plankton communities have been applied, and intercalibration of sampling gear has been necessary to deal with historical samples collected using different methods.

It is widely known that the catch of commercially important fish, such as sardine, salmon, herrings etc., many of them target species (see Gifford *et al.*, Chapter 4, this volume), fluctuates on a multi-decadal scale. Retrospective studies in the early years of GLOBEC detected significant correlations between regional ecosystem changes and large-scale climatic forcing indicated by the various climatic indices, for example North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), Southern Oscillation Index (SOI), etc. (see Drinkwater *et al.*, Chapter 2, this volume). The Kawasaki diagrams (Kawasaki 1991) exhibited global synchrony at a multi-decadal scale of variations in the abundance of common fish species, providing evidence of the influence of large-scale climatic forcing on regional ecosystems. Analysis of fish scales in anoxic sediments has revealed the fluctuation of fish abundance over the past 2 millennia far before commercial exploitation started (see Box 6.5 for the details). All these facts demonstrate obvious climate-ecosystem links, but what mechanisms lie behind these links?

Box 6.5 Fish debris indicate many modes of variability

As GLOBEC-related studies have the overall objective of understanding the mechanisms of physical and biological change, it is worthwhile to review palaeo studies when considering recent observations of ecosystem change. Fishery catches in the twentieth century suggest several paradigms of ecosystem variability. There are alternations in the catch of sardines and anchovies in various regions of the world as well as opposing variations in abundance between salmon catch in the Gulf of Alaska and salmon and pelagic fish in the California Current and these fluctuations appear to have a 50–60-year periodicity (Lluch-Belda *et al.* 1989; Kawasaki 1991; Mantua *et al.* 1997; Chavez *et al.* 2003). However, the palaeo-archives from sedimentary records, such as fish scales, nitrogen isotope signatures in Alaskan lakes, and other palaeoclimate proxies, indicate that the modes of variability observed in the twentieth century only exemplify a small portion of the total range of past variability. Seasonal variations in sediment flux to hypoxic sediments results in the presence of laminae or annual varves in the bottom sediments. The lack of oxygen both inhibits benthic organisms from disturbing the sediment layers as well as preserves the remains of fish scales, which sink to the seafloor.

Box 6.5, Figure 1 Fish scales typical of an upwelling community, mostly sardines and anchovies from sediment core off Namibia (diameter of fish scales around 5–10 mm). (From Struck *et al.* 2002.)

continues