Interpreting Long-Term Fish Landings Records: Environment and/or Exploitation?

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ABSTRACT: The California Department of Fish and Game data base of California commercial fish landings for the period 1928 to 1985 has been assembled in computer accessible form at the Pacific Fisheries Environmental Group in Monterey, California. Time series for fishes whose landings are known to vary during periods of ocean warming were compared to time series of sea surface temperature. Expected patterns of variation were confirmed in the seasonal cycle, but were less clear on the interannual scale. When interannual variation was considered, the most serious hindrance to interpretation of the landings series appeared to be the continued reduction of the fish stocks due to commercial exploitation; other factors are discussed. Landings data contain information potentially useful in climatological studies, but problems should be anticipated in their use.

INTRODUCTION

Fish landings data are one of few types of marine biological data that exist for periods of time sufficient for climatological investigations. This report announces the digitization and archiving of 58 years of commercial fish landings data from California Department of Fish and Game (CDF&G) records. It discusses a preliminary investigation into the value of this data set as a source of information on temporal variation in the marine ecological system, and it gives examples of problems encountered in extracting useful information from them.

The approach used here to test the utility of the data set has been to state a well known hypothesis relating landings variability to ocean warming; to test this hypothesis using a subset of the data; and then to examine the results of the test from two points of view. First, how well is the hypothesis demonstrated? Second, identify factors other than the one hypothesized that influence variability in landings.

Previous studies have shown that increased commercial and sport landings of albacore, bonito, barracuda, bluefin tuna, skipjack tuna, swordfish, and white seabass along the California coast vary simultaneously with warming of the coastal waters (Walford, 1931; Hubbs, 1948; Radovich, 1960, 1961, 1975; MacCall et al, 1974; Squire, 1987.) This well established relationship is the known hypothesis to be tested below using the newly archived data. Our results may not be expected to be new, but they will amplify past work and will provide a framework for discussion of some of the problems encountered in the use of landings data.

DATA

The newly archived data series for the 1928 to 1985 period was obtained from the CDF&G. For the years 1928 to 1977, these data are in publications of the CDF&G *Fish Bulletin* series. The data since 1978 have not been published, but corresponding records for 1978 to 1985 were obtained from the Monterey, CA, office of CDF&G. These all have been archived digitally at the Pacific Fisheries Environmental Group for the six California statistical regions shown in Figure 1. This report uses data from the Santa Barbara, Los Angeles, and San Diego statistical regions. The species of fish selected for consideration are commonly known to have their presence and/or levels of abundance related to warming *(op cit)* of the coastal ocean environment.

The Scripps pier temperature data set is one of few environmental time series of length comparable to the fish landings time series. It is used as an index of conditions in the Southern California region (Mooers et al., 1986; Smith and Eppley, 1982; Fiedler, 1984).

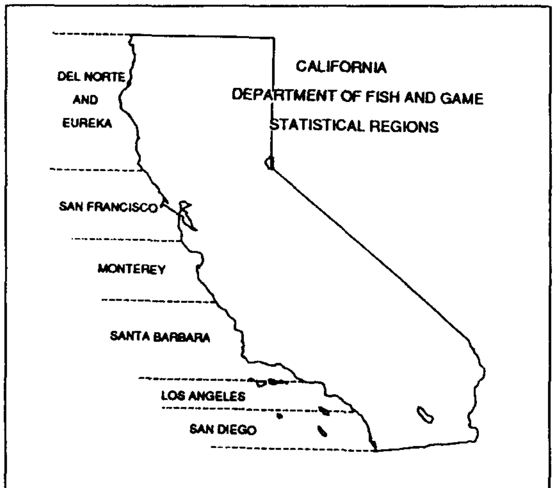

Figure 1. Statistical regions from which landings of commercially caught fishes are reported by California Department of Fish and Game.

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PROBLEMS AND EXAMPLES

A representative time series plot of monthly landings (Figure 2) shows that the seasonal cycle is conspicuous, as are interannual variations and multi-year trends in the level of landings.

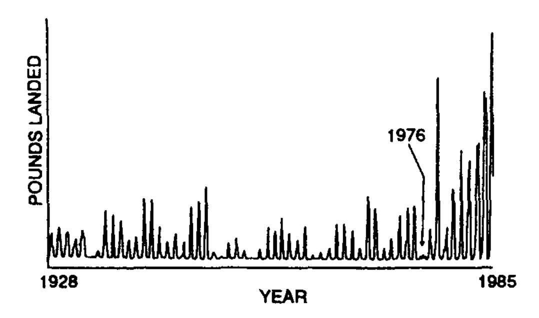

Figure 2. Monthly landings of swordfish at Southern California ports, 1928 to 1985. Note major change in trend at about 1976; see text.

Plots of long-term average monthly landings (annual seasonal cycle) of selected warm - water species (Figure 3) illustrate that albacore, bluefin, skipjack, white seabass, bonito, and swordfish landings peak in August and September (skipjack landings have an additional minor peak in April). Barracuda landings peak in June and July. The principal peaks of landings of all the species except barracuda occur when the Scripps pier SST is at a maximum (last panel, Figure 3). The composited (normalized and summed) long-term monthly mean landings and SST correlate at $r=0.96$, and all except barracuda are individually correlated at significance levels over 99% (r over 0.69). In terms of seasonality then, the hypothesis that the test species are associated with periods of warm water is well validated by the commercial landings data set. The correlation of $r=0.96$ shows a close seasonal phase relationship between the warm-water species and the ocean temperature indicator.

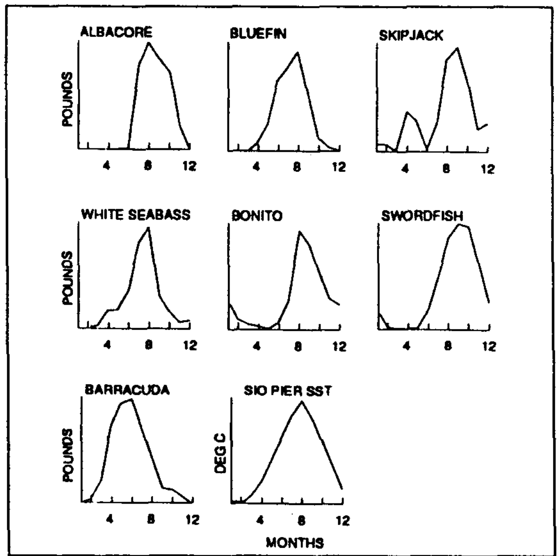

Figure 3. Long-term average monthly landings of warm-water fishes in the Southern California bight. Plots show types of seasonal patterns in landings. Vertical axes are not labeled because each panel is scaled to give the maximum value full scale.

We next made an exploratory test of the interannual relationship between summed annual landings and SST. The annual total landings for the test species were normalized to standard deviation units and summed for each year; the data were combined for all species then were compared to Scripps pier SST. This simple approach of summing the annual landings for each species for each year and correlating this with SST gives a seemingly correct association, $r=0.61$, between fish landings and warm ocean conditions on the interannual scale (MacCall et al., 1974; Radovich, 1961, 1975). However, the SST time series pattern is dominated by four warm-water periods at 1931, 1941, 1957-60, 1982-84 (see smoothed SST curve, Figure 4), seemingly related to the timing of major warm (El Niño Southern Oscillation, or ENSO) events. And the landings data show trends and shifts in levels that are due to natural and anthropogenic causes. Factors such as these partly obscure the environmental influence on landings and contribute to reducing the effective degrees of freedom (n = 58) by introducing autocorrelation.

When the species are tested individually against SST, it is noted that only skipjack has an r-value comparable to the composite series ($r=0.51$; Figure 4). Further examination of the individual series shows conspicuous overall trends in all the fish landings time series plots except albacore and skipjack.

The plot of annual albacore landings for the three southern regions may be misleading, because albacore landings distributions change between Southern California waters and the region from Northern California to British Columbia. Albacore apparently enter those northern regions from the west. Thus the plot presented may not reflect the coastwide landings of albacore. The other species appear to enter the Southern California region from the south or southwest.

White seabass landings show a general decline. An exceptional increase in landings occurred during the 1957-59 ENSO event, in which they reached an all time peak of 3.4 million pounds. Increases of lesser magnitudes also occurred at the times of warm events in 1931, 1941 and 1972-73.

Barracuda landings show an even more abrupt decline. Increases in landings, apparently associated with the 1957-59 ENSO event, as well as the prior major event in 1940-41, are evident.

The bluefin tuna landings time series shows noticeable maxima during the 1941 and 1957-59 warm water events.

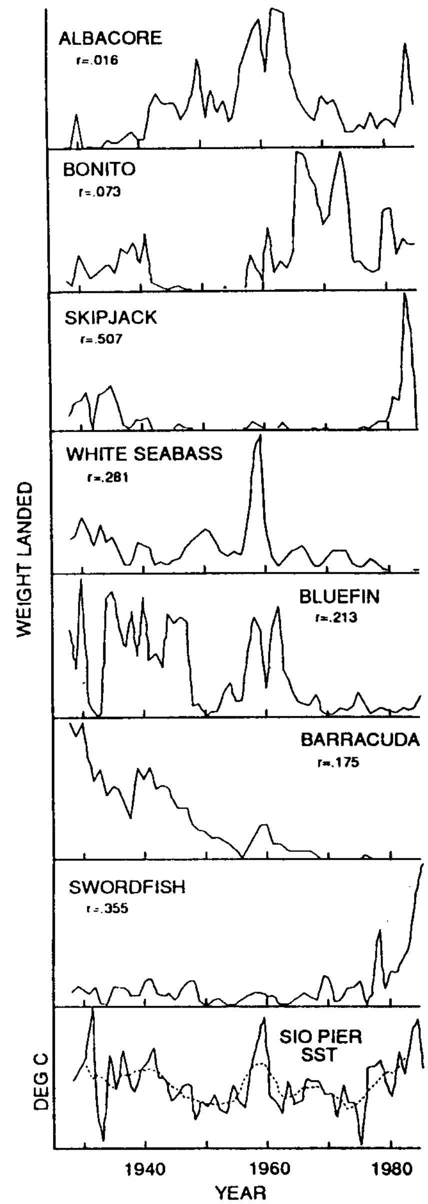

Figure 4. Time series plots of annual landings of warmwater fishes and Scripps pier surface temperature, 1928-1985. Correlation coefficients (*r*) for each species and SST are given in each panel. Vertical axes are not labeled because each panel is scaled to give the maximum weight landed full scale. Dashed line in SST panel is 5-year running mean.

COMMENTS AND DISCUSSION

Commercial fish landings statistics are one of only few kinds of data on biological variation in the ocean available over periods of time of sufficient length to permit their use in bioclimatological investigations. To make good use of these data, however, requires considerably more information. Data concerning any resource highly impacted by man's economic or other activities are likely to have variability in amplitudes and frequencies that are greater than those induced by non-anthropogenic factors. This appears to be demonstrated by the commercial fish landing data.

Bluefin tuna and barracuda have generally declined in abundance over the 58-year period studied. Commercial fishing probably has been an important factor contributing to this decline. Reduction in stock size may have occurred during periods of increased availability to the commercial fisheries.

Episodic increases in landings followed by declines may mean that the total populations were more accessible to fishing during warming events, but not necessarily more abundant at those times. Landings for barracuda and white seabass declined rapidly after reaching peaks occurring simultaneously with warmings (Figure 4). This may explain why the association between the landings of the fishes studied herein and warm water is not as evident during the warm events that occurred since 1959; there may not have been sufficient stocks size for an expression of the environmental relationship to be evident.

There has been an increase in swordfish landings (Figures 2 and 4) that began simultaneously with the onset of an ocean climate shift in 1976 (Norton et al., 1985; PACLIM Abstracts, 1986, 1987, 1988). Because the swordfish market demand usually exceeds supply, all fish landed can be sold. In the mid-1970s it was discovered that swordfish could be caught more easily with gillnets than by the traditional harpoon method (Bedford and Hagerman, 1983). The catch by harpooning has remained about constant (*ibid*), but introduction of the new gillnet gear made it possible to extend the fishery into waters that had been unsuitable for harpooning. This expanded the area subject to fishing and also extended the time fish were available to exploitation. The result has been a major increase in landings that occurred simultaneously with a major environmental shift. The connection between ocean climate (SST) and catch is, at this point, unclear because the new fishing methods were introduced coincidentally with the onset of the environmental change.

Various methods for combining data from different sources are being developed. Independent scientific surveys of adults may be used to determine species abundance. This approach has been used for sablefish, rockfish, and some species of wet fish. Other surveys might monitor changes in numbers of eggs, larvae and juveniles. From these surveys, fisheries independent estimates of stock abundance may be possible.

Combination of sport and commercial catch records may help to interpret trends. These two data sets are controlled by somewhat different variables. Sportfishing is not for profit, whereas commercial fishing is profit driven; but a certain level of success is necessary in either case.

In a recent report to the Pacific Fisheries Management Council, Methot and Hightower (1988) combined information from scientific surveys and tagging experiments to arrive at estimates of current and previous sablefish stock sizes.

We have explored the climatological variations in the relationship of SST and commercial fish landings. The expected linkage seems confirmed; but we demonstrated that users of landings data should be aware of the presence and possible effects of other factors on landings variability. These include:

- Autocorrelation introduced by extreme environmental events,
- Depletion of the species,
- Fishing gear changes,
- Merchandising demand factors,
- Availability of market replacement species, etc.

SUMMARY

- Commercial fish landing data compiled by the CDF&G have been refined into a uniform, computerized data base at the PFEG.
- These data have been tested with a commonly accepted hypothesis relating ocean warming and landings variability. The data strongly support the hypothesis on the inter-monthly or seasonal scale, but the relationship is less decisive on the interannual scale. That linkage is partially obscured by the interplay of numerous factors.
- Declines in fish landings over time, as a possible result of high exploitation during warm water periods and high abundance, is thought to be a major factor which confuses simple interpretation of these commercial landings data.
- Other data sources and data processing techniques will be used to obtain additional information on the marine ecosystem from the commercial fish landings data set.

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