Review

The Peruvian upwelling ecosystem: dynamics and interactions. Proceedings of the Workshop on Models for Yield Prediction in the Peruvian Ecosystem, 24–28 August 1987, Callão.
D. Pauly, P. Muck, J. Mendo, and I. Tsukuyama (Eds.) 1989. Instituto del Mar del Perú; Deutsche Gesellschaft für Technische Zusammenarbeit and International Centre for Living Aquatic Resources Management, Manila. ISBN 971-1022-47-8. 438 pp.

Under Dr Pauly's leadership, a second volume of papers has now been published on oceanography, primary production, and zooplankton. There are seven papers. Chavez, Barber, and Sanderson estimate potential primary production from the quantity of nitrate upwelled to a distance offshore defined by the Rossby radius of deformation (25 to 30 km). An interesting point is that differences in primary production from year to year are more prominent than those due to El Niño; further, although the rate of upwelling has increased since 1972, the potential primary production has not matched this increment, so primary production is not proportional to the rate of upwelling. Mendo, Bohle-Carbonell, and Calienes also estimate potential primary production by analogous methods, depending on variable depths of upwelling and variable widths of the upwelling zone. Carrasco and Lozano examine the larger zooplankton (caught by a Hensen net with a mesh of 300 µm) and find a distinct reduction in displaced volume during the period of enhanced upwelling.

Muck, de Moreno, and Aranda relate the area of anchoveta abundance to the sea surface temperatures and find that the fish lived in areas <17°C, but that they were more densely distributed in the warmer water. Bohle-Carbonell examines ten variables in monthly time series and finds that all were non-stationary; the extraordinary point is that the physical signals appeared to be of random origin, but the anchoveta biomass carries the signals of El Niño. Perhaps the physical processes need samples more frequently than just once a month.

The second major section describes the food and feeding habits of the anchoveta. Muck, de Mendiola, and Antonietti show that the larval sardines and anchoveta feed first on phytoplankton and then at about 4 mm in length they switch to zooplankton as the larvae of many species do. Pauly, Jarre, Sambilay, de Mendiola, and Alamo convert the food consumption to daily ration. They show that occurrences of phytoplankton and zooplankton species in the guts were about the same, but of course that the zooplankton predominated considerably in weight. Tsukuyama links the fat content of the fish to the condition factor.

In the third section reproduction of the anchoveta is examined. Pena, Mendo, and Pellon show that the mean stage of maturation increased from stage III to stage IV between 1963 and 1987. Senocar, Schnack, and Pauly find that the egg production between August and October was sharply reduced after the El Niño of 1971–1972; were spring spawners (as opposed to summer spawners) reduced by the El Niño of 1971–1972. Pauly and Soriano describe the production and mortality of anchoveta eggs off Peru. They estimate the death rate of the eggs from the ratio of numbers at their mean age to the population fecundity. This material was used as evidence of egg cannibalism by the anchoveta. The survival index per unit parent stock is inversely related to parent stock, which implies that the eggs are being treated as recruitment. As part of a multiple regression, egg mortality is positively related to the parent stock in the form of a power function. The factors of the regression included the sardine stock, the Sea Surface Temperature (SST) anomaly, SST itself, and the square of the SST (strictly speaking, such factors should be independent). For August–September 1987, egg mortality was about 88% d^{-1}. Can this mortality occur in one day? I wrote to Dr Pauly asking this question and he referred me to Smith *et al.* (1990), who confirm the observations by independent methods.

Section four includes other studies. Morales-Nin describes the use of otoliths for aging the anchoveta and she compares the growth parameters obtained with those found from length–frequency analyses. These were probably more reliable. Pauly and Palomares give new estimates of the biomass and recruitment of the anchoveta. Estimates of mortality by birds, mackerel, bonito, hake, and mammals are incorporated in the length–frequency sequential analysis. The new estimates differ considerably from those published earlier, because new estimates of natural mortality are incorporated. F = M, but both are high since Z ranges from 2.5 to 5.0. From the inverse relation between catchability and biomass, Čsirke creates a complex dependence of biomass on fishing effort.

Mathisen draws imaginative comparisons between the Norwegian herring, the Pacific salmon, and the anchoveta population. It is well known that there are many spawning groups in populations of the Pacific salmon. Mathisen suggests that the shift in time of

spawning during the recent decline of the Norwegian herring was in fact a shift from local population to local population. He further suggests that spawning groups of the anchoveta may depend on the fixed upwellings that occur at certain capes. He asks whether some groups have been effectively fished out. Bakun suggests that density dependent growth may arise from differences in the way in which schools maintain themselves under predation.

There are three papers on the hake. Castillo and her colleagues find that the numbers of hake larvae are inversely related to the stock of anchoveta: Espino and Wosnitza-Mendo show that the biomass of hake is inversely related to that of the anchoveta. Muck develops a good model of the exploitation of the anchoveta by the hake. Parrish reviews the systematics of *Trachurus*. Majluf describes the survival of furseal pups from the results of tagging experiments; Majluf and Reyes list the mammals off Peru and describe the history of exploitation.

Mendelssohn analyses the new estimates of recruitment with methods of time series analysis. Spectral analyses are given for oceanic and local transport, for the index of the Southern Oscillation and turbulence off Trujillo. He shows a very rough periodicity of about five years in the survival indices of the anchoveta. Muck sketches the outline of a multispecies and multi-environmental model embracing the many factors that might affect the anchoveta stock. Indeed the SST affects the

stock in area, in vulnerability, and in the availability of food. The report of the workshop gives a sketch of the proposed model and the steps needed to implement them.

In Europe and North America, results of population studies are presented as working group reports based on sequential analyses. In contrast to Dr Pauly's group, they do not present the complete time series although they are of course available on request. In common with the Peruvian group, estimates of biomass and recruitment have changed. I know quite well why this is so, but it would be desirable that new and old time series are set down with the reasons for change. In this respect, Dr Pauly's group has nearly reached the promised land, but in the foggy north there is a long way to go.

This second volume of Peruvian studies under the leadership of Dr Pauly is a worthy successor to the earlier volume.

Reference
Smith, P. E., Santander, H., and Alheit, J. 1990. Comparison of the mortality rates of Pacific sardine, *Sardinops sagax* and Peruvian anchovy, *Engraulis ringens*, eggs off Peru. Fish. Bull. U.S. 87: 497–508.

D. H. Cushing
198 Yarmouth Road
Lowestoft
Suffolk, NR32 4AB
England