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Future projection using an integrated marine ecosystem model linking climate change with fish resources

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To clarify the impact of global climate change associated with the increase in atmospheric carbon dioxide on natural marine environments, we need integrated ocean models linking climate change with fish resources. Such models are also useful to assess systematically many human impacts such as overfishing, eutrophication and pollution in addition to global warming.

Increasing temperatures near the sea surface due to global warming will shallow the annually maximum mixed layer depth in winter and reduce nutrient supplies from the sub-surface water. As a general hypothesis, marine biological production will decrease with sea surface temperature. Hashioka and Yamanaka (2007) demonstrated effects of global warming on ecosystems in the North Pacific, such as earlier and weaker spring blooms in the transition subarctic-subtropical region, and suggested that this change in spring bloom might reduce fish resources of small pelagic fish such as anchovy, sardine and Pacific saury, because the timing of the spring bloom and the subarctic-subtropical transition region are essential for growth and survival of fish.

We developed a 3-D high-resolution (1/4 x 1/6 degrees horizontally) ecosystem model, COCO-NEMURO, which consists of the North pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO) developed by the North Pacific Marine Science Organization (PICES) coupled with an OGCM, the Ocean Component Model (COCO) developed by Center for Climate System Research (CCSR). We evaluated the impact of global warming on the ecosystem in two ten-year scenarios: a control experiment (present climate state), and a double CO_2 experiment (gradually increasing atmospheric CO_2 by +1% per year from the present to approximately double by the 70th-80th year). In the double CO_2 scenario, the spring bloom occurs 10-20 days earlier than that under the present climate in both the transition and the subarctic regions. The signal of global warming is statistically significant at the 95% level, relative to natural variability. In present High Nutrient Low Chlorophyll (HNLC) regions, the biomass maximum associated with the spring bloom increases because the positive effect of increased temperature on growth rate overwhelms the negative effect of reduced nutrient supply from the sub-surface water. In both regions, annually averaged primary production slightly increases due to faster regeneration in the surface waters under global warming, but export production from the surface to the deep waters significantly decreases, in agreement with the general hypothesis of reduced nutrient supply from the sub-surface water. A shift in dominant phytoplankton also occurs from large diatoms to other small phytoplankton, and this, together with enhanced regeneration causes the rain ratio of calcium carbonate to Particulate Organic Carbon (POC) to increase.

A pelagic fish model is also developed based on NEMURO For Including pacific Saury and Herring (NEMURO.FISH, Okunishi et al., 2009). Global warming might significantly decrease the abundance of fish resources via change in spring bloom. In future projections for Japanese Sardine, based on our ecosystem simulations, spawning period in winter near the south coast of Japan shortens by around two months, and growth rate decreases for the juvenile stage, which reduces their survival rate. However, the size of adult fish remains the same due to the temperature dependence of their growth rate.

The results introduced above are mainly conducted by young researchers collaborating with the Author.