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The environmental evaluation of coastal pine forests of the Łebsko sand bar by zooindication based on epigeic staphylinid communities (*Coleoptera, Staphylinidae*)[x]

Abstract: The coastal pine forest bioindication has been carried out with use of epigeic staphylinid communities and applying the test containing seven zooindicative indices. The empirical standard of *Empetro nigri Pinetum* epigeic communities of staphylinids enabled the natural value valorization and man-made changes assessment in the ecosystem. The natural valorization of coastal pine forest of the Mierzeja Łebska sand bar has been based on the four indices: the index of uniqueness S_c, natural quality B_c, equability J' and general species diversity H'. The system of natural valorization discriminates the ecosystems into six valorization classes: from the most valuable to the poorest one.

Key words: natural valorization, zooindication, communities, *Staphylinidae, Empetro-nigri pinetum* – coastal pine forest, Słowiński National Park

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INTRODUCTION

As a result of ten years of study (June 1989 – June 1998) the pine forest coastal communities of Mierzeja Łebska staphylinids have been rather well recognized (SMOLEŃSKI 1997, 2000). They created therefore an excellent basis for the comprehensive natural assessment of the forest community, the latter has been considered the most natural and anthropopressure free coniferous forest ecosystem of the Vistulian glaciation landscape in Poland.

THE ALGORITHM OF VALORIZATION PROCEDURE

When valorizing the natural pine forests using the zooindication method with use of staphylinid epigeic communities the following procedure has been accepted:

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1. The selection of research object, the natural environment, such that would be free of anthropopressure and at the same time would represent the coniferous ecosystems of the Vistulian glaciation landscape. In the present study there were used the *Empetro-nigri Pinetum* forests of Mierzeja Łebska in the Słowiński National Park.
2. The survey of the alive resources of the environment included the following:
   a) The description of site mosaics on the basis of soil and phytosociological analysis;
   b) The description of epigeic staphylinid community with a test consisted of seven zooindicative indices (SMOLEŃSKI 2001):
      - the share of exclusive characteristic species F_3 and the sum of characteristic exclusive and choosing species F_3+F_2;
      - the index of community uniqueness S_c;
      - the index of community stability N_c;
      - the index of species diversity H';
      - the index of community natural quality B_c;
      - the index of dynamic heterogeneity DHt;
      - the index of habitat species capacity P_c.
3. The assessment of natural value of alive resources of the environment based on the determination of attractiveness degree of the habitat for the epigeic community of staphylinids. The environmental attractiveness is suggested by the values of indices describing a given community.
4. Elaboration of the standard of epigeic staphylinid community of the coastal coniferous forest.

STUDY AREA – MIERZEJA ŁEBSKA; SŁOWIŃSKI NATIONAL PARK

The most valuable fragment of the Mierzeja Łebska is that in the Słowiński National Park, between the Łebsko Lake and the Baltic Sea (Fig. 1). The relief of the Mierzeja has been subjected to dynamic alteration as a result of the eolian processes. This area consists of elevated forms – dune bars parallel to the equator, dune belts and barchan-belts as well as concave forms – ditches, basins and deflation fields. The geomorphological forms present are at a range of stabilization stages: ranging from the non-covered by vegetation dynamic forms, through the successional series of intermediate forms, to the stable forms, covered by all varieties of the coastal pine forest type. The coastal variety of Scots pine forest type (*Empetro nigri-Pinetum*) dominating in the Mierzeja Łebska is the climax association. It may occur, depending on the terrain relief as eiter subassociation:

- Typical (*Empetro nigri-Pinetum typicum*) representing the fresh pine forest;
- Cladonia type (*Empetro nigri-Pinetum cladonietosum*) representing the arid coniferous forest;
- Erica type (*Empetro nigri-Pinetum ericetosum tetralicis*) representing the moist coniferous forest.

The coastal pine forest of Mierzeja Łebska subjected to legal protection (from more than 100 years now) has not been subjected to the prevailing clear cut type of forest management. The primary forest succession has been forming the landscape under the condition of full microsite mosaic (SMOLEŃSKI 1997) the latter has been the result of:

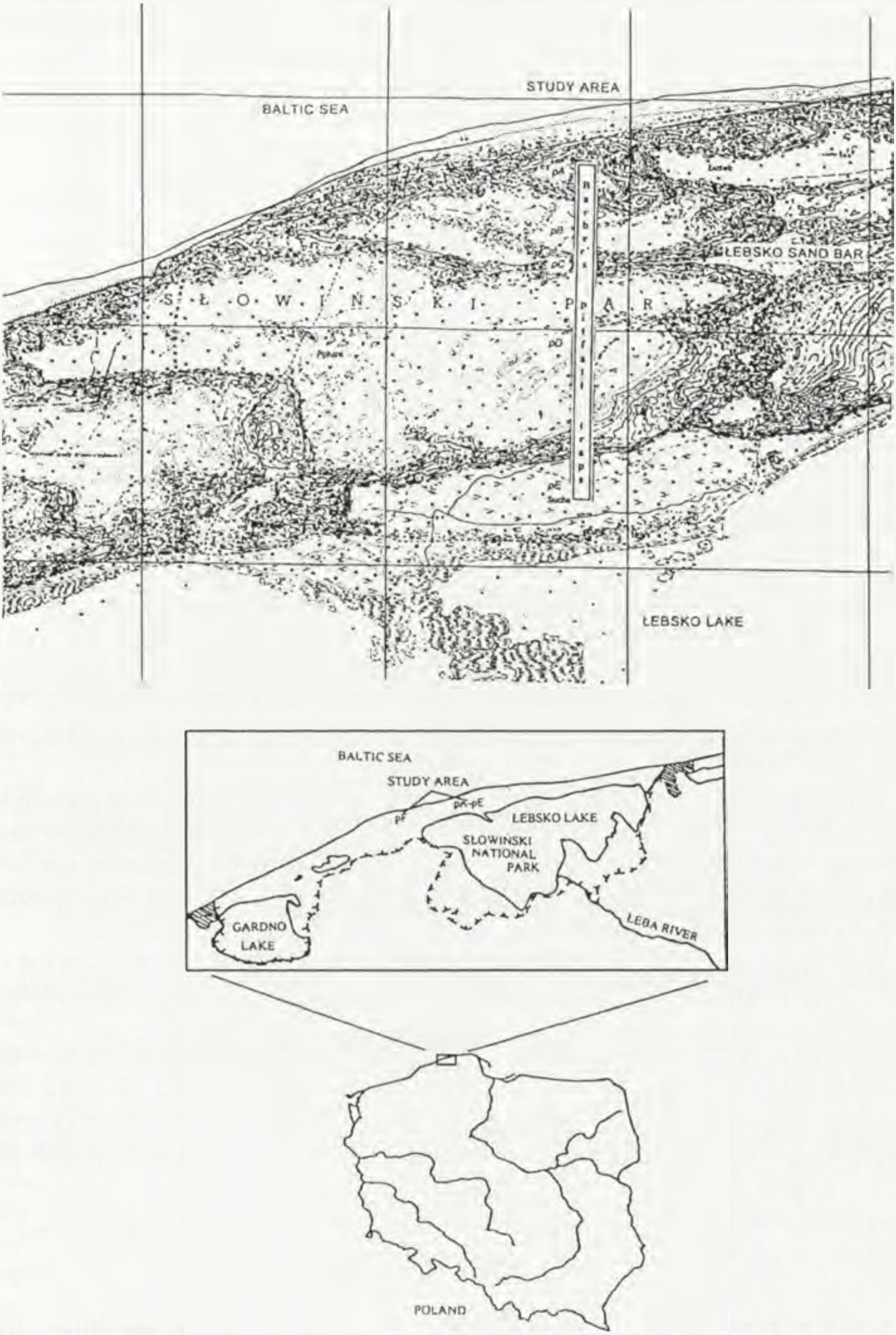

Fig. 1. Location of study area.

- dynamic relief,
- changing ground water table (significant share of small sized non covered with vegetation marshes, hollows made by windfallen trees etc.),
- frost prone sites and xerothermic sites,
- differentiated degree of development of the humific horizon, and mainly the strongly acidic mor type of humus,
- changing tree clown closure degree,
- changing vertical structure of the stand (unevenaged stand),
- natural succumbing and regeneration of the stand layer.

The following five microsite types have been distinguished within the coastal variety of pine forest in the course of valorization of the ecosystem with the use of the zooindicative method, on the basis of epigeic fauna (SMOLEŃSKI 1999):

The extremely arid type (*ms 1*). Southern slope of dune or the non-stable sandy elevated belts located in the deflation depressions. The open area, extremely dry, strongly insolated and without any herbaceous or mossy vegetation. The ground surface covered with lichens and dune grasses (*Ammophila arenaria, Carex arenaria* and *Corynephorus canescens*). The initial stage humification process.

The arid type (*ms 2*). Northern slope of dune or heather at the edge of forest. The stand thinned, the area partially open. Soil with thin humus layer, covered with thick forest floor vegetation, mainly mossy and, in part, heather.

The fresh (moderately humid) type (*ms 3*). Deflation depressions covered with typical form of *Empetro-nigri Pinetum* coniferous forest, characteristic of varying degree of thinning, with rich shrubby forest floor vegetation (*Empetrum nigrum, Erica tetralix, Calluna vulgaris, Vaccinium vitis-idaea, Vaccinium myrtillus*), with well developed humus layer.

The humid type (*ms 4*). Terrain depressions within deflations, the latter present in the form of hollows made by windfallen trees. Microsites of the belt character and spot character with water stagnating in some seasons of the year, frequently used by game as bathing spots. The humid variety of the *Empetro-nigri Pinetum*: either poorer with *Sphagnum sp*. or richer with *Juncus sp*.

The frost prone type (*ms 5*). Shadowy deflation depressions with either flowing or stagnating masses of cold air, strongly humid and with forest floor vegetation characteristic of the elevated heather.

Another important feature of Mierzeja Łebska is its strong isolation. Part of the sand bar making a clear border between the Łebsko Lake (7140 ha) and the Baltic Sea, is about 16 km long and 1.0 – 1.5 km wide. Additionally, the coastal variety of Scots pine forest occurs in this region in deflation depressions that are additionally isolated by the more or less stabilized dune embankments.

RESEARCH PLOTS

While selecting research plots, there was considered first of all the clear differentiation of size and isolation degree of particular deflation depressions (Fig. 1, 2). There was established the set of five, strongly isolated research plots in the central part of

Mierzeja. They constituted a belt from the Baltic coast in the north to the Łebsko Lake banks in the south. Those were four deflation depressions (*pA*, *pB*, *pD* and *pE*) and a double dune embankment (*pC*). Additonally, the sixth study plot were selected in the western part of Mierzeja, between two lakes: the Łebsko and Dołgie Wielkie Lake (*pF*). This was a large non-isolated deflation depression (Table 1).

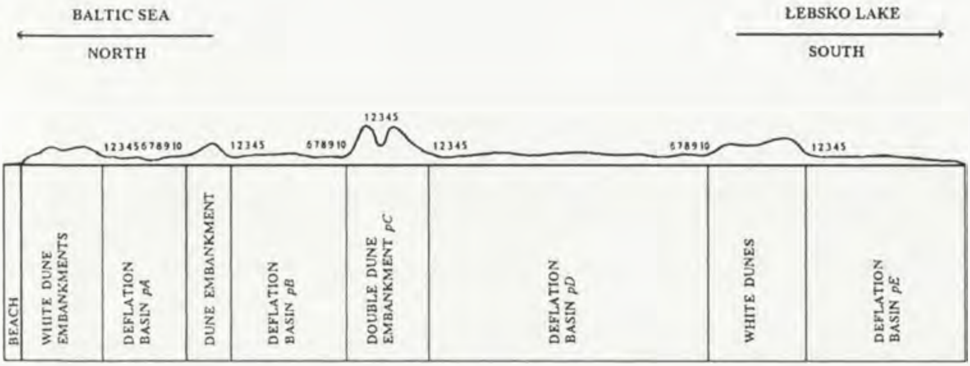

Fig. 2. Transversal profile of Łeba Bar (196 km of Polish cost) with trap's location: *pA*, *pB*, *pC*, *pD*, *pE* – study plots subjected to analysis using barber's pitfall traps; 1, 2,…,10 – samples.

Table 1. Selected parameters of five study plots – deflation basins *pA*, *pB*, *pD*, *pE* and *pF*.

Parameters of deflation basins	*pA*	*pB*	*pD*	*pE*	*pF*
Area [ha]	3.4	25.2	130.8	66.1	363.1
Length [m]	380	1280	2880	2630	4500
Width of the traps belt [m]	120	230	550	350	625
Maximal width [m]	120	280	870	420	1500

Description of deflation basin *pA*

The surface of the depression is strongly diverse considering its relief and water relationships (Table 2). It is covered with loose, unevenaged Scots pine stand 4–6m high, aged up to 60 years. The stand has still been in the stage of juvenile forest (SZWAGRZYK 1988; SZYMAŃSKI 1986). The humid basins and arid patches are partly covered with forestless heather vegetation (*Vaccinio uliginosi-Empetretum* and *Carici-Empetretum*). The north margin of the depression, situated on the foot of the patches of the white dune, represents the initial stage of development of the typical variety of the coastal pine forest (*Empetro nigri-Pinetum typicum*). At the southern part of the depression there occurs (at the threshold of embankment dune) the subassociation *Empetro nigri-Pinetum cladonietosum*. Besides, represented are also intermediate forms between the humid heather and humid heath coniferous forest: *Empetro nigri-Pinetum ericetosum tetralicis*.

Table 2. Deflation depression's *pA* microsites description (of those microsites where there were collected faunistic samples with use of Barber's pitfall traps)

No. of sample	Location	Subassociation of the coastal pine forest	Stand	Herbaceous vagetation	Microsite type
1	Moderately humid basin of the southern foreground of white dune at northern edge of depression	Typical – initial stage	Pine 40 yr old, 4m high, moderate crown closure	Poor–shrubby-grassy	*ms* 3 fresh
2	Patch of southern foreground of white dune at the northern depression edge	Typical – initial stage	Pine 40 yr old, 4m high, moderate crown closure	Poor–mossy-grassy	*ms* 3 fresh
3	Humid basin of the northern part of depression	Humid heather – heath	Fully open area	Rich mossy	*ms* 4 humid
4	Arid patch in central part of depression	Arid heather – heath	Fully open area	Poor shrubby	*ms* 1 extremely arid
5	Arid patch in central part of depression	Typical – initial stage	Pine 40 yr old, 4m high, loose crown closure	Poor–mossy-shrubby	*ms* 2 arid
6	Humid basin in central part of depression	Humid – initial stage	Pine 40 yr old, 4m high, moderate crown closure	Rich–mossy-shrubby	*ms* 4 humid
7	Patch in central part of depression	Typical	Pine 60 yr old, 6m high, loose crown closure	Poor – mossy-shrubby	*ms* 2 arid
8	Patch of northern foreground of embankment dune at the southern edge of depression	Arid	Pine 60 yr old, 6m high, moderate crown closure	Poor–mossy-shrubby	*ms* 2 arid
9	Northern slope foots of embankment dune at the southern edge of depression	Arid	Pine 60 yr old, 6m high, moderate crown closure	Poor–mossy-shrubby	*ms* 2 arid
10	Northern slope foots of embankment dune at the southern edge of depression	Arid	Pine 40 yr old, 3m high, moderate crown closure	Poor–mossy-grassy	*ms* 2 arid

Description of deflation basin *pB*

It is covered by loose pine stand of uneven age (Table 3). The overstory, partly at the stage of disintegration, is up to 15 m high and aged from 80 to 140 years. The understory, in the form of clumps is aged between 15 and 40 years. The plot is characteristic of the frequent fallen, dead trees in different stage of decomposition. Locally, there occur gray alder (*Alnus incana*) trees: close to the humid basins with stagnating water. Depressions are, in most cases, covered by the typical form of heath coniferous forest. The *Erica* subassociation is sporadically present at the area of humid basins in the central part of depression, while the *Cladonietum* subassociation is met at the foot of white dune (in its northern part).

Table 3. Deflation depression's *pB* microsites description (of those microsites where there were collected faunistic samples with use of Barber's pitfall traps)

No. of sample	Location	Subassociation of coastal pine forest	Forest stand	Herbaceous vegetation	Micosite type
1	Foothil of southern slope of white dune in northern part of depression	Arid	Pine 80 yr old, 10m high, loose crown closure	Poor grassy	*ms 2* arid
2	Basin in southern foothill of white dune – in northern part of depression	Typical	Pine 140 yr old, 15m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
3	Basin in southern foothill of white dune – in northern part of depression	Typical	Pine 80 yr old, 10m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
4	Basin in southern foothill of white dune – in northern part of depression	Typical	Pine 140 yr old, 15m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
5	Patch in central part of depression	Typical	Pine 140 yr old, 15m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
6	Patch in central part of depression	Typical	Pine 80 yr old, 10m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
7	Patch in central part of depression	Typical	Pine 80 yr old, 10m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
8	Humid basin in southern part of depression	Humid	Pine 80 yr old, 10m high, loose crown closure	Rich mossy-shrubby	*ms 4* humid
9	Basin in northern foothill of dune embankment – in southern part of depression	Typical	Pine 80 yr old, 10m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
10	Foothill of northern slope of dune embankment at southern edge of depression	Typical	Pine 25 yr old, 4m high, moderate crown closure	Rich mossy-shrubby	*ms 3* fresh

Description of the central double dune embankment *pC*

Double, 15 m high dune embankment is covered with not dense Scots pine stand aged more than 100 years and 14 m average height (Table 4). The stand is situated on the border line between the deflation depressions *pB* and *pD*. The stand is at present at the stage of optimal development. Herbaceous vegetation spots are diverse: from the poor initial stages to the mature forms of the arid variety of *Empetro nigri pinetum*. Southern slope of the embankment is occupied by the non-forest association of gray dune – in the form of coastal psammophilous vegetation (*Helichryso-Jasionetum*).

Table 4. Central double dune embankment *pC* microsites description (of those microsites where there were collected faunistic samples with use of Barber's pitfall traps)

No. of sample	Situation	Subassociation of coastal pine forest	Forest stand	Herbaceous vegetation	Microsite type
1	Northern slope of double dune embankment	Typical, initial stage	Pine 25 yr old, 4m high, moderate crown closure	Rich mossy-shrubby	*ms 3* fresh
2	Northern ridge of double dune embankment	Arid	Pine 100 yr old, 14m high, loose crown closure	Poor mossy-grassy	*ms 2* arid
3	Inner depresssion bottom between slopes of double dune embankment	Arid	Pine 100 yr old, 14m high, moderate crown closure	Rich mossy-shrubby	*ms 3* fresh
4	Southern slope of double dune embankment	Arid	Pine 100 yr old, 14m high, loose crown closure	Rich mossy-shrubby	*ms 2* arid
5	Southern slope of double embankment dune	Gray dune	Open area partly Shadowed from the south	Poor psammophilous vegetation	*ms 2* extremely arid

Description of the deflation basin *pD*

The depression is covered with unevenaged Scots pine stand of moderate crown closure degree, aged up to 80 years and 9–12m height (Table 5). The stand is currently at the optimal developmental stage. Both age and height of the stand are higher close to the northern edge of depression. There prevails the humid form of the *Empetro-nigri pinetum* association. In elevated belts there occurs the typical variety of the association.

Table 5. Deflation depression's *pD* microsites description (of those microsites where there were collected faunistic samples with use of Barber's pitfall traps)

No. of sample	Situation	Subassociation of coastal pine forest	Forest stand	Herbaceous vegetation	Microsite type
1	Foothill of southern slope of doubled embankment dune, edge of coastal pine forest type association at the northern edge of depression	Arid	Pine 40 yr old, 8m high, moderate crown closure	Poor grassy-shrubby	*ms 2* arid
2	Basin of southern foothill of double embankment dune in the northern part of depression	Humid	Pine 80 yr old, 12m high, loose crown closure	Rich shrubby	*ms 4* humid
3	Basin of southern foothill of double embankment dune in the northern part of depression	Humid	Pine 80 yr old, 12m high, loose crown closure	Rich mossy-shrubby	*ms 4* humid
4	Basin in central part of depression	Humid	Pine 80 yr old, 12m high, loose crown closure	Rich mossy-shrubby	*ms 4* humid

5	Elevated belt in central part of depression	Typical	Pine 80 yr old, 12m high, loose crown closure	Poor mossy-shrubby	*ms 2* arid
6	Elevated belt in central part of depression	Typical	Pine 45 yr old, 9m high, moderate crown closure	Mossy-shrubby	*ms 3* fresh
7	Humid basin in central part of depression	Humid	Pine 45 yr old, 9m high, loose crown closure	Rich mossy-shrubby	*ms 4* humid
8	Elevated belt in southern part of depression	Typical	Pine 45 yr old, 9m high, moderate crown closure	Mossy-shrubby	*ms 3* fresh
9	Humid basin in northern foothill of gray dune – at southern part of depression	Humid	Pine 45 yr old, 9m high, moderate crown closure	Rich mossy-shrubby	*ms 4* humid
10	Humid basin in northern foothill of mild slope of gray dune at the southern edge of depression	Humid	Pine 45 yr old, 9 m high, loose crown closure	Rich mossy-shrubby	*ms 4* humid

Description of deflation basin *pE*

Scots pine stand aged more than 130 years, at the optimal developmental stage, reaching to 20 m height (Table 6). The stand has originated following artificial drying of the northern banks of Łebsko Lake and the subsequent planting of pine culture in the place of the original marshy birch community (*Betuletum pubescentis*). At present the newly introduced association is a strong competitor to the suboceanic fresh coniferous forest (*Leucobryo-Pinetum*).

Table 6. Deflation depression's *pE* microsites description (of those microsites where there were collected faunistic samples with use of Barber's pitfall traps)

No. of sample	Situation	Subassociation of coastal pine forest	Forest stand	Herbaceous vegetation	Microsite type
1	Foothill of southern slope of white embankment dune, the edge of coniferous forest at the northern border of depression	Arid	Pine 130 yr old, 20m high, loose crown closure	Poor grassy	*ms 1* extremely arid
2	Ridge at southern foothill of white embankment dune, in northern part of depression	Typical with elements of *Leucobryo–Pinetum*	Pine 130 yr old, 20m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
3	Elevated edge in northern part of depression	Typical with elements of *Leucobryo–Pinetum*	Pine 130 yr old, 20m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
4	Basin in northern part of depression	Typical with elements of *Leucobryo– Pinetum*	Pine 130 yr old, 20m high, loose crown closure	Rich mossy-shrubby	*ms 3* fresh
5	Humid basin in the central part of depression	Humid with elements of *Leucobryo–Pinetum*	Pine 130 yr old, 20m high, loose crown closure	Rich mossy-shrubby	*ms 4* humid

Description of deflation depression *pF*

The surface of the depression is very homogenous, covered with the typical form of *Empetro-nigri Pinetum*. The stand has been in the optimal developmental stage. The stand in the western part about 120 years of age and some 10 m high. In the eastern part the stand is about 70 years old and 6 m high. The presence of Austrian pine in the western part gives evidence for the artificial origin of the whole of forest stand.

The faunistic empirical data from the depression were not subjected to analyses considering particular microsites.

THE COLLECTION OF FAUNISTIC MATERIAL

The faunistic material had been collected during two years: from July 1996 till July 1998, using 250 Barber's pitfall traps. One sample – the basic primary unit of the faunistic analysis – was constituted by a sequence of five individual traps established within a homogenous fragment of vegetation (Fig. 2; Tabs. 1–6). Particular samples were distanced some 10–20 m from one another. At the place of each sample collection a phytosociological relievé has been made.

THE METHOD OF ANALYZING THE FAUNISTIC MATERIAL

In order to describe the epigeic staphylinid communities, the seven-step test has been applied (Smoleński 2001). In steps one through three of the test there was used the characteristic of species fidelity, according to the classification system proposed by Szujecki (1983). In step four there was used the characteristic of species diversity. In step five there were used four characteristics: species fidelity, microsite preferences, geographical distribution and species diversity. In two last steps the characteristic of species diversity as based on microsite differentiation has found its application.

The detailed plan of the test is as outlined below:

1. **The assessment of distinctive species share expressed in terms of the share in the dominance structure of community:**
   - **characteristic exclusive species F_3;**
   - **sum of characteristic exclusive and choosing species F_3+F_2.**
2. **The assessment of departure degree of community from the standard system as expressed in terms of the index of community uniqueness**

$$S_c = \sqrt{\frac{\log F_3}{\log f_3}\left(\frac{\log F_{32}}{\log f_{32}}\right)^2} \qquad \text{(formula 1)}$$

where:

F – per cent share (specimen number) in the domination structure of community:

F_3 – of exclusive characteristic species,

F_{32} – of the sum of characteristic species (exclusive + choosing ones),

f – minimum per cent share in the dominance structure of the natural and stable community of epigeic staphylinids of the coastal variety of Scots pine forest type:

$f_3 = 20$ – of exclusive characteristic species,

$f_{32} = 60$ – of the sum of characteristic species (exclusive + choosing ones).

3. The assessment of resistance degree of community against the deformation as expressed by the index of community stability

$$N_c = \frac{F_{32} \log F_3}{f' \log(F_{10} + 1{,}1)} \qquad \text{(formula 2)}$$

where:

F – per cent share (specimen number) in the dominance structure of community:

F_3 – of exclusive characteristic species,

F_{32} – of the sum of characteristic species (exclusive + choosing ones),

F_{10} – of the sum of accompanying and alien species,

$f' = 48.37$ –the coefficient proper for the coastal variety of pine forest epigeic staphylinids.

4. The assessment of species diversity of community as measured by the Shannon and Wiener index of species diversity

$$H' = -\sum_{i=1}^{S} P_i \log P_i \qquad \text{(formula 3)}$$

where:

P_i – proportion of number of individuals (n_i) of *i-th* species to the number (N) of individuals of the entire community containing (S) species.

5. The assessment of natural quality of community as expressed in terms of the index of community natural quality

$$B_c = \sqrt[4]{J' N_c D_k D_E} \qquad \text{(formula 4)}$$

where:

J' – index of evenness (formula 5);

N_c – index of community stability (formula 2);

D_k – per cent portion (in the dominance structure of the community) of species characterizing the food availability in the habitat. Considering epigeic staphylinid communities these are detritophilous species;

D_E – per cent portion (in the dominance structure of the community) of species characterizing the ecosystem value for the preservation of local forms. Considering epigeic staphylinid communities these are European species.

J' – Pielou index of evenness:

$$J' = \frac{H'}{H'_{max}} = \frac{H'}{\log_2 S} \qquad \text{(formula 5)}$$

where:

H' – index of species diversity (formula 3),

S – species number in community.

6. **The assessment of microsite diversity degree as expressed in terms of the index of dynamic heterogeneity**

$$DHt = I_{ds}(1 - \frac{S'}{S}) \quad \text{(formula 6)}$$

where:

S – real value of species number of the entire community,

S' – expected value of species number expressed as arithmetic (or weighed) means from all samples,

$I_{ds} = dV_d$ –coefficient of species richness diversity of the site, where:

d – real value of the index of species richness for the entire community (according Margalef index:

$$d = \frac{S-1}{\log N} \quad \text{(formula 7)}$$

where:

S – species number in the community,

N – total number of individuals;

V_d – coefficient of variation of the index of species richness (the proportion: standard deviation/ expected value of the index, where expected value is the arithmetic or weighed means from all samples).

7. **The assessment of site attractiveness for a given community as expressed in terms of the index of habitat species capacity**

$$P_c = \frac{\sum_{i=1}^{S} C_{si}'}{\log S} \quad \text{(formula 8)}$$

where:

C_{si}' – index of site heterogeneity utilization by *i-th* species (formula 9),

S – species number in community.

The index of site heterogeneity utilization by a given species:

$$C_s' = \frac{2\sum_{j=1}^{R} c_{sj}}{R} \quad \text{(formula 9)}$$

where:

c_{sj} – index of microsite preferences of a species for *j-th* sample (formula 10),

R – number of samples.

The index of microsite preferences of a species

$$c_s = \frac{I_{fd}}{I_{fd}\,(\max)} \quad \text{(formula 10)}$$

where:

$I_{fd} = \sqrt{\frac{n_j^2}{N_j}}$ is coefficient of a given species dominance for *j-th* sample,

$I_{fd}(max)$ – the highest value of the dominance coefficient of a given species as revealed in all samples (*R*),

n_j – number of individuals of a given species for *j-th* sample,

N_j – total number of individuals for *j-th* sample.

RESULTS

1. Description of staphylinid epigeic community

1.a. Step one of the test assessing the epigeic community of staphylinids: The assessment of distinctive species share

The staphylinids were divided between four classes of fidelity toward the community of *Empetro-nigri Pinetum*. Those were:

- coniferous forest characteristic species – 3 (the highest fidelity class),
- forest accompanying species – fidelity class 2,
- eurytopic species – fidelity class 1,
- alien species – the lowest fidelity class 0.

The coniferous forest species are strongly stenotypic prone. Forest accompanying species are characteristic for the more fertile varieties of forest ecosystems. Both coniferous forest characteristic and forest accompanying species were grouped together into one category: the forest species.

In general, there occurred in all research plots 33 coniferous forest characteristic species, 50 forest accompanying species, 55 eurytopic species, and 23 alien species (Table 7).

Table 7. Frequency of occurrence of staphylinids (*Coleoptera, Staphylinidae*) of the coastal variety of Scots pine forest (*Empetro-nigri Pinetum*) of Mierzeja Łebska.

Research plots: *pA; pB; pD; pE; pF* – deflation depressions; pC – dune embankment; Σ – all plots

R – Geographical distribution: E – European species, Ek – Euro-Caucasian species, H – Holarctic species, Hp – North-Holarctic species, P – Palearctic species, Pp –North-Palearctic species, Pz – West-Palearctic species.

S – Microsite preferences: d – underbark species, e – epigeic species, g – fungi- and decay wood loving species, k – species connected with decaying organic matter, compost and/or carcass, n – species living in hollows or nests, r – species of herbaceous vegetation layer and shrubs, s – myrmecophilous species.

F – Species fidelity toward the coastal variety of pine forest: 3 – coniferous forest characteristic species, 2 – forest accompanying species, 1 – eurytopic species, 0 – alien species.

	Species	R	S	F	*pA*	*pB*	*pD*	*pE*	*pF*	*pC*	Σ
1	*Acidota crenata* (FABRICIUS, 1792)	H	er	2	40	44	40	15	72	12	223
2	*A. cruentata* MANNERHEIM, 1831	E	en	2	2	5	4	4	–	–	15
3	*Aleochara bipustulata* (LINNAEUS, 1761)	H	k	1	1	–	–	–	–	–	1
4	*A. lanuginosa* GRAVENHORST, 1802	Pp	gk	2	–	–	–	–	–	–	–
5	*Aloconota gregaria* (ERICHSON, 1839)	E	e	1	–	–	–	–	–	–	–
6	*Amischa analis* (GRAVENHORST, 1802)	H	e	1	–	1	–	–	–	1	2
7	*A. soror* (KRAATZ, 1856)	E	e	2	–	–	–	–	–	–	–
8	*Anotylus rugosus* (FABRICIUS, 1775)	P	ek	0	–	–	–	–	–	–	–
9	*A. tetracarinatus* (BLOCK, 1799)	P	k	1	–	–	–	–	–	–	–
10	*Anthobium athrocephalum* (GYLLENHAL, 1827)	Hp	ek	2	11	7	9	1	2	3	33

	Species	R	S	F	pA	pB	pD	pE	pF	pC	Σ
11	*Atemeles emarginatus* (PAYKULL, 1789)	E	s	2	5	2	–	1	–	4	12
12	*A. aterrima* (GRAVENHORST, 1802)	H	k	1	–	–	–	–	–	–	–
13	*A. cauta* (ERICHSON, 1837)	H	gk	1	–	1	1	–	–	–	2
14	*A. corvina* (THOMSON, 1856)	E	g	2	–	–	–	–	–	–	–
15	*A. crassicornis* (FABRICIUS, 1792)	E	g	2	–	–	–	–	1	2	3
16	*A. cribrata* (KRAATZ, 1856)	E	e	1	1	–	–	–	–	–	1
17	*A. elongatula* (GRAVENHORSt, 1802)	H	e	2	4	–	1	–	–	–	5
18	*A. excelsa* BERNHAUER, 1811	E	e	3	–	–	–	–	–	–	–
19	*A. fungi* (GRAVENHORST, 1806)	H	egk	1	8	2	6	4	–	6	26
20	*A. gagatina* (BAUDI, 1848)	Ek	gk	2	–	–	1	–	–	–	1
21	*A. ganglbaueri* BRUNDIN, 1948	E	k	1	–	–	–	–	–	–	–
22	*A. graminicola* (GRAVENHORST, 1806)	Pp	ek	3	–	–	–	–	–	–	–
23	*A. hypnorum* (KIESENWETTER, 1850)	Hp	ek	3	–	–	1	–	–	–	1
24	*A. laticollis* (STEPHENS, 1832)	Pz	gk	1	–	–	–	–	–	–	–
25	*A. longicornis* (GRAVENHORST, 1802)	Pz	k	1	–	–	–	–	–	–	–
26	*A. macrocera* (THOMSON, 1856)	E	k	1	–	–	–	–	–	–	–
27	*A. muscorum* (BRISOUT, 1860)	E	gk	1	–	–	–	–	–	–	–
28	*A. nigra* (KRAATZ, 1856)	E	gk	1	–	1	–	–	–	–	1
29	*A. occulta* (ERICHSON, 1837)	E	gk	1	–	–	–	–	–	–	–
30	*A. parvula* (MANNERHEIM, 1831)	H	gk	1	–	–	–	–	–	–	–
31	*A. sodalis* (ERICHSON, 1837)	H	ek	2	–	–	2	–	–	1	3
32	*A. xanthopus* (THOMSON, 1856)	E	g	2	1	–	–	–	–	–	1
33	*Bolitobius analis* (FABRICIUS, 1787)	H	ek	2	2	–	8	–	9	–	19
34	*B. cingulatus* MANNERHEIM, 1831	Hp	eg	2	4	4	–	–	–	–	8
35	*B. formosus* (GRAVENHORST, 1806)	E	ek	3	43	19	38	6	13	18	137
36	*Bolitochara pulchra* (GRAVENHORST, 1806)	Pp	g	3	4	–	2	–	–	–	6
37	*Bryoporus crassicornis* (MäKLIN, 1847)	E	eg	2	2	–	–	–	–	–	2
38	*Callicerus obscurus* GRAVENHORST, 1802	E	ek	1	–	–	–	–	–	–	–
39	*Calodera aethiops* (GRAVENHORST, 1802)	P	e	2	–	–	–	1	–	1	2
40	*Carpelimus elongatulus* (ERICHSON, 1839)	E	ek	0	–	–	–	–	–	–	–
41	*Coryphium angusticolle* STEPHENS, 1834	E	eg	3	–	–	–	–	1	–	1
42	*Cypha longicorne* (PAYKULL, 1800)	E	eg	1	–	–	1	–	–	–	1
43	*Dinaraea angustula* (GYLLENHAL, 1810)	Pz	d	2	–	–	–	1	–	–	1
44	*Drusilla canaliculata* (FABRICIUS, 1787)	P	ek	1	53	109	135	197	43	20	557
45	*Euaesthetus bipunctatus* (LJUNGH, 1804)	Pp	ek	1	1	–	1	–	–	–	2
46	*Evanystes circellaris* (GRAVENHORST, 1806)	Pp	egk	3	39	24	26	8	–	54	151
47	*Gabrius appendiculatus* SHARP, 1910	Pz	e	1	1	1	–	–	1	–	3
48	*G. pennatus* SHARP, 1910	Ek	ek	1	12	–	–	–	–	–	12
49	*G. nigritulus* (GRAVENHORST, 1802)	E	ek	1	–	–	–	–	–	–	–
50	*G. splendidulus* (GRAVENHORST, 1802)	Pz	d	3	–	–	–	–	–	–	–
51	*G. trossulus* (NORDMANN, 1837)	E	ek	3	1	–	–	–	–	–	1
52	*Gyrohypnus angustatus* STEPHENS, 1833	P	ek	1	2	–	–	–	–	1	3
53	*G. liebei* SCHEERPELTZ, 1926	H	k	1	4	2	–	–	–	–	6
54	*Habrocerus capillaricornis* (GRAVENHORST, 1806)	Ek	gk	2	–	–	1	–	–	–	1
55	*Heterothops dissimilis* (GRAVENHORST, 1802)	H	ek	1	–	–	–	–	1	–	1
56	*Ilyobates nigricollis* (PAYKULL, 1800)	E	es	2	–	–	1	1	–	–	2
57	*Ischnopoda atra* (GRAVENHORST, 1806)	E	ek	0	–	–	–	–	–	–	–
58	*Lamprinodes saginatus* (GRAVENHORST, 1806)	E	e	3	9	5	11	5	6	2	38
59	*Lathrobium brunnipes* (FABRICIUS, 1792)	E	ek	3	15	2	24	–	–	–	41
60	*L. filiforme* GRAVENHORST, 1806	Pz	ek	1	6	–	–	–	–	–	6
61	*L. fovulum* STEPHENS, 1833	E	ek	1	1	–	–	–	–	–	1
62	*L. longulum* GRAVENHORST, 1802	Pz	ekn	2	10	1	2	2	–	–	15
63	*L. ripicola* CZWALINA, 1888	E	e	1	–	–	–	3	–	–	3
64	*L. terminatum* GRAVENHORST, 1802	Pz	ek	3	4	–	–	–	–	–	4
65	*L. volgense* HOCHHUTH, 1851	Pp	e	1	1	–	1	2	–	–	4
66	*Leptusa pulchella* (MANNERHEIM, 1831)	Pz	d	3	1	–	–	–	–	–	1
67	*Lordithon exoletus* (ERICHSON, 1839)	P	g	2	–	–	–	–	–	1	1
68	*L. lunulatus* (LINNAEUS, 1761)	Pp	g	2	–	–	–	1	–	–	1
69	*L. thoracicus* (FABRICIUS, 1776)	H	g	2	5	5	2	–	–	–	12
70	*L. trinotatus* (ERICHSON, 1839)	Pz	g	2	–	1	–	–	–	1	2
71	*Mycetoporus baudueri* MULSANT et REY, 1875	Pz	e	3	12	1	4	–	1	7	25
72	*M. brunneus* (MARSHAM, 1802)	H	ek	2	177	21	36	7	86	37	364

	Species	R	S	F	pA	pB	pD	pE	pF	pC	Σ
73	*M. clavicornis* (STEPHENS, 1832)	Ek	ek	3	46	7	38	4	3	3	101
74	*M. forticornis* FAUVEL, 1875	Ek	ek	3	3	–	–	–	–	–	3
75	*M. piceolus* REY, 1883	E	ek	2	–	–	1	–	–	1	2
76	*M. rufescens* (STEPHENS, 1832)	E	egk	3	19	17	49	10	69	6	170
77	*M. splendidus* (GRAVENHORST, 1806)	P	ek	2	103	39	16	4	17	18	197
78	*Notothecta flavipes* (GRAVENHORST, 1806)	Pz	s	2	–	–	–	–	–	–	–
79	*Ochthephilum fracticorne* (PAYKULL, 1800)	P	k	2	32	4	3	–	–	–	39
80	*Ocypus copressus* (MARSHAM, 1802)	E	e	0	1	1	–	–	–	4	6
81	*O. melanarius* (HEER, 1839)	Ek	ek	1	1	–	–	–	–	–	1
82	*Olophrum fuscum* (GRAVENHORST, 1806)	Ek	ek	2	–	1	6	1	–	–	8
83	*O. piceum* (GYLLENHAL, 1810)	E	egk	2	12	11	15	10	1	–	49
84	*Omalium littorale* KRAATZ, 1858	E	k	3	2	–	–	–	–	–	2
85	*Ontholestes murinus* (LINNAEUS, 1758)	P	k	0	1	–	–	–	–	–	1
86	*Othius angustus* STEPHENS, 1833	Ek	e	3	–	1	–	–	–	–	1
87	*O. myrmecophilus* KIESENWETTER, 1843	Ek	e	3	40	35	51	38	73	5	242
88	*O. punctulatus* (GOEZE, 1777)	Pz	e	2	3	1	3	5	1	12	25
89	*Oxypoda abdominalis* (MANNERHEIM, 1831)	P	k	2	–	–	–	–	1	–	1
90	*O. elongatula* AUBÉ, 1850	Pz	ek	2	–	–	1	–	–	–	1
91	*O. lividipennis* MANNERHEIM, 1831	Pz	ek	2	–	–	3	–	–	–	3
92	*O. opaca* (GRAVENHORST, 1802)	P	k	1	–	–	–	–	–	–	–
93	*O. procerula* MANNERHEIM, 1831	Pp	ek	2	15	1	23	–	11	–	50
94	*O. vittata* MÄRKEL, 1842	E	gkn	1	–	–	–	1	–	–	1
95	*Pachnida nigella* (ERICHSON, 1837)	E	r	0	1	–	–	–	–	–	1
96	*Paragabrius furcifer* (RENCONEN, 1937)	E	ek	0	–	–	–	–	–	–	–
97	*P. micans* (GRAVENHORST, 1802)	H	e	0	–	1	–	–	–	–	1
98	*Philonthus alpinus* EPPELSHEIM, 1875	E	k	0	–	–	–	–	–	–	–
99	*P. carbonarius* (GRAVENHORST, 1802)	P	gk	1	1	–	1	–	–	–	2
100	*P. cephalotes* (GRAVENHORST, 1802)	H	k	0	–	–	–	–	–	–	–
101	*P. chalceus* STEPHENS, 1832	Pp	k	1	–	1	–	–	–	–	1
102	*P. cognatus* STEPHENS, 1832	Hp	gk	2	–	–	–	–	2	–	2
103	*P. concinnus* (GRAVENHORST, 1802)	P	k	1	–	–	–	–	–	–	–
104	*P. decorus* (GRAVENHORST, 1802)	E	gk	2	–	1	1	–	1	–	3
105	*P. fimetarius* (GRAVENHORST, 1802)	P	k	1	–	–	–	–	–	–	–
106	*P. jurgans* TOTTENHAM, 1937	E	k	0	–	–	–	–	–	–	–
107	*P. nigrita* (GRAVENHORST, 1806)	Pz	e	2	1	–	–	–	–	–	1
108	*P. nigriventris* THOMSON, 1867	E	k	3	–	–	–	–	–	–	–
109	*P. nitidus* (FABRICIUS, 1787)	Pz	k	0	–	–	1	–	–	–	1
110	*Phloeocharis subtilissima* MANNERHEIM, 1831	E	dek	1	4	–	4	–	–	1	9
111	*Platydracus chalcocephalus* (FABRICIUS, 1801)	Ek	e	1	–	–	–	2	4	–	6
112	*P. fulvipes* (SCOPOLI, 1763)	Pz	e	0	–	–	–	5	–	1	6
113	*P. stercorarius* (OLIVIER, 1795)	Ek	e	3	127	9	37	–	–	2	175
114	*Platystethus arenarius* (GOEFFROY, 1785)	P	k	1	–	–	–	–	–	–	–
115	*Proteinus brachypterus* (FABRICIUS, 1792)	Hp	gk	1	4	13	–	–	–	2	19
116	*P. ovalis* STEPHENS, 1834	E	gk	1	–	1	–	–	–	–	1
117	*Quedius boops* (GRAVENHORST, 1802)	P	e	3	7	2	1	–	–	1	11
118	*Q. fuliginosus* (GRAVENHORSt, 1802)	P	e	2	2	–	2	1	2	–	7
119	*Q. maurorufus* (GRAVENHORST, 1806)	E	ek	2	1	1	–	1	–	–	3
120	*Q. maurus* (C.R. SAHLBERG, 1830)	E	en	3	–	1	–	1	–	1	3
121	*Q. molochinus* (GRAVENHORST, 1806)	E	e	3	69	25	21	–	12	2	129
122	*Q. nigriceps* KRAATZ, 1857	E	e	3	2	1	–	–	1	–	4
123	*Q. vexans* EPPELSHEIM, 1881	E	n	1	–	–	–	1	–	–	1
124	*Rugilus erichsonii* (FAUVEL, 1867)	E	e	0	1	–	–	–	–	–	1
125	*R. rufipes* GERMAR, 1835	Ek	ek	1	3	1	13	–	1	1	19
126	*Schistoglossa curtipennis* (SHARP, 1869)	H	ek	0	–	–	–	–	–	–	–
127	*Sepedophilus bipunctatus* (GRAVENHORST, 1802)	E	dg	2	–	–	2	–	–	–	2
128	*S. immaculatus* (STEPHENS, 1832)	Ek	ek	3	6	36	2	13	5	4	66
129	*S. marshami* (STEPHENS, 1832)	E	ek	3	37	22	84	23	7	16	189
130	*Spatulonthus longicornis* (STEPHENS, 1832)	H	k	0	–	–	–	–	1	–	1
131	*Staphylinus erythropterus* LINNAEUS, 1758	H	e	2	320	322	15	160	2	80	899
132	*Stenus bimaculatus* GYLLENHAL, 1810	Pp	ek	1	–	–	–	–	–	–	–
133	*S. brunnipes* STEPHENS, 1833	E	k	0	–	–	–	–	–	1	1
134	*S. cautus* ERICHSON, 1839	E	r	0	–	–	–	–	–	–	–

	Species	R	S	F	pA	pB	pD	pE	pF	pC	Σ
135	*S. clavicornis* (SCOPOLI, 1763)	P	ek	1	6	11	26	1	–	2	46
136	*S. excubitor* ERICHSON, 1839	Ek	e	0	–	–	2	–	–	–	2
137	*S. geniculatus* GRAVENHORST, 1806	Pp	e	3	3	–	–	–	–	–	3
138	*S. impressus* GERMAR, 1824	E	ek	2	9	2	9	1	1	1	23
139	*S. juno* (PAYKULL, 1789)	P	e	1	–	–	–	–	–	–	–
140	*S. nanus* STEPHENS, 1833	Pz	ek	0	2	–	–	–	–	–	2
141	*S. pusillus* STEPHENS, 1833	Pz	r	0	–	–	–	–	–	–	–
142	*Tachinus pallipes* (GRAVENHORST, 1806)	H	ek	0	–	–	–	–	–	–	–
143	*T. rufipes* (LINNAEUS, 1758)	H	ek	0	–	1	–	1	–	–	2
144	*Tachyporus atriceps* STEPHENS, 1832	Pz	e	1	–	–	–	–	–	–	–
145	*T. chrysomelinus* (LINNAEUS, 1758)	Hp	ek	1	1	2	1	1	1	2	8
146	*T. corpulentus* J. SAHLBERG, 1876	E	es	3	11	5	11	3	3	–	33
147	*T. hypnorum* (FABRICIUS, 1775)	P	ek	2	2	–	1	–	1	–	4
148	*T. nitidulus* (FABRICIUS, 1781)	Hp	ekn	1	–	–	–	–	–	1	1
149	*T. pusillus* GRAVENHORST, 1806	P	e	3	1	1	1	–	–	–	3
150	*T. solutus* ERICHSON, 1839	Pz	ek	1	–	–	1	–	–	1	2
151	*T. transversalis* GRAVENHORST, 1806	E	ek	3	19	–	2	–	–	–	21
152	*Xantholinus laevigatus* JACOBSEN, 1849	E	e	2	10	2	4	–	11	3	30
153	*X. linearis* (OLIVIER, 1795)	P	e	1	21	9	53	5	30	10	128
154	*X. longiventris* HEER, 1839	E	e	1	59	57	79	14	108	43	360
155	*X. tricolor* (FABRICIUS, 1787)	E	e	2	17	26	–	–	31	8	82
156	*Zoosetha procidua* (ERICHSON, 1837)	E	ek	3	8	3	1	–	–	18	30
157	*Zyras cognatus* (MÄRKEL, 1842)	E	s	1	18	3	8	–	3	–	32
158	*Z. collaris* (PAYKULL, 1800)	Ek	k	0	–	1	–	–	–	–	1
159	*Z. funestus* (GRAVENHORSt, 1806)	E	ds	2	1	1	7	–	–	–	9
160	*Z. laticollis* (MäRKEL, 1844)	E	s	2	9	2	9	–	–	–	20
161	*Z. lugens* (GRAVENHORST, 1802)	E	s	2	–	1	1	–	–	–	2
	Total specimens				1543	940	967	565	639	421	5075
	Total species				79	63	67	41	40	46	123

Table 8. Indices describing the epigeic staphylinid (*Coleoptera*, *Staphylinidae*) communities of the coastal pine forest (*Empetro-nigri Pinetum*).

F_3 – share [%] of coniferous forest characteristic species,
F_2 – share [%] of forest accompanying species,
F_1 – share [%] of eurytopic species,
F_0 – share [%] of alien species,
N_c – index of community stability,
S_c – index of community uniqueness,
H' – Shannon and Wiener index of species diversity,
J' – Pielou index of evenness,
D_k – share [%] of detritophilous species,
D_E – share [%] of European species,
B_c – index of community natural quality,
DHt – index of dynamic heterogeneity,
I_{ds} – coefficient of species richness diversity of the site,
P_c – index of habitat species capacity,
pA; pB; pD; pE; pF – deflation depression;
pC – dune embankment.

	pA	pB	pD	pE	pF	pC	Total
F_3	34.2%	23.0%	41.8%	19.6%	30.4%	33.0%	29.8%
F_2	51.9%	53.7%	23.7%	38.5%	39.4%	44.0%	44.0%
F_1	13.6%	22.9%	34.2%	40.8%	30.0%	21.6%	25.5%
F_0	0.3%	0.4%	0.3%	1.1%	0.2%	1.4%	0.7%
N_c	2.37	1.57	1.42	0.95	1.44	1.77	1.57
S_c	1.29	1.15	1.16	0.98	1.15	1.22	1.17
H'	4.62	3.95	4.79	3.20	3.88	4.26	5.04
J'	0.73	0.66	0.79	0.60	0.73	0.77	0.68
D_k	45.37	36.70	59.77	51.16	42.72	49.40	47.15
D_E	25.28	23.09	40.02	15.04	42.10	31.12	29.14
B_c	6.65	5.44	7.20	4.58	6.59	6.77	6.19
DHt	2.90	2.39	1.88	0.70	–	1.41	–
I_{ds}	4.66	3.60	3.09	1.32	–	2.43	–
P_c	12.83	8.45	11.77	9.54	–	9.75	–

The share in domination of alien species F_0 is insignificantly small: from 0.2% to 1.4%. The share of distinguishable species domination F_3 ranges from 19.6% to 1.8%, while the portion of forest species ($F_{32}=F_3+F_2$) has been maintained within the range 58.1% – 86.1% (Table 8). Following the data, and supported with ten years' study results (SMOLEŃSKI, 1999), critical shares of domination were determined for particular fidelity classes of the staphylinid community of natural coniferous forest ecosystems. The natural coniferous communities of epigeic staphylinids are characteristic of:

- at least 20% share of coniferous characteristic species (F_3) in the dominance structure of community;
- at least 60% share of species belonging to the forest formation ($F_{32}=F_3+F_2$).

If an epigeic staphylinid community present in the biocenosis of coastal pine forest possesses the above outlined features, it can be assessed stable and unique (SMOLEŃSKI 2001).

The staphylinid community of the deflation depression *pE* does not meet the condition. The *pE* depression biocenosis is not stable, and it is subjected to the process of renaturalization: from the *Empetro-nigri pinetum*, through the suboceanic fresh coniferous forest, into the marshy birch forest type (BMw). This process has been connected with the anthropogenous origin of the stand. The high value of alien species share (1.4%) at the area of dune embankment *pC*, may be explained by the migration, and inflow of forestless habitats species (rushes fields, heather, gray dune etc).

The detailed analysis of forest species share in staphylinid communities shows the large microsite diversity of the studied plots (Table 9). Out of the 40 analyzed microsites, nine were identified as unstable ones, under the process of alteration. Five of the latter, located in the depressions *pB* and *pD*, were located in the biocenosis of the coastal variety of pine forest under the stage of disintegration. Four other, in the *pE* depression, were identified in the biocenosis of marsh birch forest under the process of renaturalization.

Table 9. Indices characterizing epigeic subcommunities of staphylinids (*Coleoptera, Staphylinidae*) of coastal pine forest

F_3 – share [%] of coniferous forest characteristic species,
F_2 – share [%] of forest accompanying species,
F_{32} – share [%] of forest species (F_3+F_2),
N_c – index of community stability,
S_c – index of community uniqueness,
H' – Shannon and Wiener index of species diversity,
J' – Pielou index of evenness,
D_k – share [%] of detritophilous species,
D_E – share [%] of European species,
B_c – index of community natural quality,

	Number of sample in deflation depression *pA*									
	1	2	3	4	5	6	7	8	9	10
F_3	22.0	21.3	29.2	64.9	41.5	36.7	43.0	23.1	27.6	36.3
F_2	60.9	72.5	56.2	24.6	41.6	35.4	43.1	49.2	63.2	57.8
F_{32}	82.9	93.8	85.4	89.5	83.1	72.1	86.1	72.3	90.8	94.1
N_c	1.85	3.23	2.21	3.26	2.25	1.60	2.53	1.40	2.79	3.91
S_c	1.18	1.24	1.25	1.42	1.30	1.20	1.33	1.12	1.28	1.35
H'	3.86	3.41	4.13	2.68	4.57	4.14	4.07	3.83	3.24	3.35
J'	0.77	0.66	0.80	0.59	0.88	0.79	0.85	0.83	0.78	0.75
D_k	35.96	51.89	47.02	21.45	40.13	41.81	45.55	52.31	67.11	75.48
D_E	27.45	12.37	22.69	20.93	45.74	40.95	36.73	18.48	18.43	14.70
B_c	6.12	6.08	6.59	5.42	7.76	6.82	7.74	5.79	7.20	7.55

	Number of sample in deflation depression *pB*									
	1	2	3	4	5	6	7	8	9	10
F_3	37.0	14.4	16.8	23.6	25.0	22.4	26.9	24.3	13.6	37.9
F_2	29.3	60.3	67.2	60.9	58.3	49.2	47.7	50.5	53.4	46.9
F_{32}	66.3	74.7	84.0	84.5	83.3	71.6	74.6	74.8	67.0	84.8
N_c	1.40	1.27	1.75	2.00	1.95	1.37	1.56	1.52	1.03	2.32
S_c	1.15	1.05	1.14	1.21	1.21	1.11	1.16	1.15	0.98	1.30
H'	4.12	2.93	3.00	2.93	2.95	4.28	3.41	3.53	3.23	3.80
J'	0.87	0.63	0.67	0.66	0.72	0.89	0.79	0.78	0.77	0.88
D_k	45.65	32.84	27.20	30.93	18.02	46.28	23.87	47.69	45.44	54.51
D_E	41.32	14.35	17.60	19.11	19.46	38.80	49.25	14.00	12.51	24.28
B_c	6.92	4.41	4.87	5.29	4.71	6.84	6.17	5.30	4.61	7.21
	Number of sample in deflation depression *pD*									
	1	2	3	4	5	6	7	8	9	10
F_3	41.7	39.3	26.8	50.9	17.3	50.7	65.4	50.9	35.3	45.1
F_2	20.8	39.3	21.2	17.0	23.4	29.3	21.0	25.0	17.6	25.1
F_{32}	62.5	78.6	48.0	67.9	40.7	80.0	86.4	75.9	52.9	70.2
N_c	1.32	1.93	0.82	1.58	0.58	2.15	2.85	1.92	1.00	1.62
S_c	1.14	1.26	0.94	1.22	0.80	1.31	1.40	1.28	1.02	1.22
H'	3.72	4.29	3.74	3.84	3.71	3.97	4.28	4.31	4.22	4.61
J'	0.89	0.96	0.77	0.90	0.82	0.87	0.89	0.87	0.86	0.88
D_k	45.81	57.14	61.40	41.52	48.12	53.36	60.47	68.77	55.45	70.29
D_E	45.81	37.51	21.27	43.41	35.78	39.98	41.96	54.47	50.41	37.24
B_c	7.05	7.94	5.36	7.12	5.35	7.95	8.96	8.89	7.00	7.82
	Number of sample in deflation depression *pE*					Number of sample on dune embankment *pC*				
	1	2	3	4	5	1	2	3	4	5
F_3	27.0	20.9	15.9	12.5	20.4	21.0	36.2	24.4	22.2	48.3
F_2	28.0	20.2	27.0	45.8	75.0	61.9	40.4	64.6	60.3	16.3
F_{32}	55.0	41.1	42.9	58.3	95.4	82.9	76.6	89.0	82.5	64.6
N_c	0.98	0.63	0.60	0.81	3.87	1.82	1.79	2.43	1.83	1.44
S_c	1.00	0.83	0.81	0.91	1.24	1.17	1.23	1.24	1.18	1.18
H'	3.06	3.36	3.50	3.36	3.52	3.17	2.45	2.61	2.93	2.70
J'	0.70	0.84	0.77	0.91	0.77	0.73	0.57	0.67	0.68	0.61
D_k	56.30	64.62	63.51	44.16	25.03	42.14	68.06	34.14	60.00	54.42
D_E	18.91	14.09	6.35	15.00	17.62	11.41	25.54	19.52	32.50	53.05
B_c	5.25	4.25	3.57	4.37	5.68	4.97	7.15	5.94	7.55	7.52

1.b. Step two of the test assessing the epigeic community of staphylinids: the assessment of departure degree of the community from the standard system as expressed by the index of community uniqueness

$$S_c = \sqrt{\frac{\log F_3}{\log f_3}\left(\frac{\log F_{32}}{\log f_{32}}\right)^2} \qquad \text{(formula 1)}$$

The stability index N' for staphylinids of the coastal pine forest was so constructed that it was equal 1 for the critical values F_3=20% and F_{32}=60%. As a consequence, f_3=20% and f_{32}=60%. The S_c index reaches the maximum value S_c=1,57 when $F_3=F_{32}$=100% and it reaches the minimum $S_c \to 0$ when $F_3= F_{32} \to 0$. In the simplified, synanthropic system of pine forest where there predominate eurytopic and alien species (specifically when F_{32}<47) the S_c index value is S_c<1. In balanced systems, with limited share of eurytopic species, the index reaches values S_c>1. The closer to maximum is S_c index real value, the least penetratable by accidental or synanthropic species is the system and it is more stable in this sense.

The threshold values of forest species (F_{32}) dominance shares and characteristic coniferous forest species (F_3) characterized by the community uniqueness index critical value S_c=1 are presented in Table 10.

Table 10. Shares [%] of forest species (F_{32}) and coniferous forest characteristic species (F_3) for the critical value of uniqueness (S_c) and stability (N_c) indices of the community equal 1.

	S_c=1 when:											
F_3	6.7	7.3	8	9	10	12	14	16	20	27	37	47
F_{32}	100	95	90	85	80	75	70	65	60	55	50	47
	N_c=1 when:											
F_3	1.0	2.3	3.5	4.8	6.3	8.2	10.9	14.5	20	30	46	49.2
F_{32}	98.9	95	90	85	80	75	70	65	60	55	50	49.2

The uniqueness index for the whole of six staphylinid communities equaled 1.17, varying from 0.98 to 1.28 for particular communities. It was below 1 only in the case of the *pE* community (Table 8). After similar analysis had been carried out for microsites (Table 9), the S_c index was possible to be calibrated. It was found that considering the coastal variety of pine forest staphylinid communities the following ranges of the uniqueness index suggest:

(1) $S_c \geq 1.3$ – biocenoses showing features of standard ones (the model type biocenosis);
(2) $1.3 > S_c \geq 1.2$ – stable biocenoses, close to the model systems (highly specific community type);
(3) $1.2 > S_c \geq 1.0$ – stable and specific biocenoses (specific community type);
(4) $S_c < 1.0$ – non-specific and unstable biocenoses, always however in natural habitats there holds the condition $S_c > 0.8$ (the nonspecific community type).

The model types of community were detected in the five samples:

- In *pA* depression

S_c=1.42 in sample number 4. The patch of arid heath is the model example of the extremely arid microsite type (*ms 1*). The dominants in the model staphylinid subcommunity, characteristic for this type of microsite, are: *Platydracus stercorarius* (D≈54%), *Mycetoporus brunneus* (D≈12%), Xantholinus *longiventris* (D≈7%), *Staphylinus erythropterus* (D≈6%).

S_c=1.33 in sample number 7. The patch of typical heath coniferous forest is the arid microsite type model (*ms 2*). In this model staphylinid subcommunity characteristic dominants are: *Staphylinus erythropterus* (D≈25%), *Sepedophilus marshami* (D≈8%), *Bolitobius formosus* (D≈6%), *Lamprinodes saginatus* (D≈6%).

S_c=1.35 in sample 10. The patch of heath coniferous forest is the arid microsite type model (*ms 2*). In this model staphylinid subcommunity characteristic dominants are: *Mycetoporus brunneus* (D≈33%), *Mycetoporus splendidus* (D≈18%), *Evanystes circellaris* (D≈11%), *Mycetoporus clavicornis* (D≈6%).

- In *pB* depression

S_c=1.31 in sample 6. The patch of typical heath coniferous forest is the fresh microsite type model (*ms 3*). In this model staphylinid subcommunity characteristic dominants are: *Platydracus stercorarius* (D≈20%), *Sepedophilus marshami* (D≈13%), *Xantholinus longiventris* (D≈9%), *Mycetoporus brunneus* (D≈8%).

- In *pD* depression

S_c=1.40 in sample 7. The patch of heath coniferous forest is the humid microsite type model (*ms 4*). In this model staphylinid subcommunity characteristic dominants are: *Sepedophilus marshami* (D≈15%), *Othius myrmecophilus* (D≈10%), *Platydracus stercorarius* (D≈9%), *Bolitobius formosus* (D≈7%).

1.c. Step three of the test assessing the epigeic community of staphylinids: the assessment of resistance degree of the community against deformation expressed in terms of the index of community stability

$$N_c = \frac{F_{32} \log F_3}{f' \log(F_{10} + 1{,}1)} \quad \text{(formula 2)}$$

This index, for the critical values: F_3=20% and F_{32}=60% reaches, also, the value 1 in the coastal variety of pine forest. Consequently, *f'* coefficient reaches the value 48.37. This index reaches its maximum: N_c≈100 when F_3=F_{32}=100% and it shows its minimum N_c=0 when F_3=F_{32}=0. N_c index values below 1 suggest the unstable systems, under the alteration processes. On the other hand, N_c>1 shows the stable systems, yet not necessarily natural ones.

The threshold (critical) domination shares of forest species (F_{32}) and coniferous forest characteristic species (F_3) for the coastal variety of Scots pine forests are given in Table 10 (for those cases when the stability index of community reaches the critical value N_c=1).

The general index of stability (determined for the whole of the six staphylinid communities considered) was equal 1.57, ranging dependenting on the actual community from 0.95 to 2.34. It was below 1 only in the case of the *pE* depression community (Table 8). After carrying a similar analysis for microsites (Table 9), the S_c index has been calibrated as follows:

The below specified ranges of the stability index are indicative in the epigeic staphylinid communities of the coastal pine forest for:

(1) N_c≥3.0 – the stable and fully closed biocenoses (the inertia community type);
(2) 3.0>N_c≥2.0 – the stable and near-closed biocenoses (the highly resilient community type);
(3) 2.0>N_c≥1.0 – the stable and partly closed biocenoses (the resilient community type);
(4) N_c<1.0 – the unstable and not closed biocenoses; in the natural habitats however, the N_c is always >0.5 (the unstable community type).

Considering the foregoing, the community inertia type has been revealed in four samples:

- In *pA* depression

N_c=3.26 in sample number 4. The patch of arid heather. The extremely arid microsite type (*ms 1*). The dominants in the inertia type staphylinid subcommunities, characteristic for this type of microsites, are: *Platydracus stercorarius* (D≈54%), *Myce-*

toporus brunneus (D≈12%), *Xantholinus longiventris* (D≈7%), *Staphylinus erythropterus* (D≈6%).

N_c=3.91 in sample 10. The patch of arid heath. The arid microsite type (*ms* 2). The dominants in the inertia type staphylinid subcommunities, characteristic for this type of microsites, are: *Mycetoporus brunneus* (D≈33%), *Mycetoporus splendidus* (D≈18%), *Evanystes circellaris* (D≈11%), *Mycetoporus clavicornis* (D≈6%).

N_c=3.23 in sample 2. The patch of typical heath coniferous forest in the initial stage. The fresh microsite type (*ms* 3). The dominants in the inertia type staphylinid subcommunities, characteristic for this type of microsites, are *Staphylinus erythropterus* (D≈35%), *Mycetoporus brunneus* (D≈18%), *Mycetoporus splendidus* (D≈13%), *Mycetoporus clavicornis* (D≈5%).

- In *pE* depression

N_c=3.87 in sample 5. The patch of humid heath coniferous forest, with elements of suboceanic fresh coniferous forest. The humid microsite type (*ms* 4). The dominants in the inertia type staphylinid subcommunities, characteristic for this type of microsites, are: *Staphylinus erythropterus* (D≈57%), *Acidota crenata* (D≈6%), *Bolitobius formosus* (D≈5%), *Othius myrmecophilus* (D≈5%).

1.d. Step four of the test assessing the epigeic community of staphylinids: species diversity assessment expressed in terms of the Shannon and Wiener index of species diversity

$$H' = -\sum_{i=1}^{S} P_i \log P_i \qquad \text{(formula 3)}$$

The value of the index of species diversity H' for the epigeic communities and subcommunities of the coastal coniferous forest staphylinids are presented in Tables 8 and 9. In case of natural and stable communities of the coastal coniferous forest staphylinids the index' mean value is 4.12 and its standard deviation is equal 0.57. In this case, the expected value of H' ranges within 3.6 –4.7. Higher than expected H' values occurred in the *pD* community, while lower than expected were observed in the *pE* community (Table 8). Similarly, considering particular microsites of the coastal pine forest, the natural and stable epigeic subcommunities showed the mean value equal 3.57 and standard deviation 0.57; in this case, the expected H' value ranges within 3.0 – 4.1.

Higher than the expected H' values were recorded in the *pA* depression: in 10% of its area; in *pB* in 10% of its area and in *pD* in 40% of its area. Lower than expected values were found in 10% of area of the *pA* depression, in 30% of the *pB* depression area as well as in 80% of *pE* area (Table 9).

1.e. Step five of the test assessing the epigeic community of staphylinids: the assessment of natural quality with use of the index of community natural quality

$$B_c = \sqrt[4]{J' N_c D_k D_E} \qquad \text{(formula 4)}$$

The value of B_c index may be determined after the following values have been found:
- index of evenness (formula 5),
- index of community stability (formula 2),

- share [%] of detritophilous species in the dominance structure of community,
- share [%] of European species in the dominance structure of community.

Evenness

The Pielou index was applied for the present analysis. Tables 8 and 9 present the values obtained for the epigeic communities and subcommunities of the coastal pine forest staphylinids. On average, the index value was 0.71 and the standard deviation equaled 0.07. The expected values of the index J' ranged within 0.64 – 0.78. Higher than expected J' values occurred in the *pD* community, while lower than expected in *pE* community (Table 8). Similarly, for the natural and stable epigeic subcommunities living in particular microsites of the coastal variety of pine forest, the mean value of the index was 0.78 and standard deviation was 0.10. The expected values of J' varied from 0.68 to 0.88.

Higher than expected values of J' were recorded in the 10% of area of *pA* depression, 10% of *pB* and in as much as 40% of *pD*. Lower than expected were J' index values of the following: the *pA* depression (in 10% of its area), *pB* (30%) and *pE* (80%) – Table 9.

Microhabitat preferences

The actual share of those staphylinid species connected with decaying organic matter D_k allows for drawing conclusion on the accumulation degree and availability of organic matter at the epigeic level of the ecosystem. It gives also some indirect information on the complexity degree of trophic nets (Tabs. 8–9).

Considering natural and stable epigeic staphylinid communities of the coastal pine forest: the expected D_k values are within 40 – 55% (versus the overall mean D_k equal 47.5% and standard deviation 7.8%). Higher than expected D_k were stated in the *pD* community and it is just this depression where the highest load of available food is to be expected (Table 8). Similarly, considering the natural and stable epigeic subcommunities occupying particular microsites of the coastal variety of Scots pine forest the mean value of D_k is 48.2%, standard deviation 14.3%; the expected D_k values range within 34%–63%. Higher than expected D_k values were those in depression *pA* (20% of its area), *pD* (20%), *pE* (40%) and the dune embankment *pC* (20%). Values lower than the expected ones were found in *pA* depression (10% of its area), *pB* (50%) and *pE* (20%)–Table 9.

Geographical distribution

The actual portion of staphylinids occurring exclusively in the European region D_E enables drawing conclusion on the usefulness of studied ecosystems for the conservation of the local taxons (Tabs. 8–9).

Considering natural and stable epigeic staphylinid communities of *Empetro nigri pinetum*, it is to state that the mean D_E value was 29.5% and standard deviation equaled 10.4%. Considering this, the expected D_E values are within the range 19%–40%. Higher than expected D_E values were recorded in communities *pF* and *pD*. These two depressions are the most important ones for the protection of local taxons (Table 8). Similarly, in natural and stable epigeic subcommunities in particular microsites of the coastal pine forest the mean value of D_E was equal 28.3% and standard deviation was 13.7%. The expected D_E values are in the range of 15%–42%.

Higher than expected values of D_E were observed in depression *pA* in 10% of its area, in depression *pB* in 20%, in *pD* in 50% as well as in dune patch *pC* in 20% of its area. Higher than expected values of D_E were found in depression *pA* (10% of its area), in *pB* (30%), *pE* (40%) as well as in dune embankment *pC* in 20% of its area (Table 9).

Natural quality

High values of the B_c index show either the naturally most valuable ecosystems or their fragments. The higher is actual value of the index of natural quality the more diverse (considering the number of species) is the community, more mature and stable, containing more valuable local forms and functioning under the condition of food sufficiency. In the case of epigeic staphylinid communities, the B_c index value varies within 4.58–7.20 (Table 8), with mean value 6.19 and standard deviation 0.99. It gives the following valorization of the coastal variety of pine forest:

(1) when B_c>7.2 the ecosystem of the coastal variety of pine forest has more than average natural value;
(2) when 7.2≥ B_c≥5.2 the ecosystem of the coastal variety of pine forest has moderately good natural value
(3) when B_c<5.2 the ecosystem natural value is below the average.

The deflation depression *pD* is characteristic of more than average natural value, unlike the deflation depression *pE*, the latter's natural value is below the average.

Considering the staphylinid subcommunities, the B_c value is within the range 3.57–8.96 (Table 9), with the mean equal 6.33 and standard deviation 1.34. This index gives the following valorization of particular fragments of the coastal coniferous forest:

(1) if B_c>7.7 then the microsite has more than average natural quality;
(2) if 7.7≥ B_c≥5.0 then the microsite has the average natural quality;
(3) if B_c<5.0 then the microsite's natural quality is below the average value.

Considering the set of 40 microsites subjected to the present analysis, seven of them have more than average natural value. Out of them, five were found in the deflation depression *pD*, and two other in deflation depression *pA*:

- *pD* depression

Sample number 7 – B_c=8.96. Humid variety of the coastal coniferous forest. Moist terrain depression, only partly shadowed by pines with rich mossy-shrubby forest floor. Type *ms 3/4*. Source for: *Bolitobius formosus, Othius myrmecophilus*. Dominant: *Sepedophilus marshami, Othius myrmecophilus*.

Sample number 8 – B_c=8.89. Typical coastal coniferous forest. Elevated terrain, under the shadow of pine stand with mossy-shrubby forest floor vegetation. Type *ms 3*. Source for: *Mycetoporus rufescens, Oxypoda procerula, Sepedophilus marshami, Stenus clavicornis*. Dominants: *Sepedophilus marshami, Mycetoporus rufescens*.

Sample number 6 – B_c=7.95. Typical coastal coniferous forest. Elevated terrain, under the shadow of pine stand with mossy-shrubby forest floor vegetation. Type *ms 3*. Source for: *Stenus impressus*. Dominants: *Platydracus stercorarius, Sepedophilus marshami*.

Sample number 2 – B_c=7.94. Humid coastal coniferous forest. Terrain depression under the shadow of pine stand with rich shrubby undergrowth vegetation. Type *ms 3/4*. Source for: *Olophrum piceum*. Dominants: *Olophrum piceum, Othius myrmecophilus*.

Sample number 10 – B_c=7.82. Humid coastal coniferous forest. A moving dune embankment from the south. Terrain depression under the shadow of pine stand with rich mossy-shrubby undergrowth vegetation. Type *ms 3/4*. Source for: *Lathrobium brunnipes, Mycetoporus clavicornis, Mycetoporus rufescens, Rugilus rufipes*. Dominants: *Drusilla canaliculata, Sepedophilus marshami*.

- *pA* depression

Sample number 5 – B_c=7.76. Typical coastal coniferous forest, initial stage. Terrain elevated, shadowed with low height pine stand with poor mossy-grassy forest floor vegetation. Type *ms 2/3*. Source for: *Othius myrmecophilus, Zyras laticollis*. Dominants: *Xantholinus longiventris, Othius myrmecophilus*.

Sample number 7 – B_c=7.74. Typical coastal coniferous forest. Terrain elevation partly shadowed by pine stand with poor mossy-shrubby forest floor. Type *ms 2*. Source for: *Lamprinodes saginatus*. Dominants: *Staphylinus erythropterus, Sepededophilus marshami*.

1.f. Step six of the test assessing the epigeic community of staphylinids: the assessment of microsite diversity degree as expressed in terms of the index of dynamic heterogeneity

$$\mathrm{DHt} = \mathrm{I_{ds}}(1 - \frac{S'}{S}) \quad \text{formula 6)}$$

The empirical data collected in plots pA, pB, pC, pD and pE made it possible to calibrate the index of dynamic heterogeneity DHt. The results of the calibration are for the staphylinid communities as follows:

(1) DHt≥2.0 – suggests high level site dynamic heterogeneity

(2) 2.0>DHt≥1.0 – suggests average level site dynamic heterogeneity

(3) DHt<1.0 – suggests low level site dynamic heterogeneity

The depressions pA, pB and pD are characteristic of large differentiation of microsite capacity (I_{ds}) while high dynamic heterogeneity (DHt) was found in depressions pA and pB. The only plot characteristic of low level dynamic heterogeneity is depression pE (Table 8).

1.g. Step seven of the test assessing the epigeic community of staphylinids: the assessment of site attractiveness for a given community as expressed in terms of the index of habitat species capacity

The value of P_b index may be determined after selecting the extreme microsites for particular species using the c_s index and determining the utilization by the species of degree of the actual site diversity with use of the index C_s'.

Selection of extreme microsites – sources and sinks for particular species, on the basis of index of microsite preferences of a species

$$c_s = \frac{I_{fd}}{I_{fd}(\max)} \qquad \text{(formula 10)}$$

This index expresses a given microsite saturation level with a species as related to the maximum saturation and it may range from 0 to 1. The below discussed three situations may occur:

(1) if c_s>0.85, the population is in the source region of its distribution range;

(2) if 0.85≥ c_s≥0.15, the population is in the standard region of its distribution range;

(3) if c_s<0.15, the population is in the sink region of its distribution range.

The assessment of utilization of site diversity by a given species as measured by the index of site heterogeneity utilization by a given species

$$C_s' = \frac{2\sum_{j=1}^{R} C_{sj}}{R} \qquad \text{(formula 9)}$$

This index supplies the quantitative approach to the problem of site saturation with a given species population. The following situations should be identified:

(1) if C_s>1, the microsite mosaic favors a given population in more than average level. The habitat is dominated by the sources of population distribution range;

(2) if 1≥C_s≥0.3, the microsite mosaic favors a given population in average level. The sources and sinks of population distribution range are in balance;

(3) if C_s<0.3, the population does not prefer the analyzed microsite mosaic, and the habitat is dominated by the sinks of the population distribution range.

The assessment of site attractiveness degree for a given community as measured by the index of habitat species capacity

$$P_c = \frac{\sum_{i=1}^{S} C_{si}'}{\log S} \quad \text{(formula 8)}$$

This index determines the efficiency of utilization of site potential biological diversity. It is possible to assess site attractiveness for a given community with use of the index. Table 8 presents the values of the P_c index for staphylinid epigeic communities of the coastal variety of coniferous forest. The P_c is not sensitive to actual size of sample collected (within the range 5–40 samples), nor to the number of recorded species (within the range 41 to 117). The mean expected value P_c = 9.98 for the coastal coniferous forest should be in theory smaller than respective values for more fertile sites; and it should be relatively smaller in poorer sites.

2. The standard of coastal variety of pine forest epigeic staphylinid community

The standard based on seven point test is characteristic of:

1. The share in the dominance structure of community:
   - coniferous forest characteristic species F_3≥20%
   - all forest species F_3+F_2≥60%
2. Departure degree of a given community from the model system S_c≥1
3. Resistance degree to deformation N_c≥1

4. Species diversity $H' \geq 3.6$, given the expected maximum value equal 4.7
5. Natural quality of community $B_c \geq 5.2$, given the expected maximum value equal 7.2
6. Dynamic heterogeneity $DHt \geq 1.4$, given the expected maximum value equal 2.9
7. Habitat species capacity $P_c \geq 8.5$, given the expected maximum value equal 12.8.

The lower values observed in pine forest of the indices suggest the process of degradation, or simplification and destabilization of coniferous ecosystems. Higher values (considering those indices with determined maximum values) may be the effect of either natural forest succession or man-induced eutrophication. In any case this is connected with enrichment of the coniferous forest habitat.

3. Valorization of coastal pine forest communities

The indices describing epigeic staphylinid communities and subcommunities: the indices of uniqueness and natural quality characterizing the natural quality of a community as well as the indices of species diversity and evenness characterizing the species diversity of a community, enable classifying particular sites and microsites and ascribing them to valorization classes and groups (Table 11).

Table 11. Threshold values of selected indices of natural quality and species diversity for particular classes and valorization groups – the example of coastal pine forest staphylinid (*Coleoptera*, *Staphylinidae*) communities.
B_c – index of community natural quality H' – index of species diversity
S_c – index of community uniqueness J' – index of evenness

	Indices of			
	Natural quality		Species diversity	
	B_c	S_c	H'	J'
For staphylinid communities				
Class I	>7.2	≥1.3	>4.7	>0.78
Class II	>6.2	<1.3–1.2	>4.1	>0.71
Class III	>6.2	<1.3–1.2	3.6–4.7	0.64–0.78
Class III	7.2–5.2	<1.2–1.0	>4.1	>0.71
Class IV	7.2–5.2	<1.2–1.0	3.6–4.7	0.64–0.78
Class V	7.2–5.2	<1.2–1.0	<3.6	<0.64
Class V	<5.2	<1.0	3.6–4.7	0.64–0.78
Class IV	<5.2	<1.0	<3.6	<0.64
For staphylinid subcommunities				
Group I	>7.7	≥1.3	>4.1	>0.88
Group II	>6.3	<1.3–1.2	>3.5	>0.78
Group III	>6.3	<1.3–1.2	4.1–3.0	0.88–0.68
Group III	7.7–5.0	<1.2–1.0	>3.5	>0.78
Group IV	7.7–5.0	<1.2–1.0	4.1–3.0	0.88–0.68
Group V	7.7–5.0	<1.2–1.0	<3.0	<0.68
Group V	<5.0	<1.0	4.1–3.0	0.88–0.68
Group VI	<5.0	<1.0	<3.0	<0.68

Each of the analyzed study plots was included to one of the six valorization classes. The classes themselves had been determined as follows (Table 12):

Class I, naturally most valuable – none of the analyzed plots was given the status of naturally most valuable habitat that is habitat possessing both the highest natural quality and highest species diversity.

Class II, naturally valuable – none of the analyzed plots was given the status of naturally valuable habitat that is habitat possessing both the high natural quality and high species diversity.

Class III, above average natural value – to this class included were deflation depressions *pA* and *pD* and the central dune embankment *pC*. The plots *pA* and *pC* represent those sites characteristic of high natural quality and average species diversity. Plot *pD* represents the highest species diversity and moderate natural quality.

Class IV, average natural value – to this class included were deflation depressions *pB* and *pF*. They represent sites characteristic of average natural quality and species diversity.

Class V, below average natural value – none of the analyzed plots was given the status of below-average natural habitat that is such habitat that is characteristic of either moderate natural quality and low species diversity or low natural quality and moderate species diversity.

Class VI, poor natural value - to this class included was deflation depression *pE*. It is representative of sites characteristic of poor value of both natural quality and species diversity.

The coastal coniferous forest microsites may belong to the following six valorization groups, as described below (Table 12):

Group I – it covers microsites where the cenosis is characteristic of the highest natural quality and highest species diversity, which means the naturally most valuable microsites.

To this group belong the microsites of the deflation depressions *pA* (sample 5) and *pD* (samples 6 and 7), in the fragments of both typical and humid varieties of vegetation of the coastal coniferous forest, only partly shadowed by pine stand, characteristic of either poor mossy-grassy undergrowth vegetation (*ms* 2) or rich mossy-shrubby vegetation (*ms* 3 and *ms* 4). They are source for: *Bolitobius formosus, Othius myrmecophilus, Stenus impressus* and *Zyras laticollis*.

Group II – it covers valuable microsites where the cenosis is characteristic of the high natural quality and high species diversity.

To this group there belong the following microsites: in depression *pA* sample 7, in deflation *pB* sample 10, and in deflation *pD* samples 2, 8 and 10. Typical coastal coniferous forest microsites; situated in elevated terrain, partly under shelter of pine; poor mossy-grassy vegetation (*ms* 2) or rich mossy-shrubby forest floor (*ms* 3 and *ms* 4). They are the source for: *Lamprinodes saginatus, Lathrobium brunnipes, Mycetoporus clavicornis, Mycetoporus rufescens, Olophrum piceum, Oxypoda procerula, Rugilus rufipes, Sepedophilus marshami* and *Stenus clavicornis*.

Group III – it covers microsites of above-average value, with the cenosis characteristic of high natural quality and average species diversity or on the opposite: average natural quality and high species diversity.

To this group of microsites belong samples number 3, 6, 9 and 10 in deflation depression *pA;* samples number 1 and 10 in deflation *pB;* sample number 6 in depression *pD* and samples 2 and 3 in dune embankment *pC*. These are mainly ecotonal microsites, thinned, situated at the foot of southern and northern slopes of dunes. They represent either the arid subvariety of the coastal coniferous forest, partly under shadow of pine trees, with poor grassy-mossy-shrubby vegetation (*ms 2, ms 3*), or the moist one, also under partial shelter of pine trees and with rich mossy-shrubby undergrowth (*ms 3* and *ms 4*). The source for: *Anthobium atrocephalum, Gabrius pennatus, Mycetoporus baudueri, Mycetoporus brunneus, Ocypus compressus, Quedius molochinus, Tachyporus transversalis* and *Zyras cognatus*.

Group IV – it covers average microsites, with their cenosis characteristic of moderate natural quality and species diversity.

To this group of microsites belong samples 1, 2 and 8 in depression *pA,* samples 7 and 8 in depression *pB,* samples 1 and 9 in *pD,* sample number 1 in depression *pE,* and samples 4 and 5 in dune embankment *pC*. Such microsites occur mainly in dried elevated spots of terrain. They represent the arid and typical subvarieties of the coastal pine forest – in mild hills or dune slopes, or the moist subvariety – in small terrain depressions (*ms 1, ms 2, ms 3* and *ms 4*). It is the source for many species: *Anthobium atrocephalum, Bolitobius formosus, Evanysthes circellaris, Lathrobium brunnipes, Mycetoporus brunneus, Mycetoporus splendidus, Othius myrmecophilus, Othius punctulatus, Sepedophilus immaculatus, Staphylinus erythropterus, Xantholinus longiventris, Xantholinus tricolor* and *Zoosetha procidua*.

Group V – It includes below-average microsites, with the cenosis characteristic of high or average natural quality and poor species diversity or vice versa: poor natural quality and either high or average species diversity.

The following microsites belong to this group: sample 4 in *pA* depression, samples 4, 5 and 9 in *pB* depression, samples 3 and 5 in depression *pD,* sample 5 in depression *pE,* and sample 1 in dune embankment *pC*. The microsites are situated in central parts of depressions and are loosely connected with the coastal coniferous forest. They represent the dissipation stage of the coniferous forest or the arid heather, with poor shrubby forest floor vegetation or the marshy birch forest type currently under the process of renaturalization – in the moist hollows of the terrain. They characterize also the typical subvariety of coastal coniferous forest in mildly elevated locations or northern dune slopes, partly under the shelter of pine trees, with mossy-shrubby forest floor vegetation (*ms 1, ms 2, ms 3* and *ms 4*). They are the source for: *Acidota crenata, Platydracus stercorarius, Staphylinus erythropterus, Tachyporus corpulentus* and *Xanthollinus linearis*.

Group VI – It covers poor value sites, with the cenosis characteristic of both low natural quality and low species diversity.

To this microsite group belong samples 2 and 3 of depression *pB* as well as samples 2, 3 and 4 of depression *pE*.

The microsites, representing edge regions of deflation depressions are typical coastal coniferous forest in the stage of dissipation or marshy birch forest in the stage of renaturalization. They are under partial shelter and with rich mossy-shrubby vegetation (*ms 3*).

They are the source for: *Drusilla canaliculata, Othius myrmecophilus, Platydracus fulvipes, Proteinus brachypterus* and *Staphylinus erythropterus.*

Summing up, 7.5% coniferous forest microsites have been included to the most valuable group considering their natural value; 12.5% were identified as valuable ones; 22.5% microsites are above average value microsites; 25% were considered average value microsites, 20% – below average and there were as much as 12.5% of poor value microsites.

Table 12. Point based valorization of the coastal variety of pine forest of Mierzeja Łebska with use of selected zooindicative indices – the example of epigeic communities and subcommunities of staphylinids (*Coleoptera, Staphylinidae*)

For the index of community natural quality [B_c]
3 – biocenoses characteristic of high natural quality
2 – biocenoses characteristic of average natural quality
1 – biocenoses characteristic of poor natural quality

For the index of community uniqueness [S_c]
3 – standard biocenoses
2 – highly unique biocenoses
1 – unique biocenoses
0 – non-unique biocenoses

For the index of species diversity [*H'*] and index of evenness [*J'*]
3 – biocenoses characteristic of high species diversity
2 – biocenoses characteristic of average species diversity
1 – biocenoses characteristic of low species diversity

General conclusion based on all indices analyzed [O]
6 – naturally most valuable biocenoses
5 - naturally valuable biocenoses
4 - biocenoses characteristic of above average natural value
3 - biocenoses characteristic of average natural value
2 - biocenoses characteristic of below average natural value
1 – naturally poor biocenoses

Point based valorization of biocenoses											
	B_c	S_c	*H'*	*J'*	O		B_c	S_c	*H'*	*J'*	O
Deflation depression *pA*						Deflation depression *pB*					
Total	2	2	2	2	4	Total	2	1	2	2	3
Sample 1	2	1	2	2	3	Sample 1	2	1	2	3	4
Sample 2	2	2	2	1	3	Sample 2	1	1	1	1	1
Sample 3	2	2	2	2	4	Sample 3	1	1	2	1	1
Sample 4	2	3	1	1	2	Sample 4	2	2	1	1	2
Sample 5	3	3	3	3	6	Sample 5	1	2	1	2	2
Sample 6	2	2	2	2	4	Sample 6	2	1	3	3	4
Sample 7	3	3	2	2	5	Sample 7	2	1	2	2	3
Sample 8	2	1	2	2	3	Sample 8	2	1	2	2	3
Sample 9	2	2	2	2	4	Sample 9	1	0	2	2	2
Sample 10	2	3	2	2	4	Sample 10	2	3	2	3	5
Deflation depression *pD*						Deflation depression *pE*					
Total	3	1	3	3	4	Total	1	0	1	1	1
Sample 1	2	1	2	3	3	Sample 1	2	1	2	2	3
Sample 2	3	2	3	3	5	Sample 2	1	0	1	1	1
Sample 3	2	0	2	2	2	Sample 3	1	0	1	1	1
Sample 4	2	2	2	3	4	Sample 4	1	0	1	1	1
Sample 5	2	0	2	2	2	Sample 5	2	2	1	1	2
Sample 6	3	3	2	3	6	Central double dune embankment *pC*					
Sample 7	3	3	3	3	6	Total	2	2	2	2	4
Sample 8	3	2	3	3	5	Sample 1	1	1	2	2	2
Sample 9	2	1	3	2	3	Sample 2	2	2	2	2	4
Sample 10	3	2	3	3	5	Sample 3	2	2	2	2	4
Deflation depression pF						Sample 4	1	1	2	3	3
Total	2	1	2	2	3	Sample 5	2	1	2	2	3

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STRESZCZENIE

[Tytuł: Waloryzacja borów bażynowych Słowińskiego Parku Narodowego metodą zooindykacji przy wykorzystaniu epigeicznych zgrupowań kusakowatych (*Coleoptera, Staphylinidae*)]

I. Przedstawiono waloryzację przyrodniczą borów bażynowych z zastosowaniem epigeicznych zgrupowań kusakowatych. Zaproponowano opisanie każdego badanego zgrupowania tymi samymi, siedmioma wskaźnikami, których wartości będzie można porównać z opracowanym, dla tego typu ekosystemu, wzorcem zgrupowania naturalnego.

Waloryzacji dokonano według następującego schematu:

1. Wybór poligonu badawczego: pozbawione antropopresji bory bażynowe Mierzei Łebskiej.
2. Inwentaryzacja żywych zasobów środowiska:
   - opis mozaikowatości siedliska na podstawie analizy glebowej i fitosocjologicznej,
   - opis epigeicznego zgrupowania kusakowatych siedmiopunktowym testem, na który składają się wskaźniki: udziału w strukturze dominacji gatunków charakterystycznych F_3 i F_{32}, stabilności N_c, swoistości S_c, ogólnej różnorodności gatunkowej H', jakości przyrodniczej B_c, heterogenności dynamicznej DHt i pojemności gatunkowej siedliska P_c.
2. Oszacowanie wartości przyrodniczej żywych zasobów środowiska na podstawie określenia stopnia atrakcyjności środowiska dla epigeicznego zgrupowania kusakowatych. O atrakcyjności środowiska świadczą uzyskane wartości wskaźników opisujących dane zgrupowanie.
3. Opracowanie wzorca naturalnego zgrupowania epigeicznych kusakowatych.

II. Wzorzec epigeicznego zgrupowania kusakowatych nadmorskich borów bażynowych charakteryzuje się:

1. udziałem w strukturze dominacyjnej zgrupowania:
   - borowych gatunków charakterystycznych $F_3 \geq 20\%$
   - wszystkich gatunków leśnych $F_3+F_2 \geq 60\%$
2. stopniem odkształcenia zgrupowania od układu modelowego $S_c \geq 1$

3. stopniem odporności na odkształcenia $N_c \geq 1$
4. ogólną różnorodnością gatunkową $H' \geq 3,6$ przy oczekiwanej wartości maksymalnej $=4,7$
5. jakością przyrodniczą zgrupowania $B_c \geq 5,2$ przy oczekiwanej wartości maksymalnej $=7,2$
6. heterogennością dynamiczną $DHt \geq 1,4$ przy oczekiwanej wartości maksymalnej $=2,9$
7. pojemnością gatunkową siedliska $P_c \geq 8,5$ przy oczekiwanej wartości maksymalnej $=12,8$

III. Przedstawiono system przyrodniczej waloryzacji ekosystemów, oparty na czterech wskaźnikach zooindykacyjnych: swoistości S_c, jakości przyrodniczej B_c, równomierności J' i ogólnej różnorodności gatunkowej H'. Systemem tym, złożonym z 6 klas (dla siedlisk) i 6 grup (dla mikrosiedlisk) waloryzacyjnych, sklasyfikowano bory bażynowe Mierzei Łebskiej. Wśród sześciu analizowanych nie znaleziono biocenoz, które zgodnie z zastosowaną metodą można by uznać za przyrodniczo najcenniejsze lub cenne. Najwyższe wartości przyrodnicze jakie uzyskały zgrupowania dla dwóch zagłębień deflacyjnych i jednego wału wydmowego, pozwoliły zakwalifikować je do klasy przyrodniczo ponad przeciętnej. Kolejne zgrupowania zagłębień deflacyjnych uzyskały status przyrodniczo przeciętnych (dwa zagłębienia) i przyrodniczo miernych (jedno zagłębienie). 7,5% z analizowanych mikrosiedlisk borowych znalazło się w grupie przyrodniczo najcenniejszych; 12,5% sklasyfikowano jako cenne; 22,5% jako ponad przeciętne, 25% jako przeciętne, 20% jako poniżej przeciętne i 12,5% jako mierne.