MONITORING OF THE UPDATE STATE OF PETER THE GREAT BAY WATERS BASED ON OBSERVATIONS OF NOVEMBER 1999 – APRIL 2000

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Introduction

Seasonal processes in the shelf area of the Sea of Japan are still not sufficiently studied, because the main attention of investigators has been confined to the open sea. Now we've got the opportunity to research an annual cycle of hydrological variation in one of the extended shelf zones of the sea, namely, in Peter the Great Bay. Some studies concerning this theme are still not available for a wide circle of readers. Most complete studies of the northern part of Peter the Great Bay (Ussuri and Amur Bays) conducted in early 60^s are described by Lastovetskii (Lastovetskii & Vescheva, 1964).

From scientific point of view, during a cold period this region could be a potential area of intense ventilation and formation of deep waters of the Sea of Japan, as well as the area of the Tatar Strait. Besides the research aims, some practical purposes are to be found out, namely: extent of water contamination, composition and distribution of bottom sediments, seasonal variations of nutrients, their biological consumption and a mechanism of their restoration, and so on. In order to resolve these problems and to clear out some features of winter convection and ventilation, to reveal which way and where the dense and saline water formed due to the brine rejection extends to, we attempted to conduct the annual cycle of oceanographic observations aboard R/V “Lugovoye”.

The main motivation of this preliminary report is to show that an intense ventilation process might occur in this region and this process is related to the ventilation in the open sea area. In future, we can estimate quantitatively the bottom dense water formation. Besides, we can already estimate the scale of variability of nutrients and the rate of their biological consumption.

Data and Results of Observations

The program of observations includes four seasonal surveys consisting of about 100 CTD-stations and monthly CTD-observations at the conditional sections along 131°41'E and 132°E off the shore to the isobath of 200 m. Station spacing at the sections is 5 miles. Because of unusual complicated ice situation it was quite impossible to conduct surveys in January and February of 2000. So, we have four series of observations now (Fig. 1). Temperature and salinity measurements have been conducted using probe CTD-1000, Alec Co., Ltd. (Japan). Its accuracy is 0.01 °C and 0.02 psu for temperature and salinity relatively. Water samples have been taken at the specified depths for chemical and biological analysis using 5-liter Niskin bottles. Depths for water sampling have been defined after examining the temperature profiles, but in any case the samples at the sea surface and bottom horizons have been collected.

Some preliminary results are presented here. Sea surface distribution of hydrological characteristics in early March 2000 (Fig. 2) shows that the coldest water (temperature is less than -1.4 °C) is located to the north of 42.9°N in the central part of Ussuri Bay and probably in Amur Bay. The latter was covered by ice, thus there were no observations there. So we can only guess that there was the most cold and saline water if judged from the tongue of cold and saline (temperature less than -1.6 °C, salinity more than 33.9 psu) outflowing through the strait between the continent and Russky Island. Density distribution at the sea surface in March completely follows the salinity distribution. The most dense surface water was located near the western coast of the region. It is not surprising because the most dramatic changes in temperature and salinity occurred there (Fig. 3). Since the winter convection in the most part of the study area extends to the seabed it seems reasonable to trace the changes in water characteristics from November to March using their bottom distributions.

Temperature of the bottom water lowered by more than 7.0 °C and salinity rose by 0.45 psu in comparison with November values. So, temperature and salinity variations in equal degree are responsible for density increase in the western part of the region. In the eastern part density was much less increased because salinity changes were insignificant. This site was more influenced by advection of the deep water from the open sea than the western shallower part.

It should be noted, that at a number of stations, to the south-east of Russian Island, in early March 2000, in the bottom layers in the seabed depressions, very dense water with the temperature of about -1.7 °C and salinity 34.5 psu, was marked. Possibly, this water was formed due to the brine rejection in Amur Bay and penetrated into Ussuri Bay through the strait between Russky Island and continent. But it may be also a local phenomenon, since a large part of Ussuri Bay was covered by ice. In any case, in late March, the traces of this dense water were not revealed.

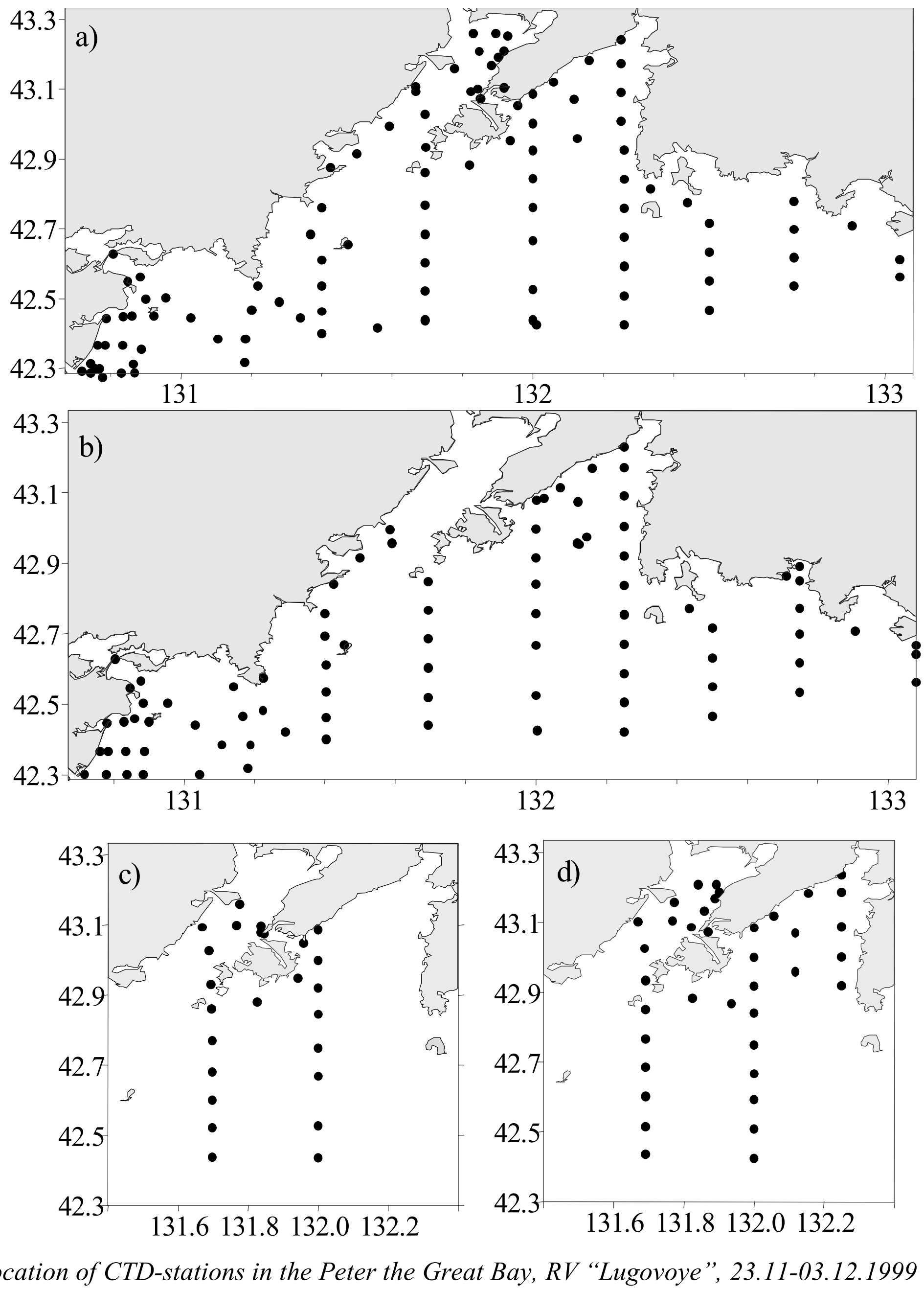

Fig. 1. Location of CTD-stations in the Peter the Great Bay, RV "Lugovoye", 23.11-03.12.1999 (a), 04.03-12.03.2000 (b), 23.12-24.12.1999 (c) and 30.03-01.04.2000

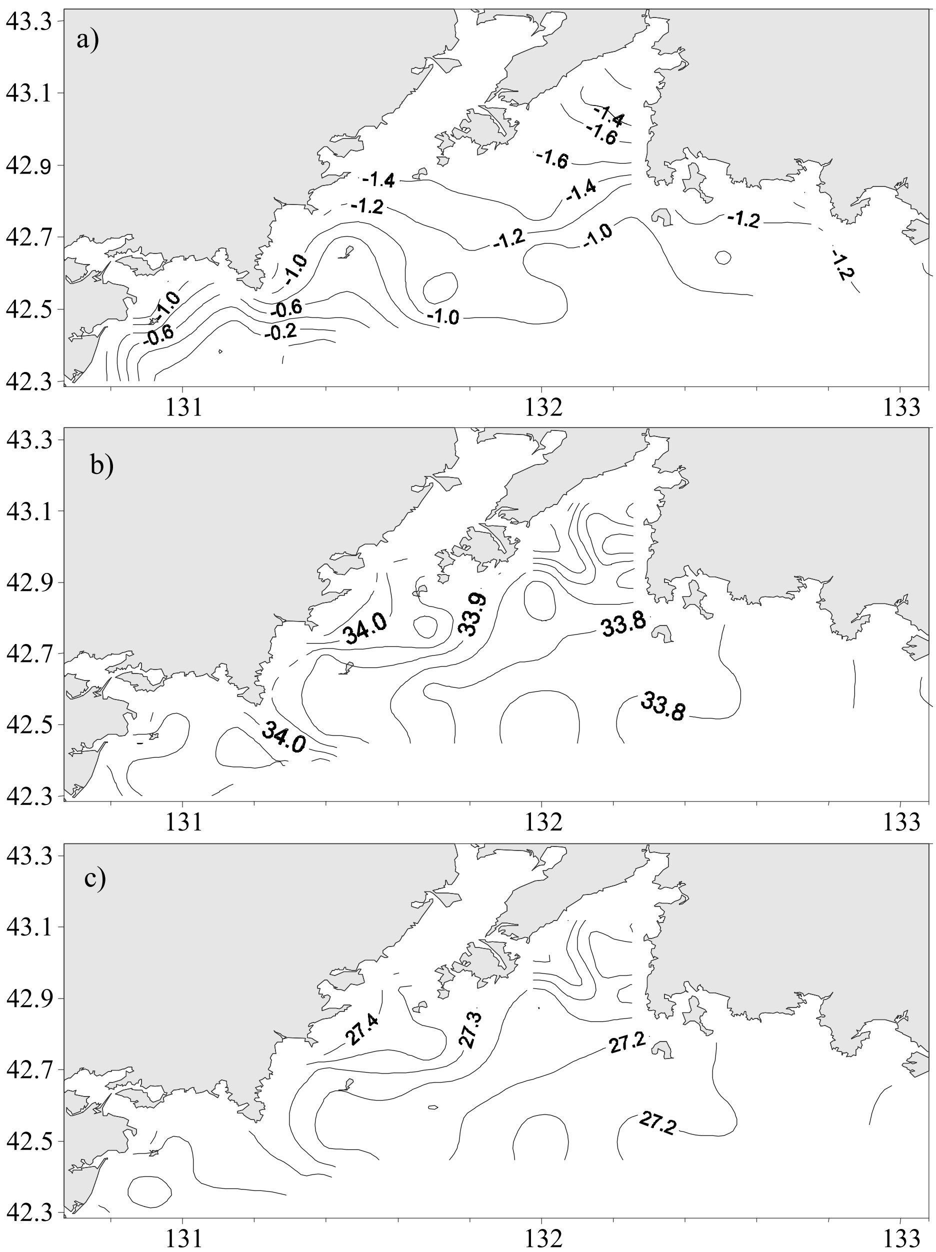

Fig. 2. Temperature (a, °C), salinity (b, psu) and density (c) distribution at the depth of 2 m in Peter the Great Bay in early March 2000

Oxygen distribution at the sea surface in November (Fig. 4) shows its insignificant rise (from 300 to 330 µM/kg) from Amur Bay to the eastern boundary of the region. Most saturated (more than 100%) were the coastal surface waters to the south of Amur Bay. Poor saturation (92%) was observed in Amur Bay, as well as in Ussuri Bay. The most noticeable feature of the oxygen distribution at the seabed is an area of minimal concentrations (below 250 µM/kg) to the south of Russky Island, where saturation was only 74%. At the rest area, the oxygen saturation was more than 80%. Observations conducted in late March (Fig. 4d) have shown very high increase (up to 450 µM/kg and 380 µM/kg) in dissolved oxygen in Amur Bay and in Ussuri Bay, relatively. Oxygen concentrations there were by 50 and 25% more than these were in November and from the sea surface to the seabed, the oxygen saturation reached up to 125 and 104% in Amur and Ussuri Bay, relatively. Even in the region to the south of Russky Island the oxygen saturation rose from 74 to 107%.

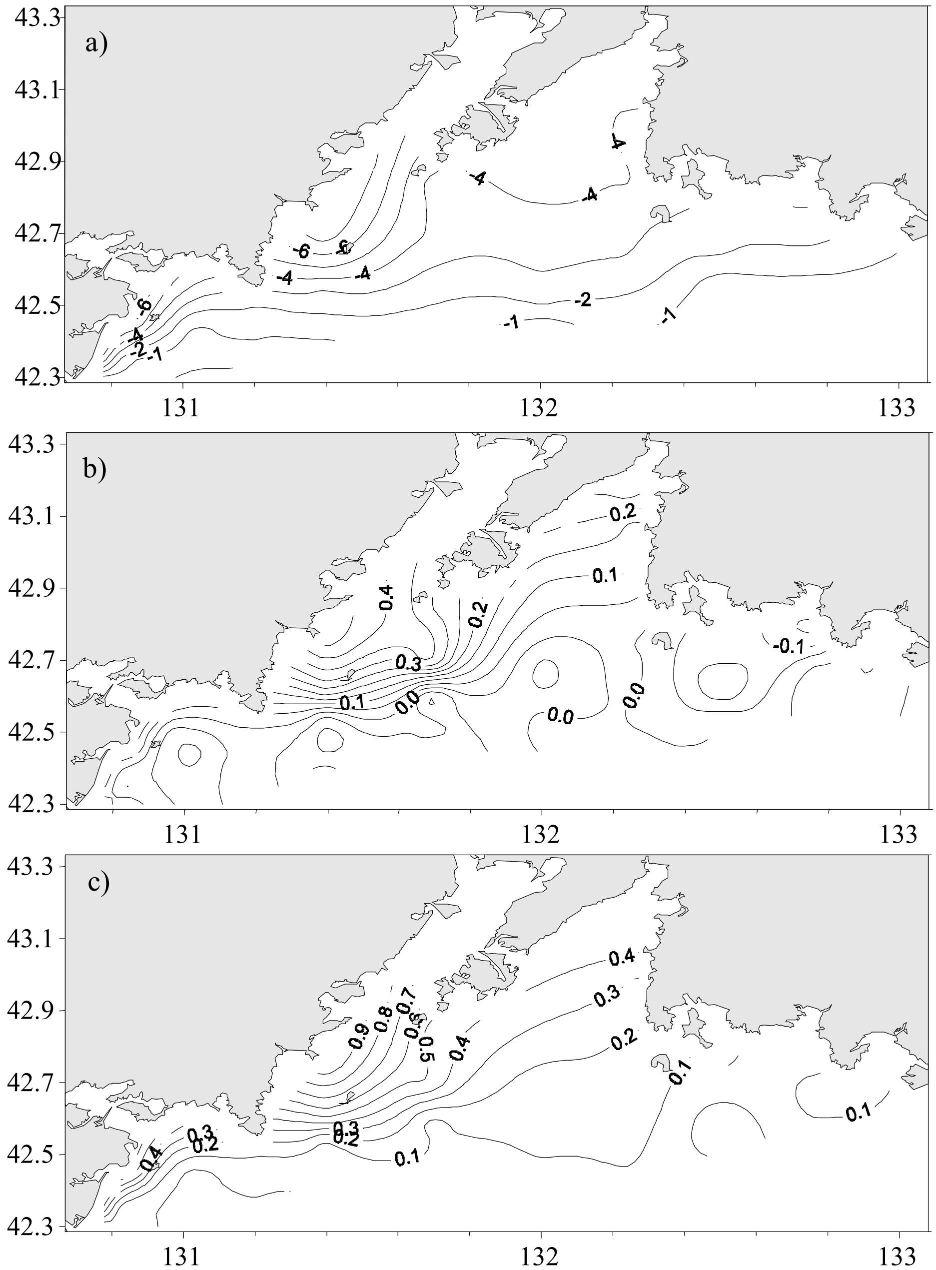

Fig. 3. Temperature (a, °C), salinity (b, psu) and density (c) changes at the seabed of Peter the Great Bay from late November 1999 to early March 2000

Distribution of nutrients at the sea surface and at the seabed (Fig. 5) in November of 1999 shows a very similar patterns for different components. At the sea surface, a gradual rise of nutrients concentrations from the west to the east was observed. Raised concentrations were stated also in the central part of Amur Bay. This is obviously caused by the water transport from the open sea through the strait between Russky Island and the continent.

At the seabed, lowered concentrations of silicate, phosphates and nitrates were observed along the western boundary of the region, in the central part of Ussuri Bay, and in the eastern coastal area of the region. The most interesting feature is the area of maximal concentration of nutrients located to the south of Russky Island. As it was mentioned above, minimal oxygen concentrations were observed here. All this testifies to penetration of deep water from the open sea to this site, and a cyclonic eddy has been possibly formed here.

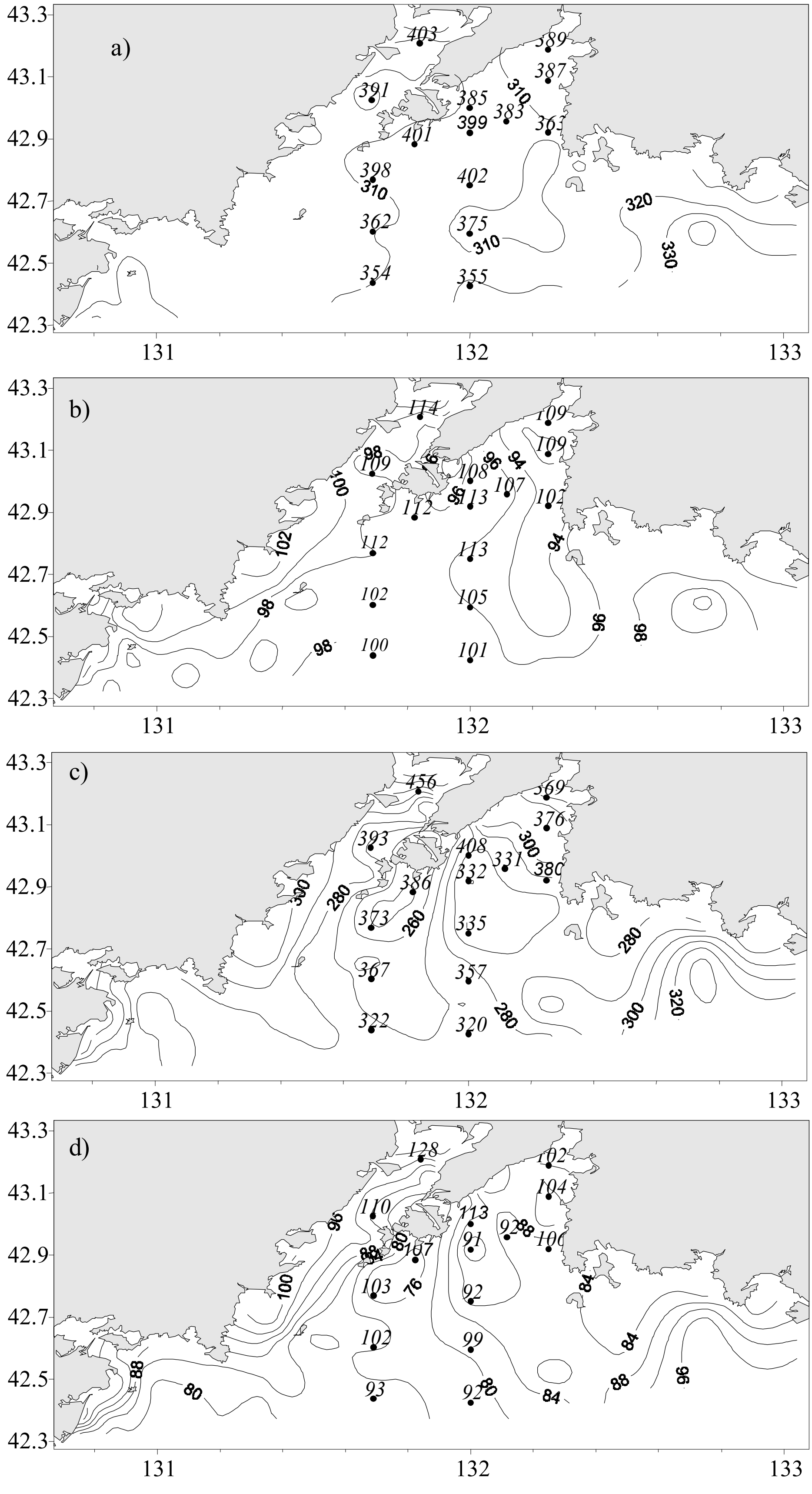

Fig. 4. Dissolved oxygen distribution (μM/kg) and its saturation (%) in Peter Great Bay in late November 1999 at the sea surface (a, b) and at the seabed (c, d). The values obtained in late March 2000 are depicted by cursive

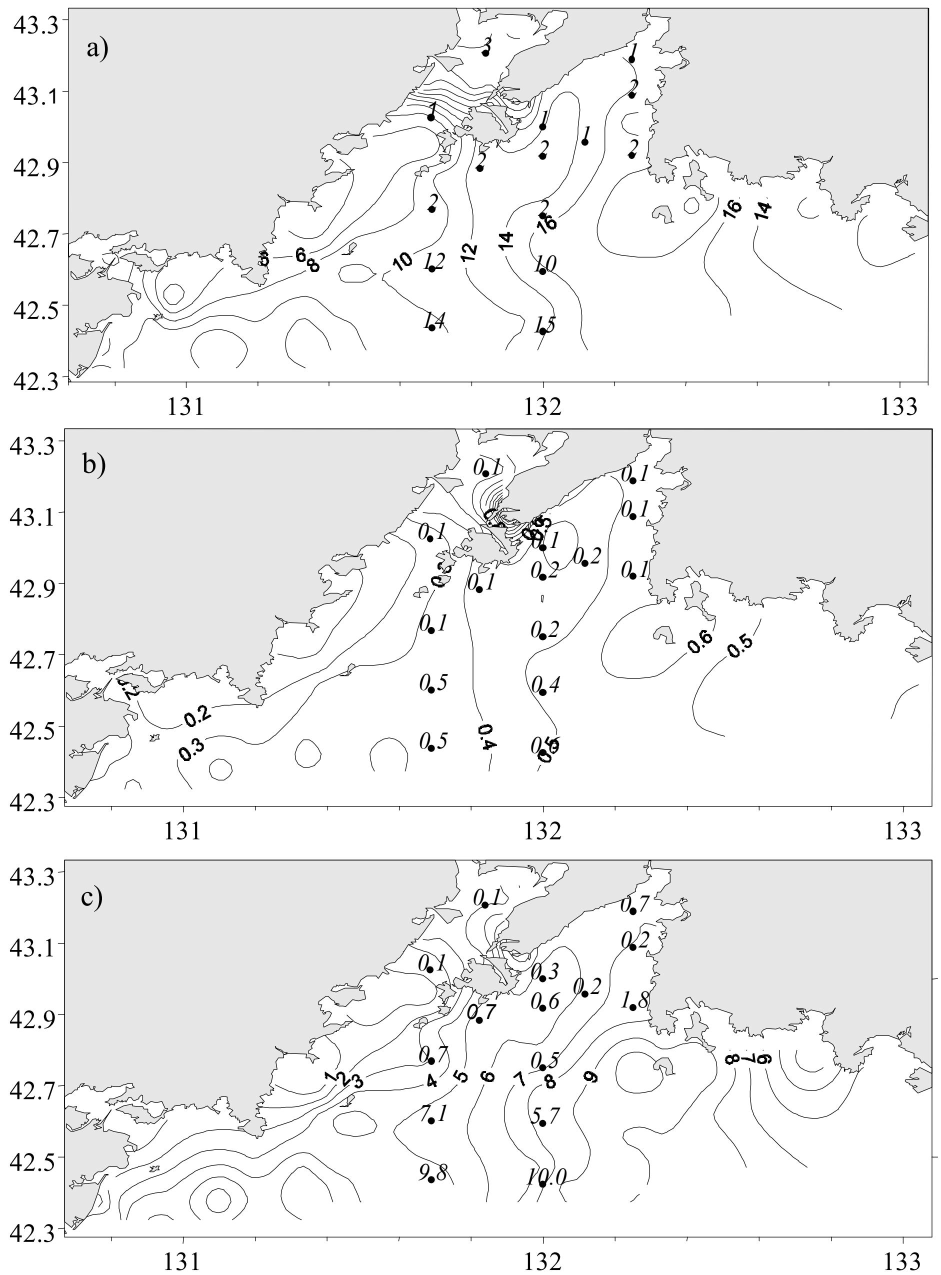

Fig. 5. Silicate (a), phosphates (b) and nitrates (c) distribution (μM/L) in Peter the Great Bay in late November 1999 at the sea surface. The values obtained in late March 2000 are depicted by cursive

Relatively to seasonal variations of the nutrient concentration, it should be noted that the most significant decrease from November to March occurred in the northern shallow part of Peter the Great Bay. So, silicate concentration has dropped by 6-7 times in Amur Bay and by 8-10 times in Ussuri Bay. Concentration of phosphates and nitrates has also lowered by 3-5 and 10-30 times there. But in the southern part of the region, where the depths exceed 100 m, their concentration practically remained at the same level. It should be noted, that in late December, at the sea surface, nutrients concentration in the southern part of Peter the Great Bay raised by 1.5-2 times, at the same time, in the northern part, it increased by 10-20% only. Near the seabed, in a shallow part, the nutrients content decreased by 2 times, but in the deep part it was practically unchanged. So, maximal concentrations of nutrients in the surface layer were observed in late December and were caused by intense vertical mixing and upwelling of deep water.

Discussion

The most ventilated site in the research region is Amur Bay water area. The saltiest and coldest water was observed there in late March of 2000. Oxygen content raised there by 50% comparing with November values. In Ussuri Bay this rise was only 20%. Since in winter the most part of Amur Bay is covered by ice rather than water exchange with the open sea area is not large and occurs mainly along the southern boundary near the ice edge. Along with that, some part of water from Amur Bay penetrates evidently into Ussuri Bay forming a clockwise circulation around Russky Island. Direct measurements in the strait between Russky Island and the continent (Lastovetskii, 1964) have shown that in the surface layer a permanent flow from Ussuri Bay into Amur Bay is observed. But at the depths of more than 25 m a reverse flow from Amur Bay into Ussuri Bay is observed and this outflow we fixed in March if judged from the bottom temperature and salinity distribution in the central part of Ussuri Bay. During the warm period, once summer monsoon has developed, a reverse circulation is observed, *i.e.* the water from Ussuri Bay extends mainly into the central and northern part of Amur Bay. Typical nutrient distribution testified to this process in the bottom layer in late November of 1999.

Very dense water revealed in Ussuri Bay during early March at some bottom depressions has been formed due to the brine rejection. But it is still not clear whether this water was formed in Ussuri Bay or in Amur Bay and was transported here through the strait. In any case, in late March this water was not traced. Such fast disappearance of this water testifies to the intense water exchange between the shallow and deep parts of the region and to the slipping of the dense bottom water into the intermediate layer of the open sea. Rate and volume of this water formation are still to be estimated.

Lowered oxygen concentration and saturation as well as raised nutrients concentration in late November of 1999 at the seabed evidently have pointed out the upwelling of the deep water of the open sea in the region to the south of Russky Island. This event occurred evidently in late March too, since the nutrients concentration has not changed though the dissolved oxygen content increased by 50% due to the convection process. In general, during the late March, the oxygen concentration gradually has been increased to the north. But it is surprising, that the oxygen concentrations in Ussuri Bay in late March were less than in Amur Bay, since the latter was completely covered by ice till early March. Oxygen concentrations there were by 50 and 25% higher than these in November and from the sea surface to the seabed the oxygen saturation has reached up to 125 and 104% at Amur and Ussuri Bay, relatively. This fact can be explained by the intense process of photosynthesis only.

Nutrients distribution for different components in late November has shown their gradual increasing from the west to the east, pointing out that their source is located in the open sea area. Nutrient concentrations in Peter the Great Bay have large seasonal variations. Maximal values are observed in fall-winter period with decreasing by 7-10 times in summer (Lastovetskii, 1964; Vinokurova, 1977). During our surveys, the concentration of nutrients in the northern shallower part of the region has dropped from November to March by several times (or much more) and has remained practically at the same level in the southern deep part. It can be explained only by intense biological consumption. Nutrients extraction from water due to photosynthesis and their regeneration caused by decomposing of organic matter occurs with permanent ratio (23:16:1) of their main components Si, PO_4, NO_3 relatively (Grill & Richards, 1964). Since as a whole, this ratio was quite fair for Peter the Great Bay one can consider that intense biological consumption of nutrients occurred in the northern shallower part of the region, as well as in the southern deep part. But in latter case this consumption was compensated by the vertical water mixing and by the nutrients input from the depth. In the northern part, such vertical compensation was absent, and this was the main reason such a dramatic dropping of nutrients concentration. Regeneration of the nutrients concentration in the shallow part of the region will be possible only due to the destruction of organic matter and the advection of the open sea waters which is enforced after establishing of summer monsoon circulation in atmosphere. This process should be traced in subsequent oceanographic surveys.

Conclusions

Next preliminary conclusions can be made from the analysis of temperature, salinity, oxygen and nutrients observations for the period from November 1999 till April 2000:

- Peter the Great Bay area can be used as a model domain to check the processes of winter convection and ventilation of the adjacent intermediate water. More careful study is required to trace how the process of dense water formation and its subsequent slipping along the bottom occurs;
- processes of photosynthesis are extremely expressed in a shallower part of Peter the Great Bay. Dropping of nutrient concentrations in the northern part during summer and their restoration in winter is closely related to the seasonal features of circulation. Biological consumption of nutrients in the southern deeper part of the region is compensated by an intense vertical mixing, so the seasonal variation of the nutrient concentration here is much less than in the northern part of Peter the Great Bay.

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