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Interannual and seasonal variation of dolphinfish (*Coryphaena hippurus*) catch rates in the southern Gulf of California, Mexico

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ABSTRACT

Dolphinfish (*Coryphaena hippurus*) is found in tropical and subtropical waters, and is an important sport and commercial species. The migrations of this species are associated with sea surface temperature changes and therefore climatic events such as an El Niño have an effect on its distribution in the Pacific Ocean. Our objectives were to determine the seasonal and interannual variations in catch rate and to correlate these with sea surface temperature. The database used in this study was the catch rate (number of organisms/trip) made by the recreational fleet that operated in Cabo San Lucas, B.C.S. from 1990 to 2000. To identify trends that may exist due to fluctuations in tourism, which could generate a bias in the use of the catch rates as relative indices of abundance, we analysed the daily data base of the effort (number of trips) that were recorded by the harbor authorities. Significant differences were found in the monthly average of effort during summer–autumn, which is the hurricane season in this area. The monthly average stayed above 1700 trips. Although interannual variation was not significant (ANOVA, $P > 0.05$), the seasonal effect showed significant differences with the highest average catch rates in summer–autumn (ANOVA, $P < 0.05$). A significant relationship between catch rate and sea surface temperature was found ($P < 0.05$), with a correlated coefficient value of $r = 0.78$.

1. Introduction

The dolphinfish (*Coryphaena hippurus*) is an epipelagic predator that inhabits tropical and subtropical waters. Its distribution is limited by the 20 °C isotherm in both hemispheres (Palko et al., 1982). In the northern Pacific Ocean this species is distributed throughout the tropical region from the equator to Baja California Sur (22.8°N). Fluctuations in the regional distribution of this species are believed to be dependent on physical changes in oceanographic conditions especially in regards to sea surface temperature (SST) (Norton and Crooke, 1994). The dolphinfish supports both commercial and sport fisheries and the stability and magnitude of the catch rates suggest that it is a resilient resource that is able to support high catch rates and adapt to a variable environment(Rose and Hassler, 1974; Campos et al., 1993; Oro, 1999; Massuti et al., 1999; Mahon and Oxenford, 1999).

The studies thus far on the dolphinfish in different fisheries, in both the Atlantic and Pacific, have shown a clear seasonality in catch rates and peaks of abundance (Tester and Nakamura, 1957; Springer and Pirson, 1958; Rose and Hassler, 1969). These data have generated several hypotheses, suggesting the existence of different populations and migratory patterns associated with changing environmental conditions (Wang, 1979; Palko et al., 1982; Oxenford and Hunte, 1986; Massuti et al., 1999; Kraul, 1999).

In the Mexican Pacific *C. hippurus* is distributed along the Gulf of Tehuantepec to the south of the Baja California Peninsula and through the Gulf of California. Similar to the billfish, this resource has been reserved as a recreational resource since 1986 (Sosa, 1998). However, in coastal regions recent studies have shown this species to compose 55% of the total catch made by artisanal fleets Madrid and Beltran (2001). This species is also reported as bycatch in the tuna purse-seine and long-line fleet fisheries (Santana, 2001).

The most economically important sportfishing location in Mexico is Cabo San Lucas (CSL), Baja California Sur (B.C.S.) where more than 400 vessels of diverse dimensions make more than 25,000 fishing trips annually (Ortega et al., 2003). This location also has an undetermined number of private vessels whose frequency of operation has not been quantified (Klett et al., 1996). Although the target species is typically billfish, the dolphinfish is also a common catch (Klett et al., 1996). This species is found all year in the CSL region with the highest catch occurring during summer and autumn,

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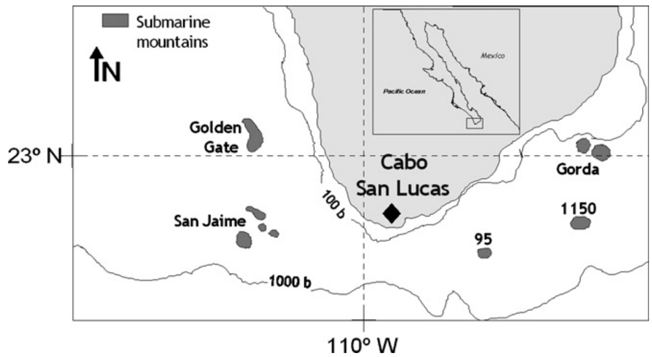

Fig. 1. Study area.

corresponding to warmer sea surface temperatures (28–30 °C), and the minimum catch in winter and spring when the SST is about 22 °C (Torres, 1996). High dolphinfish catch rates are associated with the warm water masses of the northequatorial current, the northequatorial countercurrent, and the coastal current of Costa Rica, where the sea surface temperatures are above 26 °C (Santana, 2001).

Given the economic importance of sportfishing in northwest Mexico the goal of this study was to determine whether there was any correlation between the seasonal and interannual fluctuations in dolphinfish catch rates and the variability in the SST in the region in an attempt to explain the variability in catch rates.

2. Materials and methods

Our study area was the fishing grounds of the sportfishing fleet of CSL. The grounds are located in the western Gulf of California (22°53′N and 109°54′W) and extend radially about 30 nautical miles. This area includes many submarine mountains that are important areas of capture (Fig. 1).

The information used in this study corresponds to the nominal catch rates (number of fish/per trip) provided by the Centro Regional de Investigacion Pesquera at La Paz B.C.S. (CRIP-La Paz) and consists of a monthly compilation of catch and effort data from 1990 to 2000 from the operations of three sportfishing fleets of CSL that represent approximately 40% of the total operations in the area. An additional database used in this analysis were the records of the administracion Portuaria Integral in CSL for the period 2000–2002. These records consist of the total number of fish caught by month in the CSL region. Because the dolphinfish is one of the target species of the CSL fleet, we feel that the catch rates provide a useful index of abundance (Mahon and Oxenford 1999). However to identify any trends in the applied effort that could generate a bias in the use of this index, we analysed the daily database that was based on the effort (number of trips) that was recorded by the harbor authorities at CSL.

For this study we considered January, February and March as winter; April, May and June as spring; July, August and September as summer and October, November and December as autumn.

Sea surface temperature records correspond to the Reynolds database (Reynolds and Smith, 1994), from which the monthly average SST was estimated for four 1° × 1° quadrants defined by coordinates 22.5°N–109.5°W, 22.5°N–110.5°W, 23.5°N–109.5°W, 23.5°N–110.5°W.

To determine if there were seasonal and interannual variability we used analyses of variance (ANOVAs) and to identify rhythmic patterns (periodicities) within the catch rate series data a spectral (Fourier) analysis was made. To determine the degree of similarity between the monthly average values of catch rates between years, a cluster analysis was performed using the Euclidean distance and the complete linkage to determine the distances between clusters (StatSoft, 2001).

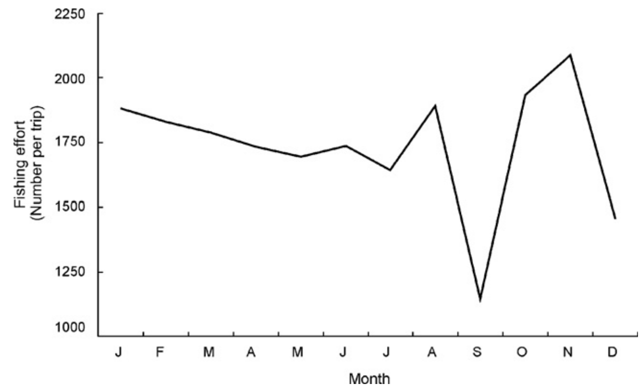

Fig. 2. Monthly average of the number of trips made by the sportfishing fleet of Cabo San Lucas, B.C.S. during 2001 and 2002.

Monthly average anomalies of catch rates and sea surface temperatures (SSTs) were calculated using the equation:

$$\mathrm{Ast}_{ij} = (X_{ij} - \bar{X})/s$$

where, $\bar{X} = (\sum_{i=1}^{n} X_{ij})/n$ and Ast_{ij}: the ith monthly or annual standardized anomaly, X_{ij}: the ith monthly or annual value, $\bar{X}$: the average from 1990 to 2000, s: is the standard deviation of the catch rates and SST.

A smoothing filter, which consisted of several passes of the moving average-median smoothing (StatSoft, 2001), was used in the catch rate series and the SST, and cross-correlation analyses (correlation between two series where the first one could be lagged). These analyses were done to determine the relationship between these variables.

3. Results

An ANOVA applied to monthly average effort showed significant differences ($F_{(11, 6477)} = 2.6314$, $P < 0.05$) that may be related to the high variance that was recorded during summer and autumn (Fig. 2). The monthly changes in capture were more related to the catch rate variations than to the applied effort (Fig. 3).

During the period analysed, the average catch rate of dolphinfish recorded in Cabo San Lucas was 1.33 fish per trip. The maximum monthly average catch rate recorded was 5.08 fish per trip and the minimum was 0.03 fish per trip. Although interannual variability was observed for these measures, with a minimum in 1998 (1.01) and a maximum in 1992 (1.80), the differences were not significant ($F_{(1, 121)} = 0.467$, $P > 0.05$) (Fig. 4).

For the total period, significant seasonal differences ($F_{(3, 128)} = 39.39$, $P < 0.05$) were found in the catch rates. The highest was recorded during autumn, 2.63 fish per fishing trip, and the lowest in winter, 0.4 fish per fishing trip (Fig. 5).

The lowest monthly SST recorded during the 1990–2000 period was 20.8 °C, and the highest was 30.4 °C, with the mean SST for the study period 25 °C. On average, the highest catch rates were recorded between 26 °C and 29 °C (July to November) (Fig. 6), with lower catch rates found to occur during the periods with the lowest SST values (December to June). The correlation coefficient value between SST and the catch rate time series was 0.61 for the original raw data, 0.67 for the smoothed series data, and 0.78 for the data with 1 month delay (Fig. 7).

In the cluster analysis four groups were identified. One group was represented by the years 1993, 1994, 1999 and 2000. The sec-