Dynamics of the ecological structure of fauna birds in lake Baikal hollow (late XYII – early XXI centuries)

Yuriy Mel’nikov

1 Baikal Museum of the Siberian Branch of the Russian Academy of Sciences, 1 Academic str., Listvanka setl., Irkutsk Oblast, 664520, Russia

Abstract. The work was performed in the hollow of Lake Baikal (1965-2023). For comparative analysis, the generalizing materials of T.N. Gagina (the end of the XYII – the first half of the XX centuries) were used. By this author, the hollow of Lake Baikal was not identified as an independent ornithogeographic unit and was part of several ornithogeographic sites. At the same time, the hollow differs from the surrounding territories in terms of a complex of physical and geographical conditions and represents a united region. It should be considered as an independent zoogeographic unit – the Baikal complex. Modern climate warming has had a strong impact on the bird fauna of the region. Their fauna increased by 106 species in the second half of the XX – early XXI centuries and now amounts to 427 species of birds (previously 321 species). It should be borne in mind that a slight warming has been observed since the middle of the XVIII century. By the middle of the 20th century, 57 vagrant species had already been recorded here, which clearly expanded the area. However, most of the new species appeared towards the end of the last century and were associated with a series of large, extensive and frequently recurring droughts, followed by long periods of low water, in Central Asia. The process of eviction of birds continues, but at a very slow pace. Few species, ichthyophages and insectivorous, have reached high numbers in the new areas. The remaining species are found in limited numbers as vagrant birds. As a result, the species diversity of birds in the hollow of Lake Baikal has sharply increased, but the number of their main part has remained low.

1 Introduction

Baikal Siberia (as defined by C.F. Ledebour [1]) covers the entire south of Eastern Siberia and the hollow of Lake Baikal, despite its very large size, is completely included in this territory. As a result of quite intensive scientific research, the fauna of its birds has been well studied since the middle of the XVIII century. A complete review of it from the end of the XVIII to the first half of the XX centuries was made by the famous Siberian ornithologist, Doctor of Biological Sciences T.N. Gagina [2]. Intensive research conducted
in the hollow of Lake Baikal in the second half of the XX – early XXI centuries made it possible to make a complete generalization of the bird fauna of the region during this period [3]. It should be noted that despite the preparation of several large surveys on the fauna of birds of the Baikal region and Eastern Siberia, in none of them was the hollow of Lake Baikal allocated to an united zoogeographic region [4-8]. Meanwhile, the physical and geographical peculiarity of this area of Baikal Siberia required its special consideration [9]. This is exactly what we did when analyzing the bird fauna of the Lake Baikal hollow [3, 9]. As a result, for the first time, information was obtained that gives a complete description of the bird fauna of this region over a long period of special study.

The hollow of Lake Baikal is the central link of the Baikal rift zone, with a total length of more than 2000 km, with very high seismicity [10-12]. Individual earthquakes here reach a strength of 10-11 points. It is a major geographical boundary in the distribution of birds, both in latitudinal and longitude directions [13]. This has become especially evident in the current conditions of a sharp warming of the climate. Despite the power of this boundary, a number of species have managed to overcome it and have advanced their areas far to the north and west. However, a much smaller number of species have expanded their areas to the south and east [14]. Nevertheless, the bird fauna of the Lake Baikal hollow, as well as the entire Baikal Siberia, has changed significantly [3, 9, 13-16]. However, there is still no general analysis of these changes in the specialized literature.

It should be noted that the structure of the bird fauna of large regions is relatively rarely analyzed in detail. Meanwhile, when analyzing it over long periods of time, its features related to the dynamics of the conditions of existence of birds in specific regions are well identified. Baikal Siberia is the region in which the effects of modern climate change on the bird fauna are most clearly identified [15-16]. The latter is related to the location of the region (central regions of Inner Asia) and its physical and geographical features. The Transbaikal Natural Territory is located here - the geocological core of Eurasia with its characteristic orographic and climatic isolation [17]. In this core, the general warming of the climate, compared with the adjacent regions of the Northern hemisphere of the Earth, is most pronounced [18]. Taking into account the peculiarities of the modern geological epoch in the history of the Earth (the modern interstadial of the Holocene), a detailed analysis of such changes, which is well reflected in the fauna of birds, is of paramount importance. This paper shows the changes in the ecological structure of the bird fauna of the Lake Baikal hollow, as one of the most important elements of the general ecosystem of Baikal Siberia, during the modern stage of the Holocene.

2 Research area, materials and methodologies

Lake Baikal belongs to one of the largest freshwater reservoirs in the continental part of North Asia. Its length is 635 km, its width ranges from 25 km to 79.5 km, and the area of the water mirror is 31.5 thousand km² (Figure 1). It is limited by mountain ranges that prevent the free circulation of the atmosphere between the surrounding territories and its hollow is characterized by peculiar climatic conditions (seaside climate) [19].

The lake is characterized by strong winds reaching hurricane strength (40-50 m/sec.). The highest frequency of their recurrence occurs in the late autumn period, and the lowest in February and July [20]. A huge mass of water (23.0 thousand km³), heated during the summer, in autumn gives off accumulated heat to the surrounding spaces and strongly warms its coast. In early spring, on the contrary, the huge mass of ice of the lake strongly cools its coast. As a result, spring is short and cold here and comes almost a month later than in the surrounding plots, and autumn is very long and warm. The actual influence of the Baikal climate on the surrounding territories can be traced to the crests of the mountain
ranges around the lake and inland along the river valleys, the mouths of which open into the lake Baikal penetrates to a distance of about 40.0 km [21-22].

![Research area](image)

**Fig. 1.** The Hollow of Lake Baikal and its division into climatic districts (on 10) Conventional signs: I - South Baikal Climatic District, II - Middle-Baikal Climatic District, III - North Baikal Climatic District

Probably, in this regard, the composition of the bird fauna of the Lake Baikal hollow is noticeably changing from south to north. In addition, the species composition of birds is undoubtedly strongly influenced by the diversity of bird habitats in different areas. The composition of habitats is noticeably more complex in the central regions of the lake, where the main shallow waters are concentrated, as a rule, concentrated in the mouths of large rivers and deltas. They are the most productive wetland ecosystems of the entire Baikal Siberia (delta of the Selenga River). From south to north, bird habitat conditions in the hollow of Lake Baikal become harsher and the coefficient of climate hardness (according to Tsenker) increases from 62 to 64 [20]. In this regard, three sites stand out well here: the South Baikal, Middle Baikal and North Baikal climatic districts (Figure 1) [20]. This allows us to confidently analyze the differences in the fauna of birds in this region due to the severity of climatic conditions.

Own materials on the bird fauna of the Baikal hollow were collected in all areas of the lake from 1968 to 2024. In addition, all available literature on the composition of birds in this region has been processed. Standard bird accounting methods were used, as well as special approaches to the analysis of faunal lists divided into separate groups [23-26]. We compared the faunal lists of birds obtained over long periods of time, and in such cases the most important quality is the completeness of the identification of species over different periods of time. Due to the long analyzed periods and the complete survey of the region, the collected materials are not selective and can be considered as general aggregates.
Therefore, comparing the shares of different groups of birds by the number of species included in them does not require the use of statistical approaches [26]. However, to verify the reliability of the identified trends, we used special methods of nonparametric statistics [26–27].

The composition of the bird fauna for the first half of the research differs slightly from the materials provided by T.N. Gagina [2]. This is due to the appearance of new works by bird taxonomists, which have transferred some subspecies from her list to the status of species [28]. In addition, working with the literature made it possible to find new species that were previously overlooked by this author [15]. The status of a number of species that were listed in her list was also clarified, but their meetings required additional confirmation.

Special attention was paid to the identification of the composition of the winter fauna of birds. This group includes species found in the hollow of Lake Baikal after the cessation of autumn migrations and before the beginning of their spring movements (the second half of March). The peculiarities of the formation of the winter bird population indicate that for the majority of species (except sedentary and wintering) such wintering is forced. As a result of long-term work, we have added several additional categories to the already existing groups of sedentary and wintering birds: ordinary forced wintering, random or very small forced wintering species, birds that have flown out of cages and aviaries [3]. We believe that since birds of the latter group are able to withstand harsh winter conditions for a long time and live in the wild for a long time, they should be isolated as a separate group of wintering birds.

And finally, it was necessary to resolve the issue with the finds of birds found in small numbers in other selected groups, while most of them belonged to a very specific category of species. It turned out that the proportion of such birds increases with warming, and this is especially sharp and noticeable among wintering birds. It is simply impossible to ignore this fact. Therefore, in the main category, the number of species that occur among it in limited numbers is indicated in parentheses. Such data well reflect the general response of birds to climate warming. Their numbers in new categories are growing as the level of climate warming increases.

The work compared the species lists and abundance of species obtained in the hollow of Lake Baikal in the first half of the research (late XVII - first half of XX centuries) [2] and similar materials collected in the second half of XX – early XXI centuries [3]. It should be noted that previously the hollow of Lake Baikal was not distinguished as an independent ornithogeographic region [2] and was divided into several ornithogeographic sites, including territories outside the Baikal Hollow. In this regard, we have completely revised all available literature on this issue [3, 9, 13-16]. The presented review of the bird fauna of the Baikal Hollow covers the period of the last centuries-old Holocene climate cycle from the period of maximum cooling to the end of the warm-dry period at the present time.

### 3 Results

The analysis of the collected materials shows that the period of mild climate warming (mid–XVIII – the first half of XX centuries) differs significantly from the modern period (the second half of XX - the beginning of XXI centuries) in the structure of the bird population. In the first case, it was simpler and less diverse, with a clear predominance of breeding and migratory species, which is quite typical for regions of temperate latitudes. The number of vagrant bird species was relatively small, but still quite noticeable, which indicates the initial processes of restructuring the bird population structure, undoubtedly associated with general climate warming (Table 1). At this time, the meridional air mass transfer of the North Atlantic sector of Eurasia was formed (late 50s – early 60s years of the...
XX century). This is confirmed by the work of climatologists, who pointed to a weak trend of increasing surface air temperature in Eastern Europe and western regions of North Asia [29-31]. During the same period, there was a clear trend towards the development of severe, extensive and often catastrophic droughts that engulfed the eastern regions of North Africa and gradually moved eastward through Near and Middle Asia [9, 16, 32-34]. It coincided with the formation of a clear stream of Western migrating birds, which expanded their areas in an easterly direction. At the same time, with the development of this direction, there was an intensive advance of bird areas to the north [13-16].

Table 1. Distribution of bird fauna of Lake Baikal Hollow by climatic districts at the end XYII – the first half of the XX century.

<table>
<thead>
<tr>
<th>Species status</th>
<th>South Baikal Climatic District</th>
<th>Middle-Baikal Climatic District</th>
<th>North Baikal Climatic District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settled species*</td>
<td>32 (2)</td>
<td>34 (3)</td>
<td>35 (1)</td>
</tr>
<tr>
<td>Nesting and flying species**</td>
<td>140</td>
<td>152</td>
<td>128</td>
</tr>
<tr>
<td>Flying species</td>
<td>60</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Vagrant species</td>
<td>21</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>Summering species</td>
<td>5 (1)</td>
<td>6 (3)</td>
<td>5 (4)</td>
</tr>
<tr>
<td>It is found only on the autumn flight</td>
<td>3 (1)</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Acclimatized species</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Wintering species***</td>
<td>10 (9)</td>
<td>8 (9)</td>
<td>4 (4)</td>
</tr>
<tr>
<td>Forced wintering common species***</td>
<td>- (8)</td>
<td>- (5)</td>
<td>-</td>
</tr>
<tr>
<td>Forced wintering random very scarce species***</td>
<td>1 (9)</td>
<td>2 (4)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>A species that escaped from a cage or aviary</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>272 (30)</td>
<td>281 (24)</td>
<td>252 (11)</td>
</tr>
</tbody>
</table>

Note: * Here and further, the number of species that are found in small numbers in this category of birds is indicated in parentheses, and most of them belong to another category. **The total number of breeding species is equal to the sum of birds of this graph and settled species. ***The number of species in which few birds still remain for the winter is indicated in brackets.

The species composition of birds that expanded their ranges was quite simple and included mainly widespread species. By the middle of the XX century (it was by this time that the material necessary for analysis was accumulated), 29 new bird species (Prebaikal region) settled from the western direction to Baikal Siberia, and 26 of them were recorded in the hollow of Lake Baikal. At the same time, by this time only 3 species had penetrated into Transbaikalia [14]. In the early stages of climate warming, the eastern (oncoming) bird flow was much weaker. By this time, 35 new bird species had been registered in Transbaikalia, which settled from the south of this region to the north, of which only 13 species were new to this territory (they entered here from Mongolia and China). All other 22 species have previously been recorded in the south of Transbaikalia, but have significantly expanded their areas to the north and west, reaching the hollow of Lake Baikal. Having crossed the Baikal zoogeographic border, 16 of them penetrated into the Prebaikal region [13-16]. Consequently, birds from the eastern part of their areas were under greater pressure from adverse factors associated with severe desiccation of the territory. And this is quite understandable – the Transbaikal natural territory is experiencing the most severe moisture deficiency in its main part [17]. It is also certain that the western flow of dispersing birds was caused by severe droughts in the southern part of Asia, consistently shifting to the east [32].
The further development of this situation is connected only with the eastern meridional transfer of air masses in the Pacific sector of Asia, which manifested itself from the mid-late 60s of the XX century, which led to the development of catastrophic droughts in Mongolia and Eastern China (1968-1978) [9, 14, 16, 32-34]. They caused intensive dispersal of birds to the west and north (counter flow). The formation of an eastern stream of dispersing bird species is also possible, but it has not yet been identified by ornithologists. To date, 127 species of birds have been registered in the hollow of Lake Baikal, which were not previously recorded here. The number of such species has increased in the main categories of birds in this region (Table 2). However, this process is most noticeable in the category of vagrant species – there are 3 or more times more of them.

Table 2. Distribution of bird fauna of Lake Baikal Hollow by climatic districts in the second half of the XX and the beginning of the XXI centuries.

<table>
<thead>
<tr>
<th>Species status</th>
<th>South Baikal Climatic District</th>
<th>Middle-Baikal Climatic District</th>
<th>North Baikal Climatic District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settled species*</td>
<td>44</td>
<td>41(1)</td>
<td>42</td>
</tr>
<tr>
<td>Nesting and flying species**</td>
<td>183</td>
<td>176</td>
<td>159</td>
</tr>
<tr>
<td>Flying species</td>
<td>93</td>
<td>85</td>
<td>68</td>
</tr>
<tr>
<td>Vagrant species</td>
<td>59</td>
<td>62</td>
<td>73</td>
</tr>
<tr>
<td>Summering species</td>
<td>1(2)</td>
<td>-(4)</td>
<td>-(2)</td>
</tr>
<tr>
<td>It is found only on the autumn flight</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Acclimatized species</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wintering species***</td>
<td>5(14)</td>
<td>4(14)</td>
<td>2(8)</td>
</tr>
<tr>
<td>Forced wintering common species***</td>
<td>-(26)</td>
<td>-(11)</td>
<td>-(3)</td>
</tr>
<tr>
<td>Forced wintering random very scarce species***</td>
<td>-(23)</td>
<td>-(14)</td>
<td>-(30)</td>
</tr>
<tr>
<td>A species that escaped from a cage or avairy</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>388(64)</td>
<td>370(44)</td>
<td>346(43)</td>
</tr>
</tbody>
</table>

Note: *The total number of breeding species is equal to the sum of birds of this graph and settled species.  **Mainly wintering birds, since in some species a scarce number of individuals can nest in this territory. *** The number of species in which few birds still remain for the winter is indicated in brackets.

Quite unexpectedly, the number of only wintering species has decreased. This phenomenon is undoubtedly due to the fact that they began to winter in more northern territories. We have noted a noticeable shift in areas to the north even among sedentary bird species [42]. At the same time, the number of accidental forced wintering of common and a few bird species has increased dramatically – their number is indicated in parentheses (Tables 1-2). In general, this process is understandable – mild, prolonged autumns cause delays for birds at the stops for fishing and recreation. By the time they can continue migration, it becomes impossible for them. Snow cover falls, constant negative air temperatures are established, mountain passes used for bird flight are closed and the availability of food resources is sharply reduced. Therefore, wintering is forced for all such types. However, in the new conditions, some of these birds can survive until spring, which was not previously observed. And this is an evolutionary prerequisite for the formation of a new composition of wintering bird species.

In general, 156 new bird species have been registered in the Prebaikal region to date (compared with the end of the XIX century), 127 new species have been discovered in the hollow of Lake Baikal and 131 species have been found in Transbaikalia. At the same time, spreading eastward from the western direction, 37 species of new birds overcame the
Baikal rift zone and appeared in Transbaikalia. New species 77 crossed it from the east and began to explore the Prebaikal and more northern regions, even entering the tundra zone of Yakutia. These are the data of a new analysis that takes into account the latest information obtained on the territory of Baikal Siberia [35-36]. A much larger number of new bird species recorded in the Prebaikal region is due to the fact that species that previously inhabited Western and Central Siberia, Transbaikalia and the northern regions of Mongolia and China appeared here. In Transbaikalia, however, bird species that have come here only from Mongolia and China and even more southern regions of Asia are new. And their total number is clearly less than the number of species evicted from the above regions. Southern species are more demanding of habitat conditions compared to species of northern regions.

4 Discussion

The climatic features of Baikal Siberia were associated with an increase in the meridional transport of air masses, first in the North Atlantic sector of Europe (late 50s - early 60s of the last century), and then in the Pacific sector of Asia (from the mid-late 60s of the XX century) [33-34, 39-41]. Obviously, this is due to the weakening of the zonal atmospheric circulation, which equalizes the temperatures of adjacent regions [33-34]. This process was associated with increased warming of the Central Asian region and, above all, the Transbaikal natural territory and adjacent areas, i.e. Baikal Siberia [17]. A large hearth with an elevated temperature of the surface air layer has formed here. If the average warming level in the Northern hemisphere of the Earth was 0.7 °C / 100 years, then in Baikal Siberia, including the Baikal Hollow, an average of 1.9 °C / 100 years [9, 15-16, 21, 32-34, 37-41].

Modern climate changes in China, Mongolia and adjacent areas of Baikal Siberia were caused by a general weakening of atmospheric circulation in the area of contact of air masses of temperate latitudes on the periphery of south-western directions and the East Asian monsoon [9, 16, 39]. This is the reason for the emergence of a vast region with a higher temperature of the surface air layer. The strongest changes in the fauna of birds were observed in the southern regions, where large lake systems and tributaries of the second and third orders of large watercourses completely dried up [43]. The main role in this process was played by severe and extensive droughts with a high frequency of recurrence, followed by long periods of low water [9, 15-16, 18, 32-34, 39-42]. And only now there is a tendency to increase the level of flooding of these territories and the water level in Lake Baikal has been restored.

The ecological structure of the bird fauna of the Lake Baikal hollow in the previous period (the middle of the XYIII – the first half of the XX centuries) differed between the Southern and Northern climatic districts - \( \chi^2 = 21.8 > 18.5 \chi^2_{8,0.01} \), and there were no significant differences between the other districts. Currently, differences in the ecological structure of birds between all districts do not reach reliable values (P>0.05). However, significant differences were found between different periods of work in all districts: \( \chi^2 = 34.4-46.3 > 24.3-26.1 \chi^2_{8,0.001} \). They are mainly due to a sharp increase in the number of vagrant bird species. Consequently, the changes that have occurred in the structure of the bird fauna of the Lake Baikal hollow are significant and reflect its profound changes associated with severe climate warming. At the same time, these materials confirm that the bird fauna of the hollow Lake Baikal is a single complex.

At the same time, the differences in the species composition of birds in modern times in its various plots are clearly higher than in the previous period. The Hollow of Lake Baikal occupies a central place in the Baikal rift zone, with a total length of more than 2000 km, and its mountainous frame contributes to the formation of a peculiar climate here [10-12,
19, 21-22]. Undoubtedly, this affects the species structure of birds in the region. Despite the wide exchange of species, the settlement of the southern and northern plots of Lake Baikal proceeded from different directions. The southern part of the hollow was developed by mixed flows of the western, southwestern and eastern directions [13]. The northern part of the Baikal hollow was inhabited mainly by species that came from the east and southeast [13]. This is especially emphasized by the migration routes of birds, along which they entered this Hollow [9, 13-16]. In accordance with this, the species composition of birds in different areas differs markedly.

The peculiarities of the physical and geographical conditions of the Lake Baikal hollow, within the framework of the ornithogeographic division of Eastern Siberia conducted by T.N. Gagina [2], make it possible to distinguish it into a separate Baikal ornithogeographic complex. The existence of clear climatic differences between different sites, the peculiarities of the distribution of bird habitats, the nature, direction and time of their settlement of the hollow make it possible to distinguish three sites here (within the framework of climatic districts): South Baikal, Middle Baikal and North Baikal ornitogeographic sites (Figure 1) [2-3, 9, 13-16, 19, 22]. This division corresponds to the peculiarities of the distribution of birds across the territory, deepens our understanding of the nature of the bird fauna of the region and facilitates its study.

5 Conclusions

A detailed analysis of the collected materials shows that the dynamics of the ecological structure of birds in the Lake Baikal hollow is quite complex and reflects the peculiarities of its settlement from various directions. At the first stage of warming, the western flow of migrants clearly prevailed, which gradually changed to the eastern flow. Both streams still exist, but the intensity of evictions has decreased dramatically. The Baikal rift zone, the central link of which is the Hollow of Lake Baikal, being a zoogeographic boundary in the distribution of birds, restrained this process at the first stages of evictions. However, very severe, prolonged and extensive droughts, which were replaced by long periods of low water, forced the birds to evict, and they began to cross this border, developing the surrounding territories.

The Hollow of Lake Baikal, characterized by its huge size, was on the way of settling birds. Breaks in mountain chains along the valleys of large rivers flowing into the lake Baikal formed the main channels of migration flows, through which birds mastered the adjacent territories. At the same time, new species of birds were exploring the hollow of the lake and their diversity here increased dramatically. Currently, the bird fauna of this area includes 427 species (previously 321 species), of which 106 are new to the region. As a result of these processes, the species diversity of birds has increased dramatically, while their abundance has decreased. According to the totality of physical and geographical conditions, the Hollow has been isolated by us into an independent Baikal ornithogeographic complex, including three sites: South Baikal, Middle Baikal and North Baikal ornithogeographic plots (within the boundaries of climatic districts).

References


4. Ts.Z. Dorzhiev and E.N. Yelaev, Arealogical structure of avifauna of Baikal Siberia, Ornithological studies in Russia, 2 (Buryat Univrtsty Publ., Ulan-Ude, 2000)

5. V.V. Popov, Birds (Aves), An annotated list of the fauna of Lake Baikal and its catchment area. Lake Baikal, Novosibirsk, Russia, 1, 2 (2004)


10. E.V. Pavlovsky, Geological history and geological structure of the Baikal Mountain region (Publishing House of the USSR Academy of Sciences, Moscow, 1948)


18. Yu.I. Mel’n’ikov, The climate of the Late Holocene and its influence on the dynamics of the bird fauna of Eastern Siberia, in Proceedings of the Second All-Russian Ornithological Congress, Moscow, Russia (2023)


22. G.I. Galaziy, Baikal in questions and answers (Forward LLC, Irkutsk, 2012)
29. E.E. Syroechkovsky, Changes in bird habitats in Central Siberia as a result of climate warming and human impact, Ornithology, 3 (Moscow State University Publ., Moscow, 1960)
32. I.V. Koshelenko, Droughts and control of them. Overview 4 (VNIIGMI-MCD Press, Obninsk, 1983)
35. V.A. Bogdanovich, Meetings of rare and little-studied birds in Buryatia in 2023, Baikal. zool. journal, 3(35) (2023)
36. I.V. Fefelov, Review of rare bird finds in the Baikal region in spring and summer 2023, Baikal. zool. journal, 3(35) (2023)
40. V.A. Obyazov, Climate change and hydrological regime of rivers and lakes in the Daurian ecoregion, Problems of adaptation to climate change in the Dauria river basins: environmental and water management aspects, 5, (Express Publishing House, Chita, 2012)
41. V.A. Obyazov, Regional response of surface air temperature to global changes (on the example of Transbaikalia), Reports of the Academy of Sciences 461 4 (2015)
