THE VARIABILITY OF SEEDS IN *SPERGULARIA MARINA* (L.) GRISEB. (= *S. SALINA* J.ET C. PRESL) GROWING ON SEACOAST AND INLAND SALINE SOILS IN POLAND

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(Received: March 26, 1991. Accepted: November 22, 1993),

ABSTRACT

The objective of this study was to analyse Polish populations of *Spergularia marina* in terms of seed variability, which was found to be independent of the environment to some degree. It was shown that the populations from industrialized and natural, but clearly unstabilized, habitats have less diversified seeds than populations from relict inland stands and some stabilized seacoast stands

KEY WORDS: *Spergularia marina*, halophytes, seeds, flora, relicts

INTRODUCTION

Spergularia marina is a polymorphic species occurring in Poland in widely dispersed stands. The high degree of diversification of this species is manifested in, among others, its seed morphology. Seed morphology is one of the key traits by which species from the genus *Spergularia* Presl are identified (Tutin et al. 1964) Lack of information about the full scale of seed and fruit variability of the species and genus in question can lead to mistakes in identifying plants.

The best known populations of *S. marina* in Europe are the Dutch populations, described in detail in several papers by Sterk (1969a, b, c, d). This author paid special attention to the various proportions of winged and unwinged seeds in the capsules of *S. marina*. Among the populations of northern Netherlands he found some that differed from the others in the proportion of capsules with predominantly winged seeds. The occurrence of a similar population was reported in Poland as early as 1963 by Wilkoń-Michalska. A detailed description of *S. marina* seeds was presented by Kowal (1966). However, it covered only part of the seeds of the species in question.

In the present study, the variability of *S. marina* seeds from populations growing in habitats differing in respect to their geographical, ecological and historical aspects is presented.

MATERIAL AND METHODS

The study was conducted on specially collected plants and on material borrowed from the following herbaria: TRN, KRAM, KRA and GDU. The capsules of 21 population samples from various regions of Poland (Fig.1) were analyzed in detail. The samples and stands are listed below:

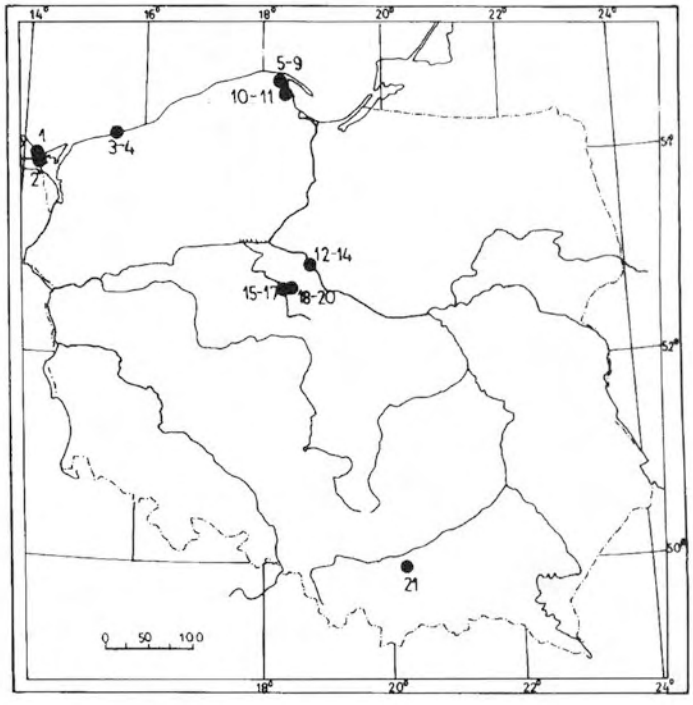

Fig. 1. Distribution of the population samples

1. Świnoujście (N.W. Poland), saline meadow, on a sandy site near a dock, July 21, 1990
2. Southern part of Melin Island on the side of the Piastowski Canal (N.W. Poland), near a metal jetty, on a site sprayed by sea water, August 10, 1990
3. Kołobrzeg (N. Poland), among reeds *(Phragmites australis)* near the Parsęta River, July 15, 1982

4. Kołobrzeg, near the stand of the previous sample, beyond the reed belt, on a grazed and trampled site, August 7, 1984
5. Władysławowo (N. Poland), on the Puck Bay, on peat in a depression recently exposed by water, with a scant plant cover, August 7, 1978
6. Władysławowo, near the previous stand, on a vailroad embankment with scant vegetation, on a sandy loam substrate formed by several layers turned over during recent clearing of a ditch, August 24, 1988
7. Władysławowo, near the previous stand, on peat, among very dense and low sod, August 24, 1988
8. Władysławowo, near the previous site, on a similar stand with thick vegetation, July 25, 1989
9. Władysławowo, in a meadow near the previous stand, but somewhat drier with a thick plant cover, July 25, 1989
10. Mrzezino (N. Poland) near the estuary of the Reda River, on sand with a scant plant cover, July 27, 1988
11. Mrzezino, in the old locality of Beka, about 80 km from the previous stand, August 27, 1988
12. Ciechocinek (Central Poland) along the graduation works on a site sprayed by the salt spring, October 13, 1983
13. Ciechocinek, next to the previous stand, on the west side of the graduation works, July 26, 1986
14. Ciechocinek, on the east side of the works, July 26, 1989
15. Janikowo (Central Poland) on a meadow near the sodium works, on peat soil, October 11, 1983
16. Janikowo, near a waste dump belonging to the sodium works, on peat soil with dense sodding, September 5, 1988
17. Janikowo, next to the previous stand, on a site with a poorer vegetation cover, September 5, 1988
18. Mątwy, (Central Poland), next to railroad tracks near the sodium works, October 11, 1983
19. Mątwy, near a waste sewer from a factory, at the base of a limestone heap, July 14, 1989
20. Mątwy, near the previous stand, in a ditch at the edge of a reed patch, July 14, 1989
21. Barycz near Wieliczka (S. Poland) along a ditch with salt spring water, August 8, 1948.

The habitats from which most of the samples were taken are unstable. They are affected by man as well as natural factors, particularly intense near river estuaries. Only the habitats of some of the samples from Władysławowo (7, 8, 9) can be considered somewhat stable. The stands of samples from Kołobrzeg and Ciechocinek are considered relict stands, although not immune from the influence of man. The stands which surround the industrial works in Mątwy and Janikowo in the Kujawy region of Poland are secondary and, to a large degree, anthropogenic.

Taking several samples from the same locality was necessary not only because of the diversified nature of the stands, but also due to the visible differences in plant shapes. The populations which scantily covered the ground were usually made up of highly branched and multiflowered specimens, while those growing densely, of small, only slightly branched specimens with few flowers. The size of the plot from which specimens were collected ranged from 1 m^2 to tens of m^2, depending on the size and density of the plants in the given population.

A single sample was composed of 50 capsules collected randomly, mainly from among distal capsules, one from each plant. The seeds in each capsule were counted and classified using a Carl Zeiss Jena stereomicroscope. Selected seeds were viewed in a Biolar microscope and their images drawn using a drawing apparatus. A scanning microscope was used for photographing samples prepared by the routine gold dusting procedure.

Four categories were used in the classification of seeds. Winged seeds: seeds with border wider than 0.15 mm. Unwinged seeds: seeds with no border or a barely visible border less than 0.15 mm wide. Tuberculate seeds: seeds with nodules on their coats, similar to papillae, sometimes as high as they were wide. The remaining seeds were classified as smooth or rugose.

After drying in room temperature, 100 mature seeds from each category were weighed on an analytical scale (Zakłady Mechaniki Precyzyjnej, Gdańsk).

LIST OF LOCALITIES OF *SPERGULARIA MARINA* (L.) GRISEB. WITH SEEDS SMOOTH AND SLIGHTLY RUGOSE

N. Poland: 1. Świnoujście, coll. H. Piotrowska 1963, GDU; 2. Łunowo, coll. H. Piotrowska 1962, GDU; 3. Bożyce, coll H.Piotrowska 1956, GDU; 4. Karsibórz coll. D. Bronisz-Wolnomiejska 1990 TRN; 5. Mielin – island (S. part), coll. D. Bronisz-Wolnomiejska 1990 TRN; 6. Mrzeżyno, coll. H. Piotrowska 1960 GDU; 7. Kołobrzeg (N of Kołobrzeg), coll. H. Piotrowska 1960 GDU; 8. Jastarnia, coll. K. Starmach 1929, KRAM, 9. Władysławowo, coll. M. Ceynowa-Giełdon 1978, KRAM; 10. Swarzewo, coll. J. Wilkoń-Michalska 1959, TRN; 11. Puck, coll. Straube 1897, TRN; 12. Mrzezino, coll. M. Janczak 1971, GDU; 13. Wielki Kack, coll. Klinsmann 1862, TRN; 14. Zaspa, coll. C. Lützow 1896 TRN; 15. Brzeźno, coll. Helm 1861, TRN; 16. Nowy Port, coll. C. Lützow 1883, TRN; 17. Składy, coll. Scholz 1896, TRN; 18. Westerplatte, coll. Lange 1887, TRN; 19. Stara Pasłęka, coll. F. Seydler 1868 TRN.

Central Poland: 20. Toruń-Podgórz, coll. Nowicki, TRN; 21. Ciechocinek, coll. H. Piotrowska 1960 GDU; 22. Słonawy near Szubin, coll. J. Wilkoń-Michalska 1958, TRN; 23. Solno near Inowrocław, coll. J. Wilkoń-Michalska 1959, TRN; 24. Janikowo, coll. M. Rejewski 1966, TRN; 25. Mątwy, coll. J. Wilkoń-Michalska 1966, TRN; 26. Łęczyca, coll. J.Wilkoń-Michalska 1959, TRN; 27. Leszcze, coll. J. Wilkoń-Michalska 1959, TRN;

S. Poland: 28. Szczerbaków near Wiślica, coll. T. Tacik 1977, KRAM; 29. Kraków, coll. H. Trzcińska-Tacik 1974, KRA; 30. Wieliczka, coll. J. Wilkoń-Michalska TRN; 31. Barycz near Wieliczka, coll. M. Sychowa, D. Wcisło 1975, KRAM.

LIST OF LOCALITIES OD *SPERGULARIA MARINA* (L.) GRISEB WITH TUBERCULATE SEEDS

N. Poland: 1. Łunowo, cool. H. Piotrowska 1962, GDU; 2. Karsibórz, coll. H. Piotrowska 1962, GDU; 3. Mielin-island (S. part.), coll. D. Bronisz-Wolnomiejska 1990, TRN, 4. Kołobrzeg, coll. H. Piotrowska 1963, GDU; 5. N of Kołobrzeg, coll. H. Piotrowska 1963, GDU; 6. Jastarnia, 1957, KRA; 7. Władysławowo, coll. M. Ceynowa-Giełdon 1988 TRN; 8. Nowy Port, coll. C. Lützow 1894 TRN; 9. Westerplatte, coll. H. Klinggraff 1894, TRN; 10. Stara Pasłęka, coll. Straube TRN;

Central Poland: 11. Ciechocinek, coll. J. Wilkoń 1955, TRN;

S. Poland: 12. Owczary near Busko, coll. B. Jarosz 1936, KRA; 13. Szczerbaków near Wiślica, coll. T. Tacik 1977, KRA;

LIST OF LOCALITIES OF *SPERGULARIA MARINA* (L.) GRISEB. PLANTS WHOSE CAPSULES *CONTAIN MAINLY BROADLY WINGED SEEDS.*

N. Poland: 1. Władysławowo, coll. M. Ceynowa-Giełdon 1988 TRN;

Central Poland: 2. Słonawy near Szubin, coll. J. Wilkoń-Michalska 1958, TRN; 3. Ciechocinek, coll. J. Wilkoń-Michalska 1959, TRN, 4. Łęczyca, coll. J. Wilkoń-Michalska 1959, TRN;

S. Poland: 5. Owczary near Busko, coll. M. Ceynowa-Giełdon 1968, TRN.

RESULTS

Overall variability of seeds – The length of the brown disk of borderless *Spergularia marina* seeds ranged from 0.6-0.9 mm, width 0.4-0.8 mm and thickness 0.2-0.4 mm. The outline of the seed can be described as inverse egg-shaped or triangular-kidney shaped.

The ifferentiation in seed morphology manifested itself in, among others, seed coat morphology (Figs. 2-5). In some of

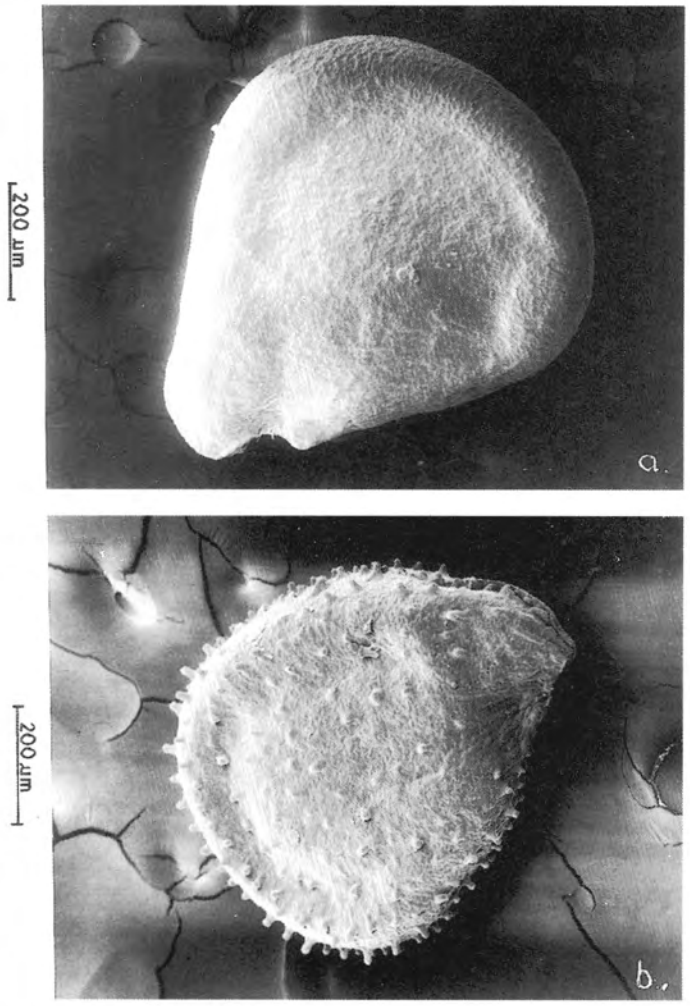

Fig. 2.
Spergularia marina (L.) Griseb. seeds;
a – smooth seed, only slightly rugose, from Ciechocinek, x 100,
b – tuberculate seed from Kołobrzeg, x 100

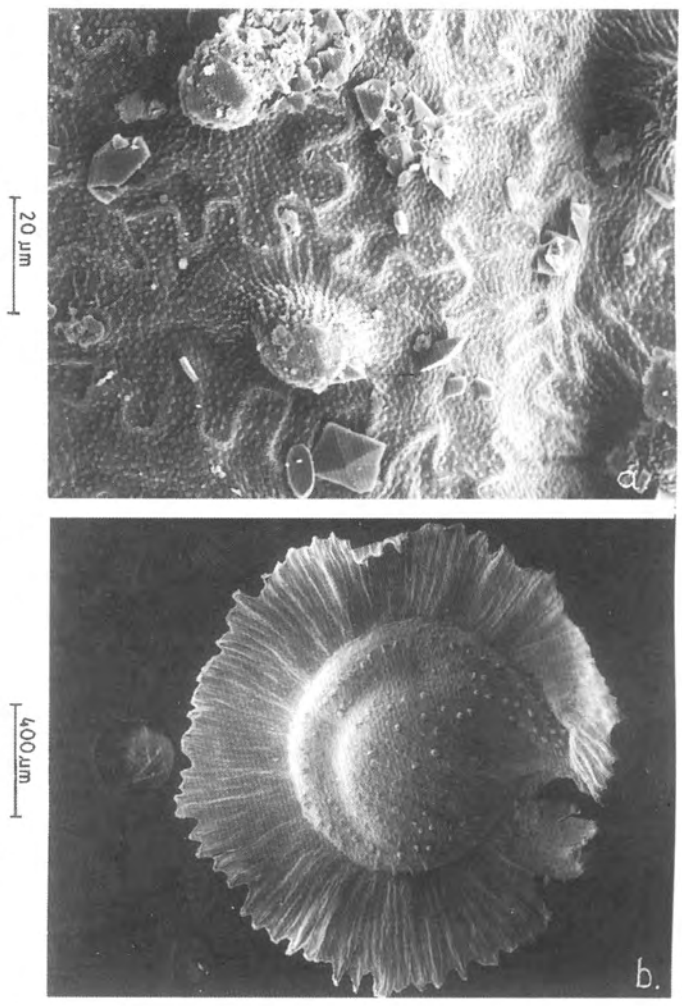

Fig. 3.
Spergularia marina (L.) Griseb. seeds;
a – a fragment of a tuberculate seed coat
of *S. marina* from Kołobrzeg, x 1000,
a winged seed from Ciechocinek, with a tuberculate coat, x 45

the seeds the coat was more or less smooth or rugose, whereas in others it had high nodules. These nodules were located in the central part of concavely indented epidermal cells of the testa (Figs. 3a, 5a). The nodules are formed by the highly thickened cell wall, which in smooth seeds is, at most, slightly convex, whereas in tuberculate seeds, highly convex in the central part of the seed. The microscopic examination revealed a nonuniform layer of cells of the internal part of the seed coat under the testa cells. The external walls of this layer had irregular thickenings which, in tuberculate seeds, passed into thickened processes connected with the nodules of the epidermis.

The size and distribution of the nodules on the surface of the studied seeds were not the same. The largest and most numerous were on the edges and on the lateral borders of the seed.

A membranous, sometimes thin, edging (Figs. 3b, 6b, c) projected from the lateral sides of both smooth and tuberculate seeds. It usually encompassed the entire circumference with the exception of the seed attachment. Seeds in which the ends of the edging overlapped were very rarely found (Fig. 7a), whereas seeds that were only partially winged were found much more frequently and had a border encompassing less than 2/3 of their circumference (Fig. 7c, d, i). The width of the edging varied significantly. The widest, usually called wings, reached 0.3-0.6 mm, equalling or slightly exceeding the radius of the main disk of the seed. In addition to distinctly winged and unwinged seeds, specimens with a barely microscopically visible, narrow band, less than 0.15 mm wide were also found. They were usually larger than unwinged seeds. The main disk of winged seeds was usually larger than of unwinged seeds. This is related to the greater average weight of winged seeds. For example, in the studied population from Władysławowo, the weight of 100 smooth, unwinged seeds equalled 0.00592 g while the weight of the same number of winged seeds equalled 0.00663 g, the weight of 100 tuberculate unwinged seeds equalled 0.0061 g and of 100 tuberculate winged seeds 0.00922 g.

Differentiation of seeds in one plant – The plants of the species under discussion formed either smooth, at most rugose seeds or exclusively tuberculate seeds, while winged and unwinged seeds frequently occurrred together (Figs. 8 and 9).

In most of the studied specimens, in agreement with the species description of *S. marina* (Tutin et al. 1964), the capsules contained unwinged or unwinged with small amounts of winged seeds at the bottom of the capsule. There was no lack, however, of plants in whose capsules the proportions of winged and unwinged seeds were reversed.

All or most of the capsules of one plant contained the same dominant type of seed, either unwinged or winged. *S marina* plants can thus be divided into two types, those that produce mainly un-

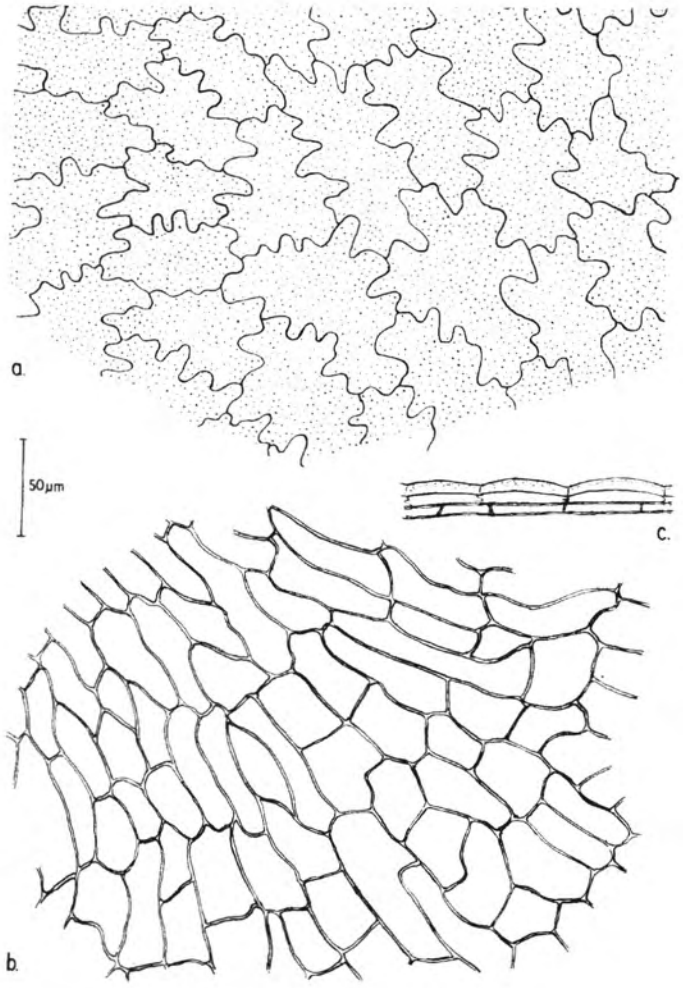

Fig. 4. Seed coat of smooth seeds, specimen from Mątwy
a – testa cells viewed from above, from the outside,
b – tegmen cells viewed from the outside of the seed,
c – cross section through the seed coat (testa and tegmen)

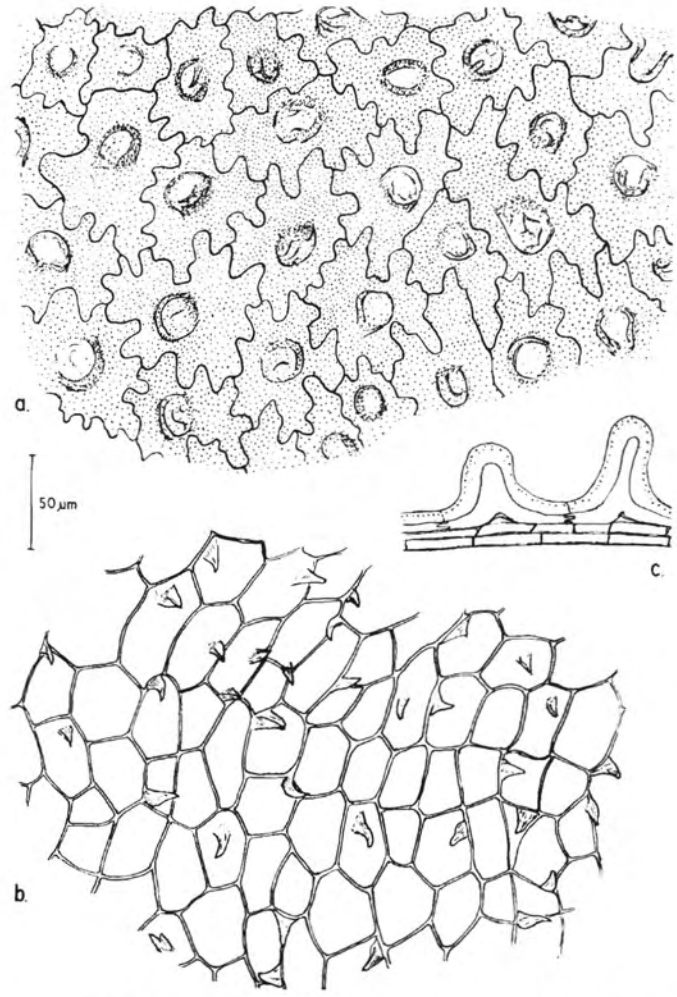

Fig. 5. Seed coat of tuberculate seeds, specimen from Władysławowo
a – testa cells viewed from above, from the outside of the seed,
b – tegmen cells viewed from the outside of the seed,
c – cross section through the seed coat (testa and tegmen)

winged seeds, and those that produce mainly winged ones. Plants that produced exclusively one type of seed were also found.

In plants producing winged and unwinged seeds, more winged seeds were usually found in the proximal capsules than in the capsules most distal from the main inflorescence axis (Sterk 1969b).

The number of stands of plants with a predominance of winged seeds were relatively few. They were found on coastal sites in Władysławowo and within the relict, inland sites of Ciechocinek and Słonawy near Szubin in the Kujawy region of Poland (Wilkoń-Michalska 1963), near Łęczyca in central Poland and in Owczary near Busko in southern Poland (Fig. 10).

In some of the plants producing mainly unwinged seeds, single capsules were found in which all of the seeds were winged. These were, however, untypical capsules, with significantly smaller amounts of seeds than usually seen in the remaining capsules of this species.

The examined capsules of *S. marina* contained an average of 55 developed seeds. This number was, however, significantly higher in some populations (Table 1).

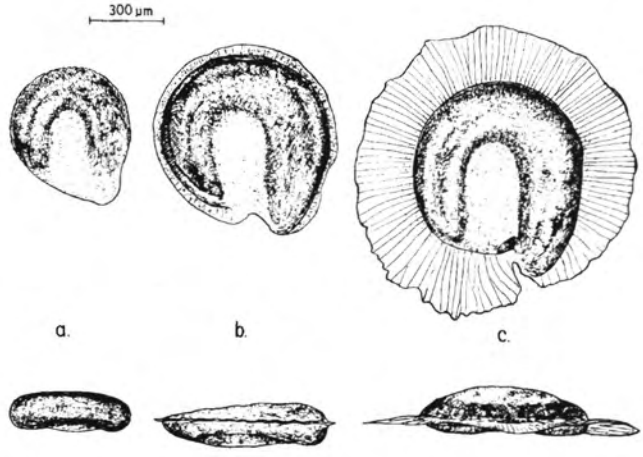

Fig. 6. Types of *Spergularia marina* (L.) Griseb. seeds, specimens from Barycz near Wieliczka
a – unwinged seed viewed from above and side,
b – seed with a very narrow border seen from above and side,
c – winged seed from above and side

Differentiation of populations – Both in the coastal and inland populations of *Spergularia marina*, specimens which produced mainly unwinged seeds with smooth or rugose coats dominated (Table 1). Plants that produced tuberculate seeds were usually a small part of some of the coastal and inland re-

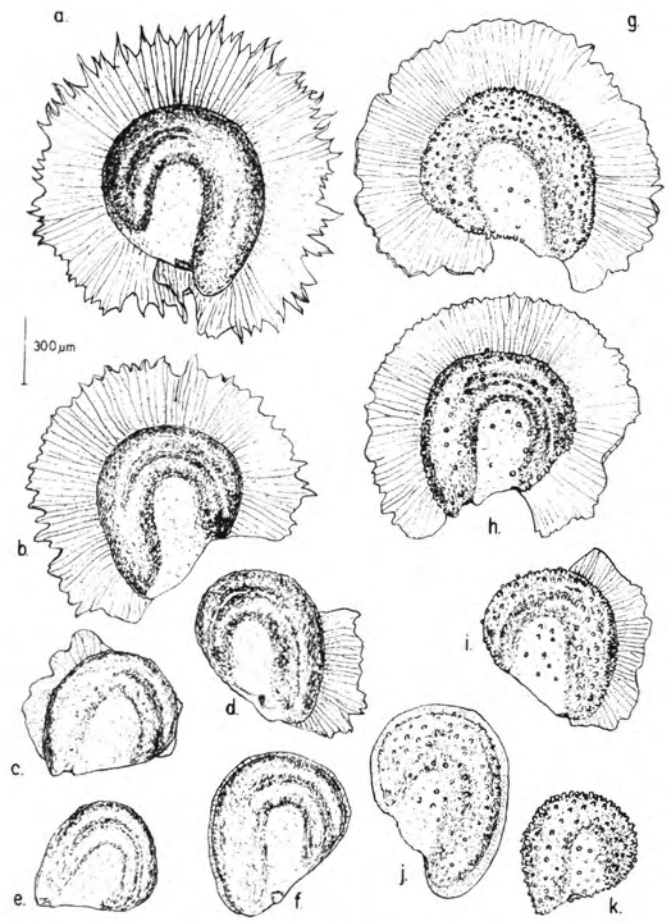

Fig. 7. Types of *Spergularia marina* (L.) Griseb. seeds, specimens from Władysławowo
a-f – smooth and rugose seeds,
g-k – tuberculate seeds,
a, b, g, h, – seeds with wide wings,
c, d, i – seeds partially winged,
f, j – seeds with a very narrow border,
e, k – seeds with no border

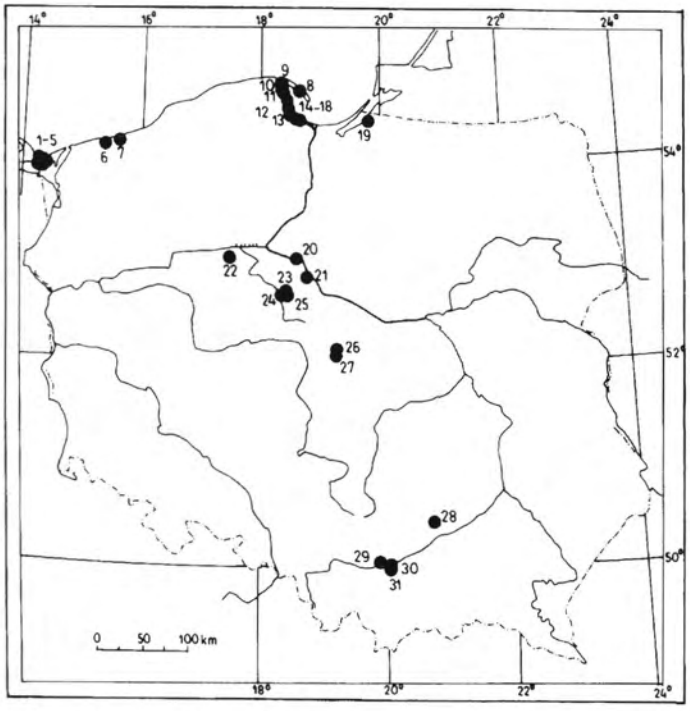

Fig. 8. The distribution of *Spergularia marina* (L.) Griseb. stands with smooth and rugose seeds, on the basis of herbaria specimens

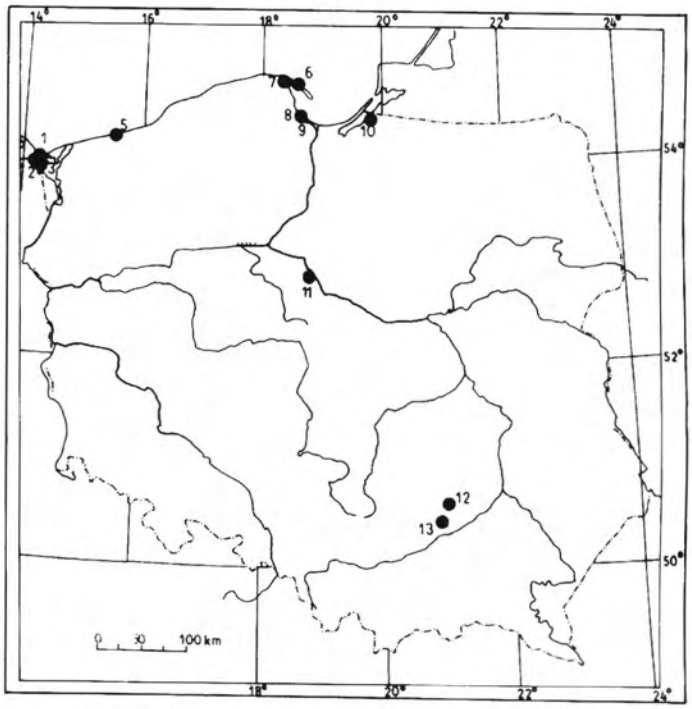

Fig. 9. The distribution of *Spergularia marina* (L.) Griseb. stands with tuberculate seeds, on the basis of herbaria specimens

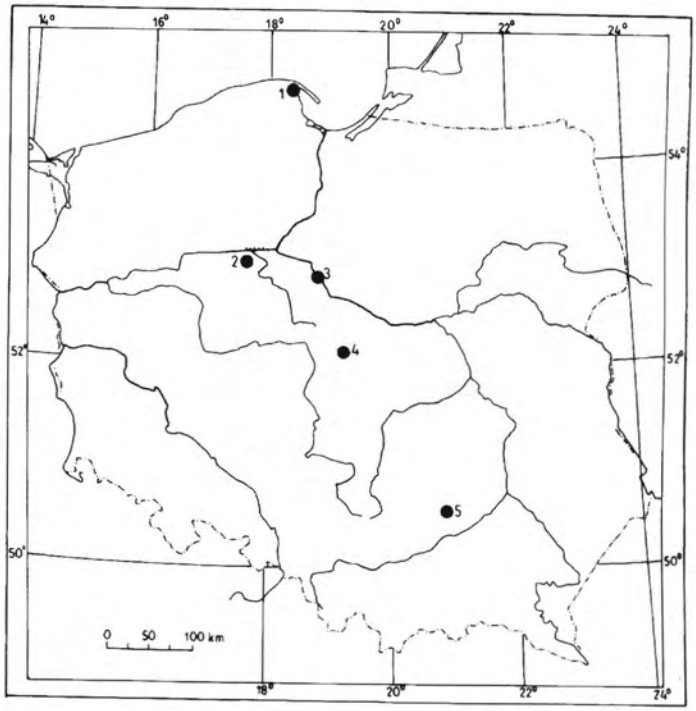

Fig.10. The distribution of *Spergularia marina* (L.) Griseb. stands with capsules containing a predominance of winged seeds, according to herbaria specimens

lict populations. Only the population in Kołobrzeg (samples 3,4) produced exclusively tuberculate seeds.

Plants in which all or most of the seeds are winged usually form small and receding populations. Only in Władysławowo on the meadows on the Puck Bay was a large population found that had an exclusively winged or only a small unwinged component in the capsules of its individuals (Fig. 11).

It was found that the plants producing exclusively winged and tuberculate seeds were usually more numerous in populations from stabilized habitats than in unstabilized ones. The

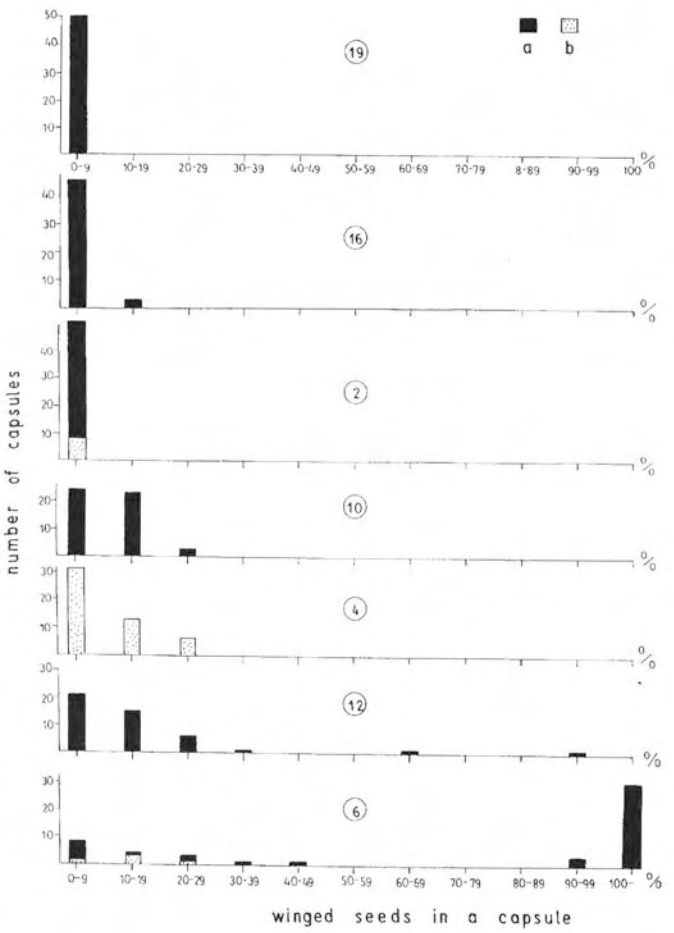

Fig.11. The distribution of capsules with various percentages of winged seeds in 7 representative population samples. Sample numbers are circled.
a – smooth and rugose seeds,
b – tuberculate seeds

variability of winged seeds was much greater in populations producing mainly winged seeds than in populations with only a small number of such seeds.

The least diversified types of seeds were found in populations from industrial areas and from sites near river estuaries, in areas frequently flooded by both salt and fresh waters.

DISCUSSION

The results of this study (Table 1). show that the differences in plant shape do not correspond with variability in seed morphology. The populations from the same locality, although having different morphologies of their vegetative parts, were usually characterized by a similar seed morphology.

The most varied seeds were found in samples from Władysławowo, where alongside capsules containing predominantly inwinged seeds, numerous ones with predominantly winged seeds were found. A similar diversity was found only in materials from relict stands, contained in herbaria. The populations colonizing new habitats, mainly surrounding factories, are much less diversified in respect to seed morphology. It is therefore necessary to protect the old, relict stands in spite of the new ones arising, in order to conserve the full gene pool of *Spergularia marina*.

Special attention is worth focusing on the finding that *S. marina* has both smooth and tuberculate seeds. These are traits of two sections distinguished from each other within the

TABLE 1. The relative frequency distributions of the seed types of 21 examined population samples

No. of samples	Type of seeds / Lokality of population	Percentage of seeds per sample				Mean number of seeds per capsule
		smooth and rugose		tuberculate		
		unwinged	winged	unwinged	winged	
1	Świnoujście	99,69	0,30			46
2	Mielin-island	80,68	0,31	18,89	0,10	58
3	Kołobrzeg			98,49	1,51	70
4	Kołobrzeg			97,04	2,96	47
5	Władysławowo	89,91	5,01	3,35	1,73	66
6	Władysławowo	30,06	60,82	8,61	0,50	59
7	Władysławowo	23,79	66,11	9,42	0,66	42
8	Władysławowo	4,95	95,05			50
9	Władysławowo	1,76	98,24			49
10	Mrzezino	97,74	2,26			55
11	Mrzezino	98,50	1,49			60
12	Ciechocinek	94,59	5,42			44
13	Ciechocinek	98,80		1,99		57
14	Ciechocinek	96,15	0,47	3,04	0,34	64
15	Janikowo	99,57	0,43			46
16	Janikowo	99,74	0,26			53
17	Janikowo	99,92	0,08			48
18	Mątwy	99,35	0,65			51
19	Mątwy	99,97	0,03			67
20	Mątwy	100				72
21	Barycz	99,72	0,28			57

sample = 50 capsules

genus *Spergularia* Presl: *Sectio* I *Tuberculatae* Kowal, with tuberculate seeds, and *Sectio* II *Rasiles* Kowal, with smooth seeds. In face of the above finding, the division of *Spergularia* into sections should not be based exclusively on seed morphology. Kowal (1966), who distinguished the above sections, could have overlooked the tuberculate seeds in *S. marina* since they are much less common in Poland than smooth seeds. The progressing industrialization of inland saline soils may lead to an increase in the already visible predominance of smooth seeds over tuberculate ones.

Fruits with exclusively winged seeds are typical for a related species, *Spergularia media* (L.) C. Presl. Mistakes could have been made for this reason. Historical data on the occurrence of *S. media* in central Poland probably refer to *S. marina* with a predominance of winged seeds.

ACKNOWLEDGEMENTS

Sincere thanks are due to the department heads and caretakers of the herbaria for lending the material, and to all those who assisted me in collecting the specimens. I am particularly indebted to Ms J. Wilkoń-Michalska for making her collections available and for her valuable suggestions.

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ZRÓŻNICOWANIE NASION *SPERGULARIA MARINA* (L.) GRISEB. (=*S. SALINA* J. ET C. PRESL) W POLSCE NA SOLNISKACH NADMORSKICH I ŚRÓDLĄDOWYCH

STRESZCZENIE

W pracy przedstawiono wyniki analizy materiałów zielnikowych oraz 21 specjalnie do badań pobranych prób populacujnych – po 50 owoców, każdy z innej rośliny. Część z tych prób pochodzi ze stanowisk sąsiednich, lecz różnych pod względem ekologicznym. Mimo znacznej różnicy w pokroju roślin w próbach z tych samych miejscowości obserwowano na ogół podobne zróżnicowanie nasion (Tab. 1). Część roślin *Spergularia marina* wytwarza w swych owocach nasiona gładkie, najwyżej lekko pomarszczone (Fig. 2a), część – nasiona guzkowate (Fig. 2b). Te ostatnie spotykano w Polsce znacznie rzadziej (Fig. 9). W obu grupach, zarówno wśród gładkich, jak i guzkowatych nasion występują nasiona nieoskrzydlone i oskrzydlone (Fig. 7). Większość roślin *S. marina* tworzy owoce, w których znajdują się wyłącznie nasiona nieoskrzydlone z jednym lub kilkoma nasionami oskrzydlonymi umieszczonymi na dnie torebki nasiennej (Fig. 11). Trafiają się jednak egzemplarze o owocach w których stosunek nasion oskrzydlonych do nieoskrzydlonych przedstawia się odwrotnie. Najwięcej tych nietypowych egzemplarzy i najbardziej zróżnicowane nasiona *S. marina* stwierdzono w populacjach z Władysławowa, nad Zatoką Pucką. Poza tym szereg ich obserwowano w materiale zielnikowym *S. marina* z reliktowych placówek śródlądowych (Fig. 10). Najuboższe pod względem typów nasion okazały się populacje z terenów przemysłowych oraz obszarów położonych przy ujściu rzek, w środowisku nieustabilizowanym, zalewanym często na zmianę wodą słoną i wodą słodką.

SŁOWA KLUCZOWE: *Spergularia marina*, halofity, nasiona, flora, relikty