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Characteristics of selected elements in the population structure of *Myrica gale*

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The aim of this study was to characterize the spatial structure, density and distribution of shoots within the individual clumps of *Myrica gale*, and the sexual structure in the populations of this species. The area of most clumps varied from 0.02 to 20 m^2. The density of shoots in the clumps was negatively correlated with the size of the clump, the mean value being 23.31 shoots per m^2. The density of shoots in different parts of the clumps was higher in the peripheral parts of the clumps than in their centers. There were more male than female shoots in the clumps (75.87% and 24.13%, respectively). In the 57% of the clumps both male and female shoots were recorded. The occurrence of monoecism and synoecism was common.

Key words: endangered plants, *Myrica gale*, population structure, reproduction

Introduction

The European bog myrtle *Myrica gale* belongs to the group of species whose numbers have decreased owing to the progressive degradation of fens and transitional bogs caused by human activity (Jasnowski *et al*. 1968). In Poland, the plant is protected by law, being in category V (vulnerable, i.e. taxa likely to move into the endangered category if the threats persist) of endangered species in Western Pomerania (Żukowski & Jackowiak 1995). In Germany, it is classified in category 3 (threatened taxa; Korneck *et al*. 1996).

In Poland, the species occurs in a narrow belt along the Baltic Sea coast, reaching its southeastern boundary of distribution there. It is chiefly concentrated above the Szczecin Lagoon and in the Rega River estuary, from Lake Gardno to the town of Puck, and in the vicinity of Lębork and Gdańsk (Browicz & Gostynska-Jakuszewska 1968). Its only inland sites in Poland were reported from the vicinitys of the towns of Lubsko and Jasień (Decker 1911).

Myrica gale prefers habitats of fairly high levels of ground water on the border of mineral and peat soils (Czubiński 1950). Most frequently the plant occurs on peat bogs and peaty meadows, and on the outskirts of wet seaside pine forests. It can also be encountered in alder buckthorn-willow (*Alnus–Rhamnus–Salix*) brushwoods in riverside parts of riparian forests or, rarely, in willow-alder thickets on lake shores and on wet coastal dunes near the city of Gdańsk (Browicz & Gostyńska-Jakuszewska 1968).

The studies carried out in the peat-bog basin

above the Szczecin Lagoon (Jasnowski 1961) showed that *M. gale* maintains good vitality in areas whose ground-water level is not below 30–40 cm under the soil surface, and does not vary much. An important factor is the lack of stagnant water, which might induce a passage into more hygrophilous communities.

Bagna Rozwarowskie (Rozwarowskie Marshland) complex lies in the area of the Kamień Pomorski district between Rozwarowo and Dobropole (the West-Pomeranian province of Poland, 53°55´–53°51´N, 14°42´–14°46´W). The Bagna Rozwarowskie area of low peat-bog character displays an outstanding floristic richness. The marshland is characterized by a complicated hydrographic net with the rivers Grzybnica and Wołczenica and a vast network of canals and ditches as the core elements. Among them rush communities of the *Phragmitetea* class are chiefly present, being accompanied by a peat alder swamp in the southern part. In recent times in the central part, salt-marshes with such rare species as *Aster tripolium*, *Triglochin maritima*, *Juncus gerardi*, *Lythrum hyssopifolia* and *Glaux maritima* (M. Ciaciura unpubl. data) have been encountered. Currently they are completely degraded owing to cultural practices (reed harvesting) carried out in this area. *Myrica gale* grows here mainly in reed rushes *Phragmitetum australis* (Gams 1927, Schmale 1939) and in peaty alder swamp *Sphagno squarrosi–Alnetum* Sol-Gorn. (1975) 1987 (Ciaciura & Stępień 1998). In 1993, the establishment of a legally protected 16-km^2 nature reserve "Rozwarowo" was proposed (M. Ciaciura unpubl. data). In 2004, Bagna Rozwarowskie was included in the network of protected areas "Nature 2000" (voivodeship code PLB 320001).

Material and methods

The aim of this study was to determine the distribution of *M. gale* in the area of Bagna Rozwarowskie and to evaluate the current state of selected elements in the population structure of this shrub.

The study was conducted during 2001–2003. In the first stage of the study, the borders of distribution ranges of five bog-myrtle sub-populations were determined and plotted on a topographic map in a scale of 1:25 000. On account of the vast area of the *M. gale* distribution, a 54.45-ha area (the research plot P) was selected in the second stage for detailed studies. The territory was divided into squares of 165 × 165 m and a number of measurements were carried out to characterize various *M. gale* clumps growing within the squares. We determined the spatial areas of the clumps, number of shoots and the share of dead and living shoots per clump, the ratio of male and female shoots, and the occurrence of fruiting shoots in the clumps. Spearman's rank correlation coefficient (r_s) between the density of shoots (live, dead, and total) and the clump area was calculated.

Differences in the density of shoots relative to the distance from the clump center were assessed using the transection method: the clumps were transected radially in 0.4-m increaments starting from the center and shoots were counted in each transect. Circular clumps from different size classes (< 1.0; 1.1–3.0; 3.1–5.0; 5.1–7.0; > 7.0 m) were selected. The Kruskal-Wallis ANOVA was carried out to evaluate the effect of the distance from the clump center on the shoot densities.

In the study area of plot, 11 phytosociological records were made according to the system of Braun-Blanquet (1964). The syntaxonomical identity of species was determined according to Matuszkiewicz (2001). Nomenclature follows that of *Flora Europaea* (1964–1980).

Results

In the area of Bagna Rozwarowskie the population of *M. gale* is one of the most abundant in Poland. It is composed of five subpopulations distributed between Rozwarowo, Nowe Rekowo, Dobropole and Lake Piaski (Fig. 1). Subpopulations 1 and 2 occur in a *Phragmitetum australis* community (Gams 1927) Schmale 1939, populations 4 and 5 in a *Sphagno squarrosi–Alnetum* Sol-Gorn. (1975) 1987 community, while in the area of subpopulation 3 both communities mentioned above are present (Ciaciura & Stępień 1998). In Poland, *M. gale* is rarely found in these communities.

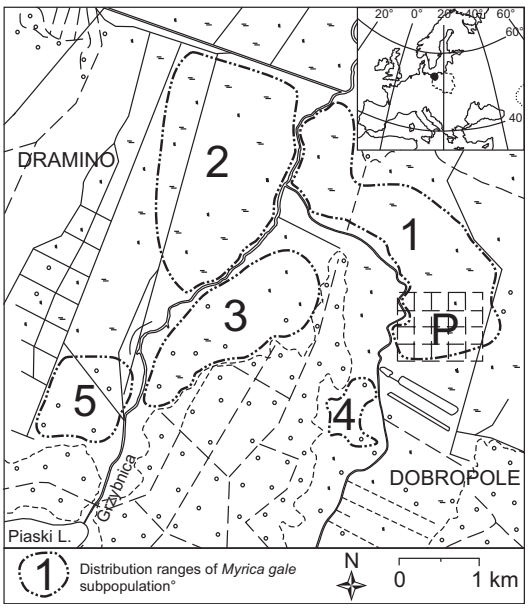

Fig. 1. Distribution of *Myrica gale* subpopulations in Bagna Rozwarowskie. Location of study plot P is indicated (1, 2, 3 = *Phragmitetum australis*; 4, 5 = *Sphagno squarrosi-Alnetum*).

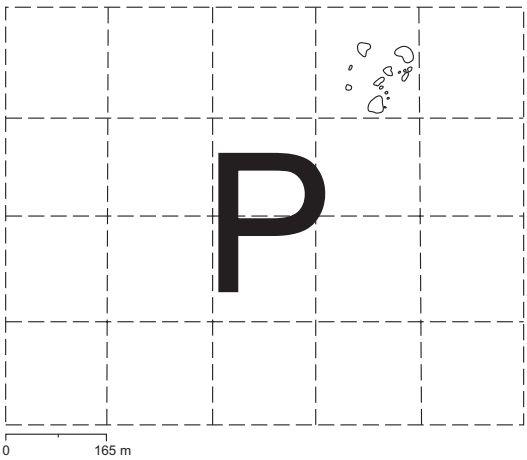

Fig. 2. Spatial distribution of *Myrica gale* clumps in plot P.

The *M. gale* subpopulations differ from one another by their vigour. The differences result from the economic use of a part of the marshland. Mowing of reeds together with *M. gale* shrubs growing there and changes in water relations caused by land reclamation measures have distinctly affected the condition of the shrubs.

Within subpopulation 1 the lowered water level was most distinctly manifested. In the northern part of the area, *M. gale* is mown with reeds. In the central part mowing was stopped yet the condition of the shrubs is very poor. During the studies on research plot P, the condition of the shrubs was fairly good and the *M. gale* shrubs were abundantly blooming and fruiting. However, in spring 2002 deterioration of the shrubs was observed. In a number of clumps, the shoots are intensively browsed by deer, frequently up to the level of past-year reeds, with only 3–4 spikes of the inflorescence remaining on the top.

Subpopulation 2, still large and abundant in 1993, has been mowed every year since the mid-1990s, this causing a gradual decline of the excessively weakened shrubs. On small non-mowed patches the *M. gale* shoots are strongly browsed and bloom rarely.

The northern mown area of subpopulation 3 is overgrown by reed rushes. In the southern part, *M. gale* growing in an alder swamp is in a good state, abundantly blooming and fruiting in spite of the fact that browsing on shoots by animals is more intensive than before.

In the area of subpopulation 4, *M. gale* is also mown within the reed rushes. The shrubs growing in a peaty alder swamp and on borders of numerous peat-hags are in a very good condition, like in the area of subpopulation 5 where intensified browsing on shoots by deer is observed.

Selected traits of the *M. gale* population were studied on plot P. The plot was located within subpopulation 1, which includes the *Phragmitetum australis* community in the *Myrica gale* variant (Table 1).

Myrica gale is characterized by a clump-like spatial organization. Most individuals usually occur in round or oval clumps. Growing clumps merge and their shapes become more and more irregular (Fig. 2). The area of clumps varies to a great degree (Fig. 3). In most cases (63.6%) their size varies from 0.02 to 20 m^2. The mean density of shoots in clumps was 23.31 shoots per m^2 (min–max = 11.73–48.68 shoots per m^2). With the increasing size of the clump the shoot density decreases (r_s = –0.620588, p = 0.0004) (Fig. 4c); this is particularly evident for dead

Table 1. *Phragmitetum communis* (Gams 1927) Schmale 1939, the *Myrica gale* variant. (Explanations: b = shrub layer. Species cover-abundance scale (left of decimal): r = 1 individual, + = few individuals, cover: 1 = 1%–5%, 2 = 5%–25%, 3 = 25%–50%, 4 = 50%–75%, 5 = 75%–100%. Sociability scale (right of decimal): 1 = growing singly, 2 = grouped or tufted, 3 = growing in small patches or cushions, 4 = growing in small colonies, extensive patches, or forming carpets, 5 = forming pure populations)

No. of relevés/No. of species	1/37	2/18	3/24	4/13	5/37	6/39	7/28	8/38	9/50	10/47	11/34	Constancy
Month in 2001	June	June	June	June	June	July	July	July	July	July	July	
Density of shrub layer (%)	20	20	10	20	10	20	20	10	+	+	min	
Cover of herb layer (%)	85	85	85	80	85	85	85	85	90	90	90	
Cover of moss layer (%)	min	min	min	min	min	min	min	min	min	min	min	
Relevé area (m^2)	300	200	200	200	200	200	200	300	200	300	200	
I. Ch. ass. *et Myrica gale*												
Phragmites communis	3.3	4.4	4.4	3.3	1.1	2.2	1.1	4.4	4.4	4.4	5.5	V
Myrica gale b	2.3	2.3	3.4	2.3	1.2	2.3	2.3	1.2	+	+	r	V
II. Ch. *Phragmition*												
Equisetum fluviatile	+	+	.	.	.	.	.	r	+	+	+	III
Sparganium erectum	.	.	.	.	r	+	.	.	r	r	+	III
Typha latifolia	.	.	.	.	.	r	.	+	r	r	+	III
III. Ch. *Magnocaririon*												
Peucedanum palustre	1.1	+	1.1	+	+	+	+	+	+	+	r	V
Galium palustre	+	+	+	1.1	.	.	+	+	.	r	+	IV
Lysimachia thyrsiflora	+	+	.	+	+	+	+	+	+	.	.	IV
Poa palustris	+	+	.	.	+	+	+	r	r	.	.	IV
Iris pseudacorus	+	.	.	.	+	r	+	r	.	r	+	IV
Scutellaria galericulata	+	.	.	+	+	+	.	.	+	.	.	III
Carex elata	+	+	.	.	+	r	+	r	.	.	.	III
IV. Ch. *Phragmitetea et Phragmitetalia*												
Rumex hydrolapathum	+	r	.	.	r	r	.	r	.	r	r	IV
V. Ch. *Filipendulion ulmariae*												
Filipendula ulmaria	+	+	+	.	+	+	.	+	+	+	r	V
Lysimachia vulgaris	.	.	+	1.1	+	.	+	+	+	+	+	IV
Lythrum salicaria	1.1	1.1	.	.	.	r	.	+	+	r	.	III
VI. Ch. *Molinion caerulae*												
Molinia caerulea	.	r	2.2	1.1	2.2	1.1	3.3	.	+	.	.	IV
VII. Ch. *Calthion palustris*												
Juncus effusus	1.1	1.1	.	.	+	+	+	+	+	+	r	V
Juncus conglomeratus	+	.	.	r	+	+	.	.	+	+	.	III
Scirpus silvaticus	+	.	.	.	.	.	r	r	+	+	+	III
Myosotis palustris	+	.	+	.	.	.	.	.	+	+	+	III
VIII. Ch. *Molinietalia caerulae*												
Cirsium palustre	1.1	1.1	.	+	+	+	+	+	+	+	r	V

Galium uliginosum	+	.	+	+	+	+	+	+	+	+	.	V
Lotus uliginosus	+	.	.	.	.	.	r	r	+	+	+	III
IX. Ch. *Molinio–Arrhenatheretea*												
Cardamine pratensis	.	.	.	.	r	.	.	r	+	+	+	III
X. Ch. *Caricetalia nigrae*												
Hydrocotyle vulgaris	.	.	.	.	.	.	r	r	r	+	+	III
Stellaria palustris	.	.	.	.	r	r	r	+	+	+	.	III
XI. Ch. *Scheuchzerio–Caricetea nigrae*												
Peucedanum palustre	+	+	.	.	.	.	.	r	+	+	+	III
XII. Ch. *Alnetea glutinosae*												
Thelypteris palustris	+	1.1	2.2	1.1	r	+	+	1.1	+	+	+	V
Solanum dulcamara	1.1	1.1	.	.	+	+	+	+	+	+	r	V
Calamagrostis canescens	+	.	2.2	3.3	4.4	3.3	4.4	2.2	+	.	.	IV
Lycopus europaeus	+	+	.	.	+	r	.	+	+	+	+	IV
XIII. Other species												
Mentha aquatica	+	1.1	+	1.1	+	+	+	1.1	+	1.1	+	V
Potentilla erecta	+	.	+	.	+	+	+	+	+	+	r	V
Agrostis stolonifera	.	.	+	.	+	+	+	r	+	r	.	IV
Urtica dioica	.	.	+	.	r	+	+	r	+	+	.	IV
Valeriana dioica	.	.	+	.	+	+	+	+	+	+	.	IV
Lysimachia nummularia	.	.	r	.	r	r	r	r	+	+	r	IV
Eupathorium cannabinum	.	.	r	.	r	r	.	.	+	+	r	III
Dryopteris carthusiana	.	.	+	.	.	.	+	+	r	r	.	III
Lemna minor	.	.	r	.	.	+	.	+	r	+	+	III
Epilobium palustre	+	+	.	.	.	.	.	+	+	+	.	III

Sporadic species: **II**. *Glyceria maxima* 9 (+), 10 (+), 11 (+); **III**. *Carex acutiformis* 2 (+), 6 (r); 7 (+), 8 (+); *Carex rostrata* 9 (+), 10 (+); *Carex paniculata* 9 (+), 10 (+), 11 (+); *Carex vesicaria* 1 (+); *Cladium mariscus* 1 (+), 6 (r), 7 (r), 8 (1.1); *Ranunculus lingua* 9 (+), 10 (+), 11 (1.1); **IV**. *Scrophularia umbrosa* 9 (r), 10 (+), 11 (+); **VII**. *Caltha palustris* 9 (r), 10 (+), 11 (+); *Lathyrus palustris* 1 (+), 2 (+), 3 (1.1), 4 (+); *Polygonum bistorta* 1 (+); **VIII**. *Deschampsia caespitosa* 1 (+), 9 (+); *Lychnis flos-cuculi* 7 (r), 9 (r); **IX**. *Ranunculus acris* 1(r); **X**. *Ranunculus flammula* 6 (r), 9 (+), 10 (+), 11 (r); *Viola palustris* 5 (+), 6 (r), 7 (r), 8 (r); **XI**. *Veronica scutellata* 3 (+), 4 (+), 5 (+); **XII**. *Betula pubescens* b 1 (r); *Calamagrostis epigejos* 7(r); *Carex hirta* 1(+); *Cirsium arvense* 5(+), 7(+); *Dryopteris cristata* 5 (+), 6 (+), 7 (r), 8 (r); *Epilobium parviflorum* 9 (+); *Hottonia palustris* 10 (r), 11 (+); *Hydrocharis morsus-ranae* 10 (r), 11 (+); *Pinus sylvestris* b 5 (r); *Salix caprea* b 9 (r); *Salix cinerea* b 6 (r), 8 (r), 9 (r); **XIII**. *Carex panicea* 3 (+), 4 (+), 9 (+), 10 (r); *Frangula alnus* 1 (r), 3 (r), 5 (r); *Inula britannica* 3 (r), 5 (r), 6 (r), 7 (r); *Ranunculus sceleratus* 9 (+), 10 (+), 11 (+).

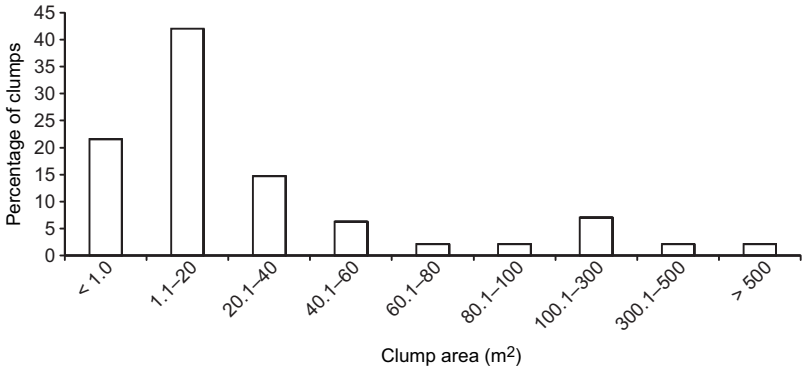

Fig. 3. Size of the areas of *Myrica gale* clumps in plot P.

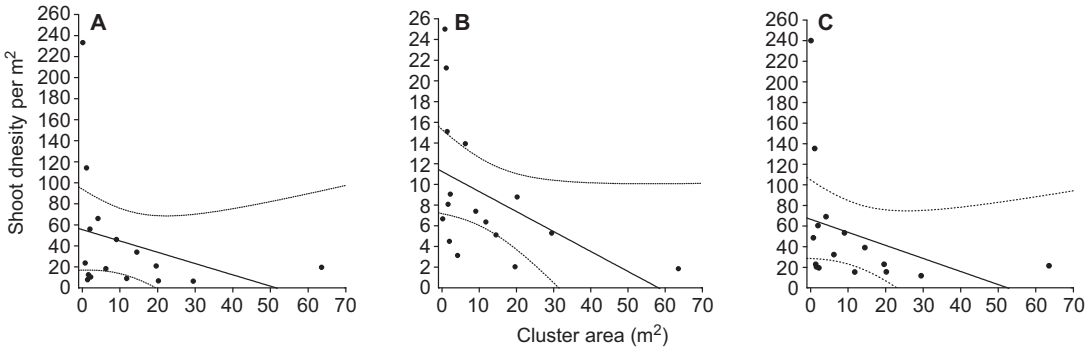

Fig. 4. Correlation between the clump size and the (**A**) living, (**B**) dead, and (**C**) living + dead shot density (dotted lines are confidence limits).

shoots (r_s = –0.597059, p = 0.001) (Fig. 4b), and less pronounced for living ones (r_s = –0.473529, p = 0.0007) (Fig. 4a).

In the outer parts of the clumps the shoot density was higher than in the center. In the center of small clumps (≤ 3 m in diameter) the mean shoot density measured using the transection method varied from 55 to 79. With an increasing clump area (clumps from 3.1 to 5 m in diameter) the shoot density decreased to 25–42 in the center, and then (in clumps exceeding 5.1 m in diameter) it increased again in the central part (Fig. 5).

In different clumps the percentages of shoots with male and female inflorescences varied (Fig. 6): 51.8% of the clumps develop shoots of the same sex, the clumps with male inflorescences prevailing (35.7%). The clumps with female inflorescences were much less common (16.1%).

Details on the selected traits of the *M. gale* populations on plot P are given in Table 2.

Discussion

In Bagna Rozwarowskie the bog myrtle population is extremely dynamic and in areas free of human activities its numbers disctibution increase. This was shown in comparative studies carried out by us during 10-year investigations (Ciaciura & Stępień 1998, M. Ciaciura unpubl. data). On numerous plots, the number and area of clumps increase and vigorously growing plants lose their primary clump structure forming stands.

Individual clumps of various spatial areas differ from one another not only in their size but also in the shoot density. A decrease in the density occurring with an increasing area of a clump is probably due to the gradually deteriorating light conditions within the clump, and the reduced amounts of nutrients in the substratum. The shoots growing in small clumps find better conditions for growth than those in large clumps,

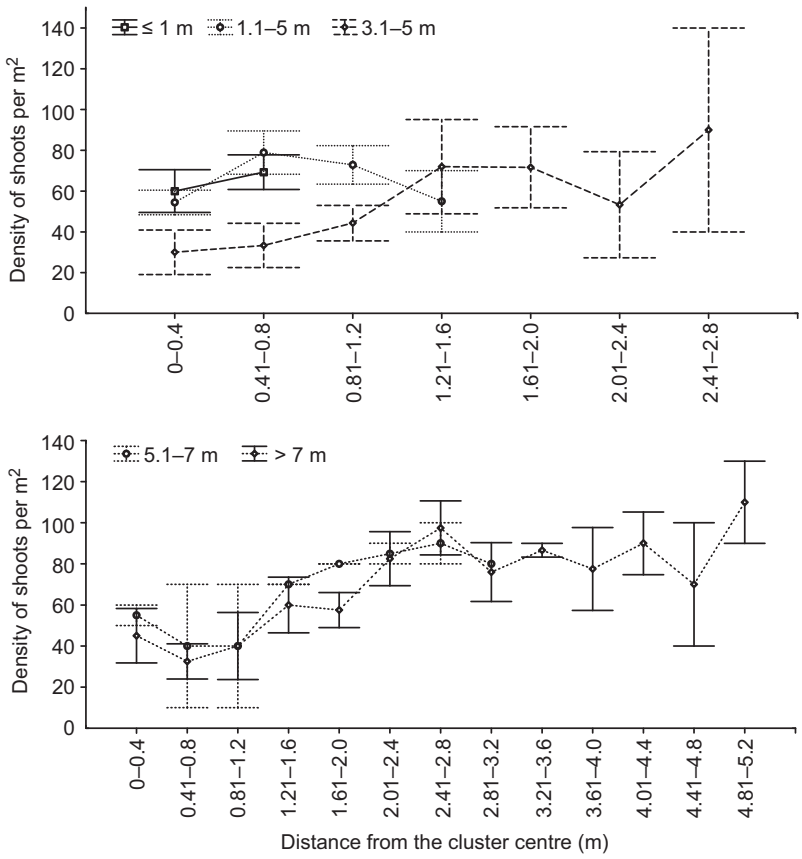

Fig. 5. Density of shoots depending on the distance from the clump centre in diferent clump size classes (indicated in the figure).

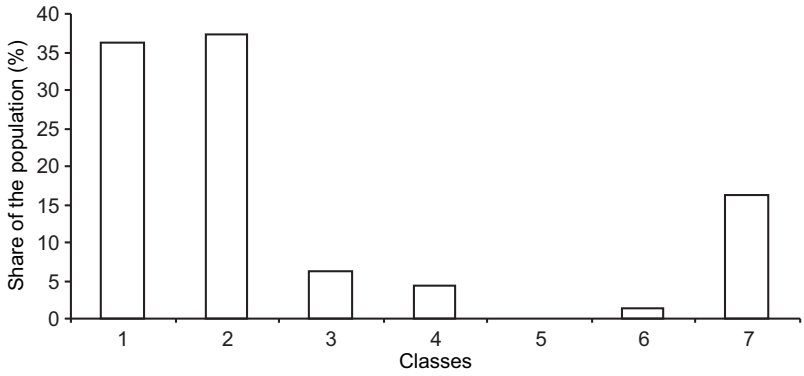

Fig. 6. Sexual structure of *Myrica gale* in plot P. Clump classes are: 1 = 100% shoots ♂; 2 = 99%–81% ♂, 1%–19% ♀; 3 = 80%–61% ♂, 20%–39% ♀; 4 = 60%–41% ♂, 40%–59% ♀; 5 = 40%–21% ♀, 60%–79% ♂, 6 = 20%–1% ♂, 80%–99% ♀, 7 = 100% ♀.

hence their density is greater. In large clumps, the density of shoots is greater in peripheral parts where the growing conditions are better than in the centre. In central parts of the clumps, a decrease in shoot density is caused by a gradual decline of old shoots. After their decline the conditions improve enough allowing young shoots to again appear in the centre, however, their density is not as great as in the periphery of the clump, probably because, in spite of improved light conditions, less mineral nutrients are accessible.

Occasionally recorded high percentage (60%) of the dead shoots is striking; it probably indicates a slightly decreased vitality of the *M. gale* plants. This is also supported by the low percent-

age of clumps where fruiting was recorded (just 33%) in spite of the high percentages (64%) of clumps with female flowers.

In the sexual structure of the *M. gale* populations, the quantitative prevalence of male shoots is striking, their mean share in clumps reaching 77.87%. This is probably associated with the way of pollen transfer: since the bog myrtle is a wind-pollinated species increased numbers of male inflorescences is an adaptation.

In Poland, *M. gale* occurs on the border of its distribution range (Hulten & Fries 1986), which probably causes various anomalies in its biology. *Myrica gale* is a dioecious plant with flowers in amentaceous inflorescences ♂ and ♀, monoecious shrubs being rare and synoecious flowers still rarer (Hegi 1981). However, mixed inflorescences occur quite widely in the populations of *M. gale* in northern Wales (Lloyd 1981). Our study shows a prevailing number of clumps with both male and female shoots (57%). Inflorescences ♂ and ♀ on the same shoot, inflorescences with both ♂ + ♀ flowers, and inflorescences with synoecious flowers were found to occur. In Bagna Rozwarowskie this is a common, not a sporadic phenomenon. We plan to investigate this further.

Table 2. Characteristics of selected traits of *Myrica gale* population in Bagna Rozwarowskie based on analysis of plot P.

Parameter or phenomenon description	Value
Number of measured clumps	143
Average clump height (m)	1.14
Max clump height (m)	1.60
Min clump height (m)	0.60
Average clump area (m^2)	202.96
Max clump area (m^2)	23100
Min clump area (m^2)	0.02
Average participation of dead shoots per clump (%)	15.06
Max participation of dead shoots per clump (%)	60
Min participation of dead shoots per clump (%)	0
Average participation ratio of male and female shoots per clump (%)	75.87/24.13
Number of clumps with fruiting shoots	52 (33.36%)
Max circumference of shoots per clump (cm)	6
Min circumference of shoots per clump (cm)	0.5

Myrica gale is an exceedingly valuable though receding species in the Polish flora. The population in the area of Bagna Rozwarowskie is rich, dynamic, and it should be protected by law against human activity.

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