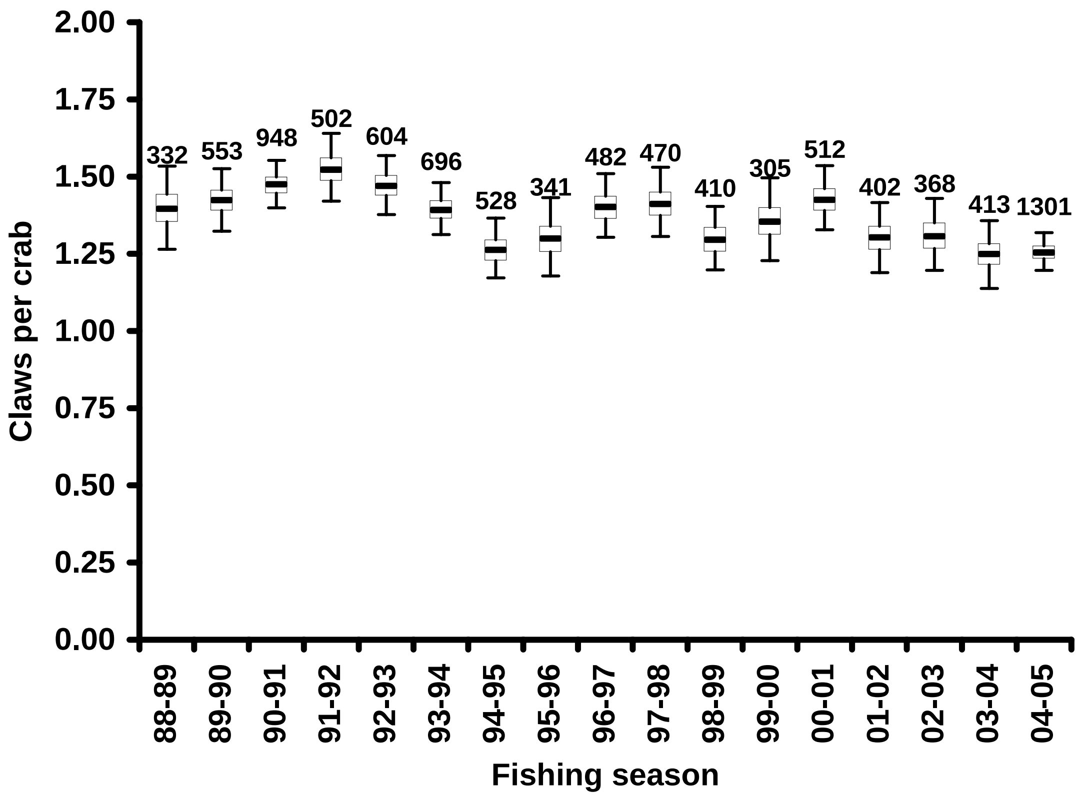



**Figure 18.** Number of legal-sized claws per crab from the combined Tampa Bay (1988-2005) and Florida Keys (2005) fishery-independent sampling programs. Number above the plot - number of traps, vertical bar - 95% confidence interval, box - inter-quartile range, and horizontal line - median.

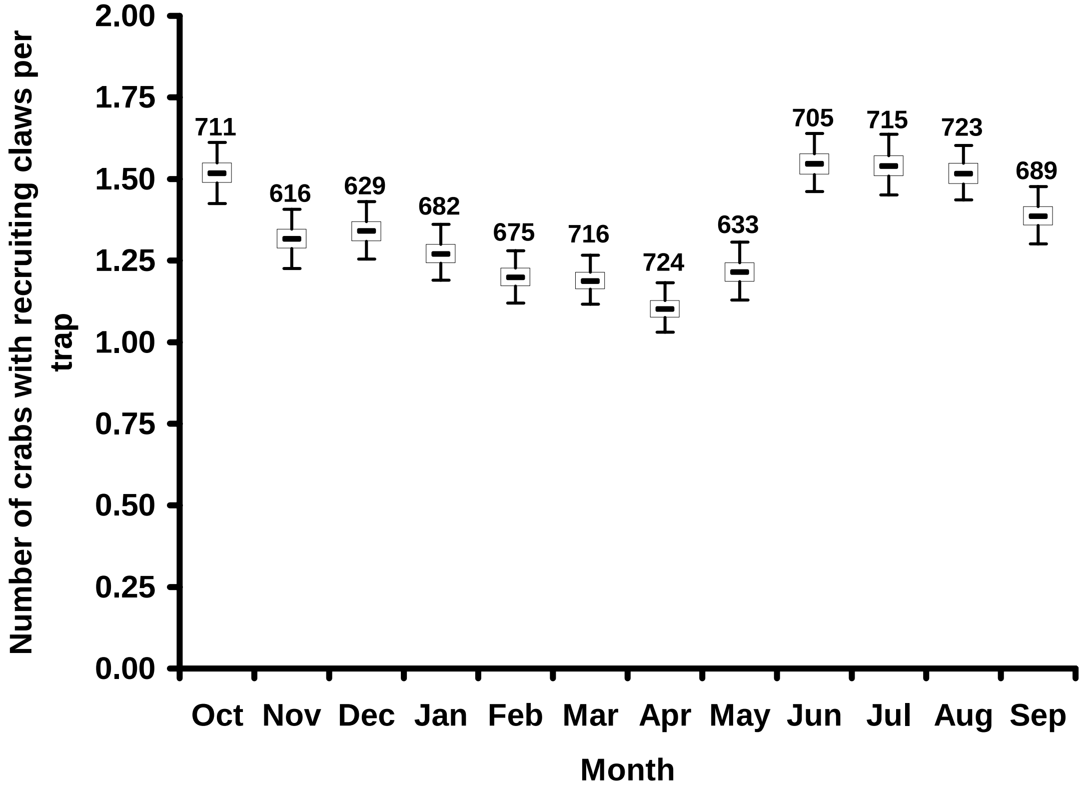



**Figure 19.** Number of crabs with recruitment-sized claws (70 - 81 mm) per trap pull by month from the Tampa Bay fishery-independent sampling program. Number above the plot - number of trap pulls, vertical bar - 95% confidence interval, box - inter-quartile range, and horizontal line - median.

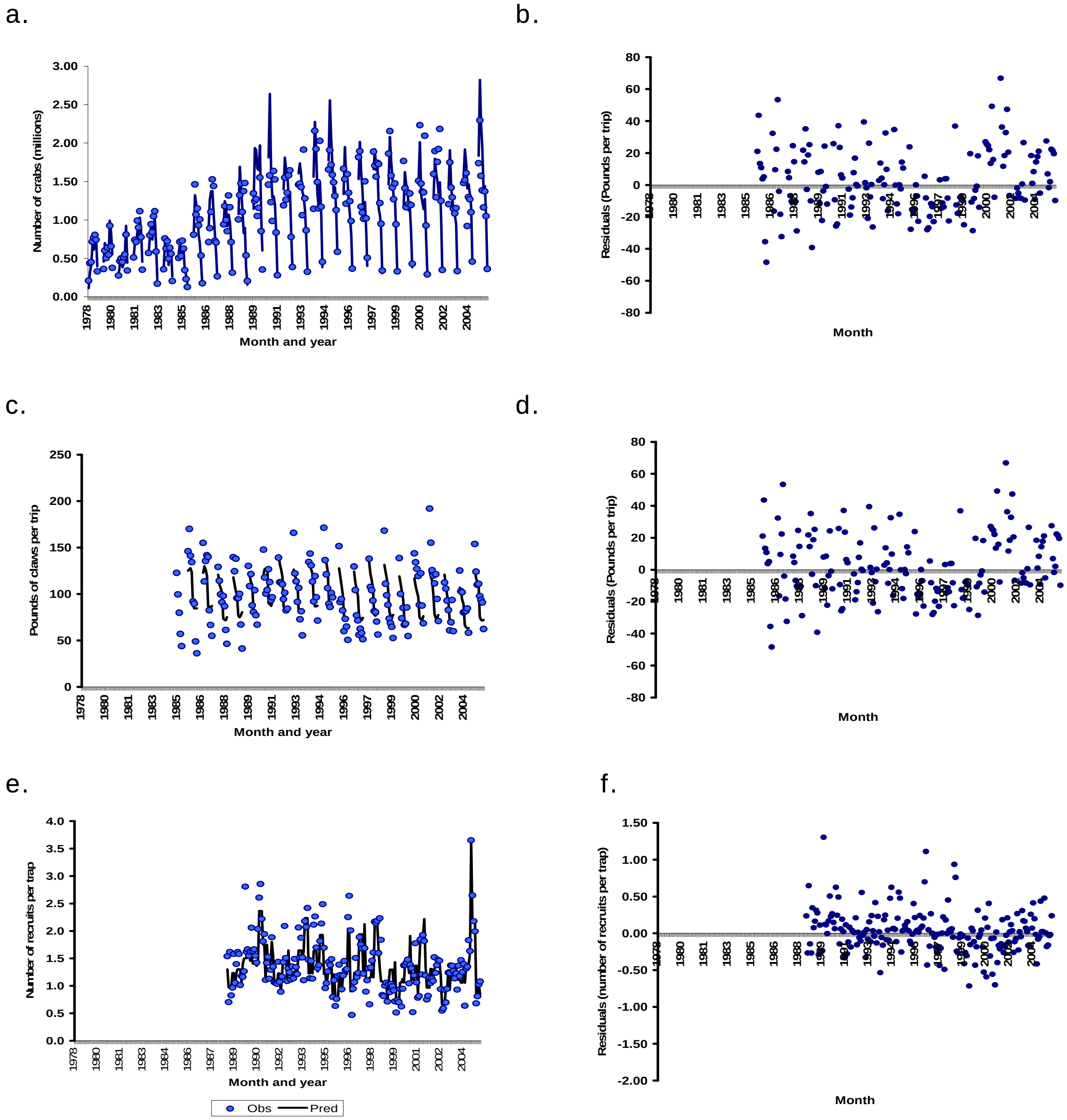



**Figure 20.** Fit of the extended DeLury model to the numbers of crabs (a) and their residuals (b), the pounds of claws per trip (c) and their residuals (d), and the number of recruiting crabs (e) and their residuals (f). Observed values are illustrated with points and the predicted values with lines (a, c, e).

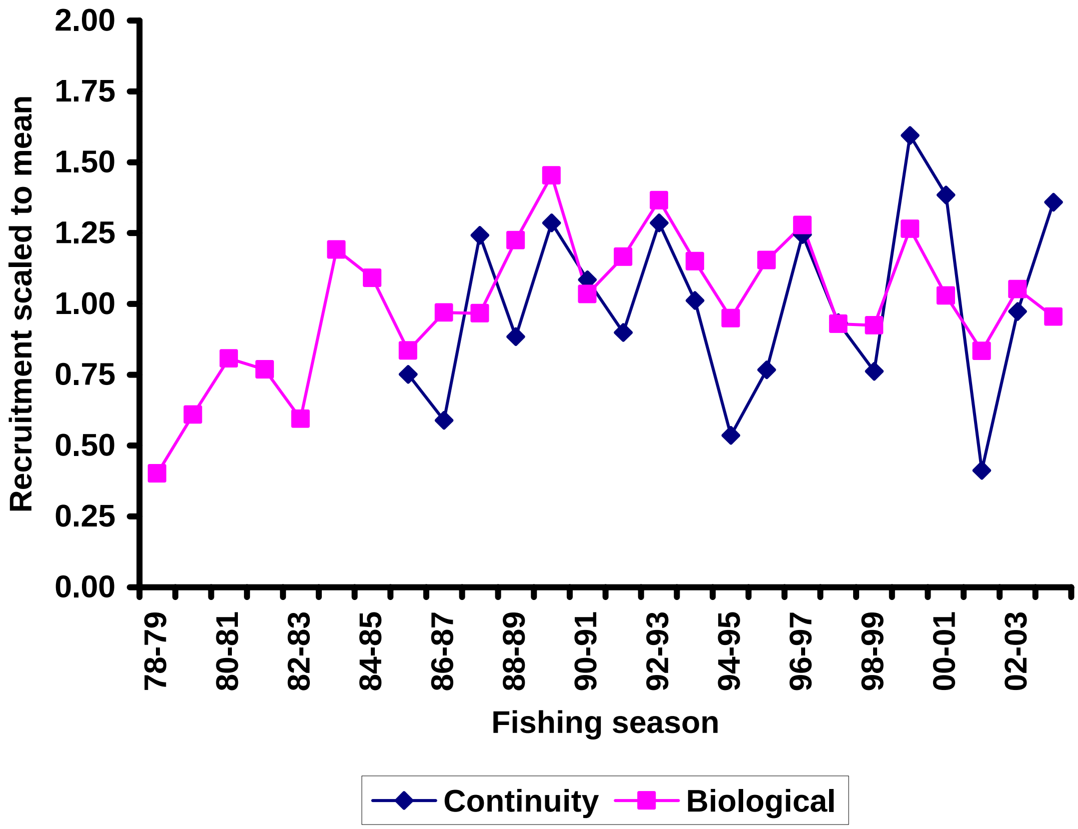



**Figure 21.** Comparison of recruitment estimated with the DeLury continuity model to that from the biological DeLury model. The continuity model included data from 1985-86 and had recruitment only occurring in October while the biological model included data from 1978-79, used a recruitment index for 1988-98 through 2004-05, and had recruitment occurring monthly. These recruitment series have been scaled to their means to facilitate comparison.