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

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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)”.

キーワード：黒潮、マイワシ、混合、栄養塩
Keywords: Kuroshio, sardine, mixing, nutrient

耳石の酸素安定同位体比と海洋同化モデルを用いたマイワシの回遊履歴推定

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

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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.

キーワード：マイワシ、耳石、酸素安定同位体比
Keywords: Sardine, Otolith, Oxygen isotope

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

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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.

キーワード：マイワシ
Keywords: Japanese sardine

2000年以降のマサバ資源量に関わる黒潮の海洋環境変動
Variation of environment around the Kuroshio influences the recruitment of chub mackerel (*Scomber japonicus*)

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マサバ (*Scomber japonicus*) 太平洋系群の加入量変動の指標である再生産成功率 (Recruit Per Spawning stock biomass; RPS) は、産卵場水温、産卵親魚量、マイワシ資源量を説明変数とする拡張リッカー型再生産モデルで高精度に推定できると考えられてきたが、2000年ごろを境に、近年推定精度が著しく低下している。しかし、このレジーム変化をもたらした海洋環境変化および近年の加入量年々変動に影響を与えている海洋環境変動に関する知見は乏しい。そこで本研究では、マサバ親魚に影響する産卵場環境や、卵仔魚輸送に影響する黒潮の動態と加入量変動の関係解明を目的として研究を行い、さらに2000年以降の加入量変動について既往モデルの改良を試みた。本研究により、黒潮域内側に分布する産卵場水温の冬季表面水温の重要性に加えて、粒子追跡によるマサバの生活史の最初期ステージの経験水温の推定が、加入量変動の高精度化に寄与することが明らかとなった (なおこの粒子追跡実験は放出場を固定したものである)。さらに、親魚が成熟して産卵期を迎える3月に黒潮が非大蛇行接岸流路をとる場合は加入成功率が高く、伊豆諸島を迂回する流路の場合は加入成功率が低～中程度であったことが示された。迂回流路の際にも、黒潮内側域沿岸付近の冬季表面水温が相対的に高い年はとりわけ加入が悪い傾向があった。これらの結果から、晩冬期～春季の産卵親魚の摂餌場としての黒潮内側域の重要性と、卵の量・質に親魚の摂餌状態が影響するマサバの、摂餌場-産卵場の空間的制約の可能性、そして黒潮流路分布に伴う春季仔魚の経験水温の年々変動が加入に与える影響が示唆された。既往モデルの推定精度が2000年以降悪くなる原因の一つとして、黒潮の流路が2000年ごろを境に変化し、伊豆諸島の東側でより沿岸側を通過するようになったことが挙げられた。

キーワード：マサバ太平洋系群、加入量変動、黒潮
Keywords: Chub Mackerel, Recruitment Per Spawning, Kuroshio

Climate driven shifts in the biogeography of the global ocean

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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.

キーワード：climate change、biogeography、Earth system model、Biogeochemical provinces、Longhurst、Non analogue Biogeographic state
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

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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

