



Recent changes in oceanographic conditions in the Northwestern Pacific and their potential impacts on migration and reproduction of sardine, mackerel and saury



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Abstract

Impacts of recent changes in oceanographic conditions on feeding migrations and reproduction of sardine (*Sardinops melanostictus*), mackerel (*Scomber japonicus*) and saury (*Cololabis saira*) in the Northwestern Pacific are analyzed. The materials of TINRO complex pelagic surveys in 2004-2025 from the "Marine Biology" and "Oceanography" databases, fisheries statistics and gridded SST, water temperature at 50 and 100 m depth and currents from the NEAR-GOOS data base were used. Various parameters reflecting climate change and multi-scale variability are assessed. The main factors causing changes in spatial distribution and reproductive success of these species have been identified. Now these changes are the most clearly cause the longer feeding period for these species in subarctic waters. Key dynamic patterns (branches and meanders of Kuroshio, Oyashio, Subarctic Current and mesoscale eddies) and related oceanographic fronts have effect on migration of the commercial species in many aspects. The transformed subtropical water spread farther north than usual to the east of 154°E in the recent 12 years. This situation is favorable for more intense northward migrations of sardine, mackerel and saury. However, the total area of the high productive waters in the western cyclonic subarctic gyre has decreased. Extremely warm conditions off Hokkaido and the relatively strong northeastward "third" branch of Kuroshio or Isoguchi Jet play the negative role for the saury fishery of Russia. Dense shoal aggregations of saury are formed in the more distant areas from the coast. The observed dynamics of the environments features indicate an intensification of variability (with a general increase in dispersion), accelerated warming, and an increase in frequency of extreme events over the past 15 years. Such rapid and significant changes can have unfavorable effect on these species.

Data and methodology

TINRO scientific fisheries independent expeditions :

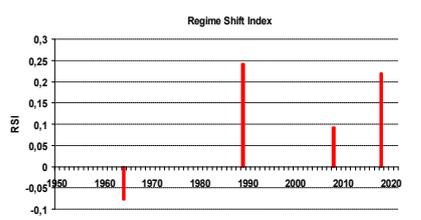
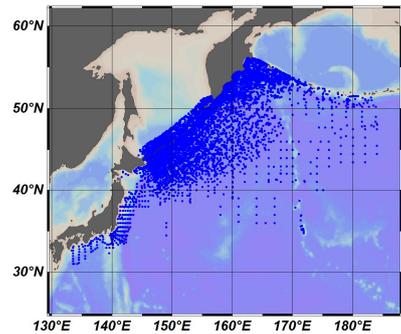
CTD, hydrochemical sampling, plankton net, pelagic trawl, acoustic survey from the TINRO databases "Oceanography" and "Marine Biology"

Satellite information: <http://www.satellite.dvo.ru/>

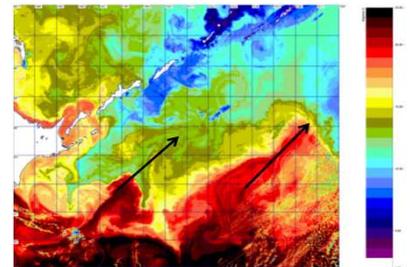
We also use NEAR-GOOS gridded SST, temperature at 50, 100, 200 and 400 m and currents <http://ds.data.jma.go.jp/gmd/goos/data/database.html>

Currents from the Ocean Surface Current Analyses Real-time (OSCAR) project ESR, 2009. OSCAR third degree resolution ocean surface currents. Ver. 1. PO.DAAC, CA, USA. Dataset accessed: <http://dx.doi.org/10.5067/OSCAR-03D01>.

For assessment of temperature and salinity anomalies from R/V survey data were used daily climatic values calculated from World Ocean Atlas WOA2013. Statistical significance for characteristics of variability ≥ 95%. Regime shift indices (RSI) according to Rodionov, 2004, 2006

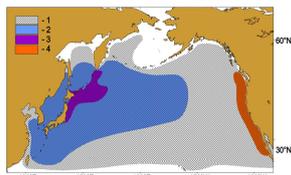


Climate regime shift indices (RSI) in the feeding area of saury, sardine and mackerel to east from the Kuril Islands, calculated from the SST time series



SST by Aqua/MODIS satellite on September 27, 2025, 17:10 UTC. The data was received and processed in the Center for Regional Satellite Monitoring of Environment, FEB RUS, Vladivostok

Pacific saury



Range (1), area of frequent occurrence (2), fishing grounds (3) of Pacific saury and spreading of the population spawned at California (Filatov, 2015)

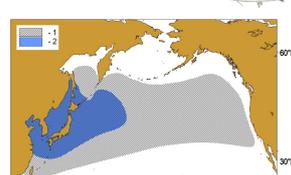
Local events can generate extreme anomalies affecting the spatial distribution, migration routes, and possibly changes in the abundance of short-cycle fish species such as Pacific saury. Since 2015 the main concentrations of saury have shifted to the east and north. The abundance of saury decreases. Fishing aggregations of saury were formed in the more distant areas from the coast. As a result, in the last 9 years the total catches of Russia and Japan saury fishing fleets were significantly lower than previous years.

The relatively strong northeastward "third" Kuroshio branch or Isoguchi Jet also contributed to the northeastern migrations of saury. In 2019, saury fishing was carried out east of 170°E. This is the most eastern position of the fishery areas for all years.

This "sardine wave" (since 2014-) differs from the previous ones because it is coincident with positive temperature anomalies. This "heat wave" may force, through feeding conditions, sardine migration for feeding far northward in the present period of the population growth.

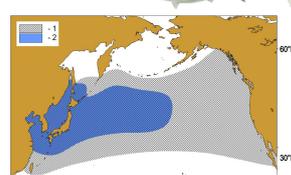
In June, the main sardine aggregations as well as mackerel aggregations have been observed on the warmer water side in high-gradient zone of the North Subarctic Front. From July to September, the maximum catches were recorded in the food-rich subarctic waters to the west from "third" Kuroshio branch or Isoguchi Jet. Sardine aggregations were observed in coastal waters, too.

Japanese sardine



Range (1) and area of frequent occurrence (2) of Japanese sardine (Filatov, 2015)

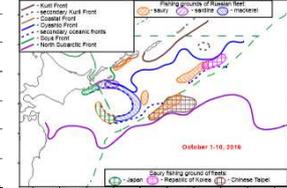
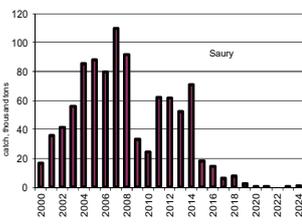
Mackerels



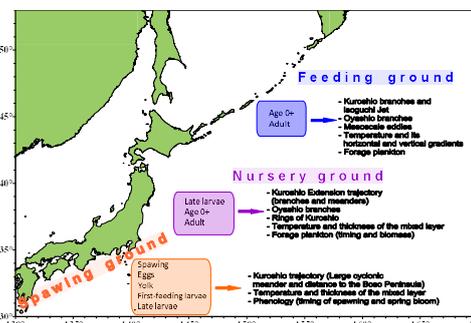
Range (1) and area of frequent occurrence (2) of chub mackerel (Filatov, 2015)

Chub mackerel forage across wide area of the Subarctic frontal zone from June to October. Migrations to wintering and spawning areas occur in October-December. Chub mackerel migrate into Russian EEZ during forage migrations and aggregate in the area off the southern Kuril Islands from July to November. Spotted mackerel (more southern species) was observed in the southeast area of the surveys in July and August.

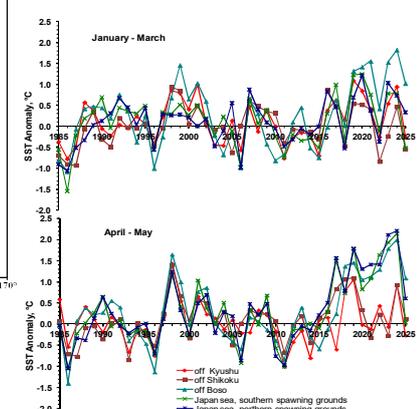
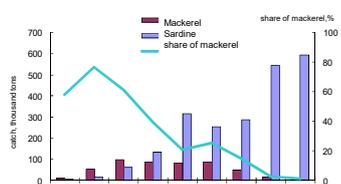
The relatively strong northeastward "third" Kuroshio branch (or Isoguchi Jet) was favorable for more intense northward mackerel migrations. In 2014-2025 the flow of transformed subtropical water spread farther north than usual, especially in 2015. To the east of the Kuril Islands, the maximum (for 2014-2025) mackerel biomass (4.74 million tons) was recorded in July-August 2015.



Surface oceanographic fronts and saury, sardine and mackerel fishing ground (Ustinova and Filatov, 2022)



Key environmental factors affecting the sardine life cycle



SST anomalies in the main reproductive areas of sardine (5 areas) and mackerel (off Boso Peninsula) in winter (top) and spring (bottom)

Summary

- Climate shifts to warming were observed here in 1990 and 2018. Less significant changes towards warming were noted in 2008.
- The transformed subtropical water spread farther north than usual to the east of 154°E in the recent 12 years.
- The penetration of sardine and mackerels into the northern regions is associated with increase in their abundance, which is formed in the reproduction zone. Furthermore, changes in the water dynamics contributed to this redistribution: more northerly propagation of subtropical origin waters (Kuroshio branches and Isoguchi Jet) and weakening of the Oyashio current and its branches.
- Climate changes are the most clearly cause the longer feeding period for these species in subarctic waters.

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