Seasonal and Annual Trends in Commercial Fisheries Landings from Puerto Rico

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ABSTRACT

Commercial landings were summarized on a monthly basis by dominant species groups for trend analysis. Both seasonal and annual trends were observed in the data. Annual trends indicated decreasing catch-per-unit effort in most species from 1983 to 1988. Seasonal trends were evident and in some instances can be ascribed to availability, especially in pelagic species. Analyses of benthic species suggest that changes in the seasonal component of the landings may be due to depletion of stocks by fishing, but natural cycles of abundance cannot be ruled out at this time.

INTRODUCTION

In many tropical areas especially islands, little information on fisheries is collected making it difficult for fishery managers to effectively manage stocks. In Puerto Rico an extensive port sampling program has been in place since 1967 and has been refined over the years to its present computerized form. Initially, landings were compiled by hand, and these data summaries are available for 1972-1982, although seasonal details are lacking (Weiler and Suarez-Caabro, 1980; Collazo and Calderon, 1988). Starting in 1981, data were entered onto a computer database. Based on these computerized data, seasonal information was presented for the first time for 1988-89 (Matos Carabello and Sadovy, 1990). Data on the intervening years 1983-1987 have not been published. Thus for purposes of retrospective analysis, data exist in a relatively easily accessible form over the last 10 years. For this initial examination we summarized the data on a monthly basis. From this summarized dataset we explored the seasonal components of the landing data by examining changes in catch and effort over six years from 1983 to 1988.

METHODS

Fishermen in Puerto Rico report their landings on a voluntary basis in the form of a "trip ticket". Ideally, this ticket would have information on an individual trip with data on species caught, pounds landed, price received, and type and amount of gear used. In reality, however, the ticket may represent several trips over a month period, with catch lumped over several gear types. Based on the multiple reporting of trips on a single ticket, the best temporal resolution would be a month for the complete dataset, but certain subsets of the data (*e.g.*, fishermen who report on a daily basis) could be amenable to even weekly or lunar analysis. We summarized the data by month to make use of the greatest portion of the data.

Although the data appeared to be entered accurately, no data checking had been carried out in the past. The lack of data verification resulted in a need for data filtering before analysis. Duplicate records were the most common problem encountered and were deleted from the database. In the past, landings reported in the annual databases were considered the complete landings rather than a subset of the landings. This is a tenuous assumption, and much of the changes and variability in total landings could simply be due to changes in the reporting efficiency. It is known that many fishermen do not report their landings, but a perusal of the database indicates that many fishermen have been consistent in their reporting frequency giving some confidence to the data available. Rather than having to assume that reporting efficiency remains constant among years, it would be simpler to calculate a catch per unit effort and take the reported landings data as a sample of the total landings. What unit of effort should be used? Ideally each ticket would represent a single trip where the exact amount of time fished and amount of gear used would be recorded. While some records have units of gear such as number of traps or length of gill net, most do not. The next higher level of assessing effort would be numbers of trips, preferably on a gear basis. Typically, tropical fishermen use multiple gear on a single trip and while multiple gears are reported on landings tickets no separation of the catch by gear is usually available.

In many cases data on number of trips, amount of gear, and fishing duration are missing from the database. In 1987 and 1988 no information in the database is available on number of trips. In the past the number of tickets has been typically used as a measure of total effort and to make use of the greatest amount of data and for consistency across the years 1983-1988 we chose the ticket as the unit of effort for this analysis.

As is common of many tropical fisheries, Puerto Rican landings comprise a wide range of ecological groups. We have examined three of these: pelagic fishes, demersal fishes, and demersal invertebrates. Two pelagic fish taxa, dorado(dolphinfish, *Coryphaena* spp.) and atun (tuna, Scombridae) were examined. Shallow-water demersal fishes make up a sizable portion of the landings. Thus, we compared four taxa, arrayado (lane snapper, *Lutjanus synagris*), boquicolorado (grunts, *Haemulon* spp.), colirrubia (yellowtail snapper, *Ocyurus chrysurus*), and mero (grouper, Serranidae). One deepwater demersal species, chillo (silk snapper, *Lutjanus vivanus*) was also analyzed. The two most targeted invertebrates, langosta (spiny lobster, *Panulirus argus*) and carrucho (queen conch, *Strombus gigas*), were also investigated. Data were summarized for each of these nine taxa from the computer database for 1983 to 1988.

To elucidate the seasonal component of the data we fit a third degree polynomial model to each of the datasets. This model is without an empirical basis but is used to better display the seasonal trend. It is obvious from examining the plot of landings that the time series is not stationary but has some overall trend through time. To show this overall trend without the seasonal component we used the LOWESS (Locally weighted regression scatterplot smoothing) method to smooth the data (Cleveland, 1979). This method does not assume any model fit to the data. Like a polynomial the LOWESS method can be adjusted to give a more curvy or straighter line fit. We selected the straighter line fit (*i.e.*, taking out the seasonal component) to examine the overall trend in the data.

RESULTS

Total effort expended in the Puerto Rico fisheries can be represented by the total number of tickets on a monthly basis (Figure 1). After an initial drop in the number of tickets in 1983, the level of effort appears relatively constant from 1984 through 1988. With this background let us compare the various components of the fishery.

Pelagic Species

Dorado (*Coryphaena* spp.): Figure 2 shows the trends in catch, effort, and CPUE for dorado. The highly seasonal nature around the coast of Puerto Rico for this pelagic species can be seen in the data with greatest catch in the winter months. There was a decline in effort in 1983 but thereafter an increase in effort through 1988. The LOEWESSS trend in CPUE remains level, though there is some indication of increasing CPUE in 1987-88.

Atun (tuna, Scombridae): A similar trend to dorado in catch and effort can be seen in atun with an initial decline and then an overall increase from 1984-1988 (Figure 3). Again, the highly seasonal nature of the catch typical of pelagic species is evident and CPUE lacks a trend with a relatively flat overall curve. A slight decline in 1985 is coupled with a major reduction in seasonal fluctuation.

Demersal Species - Shallow-water

Arrayado (lane snapper, *Lutjanus synagris*): For arrayado an initial decline in both catch and effort in 1983 are followed by level effort through 1988, but a decline in catch at least through 1986 (Figure 4). CPUE picks up

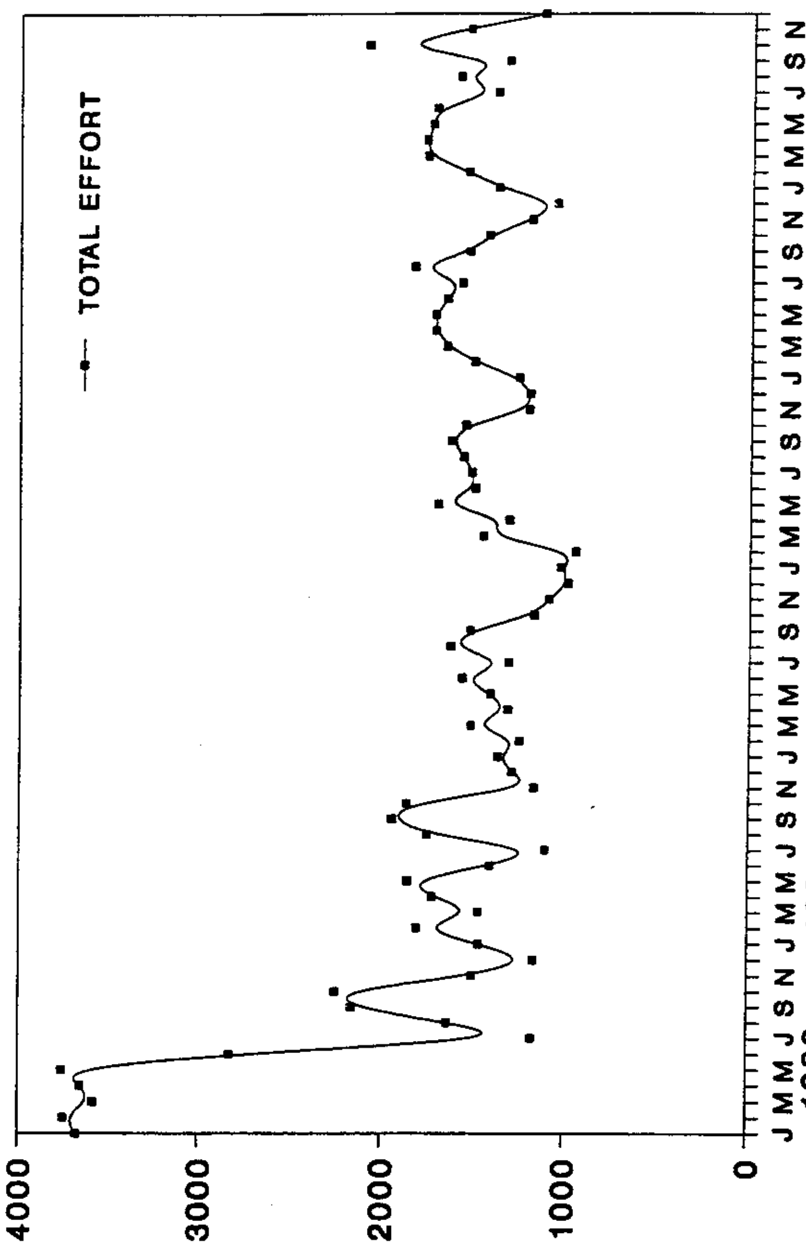

Figure 1. Total commercial fishing effort (number of tickets) by month for Puerto Rico from 1983–1988. Solid line is polynomial

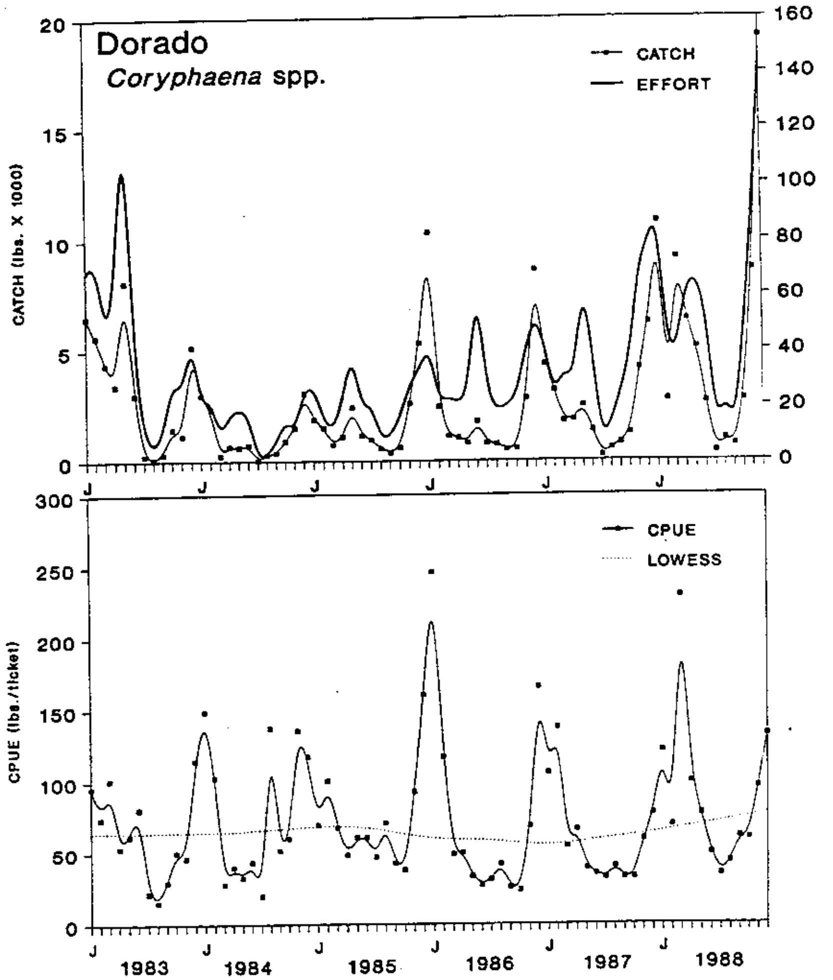

Figure 2. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for dorado (*Coryphaena* spp.) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for dorado, (*Coryphaena* spp.) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

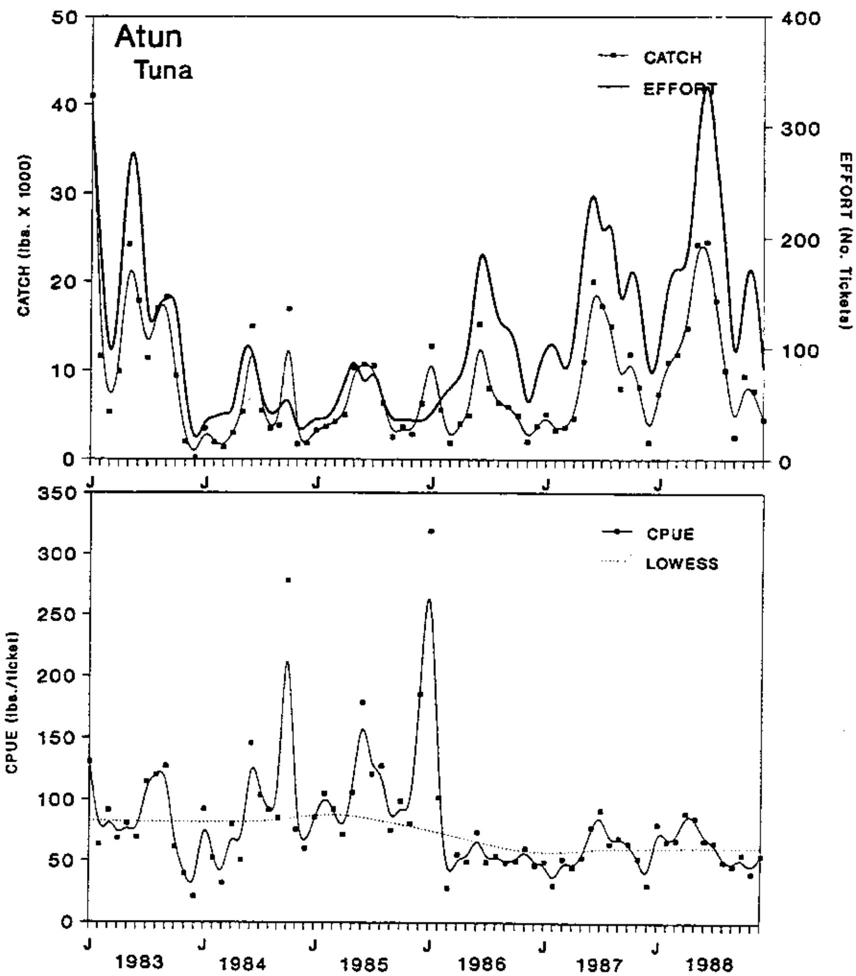

Figure 3. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for atun (tuna) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for atun (tuna) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

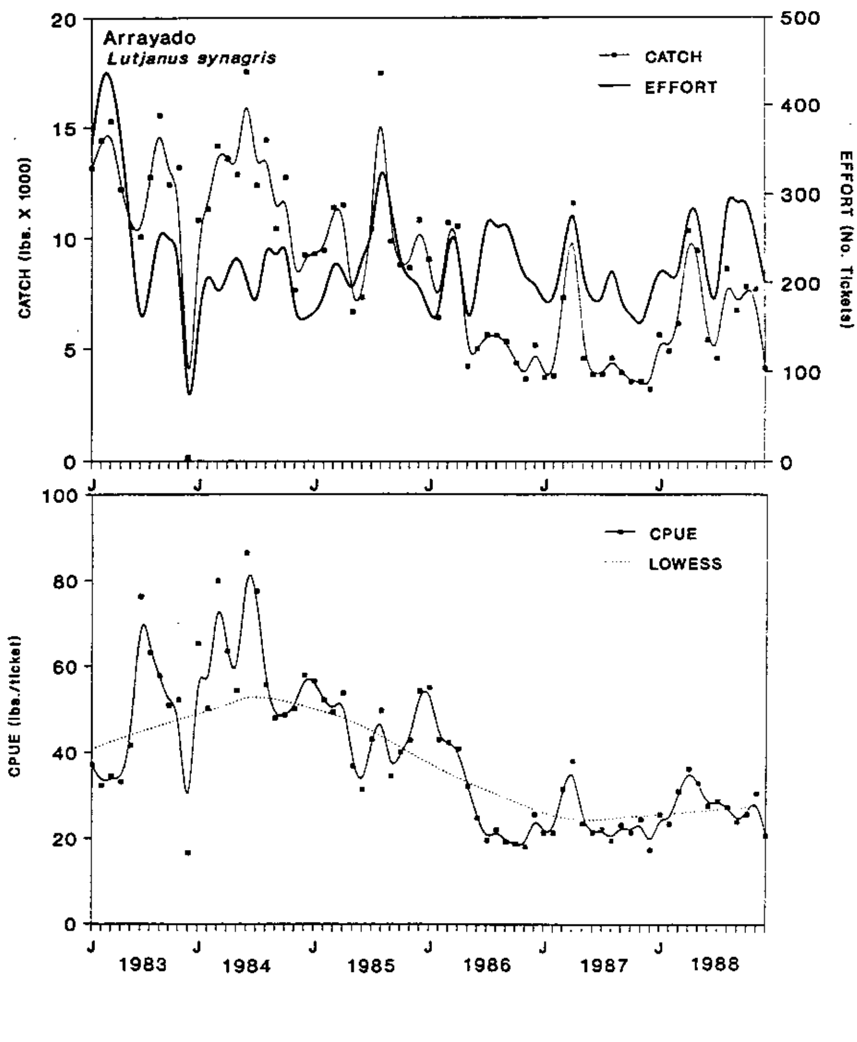

Figure 4. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for arrayado (*Lutjanus synagris*) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for arrayado (*Lutjanus synagris*) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

these trends as an initial slight rise to mid-1984 then a sharp decline from mid-1984 to 1987. In 1987-88 CPUE suggests a slight increase. This pattern could be due to inter-annual variability in stock size or depletion through increased fishing effort.

Boquicolorado (grunts, *Haemulon* spp.): A general decline in catch and effort is evident in boquicolorado from 1983 through 1988 (Figure 5). CPUE shows the re-occurring pattern of an initial increase followed by a decline in 1984-86. CPUE appears to be stabilizing in 1987-88, though there is still a slight downward slope. Also, seasonality in the data has been substantially dampened after 1986.

Colirrubia (yellowtail snapper, *Ocyurus chrysurus*): Similar patterns of catch and effort decline to other shallow-water species are evident in colirrubia (Figure 6). A more rhythmic cycle to these data suggests some interesting seasonal patterns that should be examined further. CPUE shows a similar curve in overall trend to the other species. Again, a dampening of the seasonal cycle is evident after 1986.

Mero (grouper Serranidae): A sharp decline in catch and effort is followed by a general decline thereafter in mero (Figure 7). An increase in both catch and effort in 1986 occurs during the primary dip in CPUE. A typical shallow-water CPUE pattern is evident. Limited dampening in the seasonal component is observed.

Deepwater

Chillo (silk snapper, *Lutjanus vivanus*): Though found in deeper waters, the chillo has a pattern similar to the shallow-water demersal species (Figure 8). A general decline in catch and effort is followed by a decline in CPUE after 1985. Seasonality is damped in1986-87 but is again evident in 1988.

Invertebrates

Langosta (spiny lobster, *Panulirus argus*): Langosta shows a general increase in effort after a major decline in 1983 (Figure 9). Catch appears to continue to decline gradually after 1983 with a slight recovery in 1988. CPUE has the typical sigmoid shaped curve of other species with an increase through 1984 and a decline thereafter. The increase in catch and effort in 1988 has little apparent impact on the CPUE curve. Note that the seasonality is dampened after 1986.

***Carrucho* (conch, *Strombus gigas*)**: Catch and effort show a gradual decline in carrucho through 1985 (Figure10). Effort starts to increase in 1985

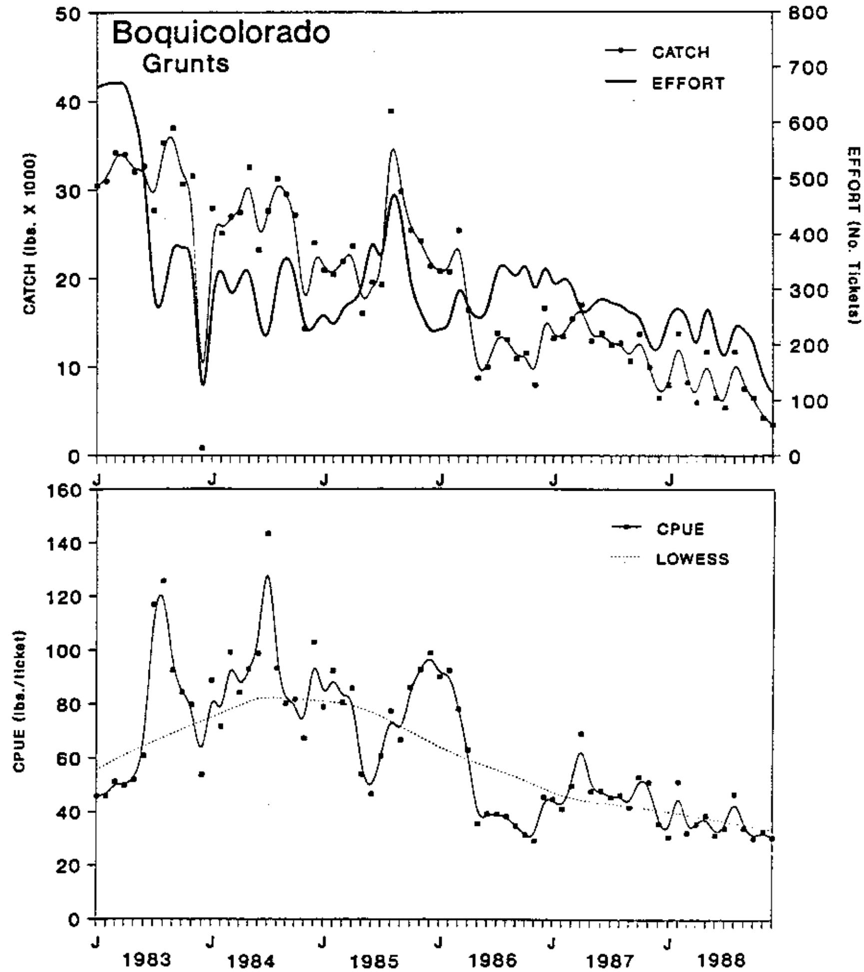

Figure 5. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for boquicolorado (grunts) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for boquicolorado (grunts) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

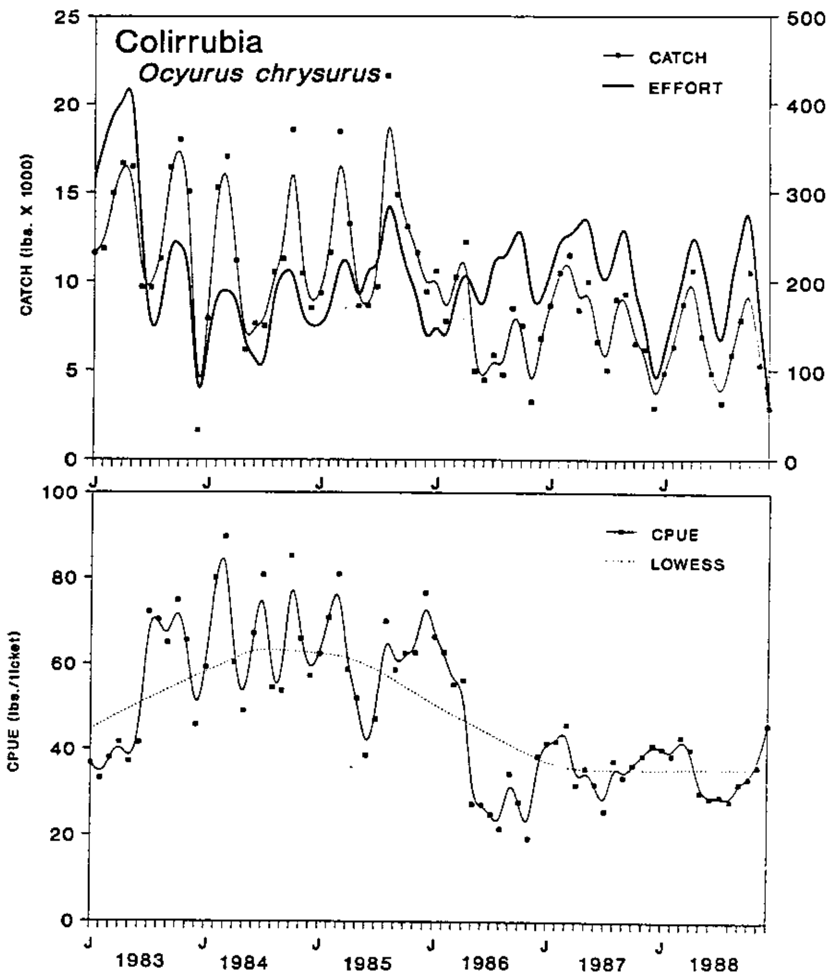

Figure 6. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for colirrubia (*Ocyurus chrysurus*) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for colirrubia (*Ocyurus chrysurus*) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

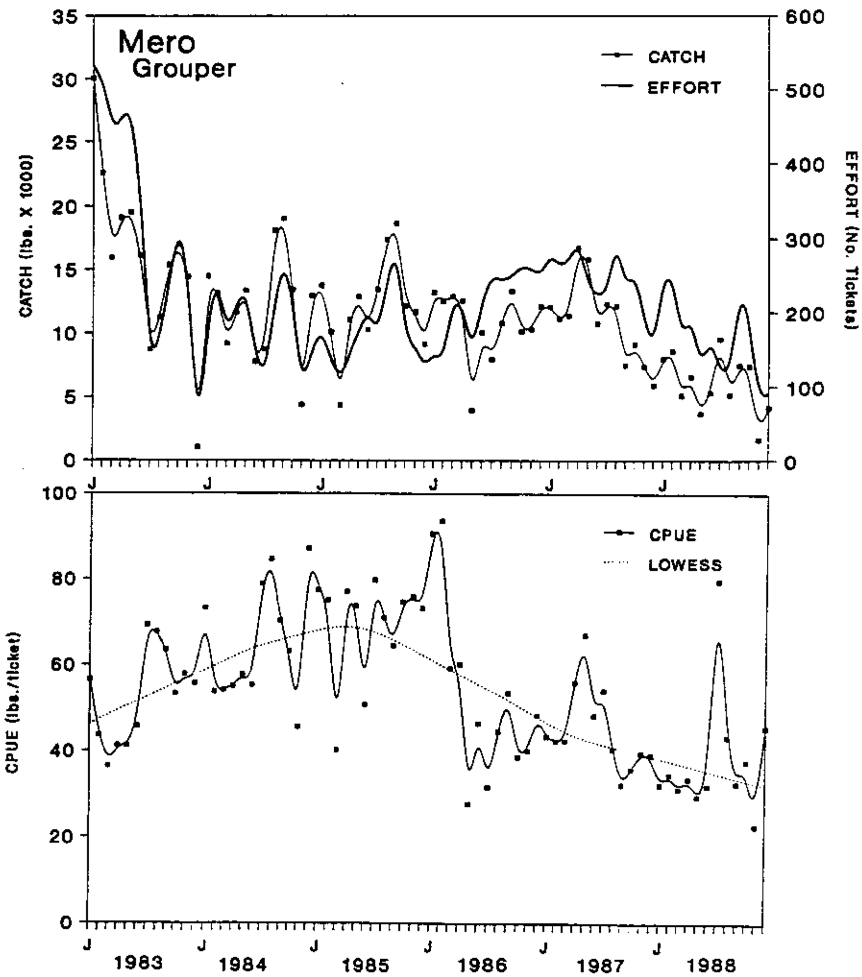

Figure 7. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for mero (grouper) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for mero (grouper) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

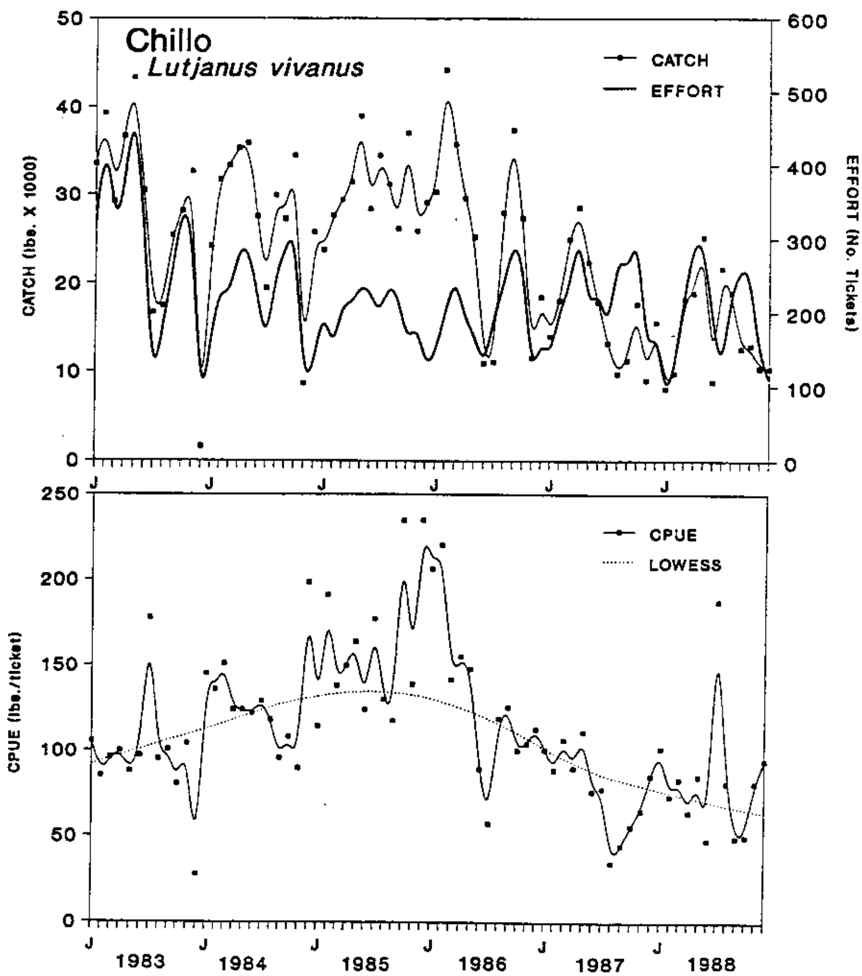

Figure 8. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for chillo (*Lutjanus vivanus*) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for chillo (*Lutjanus vivanus*) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

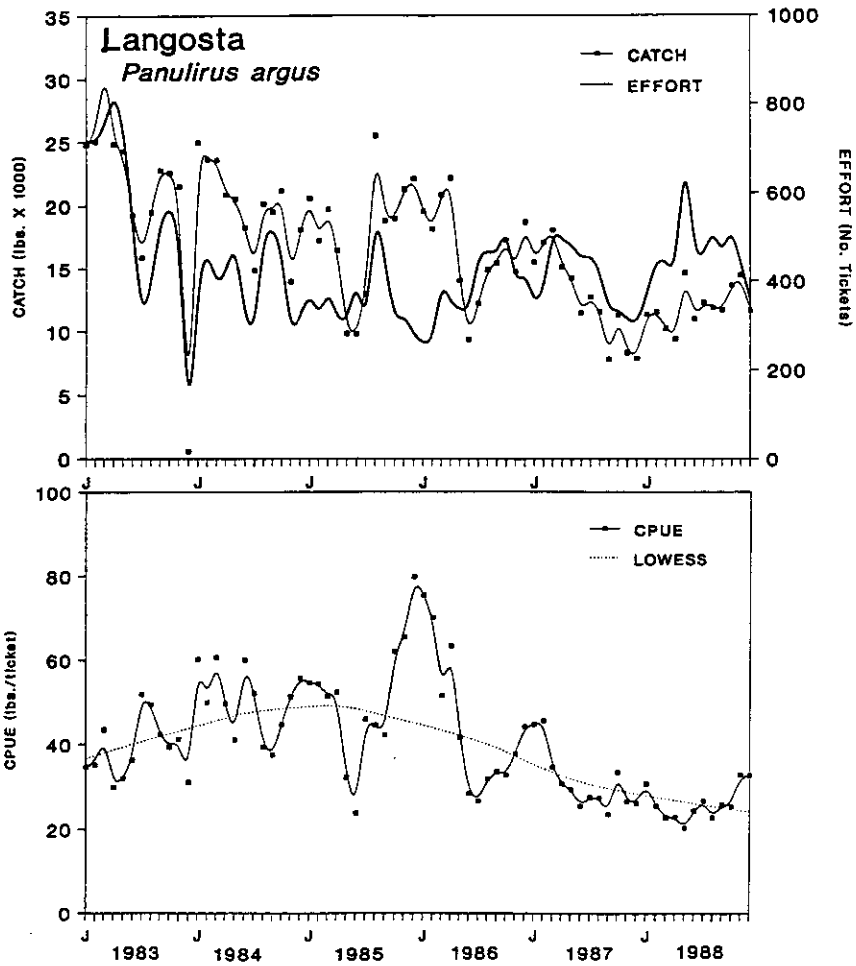

Figure 9. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for langosta (*Panulirus argus*) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for langosta (*Panulirus argus*) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

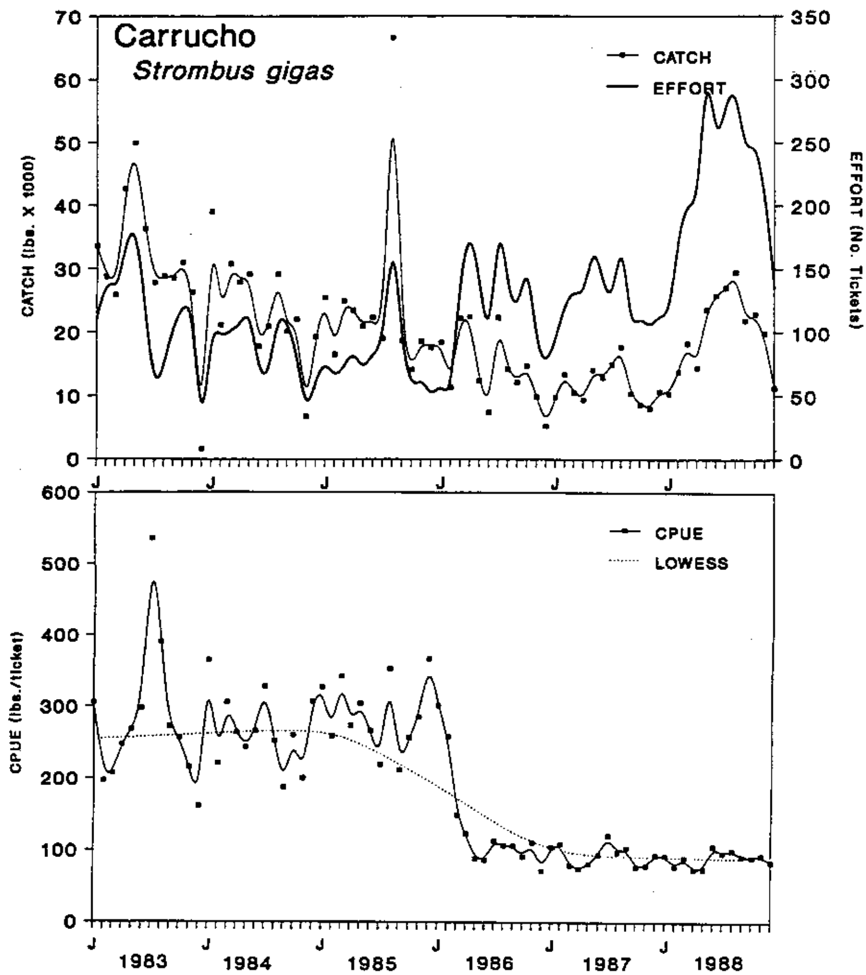

Figure 10. UPPER: Commercial catch (thousands of pounds) and effort (number of tickets) for carrucho (*Strombas gigas*) in Puerto Rico. LOWER: Catch per unit effort (CPUE; pounds per ticket) for carrucho (*Strombas gigas*) in Puerto Rico. Solid line is polynomial fit and dashed line LOWESS fit to the data.

with a major increase in 1988. Catch continues to decline through 1987 but appears to have an upward shift in response to the increased effort in 1988. CPUE shows a major decline in 1985-86 and appears to have leveled out in 1987-88. The major increase in effort in 1988 resulted in no shift in the CPUE trend. Dampening of the seasonal cycle is quite evident in the carrucho data.

DISCUSSION

Total landings have declined since 1979 with a significant drop in 1987-88. The number of fishermen continued to increase through 1985 then declined thereafter suggesting overfishing of the stocks. A declining trend in CPUE for most species occurred over the period 1983-88 and could be a symptom of overfishing. It also could reflect inter-annual variability in stock size, however, the consistency of the decline in CPUE across species of differing ecological type indicates that some factor affecting the whole system is involved. The sigmoid shape of the CPUE trend in most species indicates that a major change occurred in the fishery in 1985-86 resulting in a decline in CPUE and dampening of seasonal trends. We will need longer time series to eliminate the possibility that natural variability accounts for the patterns observed.

Serially correlated data such as fishery landings can be modeled by time series analysis (Box and Jenkins, 1970). These models are designed to make estimates in the presence of autocorrelation errors. The Box-Jenkins model has been applied to fisheries data for short-term forecasting of fisheries landings with good results (Saila, *et al.*, 1980; Mendelssohn, 1981). The general occurrence of wide confidence intervals indicate that noise in the data must be reduced to a minimum to provide useful forecasts. Forecasts could be used in fisheries management to decide whether to implement a particular management measure, such as a closed season.

Changes in time series can be detected through intervention analysis (Box and Tiao, 1975; McDowall *et al.*, 1983). Intervention analysis could be used to assess the effectiveness of management measures such as size limits or closed seasons. The implementation of a size limit or closed season should result in a measurable change in landings; an initial decline followed by an increase in CPUE might be expected. If no change in trend was detected by intervention analysis then the management measure would be considered ineffective or inappropriate, and thus could be changed.

In many cases, parametric methods are not suitable due to missing data or restrictive assumptions. Nonparametric methods have been developed to test for trends in water quality time series data similar to fisheries landings (Hirsch *et al.*, 1982; van Belle and Hughes, 1984). These methods can be used to detect whether a trend or change is significant during a given interval of time. The nonparametric tests are as powerful as the parametric (*e. g.*, Box-Jenkins model) in most cases and can be applied to monthly data records as short as 3 years (Hirsch *et al.*, 1982). Methods used to analyze annual fisheries data can be also adapted to monthly data for seasonal mortality estimates making further use of the seasonal data (Caddy, 1985).

The commercial landings database holds a wealth of data to be examined and more rigorous statistical analyses can be applied, once it is verified and corrected.

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