Assessment for effect of climate regime shifts and extreme events on the spatial distribution of sardine, mackerels and saury in the Northwestern Pacific

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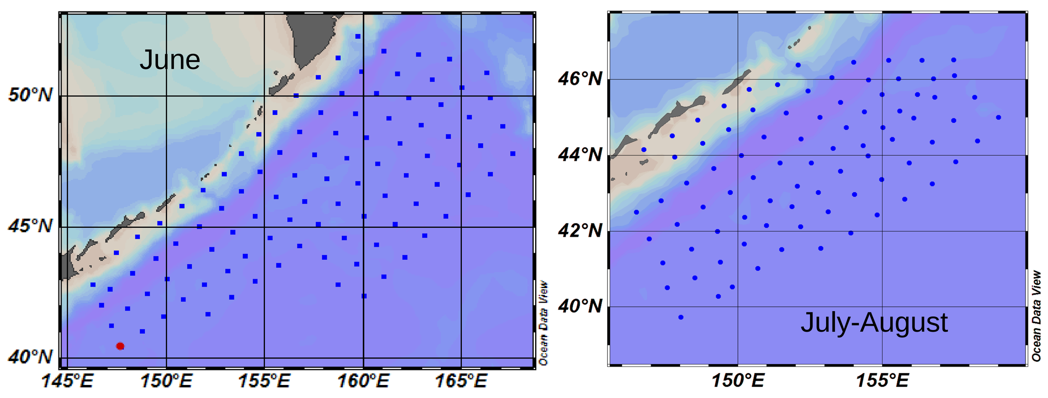
The effect of climate regime shifts and extreme events on the spatial distribution of sardine (Sardinops melanostictus), mackerels (Scomber japonicus and Scomber australasicus) and saury (Cololabis saira) in the Northwestern Pacific was analyzed. The materials of TINRO complex pelagic surveys in 2004-2021 from the "Marine Biology" and "Oceanography" databases, fisheries information and gridded SST, water temperature on 50 and 100 m and currents from the NEAR-GOOS project were used.

Significant changes in the spatial distribution of these species in the Northwestern Pacific have occurred from 2013 to 2014. Since 2014, mackerel and sardine have been observed en masse in the waters available for Russian fishery, and since 2015 the main concentrations of saury have shifted eastward and northward. 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. Historical example of the short-term impact of unfavorable factors leading to long-continued consequences is the extreme winter-spring cooling in 1963 in the Kuroshio-Oyashio system (Fujimori, 1964), which caused a mass mortality at early stage of small pelagic fish (Tsujita, 1966; Nakai et al, 1967), including saury and sardine.

Data and methodology

TINRO scientific fisheries independent expeditions in 2004-2021: CTD, hydrochemical sampling, plankton net, pelagic trawl, acoustic survey from the TINRO databases "Oceanography" and "Marine Biology"

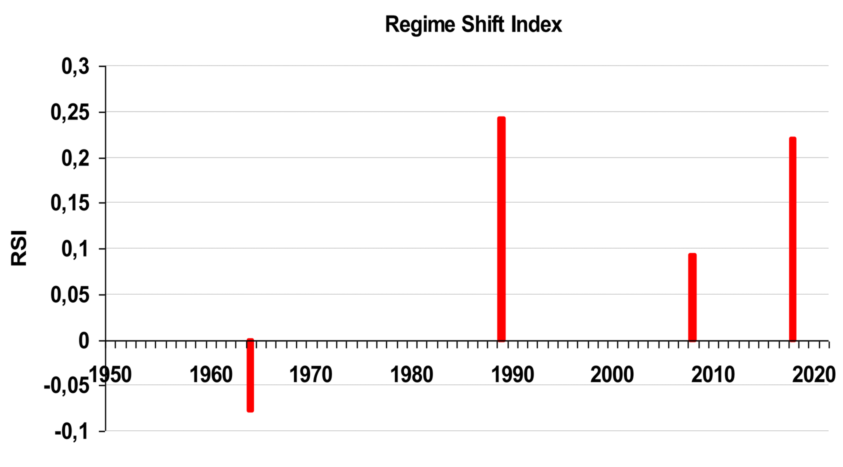


Satellite information: http://www.satellite.dvo.ru/

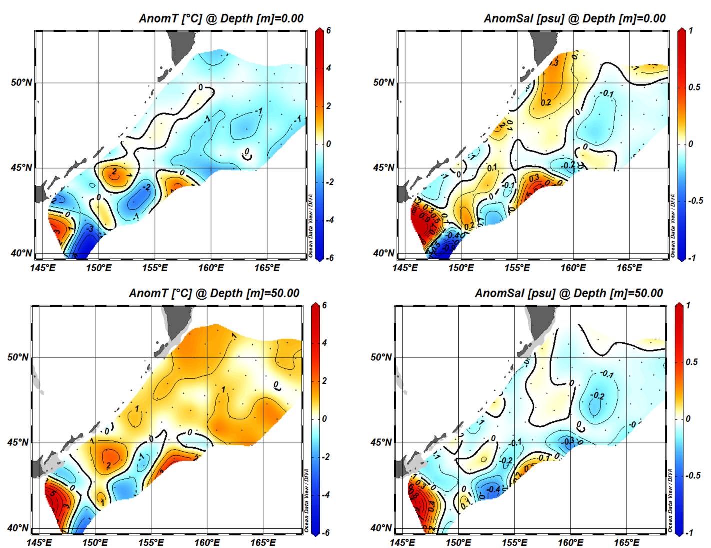
We also use NEAR-GOOS gridded SST and temperature at 50, 100, 200 and 400 m
http://ds.data.jma.go.jp/gmd/goos/data/database.html

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 evaluation of temperature and salinity anomalies there were used daily climatic values calculated from World Ocean Atlas WOA2013.



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

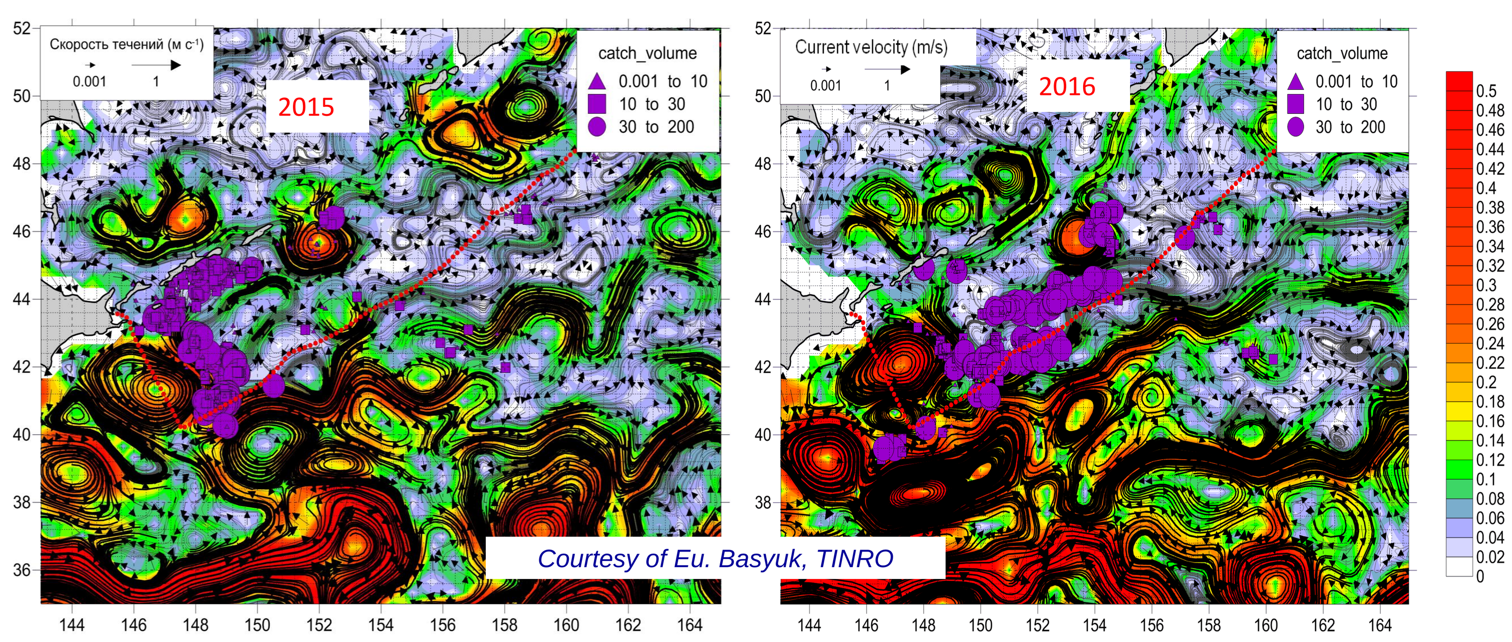


Assessment of temperature and salinity anomalies from R/V survey data, June 2018

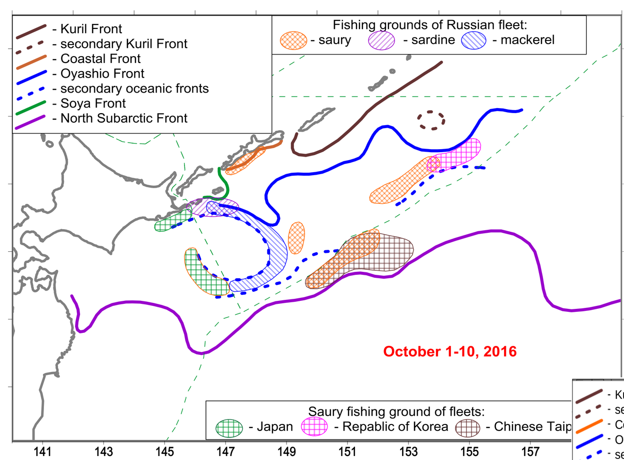
Pacific saury

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.
The example of such event is large and strong anticyclonic eddy observed east off Hokkaido Island in summer and autumn in 2015–2016.
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 7 years the total catches of Russia and Japan saury fishing fleets ware significantly lower than previous years.
The relatively strong northeastward "third" Kuroshio branch or Isoguchi Jet also contributed to the northeastern migrations of saury.

Extreme large and strong anticyclonic eddy near islands: 2015-2016

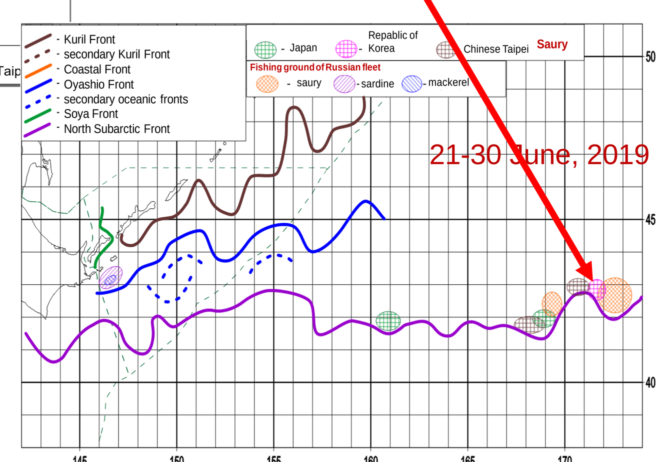


Surface currents (vectors / background contour and current streamlines) in the Northwest Pacific according to OSCAR project and saury fishing grounds areas



2016

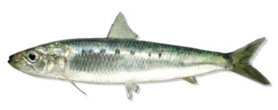
In 2019, saury fishing was carried out east of 170°E. This is the most eastern position of the fishery areas for all years.



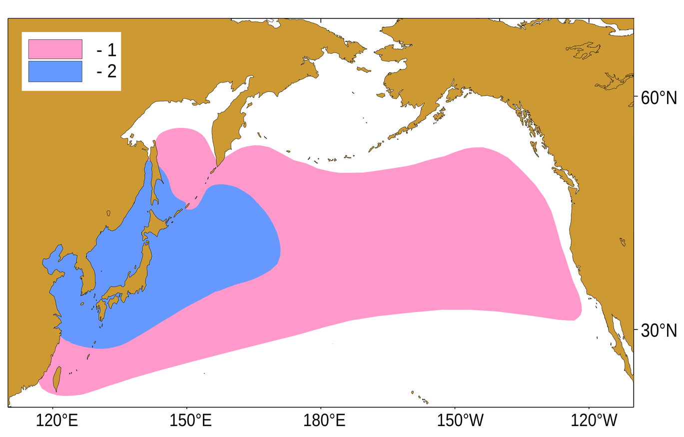
Surface oceanographic fronts and saury, sardine and mackerel fishing grounds

(Ustinova and Filatov, 2022)

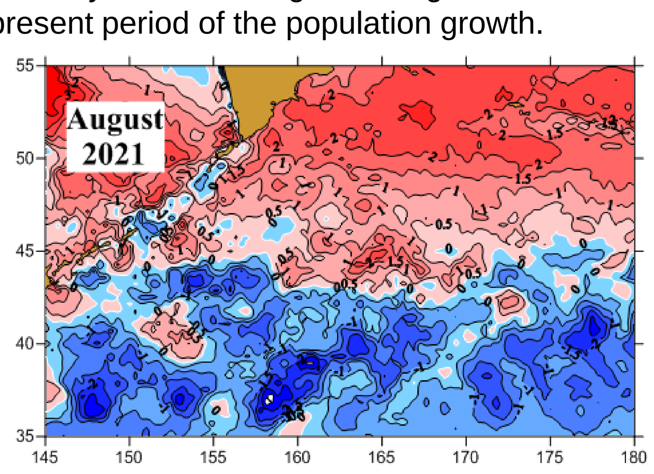
Japanese sardine



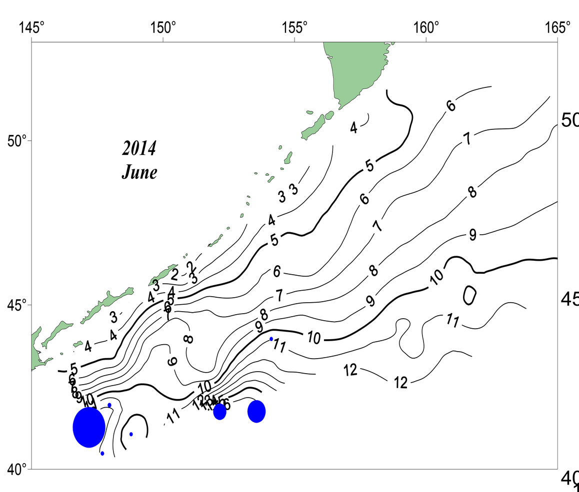
This "sardine wave" (since 2014-) differs from the previous ones because it is coincident with positive temperature anomalies. This "heat wave" may force, through feeding conditions, sardine migration for feeding far northward in the present period of the population growth.



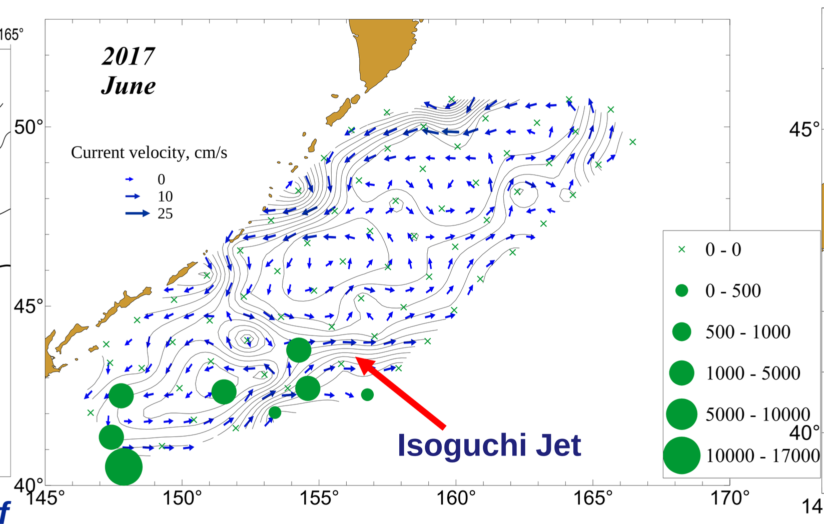
Areal (1) and area of frequent detection (2) of Japanese sardine *(Filatov, 2015)*

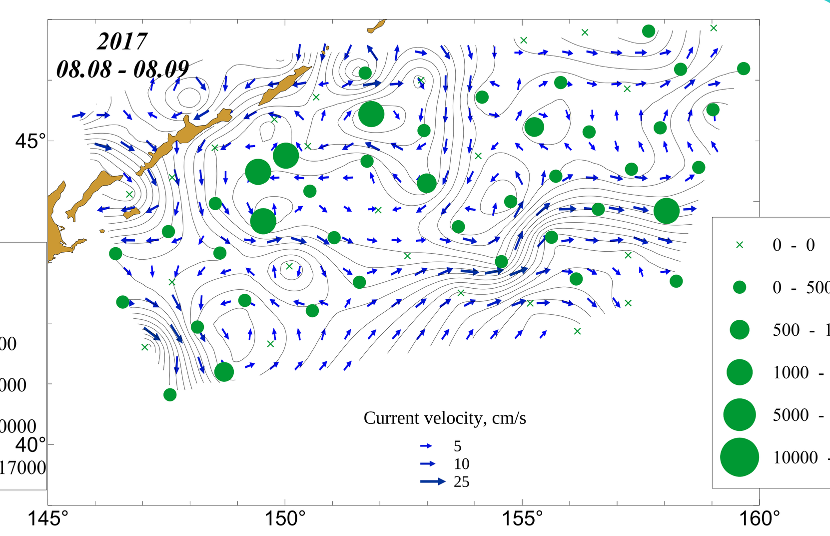


The pattern of SST anomaly contributes to weakening of the surface fronts gradients: unfavorable for the sardine aggregations' formation



Distribution of catch (kg/hour of trawling) for Japanese sardine (*Sardinops melanostictus*) in the Northwest Pacific *vs* SST in 2014



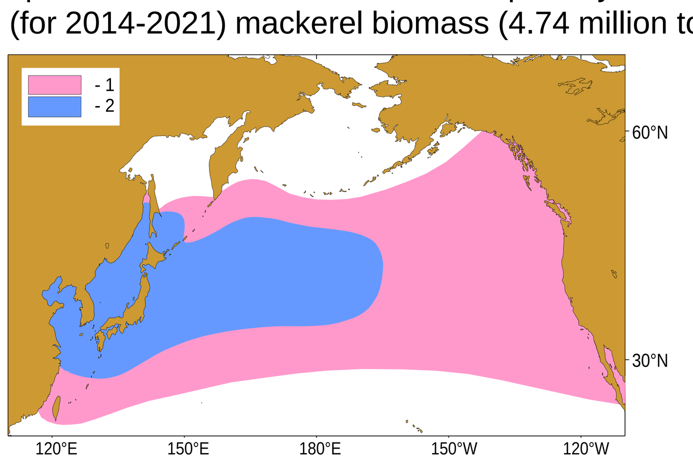


Geostrophic currents (relative to 500 dbar) in the Northwest Pacific and distribution of sardine catches (kg/hour of trawling)

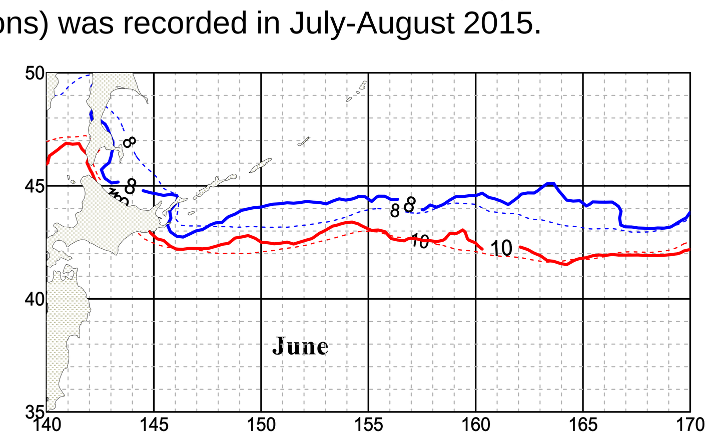
In June, the main sardine aggregations as well as mackerel aggregations have been observed on the warmer water side in high-gradient zone of the North Subarctic Front. From July to September, the maximum catches were recorded in the food-rich subarctic waters to the west from "third" Kuroshio branch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

Mackerels

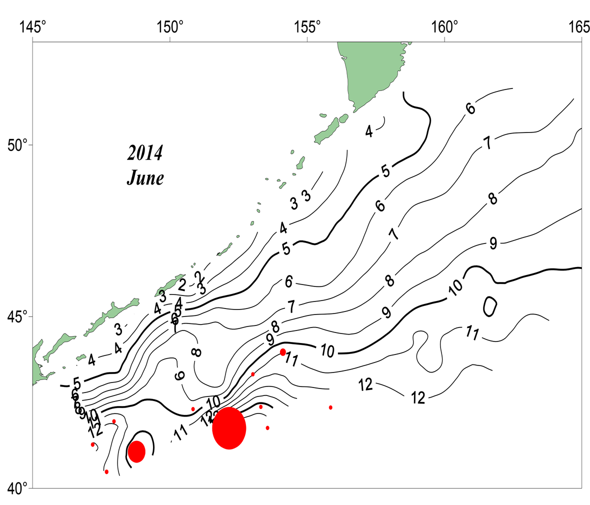
The relatively strong northeastward "third" Kuroshio branch (or Isoguchi Jet) was favorable for more intense northward mackerel migrations. In 2014-2021 the flow of transformed subtropical water spread farther north than usual, especially in 2015. To the east of the Kuril Islands, the maximum (for 2014-2021) mackerel biomass (4.74 million tons) was recorded in July-August 2015.



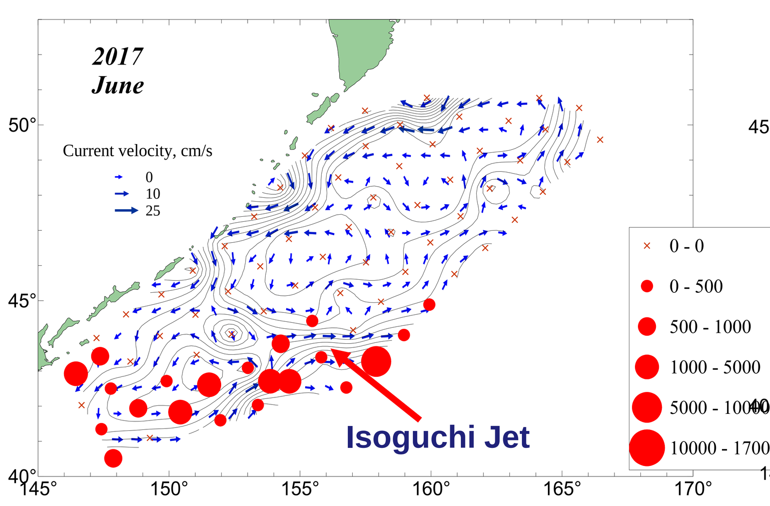
Areal (1) and area of frequent detection (2) of chub mackerel *(Filatov, 2015)*

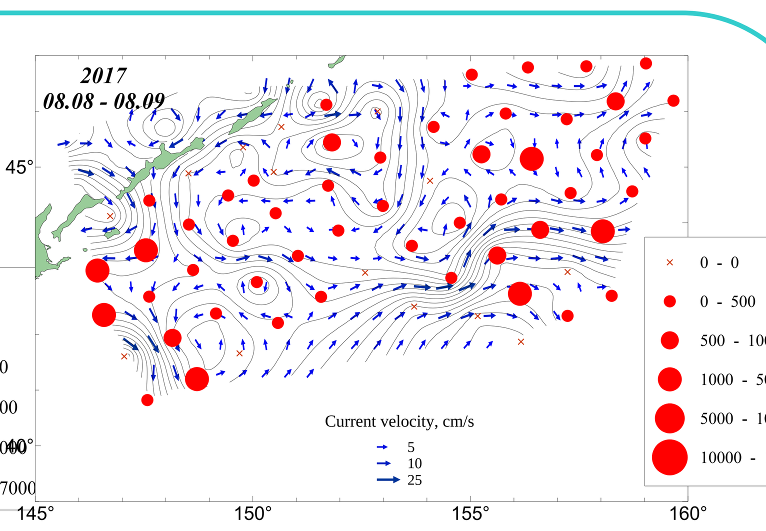


Position of 8 *(blue)* and 10°C (red) isotherms in June 2014 and the norm for 1991-2020 *(dotted line)*



Distribution of catch (kg/hour of trawling) for chub mackerel (*Scomber japonicus*) in the Northwest Pacific *vs* SST in 2014





Geostrophic currents (relative to 500 dbar) in the Northwest Pacific and distribution of mackerel catches (kg/hour of trawling)

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.

Summary

1. There is no significant linear trend in the sardine, mackerels and saury feeding area. However, climate shifts to warming were observed here in 1990 and 2018. Less significant changes towards warming were noted in 2008.
2. 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.
3. Local events can also generate extreme anomalies affecting the migration routes and possibly changes in the abundance of short-cycle fish species such as saury. So, in 2015-2016 large and extremely hot anticyclonic eddy located at the east off Hokkaido Island caused the shift in the autumn southern migrations of saury to the open waters.

Acknowledgments

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