Oceanographic and biological conditions ensuring the presence of a high productive bottom community in the Marine feeding area of gray whales near north-eastern Sakhalin Island

Sakhalin branch of the FSBSI “VNIRO” (“SakhNIRO”)

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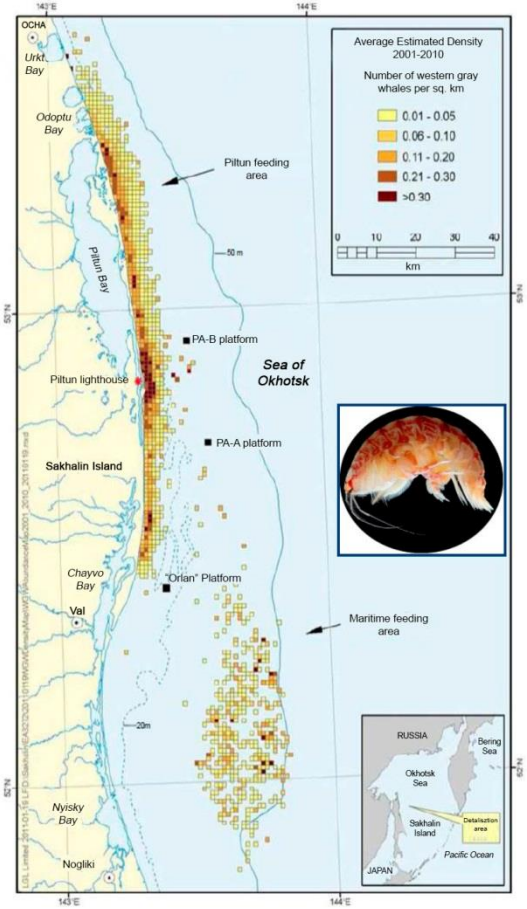
Introduction



In recent years, the main feeding area for gray whales of the Okhotsk-Korean population off North-Eastern Sakhalin became the Marine feeding area, which is due to the presence of specific bottom communities and their high productivity (Labay et al., 2019).

Based on the composition and structure of those bottom communities with the predominance of amphipods *Ampelisca eschrichtii*, two conditions must be met for the high productivity of benthos:

1. A significant volume flow of feed organic matter from surface to bottom
2. A relatively high temperature in the bottom water layer for the intensification of production processes in benthos

Labay V.S., Kim Sung Tok, A.V. Smirnov, V.N. Chastikov and others. The assessment of ecological capacity of the environment for gray whales (*Eschrichtius robustus*) in known feeding areas off the northeast coast of Sakhalin Island // Holarctic marine mammals. Collection of scientific papers. 2019. T. 1. – Moscow, 2019. – P. 174–185.

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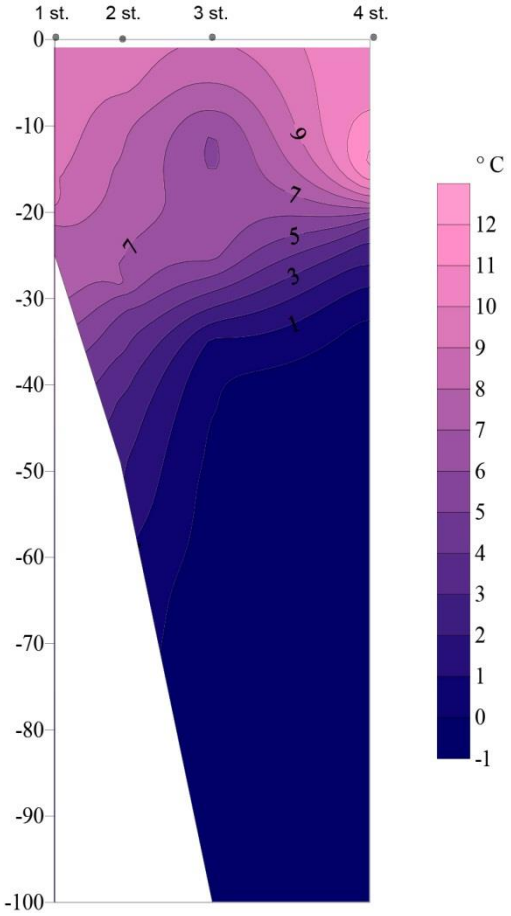


The existing water mass structure of the Sea of Okhotsk during the warm season, namely the presence of the so-called Cold Intermediate Layer (CIP), prevents the implementation of those conditions.

To eliminate this contradiction, the authors' team even hypothesized the winter phase of active production of *Ampelisca eschrichtii* in the Offshore Feeding Area, when vertical stratification is absent
(Durkina et al, 2018).

Against this hypothesis:

1. In winter, the minimum production of phytoplankton, the main supplier of organic matter to the aquatic ecosystem, is observed
2. Low water temperature, which reduces the intensity of production of bottom hydrobionts to a minimum

Durkina V.B., Chapman J.W., Demchenko N.L. (2018), *Ampelisca eschrichtii* Krøyer, 1842 (Ampeliscidae) of the Sakhalin Shelf in the Okhotsk Sea starve in summer and feast in winter. PeerJ 6:e4841; DOI 10.7717/peerj.4841

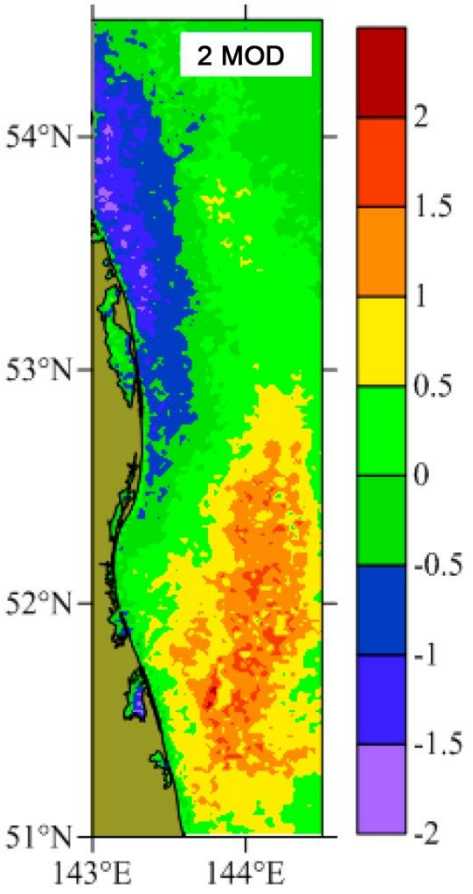
Introduction

The analysis of satellite data showed that the Offshore feeding area is characterized by a high concentration of chlorophyll-*a* and, consequently, by active production of phytoplankton in the summer period (Labay et al., 2019).

Questions:

1. How do nutrients from the bottom horizon enter the surface to support photosynthesis processes, crossing the pycnocline and thermocline boundary?
2. How does organic matter of plankton get from the near-surface horizon to the bottom horizon, crossing the boundary of the pycno- and thermocline?

Main issues of the Offshore Feeding Area aquatic ecosystem functioning



Labay V.S., Kim Sung Tok, A.V. Smirnov, V.N. Chastikov and others. The assessment of ecological capacity of the environment for gray whales (*Eschrichtius robustus*) in known feeding areas off the northeast coast of Sakhalin Island // Holarctic marine mammals. Collection of scientific papers. 2019. T. 1. – Moscow, 2019. – P. 174–185.

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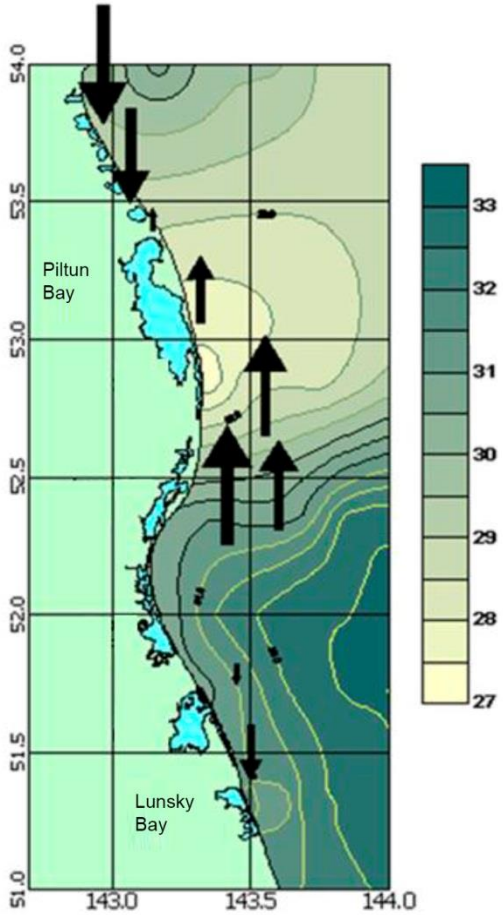


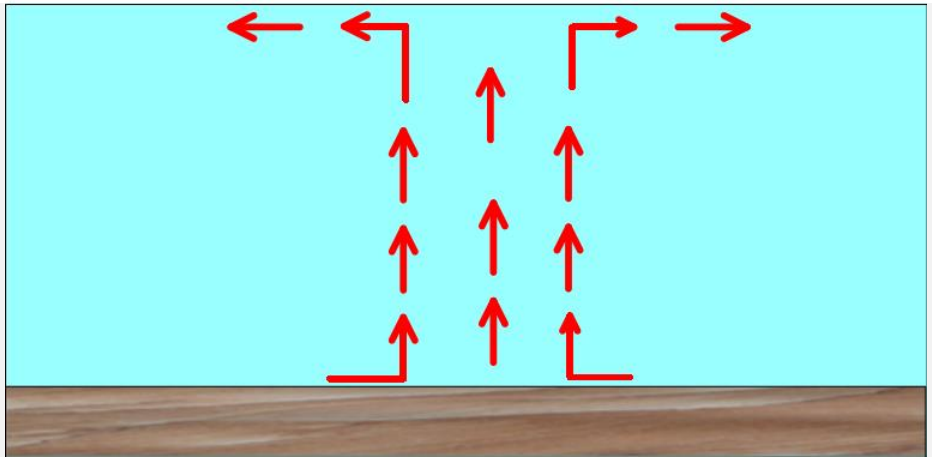
The main specific feature of oceanological conditions is the existence of daily shelf waves of tidal origin. They cause abnormally strong daily tidal currents **(up to 1 m/s)** . The wavelength is very small for tidal variations - about **300 km**, it fully fits in the section from Elizabeth Cape to Lunsky Bay. Physically, these waves are two alternating vortices that change their sign every **12 hours**.

There is an anticyclonic vortex in the northern section and surface water deepening in the coastal (Piltun) feeding area). In the southern part (Offshore feeding area) there is a zone of divergence, cyclonic vortex and water rise to the surface.

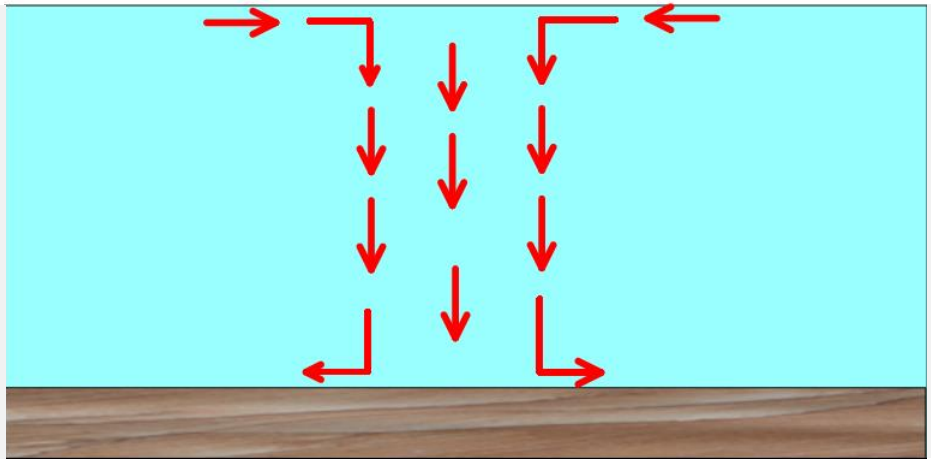
This allowed the hypothesis of intensive vertical mixing in the Offshore feeding area, which could cause high productivity (Labay et al., 2019).

Salinity distribution in August 1990.
(special FEMGEC footage for one phase of the tide).
The arrows show the size and direction
of the tidal current.

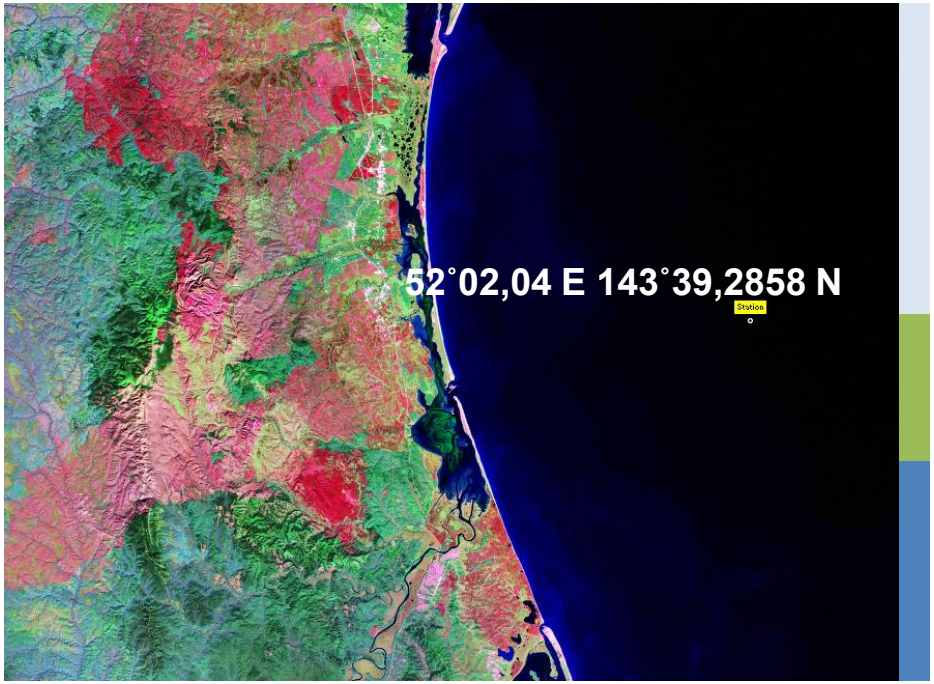
Introduction



Primitive graphic representation of hydrological processes in progress



The purpose of the work is to carry out hydrological and hydrobiological monitoring at Ayashskay LA in 2019 and to clarify the hydrological parameters of the environment, resulting in unique conditions for the existence of feeding areas of gray whales in north-eastern Sakhalin.

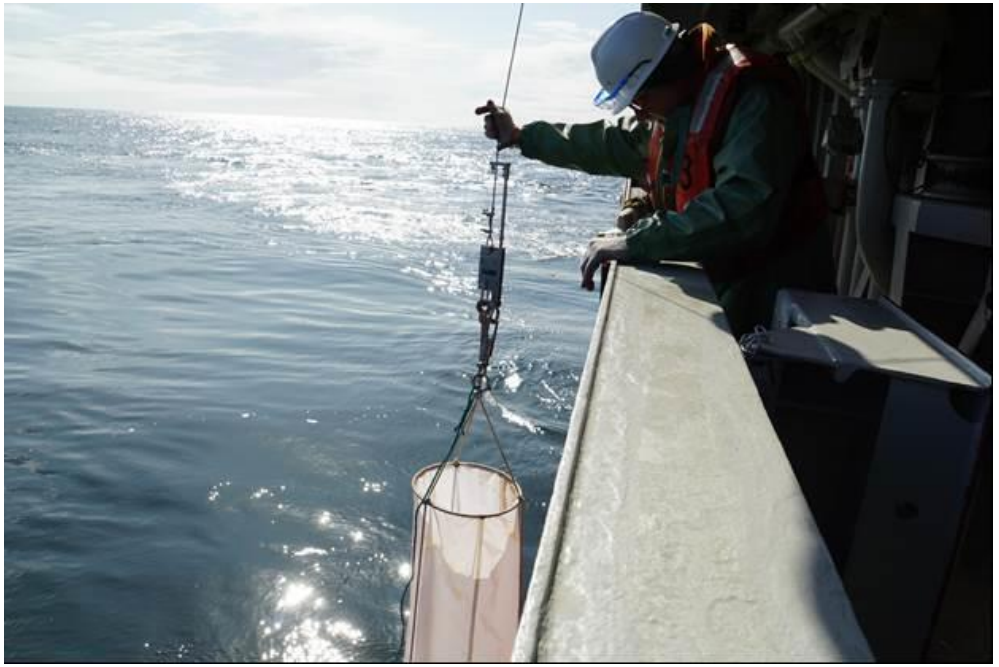


1. SOMS (oceanographic mooring station) installation (16/09-19/10/2019)
2. 3 daily stations from 16 to 17 September (9 temporary stations), 27 to 28 September (7 stations) and 19 to 20 October (9 stations) were made.

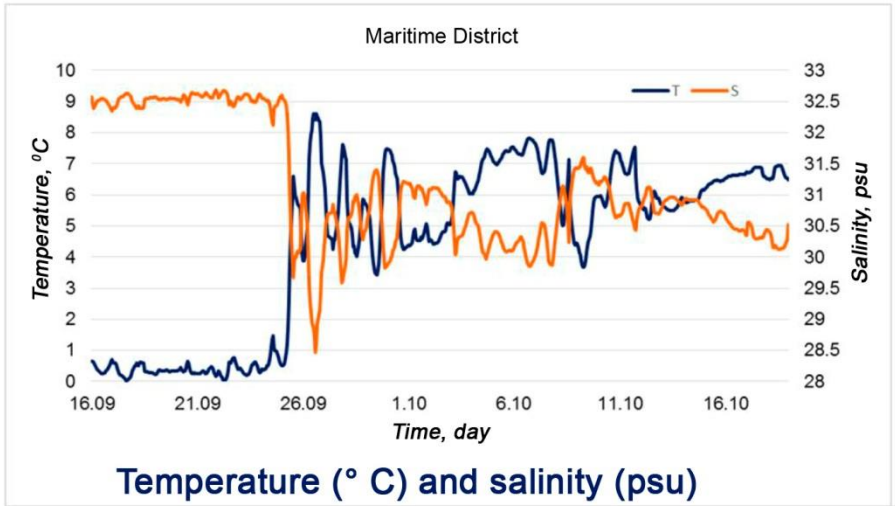
- Periodicity - 3 hours:
  T, S, chlorophyll-a with vertical intervals of 1 m;
  phytolankton (0 m, 15 m, 40 m);
  zooplankton (0-15 m and 15 m - bottom).

5*

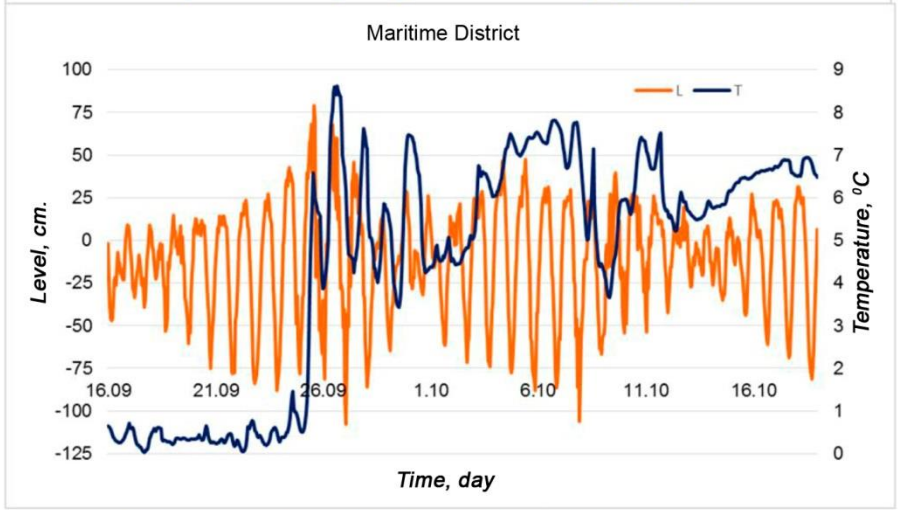
Methods



Results: hydrological regime: SOMS



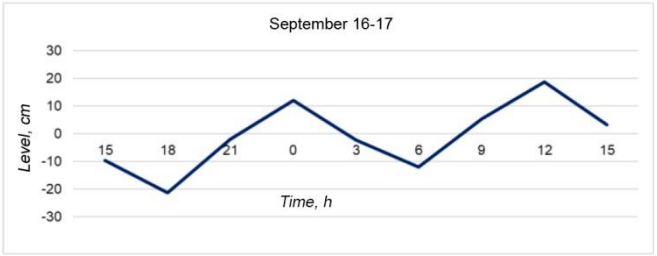
Temperature (° C) and salinity (psu)



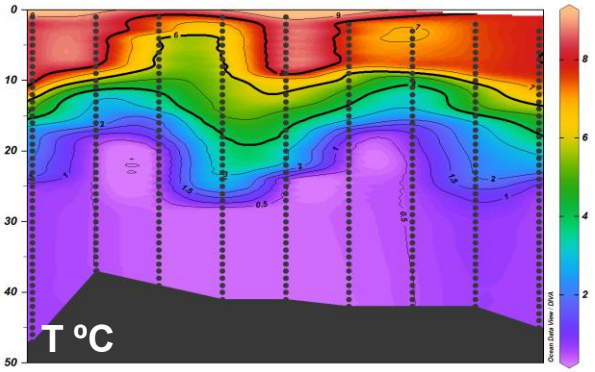
Temperature (° C) and level (cm)

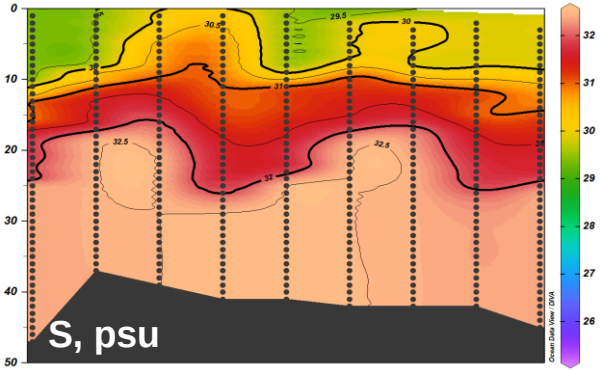
Measurement results of the oceanographic mooring station (OMS):
Measurements of temperature and salinity at a depth of about 43 m revealed significant daily variations of the oceanological elements and a sharp deepening of surface waters on 26-27 September as a result of wind field changes for the winter monsoon.

Results: hydrological regime: daily station September 16-17



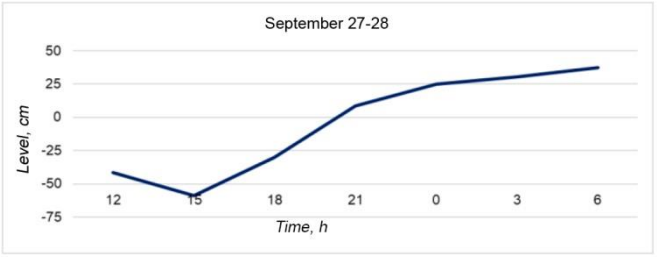
Tidal level



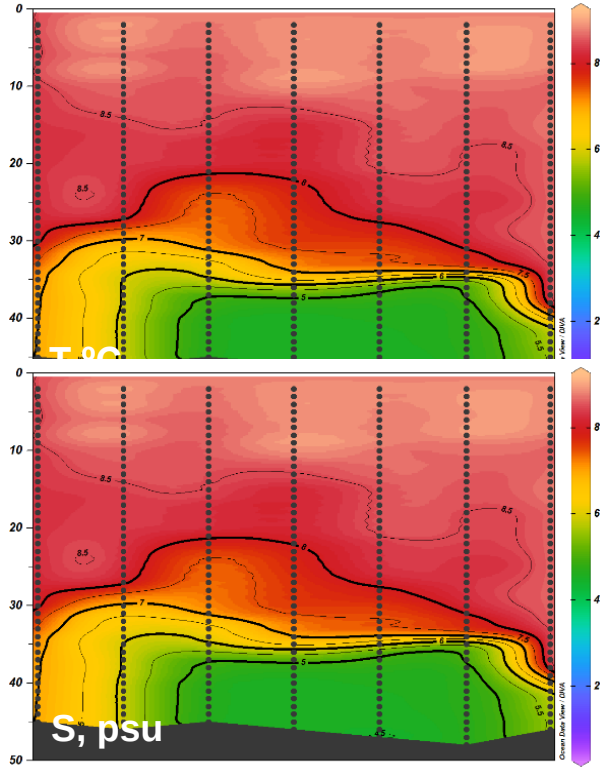


- Clearly pronounced deepening of surface warm water on the tide of cold water rise at low tide was detected.
- The depth variations of the isotherms were about 10 m despite the relatively low tide.
- Vertical changes in salinity were similar - lower tidal surface waters and the rise of saltier, nutrient-rich waters from depth.
- Variations in the depth of isogalines were also about 10 m.

Results: hydrological regime: daily station September 27-28

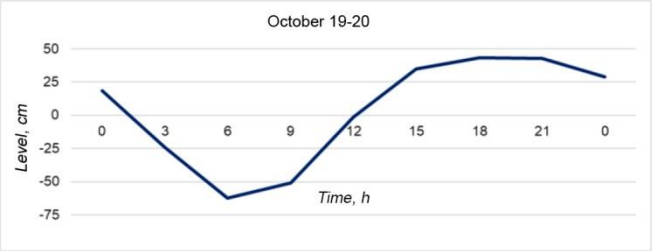


Tidal level

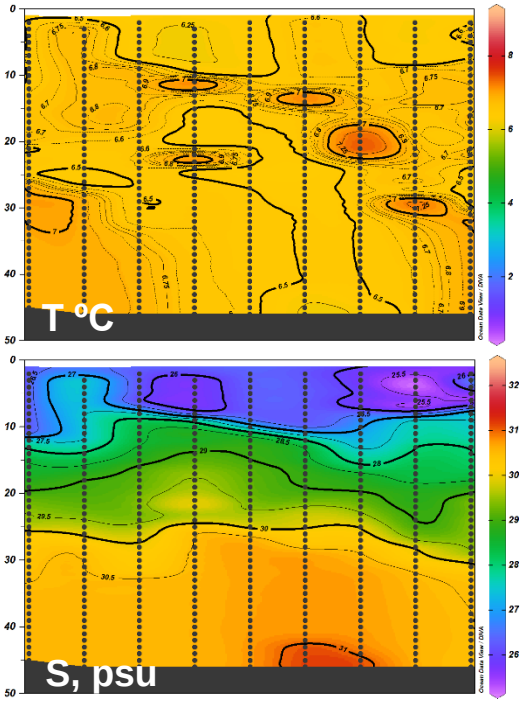


- The time of footage coincided with the beginning of seasonal surface water deepening as a result of wind field redevelopment from summer to winter monsoon.
- Alongside with this large-scale process, there is a marked deepening of surface warm water at high tide and a rise of cold water at low tide, especially in the lower layers.
- Vertical changes in salinity were similar - lower tidal surface waters and the rise of saltier, nutrient-rich waters from depth.

Results: hydrological regime: daily station October 19-20

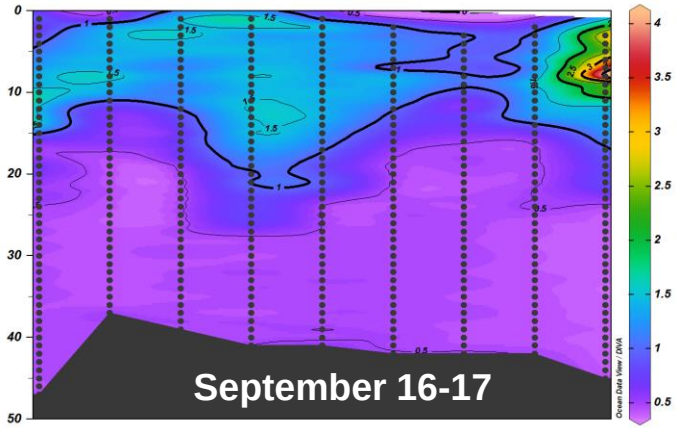


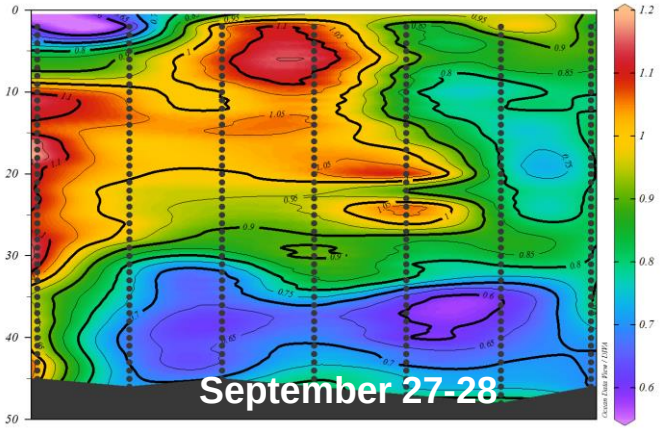
Tidal level

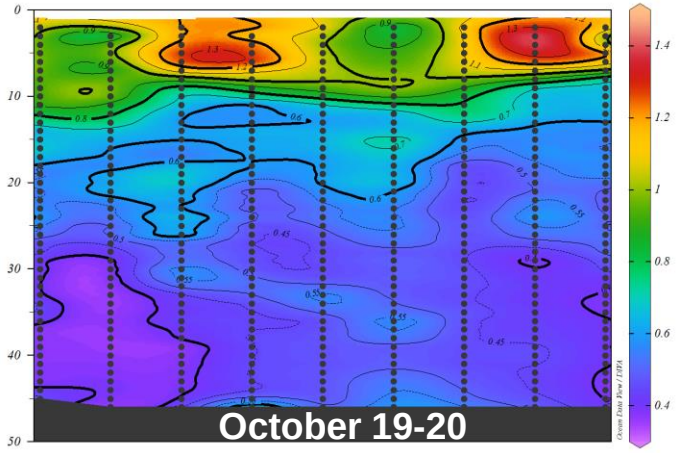


- Seasonal deepening of surface waters as a result of wind field changes from summer to winter monsoon has already occurred, the water temperature has almost evened out vertically.
- The tidal depth can be clearly seen from the position of the lens by the warmer water.
- In contrast to temperature, the vertical distribution of salinity is not homogeneous, although in general it has decreased throughout the layer by about 1.5-2 psu.
- The variations caused by the tides are noticeable, but weaker than in the "summer" character of the stratification on September 16-17.

Results: chlorophyll-*a*, mcg/l

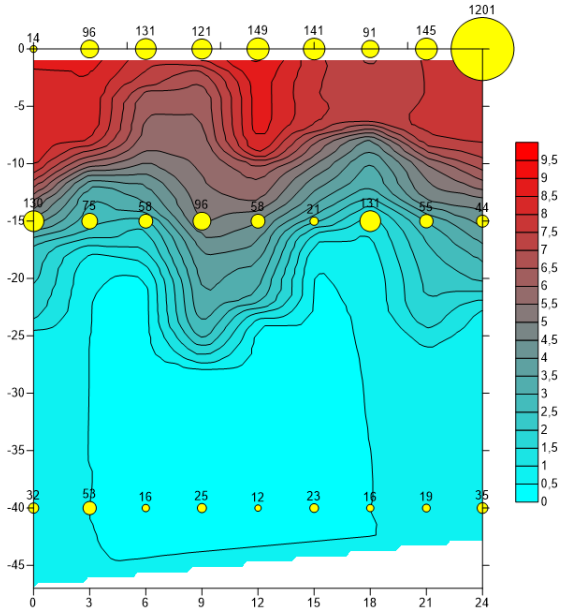




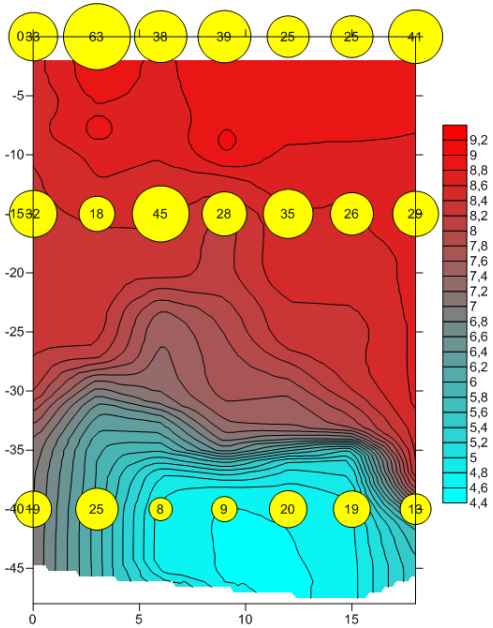


- The deepening of surface waters with a high content of phytopigment at high tide and the rise of nutrient-rich waters from the depth at low tide is noted.
- In autumn, the vertical distribution of chlorophyll is homogeneous.
- The variations caused by tides are noticeable in the surface horizon, but are weaker than in the "summer" nature of stratification.

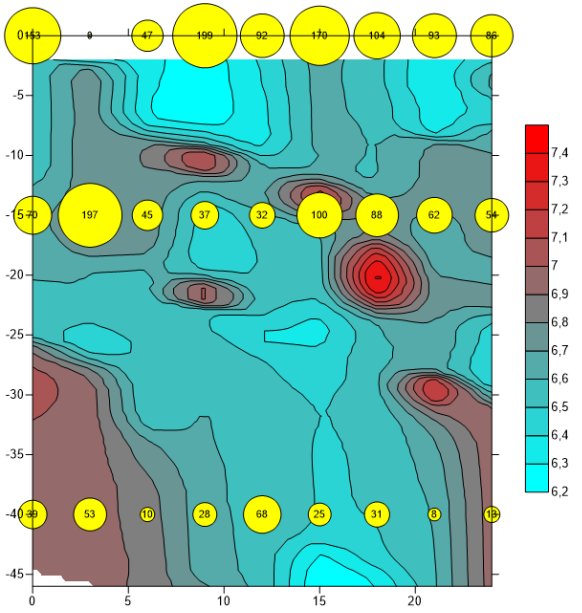
Results: phytoplankton: density, thousand c/l



September 16-17



September 27-28

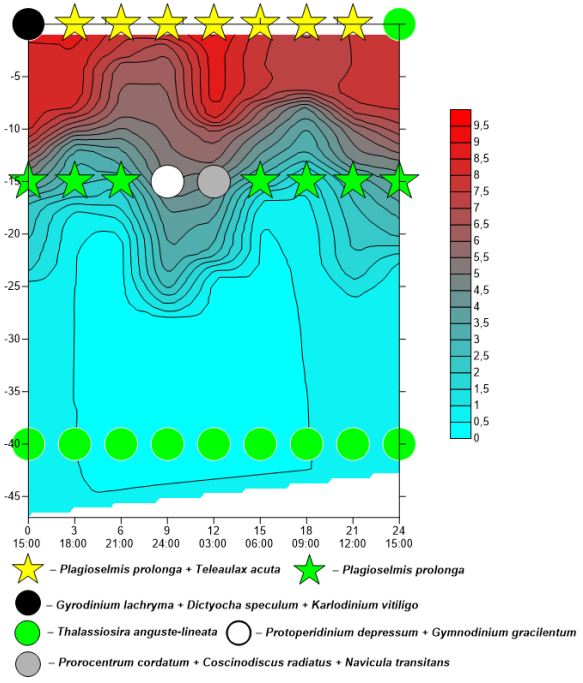


October 19-20

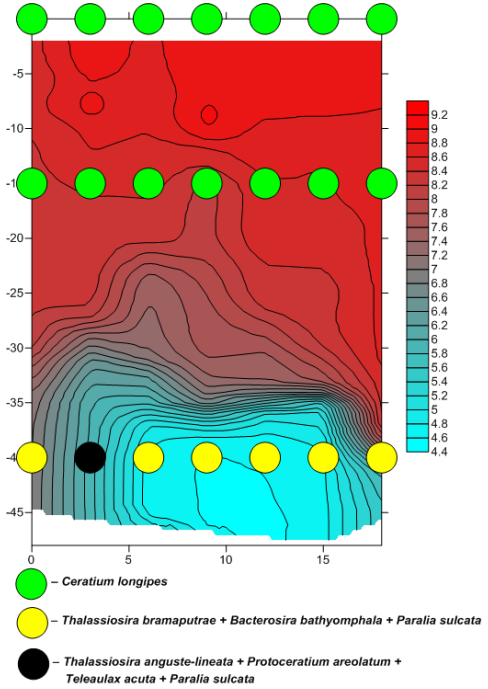
Diurnal variability and vertical transfers of phytoplankton concentrations in summer are observed, as for chlorophyll-a.
Surface water with a high content of phytoplankton at high tide, which does not affect the bottom layer on September 16-17 and reaches the bottom on September 27-28, is noted.

In autumn, the vertical distribution of microalgae is not homogeneous.
The variations caused by the tides are visible on all horizons.

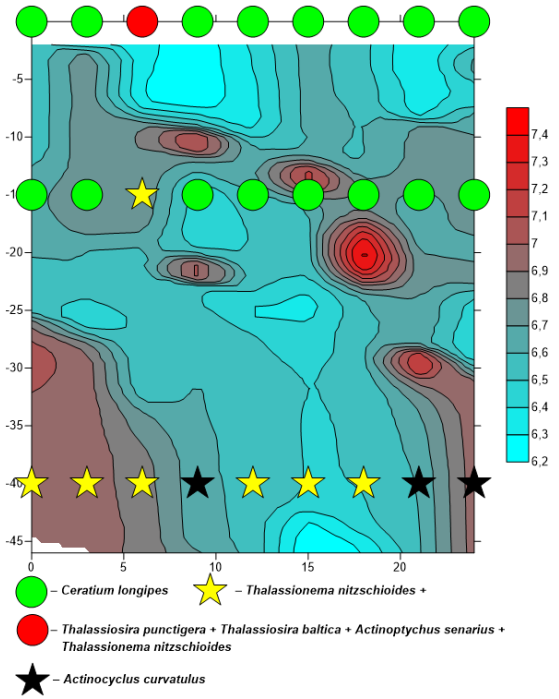
Results: phytoplankton: main communities



September 16-17



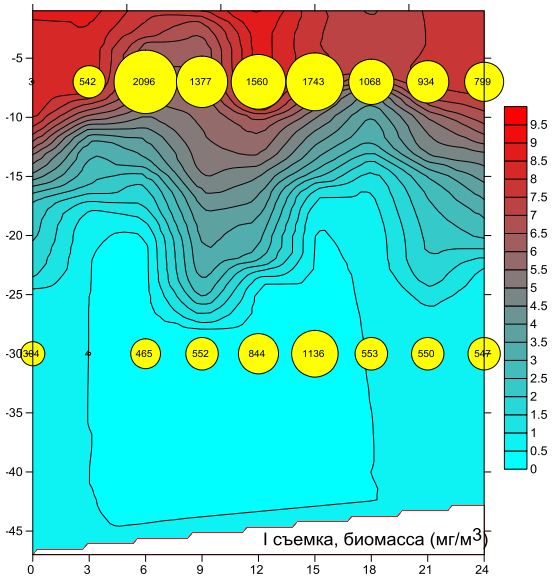
September 27-28



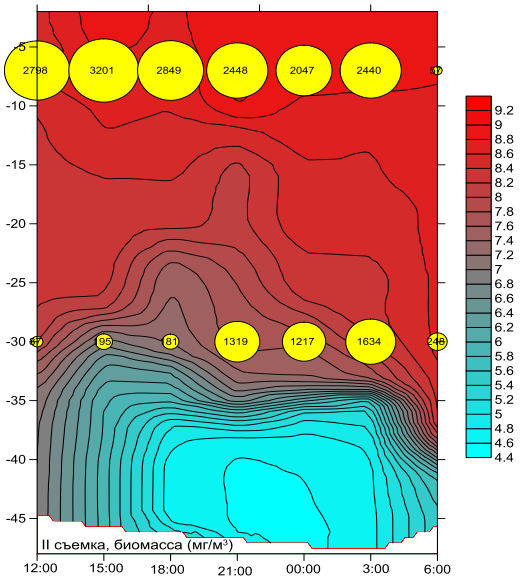
October 19-20

Diurnal variability of phytoplankton communities is observed in the zone of vertical convection: in summer, at small tides — in the surface and intermediate horizons, at large tidal amplitudes — in the bottom horizon, during autumn mixing-on all horizons.

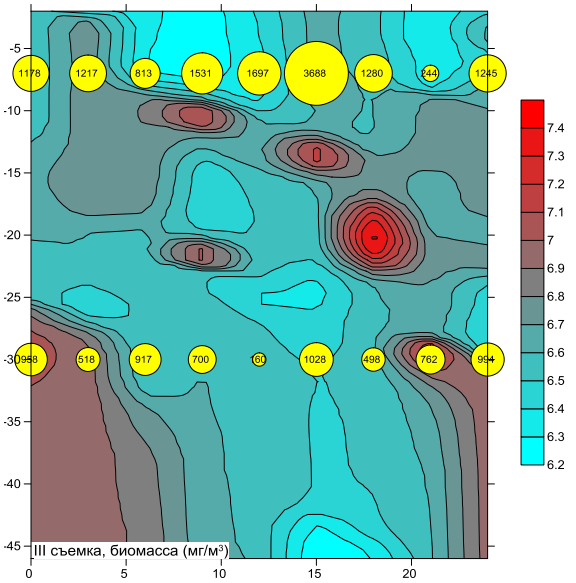
Results: zooplankton: biomass, mg/m^3



September 16-17



September 27-28



October 19-20

Daily variability of zooplankton biomass is observed in the area of vertical convections in summer and is most pronounced in the lower layer of large amplitudes of tides.

In autumn the variability of biomass corresponds to the general mixing of waters.

Results: zooplankton: features

- The average biomass of zooplankton during the study period ranged from 508.8 to 2231.9 mg/m^3 with an average value of 1126.8 mg/m^3. The minimum biomass was in the bottom horizon with average values 668.9 mg/m^3, while the maximum biomass was in the surface horizon -1584.8 mg/m^3.

- Average biomass was significantly higher than the average for the north-east Sakhalin shelf entire (for comparison, the average biomass of zooplankton varied from 276 mg/m^3 (2012) to 312 mg/m^3 (2018) for the Ayashskaya LA in general).

- Considerable **damage and destruction of various species of hydrobionts were observed**. The individual samples contained almost entirely necrotic plankton. During the first study, the proportion of dead plankton in some samples reached 80-99%. At the second stage, the share of necrotic plankton remained at the same level as during the first survey, the average value was 39.6%. During the third study, stations with good plankton condition prevailed, which also affected the total share of damaged plankton - no more than 22.8%.

Conclusions

- The studies explained the unique physical mechanism that leads to the Offshore feeding area for the gray whales of the Okhotsk-Korean population and provides intensive production of aquatic communities that serve as food for the gray whales.