Variability and mixing of the Kuroshio and impact on ecosystem and fisheries

*Ichiro Yasuda[1], Takahiro Tanaka[1], Haruka Nishikawa[2]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. JAMSTEC

The Kuroshio is spawning and nursery grounds of many kinds of fish and sustains world-largest fishing grounds around Japan, although nutrient (especially nitrate) is depleted in the subtropical North Pacific. Nutrient supply process peculiar to the Kuroshio could sustain the Kuroshio ecosystem. Decadal to inter-decadal variability of the Kuroshio also has a tremendous impact on ecosystem and fisheries, especially for the Japanese sardine (*Sardinops melanostictus*). In the period from large sardine population to declining phase during 1980s and 1990s, sardine recruitment is related to the variability from winter to spring in the frontal zone just north of the Kuroshio axis, where vertical mixing and nitrate upward flux are enhanced. We review research on the sardine variability including recent phase of the growing population and nutrient supply by enhanced vertical mixing on the basis of recent observations performed along the Kuroshio under the Japanese 5-year project “Ocean Mixing Processes: Impact on Biogeochemistry, Climate and Ecosystem (OMIX)”.

Keywords: Kuroshio, sardine, mixing, nutrient

Reproducing migration history of Japanese sardine using otolith d18O and a data assimilation model

*Tatsuya Sakamoto[1], Kosei Komatsu[2,1], Shirai Kotaro[1], Yasuhiro Kamimura[3], Chikako Watanabe[3], Atsushi Kawabata[4], Michio Yoneda[5], Toyoho Ishimura[6], Tomihiko Higuchi[1], Takashi Setou[3], Manabu Shimizu[3]

1. Atomsphere and Ocean Research Institute, The University of Tokyo, 2. Graduate School of Frontier Sciences, The University of Tokyo, 3. National Research Institute of Fisheries Science, 4. Fisheries Agency , 5. National Research Institute of Fisheries and Environment of Inland Sea, 6. National Institute of Technology, Ibaraki College

A new method to reproduce migration histories of Japanese sardine (*Sardinops melanostictus*) was developed by using the combination of otolith oxygen stable isotope ratio ($\delta^{18}O$) and a data assimilation model. Firstly, rearing experiments for three different temperatures were conducted for a month and otolith $\delta^{18}O$ were analyzed. A linear relationship between otolith $\delta^{18}O$ and temperature was determined for the first time for Japanese sardine as follows: $\delta_{otolith}=\delta_{water}$-0.181*Temperature+2.690, r^2=0.91 (1). Secondly, seawater $\delta^{18}O$ and salinity in the western North Pacific were revealed to be strongly correlated from *in situ* samplings: δ_{water}=0.5951*Salinity-20.347, r^2=0.89 (2). Micro-volume $\delta^{18}O$ analysis and our original micro-sampling technique enabled us to extract otolith $\delta^{18}O$ profile in a temporal resolution of 10-15 days through whole life of juveniles approximately 200 days post hatch. For the dates corresponding to each value of the profile, surface temperature and salinity in the range of 30-55N, 130-180E were extracted from a data assimilation ocean model FRA-ROMS which reproduces ocean environment realistically. Temperature and salinity in each grid were converted into otolith $\delta^{18}O$ value using Eq. (1) and (2). Grid points in which the calculated otolith $\delta^{18}O$ value was equivalent to actually analyzed one were considered to be the location of the individual on the date. Movements of the juveniles reproduced by this method clearly showed the northward migration from the Kuroshio-Oyashio transition zone to the Oyashio region and the estimated location on the sampling week approached to the actual sampling point, which indicated the high accuracy of the method.

Keywords: Sardine, Otolith, Oxygen isotope

Long-term variability of larvae feeding grounds of Japanese sardine and its environment

*Haruka Nishikawa[1], Yusuke Tanaka[1], Norihisa Usui[2]

1. Japan Agency for Marine-Earth Science and Technology, 2. Meteorological Research Institute

Since 1980s, many previous studies have suggested that Japanese sardine (*Sardinops melanostictus*) is influenced by climate change. Recently, two studies focused on where and what is significant for controlling the stock. One study suggested that the environment of winter Kuroshio front area controlled the stock variation because that area was main distribution area of sardine larvae in 1980s. Another study revealed the dependency of larval growth on temperature, so-called “Optimal temperature hypothesis”. According to this hypothesis, the stock variation depends on the ambient temperature of larvae.
Japanese sardine has a notable habit that their spawning grounds move drastically in decadal scale. It implies that distribution area of larvae also changed. Considering this spawning habitat, the current distribution area of larvae has already not been in the winter Kuroshio front area. On the other hand, if the optimal temperature hypothesis can totally explain the stock variation, long-term stock variation depends on ambient temperature of larvae wherever they are distributed.
Whether the significant area for the stock variation has changed and whether ambient temperature controls the stock variation in decadal scale are important points to understand how the climate change affects the sardine stock. However, there is few knowledge about long-term variability of larvae feeding grounds.
In this study, we estimated the larval distribution area and environment from 1980s to 2000s by using the most advances reanalysis dataset. Through the comparison between past environment and the stock variation, we examined above two hypotheses.

Keywords: Japanese sardine

Variation of environment around the Kuroshio influences the recruitment of chub mackerel (*Scomber japonicus*)

*Hitoshi Kaneko[1], Takeshi Okunishi[1], Takashi Seto[2], Hiroshi Kuroda[3], Sachihiko Itoh[4], Shinya Kouketsu[5], Daisuke Hasegawa[1]

1. Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, 2. National Research Institute of Fisheries Science, 3. Hokkaido National Fisheries Research Institute, 4. Atmosphere and Ocean Research Institute, The University of Tokyo, 5. Japan Agency for Marine-Earth Science and Technology

Chub mackerel (*Scomber japonicus*) in the North Pacific is one of the most important commercially fishes in Japan. It has been thought that its Recruit Per Spawning stock biomass (RPS) can be estimated based on an extended Ricker model including winter-time temperature around spawning ground, spawning stock biomass, and sardine biomass proposed by Yatsu et al. (2005). However, substantial degree of disagreement of RPS between the estimated from virtual population analyses and provided by the model is recognized especially after 2000. Because little study has been done concerning relationship between oceanic environment and annual variation of RPS after 2000, we investigate relationships between RPS and the environment such as winter time surface temperature around the spawning ground affecting spawner, and the Kuroshio pass affecting larvae thorough transports and temperature. In addition, we also attempt to improve the model concerning RPS after 2000. Then, based on particle tracking experiments conducted from mid-March to late April, we reveal importance of experienced temperature of larvae during ~10 days after hatch as well as February temperature of the spawning ground in the Kuroshio inside. Note that the experiments are made under the condition of fixed release positions for particle. It is also indicated that high RPS often occurs when the Kuroshio passes straight through the Izu islands chain during March when the spawner maturate, in contrast to lower RPS when the Kuroshio meanders along the islands. In the case of the Kuroshio meandering, worse RPS is shown when the winter time temperature in the near coast area (in the inside of the Kuroshio) is higher. These results suggest 1) importance of the inside area as a feeding grounds for spawner from late winter to early spring, 2) spatial restriction of spawning grounds tide to the inside area for chub mackerel as feeding and eggs production grounds for spawner, and 3) relationships between the pass of the Kursohio and annual variation of RPS through experienced temperature of larvae during spring related with the distance from the feeding ground for spawner to the Kuroshio axis. In addition to these results, one possibility of the poor reproducibility of the model by Yastu et al. (2005) after ~2000 is proposed as regime change of the Kursohio pass: the flow frequently passes closer to costal region east of the Izu island chain after 2000.

Keywords: Chub Mackerel, Recruitment Per Spawning, Kuroshio

Climate driven shifts in the biogeography of the global ocean

*Gabriel Reygondeau[1]

1. University of British Columbia

Examinations of oceanographic samples collected since 1860 combined with the recent use of remote sensing observations has revealed that even if global ocean appears at first sight as a homogenous domain, it is composed by discrete ecological units separated by invisible frontiers. This ecological reality has been widely studied by Longhurst who have partitioned the oceanic realm into 4 biomes and 56 biogeochemical provinces (BGCPs), each division representing regional environmental and oceanographic specificities at a basin scale. Here, we use a recently developed biogeographical approach to identify the environmental envelops of each BGCPs according to a set of parameters (temperature, salinity, oxygen, sea ice, pH,bathymetry and Net primary productuin). Thus, we readapt the static paradigm proposed by Longhurst and allow the examination of the long term variability of the spatial distribution of each BGCP according to environmental conditions derived from 3 Earth system model (IPSL, MPI and GFDL) and for two emission scenarios (RCP 2.6 and 8.5). Spatial variations of the biogeography of the global are thus identified and confronted to observations. Furthermore, projection of the global biogeography reveals a drastic shift of the biogeographical systems of the ocean suggesting a profound reorganisation of present trophic webs. Biogeographical perturbation indices are here computed and could be of interest for guiding the near future management plan of ecosystems conservation.

Keywords: climate change, biogeography, Earth system model, Biogeochemical provinces, Longhurst, Non analogue Biogeographic state

The Future Response of Fisheries Production to Integrated Anthropogenic Forcing: Climate Change and Fishing Pressure

*Colleen Mary Petrik[1], Charles A Stock[2], Ken Haste Andersen[3], James Watson[4]

1. Princeton University, 2. NOAA OAR Geophysical Fluid Dynamics Laboratory, 3. Technical University of Denmark , 4. Stockholm University

Many empirical relationships between commercial fish recruitment and population biomass with the environment exist, however the mechanisms behind these relationships are rarer. These mechanisms are often region-specific and can dissolve over time. We seek a mechanistic understanding of the variability of commercial fish recruitment and population biomass with respect to anthropogenic forcing, both fishing pressure and future climate change. To do so, we have developed a global stage- and size-based mechanistic model that represents the immature and mature stages of forage fishes, large pelagic fishes, and large demersal fishes. In this talk we will present preliminary results of fish biomass under (1) historical climate without fishing, (2) historical climate with fishing, (3) projected business-as-usual climate without fishing, (4) and projected business-as-usual climate and fishing. The stepwise addition of forcings in simulations 1-3 separate the effects of each, while simulation 4 forecasts the potential fish biomass response to the integrated anthropogenic forcings of climate and fishing.

Keywords: Fish , Climate change