Forest fires and their environmental problems on the territory of Irkutsk Region

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Abstract. The dynamics of forest fires in the Irkutsk region and its districts was studied. Over the past 30 years, there has been a tendency to increase the area of forest fires covered by fire. Areas with high forest burning were identified. Dynamics of the content of Benzo(a)pyrene in the atmosphere of cities and indicators of fires in the region and its districts are compared. It is established that the content of Benzo(a)pyrene in the air in many cities linearly depends on the area of forest fires. Dynamics of forest fires and the number of hunting fauna in the Irkutsk region districts were studied. With the help of linear correlations, the positive impact of fires on the population of the family of deer (Cervidae), canids (Canidae), cats (Felidae), bears (Ursidae) and pheasants (Phasianidae), due to one of such factors as the migration of animals from the burning nearby areas, was confirmed. Unstable and negative population dynamics was revealed for the populations of the Kunya family (Mustelidae).

1. Introduction
At the beginning of the 21st century, the intensity of natural fires in the world increased [1-3], which lead to environmental problems [4]. In this regard, studies of the impact of fires on various objects of the environment [5, 6], and biota [7-10] are relevant. In Russia, the largest forest fires were observed in Siberia and the far East [4, 8]. These include the Irkutsk region, where annually there are more than a thousand forest fires with burning up to several hundred thousand hectares of forests [11].

Forest fires cause air pollution by combustion products. Most cities in the Irkutsk region are characterized by a high level of air pollution with hazardous substances. Among them, a significant proportion belongs to carcinogenic benzo(a)pyrene (B(a)P) [12, 13], an indicator of the priority persistent organic pollutants of the polycyclic aromatic hydrocarbons (PAH) group. These compounds are formed in the processes of incomplete combustion [14-16]. At the same time, there is no convincing evidence about the contribution of forest fires to urban pollution. Relevant are studies of the impact of the fires for the forest animals, conditions of their migration and death. In many works [9, 17] the role of both negative and positive factors of influence of fires on productivity of animals is established. Damages from forest fires [11] form losses of biological resources, among which commercial hunting animals are important. First of all, this applies to the wooded regions of Russia, for example, the Irkutsk region, Krasnoyarsk and Khabarovsk territories, the Republic of Yakutia and others, in the territories of which there are specially protected natural reserves, national parks [8].

The purpose of the work is to study forest fires in the Irkutsk region and its regions as a source of environmental problems of pollution of the atmosphere of cities with carcinogenic benzo(a)pyrene and the impact on the number of hunting fauna.
2. Objects and methods of investigation
The objects of the study were the Irkutsk region, part of its districts and cities, for which the results of long-term (1987-2016) monitoring of forest fires, the content of B(a)P in the air of industrial and agricultural cities, the number of hunting fauna were analyzed. According to the data [18, 19] we studied the dynamics of two indicators of forest fires – the number of fires per year (N) and the area covered by the fire (S, thousand hectares). According to the data [18, 19] we studied the dynamics of two indicators of forest fires – the number of fires per year (N) and the area covered by the fire (S, thousand hectares). The content of B(a)P in the atmosphere of 10 cities is estimated [20] by the average annual concentration of C_{BP} (ng/m$^3$) in fractions of the maximum permissible concentration (MPC) (1 ng/m$^3$) and the standard index S_{BP} (ng/m$^3$) as the maximum average monthly concentration also in fractions of MPC. The data of the number of hunting animals of different families and species were obtained by the method of winter route accounting according to the observations of the wildlife monitoring service of the Irkutsk region [21].

The results were processed using the method of correlation analysis, calculating the correlation coefficients of linear dependencies $r_{xy}$ for significance levels $\alpha \leq 0.10$ and the number of degrees of freedom $f$ equal to $n–2$, where $n$ is the number of observations.

3. Results
Dynamics of indicators of forest fires in the Irkutsk region (1987–2016) is shown in Fig.1.

The cyclical nature of forest fires allocates maxima in the number and area covered by the fire, synchronously in 1990, 1993, 1996, 2003, 2011 and 2014. There are various trends of indicators of fires: the number of stable variation, while the total area of the trend of increasing. Of the 33 districts of the Irkutsk region, the highest rates of fires are in sparsely populated wooded Kachug and Katang districts. In them, the average area of forest fires for 10 years amounted to 65 and 47 thousand hectares, respectively. In the populated Bratsk and Irkutsk districts, the areas of fires were 12 and 15 thousand hectares, respectively. Examples of fire area dynamics for these areas are given in table 1.

Table 2 shows the dynamics of the content of B(a)P in the atmosphere of 10 large industrial and agricultural cities of the region. Not only fires in the district, but also fires in the entire region can affect the pollution of the atmosphere in them. Therefore, average concentrations of BP in the atmosphere of 10 cities were calculated.
The dynamics of the number of hunting animals in the Irkutsk region was studied by the example of representatives of the families of deer (Cervidae), canids (Canidae), cats (Felidae), kuni (Mustelidae), bears (Ursidae) and pheasants (Phasianidae). The number of animals is represented in units of individuals per year obtained by winter route records [21]. For the reindeer family there is a positive trend. Predators of the family canine, cat and bear have a constant increase with the highest intensity for the brown bear. The animals of the species Fox, wolf, sable, protein clearly expressed the reaction of reducing the number in the years of the maximum number of fires. For species, the ermine and the kolinsky family of mustelids is stably maintained negative population dynamics. In the case of squirrels, hares and muskrats, there is no increase in the number of animals. The peculiarity of pheasant birds is a strong variation in the number with different trends depending on the bird species. Stable population dynamics in wolverine, mink, badger and otter.

4. Discussion

The territory of the Irkutsk region is included in the list of the most fire-dangerous regions of Russia. The distribution of the forest area of the region in five classes of danger is as follows: the first (very high), the second (high), the third (medium), the fourth (weak) and the fifth (absent) class, respectively, 12, 24, 44, 18 and 2 %. Over the past 30 years, there has been a trend of deterioration in the fire situation of forests, especially in terms of the area covered by fire (Fig.1). The highest rates of fires in all areas were in 2014-2016. The influence of fires on the pollution of the atmosphere of cities and on the number of hunting animals in the region was studied with the help of correlation dependences, the results of which are given in tables 3 and 4, respectively.

Air pollution by benzo(a)pyrene in 10 large cities positively depends on the indicators of fires in the region (Table 3). For 5 of the cities studied, air pollution depends on the nearest fires in the district. The best correlations are obtained for the fire area index. Based on the number of animals

### Table 1. Dynamics of forest fires area on the territory of some districts of Irkutsk region.

| District     | Observation year / fire area (S, thousand ha) |
|--------------|-----------------------------------------------|
|              | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  |
| Brotherly    | 1.7   | 10.3  | 0.9   | 12.0  | 2.4   | 0.1   | 37.7  | 10.3  | 45.9  |
| Irkutsk      | 12.9  | 42.5  | 17.4  | 2.1   | 0.6   | 0.8   | 17.9  | 42.5  | 0.9   |
| Katangsky    | 1.0   | 3.1   | 0.08  | 0.9   | 1.1   | 14.1  | 224.9 | 3.1   | 216.8 |
| Kachugskiy   | 0.8   | 181.8 | 0.3   | 5.8   | 0.02  | 0.8   | 1.3   | 264.6 | 162.5 |

### Table 2. Dynamics average annual (maximum monthly average) concentrations of benzo(a)pyrene (ng/m³) in the atmospheric air of the Irkutsk region cities.

| City          | District     | Observation year |
|---------------|--------------|------------------|
|               |              | 2000  | 2005  | 2010  | 2015  |
| Angarsk       | Angarsk      | 2.0   | 4.0   | 2.6   | 1.2   |
| Baikal        | Slyudyanka   | 1.7   | 2.7   | 1.9   | 0.5   |
| Bratsk        | Brotherly    | 2.5   | 2.9   | 5.1   | 6.7   |
| Zima          | Zima         | 2.2   | 3.5   | 3.7   | 6.6   |
| Irkutsk       | Irkutsk      | 1.4   | 3.0   | 4.2   | 1.5   |
| Sayansks      | Zima         | 0.7   | 2.0   | 1.5   | 2.0   |
| Ust-Ilimsky   | Ust-Ilimsky  | 1.7   | 2.7   | 1.9   | 0.5   |
| Usolye-Sibirskoye | Usolie | 2.6   | 2.7   | 2.6   | 3.8   |
| Cheremkhovo   | Cheremkhovo  | 1.8   | 3.8   | 2.3   | 1.9   |
| Shelekhov     | Shelekhov    | 2.2   | 2.8   | 2.8   | 3.3   |
| all these 10  | all these 10 | 1.9   | 3.0   | 2.9   | 2.8   |

The influence of fires on the pollution of the atmosphere positives in the region (Table. 3). For 5 of the cities studied, air pollution depends on the nearest fires in the district. The best correlations are obtained for the fire area index. Based on the number of animals
positive for herbivores and number of predators in addition to the column and of ermine (Tabl. 4). Such patterns can be explained by the behavior of animals in fires.

Table 3. Accuracy of linear dependences of the content of Benzo(a)pyrene in the atmosphere of cities on the number (N) and area (S) of forest fires in the Irkutsk region and its districts.

| City (district) | \( CB_B=f(N) \) | \( CB_B=f(S) \) | \( SL_B=f(N) \) | \( SL_B=f(S) \) |
|----------------|-----------------|-----------------|-----------------|-----------------|
| Average \( (\bar{C}_{BP}, \bar{S}_{BP}) \) for 10 Cities\(^a\) | + 0.594 (0.02; 14) | + 0.780 (0.01; 8) | + 0.620 (0.05; 9) | + 0.865 (0.01; 8) |
| Bratsk (Brotherly) | insignificant | + 0.886 insignificant | + 0.958 insignificant | + 0.958 (0.001; 7) |
| Zima | + 0.911 insignificant | + 0.911 insignificant | + 0.750 insignificant | + 0.959 (0.02; 7) |
| Sayansk (Zima) | + 0.799 insignificant | + 0.586 insignificant | + 0.959 insignificant | + 0.959 (0.001; 7) |
| Usolye-Sibirskoye (Usolie) | insignificant | + 0.802 insignificant | + 0.708 insignificant | + 0.914 (0.001; 7) |
| Cheremkhovo (Cheremkhovo) | + 0.875 insignificant | + 0.708 insignificant | + 0.708 insignificant | + 0.914 (0.001; 7) |

\(^a\) 10 cities of Irkutsk region – Angarsk, Baikalsk, Bratsk, Zima, Irkutsk, Sayansk, Ust-Ilimsk, Usolye-Sibirskoye, Cheremkhovo, Shelekhov

Table 4. Accuracy of linear dependences of the number of animals on the area of forest fires in the Irkutsk region for the period 2004-2016 (n=13).

| Hunting animals | Correlation coefficients, \( r_{xy} (\alpha, f) \) |
|------------------|-----------------------------------|
| **Herbivorous artiodactyls** |
| *Family deer* |
| Elk \( (Alces alces L.) \) | + 0.757 (0.01) |
| Red deer \( (Cervus elaphus sibiricus Sev.) \) | + 0.724 (0.01) |
| Roe \( (Capreolus pygargus Pall.) \) | + 0.718 (0.01) |
| Musk deer \( (Moschus moschiferus L.) \) | + 0.809 (0.001) |
| *A family of pigs* |
| Pig \( (Sus scrofa L.) \) | + 0.602 (0.05) |
| **Predator** |
| *Family of dogs* |
| Wolf \( (Canis lupus L.) \) | + 0.493 (0.10) |
| *The cat family* |
| Lynx \( (Lynx lynx) \) | + 0.553 (0.10; f=8)\(^a\) |
| *The family of mustelids* |
| Sable \( (Martes zibellina L.) \) | + 0.556 (0.05) |
| Sable \( (Mustela erminea L.) \) | − 0.685 (0.01) |
| Kolinsky \( (Mustela sibirica Pall.) \) | − 0.659 (0.02) |
| **Hares, family of hares** |
| Hare \( (Lepus europaeus) \) | − 0.599 (0.05) |
| **Birds, pheasant family** |
| Grouse \( (Lyrurus tetrix L.) \) | + 0.652 (0.02) |
| Partridge white \( (Lagopus lagopus) \) | + 0.629 (0.05; f=8)\(^a\) |

Note: \(^a\) – observation Period 2007-2016 (n=10).
5. Conclusion
Based on the results of monitoring of forest fires, the content of B(a)P in the atmosphere of cities, the number of hunting animals and the correlations between them can be concluded about fires in the Irkutsk region as a source of air pollution B(a)P and the impact of fires on the hunting biota of the region. The obtained dependences pose the need for environmental measures to eliminate the causes of forest fires.

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