VARIATION IN FAT CONTENT OF NORTHERN ANCHOVY (*ENGRAULIS MORDAX*) IN RELATION TO THE BAJA CALIFORNIA ENVIRONMENT

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ABSTRACT

Anchovy landings from Baja California were sampled from 1981 through 1988. Data on fat content are compared with annual series of sea-surface temperature, an upwelling index, and biomass and capture data. In the eight-year period an increasing trend in the fat content was observed, along with a minimum in 1983, possibly associated with El Niño. There is a seasonal pattern in fat content, with maximum values during summer months and minimum values in winter.

INTRODUCTION

Along the western coast of Baja California, a group of fishes known as small pelagics is commercially exploited. This group consists of two species of clupeids: the northern anchovy (*Engraulis mordax* Girard) and the Pacific sardine (*Sardinops sagax* Jenyns); one carangid: the jack mackerel (*Trachurus symmetricus* Ayres); and two scombrids: the Pacific mackerel (*Scomber japonicus* Houttuyn) and the Pacific bonito (*Sarda chiliensis* Cuvier). These species are captured near the coast (generally as far out as twenty nautical miles) by purse seine boats. Historically, the northern anchovy has been the most exploited species in Baja California. Pedrín-Osuna et al. (1992), García-Franco et al. (1995), and Vidal-Talamantes (1995) have described various aspects of the fishery, including exploitation rates, catch by species and by zones, virtual population analysis, fishing effort, and catch composition.

The mechanisms explaining how climate affects the populations of small pelagic fishes are based on the cyclic processes of warming and cooling of the seawater masses, which cause important changes in the distribution, abundance, and availability of these marine resources (Lluch-Belda et al. 1989).

The drastic changes experienced by these small pelagic fishes during the present century, such as the alternating dominance of the anchovy and sardine, undoubtedly have been caused by climate as well as fishing. Even so, there is no consensus on the impact or the influence of each of these two components (García-Franco et al. 1995).

Metabolic processes regulate the intake and outflow of materials and energy. Organisms use part of the energy obtained by feeding for basic functioning; another part is stored in the body in the form of fat and other compounds. The fat content of fish is an indicator of their degree of success in locating, ingesting, and assimilating food. The biochemical composition of fishes can vary with age, sex, and season of the year.

According to Cowey and Sargent (1979), fishes use lipids as a source of energy and for maintaining the structure of cell membranes. Unlike the fat of terrestrial animals, the oils of marine animals are rich in fat-soluble vitamins and unsaturated fatty acids. The presence of great quantities of oil in marine fishes means that lipids, instead of carbohydrates, are the main energy reserve of these organisms.

The dynamics of fat content and the condition of the fishes are related to the linear growth of the individual. The fat content may be used as an indicator of the condition of the organism. During the first stages in the development of fish, before maturity, the food resources incorporated in the organism are used mainly for growth. In the following stage of the life cycle, linear growth is less important, so most of the energetic resources are used for developing the gonads and accumulating reserve material to sustain metabolism during periods without feeding, such as during migration (Nikolsky 1963).

It is possible to predict changes in abundance from the accumulation of fat in marine organisms. Fat reserves constitute an energy source that determines the reproductive behavior of the population. This fat concentration means that the intensity and duration of spawning depends, to a certain degree, on the fat reserves of the population.

The objective of this study is to explore the association between the fat content determined in the anchovy

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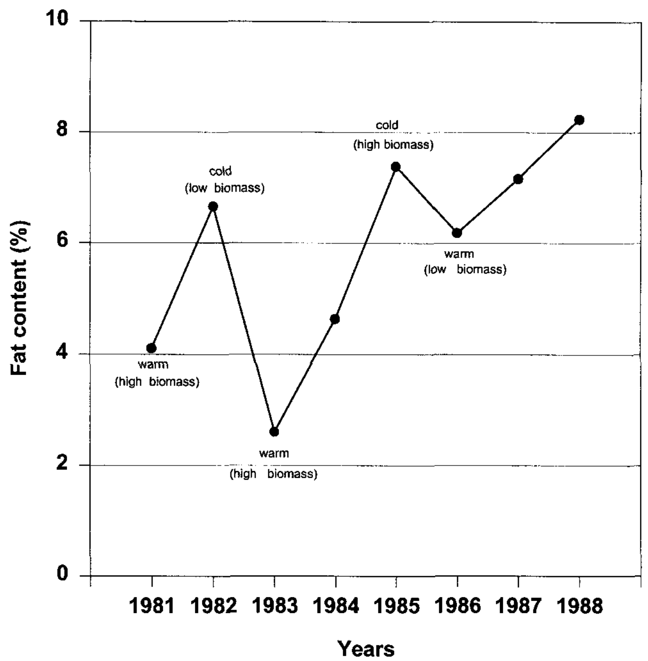

Figure 1. Annual variation of the fat content (%) of the northern anchovy in Baja California, 1981–88.

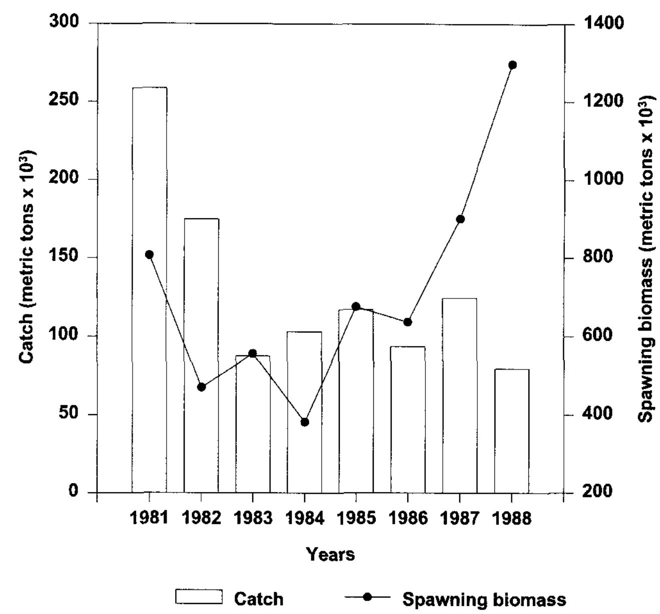

Figure 2. Annual variation of the catch (thousands of metric tons) and spawning biomass estimates (thousands of metric tons).

and other factors such as sea temperature, upwelling indexes, and anchovy biomass.

MATERIALS AND METHODS

The fat content of the anchovy was determined by extraction of the fatty compounds. We used methods 7.044 and 7.016 described in "The Official Methods of Analysis of the Association of the Official Analytical Chemist." We placed a dry sample in a cellulose cartridge by means of the Soxhlet extraction apparatus, which comprises a matrix, a refrigerant in reflux, a collector, and an electric heater. We added 100 ml of petroleum ether to the matrix to dissolve the fatty substances of the sample inside the cartridge and then heated it for 4 to 8 hours to evaporate the ether (Sidney 1984).

Subsequently, the matrix was disconnected from the equipment, and the ether was completely evaporated. We then heated the sample at 100°C until it attained a constant weight. We calculated the average weight by sample and related it to the daily catch. Finally, we calculated the monthly and annual averages.

The total sample consisted of 2,400 kg of adult anchovy, collected from 1981 to 1988. Each year we took random samples directly from holds of the commercial fleet—one kg daily from April to November (these were the months in which samples were in adequate condition on a regular basis).

Temperature data and upwelling indexes were obtained from the Northwest Biological Research Center (Centro de Investigaciones Biológicas del Noroeste S.C. CIBNOR) in La Paz, Baja California Sur.

We based our biomass evaluations on the stock synthesis model (Methot 1989; Jacobson and Lo 1990), which estimates the spawning biomass. This model is age-structured and parameterized so that the predicted values (relative abundance indexes and age composition of the catches) agree with the available data.

RESULTS

Interannual Variation

Figure 1 presents the annual variation of the fat content in wet weight of the anchovies captured in Baja California from 1981 to 1988. The general trend of the series is increasing. The maximum value was obtained in 1988 (8.24%), the minimum in 1983 (2.61%). Values greater than 5% were observed in 1982 and from 1985 to 1988.

The series of annual catch of anchovy in Baja California (fig. 2) shows a maximum value (258,000 t) in 1981 and notable drops in 1982 and 1983. From 1983 to 1988 the catch showed minor fluctuations around the 100,000 t value. The minimum catch (79,000 t) was made in 1988.

The series of spawning biomass for the anchovy in the California Current from 1981 to 1988 shows a downward trend from 1981 to 1984, but a rise from 1985 to 1988 (fig. 2). During 1981–86, relatively low values (less than 900,000 t) were estimated. In 1987 and 1988 the biomass rose to a maximum of 1,297,000 metric tons.

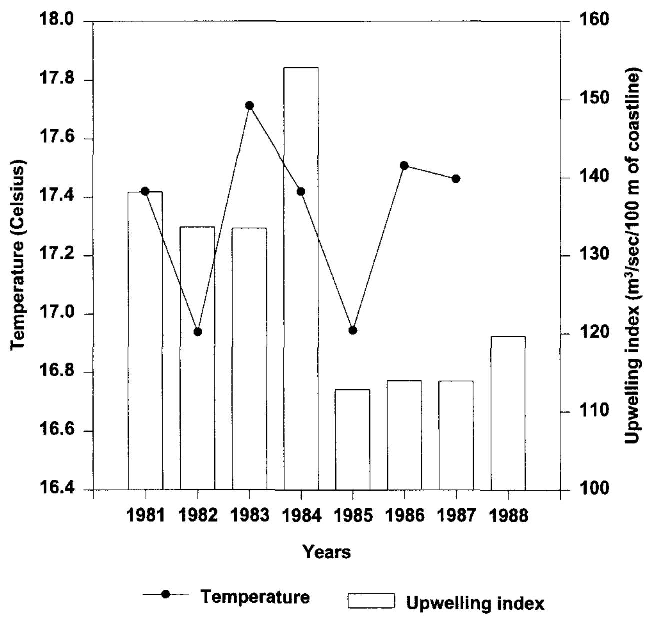

Figure 3. Annual variation of the sea-surface temperature and upwelling indexes (m^3/sec./100 m of coastline) along Baja California.

The sea-surface temperature off the west coast of Baja California (fig. 3) had an annual average value of 17.3°C. The maximum temperature in the series (17.7°C) occurred in 1983. In 1984 the temperature returned to a normal level (near 17.5°C), as it did in 1981, 1986, and 1987. The minimum values were obtained in 1982 (16.94°C) and 1985 (16.95°C).

The annual index of upwelling off Baja California (fig. 3) presented values near 135 m^3/sec./100 m of coastline during 1981–83. In 1984 it rose to a maximum of 154 m^3/sec./100 m; decreased the next year, and from 1985 to 1988 maintained a level between 110 and 120 m^3/sec./100 m.

Monthly Variation

The monthly values of fat content (fig. 4) displayed a bell-shaped pattern repeated annually, with maximums in the months from June to September. In 1981 and 1982 the maximum was observed in September. In 1983 the maximum occurred in August, although fat percentage did not increase from September to November, as it had in the two preceding years. Fat content increased in 1984 and 1985, when maximum values were reached in September and July. Relatively high values were observed from June to October during 1985–88. The maximum value for the complete series was reached in July 1988 (13.6%).

There was a regular and well-defined seasonal pattern in the monthly temperature series (fig. 4). As expected, high values were observed in summer and low values in winter. The highest values occurred in 1983 and 1984.

TABLE 1
Monthly Averages of Fat Content (%) in the Northern Anchovy, 1981–1988

Months	Average	SD	Max.	Min.	CV
April	2.26	0.86	4.20	1.40	0.38
May	3.34	1.56	5.90	1.60	0.46
June	6.63	2.94	11.00	2.50	0.44
July	8.09	3.41	13.60	3.00	0.42
August	7.81	2.19	10.60	4.70	0.28
September	7.60	2.41	11.00	3.00	0.32
October	6.31	2.49	9.90	2.10	0.39
November	4.85	2.27	8.60	1.90	0.47

TABLE 2
Monthly Average Values of Sea-Surface Temperature (Celsius) in Baja California, 1981–1988

Months	Average	SD	Max.	Min.	CV
January	15.75	0.64	16.43	14.85	0.04
February	15.60	0.42	16.15	15.04	0.03
March	15.50	0.51	16.20	14.43	0.03
April	15.89	0.42	16.55	15.31	0.03
May	16.16	0.21	16.47	15.81	0.01
June	16.93	0.57	17.71	15.95	0.03
July	18.27	0.52	18.80	17.06	0.03
August	19.43	0.73	20.77	18.23	0.04
September	20.09	0.68	21.28	19.44	0.03
October	19.34	0.61	20.39	18.56	0.03
November	18.08	0.48	18.80	17.39	0.03
December	16.81	0.49	17.36	16.06	0.03

Table 1 shows the monthly series of the average fat content from 1981 to 1988. Standard deviation, maximum and minimum values, and coefficients of variation are included for each month. Table 2 shows the monthly average temperature (1981–88) and the corresponding standard deviation.

DISCUSSION

The clupeid fish are seasonal feeders, storing great fat reserves for maintenance when food is scarce. Food consumption is the main factor determining fat reserves. The spring and autumn plankton peaks provide food, and their utilization by fish depend to a large extent on the condition of the gonads. Fish with well-developed gonads feed only lightly (Blaxter and Holliday 1963). These fishes have more fat in their tissues after the vernal plankton pulses than after spawning, the time of their leanest condition (Lagler et al. 1977). Lovern (1951) demonstrated that the fats stored in the herring are almost identical with those of their copepod prey.

The annual series of fat content for the anchovy during 1981–88 (fig.1) shows an ascending trend, similar to that of the biomass series (fig. 2). By contrast, the catch series trends downward.

Vidal-Talamantes (1995) and Pedrín-Osuna et al. (1992) have shown that anchovies caught by the com-

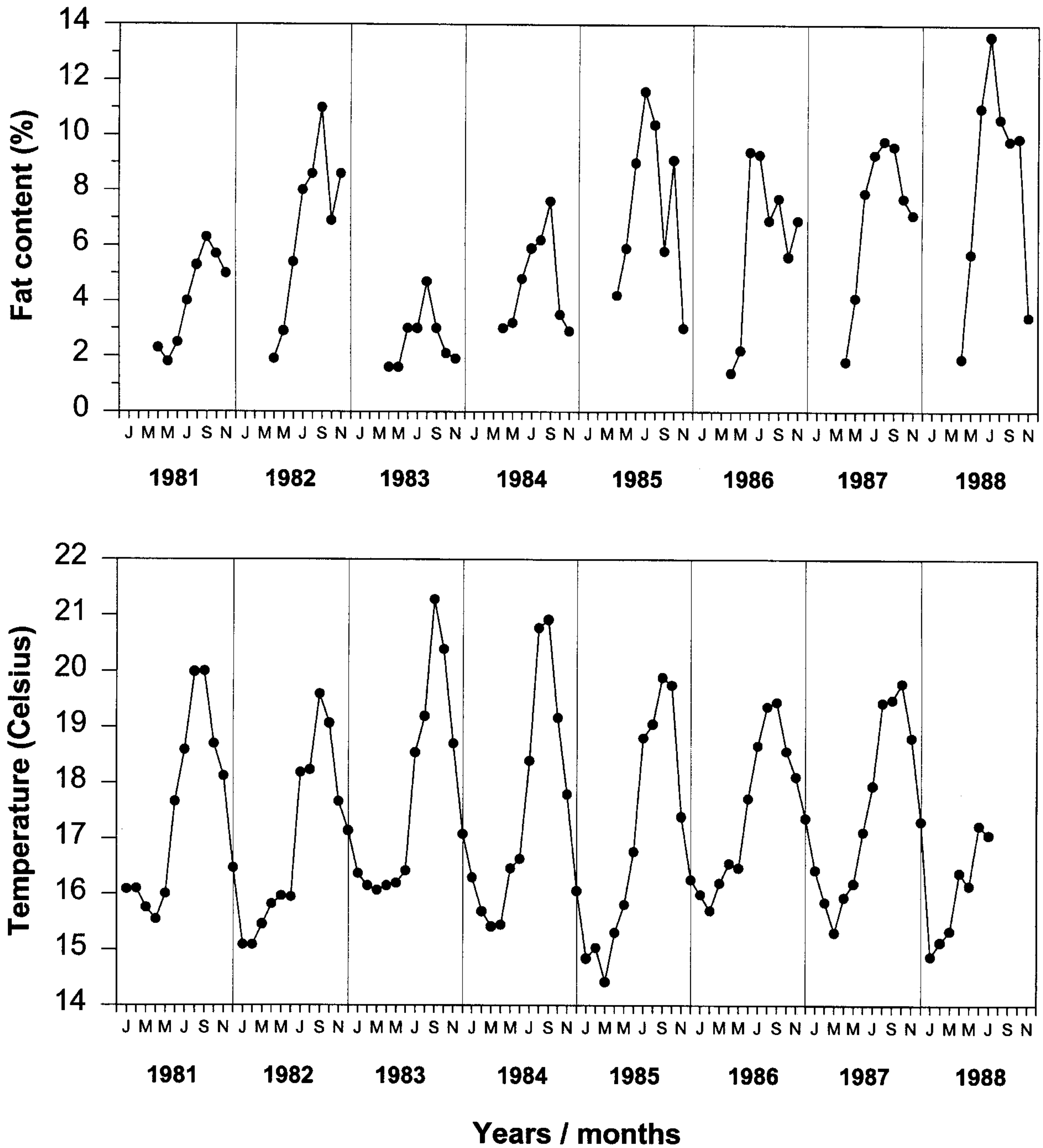

Figure 4. Monthly variations of fat percentage in the northern anchovy, and the sea-surface temperature.

mercial fleet during 1981 were mainly small-sized recruits of ages 0 and 1. The low fat content (4.2%) during 1981 (fig. 1) can be related to the small size of the individuals. The increased fat content in 1982 coincides with increased individual size (Vidal-Talamantes 1995).

There is a strong dependence between fat content and sea-surface temperature (figs. 1, 4, and 5): the warm months correspond to high fat content, cold months to low fat content. However, the yearly pattern is the opposite. The high temperatures in 1983 and 1984 (figs. 3 and 4) correspond with the 1982–84 El Niño, whose effects on the sea-surface temperature were evident in the region in 1983 (Fiedler et al. 1986). Thus the low values of fat content for 1983 may be related to the effects of El Niño. According to Vidal-Talamantes (1995), very small individuals were captured in 1983 and 1984.

The relation between biomass and temperature is not as consistent as that between fat content and sea-surface temperature. The maximum value of fat content (8.24%) was obtained in 1988, and this value coincides

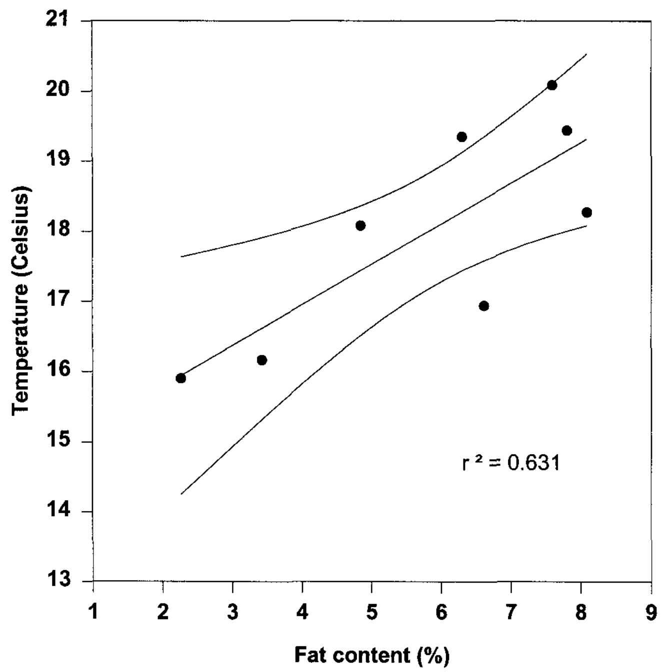

Figure 5. Relation between fat content (%) and sea-surface temperature. The points are averages for each of the eight months analyzed (April to November) for the 1981–88 period.

with the maximum biomass, the minimum catch, and a high percentage of recruits in the catch (Pedrín-Osuna et al. 1992). Perhaps the recruits did not have to compete with older individuals and thus were able to consume a greater quantity of food, accumulating more fat in their bodies. A high survival rate of the new annual class could increase the biomass of the population.

The monthly series of fat content showed a marked seasonal pattern, with higher values in the warmer months. It must be noted that the data available on fat content correspond only to eight months each year (April to November). From December to March the fat content may have been low, similar to that observed in April. The greater percentages of fat content during the warm months of summer (fig. 4 and table 1) coincide with the stronger upwelling—greater than 100 m^3/sec./100 m of coastline. Strong upwelling, producing high quantities of food for anchovy, may contribute to the accumulation of fat reserves.

When comparing the annual series of fat percentage with the biomass series (figs. 1 and 2) we note an interesting fact: A year with a low fat index was followed by a year in which the population showed a low level of abundance, as in 1981 and 1982. When the fat content was high, the biomass in the following year was high, as in 1982 and 1983. In 1983 the fat index was low, and the next year the population decreased. From 1985 to 1988 the fat content as well as the biomass were high. As in other animals, fat content in the northern anchovy represents stored energy for reproduction and survival. When fat content is low, reproductive capacity is drastically affected, because the available energy must be used mainly for survival.

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