

Research Article

Richness and Scarcity of the Flora of White Sea Islands

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Abstract. This paper provides basic information about the flora of vascular plants on more than 100 islands in the White Sea. The islands differ in size, remoteness from the mainland, aggregation into archipelagos, coastline serration, freshwater bodies and watercourses, geological structure and age, and human pressure. In total, over 700 species of vascular plants have been recorded from the islands. The number of native species varies from zero on rocky islets to 337 on Bolshoi Solovetsky Island. This depends mainly on the island's area, and to a lesser extent on isolation, geological structure, and coastline serration. On smaller and more remote islands, significant deviations from the "basic" taxonomic and geographical structure of the local boreal flora occur due to a gradual decrease in the proportion of boreal species and an increase in the proportion of species with a more northern distribution. The role of the Poaceae family increases sharply in the taxonomic spectrum. In the geographical structure, the distribution of latitudinal fractions changes significantly - the share of species with a northern distribution increases to 43%. The taxonomic structure and ratio of geographic elements of many island floras are similar to those of islands in northerner (more arctic) latitudes.

Keywords: White Sea, island, vascular plants, biodiversity

1. Introduction

The theory of island biogeography has been intensively developed for over 50 years [1]. The patterns established mainly for faunal objects on large oceanic islands state that many factors determine the composition of island biotas. The size, degree of isolation, and age of isolation of the island are considered as the three main ones. Although a vast amount of information on island biogeography has been accumulated over the past decades, the number of fundamental questions for further development of this field is still rather high [2].

White Sea islands are of great interest for solving some problems of island biogeography. There are more than 3 thousand islands of various sizes, remoteness from the

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mainland, aggregation into archipelagos, geological structure and age, etc. The White Sea drainage basin is confined to the eastern edge of the Fennoscandian shield. The western coast of the sea and nearby islands are predominantly composed of Early Precambrian (mainly Meso- and Neoproterozoic, i.e., 2.9-2.7 Ga), as well as Paleoproterozoic (2.45-1.80 Ga) rocks of the White Sea province [3]. Among the many islands of the White Sea, rocky ones with a glacier-worked surface, often dome-shaped, predominate. Islands composed of Quaternary deposits are few, but such is the largest island in the White Sea, Bolshoi Solovetsky, with an area of 246 km². Due to the continuing glacio-isostatic uplift of the territory, differing in intensity in different parts of the sea (up to 9 mm per year during the Holocene), the coastline changes and new islands appear. The biota of White Sea islands is very young – it began to form in the Holocene after deglaciation, about 10-12 Ka B.P. The cold-water White Sea juts out far into the boreal zone; therefore, the island biota is strongly influenced by cold water masses and maritime Arctic climate. Due to the severity of natural and climatic conditions, most of the islands, especially small and rocky ones, are characterized by a wide distribution of coastal crowberry - treeless tundra-like communities and of specific polygonal bogs [4] not found on the mainland coast in these latitudes. The mainland coast and relatively large islands (0.1-0.5 km², depending on the distance from the mainland) are covered with forest; smaller islands are usually treeless. Lakes and watercourses on the islands are extremely rare, except for Bolshoi Solovetsky Island. At the same time, small pools are often found on the coastal rocks, which are usually the only refuge for a few freshwater plant species.

2. Methods

Since 1987, more than 100 islands have been surveyed in Onega Bay of the White Sea and along its western coast between 63.8° N and 66.4° N. Almost all the islands were surveyed for the first time. To compare and evaluate the data obtained, we used information about the flora of islands in the Gulf of Kandalaksha and the Solovetsky Archipelago obtained by other researchers [5, 6 and references therein]. When analyzing the lists of species, the size and remoteness of the islands from the mainland or the nearest large island, the geological structure, the serration of the coastline, the percentage cover of forest vegetation, etc., were taken into account.

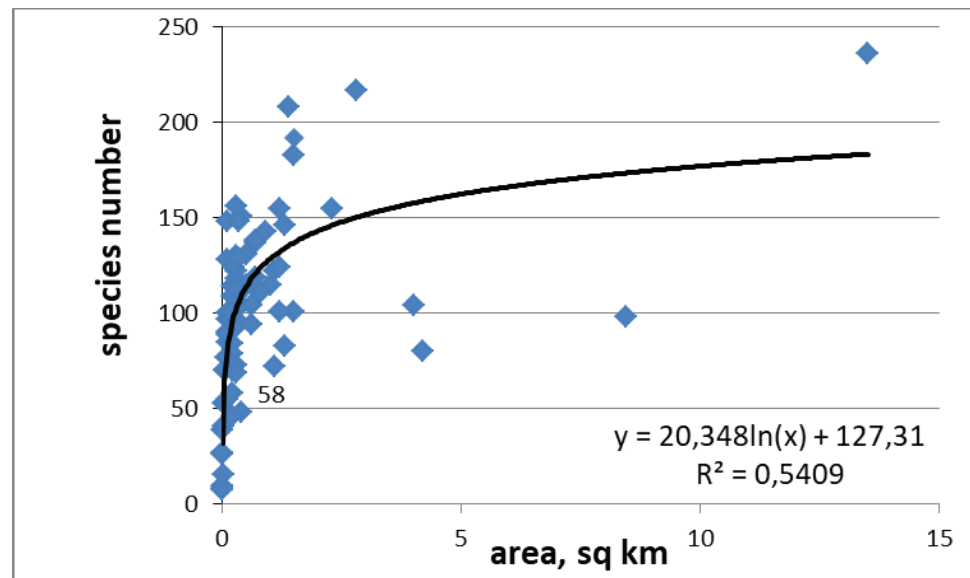


Figure 1: Dependence of the number of vascular plant species on the island size

3. Results

In total, more than 700 species of vascular plants have been identified on the islands. The number of native species varies from zero on rocky islets, barely rising above the water surface at high tide, to 236 on Kondostrov Island (64.220857 N, 36.629923 E) and 337 on Bolshoi Solovetsky Island (65.097194 N, 35.676307 E). The floristic richness of the islands primarily depends on their size (Figure 1; Bolshoi Solovetsky Island was not taken into account when plotting the diagram) but is also closely related also to the geological structure of the island and the serration of its coastline.

Given a comparable size, the number of vascular plant species is higher on rocky islands than on islands composed of loose sediments since the latter lack the obligate or facultative petrophytes widespread in the region, as well as hygro-, hydro-, and helophytes growing in pools on rock and micro bogs along the pools. Thus, Khedostrov Island (64.037428 N, 36.777551 E) is one of the largest in the White Sea; its area is 3.9 km². The island is composed of loose Quaternary sediments; it differs from all other islands in the White Sea in having unserrated coastline. There are no reservoirs, streams, or mires, and 111 native vascular plant species have been recorded on the island [7]. In comparison with other White Sea islands of similar size, the flora of Khedostrov is 1.5–2.0 times poorer.

The richness of the flora of rocky islands depends on the composition of the rocks. An overwhelming majority of the islands are composed of acid rocks - granite-gneisses, wherefore the number of species on them is rather low, and the species composition is

relatively poor and uniform. In the presence of dikes and intrusions of basic, ultrabasic, and carbonate rocks there form richer soils and the number of plant species increases by 10-15%. Species demanding soil fertility are more often found on northerner islands located in the Gulf of Kandalaksha, where rocks of basic and ultrabasic composition are more widespread. There are also small veins of alkaline ultramafic rocks and carbonatites, which predetermines the seemingly paradoxical upward trend in the species richness of vascular plants from south to north [7]. However, this pattern holds only on islands larger than 0.25-0.5 km². For example, Mramorny Island (65.420921 N, 34.631167 E), the only island in the White Sea composed of carbonate rocks - carbonatites associated with amphibolites, was found to harbor 82 species of vascular plants [3], which is slightly more than on other White Sea islands of similar size. However, there are no species specific to this very island, although the island's flora was expected to be richer and more original and to include at least some obligate calciphilic species due to the unique geological structure. The relative floristic poverty is associated with small island size (less than 0.1 km²) and a minimal array of habitats.

The formation time of island floras is comparable – almost all islands are of the same age since the last glaciation used to cover the White Sea drainage basin. Two neighboring islands - Nemetsky Kuzov (64.950683 N, 35.160424 E) and Russky Kuzov (64.934317 N, 35.123041 E) with elevations of 118 m and 123 m above sea level, became deglaciated in Late Glacial time, earlier than others. Furthermore, they were never flooded during the periods of marine transgressions in the Holocene. Oro-Arctic communities have been preserved on their tops as isolated relics of secondary periglacial vegetation. Such arctic-alpine species as *Carex bigelowii*, *Juncus trifidus*, *Kalmia procumbens*, or the hypoarctic species *Diapensia lapponica* occur in the southernmost known locations of their flatland distribution range. The flora of both islands is relatively affluent, but this is due to their large size rather than to the earlier degradation of the ice cover.

Taxonomic analysis shows that the family-species spectra of the island floras and the local, mainland floras differ markedly. The triad Cyperaceae, Poaceae, and Asteraceae is constantly at the top of the spectra of mainland floras. In contrast, the Poaceae family always occupies the first place in all island floras, followed by Cyperaceae and Asteraceae. The Ericaceae family appears in the ten leading families of island floras, sometimes occupying the 3rd-4th or even 2nd-3rd positions. Also, the leading families include Polygonaceae, and the ranks of the families Apiaceae, Betulaceae, Chenopodiaceae are higher, whereas the positions of the families Brassicaceae and Ranunculaceae are lower. The smaller the island, the more the arrangement of families, except for the top two or three, deviates from the "basic" spectrum of leading families

of the region's local floras. The role of the Poaceae family, which accounts for up to 38% of all species on rocky treeless islets (ludas), increases especially sharply [5].

The geographic analysis of the structure of the floras demonstrated significant differences of island and "coastal mainland" floras from the more inland floras. The proportion of boreal species declines significantly along the inland - coastal - island flora sequence. They account for 70-80% of the total in inland floras, 50-70% in coastal ones, and less than 50% in island floras. At the same time, there is an increase in the share of northerner species (arctic, arctoalpine, arctoboreal, hypoarctic, etc.), from 10-15% in inland floras, 15-30% in coastal floras, and up to 40% or more in island floras. In island floras, the proportion of northern species increases with a decrease in the island's size and its distance from the mainland; it is also higher on treeless islands [5, 6, 7]. On White Sea islands, many "northern" plant species penetrate far south into the boreal zone; many of them are found here in their southernmost locations in Eastern Fennoscandia. Such latitudinal fractions as nemoral, boreal-nemoral, plurizonal, and others are few. No patterns were observed in the fluctuations of the number of their representatives in the flora and their proportion in the total number of species. According to some indicators, the White Sea island floras are more similar to the floras of high Arctic latitudes (e.g., floras of Barents Sea islands) [6].

4. Discussion

The main factor determining the plant species richness on islands in the White Sea is the island's size, as a wider range of habitat types is found in a greater area under equal conditions. For islands up to 0.5 km² in area, the relationship between the number of species and the size of the island is almost linear (Figure 1). The number of species on the islands decreases insignificantly with distance from the mainland [8], which can be explained by the relatively small size of the White Sea – almost all the islands have a "coastal" location. Nevertheless, the flora of the island most remote from the mainland coast (28 km), Sennukha (64.823710 N, 35.580448 E), is significantly poorer and has only 45 species. In addition, the serration of the coastline affects the composition of the flora of an island. For example, islands with bays harbor typical halophilic species *Ruppia* spp., *Zostera* spp., *Salicornia* spp., *Eleocharis parvula*, which are absent on rocky islands of round or elliptical shape devoid of bays. Note that islands with bays are more often visited by humans since there are convenient mooring places for small vessels, and so their floras get enriched with alien species. Most islands without bays have 1-2 species of anthropochores if at all [3, 6, 8].

5. Conclusions

Islands in the White Sea are quite suitable objects for clarifying some problematic questions of the theory of island biogeography. Since the island floras are probably quite sensitive to the ongoing climate changes that strongly impact northern (Arctic and Subarctic) regions, including the White Sea basin, they deserve closer attention from researchers.

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