USING SATELLITE INFORMATION ABOUT THE EARTH

STRUCTURE OF WATER DURING THE FEEDING MIGRATION PERIOD OF THE PACIFIC SQUID IN THE SEA OF JAPAN ACCORDING TO SATELLITE DATA

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Abstract. According to the sea surface temperature archive for the years 2018–2023, reconstructed from data obtained by the AQUA and TERRA satellites (MODIS spectroradiometer) with a spatial resolution of 1 km, analyzed and processed at the Shared Use Center of the Regional Satellite Environmental Monitoring of the Far East Branch of the Russian Academy of Sciences, the thermal and dynamic conditions of the waters in the northwestern part of the Sea of Japan were examined, along with the areas for jigging Pacific squid in the Sea of Japan. The analysis of satellite data allowed for the identification of elements of thermal structure within the spatial distribution field of sea surface temperature, where successful catches of Pacific squid were made. Primarily, the formation of squid fishing areas depended on the development or weakening of the branches of the Tsushima and Primorsky currents, as well as the presence of mesoscale eddy structures in their waters. Squid aggregations were mostly associated with areas of eddy upwelling. Maximum catches were concentrated on the periphery of subtropical anticyclonic eddies bordering subarctic waters. If the eddy had a spiral structure, aggregations were primarily focused in the center of the eddy. If the inflow of subtropical waters took the form of a mushroom-shaped current, large catches were mainly observed in the current's jet and in the zones of anticyclonic and cyclonic eddies of the dipole. In the frontal zone of subtropical and subarctic waters, squid fishing areas were located on the warm side of the Subarctic (Polar) front.

Keywords: *Sea of Japan, Pacific squid (Todarodes pacificus), satellite information, temperature, eddies, advection, jet currents, mushroom currents*

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INTRODUCTION

The Pacific squid (Todarodes pacificus) is one of the mass species of the epipelagial Northwest Pacific Ocean, which is of important commercial importance in the APR countries. In years of high abundance, the biomass of the species in the Russian exclusive economic zone (EEZ) of the Sea of Japan amounted to 79–97% of the total recorded stock of nekton (Shuntov, 2016). This species is characterized by a short life cycle (about 1 year), the presence of long migrations (Fig. 1), covering the East China Sea, the Sea of Japan, the Sea of Okhotsk and the Pacific waters of Japan and the Kuril Islands, as well as significant fluctuations in abundance (Mokrin and Hen, 2004; Gong at al., 2007; Kidokoro at al., 2010; Sakurai at al., 2013). As squid abundance decreased, the geography of fishing areas also changed.

Previously, the main characteristics of the environment for the formation of squid aggregations were studied only by means of contact oceanological measurements (Mokrin and Slobodskoy, 1998; Dyakov, 2003; Savinykh et al., 2003; Mokrin at al., 2002; Novikov et al., 2007). With the appearance of new algorithms for processing satellite signals, it became possible to provide not only qualitative but also quantitative assessment of water temperature in the seas on the basis of satellite measurements (Aleksanin and Aleksanina, 2006). Satellite images of the sea surface and the results of their processing are used as information sources characterizing the hydrological features of the habitat of hydrobionts, primarily water temperature. The important ecological significance of water temperature is explained by its significant influence on all biological processes in the sea, from the production of primary organic matter to the behavior of commercial accumulations of hydrobionts. Maps of the Sea of Japan surface temperature (SST), based on satellite monitoring data, make it possible, first of all, to assess the state and dynamics of temperature conditions in the fishing area, to evaluate the spatial and temporal variability of ocean circulation manifestations: currents, frontal zones, meanders and eddies of various

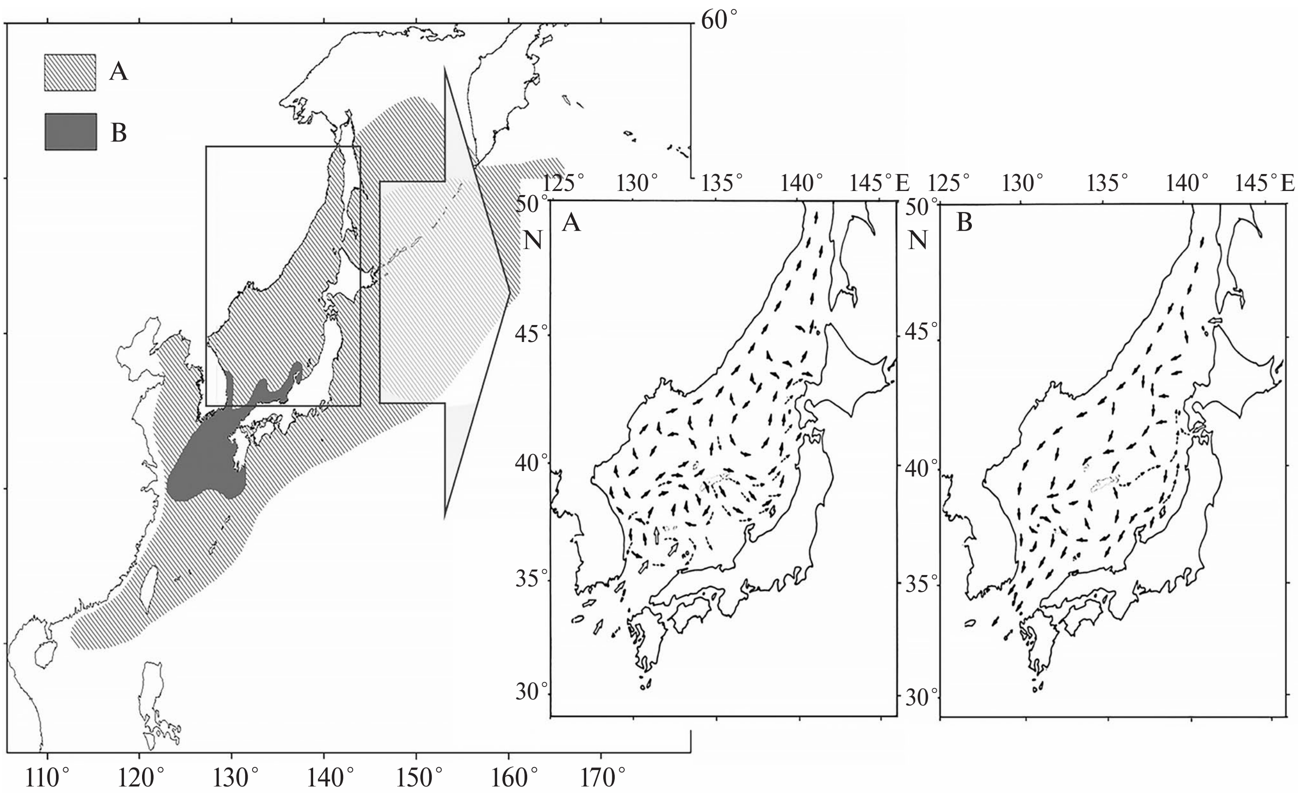


Fig. 1. Distribution of the Pacific squid in the Northwest Pacific Ocean: *a* — areal base, *b* — breeding area, migration routes of the Pacific squid in the Sea of Japan in spring-summer (*c*) and fall (*d*) periods (according to Kasahara, 1978).

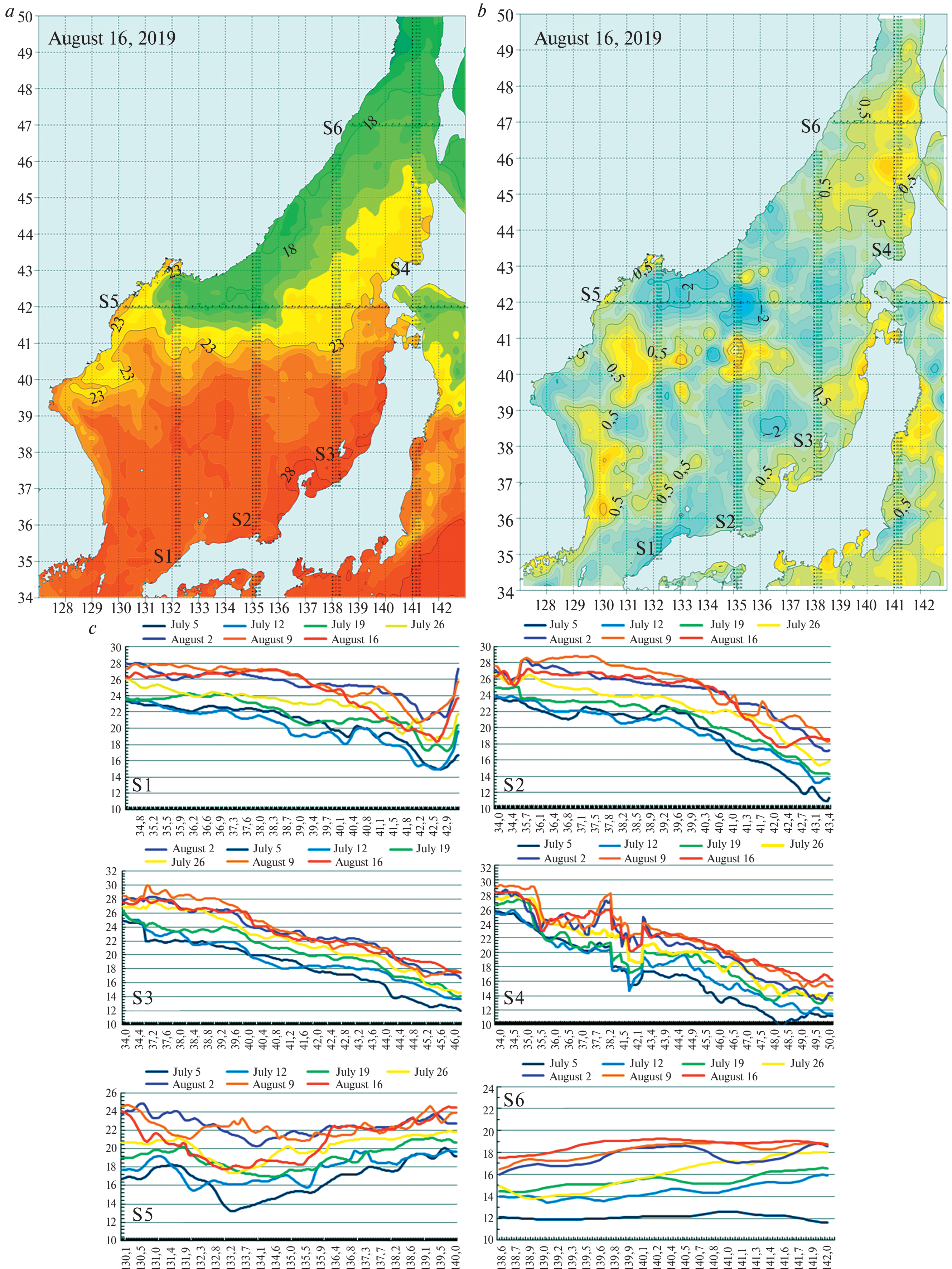
scales (Ginzburg et al., 1998; Nikitin, 2006; Nikitin, Yurasov, 2008). Eddy upwelling, which occurs at the eddy boundary, has been considered as a mechanism for creating favorable conditions for the formation of commercial aggregations of saury (Belonenko and Kozub, 2018), but this mechanism can also be considered for commercial aggregations of Pacific squid.

The position of warm eddies determines the migration paths not only of pelagic fish species, but also affects the distribution of squid. The eddy formation can indicate the beginning of migration and determine the timing of its end (Nikitin et al., 2004; Bulatov et al., 2008; Samko, Bulatov, 2014). The purpose of this work was to identify from satellite information the elements of water structure, in which the largest catches of TCs were observed, to improve short-term forecasting of areas of fishing aggregations during the poutine season.

MATERIALS AND METHODS

To achieve this goal, we compared the areas of longline (jigging) fishing for TC in the Primorye subzone of the Sea of Japan (according to the vessel daily data of the CSMS system of Rosrybolovstvo, vessel daily catches are given in tons) and elements of the hydrological situation in the Sea of Japan, obtained as a result of interpretation of infrared satellite images during the 2018–2023 fishing season. The archive of sea surface temperature (SST) reconstructed from MODIS spectroradiometer data (AQUA, TERRA satellites) in the infrared spectral range with a spatial resolution of 1 km was used. The data were obtained and processed at the Collective Use Center of Regional Satellite Environmental Monitoring of the Far Eastern Branch of the Russian Academy of Sciences (RAS). Additionally, monitoring and research in the Sea of Japan was carried out by analyzing daily satellite data of TPM and its anomalies. The data were obtained at Copernicus Marine Service (URL: http://marine.copernicus.eu). The anomalies were calculated based on the norm for 1981–2010.

To analyze the temperature regime of the waters in the northwestern part of the Sea of Japan, meridional sections were selected at 132°E (S. 1), 135°E (S. 2), 138°E (S. 3), and 141°E (S. 4), as well as zonal sections at 42°N (S. 5) and 47°N (S. 6) (Fig. *2a*, *b*). The principle of selecting transects was related to the position of intensive warm flows, which coincide with the passage of feeding migration flows of pelagic fish species and squid, as well as associated with fishing areas. Characteristics of the temperature regime


a
August 16, 2019
S1
S2
S3
S4
S5
S6
b
August 16, 2019
S1
S2
S3
S4
S5
S6
c
July 5
July 12
July 19
July 26
August 2
August 9
August 16
S1
S2
S3
S4
S5
S6

← **Fig. 2.** Spatial distribution of water surface temperature (*a*) and its anomaly (*b*) on 16.08.2019 (URL: http://marine.copernicus.eu/services-portfolio/access-to-products/) and July-August water temperature distribution (*c*) on meridional transects at 132°E (S. 1), 135°E (S. 2), 138°E (S. 3), 141°E (S. 4) and on zonal transects at 42°N (S. 5) and 47°N (S. 6).

of the fishing areas in the northwestern part of the Sea of Japan were analyzed based on the graphs of water temperature changes at the indicated transects in each decade (Fig. *2c*).

Having identified the position of intensive warm flows (Fig. *3a*), which may coincide with the passage of migratory flows of pelagic fish and squid species, we further identified hydrological elements of water structure in the temperature field, in the areas where commercial fishing for TC was conducted (Fig. *3b*). Glance 1.95 software was used to visualize the spatial distribution of TPO from satellite information. During visual-manual interpretation, by correcting the brightness thresholds of the images using the histogram, we achieved color manifestation of water masses. Anomalies of the sea surface state such as mesoscale eddies and jet mushroom-shaped currents with a eddy dipole at the end, thermal inhomogeneities of upwelling phenomena were observed. For example, Figure *4a* shows a clearer structure of the spiral anticyclonic eddy (swirling eddy) in the satellite image when the lower temperature barrier of 16 °C is established. A map-scheme was constructed from this image (Fig. *4b*).

However, eddy structures were not always clearly distinguished in the water temperature field

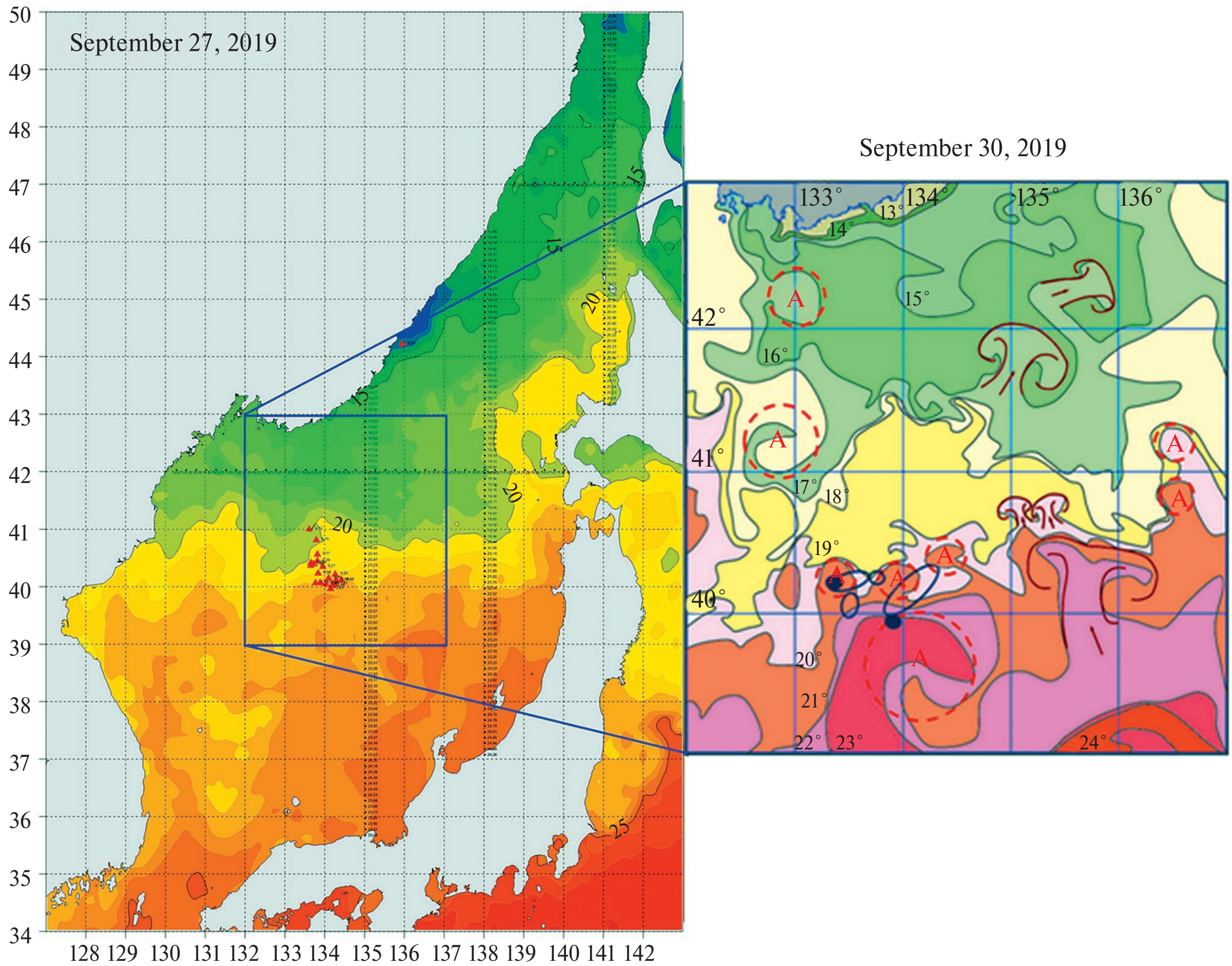


Fig. 3. Spatial distribution of sea surface temperature and fishing grounds of Pacific squid (left) (URL: http://marine.copernicus.eu/services-portfolio/access-to-products) and map-scheme of the thermal structure of waters constructed from satellite observations with squid fishing grounds in the Sea of Japan (right). Symbols: A – anticyclonic eddy; **O** — areas of TC catches; ● — places of maximum catches (t).

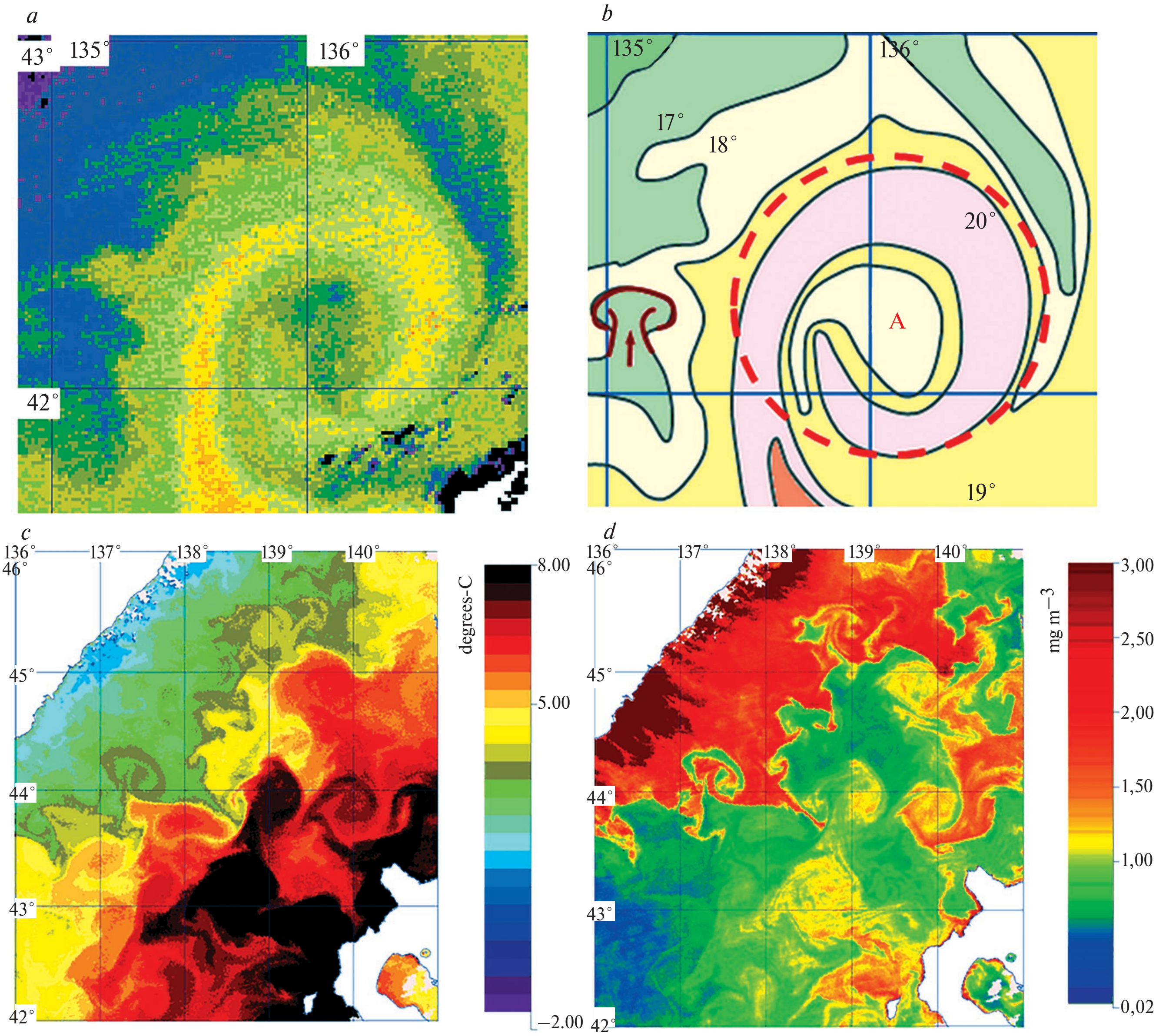


Fig. 4. Fragment of the spatial distribution of sea surface temperature reconstructed from MODIS/Terra satellite data for 19.09.2020. 12:38 UTC (*a*), fragment of the map-scheme constructed from the results of satellite image interpretation for 19.09.2020 (*b*); spatial distribution of sea surface temperature (*c*) and chlorophyll-a (*d*) for 20.04.2021. 3:36 UTC (MODIS/Aqua).

due to the warming of the surface layer of the ocean; in this case, the information of the optical range of the spectrum — the spatial distribution of *chlorophyll-a* — was additionally used to distinguish eddy boundaries when constructing map schemes. Such parameter of the upper layer of sea water is also a good enough indicator of currents, eddy formations and serves for characterization of water masses. We observed abundant phytoplankton development in cool subarctic waters of the Primorsky Current and weak in subtropical warm waters of the Tsushima Current (Fig. 4c*, d*). In the frontal zone, eddy formation is observed in satellite images during the interaction of these waters.

Based on the results of satellite imagery interpretation, schematic maps of surface water thermal structure distribution were constructed and the position of fishing vessels was plotted on them. On the maps trawling sites with maximum catch are marked with shaded circles, ovals — areas where several vessels operated.

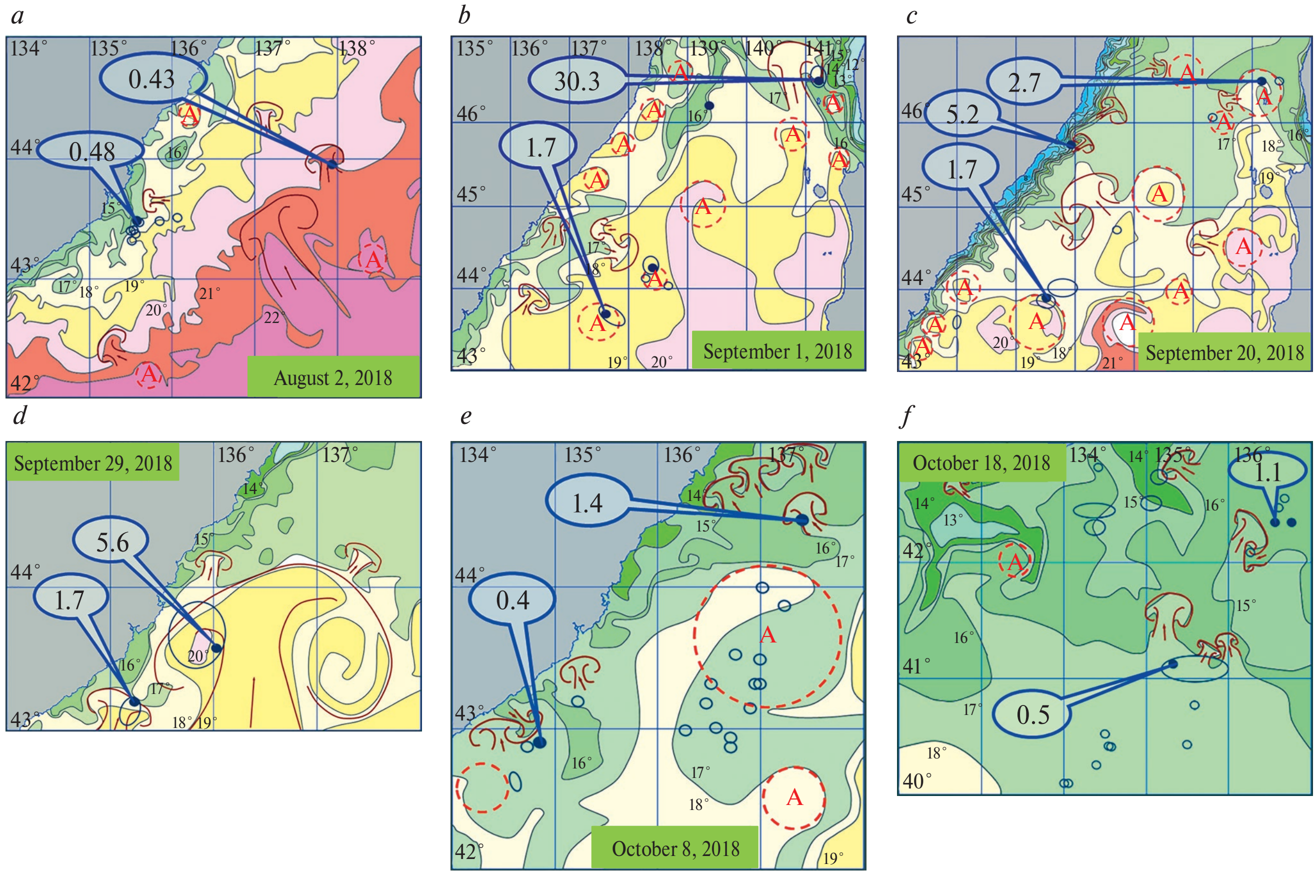


Fig. 5. Maps-schemes of the thermal structure of waters constructed from satellite observations with squid fishing areas in the Sea of Japan for August-October 2018: Notation: A — anticyclonic eddy; ○ — TC catches (t); ● — locations with maximum catches (t).

RESULTS AND DISCUSSION

Long-term satellite observations show that the dynamics of water masses is carried out by jet currents, at the top of which a eddy dipole is formed (cyclonic eddy on the left side of the motion, anticyclonic on the right). Such a coherent structure is called a mushroom current (Fedorov and Ginzburg, 1988). The Pacific squid fishery in July-August 2018–2023 began when the advection of subtropical waters intensified with the exit of tropical cyclones into the Sea of Japan zone. The branches of the Tsushima and East Korean currents were oriented in the northern, northwestern direction. The jet currents penetrated both to the area of Peter the Great Bay (PGB) and to the coast of the middle and northern Primorsky area and to the southern part of the Tatar Strait.

At the beginning of August 2018, the TC fishery was mainly conducted both at the coastal front at the seaward end of Olga Bay (0.55 t) at a temperature of 17–18 °C and to the east in the anticyclonic eddy of the mesoscale mushroom current (0.43 t). Olga Bay (0.55 t) at 17–18 °C, and to the east, in the anticyclonic eddy of the mesoscale mushroom current (0.43 t), departing from the main flow of the Tsushima Current, at 20–21 °C (Fig. *5a*). In early September 2018, commercial aggregations of TC (catches up to 1.7 t) were observed in quasi-stationary anticyclonic eddies. The intrusion of the Tsushima Current waters into the southeastern part of the Tatar Strait resulted in the formation in the area of Moneron Island. A mesoscale anticyclonic eddy of the mushroom-shaped current, in which successful fishery of TC from 13 to 31 t was noted (Fig. *5b*). Commercial accumulations of TCs were observed in the anticyclonic eddy near Moneron Island. Moneron Island, which had a spiral shape, with the largest catch of 5.6 t recorded inside the eddy at 18 °C. After the impact of northwesterly winds, the coastal front was aggravated and upwelling phenomena were manifested (Fig. *5c*). The catch of TC on this front was 5.2 tons. At the end of September 2018, the fishery continued on the coastal front with increasing advection of subtropical waters. A significant catch of 5.6 t was recorded in the cyclonic eddy of a large dipole formed near the coast (Fig. *5g*). Another fishing area was observed to the southwest in the anticyclonic

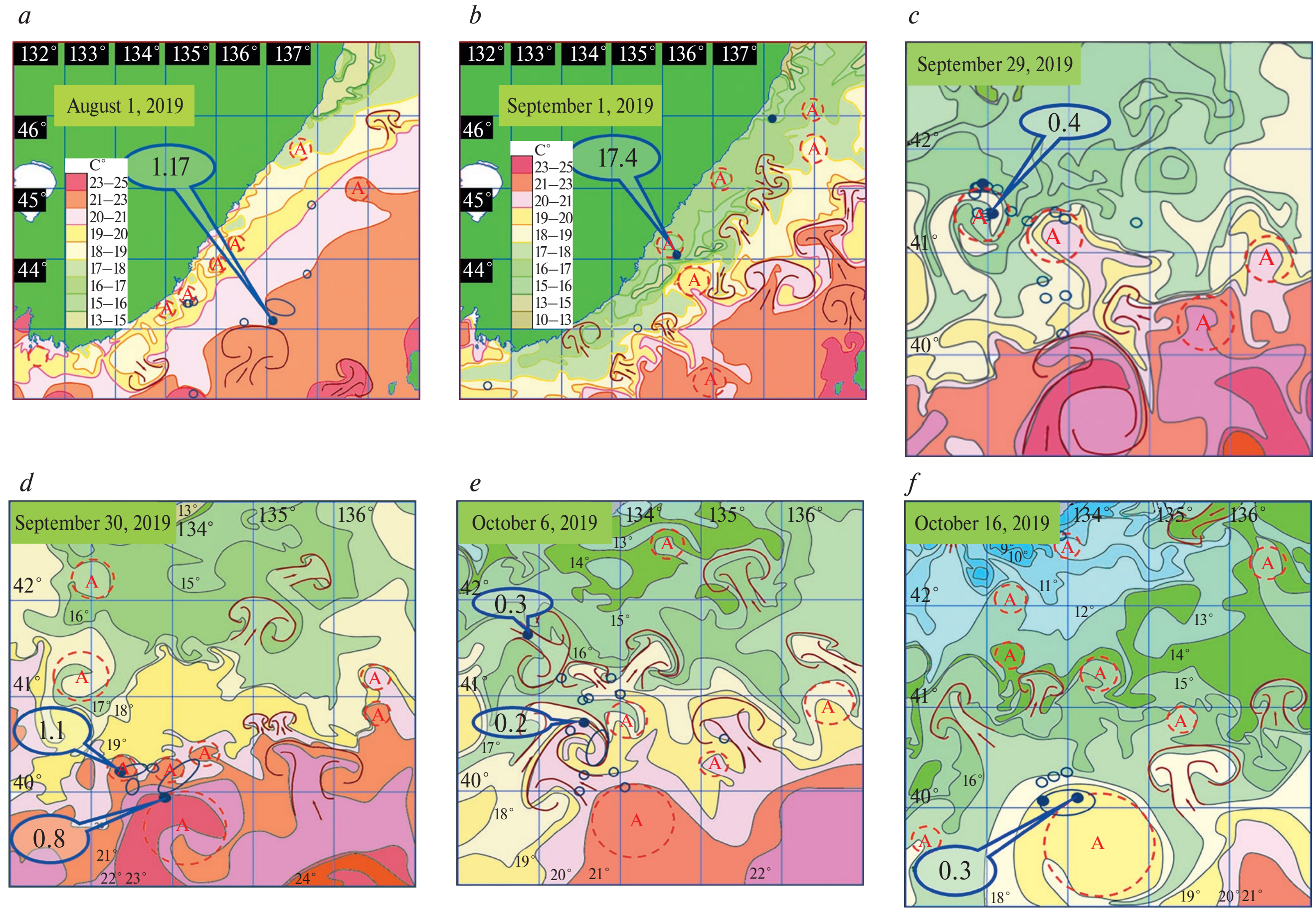


Fig. 6. Maps-schemes of the thermal structure of waters, constructed from satellite observations with squid fishing areas in the Sea of Japan for August-October 2019. Notations: see Fig. 5.

eddy of a mesoscale mushroom current at the boundary with subarctic coastal waters. The maximum catch was 1.7 tons on the "mushroom cap".

In the first decade of October 2018, the squid fishing area in northern Primorye remained in the warm current flow in a large anticyclonic eddy and near the jet feeding it (Fig. *5d*). Catches ranged from 0.2 to 0.5 t. The maximum catch of 1.5 t was observed in the cyclonic eddy of a mesoscale mushroom-shaped current directed toward the shore in a northwesterly direction (water temperature 17 °C). Catches of squid were observed near the mesoscale packing of mushroom eddies (maximum catch of 0.5 t) and near the anticyclonic eddy closer to shore at a water temperature of 17 °C. The fishing areas subsequently shifted southward (Fig. *5e*). The maximum squid catch of 1.1 t was observed in the waters of the stream from the east. Smaller catches (0.7 t) were observed further south, around . In the jet currents of warm waters (14–17 °C) approaching the coast, squid catches were 0.1–0.5 t.

In 2019, the main reason for weak squid feeding approaches to the coastal areas of Primorsky Krai and the Tatar Strait was related to the intensive Primorsky Current and weak advection of subtropical waters to the coast in summer and fall. Thus, in early August 2019, the TC fishery was conducted south of Olga Bay. Olga at the southern periphery of the mesoscale anticyclonic eddy and in the warmer waters of the Tsushima Current (Fig. *6a*). The largest catch of 0.17 t was recorded at the "cap" of the eddy dipole, while smaller catches were recorded in the frontal zone. In early September, significant catch of 17.4 t of TC was recorded in the area of the middle Primorsky Krai at the southern periphery of a mesoscale anticyclonic eddy (Fig. *6b*). Successful fishing was conducted north of on the coastal front. In late September, with the retreat of subtropical waters southward, the fishing area also shifted southward. Fishing for TC (catches of 0.3–0.4 tons) was conducted in the moray zone south of Nakhodka Bay. Finding not only in the center of the anticyclonic eddy at the top of the warm jet current, but also at its northern periphery (Fig. *6c*). The eddy had a spiral structure, and relatively cold subarctic waters were observed flowing into it. The TC catches

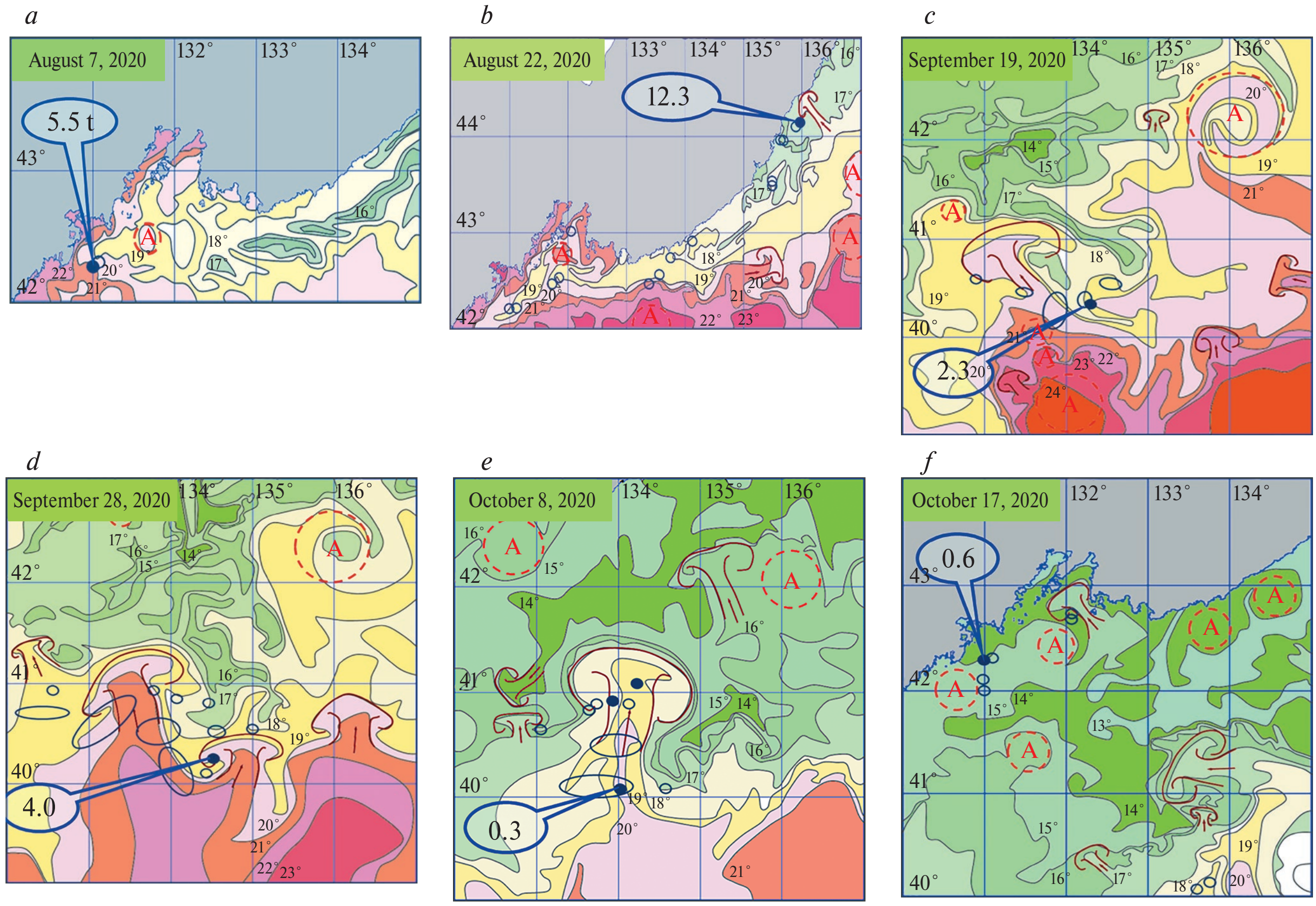


Fig. 7. Maps-schemes of the thermal structure of waters constructed from satellite observations with squid fishing areas in the Sea of Japan for August-October 2020. Notation: see Fig. 5.

associated with the frontal zone were at the northern periphery of the neighboring mesoscale eddy, which ended the jet invasion of subtropical waters at 134°E. The squid fishing was conducted at the northwestern periphery of the mesoscale anticyclonic eddy at the top of the warm subtropical water inlet with a temperature of 23 °C (Fig. *6d*). There was a catch of 0.88 t at its northwestern periphery, but the largest catch of 1.1 t was observed in the center of the mesoscale anticyclonic eddy with center coordinates 40°12’N, 133°25’E. The mesoscale anticyclonic eddy (Fig. *6d*), in which the maximum catch was observed on September 30, increased and its spiral structure was manifested. The eddy was fed by water from a large anticyclonic eddy and a jet current from the west. The marked eddy appeared to be common in the packing of the two mushroom-shaped currents, within which a catch of 0.22 t was observed. To the north, 0.3 t were caught in the main jet of a mushroom-shaped structure from the waters of the East Korea Current, whose eddy dipole located between 41–42°N and 133°E. Some small catches were associated with eddy interaction zones. In mid-October, the general temperature background decreased, and commercial aggregations were again found at the northern periphery of a large anticyclonic eddy at 18 °C (Fig. *6e*).

The hydrological conditions in 2020 differed significantly from the two previous years. In summer, the intensity of the Primorsky Current was high and the East Korean Current was low. Only some insignificant jet currents reached the Peter the Great Bay. Only some insignificant jet currents reached Peter the Great Bay. In general, the squid fishing areas were connected with subtropical water flows, anticyclonic eddies, mushroom-shaped currents in their tops and also in the zone of interaction of eddy structures. Thus, in the top of a warm current at a temperature of 19–20 °C, a catch of 5.5 tons of TC was recorded (Fig. *7a*). The map for August 22 shows the coordinates of fishing sites from August 21 to 31 (Fig. *7b*). Compared to the beginning of August, the advection of warm waters to the north increased, and squid fishing was conducted on the coastal front, in the zone of interaction between warm and relatively cold waters of the PGB (catches from 0.3 to 1.5 t). A large catch

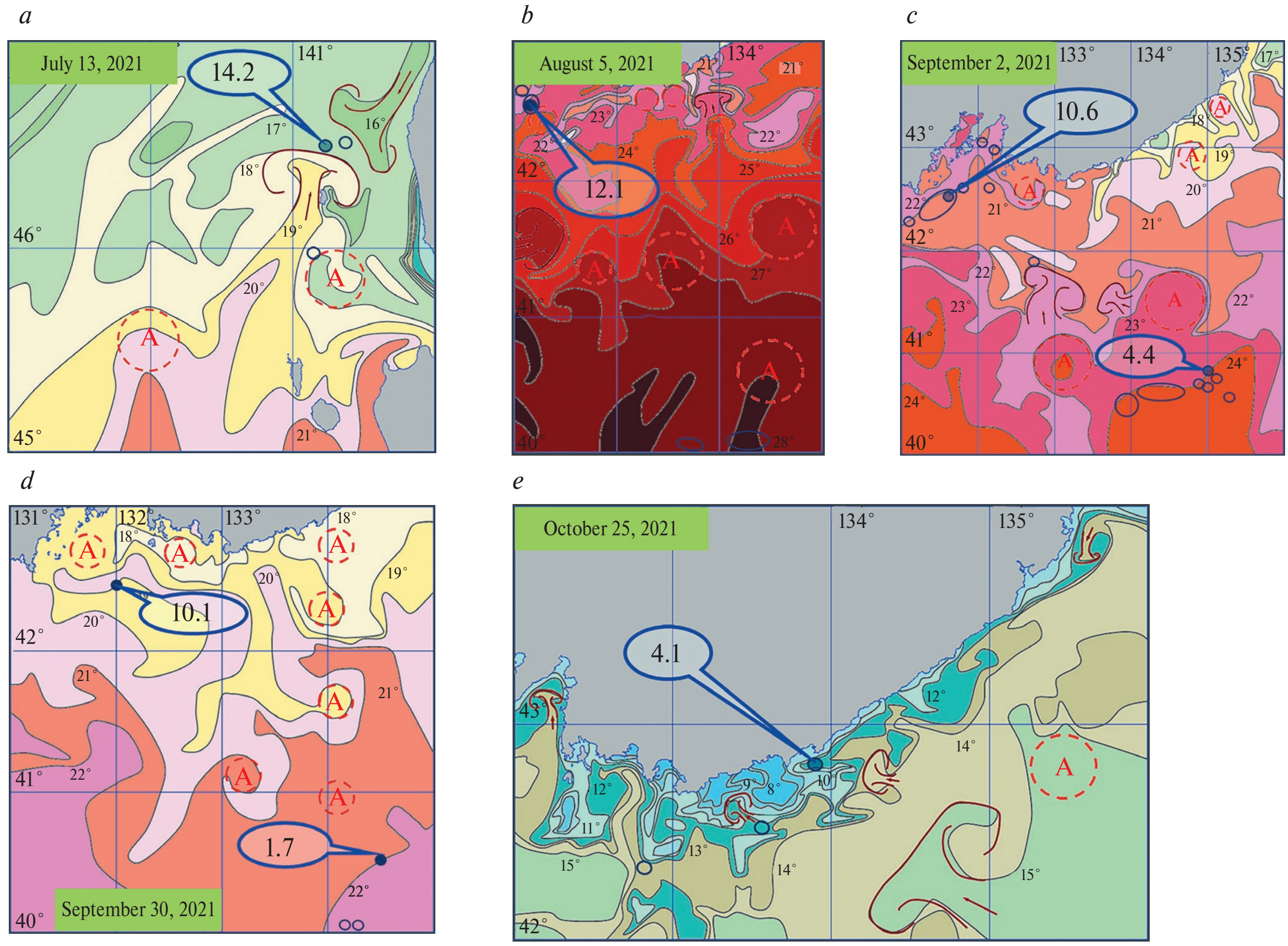


Fig. 8. Maps-schemes of the thermal structure of waters constructed from satellite observations and with squid fishing areas in the Sea of Japan for July-October 2021. Symbols: see Fig. 5.

of 12.3 t was recorded only in the vicinity of the cyclonic eddy of the mushroom-shaped mesoscale current near the coastal front. In September, the fishery was in the intrusions of warm waters of the second branch of the Tsushima Current at water temperatures of 19–21 °C, where the maximum catch was 2.3 t (Fig. *7c*). The entire fishery was conducted between 133–135° E in heterogeneities of the moribund branch of the warm current (Fig. *7d*). The largest catch of 4 t was recorded in the cyclonic eddy of the mushroom-shaped current, which separated from the main flow in the northeastern direction. In early October, fishing areas were in the main jet of the moribund branch of the warm current at 134° E, where catches were 0.3 t at water temperatures of 19–20° C (Fig. *7d*). Insignificant catches were observed in the cyclonic eddy of the dipole formed at the top of the dipole and in the anticyclonic eddy of the mesoscale mushroom current. In mid-October, small catches of squid were observed in the PGB (Fig. *7e*), and one fishing area was located in the zone of interaction of the established anticyclonic eddy with relatively warm waters of the East Korean Current and subarctic coastal waters.

The largest catch was 0.6 tons. Fishing was also conducted in the southern part of the Ussuriysky Bay at the periphery of the cyclonic eddy of the mushroom-shaped current with water temperature of 15 °C.

In 2021, the squid fishery started earlier than in previous years because the Tsushima Current and its branches were already intense in June. The main squid fishing areas were: the PGB and the moribund branch of the Tsushima Current between 133–134°E. (Figure 8). In July, squid was also caught in the southern part of the Tatar Strait. The intrusion of the Tsushima Current waters into the southeastern part of the Tatar Strait resulted in the formation of a mesoscale mesoscale in the area of Moneron Island. A mesoscale mushroom-shaped current was formed near Moneron Island (Fig. *8a*). Commercial accumulations of TC were observed in the anticyclonic eddy near Moneron Island. The largest catch of 14.2 tons was recorded

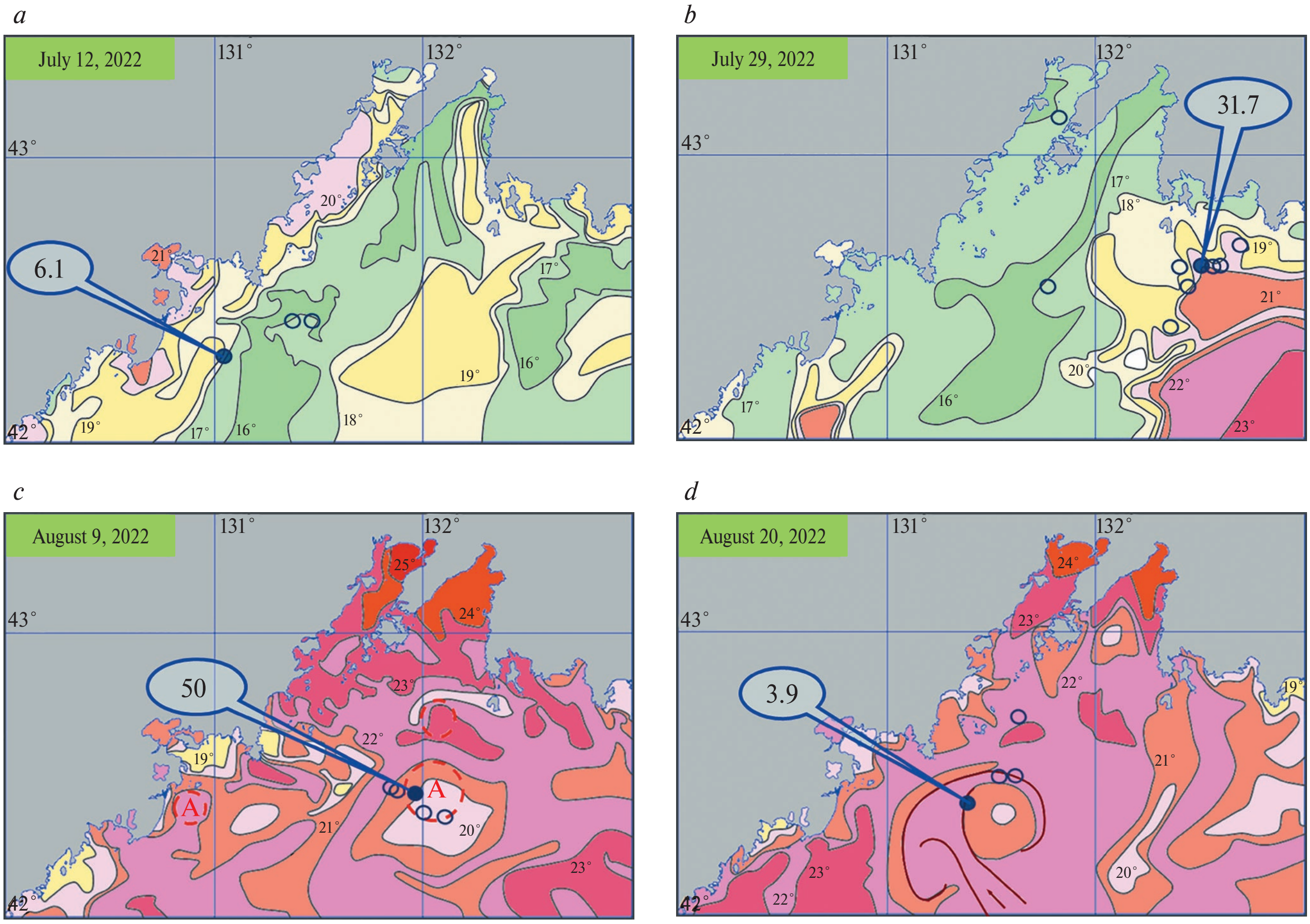


Fig. 9. Maps-schemes of the thermal structure of waters constructed from satellite observations with squid fishing areas in the Sea of Japan for July-August 2022. Symbols: (see Fig. 5).

at the top of the "cap" of the mushroom-shaped current at 17–18 °C. In general, fishing areas were associated with subtropical water flows and their interaction with subarctic waters (Fig. 8d, *e*).

During the 2022 fishing season, the main areas of fishing for TC were the PGB, its central and northeastern parts (Fig. 9), which were connected with warm water inlets by the East Korean and moribund currents (Fig. 9a, *b*). Fishing was mainly observed in the central part of the bay in the subtropical water inlets on the low-gradient front and in the zone of small-scale eddies (Fig. 9c, *d*). In the middle of August, with the retreat of warm waters and weakening of the moribund branch of the warm current against the background of strengthening of the Seaside Current, the TC fishery ended. Further, the squid approaches to the PGB were insignificant

In 2023, the squid fishery began in the PGB in the third decade of July with the approach of warm waters of the East Korean Current to the bay and their interaction with the waters of the Primorsky Current, which was characterized by strong intensity (Fig. *10a*). Its waters occupied the entire coastline of Primorsky Krai. The advection of the Tsushima Current was weak. In late August and early September, Russian vessels continued fishing for TC at the southern boundary of the PGB in the warm water inlets, while foreign vessels fished in the moribund zone (40,5°N, 135,2°E) (Fig. 10b, *c*).

The distribution of Pacific squid fishing areas in September 2018–2023 showed that in 2018squid aggregations were observed in the northern area and in the southern part of the Tatar Strait (Fig. *11a*). In subsequent years, fishing areas were observed much further south (Fig. 11b, *c, d, e*). Despite favorable hydrological conditions in the Sea of Japan, no significant northward migration of TCs was observed, which may indirectly indicate low TC abundance in the Sea of Japan, since in years of high abundance the Pacific squid fishing areas reach the Tatar Strait, while in years of low stock levels the fishing areas reach Olga Bay at best, and in recent years — Peter the Great Bay.

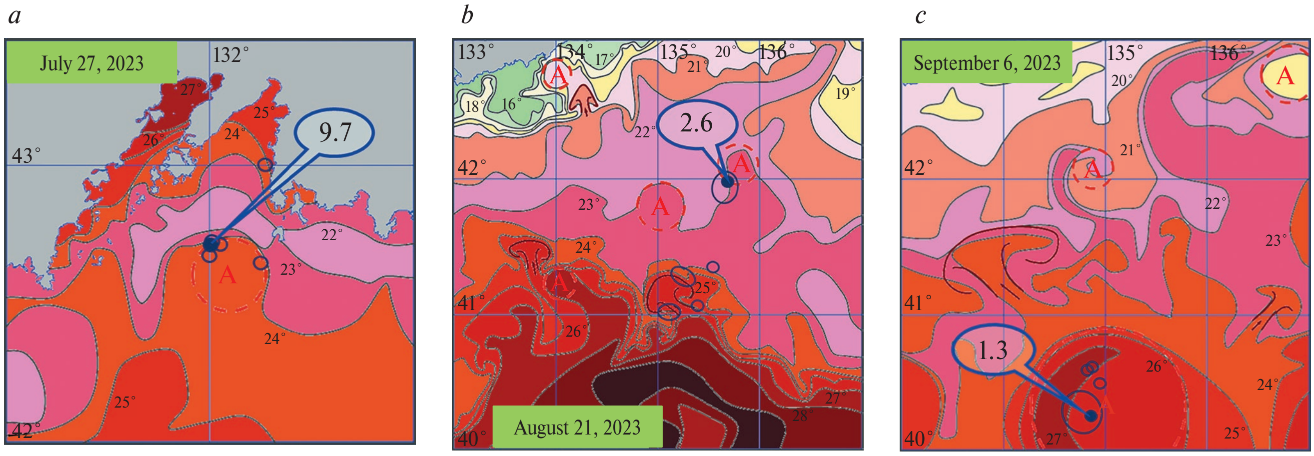


Fig. 10. Maps-schemes of the thermal structure of waters constructed from satellite observations with squid fishing areas in the Sea of Japan for July-September 2023. Symbols: (see Fig. 5).

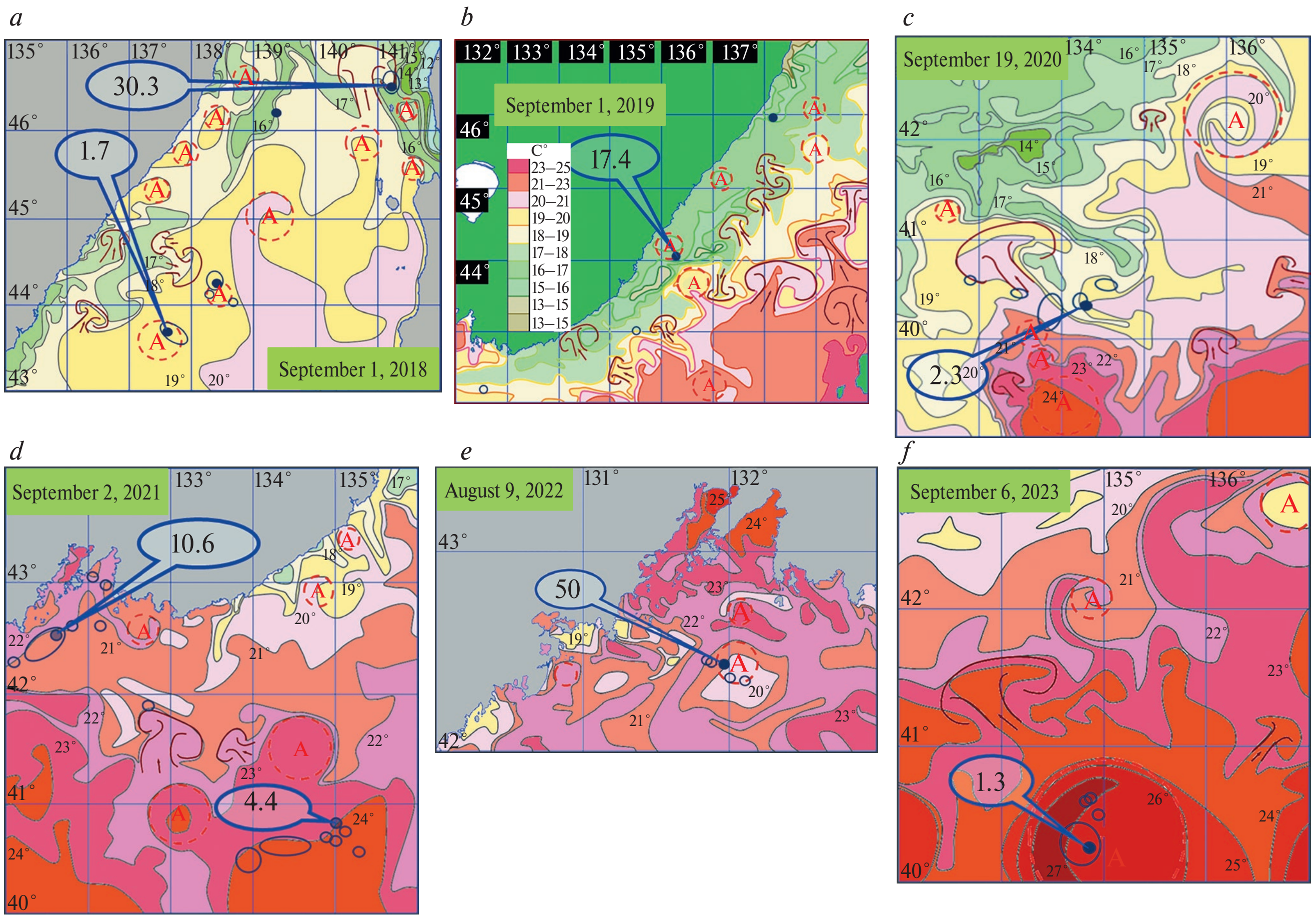


Fig. 11. Maps-schemes of the thermal structure of waters constructed from satellite observations with squid fishing areas in the Sea of Japan in September 2018–2023. Notation: (see Fig. 5).

CONCLUSION

In the field of spatial distribution of ocean surface temperature, elements of the structure of waters in which the Pacific squid fishery was successful were determined. Comparison of the elements of hydrological situation, interpreted from infrared satellite images, with fishing areas allowed to establish that the formation of TC fishing areas depended on the development or weakening of branches of the Tsushima and

Primorsky currents, the presence of mesoscale eddy structures in their waters. The accumulations of TCs in most cases were confined to areas of eddy upwelling. The maximum catches were concentrated at the periphery of subtropical anticyclonic eddies bordering subarctic waters. If the eddy had a spiral structure, the accumulations are mainly concentrated in the center of the eddy. If the outflow of subtropical waters took the form of a mushroom-shaped current, large catches were mainly noted in the jet stream and in the zone of anticyclonic and cyclonic eddies of the dipole. In the frontal zone of subtropical and subarctic waters, squid fishing areas were located on the warm side of the Subarctic (Polar) front. It was noted that with the decrease of squid abundance the geography of fishing areas also changed.

This work was carried out to accumulate statistical data on the location of commercial aggregations of TC in a particular hydrological structure identified from satellite data and to improve short-term forecasting during the fishing season.

REFERENCES

1. *Aleksanin A.I., Aleksanina M.G.* Monitoring termicheskih struktur poverhnosti okeana po dannym IK-kanala sputnikov NOAA na primere Prikuril'skogo rajona Tihogo okeana // Sovremennye problemy distancionnogo zondirovaniya Zemli iz kosmosa. Fizicheskie osnovy, metody i tekhnologii monitoringa okruzhayushchej sredy, potencial'no opasnyh yavlenij i ob"ektov. Iss. 3. Vol. II. Moskva, OOO «Azbuka-2000». 2006. Pp. 9–15 (In Russian).

2. *Belonenko T.V., Kozub P.K.* Vihrevoj apvelling kak mekhanizm sozdaniya blagopriyatnyh uslovij skoplenij sajry v YUzhno-Kuril'skom rajone // Sovremennye problemy distancionnogo zondirovaniya Zemli iz kosmosa, 2018. Vol. 15. No. 1. Pp. 221–232. 18

3. *Bulatov N.V., Samko E.V., Cypysheva I.L.* Okeanologicheskie obrazovaniya, blagopriyatnye dlya koncentracii pelagicheskih ryb po infrakrasnym dannym ISZ NOAA / Sovremennye problemy distancionnogo zondirovaniya Zemli iz kosmosa. 2008. Vol. 2. No. 2. Pp. 49–61 (In Russian).

4. *Ginzburg A.I., Kostyanoj A.G., Ostrovskij A.G.* Poverhnostnaya cirkulyaciya YAponskogo morya (sputnikovaya informaciya i dannye drejfuyushchih buyov) // Issledovaniya Zemli iz kosmosa. 1998. No. 1. Pp. 66–83 (In Russian).

5. *D'yakov B.S.* Vliyanie cirkulyacii vod na prostranstvennoe raspredelenie promyslovyh skoplenij tihookeanskogo kal'mara v YAponskom more // Izv. TINRO. 2003. Vol. 134. Pp. 258–265 (In Russian).

6. *Mokrin N.M., Slobodskoj E.V.* Rukovodstvo po poisku i promyslu pelagicheskih kal'marov v Yaponskom more i Yuzhno-Kuril'skom rajone. Vladivostok. TINRO-centr. 1998. P. 61 (In Russian).

7. *Mokrin N.M., Hen G.V.* Okeanologicheskie osnovy raspredeleniya, migracii i dinamiki chislennosti tihookeanskogo kal'mara // Gidrometeorologiya i gidrohimiya morej: Vol. VIII. Yaponskoe more. Iss. 2. SPb.: Gidrometeoizdat. 2004. Pp. 248–255 (In Russian).

8. *Nikitin A.A.* Osnovnye cherty prostranstvennogo raspredeleniya frontov v vodah Yaponskogo morya i ih izmenchivost' // Issledovaniya Zemli iz kosmosa. 2006. No. 5. Pp. 49–62 (In Russian).

9. *Nikitin A.A., Yurasov G.I.* Sinopticheskie vihri YAponskogo morya po sputnikovym dannym // Issledovanie Zemli iz kosmosa. 2008. No. 5. Pp. 1–16 (In Russian).

10. *Nikitin A.A., Danchenkov M.A., Lobanov V.B.* Puti perenosa subtropicheskih vod v rajon Dal'nevostochnogo Morskogo zapovednika. /In: Dal'nevostochnyj morskoj biosfernyj zapovednik. Issledovaniya. Kollektivnaya monografiya. Otv. red. A. N. Tyurin. Vol. 1. Vladivostok. Dal'nauka. 2004. Glava V. Gidrologiya i meteorologiya rajona zapovednika. 2004. Pp. 314–319 (In Russian).

11. *Novikov Yu.V., Slobodskoj E.V. Shevcov G.A.* Vliyanie okeanologicheskih uslovij na raspredelenie i biologicheskie osobennosti massovyh vidov kal'marov v YUzhno-Kuril'skom rajone. Okeanologiya. Morskaya biologiya. 2007. Vol. 47. No. 2. Pp. 259–265 (In Russian).

12. *Savinyh V.F., Shevcov G.A., Karyakin K. A. Slobodskoj E.V., Novikov Yu.V.* Mezhgodovaya izmenchivost' migracij nektonnyh ryb i kal'marov v tihookeanskie vody yuzhnyh Kuril'skih ostrovov // Voprosy ihtiologii. Vol. 43. No. 6. 2003. Pp. 759–771 (In Russian).

13. *Samko E.V., Bulatov N.V.* Issledovanie svyazi polozheniya ringov Kurosio s teplym yadrom i raspredeleniya promysla sajry po sputnikovym dannym // Issledovaniya Zemli iz kosmosa. No. 2. 2014. Pp. 18–26 (In Russian).

14. *Fedorov K.N., Ginzburg A.I.* Pripoverhnostnyj sloj okeana // Leningrad, Gidrometeoizdat. 1988. P. 303 (In Russian). 19

15. *Shuntov V.P.* Biologiya dal'nevostochnyh morej Rossii. Vladivostok: TINRO-Centr. Vol. 2. 2016. P. 604 (In Russian).

16. *Gong Y., Jeong H.D., Suh Y.S., Park J.H., Seong K.T., Kim S.W., Choi K.H., An I.S.* Fluctuation of Pelagic Fish Populations in Relation to the Climate Shifts in the Far-East Region // J. Ecol. Field Biol. 2007. No. 30 (1). Pp. 23–38.

17. *Kasahara S.* Descriptions of offshore squid angling in the Sea of Japan, with special reference to the distribution of common squid (Todarodes pacificus Steenstrup); and on the techniques for forecasting fishing conditions // Bull. Jap. Sea Reg. Fish. Res. Lab. — 1978. — Vol. 29. — Pp. 179–199.

18. *Kidokoro H., Goto T., Nagasawa T., Nishida H., Akamine T., and Sakurai Y.* 2010. Impact of a climate regime shift on the migration of Japanese common squid (Todarodes pacificus) in the Sea of Japan. — ICES Journal of Marine Science, 67: 1314–1322.

19. *Mokrin N.M., Novikov Yu. V., Zuenko Yu.I.* Seasonal Migrations and oceanographic conditions for concentration of rhe Japanese flying squid (todarodes pacificus steenstrup, 1980) in the northwestern Japan Sea. Bulletin of marine science. 2002. Vol. 71(1). Pp. 487–499.

20. *Sakurai Y., Kidokoro H., Yamashita N., Yamamoto J., Uchikawa K., H. Takahara.* Todarodes pacificus, Japanese common squid // Rosa R. Pierce G. O'Dor R. (ads.). Advances in squid biology, ecology and fisheries. Pt. 2: Oegopsid squids. New York: Nova Science Publishers. 2013. Pp. 250–270.