

# The impact of quarantine pests on forest health in Krasnoyarsk krai

Valentina Popova<sup>1\*</sup>, Polina Fedonova<sup>1</sup>, Svetlana Sultson<sup>1</sup>, Nadezhda Kulakova<sup>1</sup>, Pavel Mikhailov<sup>1</sup>, and Natalia Khizhniak<sup>1</sup>

<sup>1</sup>Reshetnev Siberian State University of Science and Technology, 660037 Krasnoyarsk, Russia

**Abstract.** The present study examines the dynamics of the areas experiencing outbreaks of pests classified as "quarantine" in Krasnoyarsk Krai between 2007 and 2023. It can be observed that the forest's health is deteriorating year on year, as the area affected by these pests increases. The coniferous forests of Krasnoyarsk Krai are most at risk from the Siberian moth and the four-eyed fir bark beetle, which cause significant disturbances to forest ecosystems, resulting in substantial environmental and economic damage. There are several shortcomings in the forest management system with regard to forest protection. These include the lack of effective methodologies for assessing the state of forests following extensive damage by pests, as well as the limitation of monitoring information received in the region.

## 1 Introduction

Approximately 20% of all forests on the planet are concentrated in Russia, occupying an area of approximately 809 million hectares [1]. The boreal forests of Russia represent the largest forest area on Earth, spanning approximately 10 million km<sup>2</sup>. However, these forests are relatively poor in species composition, with larch, pine, spruce, fir, birch and a number of other deciduous species representing the majority of the forest cover. [2].

Russia is also a significant exporter of forest products, with an annual export volume of approximately 25-27 million m<sup>3</sup> destined for more than 50 countries worldwide [1].

The total forest area in Krasnoyarsk Krai is 164 million hectares, of which 158.7 million hectares are forests of the state forest fund. Of these, 105 million hectares are forested lands. The forest fund of Krasnoyarsk Krai is predominantly composed of the following species: the Siberian larch (43.7 million hectares), the silver birch (15.5 million hectares), the Scots pine (13.2 million hectares) and the Siberian pine (9.7 million hectares). Coniferous forests account for 75.8% of the forested area. According to the state forest register, the total volume of timber on forest fund lands is 11,307.47 million m<sup>3</sup> [3].

Krasnoyarsk Krai is one of the three leading regions in terms of export volumes of forest products. In 2023, approximately 3.7 million m<sup>3</sup> of forest products were exported from Krasnoyarsk Krai to 16 countries. The primary importer is China [1].

---

\* Corresponding author: [Valpx@bk.ru](mailto:Valpx@bk.ru)

The trade in timber and timber products is associated with the prevention of their infestation by pests and diseases. In this respect, one of the principal challenges is the health of the forest. This is a complex phenomenon, characterized by the presence of harmful organisms (pests and diseases), their numbers, the area and degree of damage to forest stands (disturbance). The data is derived from two sources: state forest pathology monitoring (SFPM) and forest health monitoring surveys [4].

It has long been established that the occurrence of insect pests is cyclical and is closely related to fluctuations in weather and climate. These fluctuations affect not just one species of insects, but a whole series of them simultaneously.

In consideration of the threat to forests and the resulting economic damage, all pests are categorized into two distinct groups: quarantine and non-quarantine species. A number of countries have developed lists of quarantine species, which include a wide range of forest pests and pathogens. Furthermore, our country has compiled a list of quarantine species [5].

In order to maintain the SFPM, the quarantine lists of the Eurasian Economic Union (EAEU), as outlined in Decision No. 158 of the Eurasian Economic Commission's Council dated 30 November 2016, are employed [6].

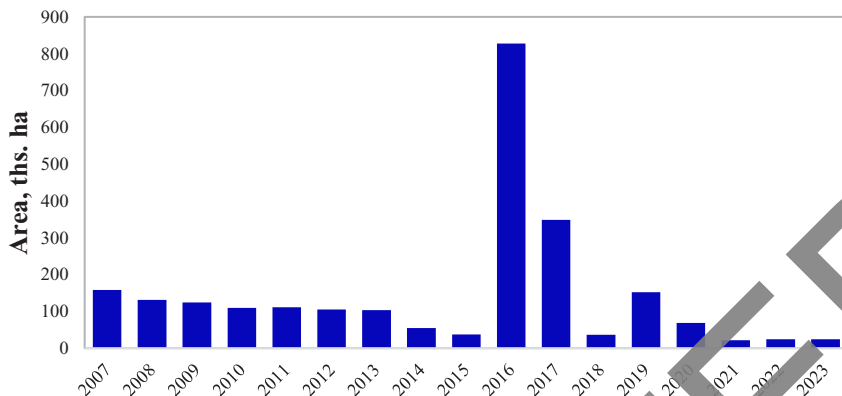
In Russia, 14 species of pests are classified as quarantine pests, with the greatest number and size of established protected zones [7].

A total of eleven species are native to Russia (or its individual regions). Six of these species are widely distributed throughout the Russian Federation, with populations ranging from 40 to 80% of the habitats [8].

## 2 Main part

A review of the register of forest areas where pest outbreaks have occurred, which is accessible via the website of the Federal Agency for Forestry of the Russian Federation [9] in Krasnoyarsk Krai from 2007 to 2023, revealed the following quarantine pest species: the Siberian moth (*Dendrolimus sibiricus* Tschekverikov), the Asian gypsy moth (*Lymantria dispar asiatica* Vnukovskij), the black pine sawyer beetle (*Monochamus urussovi* Fischer v. Waldheim), the black pine sawyer beetle (*Monochamus galloprovincialis* Olivier), the small white-mammorated longhorned beetle (*Monochamus sutor* Linnaeus), and the four-eyed fir bark beetle (*Polygraphus proximus* Blandford).

Figure 1 illustrates the general dynamics of the pest outbreak areas from 2007 to 2023. The data were analyzed at the conclusion of the reporting period, which corresponded to the end of the year. In 2016, the maximum area of outbreaks was observed (827.4 thousand hectares). By the end of 2017, there was a sharp reduction in them. In recent years (from 2021 to 2023), the area of outbreaks is relatively stable and does not exceed 25 thousand hectares. It is crucial to recognize that the current monitoring system is subject to a number of constraints. One of the limitations of the monitoring system is the restriction of information received from the region. This is because the statistics do not include information obtained from remote sensing, which introduces a degree of distortion into the description of the actual situation. This is due to the fact that in recent years, monitoring information has been based exclusively on field data. Remote sensing data, which provides information on damage to the forest, is not included in the monitoring system. The rationale for this limitation is the absence of reliable methodologies for establishing the cause of damage to forest stands using satellite imagery and for assessing the degree of forest disturbance with high reliability [8].



**Fig. 1.** The total area affected by outbreaks of pests classified as quarantine species from 2007 to 2023

Among the insect pests classified as quarantine species in Krasnoyarsk Krai over the course of several years, the most prevalent are the Siberian moth (2016 – 57,1 %, 2016 – 97,2 %, 2017 – 93,3 %, 2019 – 81,1%, 2020 – 50,8 % of the total area of outbreaks), the four-eyed fir bark beetle (2018 – 62,9 %, 2021 – 75,0 %, 2022 – 87,9 %, 2023 – 89,9 %), and the black fir sawyer beetle (2008 – 95,9 %, 2009 – 94,2 %, 2010 – 94,9 %, 2011 – 93,7 %, 2013 – 85,8 %, 2014 – 72,4 % of the total area of outbreaks) (Figure 2).



**Fig. 2.** The size of the area affected by the outbreak of pests classified as quarantine species (by insect species)

The coniferous forests of Krasnoyarsk Krai are at risk from two pests: the Siberian moth and the four-eyed fir bark beetle. These pests cause significant environmental and economic damage by leading to large-scale disturbances of forest ecosystems. They prefer fir- and Siberian pine-dominated stands.

It has been demonstrated that so-called dark-coniferous species (which include Siberian fir, Siberian spruce, and Siberian pine) are unable to tolerate needle loss. Furthermore, when defoliation reaches 75% or higher, these species die almost completely. Siberian fir displays a somewhat greater degree of resistance to partial loss of needles. Dieback at 25-75% defoliation ranges from approximately 30% [12] to approximately 75% [13], and persists for at least five years following the damage [13]. Five years after damage by the Siberian moth, fir trees that have been defoliated by 75% or less still retain a significant portion of their original composition within the stand. Partially defoliated *Abies sibirica* trees attempt to restore their crowns, but attacks by stem pests result in the death of a significant portion of them within several years [13,14]. In the third or fourth year, the large branches and tops of trees begin to fall, and the bark becomes brittle, cracking or tearing off easily. The death of the fir tree is typically followed by the trunks falling after four to five years, with a maximum period of three to five years before this occurs [15].

In stands dominated by Siberian fir, with the Siberian spruce comprising a minor component of the stand composition [13], three years after defoliation, these species are no longer present in the forest stands.

The mortality of Siberian pine in forest stands, where it participated in equal or smaller proportions with fir, is less intense. Even with defoliation of 50-75%, the total proportion of dead trees is relatively small. In only a few instances does the mortality rate for Siberian pine exceed 20% in the year of defoliation. In some cases, the death of trees occurs much more intensely with weak (up to 25%) defoliation. The aforementioned observations can be attributed to unfavorable site conditions, old age, or the impact of additional stress factors [15].

Following the dieback of the forest stand, low-density young stands dominated by birch are formed in sites disturbed by the Siberian moth. In addition, the larger the area of forests affected by the Siberian moth, the slower the forest regenerates. The primary impediment to reforestation is wildfire. The prevalence of wildfires in such forest sites is attributed to the presence of substantial reserves of forest fuels, as well as human activity that utilizes burned areas for apiaries, hayfields, and pastures [16].

The Siberian moth is a native species that has become a significant pest in the study area. The frequency of these outbreaks is cyclical, occurring on average every 10-15 years. The occurrence of these outbreaks is attributed to weather conditions that are conducive to the proliferation of the pest [17].

Over the past seventeen years, several outbreaks of the Siberian moth have been documented in Krasnoyarsk Krai.

The initial outbreak was documented in 2015 in the Yeniseiskoye forestry area, spanning an estimated 21,000 hectares. By the end of 2016, the greatest expansion in the area of the damaged zone was observed. In three of the affected forest divisions, approximately 832.4 thousand hectares were damaged (Yeniseiskoye - 631.5 thousand hectares; Nizhne-Yeniseiskoye - 200.7 thousand hectares; and Severo-Yeniseiskoye - 0.2 thousand hectares). In 2017, new outbreaks were identified in five forest divisions of the region. The largest increase was observed in the following forest divisions: Severo-Yeniseiskoye (241.1 thousand hectares), Nizhne-Yeniseiskoye (209.7 thousand hectares), and Yeniseiskoye (102.1 thousand hectares). The smallest increase was observed in Motynginskoye (0.4 thousand hectares) and Tyukhtetskoye (0.2 thousand hectares) forest divisions. By the end of 2018, the outbreak had been completely stopped due to the implementation of measures to eliminate outbreaks (1,079.6 thousand hectares,

representing approximately 80% of the total area affected) and the influence of natural factors (281.5 thousand hectares, representing approximately 20% of the total area affected).

The second outbreak was identified in 2019 on an area of 123.4 thousand hectares, of which 25 thousand hectares were in the Irbeiskoe forestry. Since 2019, information has been presented in general for Krasnoyarsk Krai, as the register does not have a breakdown by forest divisions. In 2020, the increase in outbreaks was minimal, amounting to 8.4 thousand hectares. On an area of more than 110 thousand hectares, measures were taken to eliminate outbreaks, resulting in the elimination of 94 thousand hectares. Another 35 thousand hectares died out due to natural factors in 2021. By the end of 2022, this outbreak had ceased.

The four-eyed fir bark beetle is an invasive pest that originated in the Russian Far East and has recently been discovered in the study area. The pest causes significant damage to fir stands, particularly those that are already weakened. In Krasnoyarsk Krai, the beetle was first identified in 2009 on the territory of three forest divisions. The total area affected by the fir bark beetle in the Kozulskoye, Achinskoye, and Bagotolskoye forest divisions is 724.5, 753.5, and 474.6 hectares, respectively. Each year, the area affected by outbreaks increased. The next significant outbreak occurred in 2013, with an area of 6,592.1 hectares affected. By this time, the four-eyed fir bark beetle had already been distributed in 12 forest divisions of the region on an area of 7,461.7 hectares. By 2018, the area affected by outbreaks had expanded to 22 forest divisions, encompassing a total of 22,738.6 hectares. From 2009 to 2023, measures were implemented annually to eliminate outbreaks, with a total area of 7.3 (2010) to 7595.9 (2020) hectares. The area affected by outbreaks was also reduced by natural factors (78 (2017) - 1654.2 (2021) ha), resulting in a decrease in the area of outbreaks to 16201.7 hectares by 2023. In 2022, outbreaks were already documented in 32 forest divisions, with an area of 20,000 hectares. The outbreak areas continued to expand at a steady rate, reaching 219,494.4 hectares by the end of 2023.

A competitor of the four-eyed fir bark beetle, which also utilizes the same food resource, is designated as the black fir sawyer beetle [18]. However, these species tend to settle on the same trees, and the majority of the dead fir trees in the outbreak area of *Polygraphis proximus* are colonized by *Monochamus urussovi* F. as well [19].

In Krasnoyarsk Krai, outbreaks of the black fir sawyer beetle at the end of 2007 were distributed in the territory of 33 forest divisions on an area of 153.1 thousand hectares, the largest in area in Usolskoye (24.4%), Motynginskoye (22.9%) and Irbeyskoye (22.9%) forest divisions. In subsequent years, there is no information on this pest in the register; the reason for this is unknown. There is information about the outbreak of this pest in the dark-coniferous forests of the central part of Krasnoyarsk Krai over an area of several million hectares in the 50-60s, then the occurrence of its outbreak was closely related to the outbreaks of the Siberian moth [12].

Longhorned beetles from the genus *Monochamus* are considered to be dangerous quarantining pests. In rare cases, they have been observed to preferentially feed on weakened, dying, and dead trees, with the majority of their damage occurring on healthy trees [20]. The preferred hosts are spruce, fir, and pine. During maturation, they feed on the living bark of young trees. The majority of species are known to transmit numerous tree diseases. When in high numbers, they cause significant damage [21].

One of the most destructive pests of coniferous species of the genus *Monochamus* are the black fir sawyer beetle and the small white-marmorated longhorned beetle. Once these pests have established themselves, outbreaks can persist indefinitely, with the majority of cases ending only when there are no suitable trees left for the development of larvae. The reason for such a significant decline in forest cover may be an insufficient number of natural predators that feed on the larvae and adults of the longhorned beetles [22].

In Krasnoyarsk Krai, as indicated by available data, an outbreak of the black fir sawyer beetle occurred in 2008 in 33 forest divisions, encompassing an area of approximately 162 thousand hectares. The largest proportion of this area was observed in Usolskoye (23%), Irbeyskoye (25%), and Motynginskoye (27%) forest divisions. On an annual basis, the area affected by the outbreak has consistently decreased. From 2009 to 2013, there was a consistent decline in the area affected by the outbreak, with an average of 12 thousand hectares annually. In 2014 and 2015, the area of outbreaks exhibited a pronounced decline due to natural factors, with a reduction of 49.5 thousand hectares and 34.5 thousand hectares, respectively. From 2016 to 2023, the area of outbreaks exhibited considerable variability, ranging from 1.7 thousand hectares (2023) to 5.4 thousand hectares (2018).

In 2007, the small white-marmorated longhorned beetle was observed in five forest divisions, with an area of 103.2 hectares affected. These divisions were Boguchanskoye (2%), Gremuchenskoye (4%), Tazhinskoye (70%), Tyukhtetskoye (1%) and Chunskoye (2%). In 2008 and 2009, no new outbreaks were discovered. As a result of the implemented measures, the area affected by outbreaks decreased by 7.8 hectares and 44 hectares, respectively. In 2010 and 2012, new outbreaks were discovered on an area of 14.9 hectares and 20 hectares, respectively. In 2011, 19.8 hectares of outbreaks were eliminated. For the 2013-2014 period, no changes were observed. In 2015, measures were implemented, resulting in the elimination of outbreaks on an area of 11.4 hectares. Outbreaks on an area of 29 hectares ceased spontaneously. Since 2016, no further outbreaks of this pest have been recorded.

The *Monochamus* genus is home to a number of dangerous pests, including the black pine sawyer beetle, which primarily inhabits pine forests, though has been observed in other conifer species, including spruce, larch, and Siberian pine, which have been weakened by various factors, including fire, needle-feeding insects, and disease. This particular beetle species is known for its ability to damage the stems of pine trees, which is a significant issue for forestry managers. Additionally, the adult beetles feed on needles, which can lead to a thinning of the crown, further reducing the tree's health and resilience [23].

As evidenced by data from the register [9], at the beginning of 2007, outbreaks of the black pine sawyer beetle were already recorded in seven forest divisions across an area of 1,500 hectares in Krasnoyarsk Krai. In consideration of the newly emerged and eliminated outbreaks this year, the total area affected at the end of the year was 5,200 hectares across 14 forest divisions. The largest outbreaks were observed in the Teryanskoye (26%), Kodinskoye (22%), and Chunskoye (17%) forest divisions. Over the course of six years, the area of outbreaks remained virtually unchanged. However, in 2013, there was a notable increase in the area affected, with new outbreaks occurring in six forest divisions on an area of 2.6 hectares. In 2015, there was a marked decline in the area affected by outbreaks, which was attributed to the natural attenuation of the infestation. In 2016, an outbreak occurred in the Gremuchenskoye forestry, resulting in an increase in the affected area by 5.7 thousand hectares, which remained stable for three years. In 2019, the outbreaks exhibited a decline under the influence of natural factors. At the present time, the black pine sawfly beetle is present in an area of approximately 800 hectares in Krasnoyarsk Krai.

Another quarantine pest found in Krasnoyarsk Krai is the Asian gypsy moth. This pest has been observed to cause significant damage to approximately 300 plant species, including deciduous and coniferous trees. During an outbreak, the pest has been observed to feed on dark-coniferous species [24]. The outbreak was first recorded in 2015 in the Usinskoye forest division on an area of 792 hectares. By 2016, this outbreak had ceased as a result of natural causes. However, two new outbreaks subsequently arose in the same forest division on a total area of 1961 hectares. Until 2018, no changes were observed in the course of these outbreaks. However, in 2019, this species was classified as a non-quarantine

pest in the register [9], a designation that is currently unexplained. Furthermore, the outbreak ceased at the end of 2019, presumably due to natural factors.

### 3 Conclusion

A review of the forest health dynamics in Krasnoyarsk Krai, in terms of the impact of quarantine species pests from 2007 to 2023, reveals a worsening trend. Outbreaks of pests have become more frequent, and the area of damaged forests currently exceeds 9 million hectares. This figure represents an 8% increase in comparison with the studied dynamics since 1962, which is a notable departure from the long-term average [25].

A negative trend has been observed in the majority of Russian regions with regard to the accumulation of dead forest stands that have been left standing. This is attributed to a lack of sanitation cutting and other forestry activities aimed at managing dead forest stands [25].

Krasnoyarsk Krai is a notable exemplar in this regard. It is recommended that sanitary measures be carried out in the form of clear and selective sanitation cutting on only 3.2% (51,349.8 hectares) of the total area of damaged and dead forests. A notable proportion of these areas, 55.3% (28,377.3 hectares), is situated within the boundaries of forest user lease bases. The lack of activity in the removal of dead wood creates a significant risk of catastrophic fires and the subsequent outbreak of secondary pests.

The imperfections of the forest management system in the field of forest protection can be attributed to certain methodological approaches to assessing the forest health following extensive damage to tree stands by pests, which are compounded by the bureaucratic system, which ensures transparency in the appointment of sanitation measures, in particular selective and clear sanitation cuttings.

It is also important to acknowledge the limitations of the data obtained. Recently, there has been a lack of comprehensive accounting for the dieback of forests affected by various factors. This is due to the limited number of field studies planned. A significant portion of the damaged stands are located in remote areas that are inaccessible by ground transport. Consequently, only remote observation methods are applicable. As the facts of forest death can only be established on the basis of field survey data, these areas of dead forests are not included in the official statistics of the constituent entities of the Russian Federation [7].

### 4 Acknowledgements

The research was carried out within the projects “Methodological basis for assessment of forest pathology in southern Central Siberia” (No. FEFE-2024-0016) within the framework of the state assignment, set out by The Ministry of Science and Higher Education of the Russian Federation, for the implementation by the Scientific Laboratory of Forest Health.

### References

1. Official website of the Federal Forest Inventory Manager "Roslesinforg". – URL: <https://roslesinforg.ru>
2. A. N. Filipchuk, N. V. Malysheva, T. A. Zolina, A. N. Yugov. Forestry information. **1**, 92–114 (2020). DOI 10.24419/LHI.2304-3083.2020.1.10.
3. Official website of the Ministry of Natural Resources and Environment of the Russian Federation. – URL: [https://www.mnr.gov.ru/activity/regions/krasnoyarskiy\\_kray/](https://www.mnr.gov.ru/activity/regions/krasnoyarskiy_kray/)
4. Order of the Ministry of Natural Resources and Ecology of the Russian Federation of November 9, 2020 No. 910 "On approval of the Procedure for conducting forest

- pathological examinations and the form of the forest pathological examination report".  
— URL: <https://docs.cntd.ru/document/573140196>
5. E. N. Akulov. News-Bulletin (Izvestia) of the Saint-Petersburg State Forest Technical University. **187**, 4-11 (2009)
  6. Decision of the Eurasian Economic Commission Council dated November 30, 2016 N 158 "On Approval of the Common List of Quarantine Pests of the Eurasian Economic Union" as amended on January 25, 2023.
  7. National report of the Federal Service for Veterinary and Phytosanitary Surveillance in 2022 "On the quarantine phytosanitary status of the territory of Russia." Federal Service for Veterinary and Phytosanitary Surveillance "ROSSELKHOZNADZOR" –
  8. Review of the sanitary and forest pathological state of forests in the Russian Federation for 2023. The Federal Forestry Agency (Rosleshoz).
  9. Results of State Forest Pathology Monitoring. The Federal Forestry Agency (Rosleshoz).
  10. S. M. Sul'tson, P. V. Mikhaylov, S. S. Kulakov, A. A. Gorosiko. IOP Conference Series: Earth and Environmental Science. **548**, 52051 (2020). DOI 10.1088/1755-1315/548/5/052051.
  11. E. M. Bisirova. Plant Health and Quarantine. **1(18)**, 12 (2024).
  12. V. Ya. Ryapolov. Forests of the Urals and their management. **21**, 319–333 (2001).
  13. D.L. Grodnitsky, V.G. Raznobarsky, V.V. Soldatov, N.P. Parnarchuk. Contemporary Problems of Ecology. Appendix **1**, 3-12 (2002).
  14. G.O. Krivolutsкая. Secretive stem pests in dark coniferous forests of Western Siberia damaged by the Siberian moth (Nauka, Moscow, 1965).
  15. V.D. Perevoznikova, Yu.M. Baranchikov. Entomological research in Siberia. Iss **2**, 87-102 (1999).
  16. V. V. Kuzmichev, V. P. Cherkashin, M. A. Korets, I. A. Mikhailova. Russian Journal of Forest Science. **4**, 8-14 (2001).
  17. Yu. P. Kondakov. Patterns in the Siberian moth outbreaks. Ecology of forest animal populations in Siberia. p. 206–265 (1974).
  18. A.S. Isaev. The black fir sawyer beetle *Monochamus urussovi* (Fisch.) (Nauka, Novosibirsk, 1988).
  19. D.A. Demidko, V.M. Petko, N.V. Pashenova, N.S. Babichev. Relationship between the four-eyed fir bark beetle and the black fir sawyer beetle when settling on Siberian fir. Ecology and Evolution: New Horizons. Materials of the International Symposium dedicated to the 100th anniversary of Academician S.S. Schwartz. P. 508–510 (2019).
  20. A. Rozhkov, G. Massel. Resinous substances of conifers and xylophagous insects (Nauka, Novosibirsk, 1982).
  21. A.A. Benediktov. Forest Bulletin. **1 (34)**, 34–35 (2007).
  22. N. A. Kochunova, D. K. Zhigurenko, N. A. Yust. *The influence of forest fires on the area of settlement of the black fir sawyer beetle and the small white-marmorated longicorn in the Amur Oblast*. Protection and rational use of forest resources. Materials of the X International Forum. **Vol. 1**, p. 86-88 (2019).
  23. E. I. Karagaeva. The pine sawyer beetle. Plant protection and quarantine **8**, 37-38 (2011).

24. V. I. Ponomarev, A. V. Ilinykh, Yu. I. Gninenko [et al.]. The Gypsy moth in the Trans-Urals and Western Siberia (Ural Branch of the Russian Academy of Sciences, Ekaterinburg, 2012).
25. Russian Forest Protection Center “Roslesozashchita”. Branch of the Federal Budgetary Institution "Forest Protection Center of the Krasnoyarsk Territory". Official website.  
— URL: <https://krasnoyarsk.rcfh.ru/>

RETRACTED