Digital Monitoring of Lake Baikal and its Coastal Area

Igor V. Bychkov[1], Gennadii M. Ruzhnikov[1,2], Alexey E. Khmelnov[1,3], Roman K. Fedorov[1,2], Taras I. Madzhara[1], Anastasia K. Popova[1,2]

[1] Matrosov Institute for System Dynamics and Control Theory, Siberian Branch of Russian Academy of Sciences, Lermontov st. 134, Irkutsk, Russia
[2] Irkutsk Scientific Center, Siberian Branch of Russian Academy of Sciences, Lermontov st. 134, Irkutsk, Russia
[3] Institute of Mathematics, Economics and Informatics, Irkutsk State University, Gagarin Blvd. 20, Irkutsk, Russia
rugnikov@icc.ru

Abstract. The directions of the formation of a digital environmental monitoring system for Lake Baikal and its coastal territory are considered. An approach to its digitalization is proposed, based on the use of a service-oriented paradigm, infrastructure approach, and Web technologies. The collection of large volumes of digital data (Big Data) of environmental monitoring in a single data processing center will allow combining the speed of receiving, on-line transmission with information processing services about the current state of Lake Baikal, which will improve the quality of decisions.

Keywords: Digital Monitoring, Service-Oriented Paradigm, Information and Telecommunication Platform, Web-Technologies.

1 Introduction

The aggravation of the environmental problems of Lake Baikal and the Baikal Natural Territory (BNT) is associated with forest fires, damage by bacterial diseases and insects, technological damage, the introduction of alien flora and the impoverishment of biodiversity, etc. The distribution zones of filamentous algae increase, the mass extinction of Baikal sponges is recorded, the structure and taxonomic composition of macrozoobenthos is changing, and the mass development of benthic cyanobacteria is observed. These problems justify the need for a transition to a new technological structure - the creation of an interagency scheme, methods and technologies for digital monitoring of the ecosystem of Lake Baikal and BNT.

2 Existing monitoring of Lake Baikal

State environmental monitoring is understood as a complex system of regular observations in space and time over the state of the environment and its changes under the influence of natural and anthropogenic factors [4]. To ensure unification, the monitor-

ing of strictly regulated observations is carried out according to the approved list of environmental parameters, as well as according to the specified requirements for the used means, measurement methods, sampling frequency and research methods. The environmental monitoring system includes the collection of data on the actual state of environmental pollution, careful processing, analysis of these data, followed by the identification of the dynamics of the state and the development of recommendations for the development of the economy of the region on the basis of scientifically based environmental forecasts [1-3, 10].

The state monitoring of lake Baikal ecosystem is carried out by the authorized Federal Executive authorities: the Ministry of natural resources and ecology of the Russian Federation, the Ministry of agriculture of the Russian Federation, the Federal service for Hydrometeorology and environmental monitoring, the Federal service for state registration, cadastre and cartography, the Federal forestry Agency, the Federal Agency for subsoil use, the Federal Agency for water resources and the Federal Agency for fisheries, as well as the Executive authorities of the Republic of Buryatia, TRANS-Baikal territory and the Irkutsk region according to their competence in the order established by the order of the Government of the Russian Federation of August 9, 2013 N 681 "About the state ecological monitoring and the state Fund of data of the state ecological monitoring". Interdisciplinary research, expeditions and partial monitoring of lake Baikal ecosystem and its coastal area are also carried out by RAS institutes and universities of the Ministry of education and science [6, 9].

The analysis of the existing state of the monitoring components of Lake Baikal and the BNT (implementing organization, observation points, composition of observation indicators, frequency of collection, hardware and software systems, data transmission systems, etc.) allowed us to conclude:

- Monitoring of water resources (Fig. 1) includes the collection of basic parameters - hydrochemical and hydrological characteristics, the state of the coast and bottom, water consumption, and the use of water protection zones. These data are collected by the regional departments of Roshydromet - Irkutsk UGMS, Trans-Baikal UGMS and Buryat TsGMS. FBUZ "Center for Hygiene and Epidemiology in the Irkutsk Region" checks chemical and biological pollution in intakes, wells and recreational areas several times a year. Municipal Unitary Enterprise Vodokanal estimates the cleanliness of surface water taken, the Federal State Institution Vostsibregionvodkhoz monitors hydrochemical and hydrophysical indicators during the navigation period using the ship complex, and the Yenisei Basin Water Managemen measures the volume of water during water consumption and effluent discharge.

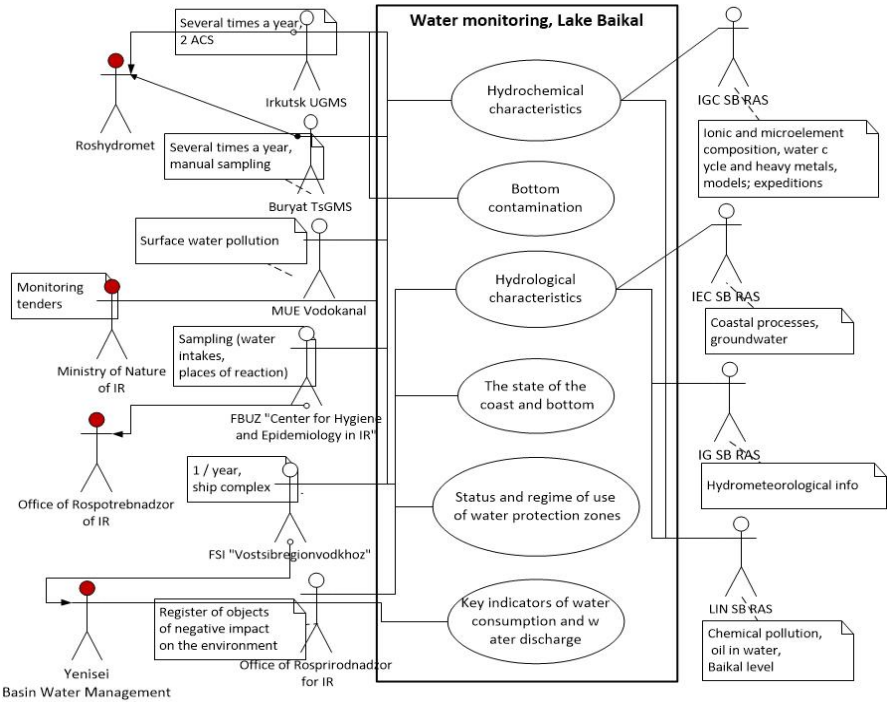

Fig. 1. Scheme of existing water monitoring, Lake Baikal.

There are only two automatic water monitoring posts in the southern part of the lake (in the city of Baikalsk and Listvyanka), measuring 7 hydrochemical indicators of water (temperature, turbidity, dissolved oxygen, pH, ammonia nitrogen, redox potential, electrical conductivity). The remaining observations on the lake and nearest rivers are carried out using manual sampling once a month or less. The ship complex operates only during the summer navigation period.

- Monitoring of atmospheric air (Fig. 2) was implemented more technologically - Roshydromet has 23 automatic stations for atmospheric control, some of the indicators are measured continuously, but most stations are not located directly on Lake Baikal, but in large cities (Irkutsk, Angarsk, Chita, Ulan-Ude). The departments of Rospotrebnadzor and Rosprirodnadzor measure pollution less frequently - from 1 time per week to 1 time per month, depending on the indicator.

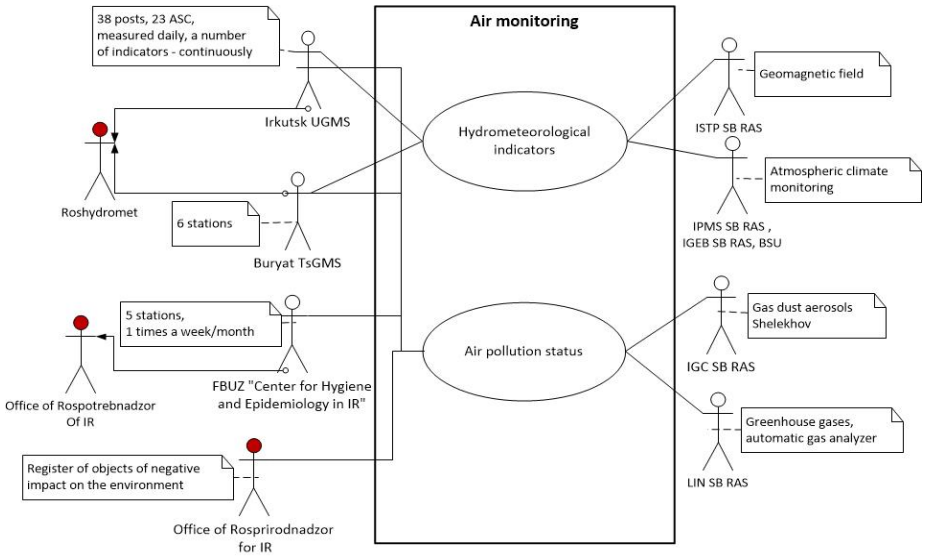

Fig. 2. Scheme of existing air monitoring.

- Monitoring of aquatic biological objects allows monitoring the number, quality, distribution of aquatic biological resources, their habitat, and fishing. Now water quality - plankton, the presence of pathogens of intestinal infections, viruses - is estimated 3-6 times a year from May to October at several stationary points.

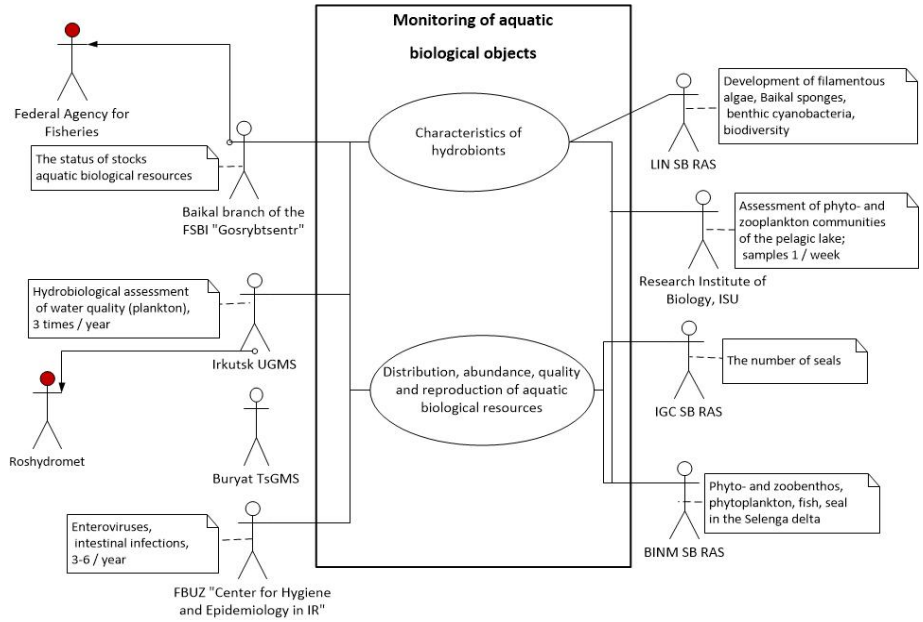

Fig. 3. Scheme of existing aquatic biological object monitoring.

- Rosreestr is responsible for state land monitoring together with the Ministry of Agriculture, Rosnedra is responsible for the state of the subsoil, Rosrybolovstvo monitors aquatic biological objects, and Rosleskhoz monitors forest pathology. Regular observations did not cover the coastal shallow zone of Lake Baikal, experiencing the greatest anthropogenic load. This is especially true of the Barguzinsky and Chivyrkuisky gulf, the area of the Small Sea, where in the summer the flow of tourists increases significantly.

- In the framework of the Unified State Fund for Environmental Data, Roshydromet collects information on pollution of Lake Baikal from third-party organizations - reports on environmental assessments, hydrometeorological work performed, and engineering surveys. Data is transmitted in different formats, in part - only on paper.

Thus, we can conclude:

- Each of the organizations that study the ecosystem of Lake Baikal and BNT, adhering to its monitoring scheme, generates and uses large amounts of spatial and thematic data, which are usually localized and not coordinated among themselves, in parametric, chronological and other aspects. It complicates the analysis, making complex assessments, forecasting, and managerial decisions based on available departmental data.
- Only fragmented data on the status and pollution of Lake Baikal and BNT are available for public access.
- There is no single system with operational monitoring information that allows you to enter, store and exchange data on the state of the ecological system of the lake in real time.
- There is no single system for identifying spatial objects as universal communication elements for departmental spatial and thematic databases.
- The assessment of the systemic sufficiency of the choice of “informative indicators” for monitoring the ecosystem of Lake Baikal was not carried out.
- Full-fledged state monitoring of hydrochemical, hydrophysical and biological parameters in real time over the entire water area of the lake is not carried out, and only seasonal observations are present.

It follows that the existing departmental systems for monitoring the ecosystem of Lake Baikal and BNT do not allow to respond promptly to changes of a natural and anthropogenic nature, to identify components of local or global genesis in them. This justifies the need for a transition to integrated digital monitoring [6, 8], the feature of which is the integration character, continuity (24/7/365 mode) and the distribution of observations, large volumes of different-format spatio-temporal data on the state of the lake from sensors and measuring instruments.

The modern stage of digital monitoring of the ecosystem of Lake Baikal should be based on the automated collection of spatio-temporal data from various sensors to obtain accurate and timely information.

Work of creating a system for digital monitoring of the ecosystem of Lake Baikal and BNT have to be focused on three areas:

- Modernization of existing seasonal monitoring schemes with a modern hardware-instrument and technological component (stations), which allows recording hydrophysical, hydrochemical, gas, video-landscape parameters of the aquatic environment and atmosphere in quasi-continuous mode, with the transmission of information to the data center. For this, it is necessary to install stations in places with high anthropogenic pressure on coastal landscapes. Stations recording the parameters of the deep lake Baikal should be installed along its axial part. Numerous variations of automatic stations and sensors are currently available. To create a distributed network, it is planned to use uninhabited underwater and surface vehicles, both autonomous and remote-controlled, automatic ship systems, robotic systems for low-altitude remote sensing based on modern UAVs, together with autonomous long-term bottom measuring stations, which are permanently installed in Lake Baikal. Remote sensing of the Earth by space systems will also be used.
- Modernization of methods, technologies for monitoring the biodiversity of Lake Baikal and BNT by introducing modern molecular genetic, mathematical methods and a “non-contact” research approach.
- Creation of an information and telecommunication platform for digital monitoring of the ecosystem of Lake Baikal and BNT, ensuring coordination of interagency (Roshydromet, Ministry of Natural Resources, Rosleskhoz, Rosvodresursov, Rosrybolovstvo RAS, Ministry of Education and Science) and interregional (Republic of Buryatia, Trans-Baikal Territory and Irkutsk Region) interactions. On the basis of Data center should be carried out storage and processing of spatial and temporal thematic data of digital environmental monitoring, with the possibility of direct information access. Collecting distributed interdisciplinary data (Big Data) in the Data center will significantly improve the quality of forecast models for the development of the Baikal ecosystem.

3 Information and telecommunication platform for digital monitoring of the ecosystem of Lake Baikal and BNT

The key components of the information and telecommunication platform of digital monitoring of the ecosystem of lake Baikal and BNT are: infrastructure of the Shared Equipment Centers of IDSTU SB RAS " Integrated information and computing network of Irkutsk Research and Educational Complex (IICN)" and "Irkutsk supercomputer center SB RAS (ISC)", as well as "Information and analytical environment" (IAE), which will ensure the collection, transmission, search, storage, and parallel processing of large amounts of data, the ability to access online data, catalogs, services and information and analytical systems, possibility of carrying out on the basis of the received data of an assessment, modeling and the forecast of ecological and climatic changes of Baikal and adjacent territories with application of means of supercomputer modeling and cloud computing.

For Lake Baikal monitoring, a distributed service-oriented information-analytical environment (IAE) of the geoportal type is being developed, which includes subsys-

tems for collecting, transmitting, storing, searching and processing large volumes of different formatted spatio-temporal data and knowledge [5, 11].

The research methodology is based on the complex application of service-oriented paradigm and modern technologies of distributed data processing, the use of declarative specifications and intellectualization using methods and technologies of deep learning. At the same time, declarative specifications provide compactness, expressiveness and subject orientation, including the possibility of interpretation by transformational and other procedures. In turn, the use of a service-oriented approach allows for a full accounting of distributed information resources in combination with ease of testing scalability and the ability to reuse the created services [5].

For the organization of integrated monitoring of ecological systems of Lake Baikal, thematic environmental monitoring services are integrated with the help of logical structures to solve data processing problems, control the flow of execution, etc. A variety of collections of services of thematic environmental monitoring will allow to transfer data between them, coordinate data formats, run asynchronous computing processes

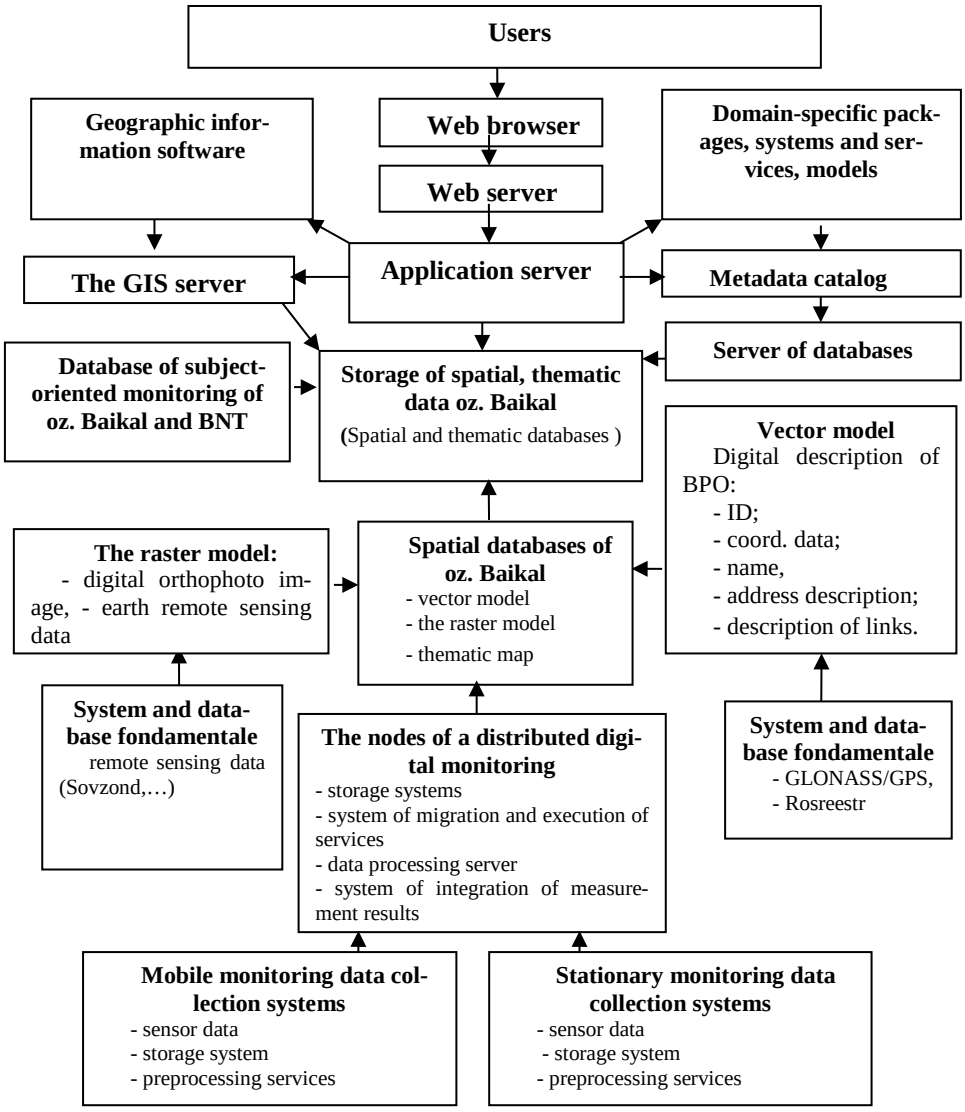

Fig. 4. Structure of IAS.

The IAE should store all types of environmental monitoring data with a given degree of reliability: time series with measurements of various sensors, expedition materials, space images, vector maps, etc. (Fig. 4). All of these data, which are spatially and temporally bound, can have a number of additional attributes specific to a particular type of information.

Geoportal service-oriented information and analytical environment for integrated digital monitoring of Lake Baikal should provide:

1. online access to distributed sensors;
2. access to archival data of sensors;
3. high speed data processing;
4. access to high-performance computing resources and data storage resources of the centers of collective use;
5. scaling of computing resources and resources for storage and processing of data from shared centers, taking into account the growth in the number of tasks and volumes of monitoring data;
6. ability to use various methods and technologies of distributed data processing.

As a hardware-software platform that provides continuous operation of the IAS, the scheme is used (Fig. 4) construction of data centers, which are based on the following fundamental principles:

1. Full redundancy of engineering infrastructure and hardware complex;
2. Efficient use of equipment by organizing pools of computing resources;
3. Virtualization of resources and applications;
4. Backup and restore systems.

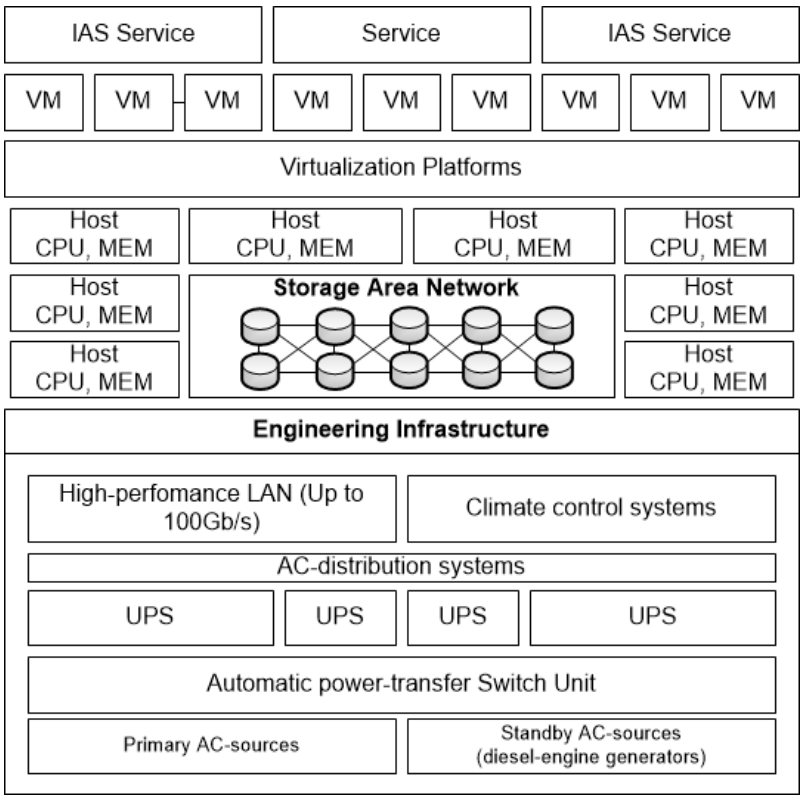

Fig. 5. The data center infrastructure

Creating a data center at the initial stage includes:

- reconstruction of engineering infrastructure – uninterruptible power supply and cooling systems;
- modernization of network infrastructure;
- deployment of servers, storage and processing systems based on HPE hardware with hybrid MS Hyper-V / VMWare vSphere virtualization platforms.
- scale compute infrastructure.

The existing and successfully functioning Shared Equipment Centers (IICN, ISC) will be used as a launch site for the deployment of data centers, which will increase the availability of high-performance computing resources for processing digital monitoring data, including the use of supercomputer modeling.

4 Conclusions

The directions of the formation of a digital environmental monitoring system for Lake Baikal and its coastal territory are considered. This will allow to move to a qualitatively new level of interdisciplinary scientific research, as well as provide operational analysis and decision-making on the problems of the lake and its natural territory.

5 Acknowledgments

The research is conducted with partial financial support of RFBR (projects: 18-07-00758-a, 17-57-44006-Mong-a, 17-47-380007-r), integration program of SB RAS (project 77), program of Presidium of RAS (project 2 and 23), the program “Information and telecommunication platform for digital monitoring of Lake Baikal, based on end-to-end technologies” and Shared Equipment Centers of ISDCT SB RAS.

References

1. NOAA'S Nartional Centers for Environmental Information, https://www.ngdc.noaa.gov, last accessed 2019/08/28.
2. Senter for International Earth Science Information Network (CIESIN), http://www.ciesin.org, last accessed 2019/08/28.
3. Biodiversity and dynamics of ecosystems: information technologies and modeling. OTV. ed. Acad. VK Noisy, Akad. RAS Yu. I. Shokin. Novosibirsk: publishing house of SB RAS. 648 p. (2006)
4. Israel, Y.A. Ecology and control of natural environment. L.: Gidrometeoizdat, 376 p. (1979)
5. Bychkov, I.V., Ruzhnikov, G.M., Khmelnov, A.E. et al. Infrastructure of information resources and technologies of creation of information and analytical systems of territorial administration. Novosibirsk: Publishing house SB RAS, 240 p. (2016)

6. Suturin, A.N. Chetyrkin, E.P., Melnik, V.V., Khanaev, I.V. et al. The Role of antropogennic factors in the development of environmental stress in the littoral zone of lake Baikal (Listvyanka village area). Geography and natural resources, №6, – Pp. 43-54. (2016)
7. Kravtsova, L. S. Izhboldina, L. A., Khanaev, I. V. et al. Violation of vertical zonality of green algae in open Larch Bay of lake Baikal as a result of anthropogenic influence Doc. WOUND. Vol. 447, №2. P. 227-229. (2012)
8. Grachev, M.A. On the current state of the ecological system of lake Baikal. Novosibirsk: Publishing house of SB RAS. 156 p. (2002)
9. Samsonov, D.P., Kochetkov, A.I., Pasynkova, E.M., et al. The Content of persistent organic pollutants in the components of the unique ecological system of Lake Baikal. Meteorology and hydrology. №5. Pp. 105-115. (2017)
10. Puzanov, A.V., Bezmaternyh, D.M., Kirillov, V.V., Zinoviev, A.T. Creating a system of integrated environmental monitoring of Lake Teletskoy. Lakes of Eurasia: problems and solutions. Materials of the II International Conference. Kazan: Publishing House of the Academy of Sciences of the RT. Vol. 1. Pp. 145-150. (2019)
11. Bychkov, I.V., Ruzhnikov, G.M., Khmelnov, A.E. et al. Information and telecommunication platform for digital monitoring of Lake Baikal. Proceedings of the "8 International Conference System Analysis and Information Technologies" SAIT - 2019 2019, Irkutsk - Listvyanka, Russia. Pp. 26-33. (2019)