7. ESTIMATING RELIABLE TIME SCALES TO MODEL CLIMATE AND STOCK CHANGES

Considering the correlations between climate and stock fluctuations, the dynamics of global climatic indices and commercial catches of abundant fish species certainly undergo synchronous regular fluctuations. To develop a predictive model, it is necessary to identify mathematical descriptions that satisfy two basic conditions: (i) a successful model should fit the past dynamics of the indices well, and (ii) it should establish future changes in the fish stocks for up to 30–40 years ahead. An important feature of the suggested model is its ability to forecast cyclic climatic trends, and therefore the corresponding future trends in commercial fish stocks.

An important practical question to be answered before modelling fish stock dynamics on the basis of climate–population dependence is: which periods (cycle lengths) are of most predictive significance? As shown above, the spectral analysis of the dynamics of global climatic (dT, ACI) and geophysical (LOD) indices point to the spectrum maxima at 50, 55 and 64 years. The reconstructed temperature time series of the "Ice core dT" from isotopic analyses suggests an average spectral maximum at 54 years, whereas the time series of commercial fish stocks has an average spectral frequency corresponding to 46 years. There are several reasons to believe that this frequency may underestimate stock size changes (see Chapter 6). The most reliable time series of commercial catches (Pacific salmon and Pacific herring) have spectral maxima at 50 and 53 years, respectively.

The average climate period estimated from the time series is close to 55 years, and this period is used as a basis to forecast the fluctuations of major commercial fish stocks and catches. Recent estimates of global climatic indices show cycles in the range of 50 to 70 years (Schlesinger and Ramankutty 1994; Minobe 1997, 1999). Thus, the data do not permit us to determine an exact period for either climate or fish population fluctuations. It is only possible to estimate that the average period varies within the ranges of 50–56 years (average of 53 years) and 60–65 years (average of 62 years). Therefore, taking into consideration all available time series, we cannot be limited to a fixed value, and shall operate with the probable spectral range of 55 to 65 years, with a base value of 55 years.

The time series of the surface air temperature for the last 1500 years, reconstructed from the Greenland ice cores (Ice core dT), is an important data source for independent estimation of climate cycles and trends. The close similarity between both the reconstructed temperature dynamics and measured dT time series is shown in Figures 5.5, 9.2 and 9.3. Box-Jenkins time series analysis (Box and Jenkins 1970) makes it possible to model the basic harmonics of the climate changes, which have taken place in the last 1000 years. Changes in global temperature are presented in Figure 7.1 as a "topographic map". Colour intensity is directly proportional to the manifestation (recurrence) of the climatic changes in the period on the X-axis. It is easy to see that the climate periodicity of 120-140 years was most pronounced from 500s to 1300s AD. A 70–75 year period was characteristic from the 900s to 1700s, whereas a 55–56 year period dominated from around 1500 to the 1970s. Most probably, this periodicity will remain into the next century. As to oscillations of higher frequency, the 20-year and (much less clear) 30-year maxima have been the most significant over the last millennium. Recent publications on climate dynamics report regular 20-year fluctuations of global climatic indices in addition to the well-known 50–70-year periodicity (Minobe 1997, 1999).

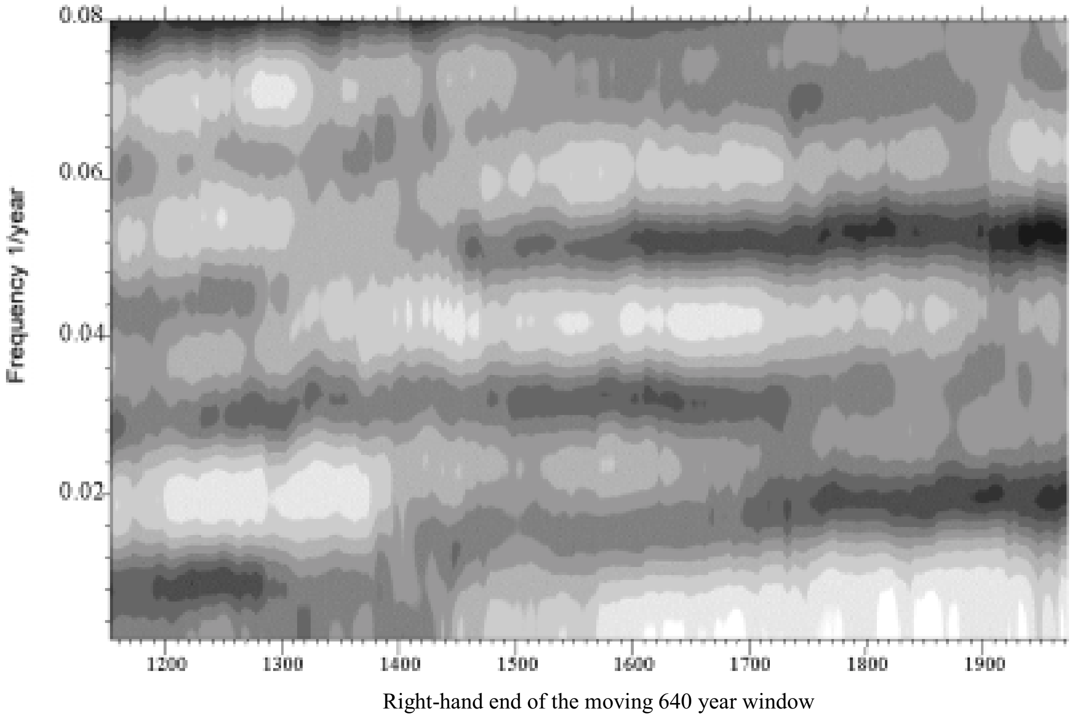

Figure 7.1 Temporal dynamics of the power spectra of the temperatures reconstructed from the Greenland ice cores (Ice Core dT) for the time period 553-1973 years AD. Shading intensity is directly proportional to the manifestation (recurrence) of the climatic changes in the period marked at the X-axis.

An advantage of Box-Jenkins models is that they enable one to trace the long-term development of the harmonics and estimate their dynamics and future trends. We analysed the data for a possible dependence of the climate indices on the variation of climate periods within the latter range. Figure 7.2 presents the generated time series of three basic harmonics of 55, 60, and 65 years. The disagreement between the three curves for the first 30 (and even 60) years is quite small in terms of our prognostic purpose and the variability of our initial data. We understand that such "forecasting" of fish stocks for 60–120 years ahead is a theoretical analysis rather than a practical or formal prognosis. However, the exercise provides a good illustration of the possibility of reliable forecasting climate changes and fish production on a smaller time scale (30-40 years).

7.1 SUMMARY

Regular climate changes have taken place over the last millennium with a period of 55–65 years. Forecasting of the major commercial fish stocks for the future 30–40 years is insensitive to the choice of periodicity within this range. Therefore, the exact period of climate changes (55, 60, or 65 years) is not critical for the purpose of catch forecasting or managing fisheries.

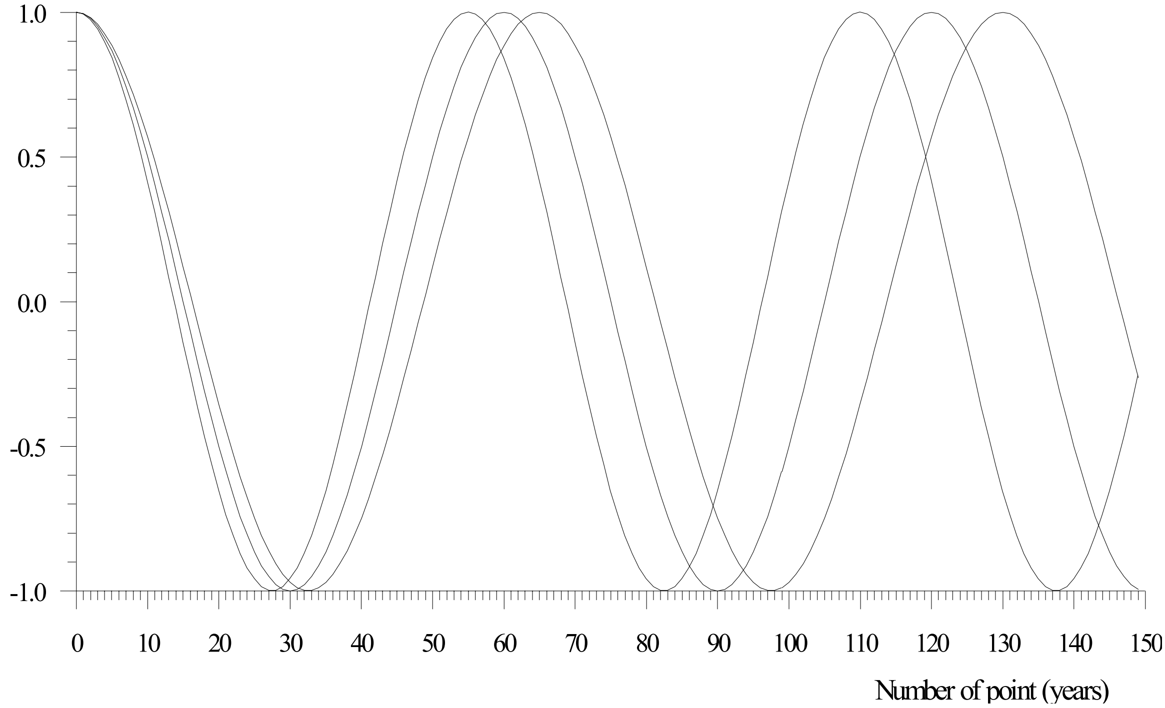

Figure 7.2 Example of the three harmonics with periods of 55, 60, and 65, with the same amplitude A=1 and the same phase angle (see the text for details)