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Woldwide large-scale fluctuations of sardine and anchovy populations

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Decade-scale regimes of sardine *Sardinops sagax* and anchovy *Engraulis* spp. have been observed in the productive coastal waters of the North-Western, North-Eastern and South-Eastern Pacific and the South-Eastern Atlantic. In each of these systems, the two genera fluctuate out of phase with each other. The subdominant genus may initiate a recovery while the other species is still abundant, so population growth is not necessarily a response to a vacant niche. Rather, it appears to be triggered by formation of one or a few powerful year-classes. At high population levels, quality of sardine and their eggs decreased in Japan, leading to decreased production and survival of eggs, poor year-classes and stock collapse. Excessive fishing of strong year-classes early in the recovery stage may prevent a species from assuming dominance, so influencing the natural succession of species. This may greatly alter the structure and functioning of an ecosystem. For example, a mesopelagic forage fish may replace an epipelagic one, with severe repercussions for predators that can only feed in the upper ocean, e.g. some seabirds. Biological factors also may influence the succession of forage fish. For example, off California, peaks in abundance of predatory species such as bonita *Sarda*, and chub mackerel *Scomber*, separate those of the planktivorous sardine and anchovy. In the Pacific Ocean, sardine distribution has change greatly. Compared with its range when scarce, a population at a high level of biomass can extend 1 000-1 800 miles farther along the coast and 400-2 200 miles farther out to sea. In different periods of high biomass, sardine did not always have the same distribution. In the 1930s and 1940s, near simultaneous fluctuations of sardine in the North-Western and North-Eastern Pacific were in phase. In the 1980s and 1990s, sardine in the North-Western and South-Eastern Pacific were fluctuating in phase. However, along the west coast of North America, sardine started their most recent increase later than in other regions of the Pacific Ocean. This increase is continuing, whereas sardine populations in the North-Western and South-Eastern Pacific have decreased both in catch and geographic distribution since the late 1980s. Therefore, the North-Eastern Pacific has moved out of phase with other major Pacific sardine populations. This may be because abundance of sardine in the California Current has not yet reached a level at which density-dependent effects exert a major influence. Sardine and anchovy in the South-Eastern Atlantic have been out of phase with



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populations in the Pacific Ocean, especially those off Peru and Chile. Over the last 300 years, episodic fisheries for Bohuslän herring *Clupea harengus* in Sweden coincide with periods of high anchovy abundance off California. Near simultaneous fluctuations of fish stocks in widely separated regions support the view that they are sometimes influenced by climate operating at a global scale. Changes of the gyre-scale circulation seem to be major factors in the decadal climate. In Australia, sardine have a wide range, but the less productive waters support a much lower biomass than is found in the other four systems. *Engraulis* occur in some systems from which *Sardinops* are absent, for example, Brazil, where they and *Sardinella* are segregated vertically in the water column.

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