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## Surplus production, variability, and climate change in the great sardine and anchovy fisheries

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We used fishery and survey data to calculate annual surplus production (ASP) and instantaneous surplus production rates (ISPR) for eight anchovy and nine sardine stocks. In addition, we calculated ASP per unit spawning area for six anchovy and six sardine stocks. Median ASP was highest for stocks with highest median biomass (mostly anchovies), and ASP was typically about 16% of stock biomass. ASP was often negative, more frequently for anchovies (36% of years) than for sardines (17% of years). ISPR was less variable for sardines and autocorrelated for longer-lived stocks (mostly sardines). Strong biomass increases tended to be preceded by short, abrupt increases in ISPR, and declines were pronounced when catches exceeded ASP for 5 years or more. The longest "runs" of positive and negative production were 21 and 4 years for sardine off Japan, 10 and 3 years for sardine off California, 8 and 2 years for anchovy off Peru, and 4 and 3 years for anchovy off California. ISPR is more sensitive to environmental changes than catch, biomass, or ASP and appear to be better for identifying environmentally induced regime shifts. Long time series show evidence of density-dependent effects on ASP in anchovies and sardines, but environmentally induced variation appears to dominate.

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