

# Development of the software tool for searching sea areas suitable for mariculture breeding

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**Abstract.** The program for searching areas of a sea body of water according to specified characteristics is presented. The parameters are the ranges of potential water temperature and salinity, as well as the date range, the initial data are three-dimensional arrays of relevant characteristics in the netCDF format (work with direct access data is provided). Copernicus marine reanalysis was used. The search is carried out at boundary points, the number of days from a given range in which the corresponding conditions are met (temperature and salinity from a given range) is calculated. Maps and binary arrays with metafiles for graphical display are created. The algorithm was tested in the White Sea and the southern part of the Barents Sea. According to calculation the Pomorskiy Coast of the Onezhskiy Bay is recognized as the most promising for trout farming in the White Sea when combined with “supporting” coastal infrastructure. However, to select the optimal site for mariculture using mathematical methods, further field work is required.

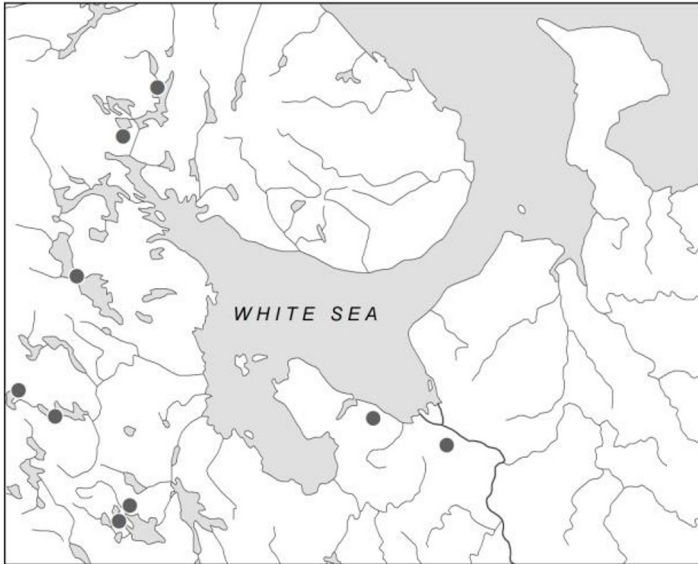
## 1 Introduction

Cage trout farming is one of the priority areas of fishery activities in inland waters of the European North [1]. The leader of this industry in Russia is the Republic of Karelia, accounting for at least 80% of total production [2]. The development of trout farms leads to the degradation of lake ecosystems, pollution, and eutrophication [3], which prevents the use of lakes as drinking water supplies and can negatively affect public health [4]. Fishery activities are also carried out in the White Sea catchment area, including trout farming (Fig. 1).

As can be seen in Fig.1, all trout farms are located quite far from the sea. Nevertheless, according to the testimony of local residents, trout is grown in the White Sea, for example, in the region of Chupa Bay. The initial raising of trout in seawater did not work out very well [5]. If first in the 70s XX century the results were contradictory, but already in the 80s it was possible to successfully solve many problems [6, 7]. Leaders in sea trout cultivation are Chile and Norway. However, it is obvious that there are very few such areas for the White and Barents Seas.

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**Fig. 1.** Trout farms in the White Sea catchment area according to Yandex maps.

In this regard, developments to justify the permissible levels of impact of fish farms on the water bodies of the Russian North, taking into account their regional biogeochemical characteristics, are becoming relevant, and the task of transferring trout farms from the White Sea catchment area to the sea is also important. In fish farming, this is called cage farming of fish in seawater.

The development of fish farming in Europe shows that over the past fifty years, aquaculture production has grown exponentially due to marine farms [6]. According to data [1] for 2003–2018, about 13,000–15,000 tons of trout were produced in Finland, with 80–85% in the waters of the Baltic Sea. Experts agree that the use of different bays of the White Sea is a promising way for growing rainbow trout. Scientists from the Institute of Northern PINRO (Arkhangelsk) have compiled a rationale for the commercial cultivation of trout in the Unskaya Bay, the Dry Sea of the Dvinskiy Bay, and in the coastal waters of the Solovetskiy Archipelago. In all these areas, experiments on trout cultivation were carried out, fish farming and biological standards and feeding regimes were developed, and the optimal volumes of commercial products were determined. It has been shown that the growth rate of trout in sea water is higher than in fresh water [3].

The technology for cage fish farming is simple and, in many ways, resembles the technology for raising fish in pond farms. Marine cage farms can be created at fishing enterprises and fish factories. The most promising are large industrial complexes, including not only cage farming but also coastal basin farming. Commercial farms can be equipped with equipment for feeding fish, caring for cages, and having convenient ways for transporting fish. Therefore, when planning such farms, it is important to have the necessary infrastructure in the coastal zone. In addition, when raising fry, you need a freshwater pond or pool, so it is important to take all these many factors into account.

## 2 Materials and Methods

In order to organize a search for suitable areas of the White Sea for trout farming, a software tool was developed that works with reanalysis and model calculation data. The

parameters are the ranges of potential water temperature and salinity, as well as the date range, the initial data are three-dimensional arrays of relevant characteristics in the netCDF format (using Fortran direct-access data files is available as an option).

The search is carried out at near-to-coast points, the number of days from a given range in which the corresponding conditions are met (temperature and salinity from a given range) is counted. Maps and binary arrays with metafiles for graphical display are created.

The COPERNICUS MARINE reanalysis was used (<https://data.marine.copernicus.eu>), in particular, two data sets:

1. GLORYS, with resolution of 0.25 degrees (the entire globe).
2. Dataset for the Arctic region (north of 60° latitude) with resolution of 0.083° (about 9 km), only the area containing the White Sea was downloaded.

The first option, apparently, has too coarse a resolution for the White Sea. The second dataset made it possible to identify promising areas in the Onezhskiy and Mezenskiy bays.

### 3 Results

Three requests were completed for 2019–2020 from May to September for the upper layer of the sea 0–4 m:

1. First request: temperature within 8–15°C, any salinity, depths from 5 m or more.
2. Second request: temperature within 8–15°C, salinity <25‰, depths from 5 m.
3. Third request: temperature within 8–15°C, salinity up to 20‰.

According to the first request, 745 points were found in the coastal waters of the White Sea and the southern part of the Barents Sea; for the second requests this number was 193; the third request found just 57.

In Fig.2, it can be seen that, within strict limits (3 requests), suitable areas for trout fish farming in the sea are limited only to the southern part of the Onezhskiy and Mezenskiy Bays. It is noteworthy that no such points have been found at all in the Dvina Bay, which is probably due to the existing inaccuracies in the COPERNICUS reanalysis data.

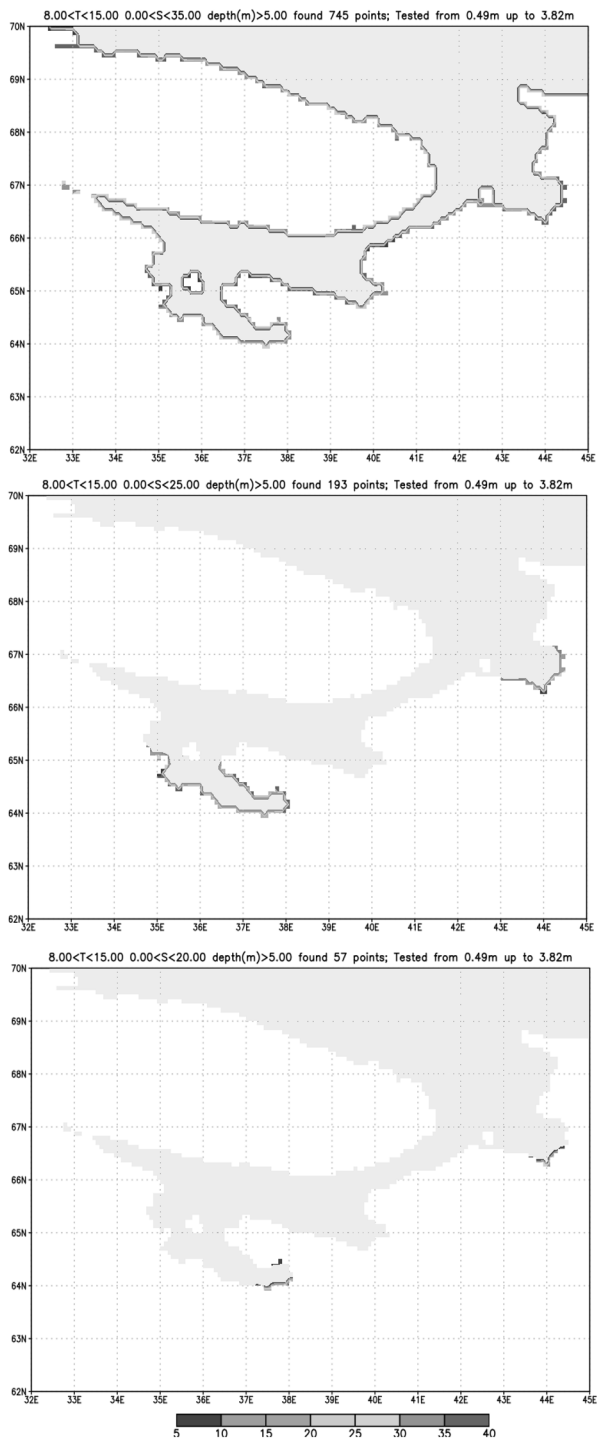
However, a tool for searching queries based on reanalysis or simulation data within the framework of the task was developed and tested.

For rainbow trout, the optimal temperature in salt water is between 8 and 20°C. The threshold temperature is about -0,1°C. Adult rainbow trout can tolerate salinity up to 32–35‰. Fish with a marketable weight of up to 500 g feels good at 20–30‰. Larvae can withstand salinity of 5–8‰, fingerlings – 12–18‰, yearlings – 20–25‰.

When rainbow trout are transferred from fresh to seawater, the diffusion of oxygen through the gills is sharply reduced, which is explained by a decrease in osmotic and ionic flows passing through them [7]. At this time, rainbow trout are very sensitive to a decrease in oxygen concentration in the water. But in most areas of the White Sea there is no shortage of oxygen. In seawater, rainbow trout are unable to tolerate temperatures below 0°C, which is obviously due to the collapse of osmoregulatory mechanisms [7]. The suitable temperature for transferring rainbow trout to seawater is 6–16, and the optimal temperature is 8–12°C.

It is undesirable to cultivate trout in water with a salinity higher than 28‰. Rainbow trout adapt best to salinities up to 20‰, since the activity of enzymes associated with adaptation remains the same as when kept in fresh water. It is best for the fish to adapt to seawater gradually.

After transferring to water with a salinity of about 10‰, the salinity should be increased by 3–4‰ every day for 5–7 days. Successful adaptation also depends on the size of the fish and partly on its age and time of year. When transferred to seawater, the survival rate of rainbow trout can be increased by more than 2 times if the NaCl content in the daily diet is increased from 7–8 to 10–12% 6–7 weeks before transfer.



**Fig. 2.** Areas of the coastal waters of the White Sea and southern part of the Barents Sea that are potentially suitable for trout farming according to calculation data. The numbers correspond to three requests (see above), the scale shows the number of days when the request condition is fulfilled.

## 4 Discussion

In the White Sea there are no problems with the timing of stocking; trout are transplanted directly from fresh water to sea water in June at a water temperature of 8-17°C and a salinity of 7-16‰ and without waste [8]. In the coastal zone of the White and Barents Seas there are areas where up to 25 thousand tons of trout products can be produced annually [8]. Due to the fact that the water temperature in the White Sea does not allow raising trout in sea water all year round, it is necessary to either equip a room with a freshwater pool on the shore, or look for a piece of land where a lake will be relatively close to the sea. Thus, the number of available places for trout breeding in the White Sea and Barents Sea is less than what the calculation algorithm provides. Therefore, after discovering suitable areas of the sea, it is necessary to work with satellite images to find the most convenient places from the point of view of coastal infrastructure. Another important factor is the closeness of the water area from the wind. The most suitable are closed bays on the rugged shores of the White Sea, with good roads and a fairly large water bodies on the shore.

Such work was carried out and it was noted that there are quite a lot of areas on the Karelskiy coast of the White Sea with good conditions. So, there is an indented coastline, many closed bays, many lakes on the shore. Weaknesses: inaccessibility from land (very often), the short period of relatively warm water for trout farming in salt water, the water is more salty and exposure to strong storms due to its geographical location.

In more southern areas (on the Pomorskiy coast) the water warms up faster, salinity here is lower than in the north and the bays are better protected from strong storms. However, the shores here are often swampy and there are far fewer favorable lakes on the coast.

It turns out that quite a lot of factors must coincide in order to organize a farm for trout in sea water.

However, this task is doable. Given the quick exchange of sea waters, such a farm can remain in one place for many years. And there will be no need to look for new areas, since eutrophication will not occur.

## 5 Conclusions

Against the backdrop of a decline in anthropogenic nutrient inputs from point sources of pollution (municipal and industrial centres) and the development of reoligotrophization processes in the bottom communities of lakes, arose potential danger of eutrophication of the reservoir from diffuse sources (trout cage farms) [2, 4, 8]. This is why it is so important to look for ways to reduce the nutrient load on water bodies. In this regard, the placement of trout farms in marine areas is justified. Mathematical methods help us to find optimal areas for mariculture farms, although field work in the found areas is certainly required. From a logistics point of view, the Pomorskiy coast of the Onezhskiy Bay of the White Sea is recognized as the most promising for growing trout in marine waters from all considered areas.

## Acknowledgements

The study was carried out within the state assignment «Comprehensive research of the White Sea and the watershed in the interests of the development of the Arctic zone of the Russian Federation» No. 121021700122-7.

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