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# The use of similarity analysis in the environmental research – a case study of multispecies invertebrate communities[x]

**Abstract:** Similarity analysis was carried out with use of two techniques, the Ward method and Renkonen method, in order to analyze staphylinid (*Coleoptera*: *Staphylinidae*) epigeic communities of the coastal pine forest. This attempt enabled a multilateral spatial description of the coastal pine forest microsite structure including the domination structure of microsites, the degree of their isolation, and the migration impact and edge effect of ecotone zones.

**Key words:** similarity, communities, *Staphylinidae*, *Empetro-nigri Pinetum* – coastal pine forest

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## INTRODUCTION

This paper gives a methodological proposal for microsite description of habitat with use of the similarity analysis. The similarity analysis was carried out considering the example of epigeic subcommunities of coastal pine forest staphylinids of Mierzeja Łebska sand bar (SMOLEŃSKI 2001). The faunistic material was completed at the level of subcommunity following the methods of Ward and Renkonen. The substantial assumption of the methods is the principle that the subcommunities are distributed within the analyzed community in accordance with the microsite mosaic of the ecosystem. The similarity analysis of the subcommunities results, except of determining the similarity of communities of interest, in the assessing such phenomena like ecosystem microsite diversity degree, domination of a given microsite type, isolation degree of biocenoses, migration effect or the edge effect of ecotone zones.

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## MATERIAL

The similarity analyses were performed based on empirical data collected with use of 200 Barber's pitfall traps in the coastal pine forest of Mierzeja Łebska sand bar in Słowiński National Park. The faunistic data were collected during a two-year period: July 1996 – July 1998. A total of 40 microsites were included to the study. Those occurred in four deflation depressions (*pA; pB; pD; pE*) and in a dune embankment (*pC*). The microsites selected for the present study are representatives of all subassociations of the coastal pine forest – the arid, the fresh (moderately humid) and moist subassociation. A total of 4436 beetles were captured belonging to 117 species of the *Staphylinidae* family. A detailed methods description as well as the complete faunistic data set are provided by the earlier paper of the Author (SMOLEŃSKI 2001).

## ENVIRONMENTAL RESEARCH – DETAILED CONCLUSIONS

### 1. Similarity of communities as measured with the Ward method (cluster analysis)

The Ward method was selected from the set of available research tools because of its common use in the natural sciences. Following this method's assumption, samples are divided into clusters using the agglomeration technique so that the variance between particular clusters is maximized (JONGMAN *et al.* 1987). Euclidean squared distance has been applied as the measure of variance between samples.

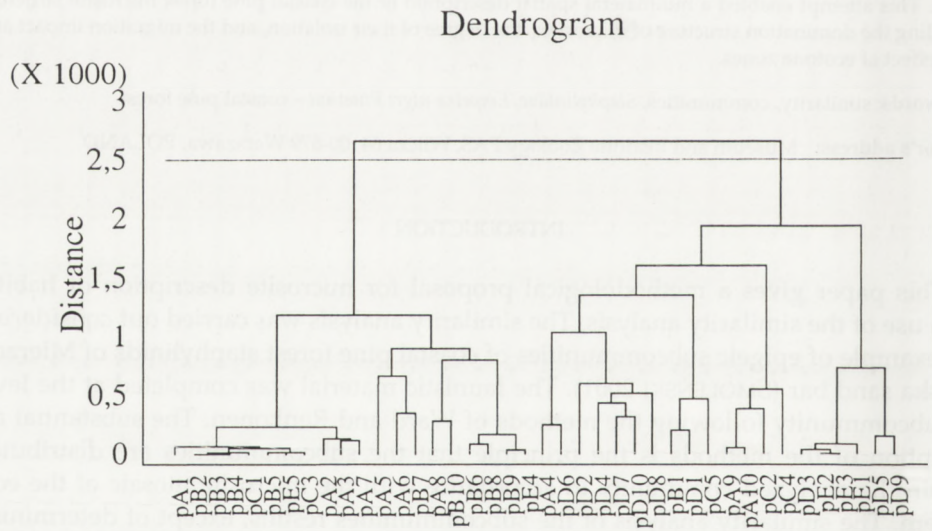


Fig. 1. Ranking of similarity between epigeic staphylinid (*Staphylinidae, Coleoptera*) subcommunities of the coastal pine forest of Mierzeja Łebska sand bar. The data presented below were originally published in SMOLEŃSKI (2001); *pA, pB, pD, pE* – deflation depressions, *pC* – dune embankment subjected to analysis using Barber's pitfall traps; 1, 2, ....., 10 – microsites.

The obtained dendrogram (Fig. 1) clearly presents that two independent faunistic groups occur considering the dominance structure of staphylinid communities; these two groups are isolated from one another by the central double dune embankment (**conclusion 1**). These are:

– the coastal northern group, (to this group belong, from the Baltic coast, the communities – representatives of deflation basins *pA* and *pB*);

– the near-lake group, southern (to this group belong, from the side of Łebsko Lake, the communities – representatives of deflation basins *pD* and *pE*).

Not all subcommunities conform however this division system based on their spatial distribution.

The exceptions from the above-presented rule are the following:

– The subcommunities of extremely arid microsites from the deflation *pA* (samples 4, 9 and 10) as well as the *pB* depression (sample 1), all these are much more similar to the southern group, instead of the northern group (**conclusion 2**);

– The subcommunities number 4 and 5 from the *pE* depression which are more strongly connected with the northern group, instead of the southern one (**conclusion 3**).

Besides, the dendrogram shows the following:

– The fauna of the dune embankment corresponds, in part, with the northern group, and more specifically: with the adjacent depression deflation *pB* (samples 1 and 3), and in part with the extremely arid microsites (samples 2, 4 and 5) (**conclusion 4**);

– The mutually isolated clusters containing samples from depressions *pA* and *pB* are characteristic of rather high degree of independence (**conclusion 5**);

– Even higher level of autonomy there exists in the lake group, between the communities – representatives of depressions *pD* and *pE* (**conclusion 6**);

– There exists large microsite differentiation within the deflation *pA* (**conclusion 7**);

– Two faunistic groups are present within the *pB* depression: the more homogenous northern group (samples 2, 3, 4 and 5) and the more diverse southern group (samples 6, 7, 8, 9 and 10) (**conclusion 8**);

– The fauna of *pD* depression is diverse and it only possess one compact group of moist microsites (samples 2, 4, 7 and 10) (**conclusion 9**);

– The fauna of *pE* deflation depression has been diversified between two groups: the homogenous group of microsites situated near the coastal forest (samples 1, 2 and 3) and the strongly differentiated group of microsites situated at the marshy birch forest (samples 4 and 5) (**conclusion 10**).

### 2. Similarity of communities as measured by the Renkonen method (dominance similarity)

The output obtained after the Renkonen method has been used (GÓRNY & Grüm 1993) is presented in two tables (Tables 1 & 2).

It can be concluded from the analysis of Table 1 data that the similarity of subcommunities within particular biocenoses may give indirect evidence of the actual microsite differentiation of the biotope:

Table 1. Renkonen coefficient of dominance similarity [%] for epigeic staphylinid (*Staphylinidae, Coleoptera*) communities of the coastal pine forest of Mierzeja Łebska sand bar. The data presented below were originally published in SMOLEŃSKI (2001); *pA, pB, pD, pE, pF* – deflation depressions, *pC* – dune embankment subjected to analysis using the method of Barber's pitfall traps,

| Plots | | | | | |
|---|---|---|---|---|---|
| | *PB* | *pD* | *pE* | *pF* | *pC* |
| *pA* | 62.2 | 50.3 | 46.0 | 41.3 | 62.5 |
| *pB* | XXXX | 52.7 | 65.7 | 41.2 | 58.5 |
| *pD* | | XXXX | 43.7 | 51.9 | 44.8 |
| *pE* | | | XXXX | 29.6 | 45.8 |
| *pF* | | | | XXXX | 43.8 |
| | | | | | XXXX |

| Number of sample in *pA* depression | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 62.9 | 58.9 | 38.1 | 47.8 | 52.4 | 55.8 | 50.8 | 33.2 | 27.0 |
| 2 | XXXX | 53.9 | 27.5 | 34.3 | 42.3 | 52.8 | 55.1 | 47.1 | 49.9 |
| 3 | | XXXX | 21.8 | 51.3 | 52.0 | 55.1 | 35.3 | 24.9 | 23.7 |
| 4 | | | XXXX | 29.6 | 22.1 | 23.5 | 36.9 | 24.1 | 24.1 |
| 5 | | | | XXXX | 46.0 | 45.3 | 38.8 | 34.8 | 27.3 |
| 6 | | | | | XXXX | 47.9 | 47.9 | 19.2 | 18.9 |
| 7 | | | | | | XXXX | 39.0 | 30.9 | 26.3 |
| 8 | | | | | | | XXXX | 40.6 | 45.6 |
| 9 | | | | | | | | XXXX | 66.6 |

| Number of sample in *pB* depression | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 39.0 | 42.5 | 44.5 | 43.2 | 48.3 | 51.3 | 38.7 | 33.1 | 53.2 |
| 2 | XXXX | 81.6 | 81.2 | 68.6 | 54.9 | 48.0 | 59.7 | 57.4 | 47.0 |
| 3 | | XXXX | 84.8 | 74.5 | 52.8 | 46.2 | 52.4 | 50.9 | 49.2 |
| 4 | | | XXXX | 71.1 | 53.0 | 53.4 | 52.5 | 54.1 | 49.4 |
| 5 | | | | XXXX | 46.1 | 48.1 | 51.7 | 46.6 | 43.3 |
| 6 | | | | | XXXX | 49.3 | 62.5 | 52.8 | 52.7 |
| 7 | | | | | | XXXX | 47.5 | 52.4 | 42.1 |
| 8 | | | | | | | XXXX | 66.3 | 52.2 |
| 9 | | | | | | | | XXXX | 43.2 |

| Number of sample in *pD* depression | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 52.4 | 42.7 | 51.0 | 46.4 | 37.5 | 41.4 | 34.5 | 49.1 | 36.9 |
| 2 | XXXX | 55.2 | 59.5 | 39.1 | 47.2 | 58.1 | 48.2 | 49.7 | 57.1 |
| 3 | | XXXX | 48.3 | 60.1 | 38.5 | 44.7 | 40.0 | 53.8 | 51.0 |
| 4 | | | XXXX | 45.1 | 55.7 | 60.8 | 52.2 | 64.8 | 54.3 |
| 5 | | | | XXXX | 32.1 | 32.1 | 32.0 | 55.3 | 44.0 |
| 6 | | | | | XXXX | 54.2 | 62.3 | 46.5 | 45.7 |
| 7 | | | | | | XXXX | 57.6 | 54.4 | 59.2 |
| 8 | | | | | | | XXXX | 48.2 | 55.4 |
| 9 | | | | | | | | XXXX | 58.9 |

| Number of sample in *pE* depression | | | | | Number of sample in *pC* dune embankment | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | | 2 | 3 | 4 | 5 |
| 1 | 71.9 | 66.6 | 70.2 | 37.2 | 1 | 31.37 | 66.19 | 37.14 | 25.99 |
| 2 | XXXX | 75.9 | 63.2 | 33.5 | 2 | XXXX | 24.05 | 52.39 | 46.01 |
| 3 | | XXXX | 67.0 | 32.4 | 3 | | XXXX | 34.27 | 16.44 |
| 4 | | | XXXX | 55.4 | 4 | | | XXXX | 29.06 |

- Deflation depression *pA*

The highest degree similarity has been characteristic for the subcommunities 1, 2, 3 and 7; these create, besides, also a very much homogenous group as proved by the cluster analysis tests (**conclusion 11**).

- Deflation depression *pB*

Except of four subcommunities (1, 5, 7 and 10), all the others are characteristic of very strong similarity towards other subcommunities. Out of the first mentioned group, four subcommunities (without subcommunity 5) correspond well in the cluster analysis with the adjacent deflation depressions (**conclusion 12**).

- Dune embankment *pC*

Particular subcommunities are strongly isolated between themselves, nonetheless the fauna of dune tops shows a lot in common (samples 2 and 4) and the fauna of northern slopes of the dune is very much similar to that of the bottom of dune embankment (samples 1 and 3) (**conclusion 13**).

- Deflation depression *pD*

A majority of subcommunities are strongly similar to others, the only exceptions being samples 1, 5 and 6 (**conclusion 14**).

- Deflation depression *pE*

Particular subcommunities are very strongly similar to one another with the exception of sample 5. The latter corresponds, in the cluster analysis with the fauna of northern group arid microsites (**conclusion 15**).

The actual degree of dominance structure differentiation of epigeic staphylinid communities may be realized after analysis of Table 2 data, following the below mentioned rules:

– The smaller are mean values of dominance similarity, the higher is degree of dominance structure diversity;

– The higher is standard deviation and coefficient of variation (accompanied by high values of dominance similarity), the larger part of subcommunities are characteristic of high autonomy degree;

– The higher is value of standard deviation and coefficient of variation (accompanied by low values of dominance similarity), the larger part of subcommunities show high affinity degree.

Considering the above one may state that the data presented suggest the following:

– The highest degree of dominance structure diversity was found in the community of depression *pA*, somewhat smaller it was in the community of dune embankment *pC* (**conclusion 16**);

– The least differentiated were the communities of depression *pB* and *pE* (**conclusion 17**);

– The community of *pD* depression is relatively closest to the whole of communities of the coastal pine forest; this community may be, thus, assented the most typical of the coastal pine forest, considering its microsite diversity (**conclusion 18**).

Table 2. Dominance similarity coefficient [%] for epigeic staphylinid (*Coleoptera, Staphylinidae*) associations of the coastal pine forest of Mierzeja Łebska sand bar

| Renkonen dominance similarity [%] for: | Real value range | Mean | Standard deviation | Expected value range | Coefficient of variation |
|---|---|---|---|---|---|
| Coastal pine forest communities | 29.6–65.7 | 49.3 | 9.4 | 39.9–58.7 | 0.19 |
| Coastal pine forest subcommunities | 16.4–84.8 | 47.3 | 13.3 | 34.0–60.6 | 0.28 |
| Deflation depression *pA* subcommunities | 18.9–66.6 | 39.8 | 12.9 | 26.9–52.7 | 0.32 |
| Deflation depression *pB* subcommunities | 33.1–84.8 | 53.2 | 11.3 | 41.9–64.5 | 0.21 |
| Deflation depression *pD* subcommunities | 32.0–64.8 | 49.2 | 8.6 | 40.6–57.8 | 0.18 |
| Deflation depression *pE* subcommunities | 32.4–75.9 | 57.3 | 15.9 | 41.4–73.2 | 0.28 |
| Dune embankment *pC* subcommunities | 16.4–66.2 | 36.3 | 14.1 | 22.2–50.4 | 0.39 |

### 3. Grouping microsites with use of the zooindication method

The microsites were so grouped, based on the Ward method's conclusions **1, 5,** and **6** and Renkonen method's conclusions **11** through **15**, that the obtained staphylinid subcommunities contain elements characteristic of strong mutual similarity (Table 3).

Table 3. Microsite groups of the Mierzeja Łebska sand bar coastal pine forest containing epigeic staphylinid (*Coleoptera, Staphylinidae*) subcommunities characteristic of strong internal similarity as assessed using the Ward method and Renkonen method. The data were originally published in an earlier paper of the Author (SMOLEŃSKI 2001); *pA, pB, pD, pE* – deflation depressions, *pC* – dune embankment subjected to analysis using Barber's pitfall traps; 1, 2, ....., 10 – microsites.

| No. of sample | Location | Subassociation of the coastal pine forest | Forest stand | Herbaceous vegetation | Microsite type |
|---|---|---|---|---|---|
| Deflation depression's *pA* microsite group | | | | | |
| 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 |
| 7 | Patch in central part of depression | Typical | Pine 60 yr old, 6m high, loose crown closure | Poor-mossy-shrubby | *ms 2* arid |
| Deflation depression's *pB* microsite group I | | | | | |
| 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 |
| | Deflation depression's *pB* microsite group II | | | | |
| 6 | 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 |
| | Dune embankment's *pC* microsite group | | | | |
| 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 |
| 3 | Inner depression bottom between slopes of double dune embankment | Arid | Pine 100 yr old, 14m high, moderate crown closure | Rich mossy-shrubby | *ms 3* fresh |
| | Deflation depression's *pD* microsite group | | | | |
| 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 |
| 4 | Basin in central part of depression | Humid | Pine 80 yr old, 12m high, loose crown closure | Rich mossy-shrubby | *ms 4* humid |
| 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 |
| 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 |
| | Deflation depression's *pE* microsite group | | | | |
| 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 |

## GENERAL CONCLUSION

In order to complete the full similarity analysis between multispecies communities, both cluster analysis and dominance similarity have to be carried out, using available data on subcommunities inhabiting the microsite mosaic of ecosystem. The analysis carried out at the level of subcommunity allows for indirect yet comprehensive enough concluding about the environment, thank the assessment of:

- Community similarity, which is adversely proportionaliy affected by the isolation degree of biocenoses (conclusions **1, 5, and 6** derived from the Ward method and conclusions **11–15** from the Renkonen method);
- Convergence of community, belonging to the same type of microsite (conclusions **2, 3** from the Ward method);
- The edge effect of ecotone zones on the similarity of communities (conclusion **4** from the Ward method);
- Species diversity of particular communities, resulting from the microsite differentiation of biotope (conclusions **7, 8** from the Ward method and conclusions **16, 17** from Renkonen method);
- Dominance of a given subcommunity type, resulting from the dominance of a given microsite type in the biotope (conclusions **9, 10** from the Ward method);
- The representation degree of a given ecosystem type by particular communities, after their species diversity has been considered (conclusions **16–18** from the Renkonen method).

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## STRESZCZENIE

[Tytuł: Przykład wnioskowania o środowisku w oparciu o analizę podobieństw wielogatunkowych zgrupowań bezkręgowców]

Praca przedstawia mikrosiedliskowy opis środowiska z zastosowaniem analizy podobieństw. Analizę podobieństw przeprowadzono w oparciu o epigeiczne subzgrupowania kusakowatych nadmorskich borów bażynowych Mierzei Łebskiej. Materiał faunistyczny analizowano na poziomie subzgrupowania w oparciu o metody Warda (analiza skupień) i Renkonena (analiza podobieństwa dominacji). Analiza podobieństw subzgrupowań pozwala, obok powinowactwa badanych zgrupowań, ocenić takie zjawiska jak: stopień zróżnicowania mikrosiedliskowego ekosystemu, dominację danego typu mikrosiedliska, stopień izolacji biocenoz, wpływ migracji czy też efekt styku stref ekotonowych.