The impact of fires on the vegetation of the North Baikal islands (Big Ushkan Island)

E V Bukharova¹,³ and N M Luzhkova¹,²

¹Federal State Establishment United Administration of Barguzinsky State Nature Biosphere Reserve and Zabaikalsky National Park (“Zapovednoe Podlemorye”), Lenina st. 21, Ust-Bargizin, 671623, Russia
²V.B. Sochava Institute of Geography SB RAS, Ulan Bator st. 1, Irkutsk, 664033, Russia
³E-mail: darakna@mail.ru

Abstract. Based on the pyrogenic successions of Big Ushkan Island (Baikal Lake) being a part of the Zabaybalsky National Park, the changes in the vegetation on the North Baikal islands are studied. The paper presents the outcomes of the first stage of the monitoring. The general features and specificity of changes in the vegetation after the fire of 2015 on the island compared to the valley side are discovered. Fires reduce the diversity of species and increase the biodiversity of the landscape. The biomass of the field layer increases, but that of the wood layer decreases. At the initial stages of the pyrogenic successions, the species composition of the communities depends on the type of fire, the floristic composition of the pre-fire community and the biodiversity of the surrounding territories. The island and the continent feature different paces of the succession processes.

1. Introduction

The Ushkan Islands, including Big Ushkan Island, are a part of the Zabaykalsky National Park. In the last decade, the studies of fires in the designated conservation areas (DCA) became very popular. It was caused by the vast natural fires that broke out in the year 2010 in the European part of Russia and in the years 2011, 2015-2019 in Siberia and the Far East. In the DCA, the primary object of research was the impact made on the flora and fauna, as well as the historical stages of the succession processes. The principal object of the studies is the forest and steppe communities, where the post-fire areas are being intensively populated by the species from the adjacent territories. The analysis of the pyrogenic impact and the recovery dynamics of small-sized islands, including the lake islands, is practically limited [1, 2].

The Ushkan Archipelago lies almost in the centre of Baikal Lake; its islands are the peaks of the underwater Academician Ridge separating the Central and North basins of Baikal. The archipelago consists of Big Ushkan Island and three Ushkan Islets named Thin, Round and Long. With the area of 9.5 km², Big Ushkan Island stands 216 m tall above the water. The island features ten Baikal terraces used as an argument in the Baikal origin problem solution suggested by V.V. Lamakin [3] who developed a theory that the islands came up above the lake surface as a result of the tectonic phenomena that occurred one million years ago. Surrounded with the Baikal water, the islands feature a special climate distinctive with a short and cold summer, long and warm autumn and late spring even compared
to the Baikal coast. The Ushkan Archipelago is the focus of the character of the entire Baikal nature [4]. This is why the fires, typical for the taiga forest of the Baikal Siberia, did not bypass the Ushkan Archipelago. There is no place in Big Ushkan Island without any signs of the previous creeping fires [5].

The largest areas in the Baikal natural territory were covered by fire in 2015. In June 2015, a stroke of lightning started a continuous and intensive creeping fire on Big Ushkan Island. Under the continuous gusting wind, the fire spread from the eastern coast to the inland. Over half a territory of the island was invaded by fire; it was stopped only by the creation of a fire barrier line of 2.6 km stretching from the southern to the northern coast of the island. In 12 days, the burning area constituted 472 ha. The objective of the study is to point out the specificity of the pyrogenic successions in the island conditions.

2. Materials and methods

For this purpose, the used methods were the direct observation over the vegetation development, sample area and quadrat allocation, geobotanic description, and herbarizing. In 2016, inside the quarters, on the northern and the southern coasts of the island 70 m from the waterline, the sample areas of 400 m² were allocated (figure 1).

![Figure 1. Layout of the Big Ushkan Island pyrogenic succession monitoring site.](image)

The vegetation layer of the areas was assessed with the standard geobotanic methods, including the geobotanic description and quadrat method. The basic method was the personal observation over the vegetation development. Moreover, the forest typology methods including the forest stand height and crown density measurement, the evaluation of the average diameter and crown condition were used. The sanitary condition of the vegetation, the scorch height, the number of dead trees including both young
and forest-forming trees were assessed; the average age of the undergrowth, the species and morphologic condition of the shrub layer, the floristic composition of the grassland vegetation were studied.

An area on the northern coast was selected in the burnt zone of the larch, rhododendron and mixed-grass forest with some spots of *Empetrum nigrum* L. in the field layer with a lower overall foliage cover degree of 15%. The ground cover consisted of dead grass, needles and leaves. The description was based on an untouched zone 150 m away from the area.

On the southern coast, the area was allocated in the burnt zone of the larch, false brome grass and mixed-grass forest with the total field layer foliage cover of 20%. In the untouched area of this forest, the signs of a previous fire are found. The same is proved by the underwood with aspen being the dominating species.

Both areas were allocated on the even surfaces of the first Baikal terrace; in both areas in the first layer, some single-standing pines were spotted.

3. Results and discussions

The creeping fire destroyed almost all of the leaf-litter together with the roots of trees and bushes, causing the emergence of fire-induced pits up to 50 cm deep. The grass cover and leaf-litter are preserved in 10-20% of the total area. Burnt almost completely, by the area allocation moment, the undergrowth and the underwood have begun falling. The greatest damage was caused to the young trees with a diameter under 15 cm. Moreover, some uprooted adult trees were found. The fall was caused by the burnt root system. In total, one third of the trees died. The surviving ones were damaged to a different extent from 90% to 10%. It creates a threat of further virus infection or forest pest invasion. It is proven by the sawyer outbreak in the years 2016-2017. At the same time, the small areas of untouched forest guarantee the fast recovery of the primary forest. Larch resisted due to its thick bark and capacity of dropping off the lower lops in the growing process; at the same time, the fire damage of the superficial root system caused the falling of more larches than Scots pine in the same situation.

The spots of survived field layer were the starting points of the sowing and vegetative recovery. In the survived grass vegetation, the foliage cover reached 40%, which is more than before the fire. Besides the species typical for these communities, the share of such Poaceae as *Calamagrostis obtusata* Trin. and *Festuca ovina* L. is growing; some fire-resistant and ruderal species including *Chamerion angustifolium* (L.) Holub, *Chelidonium majus* L., *Corydalis sibirica* (L. fil.) Pers. and *Bromopsis sibirica* (Drobov) Peschko are found. At the same time, some species dropped out from the phytocenosis composition, such as *Empetrum nigrum*, *Orthilia secunda* (L.) House, *Trientalis europaea* L., *Atragene sibirica* L., *Rubus saxatilis* L. and *Geranium pseudosibiricum* J. Mayer. All in all, the number of grass and shrub species reduced by 30%. Beyond the surviving grass vegetation, the spots of germinating fireweed were noticed. In the places where some leaf-litter remained unburnt, *Linnea borealis* L. with its long stolons and *Maianthemum bifolium* (L.) F. W. Schmidt with its stress-ruderal strategy are actively growing. Between the northern and southern areas, no difference in the state of the wood, brush and field layers was found.

The study repeated in 2019 showed a further fall of the fire-damaged trees. In total, with the complete loss of the undergrowth, around 35% of the forest stand has survived. Some vegetatively propagating species, such as single-standing bushes of *Spiraea media* Franz Schmidt and *Rosa acicularis* Lindl., have appeared. The total foliage cover of the field layer reached 70-80% with the further reduction of the species diversity and the growing proportion of the fire-resistant species. At all that, the field layer features a patchy structure caused by a large amount of dead grass, fallen logs and pits left of the burnt leaf-litter and tree roots. These factors create uneven conditions within the microsites (microhabitats) formed in the process of life and death of the plants. For this reason, the patchiness may be expected to remain for several pyrogenic successions, as proven by the monitoring of a pine and larch forest recovering after the fire of 1961 in the Bolshaya River valley (Barguzin Nature Reserve).

The greatest role in the field layer formation is played by *Chamerion angustifolium*. Fireweed is usually the first colonizer after a forest fire, as the comfortable light, absence of competitors and slightly
sour soil are advantageous for this species. This plant is useful for restructuring the damaged root system in the burnt area for its capacity of absorbing the nutrients remaining in the soil after a forest fire.

*Corydalis sibirica* has disappeared from the grass stand. In the southern area, besides the fireweed such grain crops as *Bromopsis sibirica*, *Calamagrostis obtusa* and *Brachypodium pinnatum* (L.) *Beauv.* are prominent. At the same time, compared to the southern area, the northern one features a species composition more similar to the pre-fire community regardless of the same foliage cover degree. Moreover, in the northern area, more active germination of trees is seen: there are 15 sprouts of larch and one sprout of birch per 10 km². In the southern, some single standing root shoots of aspen (1.5 m high) are found and no sprouts of pine or larch are noticed. It can be explained with a more humid climate of the northern area, getting more moisture with the prevailing northern winds and the shade created by the steep island slope.

Previously, the dendrochronological analysis revealed the years of the fires: 1812, 1857, 1907, 1937 [6]. Therefore, fires on Big Ushkan Island occur every 30-50 years. The fire in 2015 proved this cycle duration.

The authors [6] described the details of modification of the vegetation community in the first year after the fire of 1977 which covered the eastern part of the island, like the fire of 2015. Unlike the post-fire changes of 2016, in the year 1978, the forest communities saw the loss of *Bromopsis sibirica* and *Festuca ovina* from their phytocenoses. On the contrary, our observations revealed the increase in the share of these grain crops, proving their ruderal nature.

Compared to the pyrogenic successions of the Barguzin Ridge (Barguzin Nature Reserve), in the burnt areas of Big Ushkan Island no *Gyromitra esculenta* (Pers. : Fr.) Fr. mushrooms are found, though it tends to outgrow in the continental burnt areas in the first post-fire years (scored 5 in Haas scale [7]. The burnt area monitoring of the year 1961 showed succession through the small-leaved stage from birch (the Bolshaya river valley) and aspen (Davsha village surroundings). On Big Ushan Island, there is some aspen in the areas burnt in 1977 but the basis of the forest stand consists of coniferous trees, such as larch and pine. Comparing the time elapsed since the fires and the registered recovery stages, we may conclude that on the island, the recovery processes are faster due to the natural and climatic factors. The average annual temperature in Davsha (Barguzin Nature Reserve) is -4.1°C, and in Big Ushkan Island it is -2.0°C [8].

The larch and false brome forest is indicated [9] as a possible serial community emerging in the burnt areas. However, this community is common only for the warmer southern slopes of the island. For this reason, we have grounds to suppose that we are dealing with sustainable communities recovered after fires.

### 4. Conclusions
Based on the foregoing, we may formulate the conclusions to characterize the specificity and general feature of the pyrogenic successions in the vegetation cover of the western slope of the Barguzin Ridge and on Big Ushkan Island.

**General features:**

- Fires impact the biodiversity in the following ways:
  - landscape diversity increases;
  - species diversity decreases;
- Due to the active outgrowth of the pyrogenic species, the field layer biomass is increasing, and the biomass of the wood layer is decreasing;
- The fire-induced landscapes are unstable:
  - the soil erosion risk is high;
  - the phytocenoses are vulnerable to insect disturbances and diseases;
- In the year 2019, in the monitoring areas, the field layer of the pyrogenic succession was observed.

**Specificity:**
• Among the fire-resistant species, *Corydalis sibirica* (L. fil.) Pers. are abundant on the island, but *Gyromitra esculenta* typical for the continental burnt areas is not found;
• The island features a higher succession process pace compared to the continent.

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