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# Estimation of Effort for the Gulf of Mexico Shrimp Fishery

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## INTRODUCTION

This document describes the procedures for estimating fishing effort in the Gulf of Mexico shrimp fishery and presents the recent estimated trends in effort levels. Only the mathematical models and the analytical techniques applied in the effort estimation will be explained. Thus, it is advisable to become familiar with the fishery data utilized in these procedures. Therefore, this effort review should be read in conjunction with a companion report, which provides a detailed description of both the data and the procedures employed to collect these data from the Gulf of Mexico shrimp fishery (Poffenberger, 1991).[1]

## ANALYTICAL METHODS

To facilitate geographic assignment of commercial trawling effort and shrimp landings, the continental shelf of the Gulf of Mexico has been subdivided into twenty-one statistical subareas (Figure 1). Each of these subareas has been subdivided into inshore (bays and sounds) and offshore (seaward from the shoreline) zones, with offshore zones being further subdivided in five fathom depth increments from the shoreline to forty-five fathoms (depth zone 1, depth zone 2, ... depth zone 9). All fishery data collected in depths greater than forty-five fathoms are included in the forty-five fathom depth zone for analysis. Thus, each of the twenty-one statistical subareas has the potential of being subdivided into ten

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[1] Poffenberger, John. 1991. An overview of the data collection procedures for the shrimp fisheries in the Gulf of Mexico. Southeast Fisheries Center Report.

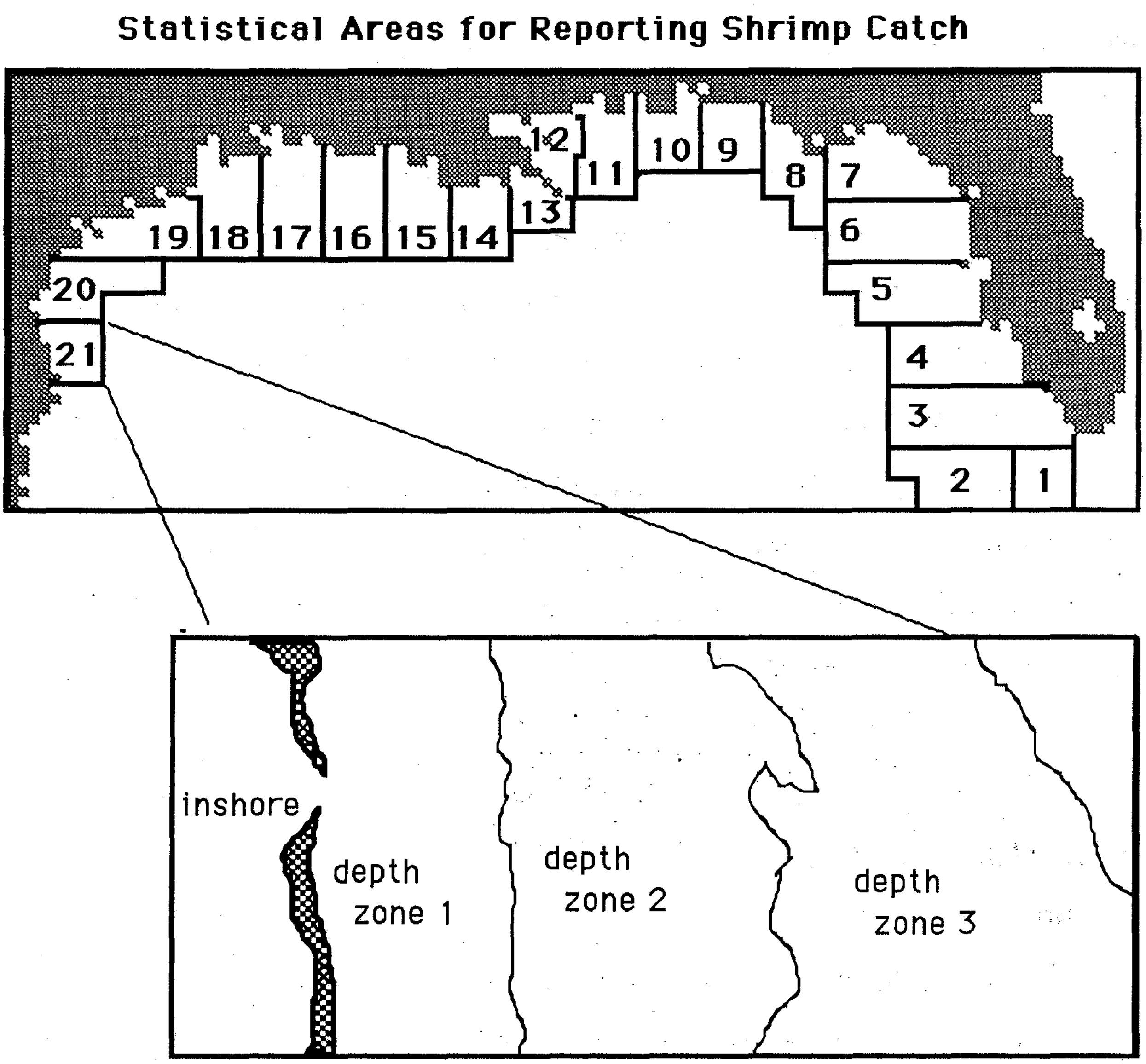


Figure 1. Diagram of statistical subareas and depth zones.

zones (one inshore and nine offshore). Each of these statistical subarea/depth zone combinations has a unique location within the Gulf of Mexico, and is termed a "location cell". The estimation of shrimp fishery effort is dependent upon data summarized by location cells.

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). Total pounds caught by species is 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 affect 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 about 70 - 80% of the pounds of shrimp caught have an average CPUE associated with them.

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) is 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.

**Table 1. July data from Subarea 15, depth zone 3.**

| **Data** | **Species A** | **Species B** | | **Total** |
|---|---|---|---|---|
| | **Days Fished** | | | |
| **Source (interview)** | **Pounds** | **Pounds** | **Pounds** | |
| 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 |

Alternatively, to calculate the effort "directed" at a particular shrimp species in a given location cell, the total pounds of that species is divided by the average CPUE estimated from only those interviewed trips that targeted that species. A trip is determined to be targeting a certain shrimp species if the catch from the trip is composed of at least 95% (by weight) of the target species. This procedure adjusts for differences in fishing strategy (e.g., day/night fishing, location within a cell) for the different species of shrimp. For example, the following procedures would be used to calculate effort directed at species A in subarea 15, depth zone 3, during July (again see Table 1). A total of 549,331 lbs of species A were captured during July at this location. Again, three captains were interviewed, but only two of the trips were "directing" effort at species A (trip 1: 3,183 lbs / 3,286 lbs = 96.8%, trip 2: 7,135 lbs / 7,444 lbs = 95.8%, trip 3: 901 lbs / 1,390 = 64.8%). Only the two trips (trips 1 and 2) that caught over 95% (by weight) of species A are used to calculate average CPUE for the cell; in this case it would be (3,183 lbs + 7,135 lbs) / (5 days + 10 days) = 687.9 lbs per day. We then divide the total pounds of species A caught in this location (549,331 lbs) by the average CPUE (687.9 lbs per day) to obtain the directed effort estimate; 549,331 lbs / 687.9 lbs per day = 798.6 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:

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

| | |
|---|---|
| $CPUE_{(ij)}$ | is the observed CPUE in year i at location cell j; |
| $\mu_{(ij)}$ | 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 |
| $\varepsilon_{(ij)}$ | 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.

## TREND SUMMARY

Over the past 30 years (1960-1989), shrimping effort has increased dramatically (Figure 2). Total effort (inshore plus offshore) has increased

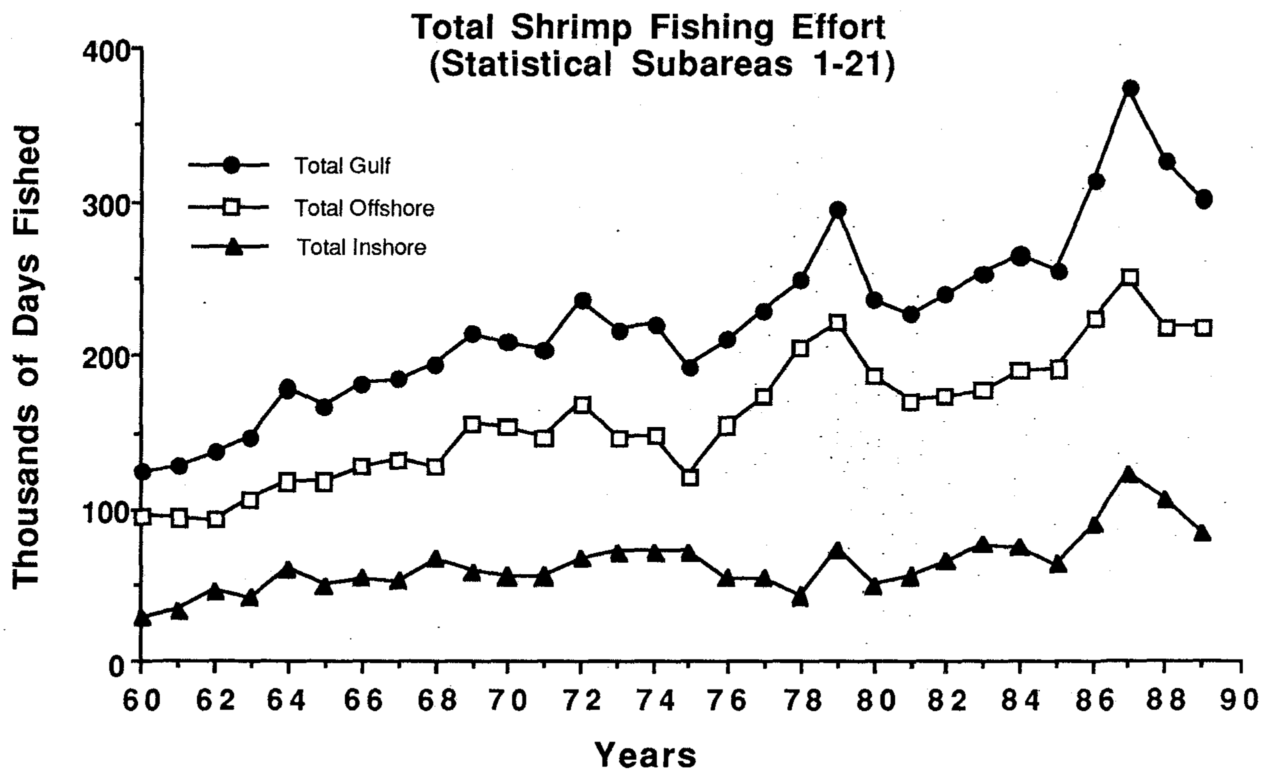


Figure 2. Total shrimping effort in the Gulf of Mexico.

from around 124,000 days fished in 1960 to around 301,000 days fished in 1989 (an overall increase of 2.5 times). Inshore effort has expanded over the 30 year period from about 28,000 days fished to around 84,000 days fished (an increase of 3 times, while offshore effort has risen from around 96,000 days fished to about 218,000 days fished (an increase of 2.3 times).

Although there has been an overall 3 times increase in inshore fishing effort, different regions of the Gulf of Mexico have experienced disproportionate changes in these effort levels (Figure 3). For example,

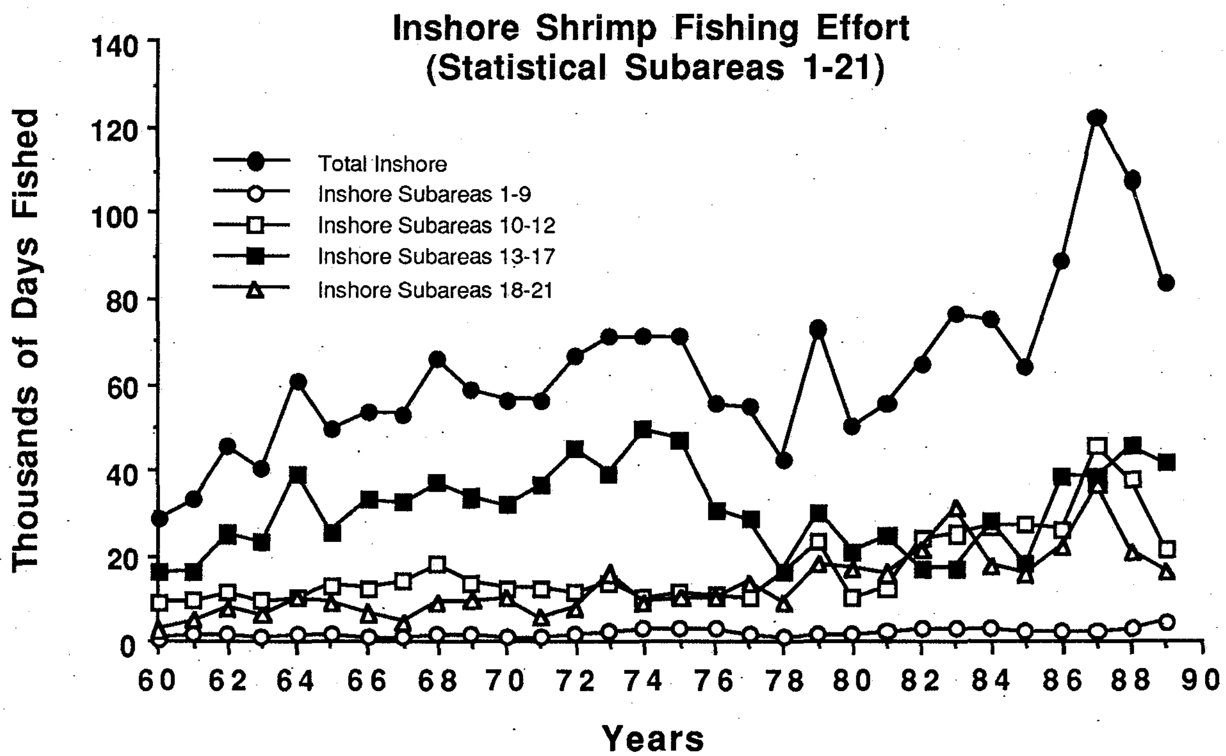


Figure 3. Offshore shrimping effort for each of the different regions (60-89).

fishing effort in subareas 1-9 has increased 6.2 times over the 30 year period (710 days to 4,404 days), while effort has only risen 2.6 times in subareas 13-17 (15,678 days to 41,322 days). During the same time period an increase in effort of 5.9 times occurred in subareas 18-21 (2,794 days to 16,537 days), while in subareas 10-12 effort increased only 2.3 times (9,204 to 21,416).

As with the inshore areas, even with the overall 2.3 times increase in offshore fishing effort, different regions of the Gulf of Mexico have experienced disproportionate changes in offshore effort levels (Figure 4).

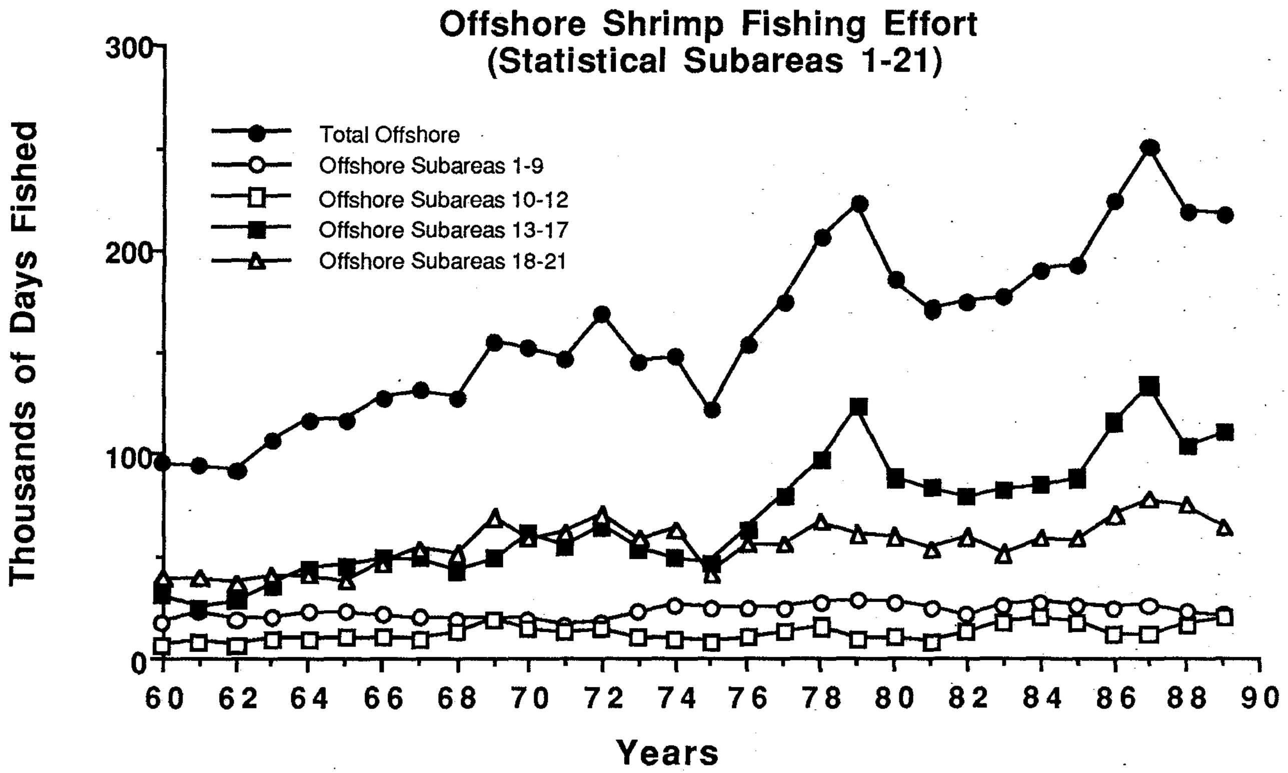


Figure 4. Offshore shrimping effort for each of the different regions (60-89).

For example, fishing effort in subareas 1-9 has only increased 1.2 times over the 30 year period (17,983 days to 21,629 days), while effort has risen 3.6 times in subareas 13-17 (31,406 days to 111,738 days). During the same time period an increase in effort of only 1.7 times occurred in subareas 18-21 (38,922 days to 64,402 days), while in subareas 10-12 effort increased 2.7 times (7,436 to 19,928).

Although the over-all trend is an increase in fishing effort, it appears from the analysis that a peak was reached in 1987 and that in most areas effort has been decreasing. From 1987 to 1989, a decrease in inshore effort of 31% has occurred in subareas 18-21, and a decrease of 53% in subareas 10-12. Effort has increased slightly in subareas 13-17 and subareas 1-9 during the 3 year period.

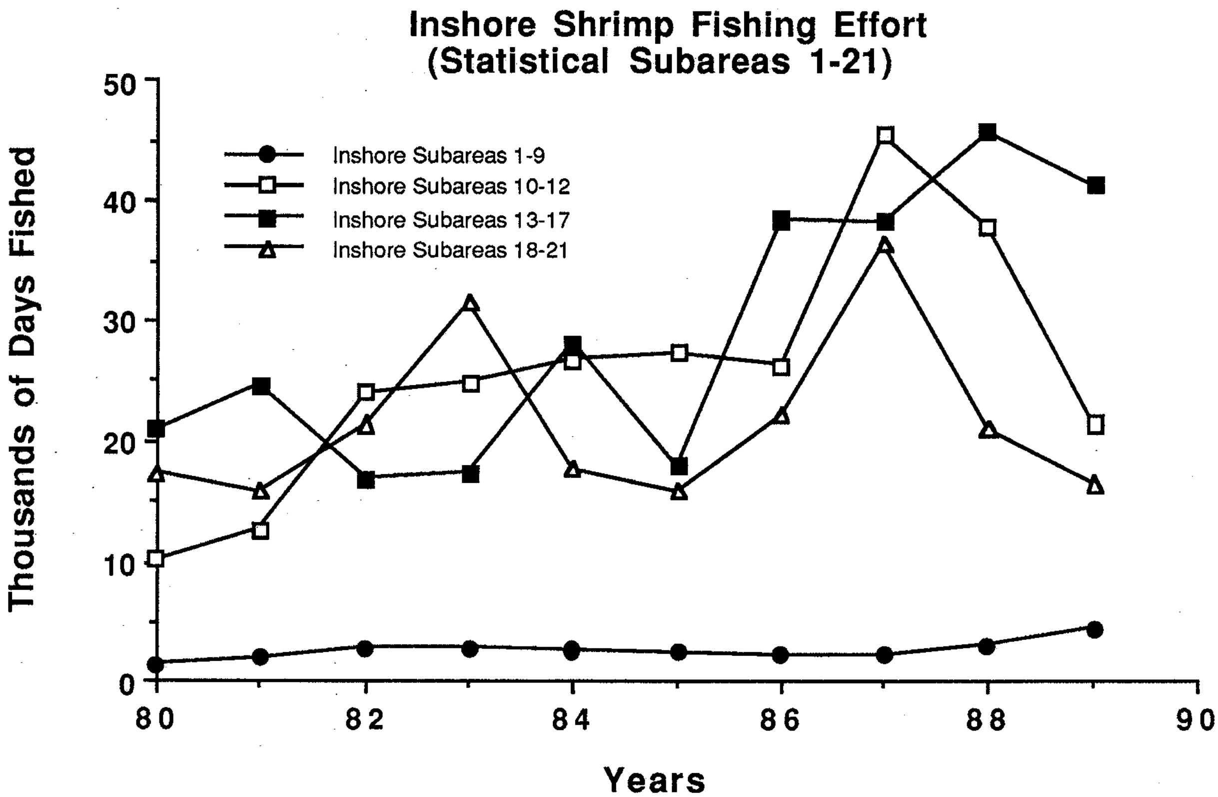


Figure 5. Inshore shrimping effort for each of the different regions (80-89).

From 1987 to 1989, a decrease in offshore effort of 18% has occurred in subareas 18-21, a decrease of 17% in subareas 13-17, and a decrease of 16% in subareas 1-9 (Figure 6). A slight increase in effort was observed in subareas 10-12. Early analysis of the 1990 offshore effort data shows that a further decrease in effort from the levels experienced even in 1989 has occurred in most regions.

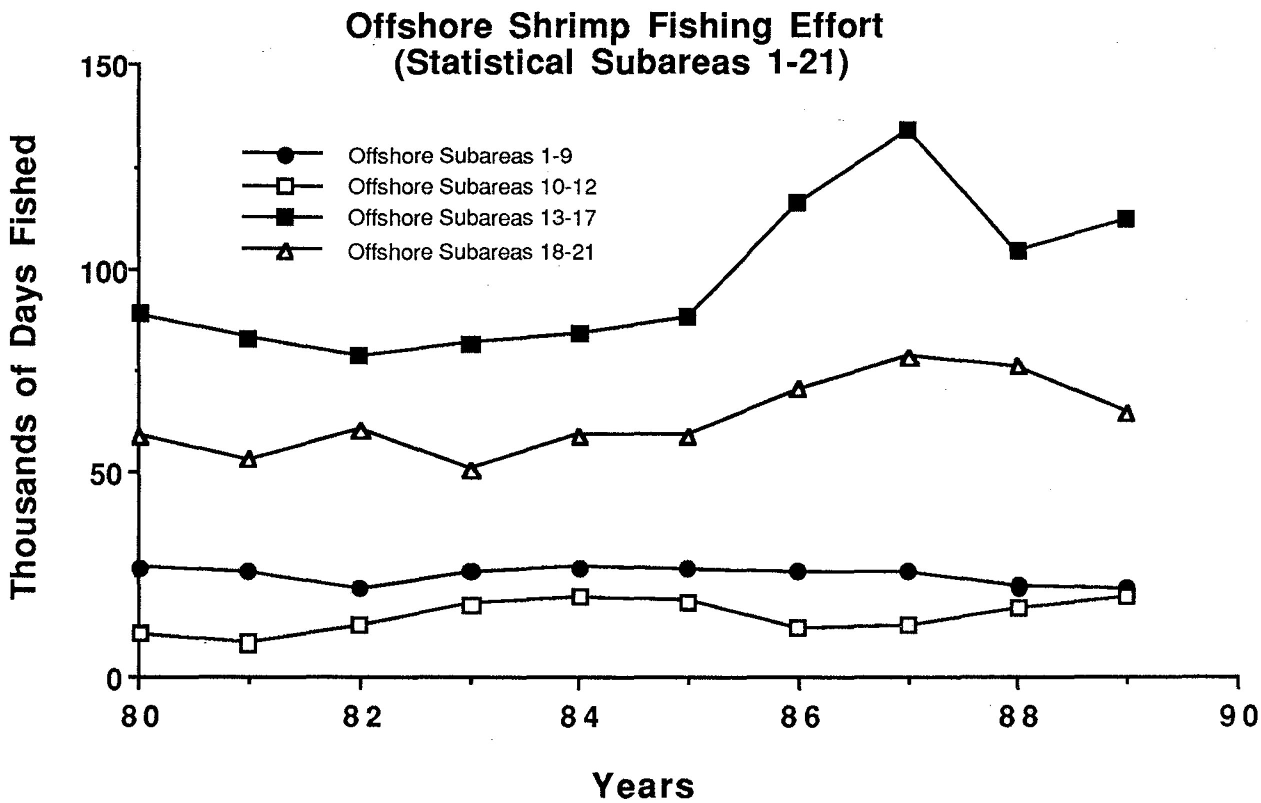


Figure 6. Offshore shrimping effort for each of the different regions (80-89).