SEDAR7-DW24: Estimation of Effort in the Offshore Shrimp Trawl Fishery of the Gulf of Mexico

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# Estimation of Effort in the Offshore Shrimp Trawl Fishery of the Gulf of Mexico

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## Introduction

This report provides a description of the data and data collection procedures that are used to collect statistics from the shrimp fisheries in the Gulf of Mexico, and also discusses the procedures currently used in the calculation of shrimp fishing effort in the nearshore and offshore areas of the Gulf of Mexico.

The Southeast Fisheries Science Center (SEFSC) maintains shrimp databases from the commercial harvesting sector. These statistics do not include shrimp caught by recreational shrimpers for personal or family consumption. Similarly, SEFSC databases do not include catch by commercial fishermen sold through non-dealer channels. In addition, the program does not include data on catch of shrimp that are discarded at sea.

Although the Gulf of Mexico shrimp database is complex, the procedures that are used to collect these data are, at least conceptually, straightforward. The data collection procedures are described below in the section entitled "Data Collection Procedures", and a detailed description of the data files follows entitled "Data File Descriptions".

## Shrimp Data Files

### Data Collection Procedures

Currently, there are about 20 port agents employed by state or Federal agencies participating in the SEFSC Gulf shrimp program. Shrimp statistics for commercial fisheries are collected by these port agents located in coastal ports around the Gulf of Mexico and also by dealer trip ticket programs in the states of Alabama and Louisiana.

Florida has a dealer trip ticket system, but the data are not used in the current shrimp system.

Port agents collect shrimp statistics from two sources, seafood dealers and fishermen, while the trip ticket system collects data only from the seafood dealer. Data on the amount and value of the shrimp that are unloaded (i.e., landed) at the dealers are collected from dealer records. For discussion purposes, these data are referred to as "dealer data" in the landings file. The second type of data includes detailed information on fishing effort and location for an individual trip and is collected by interviewing either the captain or a crew member. These data are referred to as "interview data" in the landings file.

Because a port agent is responsible for a specific geographical area, the same person collects the landings statistics, and interviews fishermen for effort and location information. Consequently, it is the port agent's responsibility to assure that the right effort and location information are associated with the landings data from the same trip. This procedure guards against the possibility of double counting fishing activity that could occur if more than one individual were responsible for collecting data in the same geographic area. The trip ticket system has added a little more complexity to the issue. Currently, NMFS Galveston Laboratory is responsible for merging the dealer information from the state trip ticket collection system with the interview information from NMFS port agents.

Because the fishing trip is the basic sampling unit, the fundamental principle of the data collection procedures is to collect both landings and interview data on a trip-by-trip basis. However, because the number of fishing trips that occur in the Gulf shrimp fishery is so large (i.e., 155,138 total trips in 2002), it is difficult for a record to be made of every fishing trip.  Consequently, data collection procedures include two modifications to this principle.

The first modification is that the port agents are only required to record landing statistics for fishing trips made by documented vessels (fishing craft registered with the U.S. Coast Guard) that fish nearshore and offshore (seaward of the COLREG line).  The port agents may combine the landings statistics and record only monthly totals for the pounds, value and number of trips that are made by boats (state licensed fishing craft) in these nearshore and offshore areas.  In contrast, port agents may combine the landings statistics and record only monthly totals for the pounds, value and number of trips that are made by both boats and vessels that fish in inshore areas (inside the COLREG line). Consolidation of data is also used for trips that are made in nearshore and offshore areas, when the vessel that made the trip could not be identified from the dealer's records.

The second modification is that port agents only conduct interviews from a sample of the vessels that fish nearshore and offshore.  The intent of this protocol is to select a few individuals that are representative of the total population and collect information from the sample rather than the entire population.  The logistics of fishing, however, make it impossible for the port agents to perform interviews that are selected randomly from the vessel population.  Most of the time port agents do not know where and when vessels are going to land, so specific vessels cannot be targeted in advance for selection.  As a result, the port agents are instructed to regularly visit the docks in their areas and interview vessel captains as the opportunity arises.  If there are more vessels in port than can be interviewed, the agents are instructed to select the vessels by "random" process, in an attempt to avoid systematic bias (i.e., always interviewing the same vessels, at the same port).

In summary, port agents visit all the shrimp dealers in their assigned area at least once per month, and collect landings statistics for individual fishing trips for all the vessels fishing nearshore and offshore that can be identified.  From a sample of these trips, the port agents interview the captain or crew member to collect fishing effort and catch location information.  For nearshore and offshore trips made by boats, and inshore trips made by both boats and vessels, the port agents may combine the landings statistics for the trips made each month.

Data File Descriptions

Port agents record the landings and interview data on a standard collection form.  If landings statistics alone are collected (or if the data come from a trip ticket system), only part of the form or record is completed.  If both landings and interview data are collected for the same trip, the entire form is completed.  The individual data elements for the landings and interview portions of the database are listed below.  The data elements that are collected from the dealer's sales receipts or pack-out sheets are listed under the column titled "Landings Information", and the elements that are recorded from interviews with the captains are listed under the column titled "Interview Information". All of the data are input into a file, which is termed the "Shrimp Landings File".

| Landings Information | Interview Information |
|---|---|
| Port | Days Fished |
| Vessel Name | Size of Trawls |
| Official Documentation Number | Port of Departure |
| Date of Unloading | Departure Date |
| Number of Trips | Number of Trawls |
| Grading | Hours Fished During Day / Night |

Dealer Number
Species
Size
Pounds
Area
Depth (not in trip ticket system)
Price per Pound

Condition (heads on or off)
Area
Depth
Number of Crew

These data elements are, for the most part, self-explanatory; however, there are several that should be explained in more detail.

The term "Days Fished" is used to record the number of 24-hour days that the trawls were in the water fishing. For example, if a vessel fished 10 hours one day, 12 hours the next, and 12 hours the third day, the number of days fished would be 1.4 (i.e., (10 hr +12 hr +12 hr)/24 hr = 1.4 days).

In order to assign fishing activity to a geographical location, the continental shelf of the Gulf has been divided into 21 statistical area or grids (Figure 1). These areas are further subdivided into 5-fathom increments from the shoreline out to 50 fathoms. The data elements, "Area" and "Depth", refer to these statistical and depth subdivisions. Note, these data elements appear in both the "Landings" and "Interview" lists, but they are collected following slightly different procedures. The area and depth information that is recorded when only landings data are collected, and no interview is conducted, is "assigned" by the port agent. To assign the landings data to a specific area and depth the port agents usually use information obtained from the dealer, or in a few cases assign the fishing location based on their knowledge of the fleet's activity. In contrast, the area and depth information for an interview is actually provided by the fishermen.

The port agents attempt to identify the species of shrimp as accurately as possible. The major commercial species, white (Litopenaeus setiferus), brown (Farfantepenaeus aztecus), and pink (F. duorarum) are familiar to most seafood dealers and properly identified by them. However, in Texas, many of the dealers combine pink and brown shrimp together as brown shrimp landings.

In addition, the port agents record all of the landings statistics by market category or size of shrimp as the dealers have recorded them on their pack-out or sales receipts. Also, the port agents record whether the shrimp have been purchased as headed or whole (i.e., heads on). This identification is important because all of the statistics are converted to the same weight (i.e., heads-on or heads-off) when reported.

As discussed in the section on data collection procedures, the distinction between a vessel and a boat is important for the Gulf shrimp data. This distinction is based on the size and registration of the fishing craft. Vessels are defined as 5 net tons or greater and registered with the U.S. Coast Guard (USCG). The USCG issues a unique six or seven-digit documentation number to each vessel, and this number is the "Official Documentation Number" that is recorded by the port agent on the shrimp data collection form. Boats, on the other hand, are defined as all fishing craft that are not registered by the USCG, but are registered with the state in which they operate. Some of these boats may be 5 net tons or greater.

The count of unique vessel numbers in the Shrimp Landings File, gives a good estimate of the number of active nearshore and offshore vessels (Figure 2). Obviously, a particular vessel has to be active in a given year to have its number associated with landings at a dealer. However, the vessel count does not include all active vessels, since some vessels may only fish inshore, or a particular vessel number may not be recorded on a dealer's pack-out records. The vessel file may also contain some miscoded vessel numbers, which would give the impression of an increase in number of vessels fishing. Port agents edit these files and check for these types of coding errors.

The SEFSC also maintains a file known as the Vessel Operating Units File (VOUF). The intent of this file is to have a list, with associated vessel characteristic information (i.e., length, age, horsepower, etc.), for all active shrimp vessels during a particular year. During each year the port agents keep a list of all the vessels landing or seen with shrimp gear at a particular port. These lists include all vessels, whether they fish nearshore, offshore or inshore. In some areas a port agent may presume that a particular vessel is in the area and may include that vessel on the active list. Port agents are reluctant to take vessels off the VOUF since it is used by many investigators to get vessel characteristic data. This list of vessels is sent to SEFSC at the end of each year so that the VOUF can be updated. Thus, the VOUF contains a list of all vessels found in the Shrimp Landings File, vessels fishing in the inshore areas, and vessels believed to still be active in the fishery. Trends seen in the VOUF may lag trends observed in other vessel files (Figure 3). The VOUF may overestimate the actual number of vessels in the fishery. The intent of the file is not to have an accurate count of the vessels, but to have vessel characteristic information available for research if these data are needed for a particular vessel.

## Generalized Fishing Effort Estimation

The goal of any estimation of effort is to approximate the instantaneous rate of fishing morality (F). Effort may be defined by a variety of different methods, each with advantages and disadvantages associated with them. Various measures of effort include number of vessels, number of fishing trips, and time fished (Nance 1993). The more analytical the estimation method, the better the relationship with F. But with this better relationship comes with detailed calculations and the need for more precise data. The more simple the estimation method, the most distant the relationship with F. But with this poorer relationship comes very simple calculations.

Number of vessels in the fishery is a very simple measure of effort. Some vessels within a particular port may be very active and fish intensively during the entire season. Other vessels may only fish during a particular month or season, while still other vessels may not fish at all. The number of vessels in the shrimp fishery can be obtained in both the landings file and the VOUF. As mentioned above the number of unique vessels in the landings file may be an underestimate of the actual number, while the number of unique vessels in the VOUF may be an overestimate of the actual number.

Number of trips represents an effort value that is more directly related to F since each trip is applying fishing pressure on the stock. Number of trips is obtained from the shrimp landings file and is not an estimated number (Figure 4). However, trip length is highly variable and may range from 1 to over 60 days in length.

Time fished represents an effort value that is the best with its relation to F. Currently we calculate nominal days fished. This present nominal days fished unit of effort is calculated from data obtained by the port agents and trip ticket systems.

## Current Estimation Method

To estimate fishing effort for each location cell on a monthly basis, there must be two elements of data for each cell: 1) total pounds of shrimp caught by species and, 2) the average catch per unit of effort (CPUE; pounds per twenty-four hours fished) (Nance 1992a). Total pounds caught by species are acquired from commercial seafood dealers located along the Gulf coast, while CPUE is obtained from interviews with captains from shrimp vessels at the termination of their trip. Although the interview level has no effect on the collection of total pounds data, it does have a direct effect on the estimation of average CPUE. Obviously, the more interviews that port agents can gather during a particular month, the more precise the estimate of average CPUE for that month. During peak shrimp production months greater than 80% of the pounds of shrimp caught have an average CPUE associated with them (Figure 5).

Monthly effort (days fished) for each location cell is estimated by dividing the monthly shrimp landings from a location cell by the average CPUE during the same time and location combination. To calculate total shrimp effort in a particular location cell, total pounds of shrimp (i.e., all species combined) are divided by the average CPUE calculated from all the interviewed trips within that location cell. For example, the following procedures would be used to calculate total effort for subarea 15, depth zone 3, during the month of July (see Table 1 for data collected from this location cell during July). During July a total of 591,361 lbs of shrimp were caught from this subarea and depth zone (549,331 lbs of species A and 42,030 lbs of species B). Interview data from three vessel captains that fished this location during July were summarized by trip number (Table 1). To estimate the total effort during the month of July from this one location cell, we first calculate the average CPUE; (3,286 lbs + 7,444 lbs + 1,390 lbs) / (5 days + 10 days + 2 days) = 712.9 lbs per day. Divide the total pounds caught in this location (591,361 lbs) by the average CPUE (712.9 lbs per day) to obtain the effort value estimate; 591,361 lbs / 712.9 lbs per day = 829.5 days fished.

For a few cells, shrimp landings are reported, but there are no interviews from which to estimate CPUE. Thus, a statistical model was devised to estimate CPUE for most of those cells. Both the number of shrimp available to the fishery in a given year and the regional differences in shrimp abundance within the Gulf of Mexico play important roles in determining the CPUE for a given location cell. Consequently, a general linear model was developed to predict current CPUE with year and geographic location as the independent variables. Monthly differences in shrimp abundance were accounted for by using a different model for each month. Each of the twelve linear models is in the general form of:

$$\log CPUE_{(ij)} = \quad_{(ij)} + year_{(i)} + location_{(j)} + \quad_{(ij)}, \text{ where}$$

| | |
|---|---|
| $CPUE_{(ij)}$ | is the observed CPUE in year i at location cell j; |
| $_{(ij)}$ | is the overall mean; |
| $year_{(i)}$ | is the effect on CPUE due to year i; |
| $location_{(j)}$ | is the effect on CPUE due to location j; and |
| $_{(ij)}$ | is a random error term with expected value 0 and equal variance for all i and j. |

Historical CPUE values calculated from interviews are used in the analysis to obtain a solution (mathematical expression in the form of a linear equation) regarding the effects of years and locations on past CPUE values (r-square = 0.50 for most monthly models). Once the equation is known, current shrimp year class strength estimates are calculated from the trip interview data and input into the year effect portion of the model. Current CPUE values of the various locations can then be predicted, but only for the cells that had CPUE observations from previous years.

For those cells without CPUE values based on past interviews, the three techniques described below are employed in sequential order until each cell is assigned a current

CPUE value. For example, if a particular cell could not be assigned a CPUE value using technique one, then technique two is applied. If this technique assigned a CPUE value to the cell, then technique three is not used for that cell. The three techniques, with examples, are as follows:

1) The mean (average) of all CPUE values for that depth, month and year, for all statistical subareas. For example, if the location cell at subarea 21, depth zone 6 needs a CPUE value for March, then all the **current year** March CPUE values (estimated from interview data) in depth zone 6 are averaged across all subareas. If no estimate can be calculated, then method two is used.

2) If no current year data are available, estimates are obtained from the mean of all CPUE values for that **depth** and month, for all statistical subareas and years combined. For example, if the location cell at subarea 21, depth zone 6 requires a CPUE value for March, then all the interview generated depth zone 6, March CPUE values from past years are averaged across all subareas to obtain a value. If no estimate can be calculated, then method three is applied.

3) If no data are available from that depth zone, estimates are obtained from the mean of all CPUE values in that month, for all depths, years and statistical subareas. For example, if the location cell at subarea 21, depth zone 6 requires a CPUE value for March, then all the interview generated past years March CPUE values from all depth zones and statistical subareas are averaged to obtain a value.

Total effort (or total directed effort) for any month is estimated by summing the effort estimates for each of the individual locations cells. Total annual effort is calculated for descriptive purposes as the sum of the monthly efforts. The total efforts are used to determine total monthly and annual CPUE values.

Current Estimation Evaluation

Prior to 1992 the ratio estimator (Σ catch / Σ effort) was used to calculate average catch per unit of effort (CPUE) for a given location cell (month/area/depth combination). Plots of catch against effort revealed that the variance of catch appears to increase as effort increases, suggesting that the ratio estimator currently used is the correct one. However, since it is total catch that is used to expand the average CPUE to total effort, the ratio used in the calculations should be the reciprocal of CPUE (Σ effort / Σ catch) (i.e., total effort = (average days fished / pounds) x (total pounds), not total effort = (average pounds / days fished) / (total pounds)). Although the total effort values calculated are identical algebraically, statistically there is a difference when standard error of the ratio is calculated.

Analysis at past effort workshops have revealed that for CPUE in a given location (area/depth) there is less difference between the same month in different years, than for adjacent months in the same year (Nance 1992b). This suggests, for example, that in a GLM it is better to use past July values for a given location to estimate the current July values in the same location, than to use current year June or August values to estimate the July value. Thus, the current GLM used to estimate effort in cells with no interview data seems to be appropriate.

Although the overall technique currently being used to estimate total shrimp effort seems valid, the present level of fishing trips being interviewed is a concern. When the estimation method was developed in the early 1980's, only about 4-5% of the shrimp landings did not have at least one interview associated with them (e.g., there was at least one interviewed trip from the many trips located in a given month/area/depth combination). Analysis of the data at a 1992 effort workshop revealed that 28% of the shrimp landings did not have at least one interview associated with them (Nance 1992b). Thus, in 1981, the GLM was estimating only 4-5% of the effort, while in 1992 it was estimating 28% of the effort (17% for the offshore only). The interview level by the port agents has not improved since that time (Figure 6).

Potential Bias Problems

Reports from past shrimp effort workshops have all concluded that time fished provides a superior measure of effort (compared to number of vessels or number of trips) for the Gulf of Mexico shrimp fishery (Nance 1992b, GMFMC 1994). Yet, any bias in either the catch from interviewed trips, or time fished from interviewed trips, or the total reported catch could result in biased estimates of total effort. This sampling bias has been a topic of discussion at most workshops. Several potential sources have been discussed over the years. The first source deals with port agent judgment with regards to assignment of area and depth of catch. It has been the opinion at most workshops that judgment may result in random sampling error, but that directional bias from these errors is unlikely (GMFMC 1994). Another source of bias would be under reporting by either dealers or fishermen. Most of these sources of bias, while not considered a significant problem, would cause effort to be underestimated. The next potential source of bias would be interviewee inaccuracy. Again this bias source has been considered random and non-directional in nature (GMFMC 1994). Although interviewee inaccuracy may increase as time away from port increases, there have been no actual data to support this assumption. The final source of bias deals with types of vessels that are in the interview pool. Reports from all workshops have agreed that if the vessel types (effort) being interviewed in each location cell are not representative (proportional of the population of vessel types (effort) within each location cell then the catch per hour estimates (and hence effort estimates) for each location can be biased (Nance 1992b, GMFMC 1994). This bias may cause either an over or an under estimation of effort. While recommendation have been made to develop a more random selection process for interview selection, to minimize such bias, the NMFS believes such changes cannot be accomplished effectively under the current data collection system.

Past workshop results and discussions with shrimp industry over the years led to the U.S. Congress in 1998 to allocate funding to the industry (Gulf and South Atlantic fisheries Foundation, Inc.) to address these issues through a series of pilot studies and other research activities in cooperation with NMFS. One of these pilot studies sought to develop inexpensive and unobtrusive alternatives to the present approach that would better estimate shrimp fishing effort. Gallaway et al. 2003a) developed an electronic logbook (ELB) that was demonstrated to accurately measure the spatial patterns of fishing effort with a trip. It was also demonstrated that total landings from a trip could be accurately allocated to specific areas fished in direct proportion to the time spent fishing in each zone. A total of 51 vessels participated in the pilot study with data from 62 out of 135 trips directly comparable to data collected through the current port agent system. These direct comparisons revealed that directional bias seemed to be occurring and that CPUE was potentially underestimated (Gallaway et al. 2003b). The pilot study also revealed that if these paired results were representative of all trips in the fishery, the midshelf effort in 2000 might have been overestimated, whereas nearshore and deepwater effort was underestimated.

Results from this pilot program have caused NMFS to investigate development of a cooperative program involving both NMFS and industry based on this ELB technology. It is felt that the ELB technology and the port agent network together could be utilized to obtain more precise and accurate estimates of shrimp trawling effort with minimal impact on the fishers. Until this program can be undertaken, the current methodology, or some alternative technique (as suggested below) should be utilized to estimate effort for the Gulf of Mexico shrimp trawl fishery.

## Alternative Techniques

During several of the past shrimp effort workshops (Nance 1993b, GMFMC 1994) certain alternative methods for effort estimation have been suggested and reviewed by the participants. The suggestions fall into two general categories; pooling of location cells into larger units (collapse interview and landing data from several depths, subareas cells, or seasons into one larger cell), and GLM (use GLM to predict values and estimate effort). A third method that has also been discussed involves using the technique of spatial statistics to estimate shrimp fishing effort. While this seems like a possible methodology that could be used, it has not been examined in detail.

With regards to the GLM methodology two general methods have been discussed at past workshops. The first involves using the GLM to fill holes in the dataset (the approach that is used in the current estimation technique). The second approach that has been suggested is that a GLM be developed that would be used to estimate effort values for the entire Gulf of Mexico (i.e., replace even observed values with predicted values). This model could also be used to produce a direct standardized estimate of annual effort. Three different dependent variables have been discussed at past workshops. The three dependent variables included -log CPUE, revenue per effort, and hours fished per trip.

The independent variables would include such items are year effect, location effect (which could be divided into separate area and depth effect components), and vessel effect (using characteristics such as length or horsepower). This method has been investigated and a model developed and used to estimate shrimp effort in the Gulf of Mexico. The effort values obtained that were quite comparable with the current GLM approach used by NMFS (Griffin et al. 1997). However, over the past several years, the estimated effort values derived by each of the two methods have become a little more separated and distinct from one another because of the low interview rates (Griffin, personal communication, 2003).

With regards to the second general category, a variety of different cell pooling strategies (area/depth/month) were investigated over the past several months (Table 2). Comparison of the estimated annual effort values obtained from each pooling technique to the annual effort obtained from the current estimation method can be observed in Figures 7 through 12. Table 3 presents the percentage of shrimp landings that did not have a certain number of observations (NOBS) associated with them, for each of the different pooling methods. If hole filling was necessary for any of the pooling technique methods (i.e., no interview for pounds in a given pooled cell) the nearest neighbor approach was used to estimate the CPUE value for the cell. In this approach the catch and effort data from the nearest cells (same depth zone and time frame) was used to calculate an average CPUE value to put into the empty cell to calculate the effort. Although two other hole-filling techniques have been suggested (GLM and further pooling), only the nearest neighbor technique was used in this analysis.

All the pooling techniques gave similar results to the current effort values during years of high interview levels (pre-1989) (Figures 13 and 14). As interviews have decreased over the years, the differences in the estimated effort values calculated by the various pooling methods have become more apparent. However, the greatest difference appears to be within 13% of current estimates.

It should be mentioned that the amount of potential bias is likely to increase as the amount of pooling gets larger, but the variance may tend to get smaller due to an increase in sample size. Several considerations have been pointed out at past workshops with regards to location cell determination and effort estimation techniques (Nance 1992b, GMFMC 1994). These include: 1) minimum acceptable number of observations used to determine average CPUE, 2) collapsed cells must be from homogeneous areas as defined by area/depth plots of CPUE, 3) collapsed cells must make biological sense, and 4) collapsed cells must make management sense. In this analysis a cell must have at least two interviews to determine an average CPUE and cells were collapsed into cells that made management sense.

As discussed above, even with the pooling of cells into larger groups, there was a need to fill some holes in the data set because no interviews took place. Discussions at past effort estimation workshops have centered on two possible techniques that could be used to estimate CPUE for a given cell. The first method is the nearest neighbor approach and is the one used in this pooling technique analysis. This method has several strong points such as: 1) ease of calculation, and 2) not a "black box" statistical analysis that is difficult to explain to non-technical individuals. However, its weak point is that it can be a very subjective procedure (i.e., what criteria does one use to pick the nearest neighbor). With the nearest neighbor approach, a cell in Florida could actually be filled with CPUE data from a cell in Louisiana.

The second method to fill holes in the dataset is the GLM approach. This method is very objective, but it is sometimes hard to explain to non-technical individuals. As mentioned, this method is the one currently used in the effort estimation technique.

## Summary

The most appropriate estimates of shrimp trawl effort come from using port agent interviews to calculate hours of fishing. Yet, as these interviews decrease in temporal and spatial coverage more bias and error can potentially be introduced into the estimation. Two general methods have been proposed to deal with the decrease in interview coverage levels. The first involves pooling of location cells into larger units (collapse interview and landing data from several depths, subareas cells, or seasons into one larger cell), while the second involves using a GLM to predict values and estimate effort. This report shows several different pooling methods and compares these to the current estimates of shrimp effort.

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# Tables

**Table 1. July data from subarea 15, depth zone 3 (example).**

| Data Source | Species A Pounds | Species B Pounds | Total Pounds | Days Fished (interview) |
|---|---|---|---|---|
| dealer records | 549,331 | 42,030 | 591,361 | --- |
| trip 1 interview | 3,183 | 103 | 3,286 | 5 |
| trip 2 interview | 7,135 | 309 | 7,444 | 10 |
| trip 3 interview | 901 | 489 | 1,390 | 2 |

## Table 2. List of various interview pooling techniques discussed in this report.

A: Current method; 21 statistical areas; 10 depth zones; monthly.
B: 21 statistical areas; 2 depth zones (<= 15 fm, > 15 fm); monthly.
B2: 21 statistical areas; 3 depth zones (<= 15 fm, > 15 fm – 30fm; >30 fm); monthly.
C: 21 statistical areas; 1 depth zones; monthly.
D: 7 statistical area groups (1-3, 4-9, 10-12, 13-14, 15-17, 18-19, 20-21); 10 depth zones; monthly.
E: 7 statistical area groups (as in D); 2 depth zones (as in B); monthly.
E2: 7 statistical area groups (as in D); 3 depth zones (as in B2); monthly.
F: 7 statistical area groups (as in D); 1 depth zone; monthly.
G: 4 statistical area groups (1-9, 10-12, 13-17, 18-21); 10 depth zones; monthly.
H: 4 statistical area groups (as in G); 2 depth zones (as in B); monthly.
H2: 4 statistical area groups (as in G); 3 depth zones (as in B2); monthly.
I: 4 statistical area groups (as in G); 1 depth zone; monthly.
BB: as in B above, except seasonally (four 3 month groups).
BB2: as in B2 above, except seasonally (four 3 month groups)
CC: as in C above, except seasonally (four 3 month groups)
DD: as in D above, except seasonally (four 3 month groups)
EE: as in E above, except seasonally (four 3 month groups)
EE2: as in E2 above, except seasonally (four 3 month groups)
FF: as in F above, except seasonally (four 3 month groups)
GG: as in G above, except seasonally (four 3 month groups)
HH: as in H above, except seasonally (four 3 month groups)
HH2: as in H2 above, except seasonally (four 3 month groups)
II: as in L above, except seasonally (four 3 month groups)
SN 4 statistical area groups (as in G); 2 depth zones (<= 10 fm, > 10 fm); seasonally (three 4 month groups).

**Table 3. Percentage of offshore landings that did not have an interview in the location cell.**

| Year | A | B | B2 | C | D | E | E2 | F | G | H | H2 | I |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1981** | 3.10 | 2.60 | 2.81 | 0.95 | 0.69 | 0.02 | 0.10 | 0.00 | 0.31 | 0.00 | 0.03 | 0.00 |
| **1982** | 1.40 | 0.50 | 0.68 | 0.13 | 1.19 | 0.02 | 0.05 | 0.02 | 0.45 | 0.00 | 0.03 | 0.00 |
| **1983** | 1.59 | 1.54 | 2.20 | 0.04 | 1.52 | 0.04 | 0.26 | 0.00 | 0.51 | 0.00 | 0.04 | 0.00 |
| **1984** | 4.64 | 2.44 | 3.41 | 1.01 | 3.40 | 0.18 | 1.17 | 0.00 | 1.62 | 0.12 | 0.49 | 0.00 |
| **1985** | 6.06 | 2.32 | 3.58 | 1.53 | 4.62 | 0.04 | 0.42 | 0.00 | 2.07 | 0.00 | 0.11 | 0.00 |
| **1986** | 5.61 | 2.31 | 3.44 | 0.19 | 4.12 | 0.47 | 1.14 | 0.00 | 1.74 | 0.06 | 0.50 | 0.00 |
| **1987** | 4.64 | 3.17 | 3.90 | 1.44 | 3.48 | 1.08 | 1.48 | 0.16 | 1.30 | 0.02 | 0.25 | 0.00 |
| **1988** | 7.79 | 2.07 | 3.97 | 0.36 | 5.19 | 0.48 | 1.49 | 0.00 | 3.15 | 0.00 | 0.90 | 0.00 |
| **1989** | 16.82 | 7.28 | 8.32 | 3.75 | 9.22 | 1.42 | 2.21 | 0.00 | 3.30 | 0.31 | 1.11 | 0.00 |
| **1990** | 13.24 | 9.81 | 10.41 | 7.11 | 11.19 | 4.77 | 5.16 | 4.09 | 5.69 | 2.58 | 2.73 | 2.35 |
| **1991** | 18.06 | 12.36 | 12.80 | 4.75 | 19.27 | 4.84 | 5.20 | 1.18 | 3.17 | 0.66 | 0.75 | 0.64 |
| **1992** | 20.08 | 11.83 | 12.50 | 5.68 | 16.26 | 1.51 | 1.73 | 0.91 | 3.68 | 0.09 | 0.24 | 0.06 |
| **1993** | 22.43 | 18.23 | 18.72 | 4.09 | 18.21 | 5.42 | 5.57 | 0.60 | 2.96 | 0.08 | 0.15 | 0.03 |
| **1994** | 23.99 | 16.93 | 18.13 | 7.73 | 15.70 | 4.53 | 5.12 | 1.50 | 4.95 | 0.00 | 0.47 | 0.00 |
| **1995** | 19.14 | 13.63 | 14.24 | 4.80 | 13.48 | 1.55 | 1.68 | 0.10 | 5.89 | 0.77 | 0.84 | 0.10 |
| **1996** | 15.62 | 10.92 | 12.41 | 3.72 | 11.67 | 1.67 | 2.10 | 0.00 | 7.06 | 0.44 | 0.52 | 0.00 |
| **1997** | 16.40 | 12.57 | 14.11 | 4.59 | 14.47 | 1.43 | 2.01 | 0.08 | 6.13 | 0.39 | 0.44 | 0.08 |
| **1998** | 13.64 | 11.91 | 12.59 | 5.83 | 12.85 | 1.82 | 2.03 | 0.01 | 6.61 | 0.24 | 0.38 | 0.01 |
| **1999** | 11.49 | 9.32 | 10.49 | 2.74 | 11.05 | 1.06 | 1.46 | 0.08 | 6.50 | 0.39 | 0.53 | 0.08 |
| **2000** | 17.45 | 10.65 | 11.48 | 1.62 | 13.49 | 2.51 | 2.59 | 0.00 | 3.53 | 0.22 | 0.28 | 0.00 |
| **2001** | 14.49 | 6.31 | 6.77 | 1.78 | 13.60 | 1.86 | 1.95 | 0.00 | 2.44 | 0.03 | 0.07 | 0.00 |
| **2002** | 27.71 | 20.95 | 31.41 | 9.32 | 43.07 | 10.55 | 20.15 | 4.90 | 32.82 | 3.42 | 11.15 | 3.40 |

**Table 3. Percentage of offshore landings that did not have an interview in the location cell (continued).**

| Year | BB | BB2 | CC | DD | EE | EE2 | FF | GG | HH | HH2 | II | SN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1981** | 0.97 | 1.00 | 0.95 | 0.22 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1982** | 0.09 | 0.11 | 0.08 | 0.09 | 0.00 | 0.01 | 0.00 | 0.05 | 0.00 | 0.01 | 0.00 | 0.00 |
| **1983** | 0.04 | 0.12 | 0.01 | 0.14 | 0.00 | 0.02 | 0.00 | 0.07 | 0.00 | 0.01 | 0.00 | 0.00 |
| **1984** | 0.22 | 0.73 | 0.10 | 1.08 | 0.00 | 0.05 | 0.00 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1985** | 0.30 | 0.55 | 0.22 | 0.83 | 0.00 | 0.02 | 0.00 | 0.19 | 0.00 | 0.01 | 0.00 | 0.00 |
| **1986** | 0.82 | 1.24 | 0.04 | 0.86 | 0.00 | 0.31 | 0.00 | 0.17 | 0.00 | 0.08 | 0.00 | 0.00 |
| **1987** | 0.40 | 0.99 | 0.25 | 0.69 | 0.00 | 0.11 | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1988** | 0.38 | 1.40 | 0.12 | 1.73 | 0.00 | 0.08 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1989** | 2.64 | 3.17 | 0.30 | 3.19 | 0.00 | 0.56 | 0.00 | 0.84 | 0.27 | 0.28 | 0.00 | 0.00 |
| **1990** | 4.37 | 4.77 | 3.17 | 4.64 | 0.00 | 0.40 | 0.00 | 1.35 | 0.00 | 0.02 | 0.00 | 0.00 |
| **1991** | 3.04 | 3.08 | 1.08 | 13.98 | 0.00 | 0.07 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| **1992** | 5.38 | 5.50 | 4.79 | 5.77 | 0.00 | 0.14 | 0.00 | 0.98 | 0.00 | 0.08 | 0.00 | 0.00 |
| **1993** | 6.03 | 6.10 | 1.59 | 8.74 | 0.00 | 0.18 | 0.00 | 0.74 | 0.00 | 0.01 | 0.00 | 0.00 |
| **1994** | 2.51 | 3.02 | 0.38 | 2.26 | 0.00 | 0.10 | 0.00 | 0.59 | 0.00 | 0.01 | 0.00 | 0.00 |
| **1995** | 5.40 | 5.55 | 1.93 | 2.51 | 0.00 | 0.05 | 0.00 | 0.89 | 0.00 | 0.05 | 0.00 | 0.00 |
| **1996** | 2.20 | 2.55 | 0.57 | 4.21 | 0.00 | 0.01 | 0.00 | 2.25 | 0.00 | 0.01 | 0.00 | 0.00 |
| **1997** | 3.20 | 3.37 | 1.42 | 1.87 | 0.00 | 0.16 | 0.00 | 0.77 | 0.00 | 0.03 | 0.00 | 0.10 |
| **1998** | 1.81 | 2.23 | 1.00 | 4.67 | 0.00 | 0.20 | 0.00 | 1.38 | 0.00 | 0.09 | 0.00 | 0.04 |
| **1999** | 1.82 | 2.08 | 1.10 | 3.52 | 0.00 | 0.08 | 0.00 | 1.65 | 0.00 | 0.02 | 0.00 | 0.00 |
| **2000** | 2.15 | 2.18 | 0.63 | 5.35 | 0.00 | 0.08 | 0.00 | 0.57 | 0.00 | 0.02 | 0.00 | 0.11 |
| **2001** | 0.94 | 1.01 | 0.05 | 3.36 | 0.00 | 0.06 | 0.00 | 0.21 | 0.00 | 0.03 | 0.00 | 0.00 |
| **2002** | 6.81 | 11.70 | 1.68 | 26.09 | 1.01 | 2.98 | 1.01 | 17.38 | 1.71 | 2.89 | 1.01 | 2.53 |

# Figures

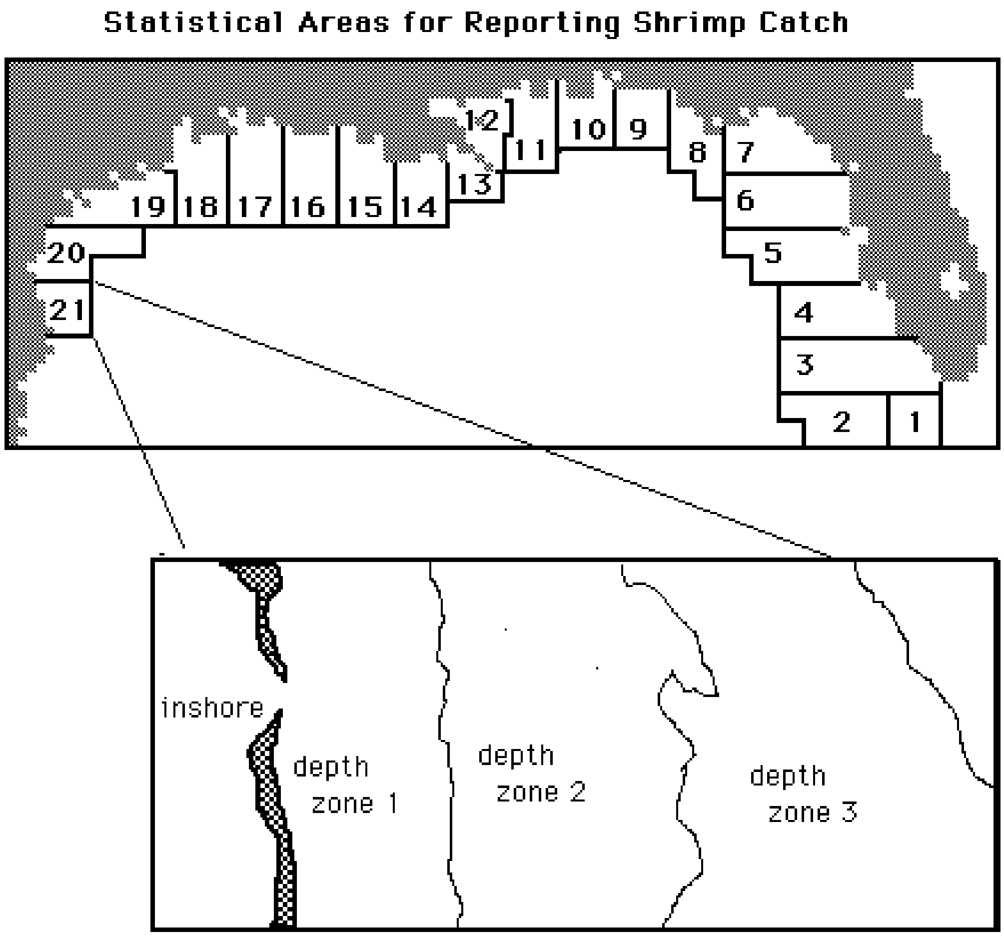


Figure 1. Diagram of statistical subareas and depth zones.

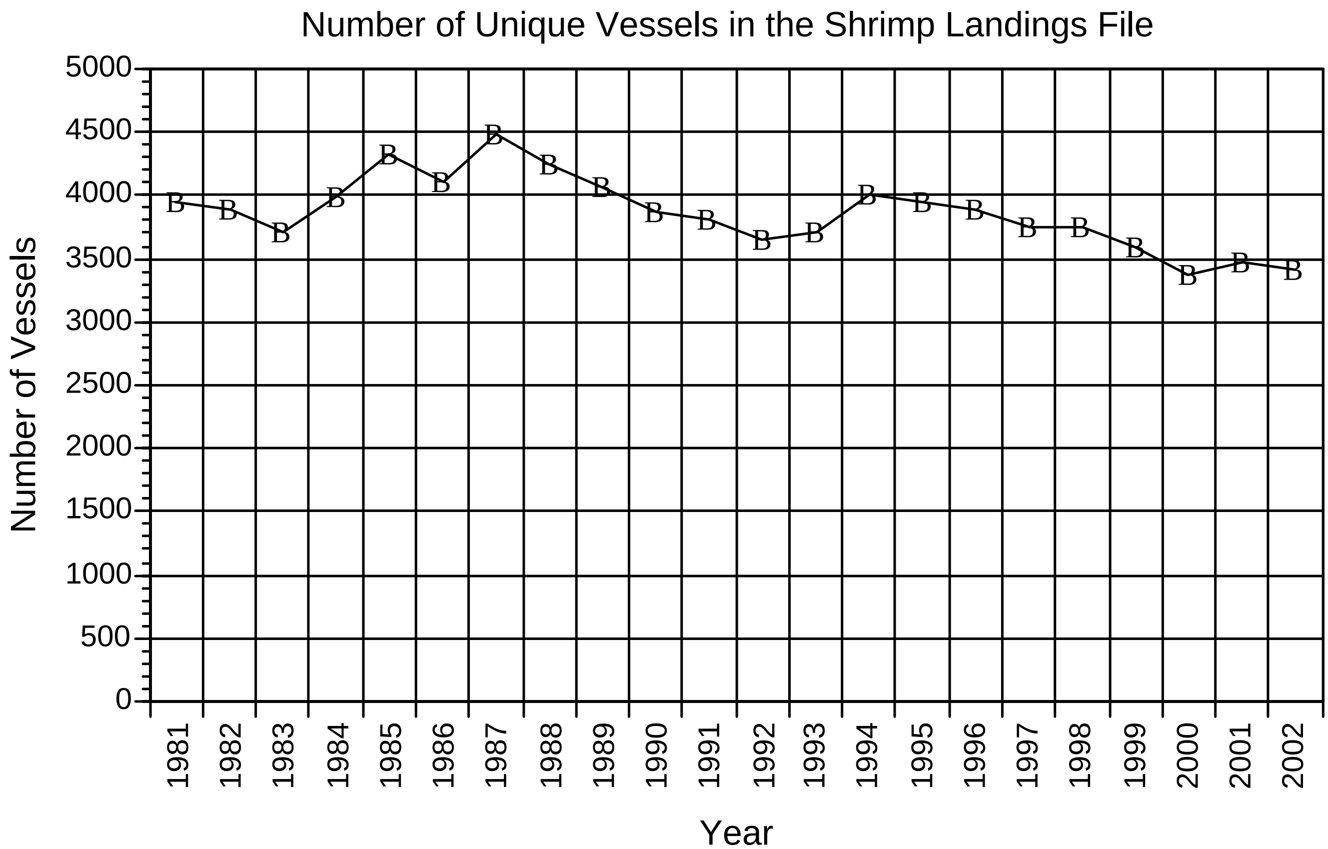


Figure 2. Annual plot of number of unique vessels found in the shrimp landings file from offshore waters.

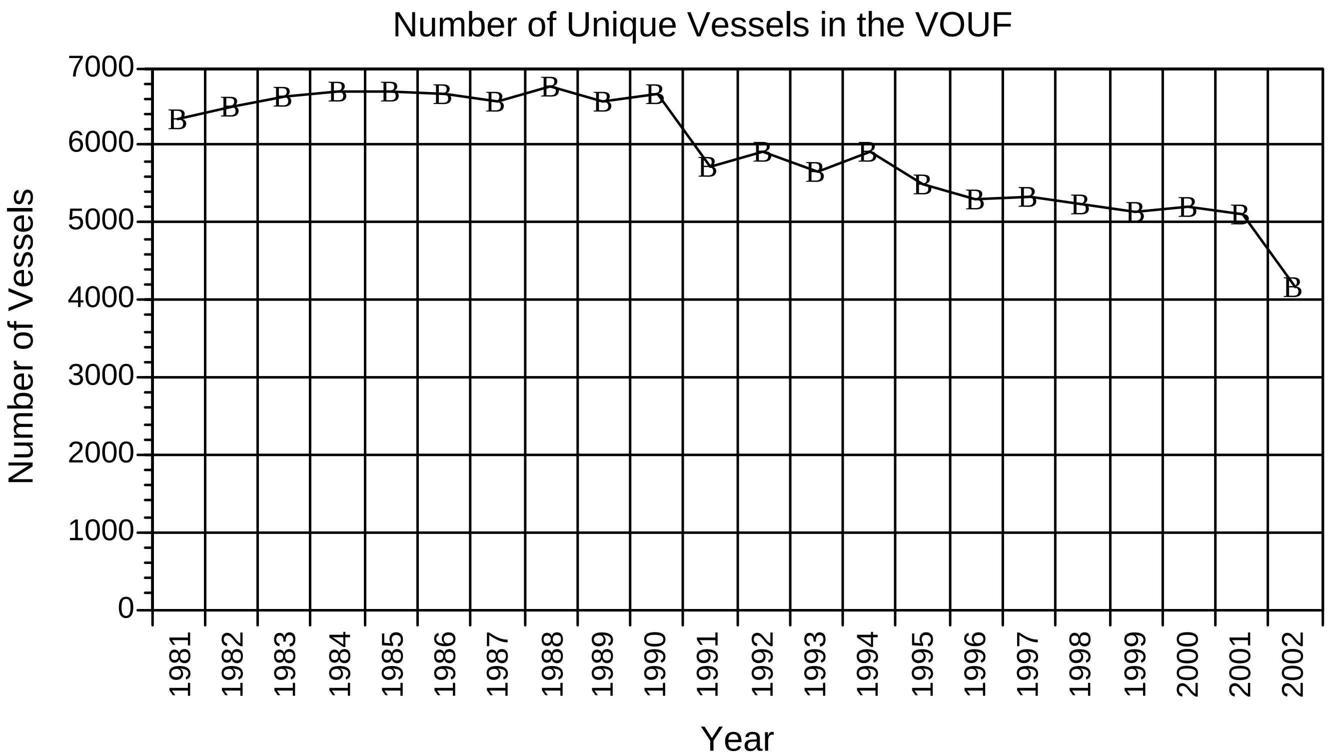


Figure 3. Annual plot of number of unique vessels found in the Vessel Operating Units File (VOUF).

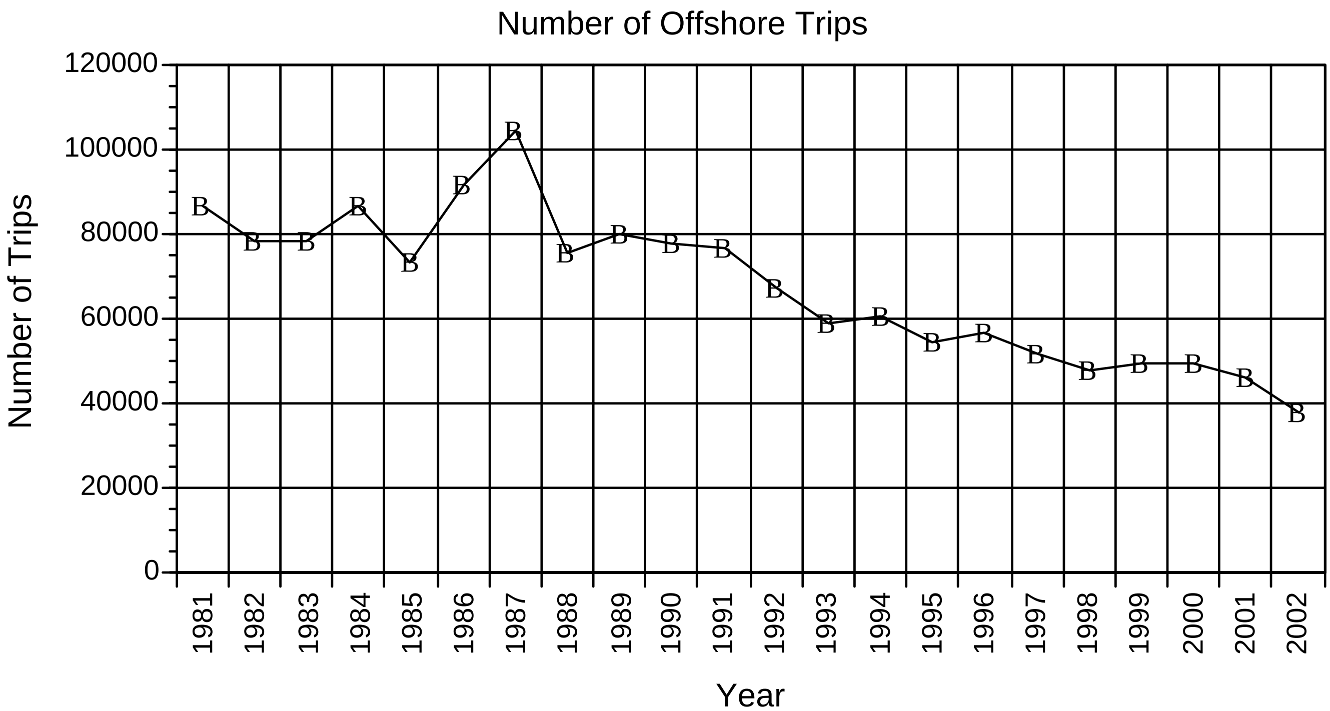


Figure 4. Annual total number of trips from the offshore waters of the Gulf of Mexico. Trips can range in length from 1 to 60 days in length.

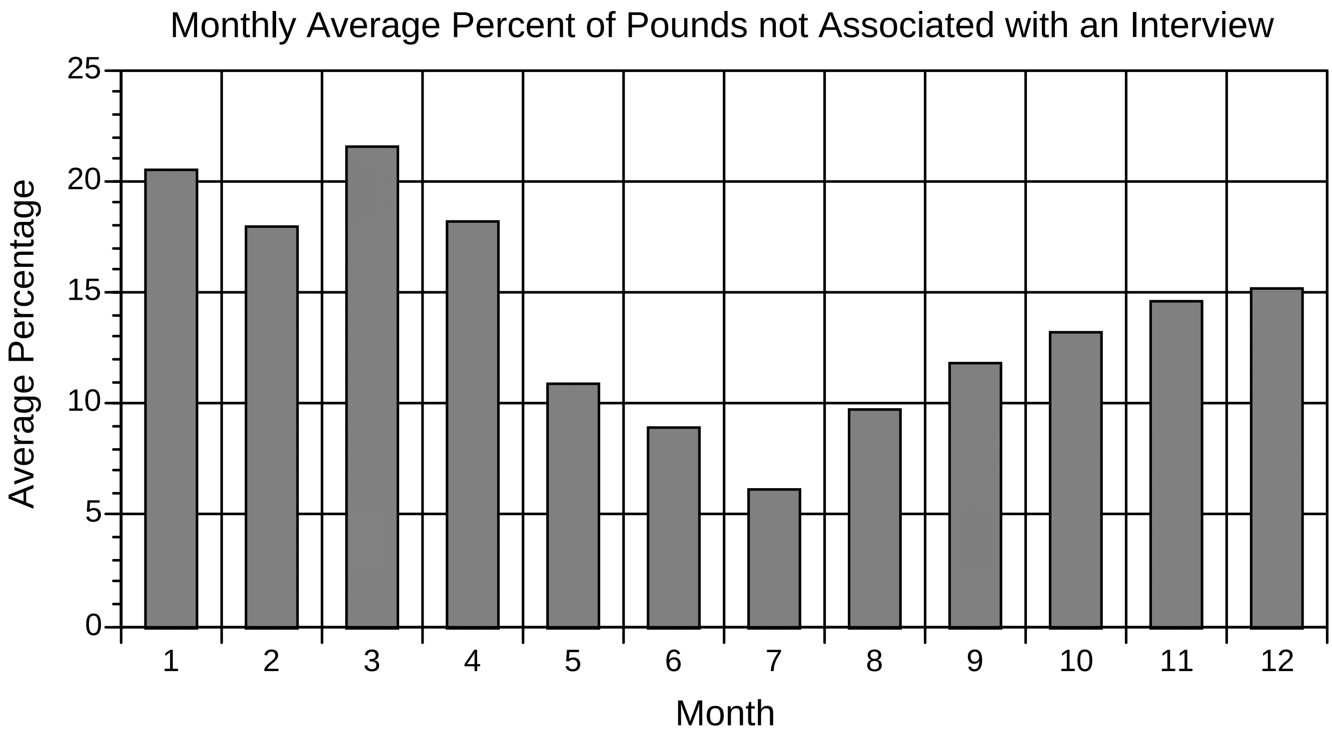


Figure 5. Average (1981 – 2002) monthly percentage of offshore pounds not associated with a port agent interview for a particular location cell.

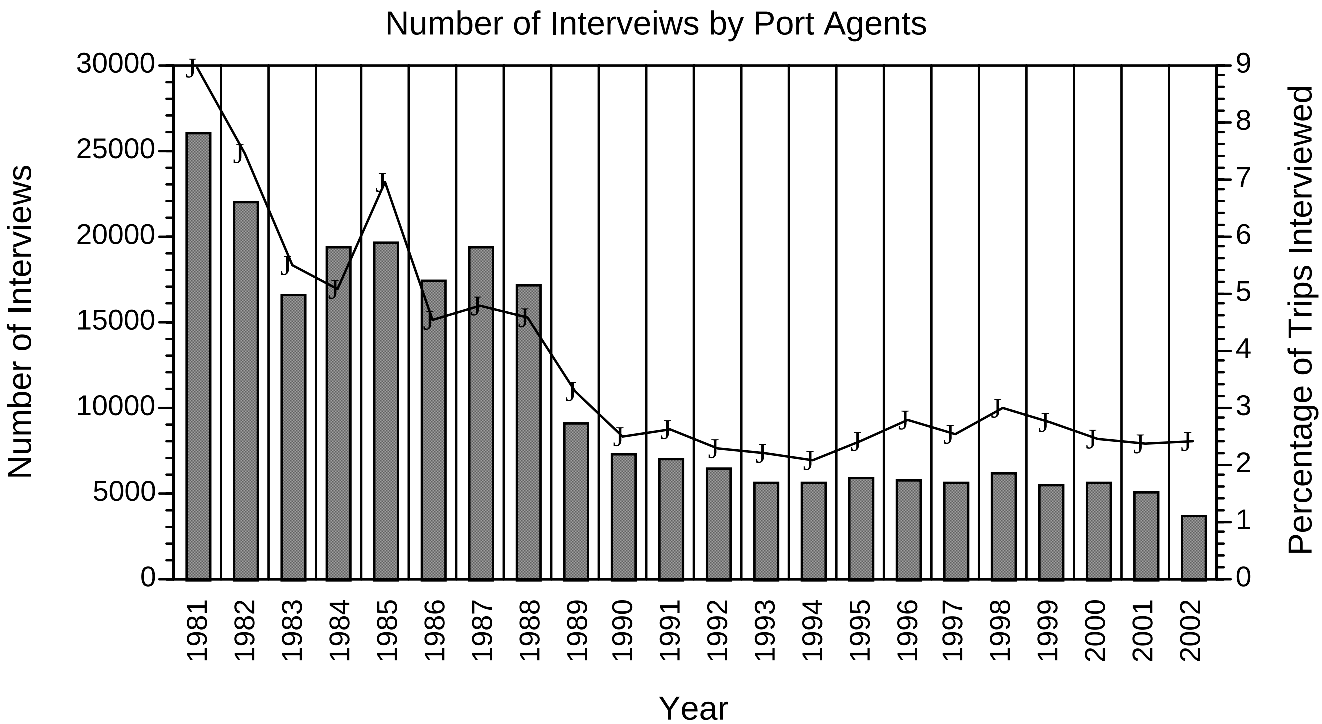


Figure 6. Annual number of interviews and the percentage of total trips interviewed for the Gulf of Mexico offshore fishery.

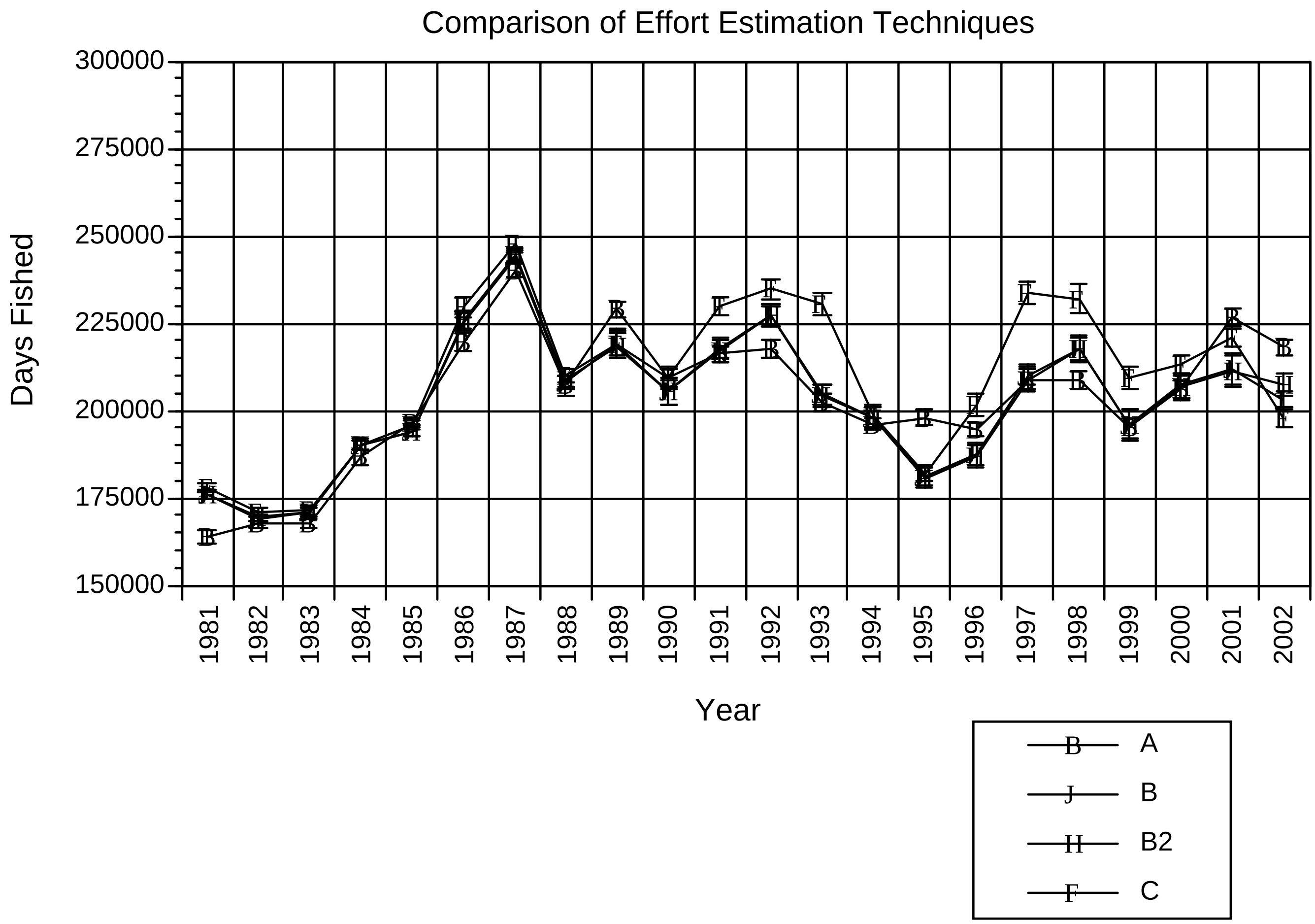


Figure 7. Comparison of annual effort values from various pooling techniques compared (pooled by month, 21 statistical areas, and various depth combinations; see Table 2 for detailed description of method) to the annual effort value from current method (method A).

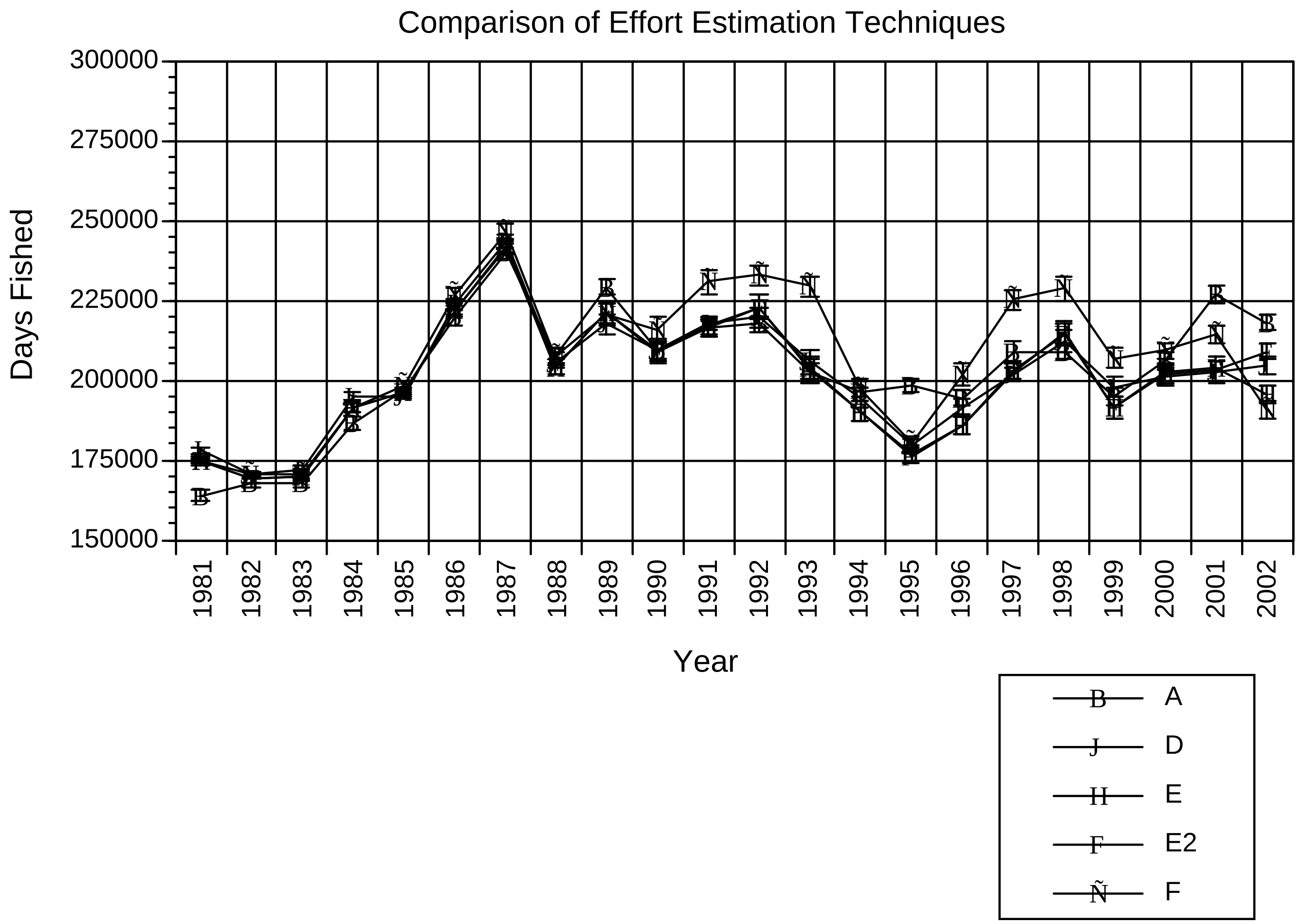


Figure 8. Comparison of annual effort values from various pooling techniques compared (pooled by month, 7 statistical areas, and various depth combinations; see Table 2 for detailed description of method) to the annual effort value from current method (method A).

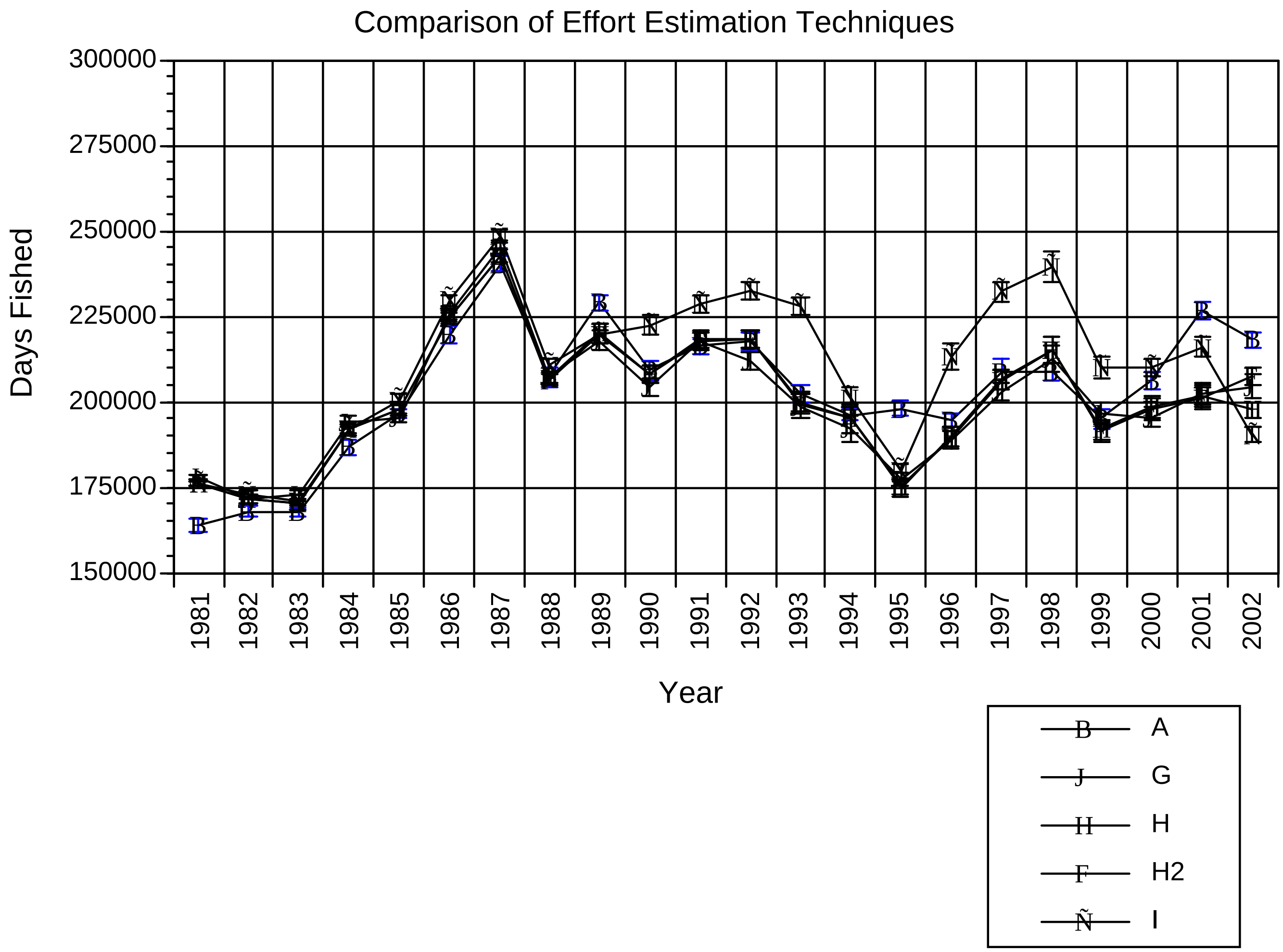


Figure 9. Comparison of annual effort values from various pooling techniques compared (pooled by month, 4 statistical areas, and various depth combinations; see Table 2 for detailed description of method) to the annual effort value from current method (method A).

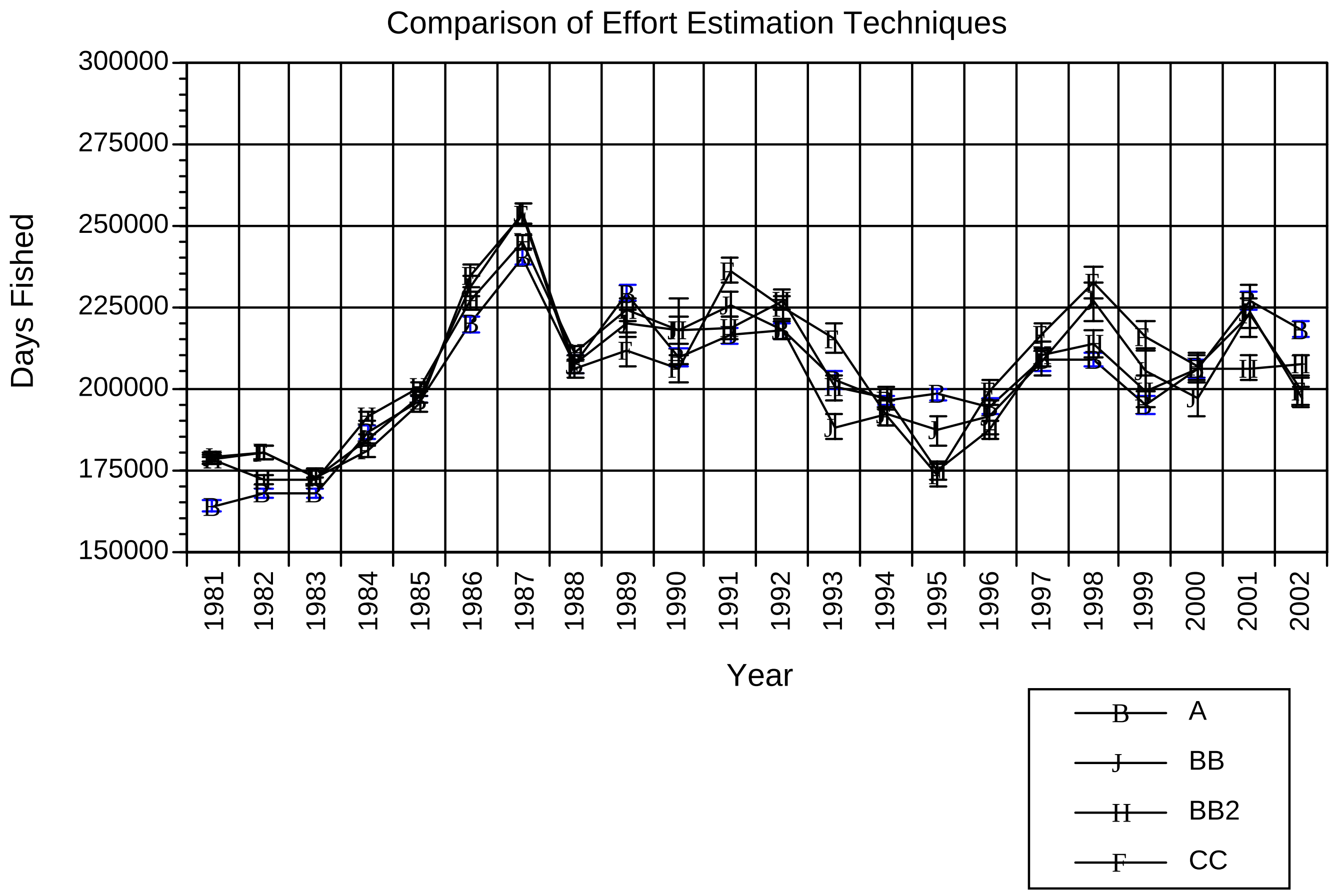


Figure 10. Comparison of annual effort values from various pooling techniques compared (pooled by season, 21 statistical areas, and various depth combinations; see Table 2 for detailed description of method) to the annual effort value from current method (method A).

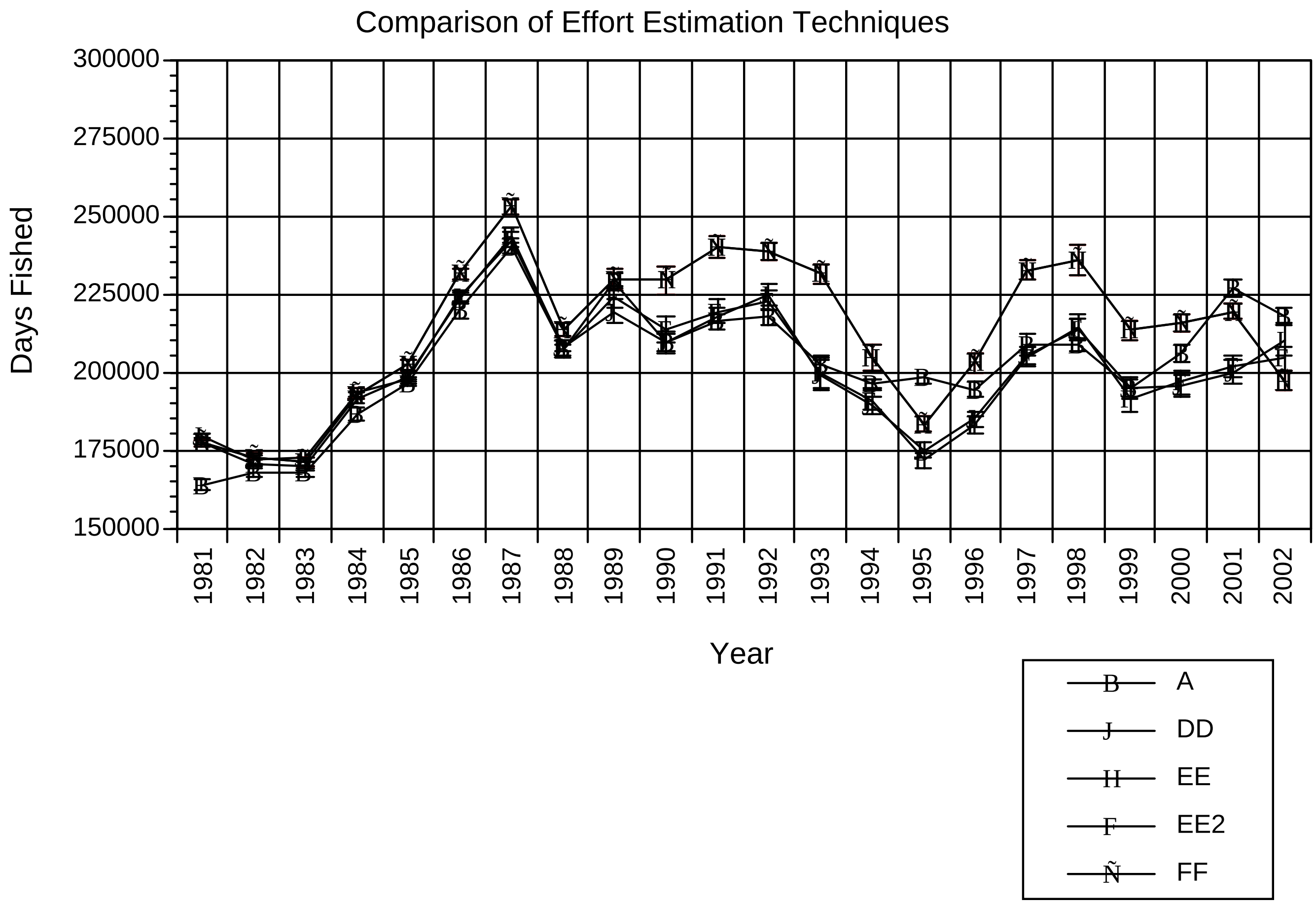


Figure 11. Comparison of annual effort values from various pooling techniques compared (pooled by season, 7 statistical areas, and various depth combinations; see Table 2 for detailed description of method) to the annual effort value from current method (method A).

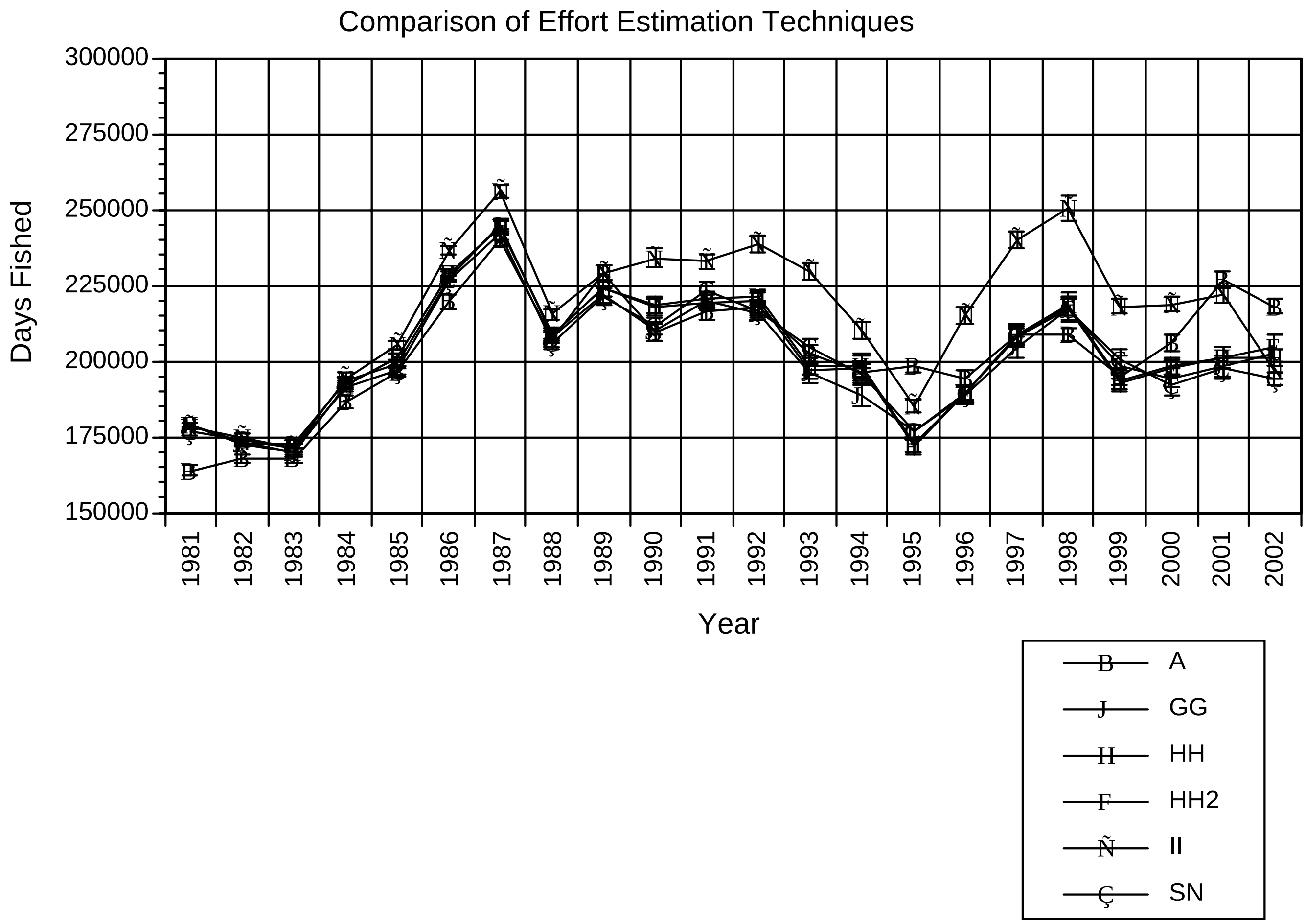


Figure 12. Comparison of annual effort values from various pooling techniques compared (pooled by season, 4 statistical areas, and various depth combinations; see Table 2 for detailed description of method) to the annual effort value from current method (method A).

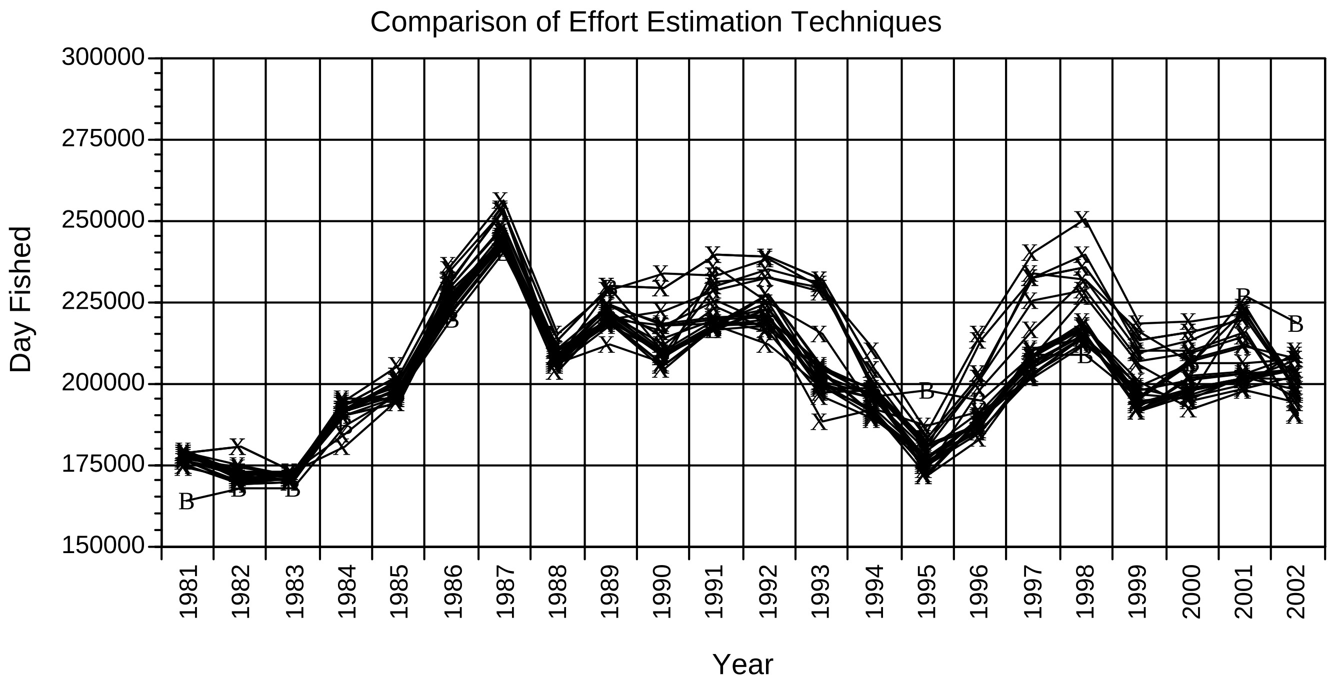


Figure 13. Comparison of all annual effort values from various pooling techniques (lines with small dots) compared to the annual effort value from current method (line with square mark).

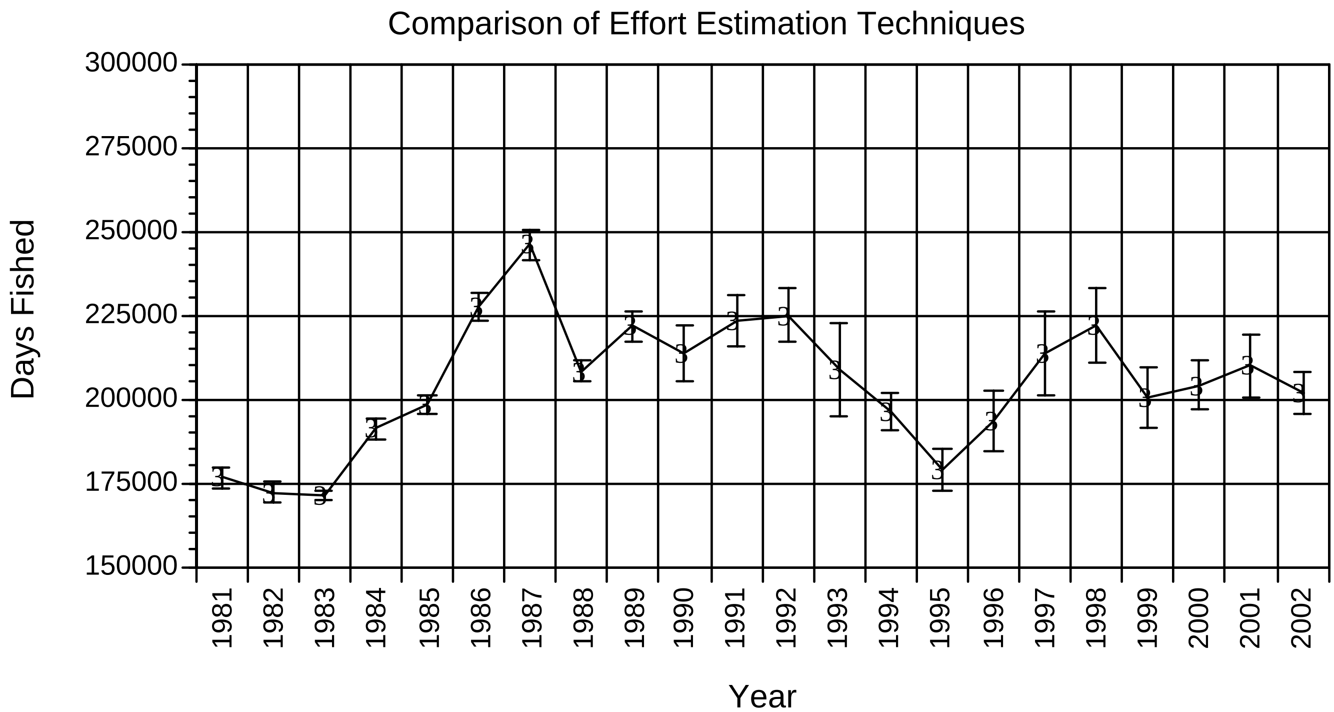


Figure 14. Average annual effort value from all the various estimation techniques.