Response of Japanese sardine and anchovy abundances to orbitally driven climate changes during the Holocene

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There remains one of the questions how pelagic fish stocks respond to orbital-scale climate change during the Holocene. Long-term relationship between pelagic fish abundances and climate change could help us to understand their responses to future climate changes. Here we present fish scale abundance records of Japanese sardine and Japanese anchovy for the last 7000 years. The record of sardine scale deposition rates showed an increasing trend before around 3,500 calendar year BP and a decreasing trend from the time period toward the present. On the other hand, anchovy scale deposition rates showed an increasing trend after 3,500 cal. yr BP. Observational studies demonstrated that growth rates of Japanese sardine and Japanese anchovy are high at ~16˚C and ~22˚C with a unimodal response to water temperatures. Only one or two degree lower and higher temperature than the optimal temperature may results in depletion of larvae’ s growth rate and recruitment failure, resulting in species alternation from sardine to anchovy and back (Takasuka et al., 2007). This is called 'optimal growth temperature' hypothesis (Takasuka et al., 2007). In fact, the equivalent temperature rise occurred in association with Pacific Decadal Oscillation, resulting in a population decrease up to ~90 part of the highest value recorded in 1988. Since mean temperatures in the spawning ground of Japanese sardine (off southern coast of Japan) during 1980s were around 17˚C, 1˚C higher than the optimal temperature, 1˚C lower than that during the present ‘sardine regime’ can be expected higher growth rates and increase in abundance. Model simulation results obtained under orbitally driven solar isolation forcing (Lorenz et al., 2006; Ohgaito et al., 2013) indicate that SST in Kuroshio extension, an area distributing sardine larvae, shows an increase trend with ~0.7˚C/6 kys in winter. The temperature at 6 cal. kyr BP is likely close to the optimal temperature for sardine larvae. Therefore, past temperature change can be expected to be a long-term decrease trend in population. However, our result suggests a decrease trend only for the last 3,500 years, but showing an increase trend before 3,500 cal. yr BP. One of the most plausible reason for this contradiction may be due to underestimation of the increasing rates of temperature for the last 6 kyrs in the narrow route 0˚ to 0.5˚ north of the Kuroshio axis and the Kuroshio Extension axis as an important nursery ground, which might be due to relatively low spatial resolution in the models used. If the past thermal condition in the route was 2˚C lower temperature than that in the present sardine regime (1˚C lower than the optimal temperature), the observed depletion in sardine abundance at 6 cal. kyr BP, which is comparable to the present day level, can be explainable by 'optimal growth temperature' hypothesis. The increasing trend in anchovy abundance can also be explained by this hypothesis. There may be a new challenge for collaboration between oceanography and paleoceanography regarding this issue.

Keywords: Japanese sardine and Japanese anchovy, climate change, Holocene, Northeast Pacific

