6. ANALYSING STATISTICAL TIME SERIES OF MAIN COMMERCIAL SPECIES

The catch alone is acknowledged to be a crude measure of abundance, but the changes in catches of main commercial species have been so marked, that there can be little doubt that they reflect real change in population size (Lluch-Belda *et al.* 1989). In Chapters 3, 4 and 5, it was shown that the catch dynamics of the most abundant commercial species is in close correlation with regular changes of climatic indices dT and ACI. Thus, the long-term time series of these indices may be used as a long-term index of population size of the major commercial species.

Specific features of the catch dynamics of these species may be discovered by spectral analysis of the long-time series of the catch statistics. The following series were analyzsed (data for period 1950-1998 taken from FAO 2000):

<u>Pacific Ocean</u>

- Pacific salmon (1920-1998)
- Pacific herring (1900-1998)(W. North Pacific, Large Marine Ecosystem No 46)
- Japanese sardine (1920-1998),
- Californian sardine (1920-1998)
- Peruvian sardine (1950-1998)
- Alaska pollock (1950-1998)
- Chilean jack mackerel (1969-1998)
- Peruvian anchovy (1950-1998)

<u>Atlantic Ocean</u>

- Atlantic cod (1930-1998)
- Atlantic herring (1930-1998)
- European sardine (1957-1998)
- South -African sardine (1950-1998)

The most interesting results were obtained from analyzing the longest time series: Pacific salmon, Japanese sardine, Californian sardine and Pacific herring. These and other spectra are presented in Figure 6.1 and Table 6.1.

The spectral characteristics of Pacific salmon, North-West Pacific herring, and Japanese sardine dynamics appear close to those of climatic series (all spectra exhibit maxima at 50–53 years). Spectral characteristics of the Alaska pollock and Atlantic cod time series (62 and 53 years, respectively) are close to the spectra of Pacific herring and Japanese sardine dynamics.

In contrast, the spectrum of Japanese sardine catch seems to be "abnormal" (basic periodicity is of 34 years), although this species is thought to be a good example of the climate–production dependence (Kawasaki 1992a, 1994; see Figure 3.3). Nevertheless, the sardine outbursts fall in the 1930s and 1980s, whereas the general dynamics of this species corresponds to roughly 50-year periodicity that are characteristic for climate fluctuations as well. However, statistical treatment of the corresponding time series does not reveal this regularity, but instead indicates a clear maximum at 34 years. A reason for this could be an artefact of the mathematical model. The applied mathematical method was

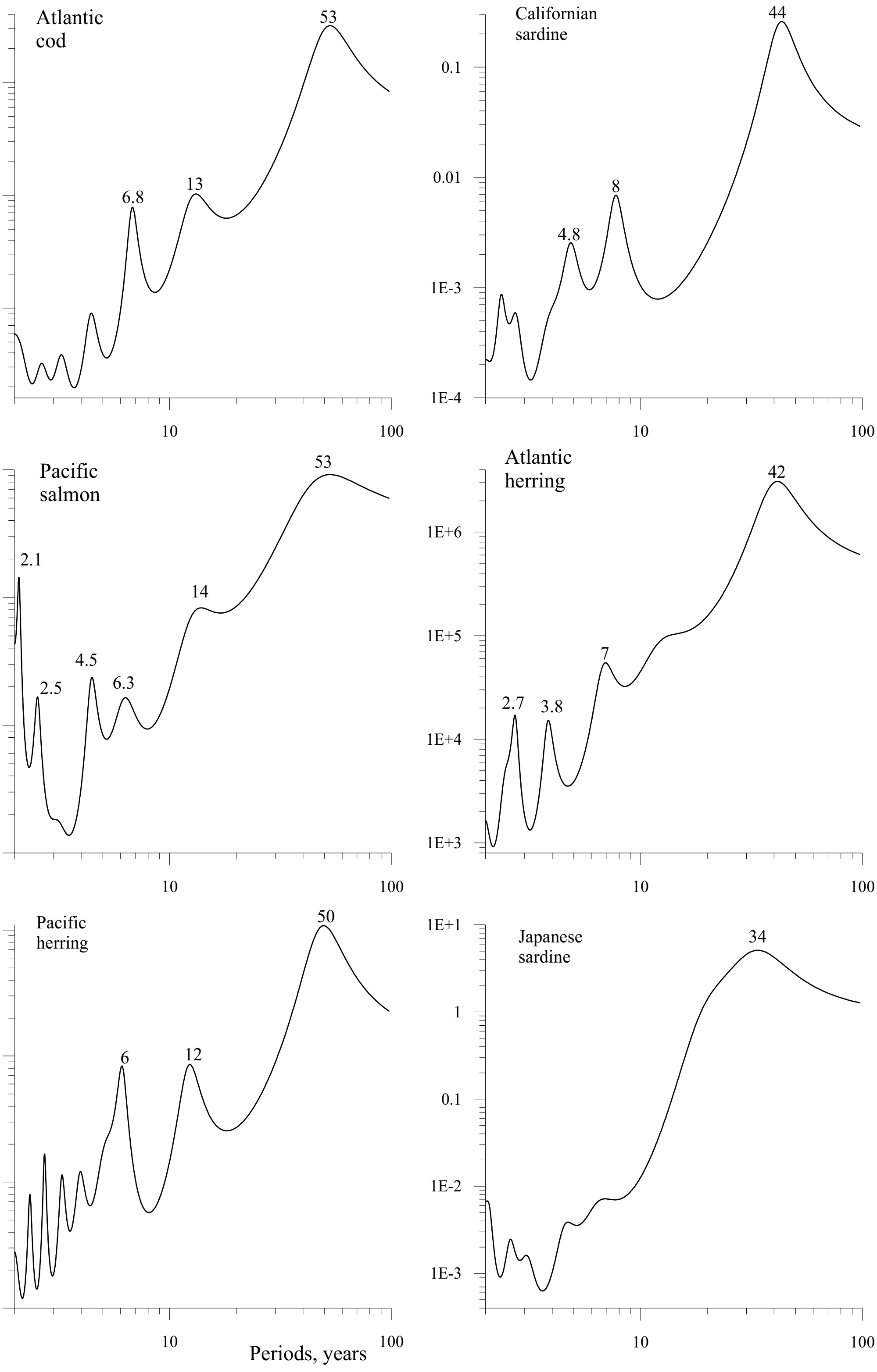

Figure 6.1 Power spectra estimates of the fish catch time series (abscissa- periods, years; ordinate-relative variance) (see text for details).

Table 6.1 Basic spectral parameters of the catch time series for the main commercial species.

Species	Main Maximum	Secondary Maxima	Comments
Pacific salmon	53	14 and 6.3	
Pacific herring	50	12 and 6	North-West Pacific
Japanese sardine	34		See comments in the text
Californian sardine	44	8 and 5	
Alaska pollock	62		
Chilean Jack	43		
Peruvian anchovy	29		See Chapter 10
Peruvian sardine	29		See comments in the text
Atlantic cod	53	13 and 7	
Atlantic herring	42	7 and 4	
European sardine	47		
S. African sardine	42		

developed to analyse sinusoidal or close to sinusoidal cyclic processes. In our case, however, the time series does not satisfy this condition, but consists of two sequential, non-sinusoidal outbursts. Strictly speaking, the considered time series is not a "continuous" process, but a sequence of two separate events with a quiescent period between. The same reason (non-sinusoidal shape of the catch dynamics) could also explain the low spectral frequency of Californian sardine (44 years).

The catch dynamics of other species: Peruvian, European and South African sardine, Atlantic herring and Chilean jack mackerel, are characterised by a single maximum, and correct estimation of their fluctuation frequency is more dependent upon the shape of their respective catch-dynamics curves, as well as their quite different life history patterns (Sharp, Csirke, and Garcia 1983).

For these very short series, we used a time series model with a single harmonic cyclic trend. This method could be called fitting an AR(2)-model with single cyclic trend with unknown period (see Chapter 8). Because of the short length of the series, it was not possible to define the period value from the power spectra estimates.

Catch dynamics depend on economic and market factors as well as stock fluctuations. If commercial fisheries always removed the same proportion of the fish production, the catch dynamics may better reflect the climate–production dependence (e.g. Pacific salmon). For example, at initial stages of an outburst, commercial fisheries seem to lag behind the fish population growth (because of information lag), whereas the corresponding shrinkage of a commercial fishery may start well before the minimum in fish stock size is reached because of decreasing profitability. This may result in "narrower" catch dynamics compared to actual stock dynamics, and underestimate the fluctuation periods derived from the spectral analysis. Such "understatement artefacts" may affect the spectra of Peruvian sardine and anchovy time series (29 years). At the same time, catch maxima of the major commercial species departs slightly from the maxima of climatic indices (for example "zonal" or "meridional" ACI epochs). These species-dependent specifics of each commercial fishery may cause the observable differences between the spectra of the climate indices and catch dynamics.

6.1 CONFORMITY OF THE CLIMATE DYNAMICS TO COMMERCIAL STOCK FLUCTUATIONS

Regular fluctuations in the stocks and catches of abundant fish species are mentioned in a number of recent publications. Beamish and Bouillon (1993), Klyashtorin and Smirnov (1995) and Klyashtorin (1997, 1998) have called attention to the approximate 60-year periodicity in the fluctuations of Pacific salmon. Reconstructed time series of sardine population for the last 1500 years (Baumgartner *et al.* 1992) also suggested around 60-year between sardine outbursts. Jonsson (1994) indicated the same periodicity in the time series of Atlantic cod catch for 300 years. In more last years, many researchers have reported on regular 50–70 year fluctuations of global climate parameters (Minobe 1997, 1999). A close correlation between the catch dynamics of the major commercial species and approximately 60-year climate fluctuations was also recently shown by Klyashtorin (1998).

Japanese chronicles contain information on the Japanese sardine outbursts for the last 400 years. Changes in availability and abundance of sardine stocks caused the development as well as collapse of various coastal fishing villages (Kawasaki 1994). Outbursts of Japanese sardine have occurred simultaneously with increasing temperature trends, up to, but not beyond the temperature dynamics maxima with the average period of about 60 years (Figure 6.2). The temperature dynamics for the period of direct measurement during the last 150 years is in good agreement with the temperature reconstructed from the Greenland ice cores.

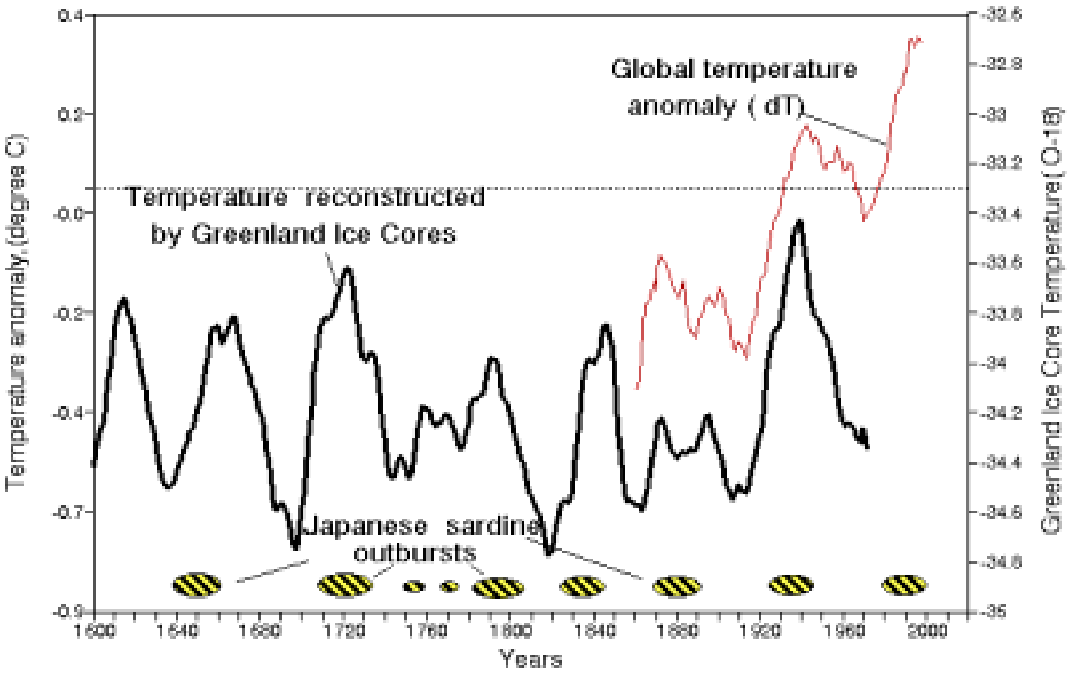

Figure 6.2 Cyclic temperature fluctuations and Japanese sardine outbursts for last 400 years by Japanese historic chronicles 1640-1880 and for 1920-1998 from fisheries statistics.