10. PECULIARITIES OF THE CATCH DYNAMICS OF PERUVIAN AND JAPANESE ANCHOVY AND SARDINE

10.1 ANCHOVETA

Total biomass and commercial catch of Peruvian anchoveta during its maximum production (outbursts) may reach 20 and 13 million tons, respectively. Stock fluctuations of Peruvian anchoveta are not as closely correlated with the dynamics of "meridional" atmospheric circulation as other "meridional-dependent" fish species (Atlantic and Pacific herring, and Atlantic cod). In addition, the population of Peruvian anchoveta undergoes catastrophic declines because of the strong El Niño events (Mysak 1986). These events complicate forecasting of Peruvian anchoveta and requires special discussion.

Figure 10.1 presents the dynamics of Peruvian anchoveta catches and biomass (Pauly *et al.*1987). The anchoveta biomass estimated using a Virtual Population Analysis (VPA) model is very close to the corresponding estimates from the independent sources (i.e., acoustic surveys, c.f. Johannesson and Vilchez 1980). However, the dynamics of Peruvian anchoveta catches and biomass are rather different.

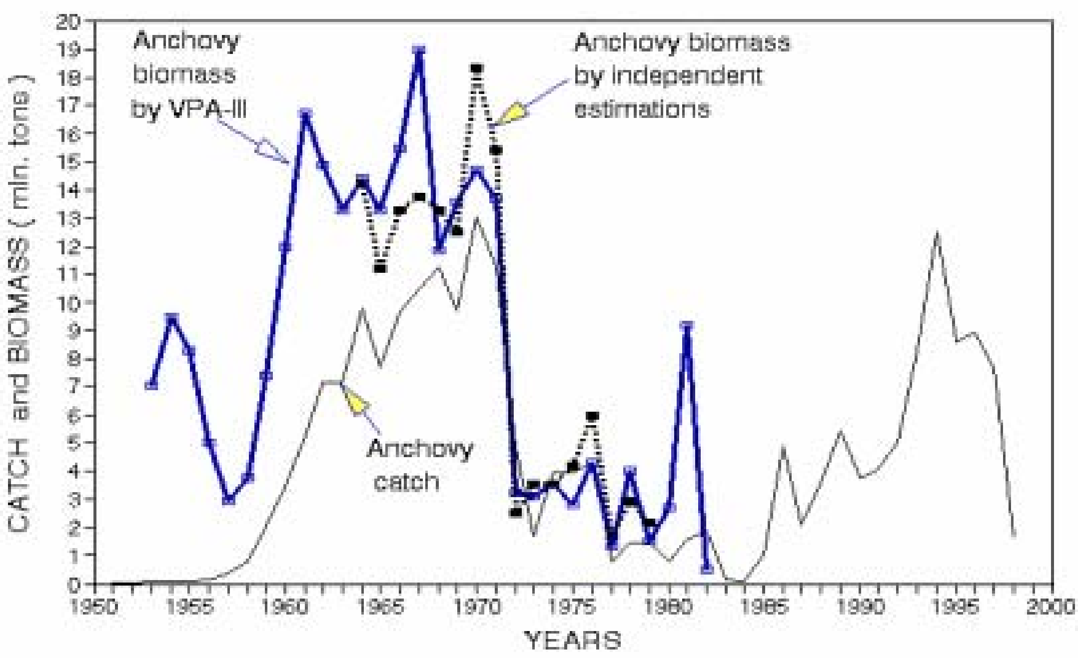

Figure 10.1 A comparison of Peruvian anchoveta catches and biomass obtained through the VPA model and independent estimates.

The effect of strong El Niño events on both the anchoveta biomass and catch dynamics is shown in Figure 10.2.

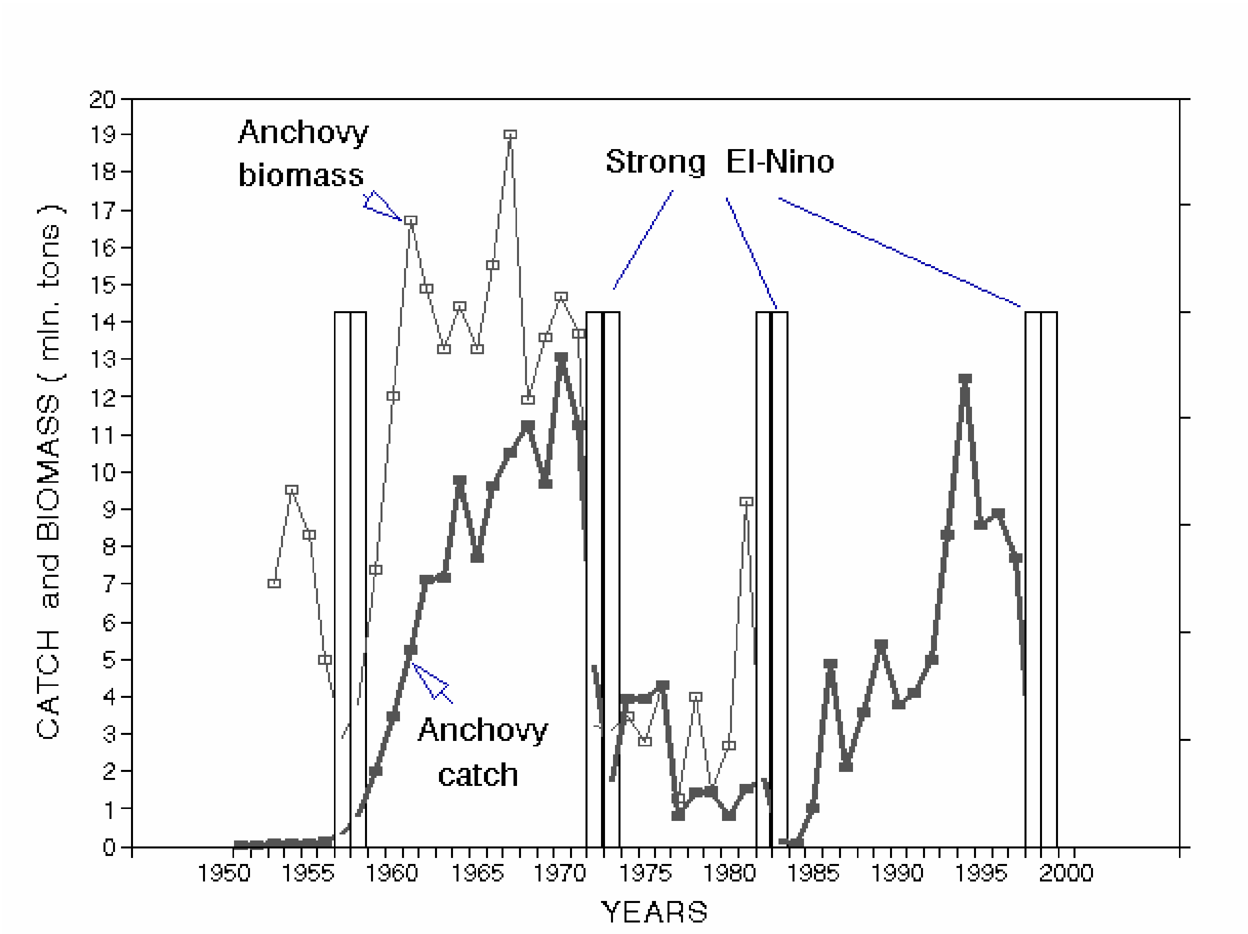

Figure 10.2 Dynamics of Peruvian anchoveta biomass, commercial catch and strong El Niño events for 1950-1998.

The strong El Niño event of 1957-58 severely reduced the anchoveta population. The anchoveta biomass dropped sharply after 1971 (the year preceding the strong El Niño of 1972-1973) by 80%. The strongest El Niño event in the century occurred in 1982-1983, causing a catastrophic collapse in the anchoveta population. Anchoveta catches dropped to the century's lowest level of 0.1 million tons. Another of the century's strongest El Niño events, that of 1997-98, also caused a sharp decrease in the anchoveta catches (to 1.7 million tons). However, preliminary data suggest that the expected anchoveta catch in 2000 to be about 7-8 million tons.

In contrast to anchoveta, Peruvian sardine did not respond much to the strongest El Niño event of 1982-83, and sardine catches reached their maximum (6.5 million tons) in 1985.

Figure 10.3 shows that the anchoveta and sardine outbursts are out of phase. The sardine outbursts are attributed to the "zonal" ACI epochs (Fig. 3.3), and Peruvian anchoveta increase considerably during the "meridional" ACI epochs.

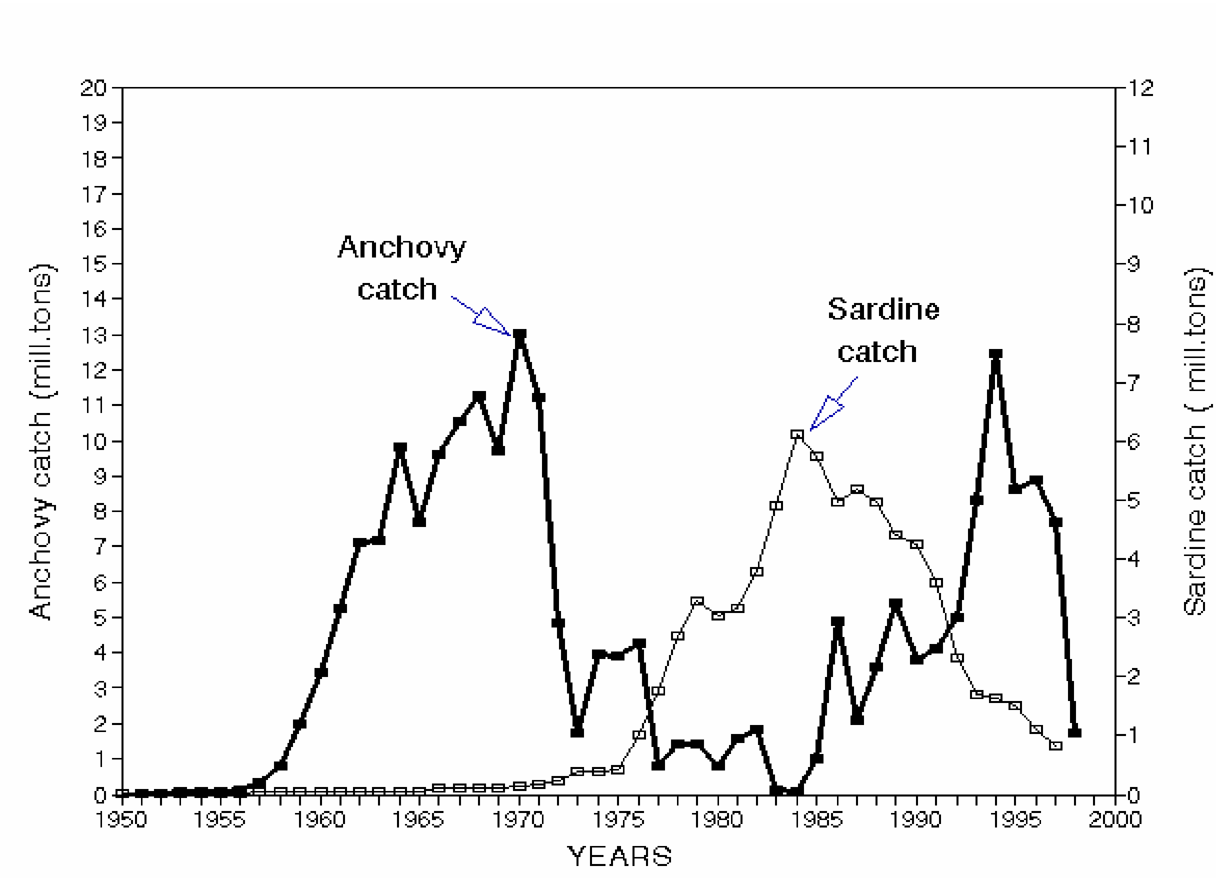

Figure 10.3 Dynamics of Peruvian anchoveta and Peruvian sardine catch 1950-1998

Strong El Niño events cause gaps in the time series of Peruvian anchoveta catch and biomass, obscuring the effect of the climate-governed dynamics of this species. That is why it is easier in the first instance to start with the dynamics of other "meridional-dependent" species (Japanese anchovy, Pacific and Atlantic herring), whose populations are not (immediately) affected by El Niño events.

Total catches of Japanese anchovy have been recorded since the early 20th century. Yet the total catch may hardly reflect the population dynamics of this species, particularly because the distribution of fishing effort has changed considerably in the recent 10-15 years, a result of the broad extension of fisheries for Japanese anchovy (Fig. 10.4a). For example, from the early 1960s, the number of fishing boats in South Korea has risen (particularly in 1980), and total catch increased six-fold (from 40 to 250 thousand tons). China's Japanese anchovy fishery started in 1990, and has expanded 25-fold (up to 1.28 million tons) in only 8 years, from 1990 to 1998. At the same time, the anchovy fisheries in Japan remained on more or less stable level. The number and tonnage of fishing boats have changed relatively insignificantly (by 10-15%) since the early 1960s (Fisheries of Japan, 1996).

Given these changing circumstances, the long-term changes in the population of Japanese anchovy are likely better reflected in the long-term statistics of net Japanese catch than in the total catch. The Japanese catch of Japanese anchovy versus Japanese sardine are presented in Figure 10.4b.

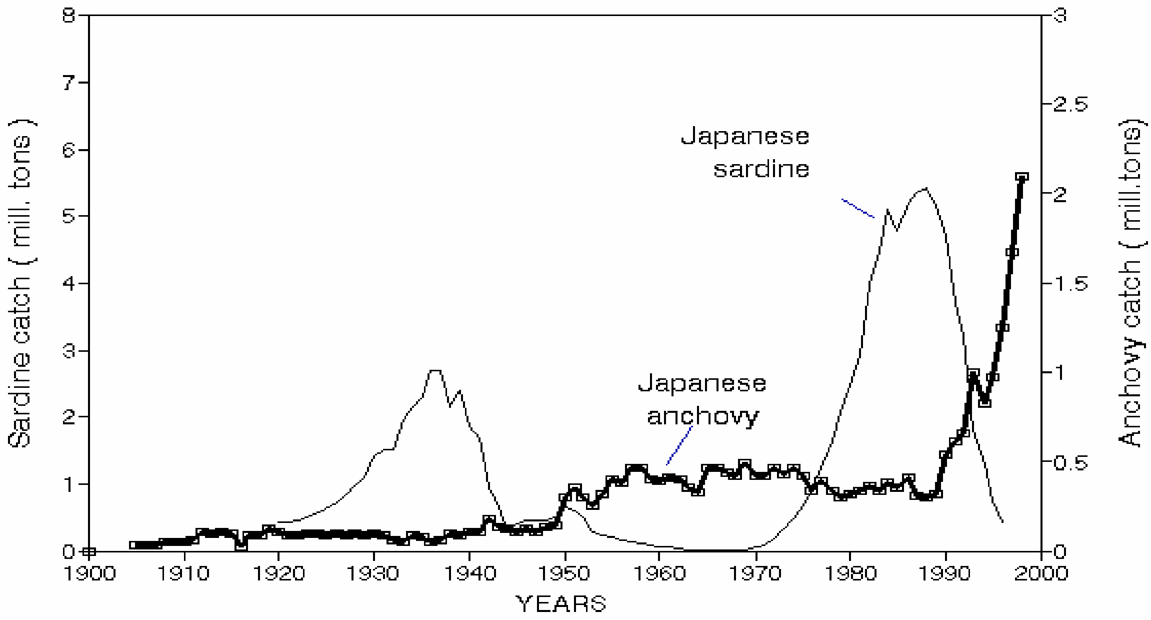

Fig.10.4a Total catch of Japanese anchovy and sardine by all countries.

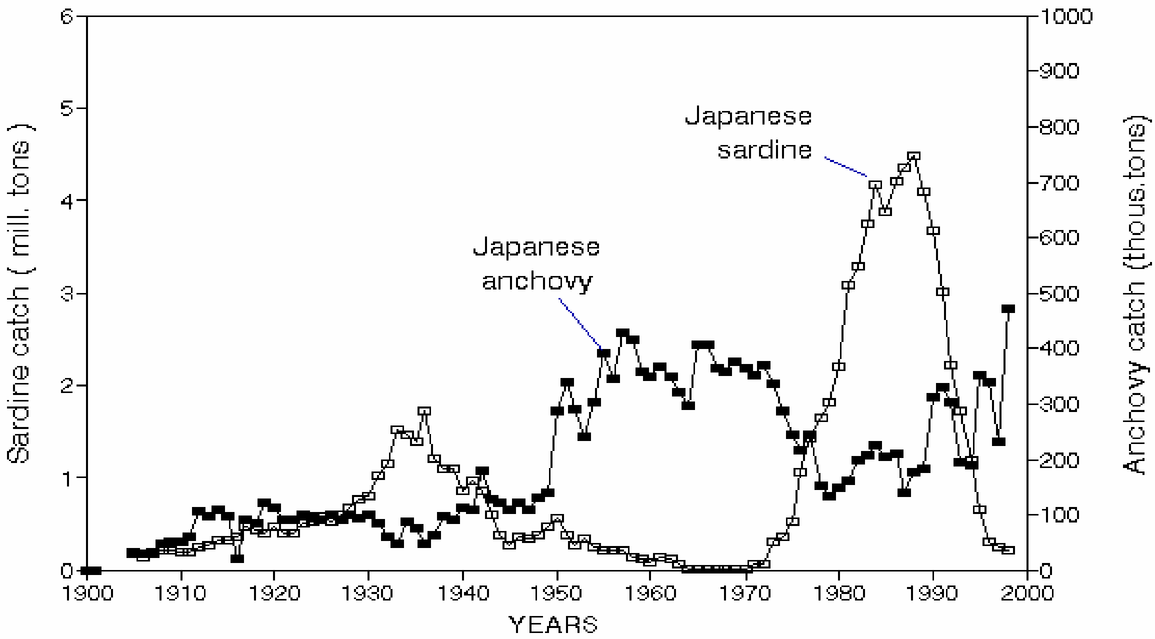

Fig.10.4b Catch trends of Japanese anchoveta by Japanese fishery fleet as compared with Japanese sardine (1905 – 1998). From 1905 to 1998, the anchovy catches were opposite in phase to Japanese sardine catches. This opposite phase relationship between sardine and anchovy catches has been most obvious since the early 1950s, when the anchovy catches in Japan exceeded 200 000 tons.

Japanese anchovy catch appears to be in phase with the dynamics of other "meridional-dependent" species. The catch series for Japanese anchovy, and Pacific and Atlantic herring suggest tentatively that the population dynamics of all these species are generally in phase (Fig. 10.5). Figure 10.6 shows that the catch dynamics of Pacific herring, and Japanese and Peruvian anchovy are in reasonably good agreement with the dynamics of "meridional" Atmospheric Circulation Index. This is supporting evidence for the dependence of these species on the dynamics of global climatic indices (See Chapter 2).

It must be mentioned that the biomass curve of Peruvian anchoveta is in somewhat better agreement with climate dynamics compared to the catch curve, since the anchoveta biomass began to rise during the early 1950s, but Peru's large-scale anchoveta fisheries started almost 10 years later (see the beginning of the this chapter).

Unfortunately the time series for commercial catch of Peruvian anchoveta are rather short. Some additional information on the long-term dynamics of this species can be obtained from scale deposition in bottom sediments at a site on the shelf off Callao (Baumgartner *et al.* (b) in prep., cited by Schwartzlose *et al.* 1999; Fig. 10.7).

We need to emphasize some important points concerning the reconstructed series:

a) The "gaps" caused by strong El Niño events are absent in the reconstruction. Despite the size of the effect, short-term fluctuations due to El Niño are likely to be smoothed in the course of fish scale accumulation in the bottom sediments.

b) It is clear that the time period between the anchoveta maxima are about 65 years, which corresponds to the fluctuation period of global climatic indices (See Chapters 1, 3, and 5-9).

c) The reconstruct series also suggests that the amplitude and periodicity of anchoveta abundance are similar to those observed recently, although they took place long before the industrial fishery began. Therefore these longer-term fluctuations depend on some unidentified natural factors only.

Similar data were obtained in the Californian upwelling where sardine and anchovy abundance series have exhibited a period of 50-70 years over the last 1700 years. As with the Peruvian data, both period and amplitude of these fluctuations are similar to the period and amplitude of the present century's directly observed fluctuations, although those occurring in the sediment record could only be the result of natural factors (Baumgartner *et al.*1992).

At the same time, the anchovy abundance maxima in the reconstructed series do not coincide with the corresponding maxima in the biomass (Fig.10.7). In the reconstructed series, the maximum falls on the 1940-1950s, while in the "measured" biomass, the maximum falls on the middle and late 1960s (i.e. the curve of actual data are ahead of the reconstructed one by 10-15 years).

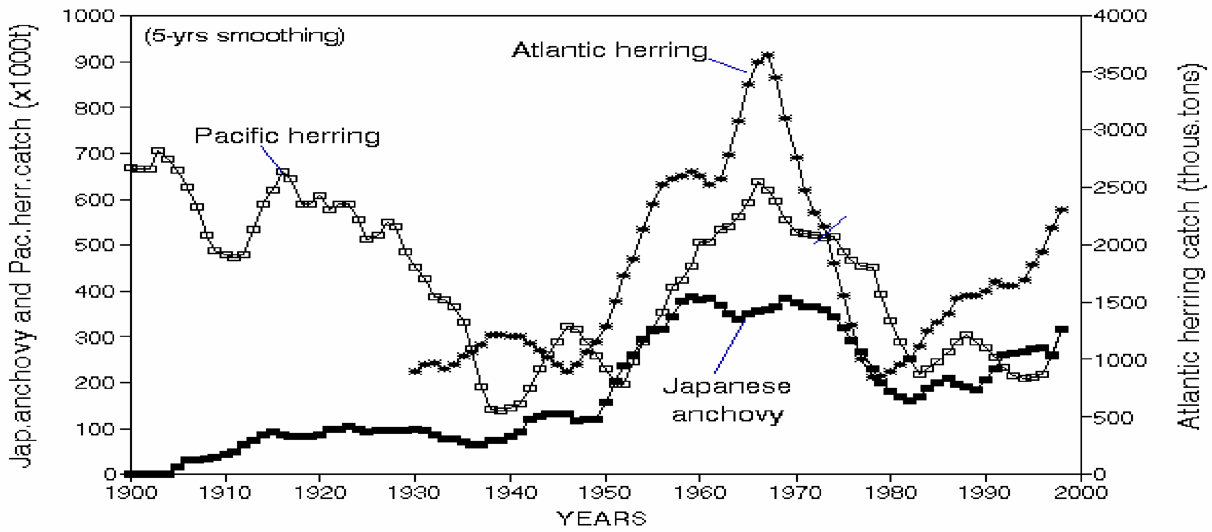

Figure 10.5. Catch dynamics of "meridional" group species: Pacific and Atlantic herring and Japanese anchovy (by only Japanese fleet).

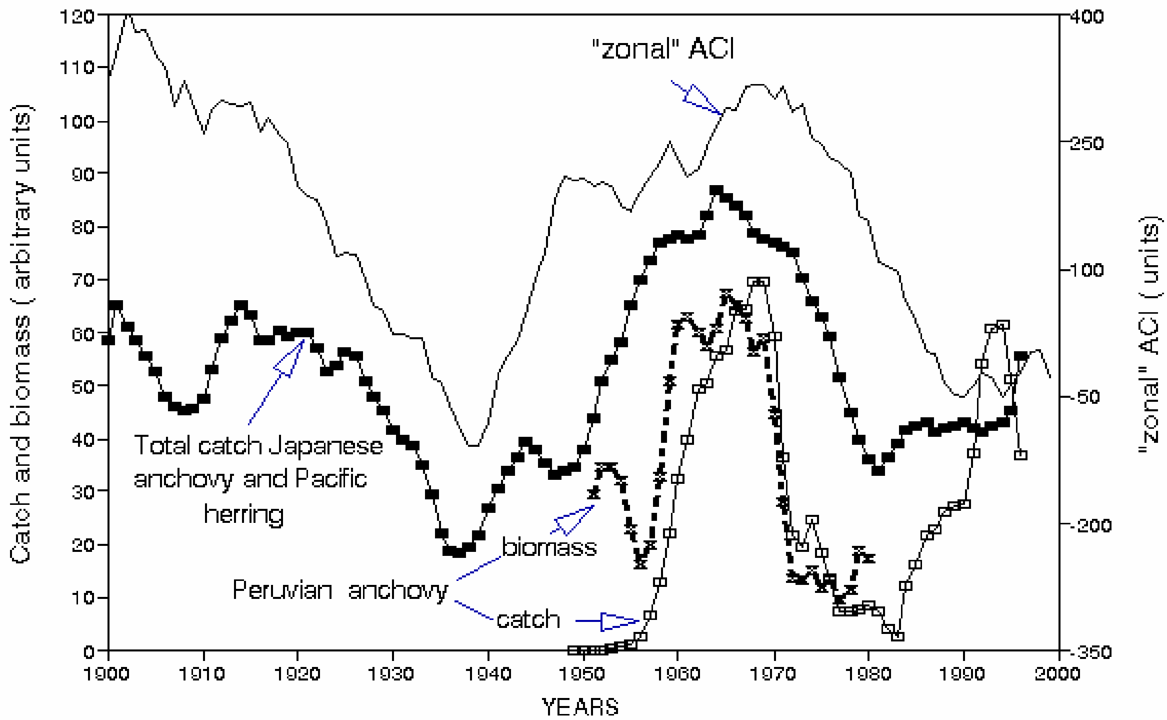

Figure10.6 Catch dynamics of "meridional" dependent species in the Pacific Ocean: Japanese anchovy, Pacific herring and Peruvian anchoveta (catch and biomass) compared with "meridional" ACI trend 1900-1998.

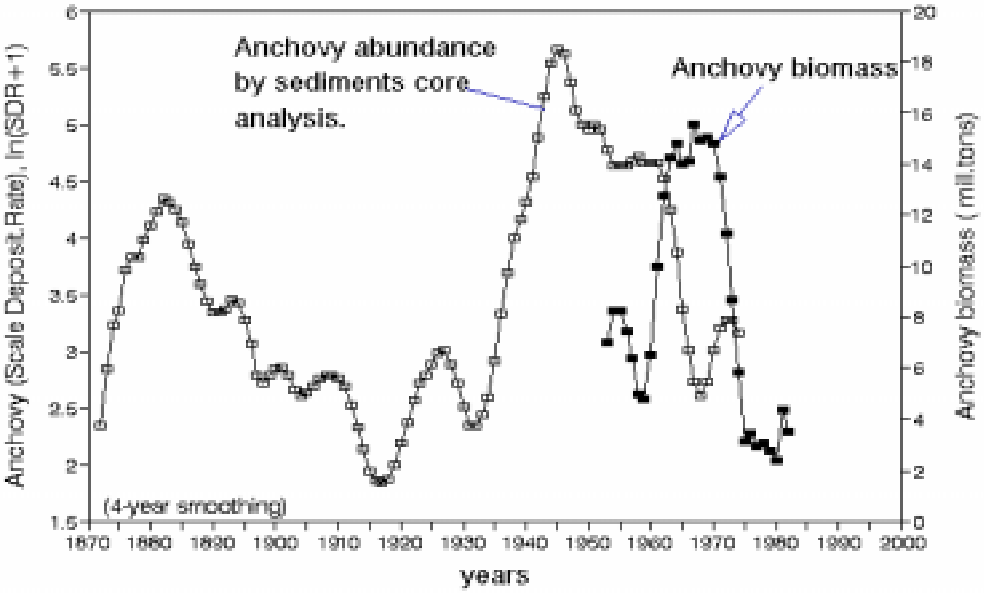

Figure 10.7 Comparison of reconstructed curve of Peruvian anchoveta obtained by scale deposition rates and anchoveta biomass obtained from VPA.

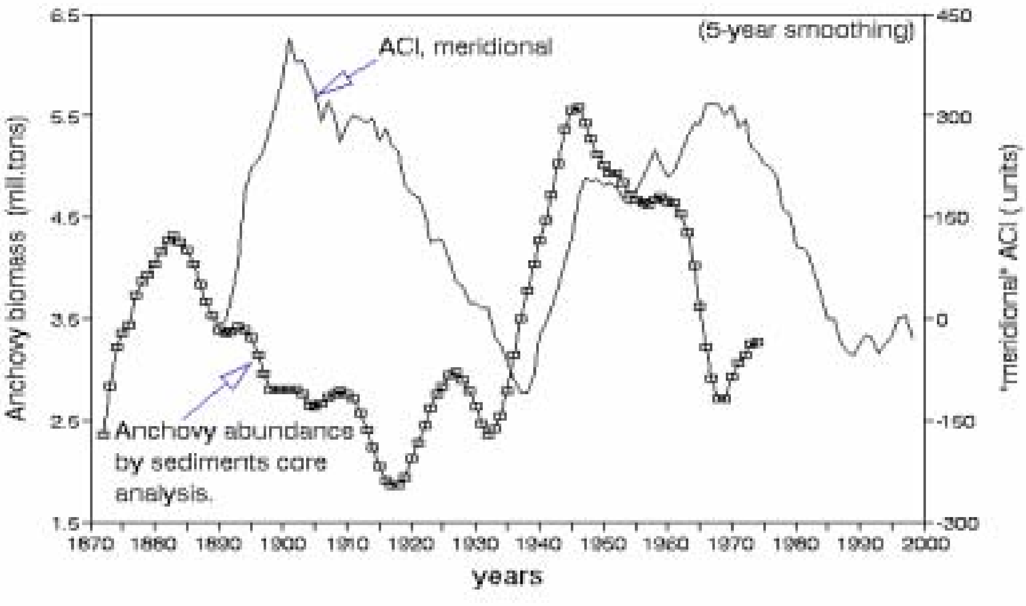

Figure 10.8 Comparison of the "meridional" ACI trend and the reconstructed Peruvian anchoveta abundance from scale deposition rate.

The same discrepancy is present between the anchovy reconstructed series and the “meridional” ACI (Fig.10.8). Both curves are similar in shape and period (about 65 years), but the ACI curve is ahead of the reconstructed population curve by 10-15 years. This inconsistency could be the result of problems with dating procedures for sediment cores.

Accurate dating of fossil structures in bottom sediments is a difficult task. Earlier attempts to reconstruct the Peruvian anchoveta population using scale deposition in bottom sediment cores (DeVries and Pearcy 1982) were not completely successful. There were considerable difficulties in constructing a continuous chronology of deposition from a 3-m long core from the upper slope off Peru (Schwartzlose *et al.*1999). Shackelton (1987), sampling along the Namibian continental shelf, also tried to reconstruct the dynamics of anchovy and sardine populations from scale deposition in bottom sediment cores. The sediments were difficult to date due to the discontinuous nature of the varved (annually layered) sediment formation. Consequently, the author was unable to provide a chronology of fish-scale deposition that could be used to reconstruct the history of the Namibian anchovy population.

The reconstructed series of the Peruvian anchoveta abundance (Baumgartner *et al.* in prep) was developed using a sediment core taken at 194 m water depth on the shelf off Callao. This core also did not exhibit continuous annual layers (varves). However, the chronology of deposition has been undisturbed by biological or physical disruption and therefore can be reconstructed using radiometric dating from the decay rates of isotopes ^{210}Pb and ^{228}Th/^{232}Th (Schwartzlose *et al.*1999). Even though minor uncertainties using these isotopic methods may result in a shift in the absolute (calendar) benchmark when analyzing the sediment core, relative dating remains accurate. Since both reconstructed and measured series of anchoveta abundance and biomass reflect the same processes, their maxima should coincide.

The recent biomass estimates from the VPA-III model (using the data from fishery statistics and independent acoustic methods), should be more reliable than abundance estimates from varved sediment cores. Given the uncertainties over dating procedures, the whole varve-based reconstructed series was shifted 15 years ahead to match up these two curves (Fig. 10.7, 10. 8 and 10.9). Figure 10.9 shows that the shifted reconstructed series and stock assessment estimates are in good agreement with the dynamics of “meridional” ACI.

Figure 10.9 superposes the global climatic indices, and catches and abundance of “meridional-dependent” fish species. It is clear that the dynamics of "meridional" ACI; Peruvian anchoveta biomass (VPA-III), abundance (shifted reconstructed series), and catch, Japanese anchovy catch; and Pacific herring catch are all temporally related.

In summary, unlike most fish species shown in Figure 10.9, the long-term dynamics of the Peruvian anchoveta biomass and catches is complicated by El Niño events. The most strongly manifested El Niño events in the 20th century occurred in the 1911-12, 1918-19, 1925-26, 1940-41, 1957-58,1972-73,1982-83 and 1997-98. The events are not regular, since the corresponding interludes have lasted from 7 to 17 years. In the 20th century, the average recurrence interval for the strongest El Niño events was 10.5 ± 2 years. This means that on average every 10 years, the population of Peruvian anchoveta undergoes catastrophic collapses.

The capability of anchoveta populations for quick recovery after strong El Niño events is astonishing. For example, the anchoveta biomass reached 12.5 million tons in only four years after the strong El Niño event of 1957-58. After the strongest El Niño event in the 20th century of 1982-1983 anchoveta catches dropped catastrophically to 0.1 million tons. However, three years later, the catches increased back to 5 million tons.

The very strong El Niño event of 1997-98 led to a severe decrease in anchoveta catches (1.7 million tons), but in 2000 the anchoveta catch is expected to be about 7-8 million tons. However, the population recovery took place much more slowly after a strong El Niño event of the 1972-73, when the catches were low for 8 years afterwards.

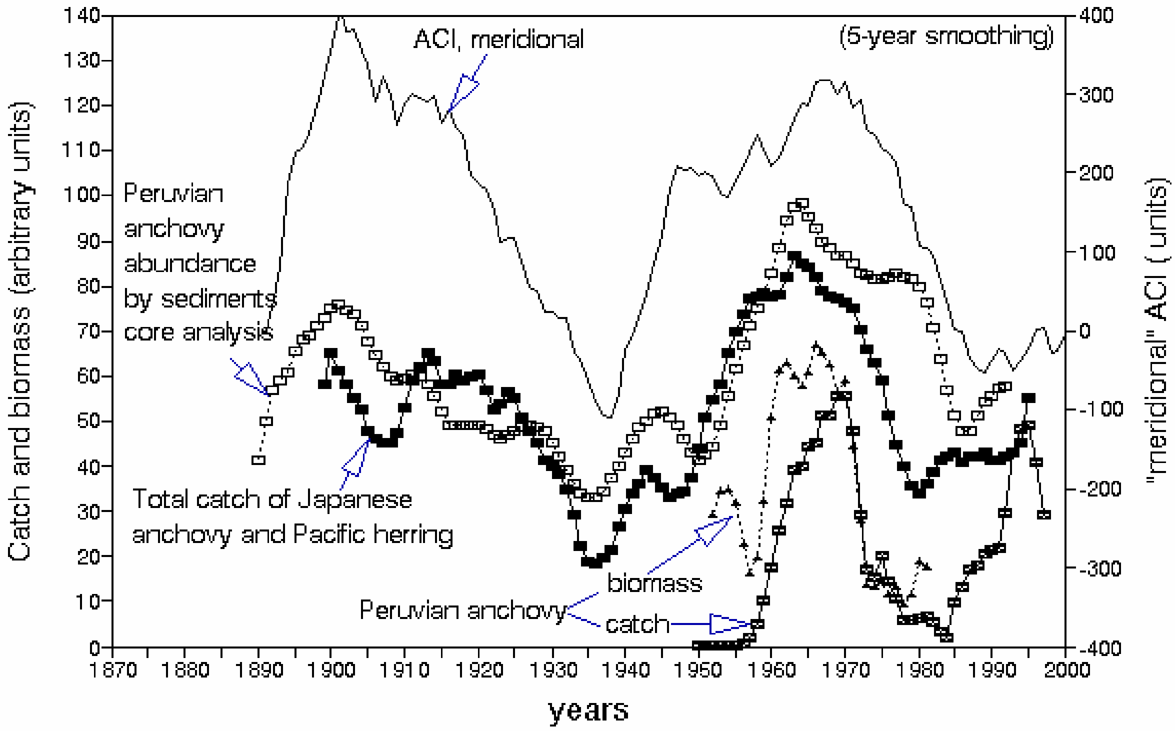

Figure 10.9 Comparison of trends: Peruvian anchoveta biomass and catch, Japanese anchovy (catch by Japanese fleet), Pacific herring, reconstructed Peruvian anchoveta abundance by scale-deposition rate (shifted 15 years to the right) and the “meridional” ACI curve.

Can we predict the long-term changes in the Peruvian anchoveta population for the future 10-20 years? According to the results discussed in Chapter 3, the present "zonal" circulation epoch comes now to its end. The next "meridional" circulation epoch is starting to dominate in the 2005-2030s. The forecasts of main trends of both “zonal” and “meridional” epochs discussed in Chapter 9 enables to us to estimate a probable future dynamics of the “meridional” ACI (Fig.10.10).

10.2 THE FORECAST

Based on the trends presented in Figures 10.9 and 10.10, it may be supposed that the abundance and catches of "meridional dependent" species (Japanese anchovy, Pacific herring, Atlantic herring and Peruvian anchoveta) will increase in line with the development of the present “meridional” epoch up to the middle 2020s, followed by a gradual decrease. However, unlike the first three species, the population of Peruvian anchoveta may be affected by strong El Niño events, which will result in “gaps” in abundance and catches and interfere with the “smooth” climate-governed dynamics of the population as portrayed below.

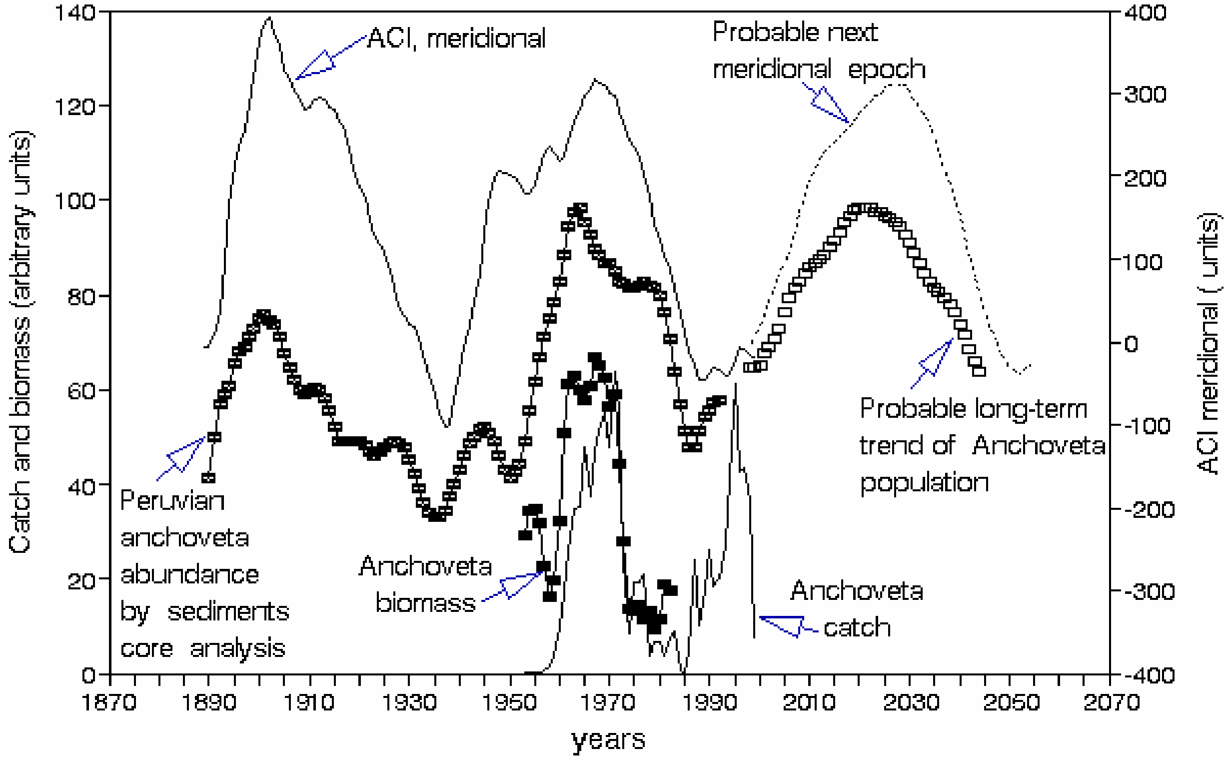

Figure 10.10 Relative trends of catch, biomass and reconstructed anchoveta abundance by scale-deposition rate as compared with "meridional" ACI trends and the probable forecasted anchoveta population. (Reconstructed anchoveta abundance curve shifted 15 years to the right; see text for details).

The model generated (Chapter 9) forecast of probable anchovy catch in the Pacific is presented in Table 10.1 and Figure 10.11.

Table 10.1. Model-generated forecast of anchovy catch (million tons) in the Pacific region for 2005–2040s.

Years	Peruvian anchovy	Japanese Anchovy	Total
2005	6. 7	2. 5	9. 2
2010	8. 6	3. 0	11. 6
2015	10. 5	3. 1	13. 6
2020	8. 5	2. 6	10. 5
2025	6. 8	2. 0	8. 8
2030	4. 6	1. 0	5. 6
2035	2. 6	0. 7	3. 3
2040	2. 4	0. 4	2. 8

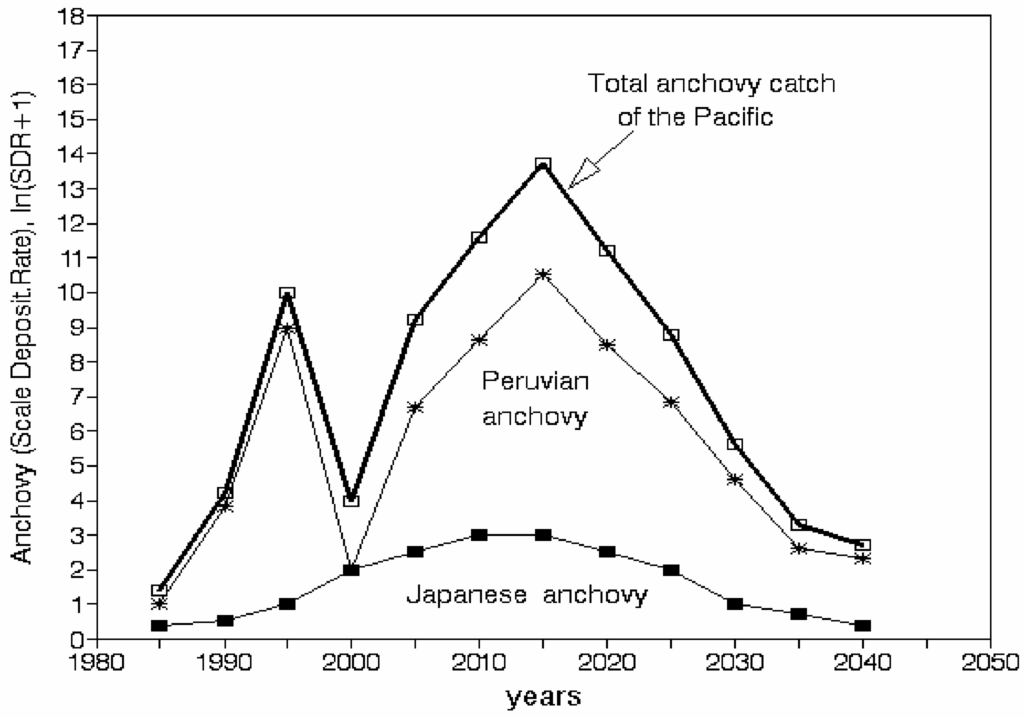

Figure 10.11 Forecasted changes of Peruvian and Japanese anchovy catches for the period of 2000-2040s

10.3 SUMMARY

Our approach makes it possible to forecast general trends of anchoveta catch for 30–40 years ahead. This is based on the following assumptions:

(1) General stock fluctuations of Peruvian and Japanese anchovies correspond to the dynamics of "meridional" ACI. This means that there should be a steady increase until the middle of 2020s.

(2) Unlike other pelagic commercial species, the climate-dependent dynamics of Peruvian anchoveta is affected by strong El Niño events, so that the future dynamics of this species are not expected to follow a smooth curve, but should be punctuated by sharp, unexpected declines in abundance;

(3) Total anchovy catch in the Pacific Ocean is dominated by Peruvian anchoveta (e.g. 70-75% during peaks), therefore the forecast of total anchovy catch presented below (Table. 10. 1 and Fig. 10.11) is only a rough approximation to the stock dynamics of this species group.