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Structural pattern of epigeic community of staphylinids (*Coleoptera, Staphylinidae*) in coastal pine forest[1]

Abstract: The dominance structure of a natural community of staphylinids in a coastal pine forest is described using a Saturation-Growth Rate (*SGR*) type function: y = ax/(b+x). The function is based on per cent contributions of individual species. This makes it possible to carry out comparative analyses of communities' actual structures and their deviation from the assumed model, regardless of the actual size of the communities being analyzed.

Key words: dominance structure, community, cumulative function, *Staphylinidae*, coastal pine forest

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INTRODUCTION

A community may be defined as an assemblage of plants and/or animals occurring in more or less stabile relationships (SMITH 1986). At the same time, the extremely diverse coastal pine forest (*Empetro nigri-Pinetum*) should be considered a unique zonal type of coniferous forest. This forest type occurs on mineral soils (MATUSZKIEWICZ 1982), characterized by diversity of moisture conditions: according to forest site typology (ZARĘBA 1980), the coastal pine forest includes arid, moderately humid and humid coniferous forest sites.

The possibility of using mathematical models for the description of the structure of multispecies communities has often been discussed in the literature. Among several authors of monographic papers, three names need to be mentioned: WILLIAMS (1964), PIELOU (1969) and TROJAN (1992). The enthusiasts of modeling emphasize the fact that

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the dominance structure of natural communities reflects all past and present interspecific dependencies, including both trophic and paratrophic relationships. It is reasonable to assume, therefore, that the highly unique dominance structure of natural communities is fully responsible for their stability and repeatability. If so, TROJAN (1992) refines the purpose of using mathematical models for description of a community. According to him, mathematical models should determine the degree of stability of their structural pattern and then allow for studying actual change of the structure. It should be possible to explore both negative changes (connected with degradation) and positive ones (connected with succession or ecosystem eutrophization). The models should be based on actual communities, present in natural ecosystems occupying large areas and free of anthropogenic impact. At the same time, TROJAN demands that such models be universal, that is, they should fit communities that differ from one another in terms of taxonomy, ecology or zoogeographic structure.

Communities demonstrating specific attributes, an inner dominance structure, spatial distribution, phenology etc can be determined in non-deformed systems (not subjected to anthropogenic impact) occurring under similar natural conditions.

After assuming that the coastal pine forest of Mierzeja Łebska sand bar is a strongly renaturalized habitat (PIOTROWSKA 1997), and accepting the opinion of SMOLEŃSKI (2001a), according to whom the structure of seminatural communities is both repeatable and foreseeable, an example is presented of how the dominance structure of staphylinid epigeic communities may be exhaustively described using only one universal mathematical formula.

MATERIAL

The results presented in this paper are primarily based on empirical material collected into 250 Barber's pitfall traps in the coastal pine forest of Mierzeja Łebska sand bar in the Słowiński National Park. The original data were collected in two consecutive years, from July 1996 till July 1998. The study area covered five deflation depressions (*pA*; *pB*; *pD*; *pE*; *pF*) and an embankment dune (*pC*), which were representative of all subassociations of the coastal pine forest: the arid, the moderately humid and the humid one. A total of 5075 beetles belonging to 123 species of the family *Staphylinidae* were captured (cf. SMOLEŃSKI 2001b).

RESULTS

The Saturation-Growth Rate (SGR) model was utilized for the description of dominance structure of seminatural epigeic communities of staphylinids. The model itself is based on the idea of cumulative value and belongs to the group of Growth Models. It can be used to analyze multispecific communities that are made up of ecologically diverse elements. It is assumed that such communities have a specific distribution of variation in the number of species and species density. The proposed cumulative distribution function is based on per cent contributions of individual species. Thus, both the number of species and the number of individuals in a community always equal 100.

This makes it possible to carry out comparative analyses of communities' actual structures and their deviation from the assumed model, regardless of the actual size of the communities being analyzed. And this, in turn, means that for a cumulative distribution function based on per cent shares rather than absolute measures the otherwise vital condition of uniqueness of data collection methods becomes unimportant. The only condition to be met is, of course, the assumption that faunistic sample data are representative for each community studied. The latter condition is especially important if one attempts to compare results obtained by different authors using different sampling methods over different time periods. WILLIAMS (1964) appreciated the importance of this problem. He proposed developing a mathematical formula that would express the invariability of natural communities structure despite the continuously changing dominance ratings of individual species within the community. The proposed *SGR* method makes it possible to obtain such a formula.

The fitting of a mathematical formula to actual cumulated dominance structure data was done using the statistical computer package "Curve Expert". Several functions were tested. Out of a group of mathematical functions precisely describing the dominance structures of actual communities, one function was selected (*SGR*) with only two constants in the formula: $y = \frac{ax}{b + x}$. All the remaining functions contained at least three constants each. Then, based on empirical data regarding six actual communities, the universal values of those two constants were obtained by progressive approximation method, such that were characteristic of the highest correlation coefficients and the least standard error of estimation between the mathematical function and the actual structures of epigeic communities of coastal pine forest staphylinids.

PROCEDURE

Assume the *X*-axis shows the per cent cumulative order of species in descending order of frequency of occurrence in the community, that is

$$100\frac{1}{S}, 100\frac{2}{S}, 100\frac{3}{S}, 100\frac{4}{S}, ..., 100\frac{S}{S},$$

and the *Y*-axis shows the respective per cent shares of abundance, that is $100\frac{n_1}{N}$,

$$100\frac{n_1 + n_2}{N}, 100\frac{n_1 + n_2 + n_3}{N}, 100\frac{n_1 + n_2 + n_3 + n_4}{N}, ..., 100\frac{N}{N}$$ (see Figures 1–6)

where:

S – number of species in a community,

$n_1+n_2+n_3+n_4+...+n_S = N$ – number of individuals in a community,

n_1 – number of individuals of the species most frequently occurring in the community,

then the model of dominance structure of a natural and stabile staphylinid (*Coleoptera, Staphylinidae*) community of the coastal pine forest (*Empetro-nigri Pinetum*) is given by:

$$y = \frac{ax}{b+x} = \frac{108.5x}{7.5+x}$$

where:

x – per cent shares of species in the community in descending order of frequency of occurrence,

y – per cent share of individuals in the community,

a = 108.5 and b = 7.5 – constants of the formula.

The above formula provided a basis for studying the distribution patterns of six different staphylinid communities of the coastal pine forest of Mierzeja Łebska. The communities significantly differed from each other with respect to the number of species and number of individuals (Table). Despite this, there was a considerable degree of fit between the *SGR* function and the empirical distributions (Appendix), which proved the formula's applicability. The very high value of correlation coefficient and the low level of standard error of estimation (Table) further support the correctness of the statement. Additionally, also Figures 1–6 show the similarity between the empirical distributions and the *SGR* function.

Table. Analysis of correlation between the model structure of a natural and stabile staphylinid community and actual structures of coastal pine (*Empetro-nigri Pinetum*) staphylinid (*Coleoptera, Staphylinidae*) communities of Mierzeja Łebska

	Research plots					
	pA	*PB*	*pC*	*pD*	*pE*	*pF*
species	79	63	46	67	41	40
individuals	1543	940	421	967	565	639
R	0.9989	0.9970	0.9973	0.9931	0.9855	0.9931
S	1.1473	3.7041	4.0248	4.7018	5.4990	3.9196

The Table shows the values of the correlation coefficient (*R*) and the standard error of estimation (*S*) for the model structure of a natural and stabile staphylinid community (as described by the formula $y = \frac{108.5x}{7.5+x}$) and the actual structures of staphylinid communities from the deflation depressions (*pA*, *pB*, *pD*, *pE*, *pF*) and the embankment dune (*pC*). The data were originally published in SMOLEŃSKI (2001b).

Figures 1–6 present the actual and estimated dominance structures of epigeic staphylinid (*Coleoptera, Staphylinidae*) communities of the coastal pine forest of Mierzeja Łebska. The six research plots: *pA* – *pF* are compared. The data were originally published in an earlier paper by the same author (SMOLEŃSKI 2001b). The *X*-axis presents the cumulative per cent order of species in descending order of ranks of frequency of occurrence in the community. The *Y*-axis represents the resulting per cent shares of community abundance: the actual (series 1) and estimated shares, according to the formula $y = \frac{108.5x}{7.5+x}$ (series 2).

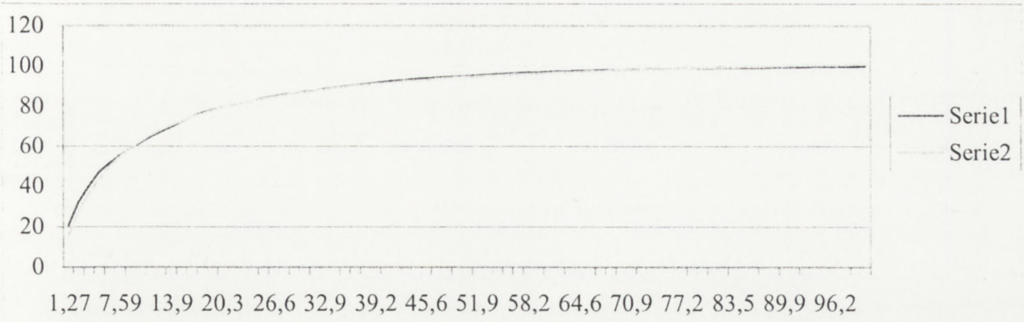

Fig.1. The actual and estimated structure of the staphylinid community of deflation depression pA. The correlation coefficient for the empirically determined and estimated values was R = 0.9989, standard error of estimation S = 1.15, and maximum error of estimation S_{max} = 5.07.

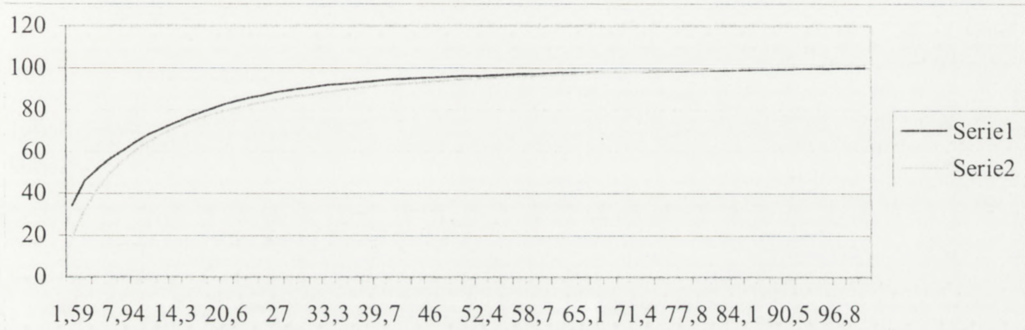

Fig. 2. The actual and estimated structure of the staphylinid community of deflation depression pB. The correlation coefficient between the empirically determined and estimated values was R = 0.9970, standard error of estimation S = 3.70, and maximum error of estimation S_{max} = 15.31.

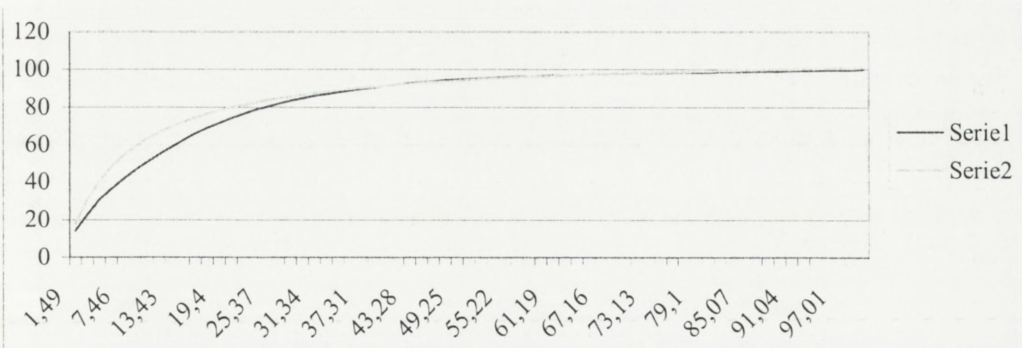

Fig. 3. The actual and estimated structure of the staphylinid community of deflation depression pD. The correlation coefficient for the empirically determined and estimated values was R = 0.9931, standard error of estimation S = 4.70, and maximum error of estimation S_{max} = 12.54.

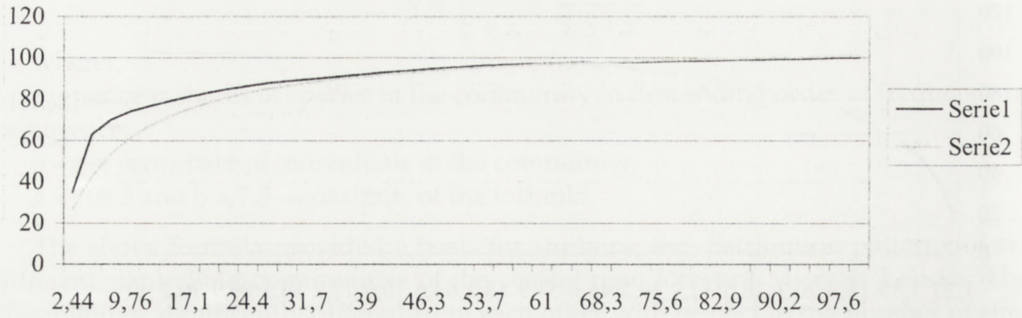

Fig. 4. The actual and estimated structure of the staphylinid community of deflation depression pE. The correlation coefficient for the empirically determined and estimated values was R = 0.9855, standard error of estimation S = 5.50, and maximum error of estimation S_{max} = 20.43.

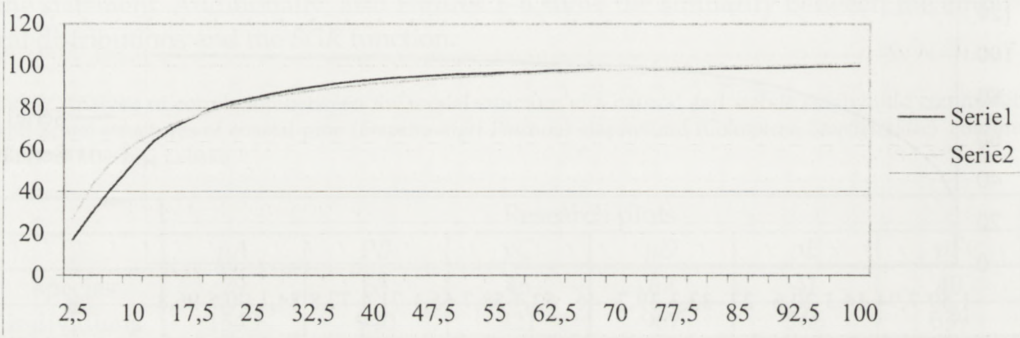

Fig. 5. The actual and estimated structure of the staphylinid community of deflation depression pF. The correlation coefficient for the empirically determined and estimated values was R = 0.9931, standard error of estimation S = 3.92, and maximum error of estimation S_{max} = 13.04.

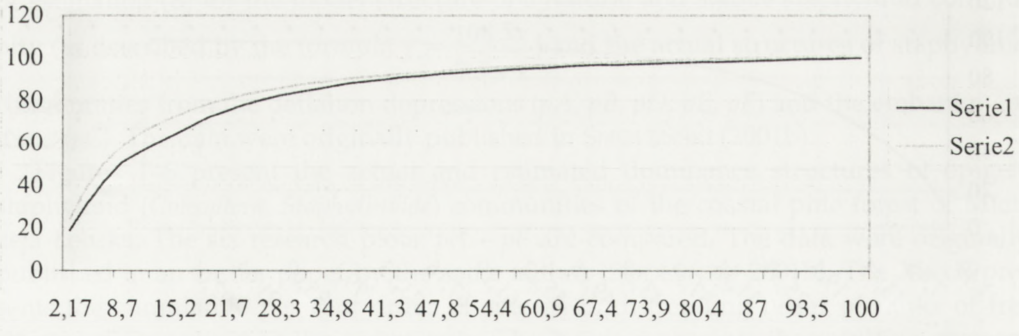

Fig. 6. The actual and estimated structure of the staphylinid community of deflation depression pC. The correlation coefficient for the empirically determined and estimated values was R = 0.9973, standard error of estimation S = 4.02, and maximum error of estimation S_{max} = 9.03.

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STRESZCZENIE

[Tytuł: Wzór struktury epigeicznego zgrupowania kusakowatych (*Coleoptera*, *Staphylinidae*) nadmorskich borów bażynowych]

Praca przedstawia propozycję metodyczną opisu struktury wielogatunkowych zgrupowań za pomocą modelu matematycznego Saturation-Growth Rate ($y = \frac{ax}{b+x}$). Dla struktury dominacyjnej naturalnego zgrupowania kusakowatych nadmorskich borów bażynowych funkcja *SGR* przyjmuje postać $y = \frac{108{,}5x}{7{,}5+x}$, gdzie:

x – procentowy udział gatunków w zgrupowaniu, uporządkowanych malejąco według rangi liczebności występowania,

y – procentowy udział osobników w zgrupowaniu,

$a = 108{,}5$ i $b = 7{,}5$ – stałe równania;

Model *SGR* bazuje na konstrukcji kumulanty i należy do modeli wzrostowych. Stosuje się do wielogatunkowych zgrupowań, zbudowanych z gatunków ekologicznie różnorodnych. Proponowana kumulanta oparta jest na procentowych udziałach gatunków. Ma tę właściwość, że liczbę gatunków i liczbę osobników w zgrupowaniu sprowadza zawsze do wartości 100. Umożliwia to porównanie ze sobą rzeczywistych struktur a także ich odchyleń od przyjętego wzorca niezależnie od wielkości analizowanych zgrupowań. Oznacza to, że dla kumulanty operującej procentowymi udziałami, bez znaczenia staje się jednolitość zastosowanych metod zbioru. Jest to szczególnie istotne, gdy trzeba porównać ze sobą wyniki badań różnych autorów, stosujących różne metody zbioru w różnych okresach.

APPENDIX

Dominance structure of epigeic staphylinid (*Coleoptera, Staphylinidae*) communities of the coastal pine forest of Mierzeja Łebska.
pA, pB, pD, pE, pF – deflation depressions; *pC* – embankment dune;
x – cumulative series of species shares in descending order of occurrence in the community [%];
y_1 – the series cumulating the actual (empirical) shares of individual species numbers and in descending order of ranks of occurrence in the community [%];
y_2 – the series cumulating estimated (according to formula $y_2 = 108.5x/(7.5+x)$) shares of frequency of species in descending order of ranks of occurrence in the community [%];
All data were originally published in an earlier paper by the present author (SMOLEŃSKI 2001b)..

pA			pB			pD			pE			pF			pC		
x	y_1	y_2	x	y_1	y_2	x	y_1	y_2	x	y_1	y_2	x	y_1	y_2	x	y_1	y_2
1.27	20.74	15.67	1.59	34.26	18.95	1.49	13.96	18.01	2.44	34.87	26.63	2.50	16.90	27.13	2.17	19.00	24.38
2.53	32.21	27.38	3.17	45.85	32.27	2.99	22.65	30.89	4.88	63.19	42.76	5.00	30.36	43.40	4.35	31.83	39.82
3.80	40.44	36.47	4.76	51.91	42.14	4.48	30.82	40.56	7.32	69.91	53.58	7.50	41.78	54.25	6.52	42.04	50.47
5.06	47.12	43.73	6.35	56.60	49.74	5.97	36.30	48.09	9.76	73.98	61.34	10.00	53.05	62.00	8.70	50.83	58.26
6.33	51.59	49.66	7.94	60.74	55.78	7.46	41.57	54.11	12.20	76.64	67.18	12.50	63.85	67.81	10.87	55.58	64.20
7.59	55.41	54.59	9.52	64.57	60.70	8.96	46.64	59.05	14.63	79.12	71.74	15.00	70.58	72.33	13.04	59.86	68.89
8.86	58.85	58.76	11.11	68.30	64.78	10.45	50.78	63.16	17.07	81.42	75.38	17.50	75.43	75.95	15.22	64.13	72.68
10.12	61.83	62.33	12.70	71.06	68.21	11.94	54.71	66.64	19.51	83.19	78.37	20.00	80.13	78.91	17.39	68.41	75.81
11.39	64.61	65.43	14.29	73.72	71.15	13.43	58.63	69.63	21.95	84.96	80.87	22.50	82.79	81.38	19.57	72.21	78.43
12.66	67.21	68.13	15.87	76.28	73.68	14.93	62.46	72.21	24.39	86.37	82.98	25.00	84.82	83.46	21.74	75.06	80.67
13.92	69.80	70.52	17.46	78.62	75.90	16.42	66.18	74.48	26.83	87.61	84.80	27.50	86.70	85.25	23.91	77.91	82.60
15.19	72.33	72.64	19.05	80.85	77.85	17.91	68.87	76.48	29.27	88.67	86.37	30.00	88.42	86.80	26.09	80.29	84.27
16.46	74.72	74.53	20.63	82.87	79.58	19.40	71.56	78.25	31.71	89.56	87.74	32.50	90.14	88.16	28.26	82.19	85.74
17.72	76.80	76.24	22.22	84.68	81.12	20.90	74.04	79.84	34.15	90.44	88.96	35.00	91.55	89.35	30.43	83.85	87.05
18.99	78.16	77.78	23.81	86.06	82.51	22.39	76.42	81.27	36.59	91.33	90.04	37.50	92.64	90.42	32.61	85.27	88.21
20.25	79.39	79.18	25.40	87.23	83.76	23.88	78.59	82.57	39.02	92.21	91.01	40.00	93.58	91.37	34.78	86.70	89.25
21.52	80.62	80.46	26.98	88.40	84.90	25.37	80.25	83.75	41.46	92.92	91.88	42.50	94.37	92.23	36.96	87.89	90.20
22.78	81.79	81.63	28.57	89.36	85.94	26.87	81.80	84.82	43.90	93.63	92.67	45.00	94.99	93.00	39.13	88.84	91.05
24.05	82.89	82.71	30.16	90.32	86.89	28.36	83.35	85.81	46.34	94.34	93.39	47.50	95.46	93.70	41.30	89.79	91.83
25.32	83.86	83.70	31.75	91.06	87.77	29.85	84.69	86.71	48.78	95.04	94.04	50.00	95.93	94.35	43.48	90.74	92.54
26.58	84.83	84.62	33.33	91.81	88.57	31.34	85.83	87.55	51.22	95.58	94.64	52.50	96.40	94.94	45.65	91.45	93.19
27.85	85.61	85.48	34.92	92.34	89.32	32.84	86.97	88.33	53.66	96.11	95.19	55.00	96.71	95.48	47.83	92.16	93.79

29.11	86.39	86.27	36.51	92.87	90.01	34.33	87.90	89.05	56.10	96.46	95.70	57.50	97.03	95.98	50.00	92.87	94.35
30.38	87.17	87.02	38.10	93.40	90.65	35.82	88.83	89.72	58.54	96.81	96.18	60.00	97.34	96.44	52.17	93.35	94.86
31.65	87.88	87.71	39.68	93.94	91.25	37.31	89.76	90.34	60.98	97.17	96.62	62.50	97.65	96.88	54.35	93.82	95.34
32.91	88.59	88.36	41.27	94.36	91.81	38.81	90.59	90.93	63.41	97.35	97.02	65.00	97.81	97.28	56.52	94.30	95.79
34.18	89.24	88.97	42.86	94.79	92.34	40.30	91.42	91.48	65.85	97.52	97.41	67.50	97.97	97.65	58.70	94.77	96.21
35.44	89.89	89.55	44.44	95.11	92.83	41.79	92.14	91.99	68.29	97.70	97.76	70.00	98.12	98.00	60.87	95.25	96.60
36.71	90.47	90.09	46.03	95.43	93.30	43.28	92.76	92.48	70.73	97.88	98.10	72.50	98.28	98.33	63.04	95.72	96.96
37.97	91.06	90.61	47.62	95.64	93.74	44.78	93.38	92.93	73.17	98.05	98.41	75.00	98.44	98.64	65.22	96.20	97.31
39.24	91.64	91.09	49.21	95.85	94.15	46.27	93.80	93.37	75.61	98.23	98.71	77.50	98.59	98.93	67.39	96.44	97.63
40.51	92.16	91.55	50.79	96.06	94.54	47.76	94.21	93.77	78.05	98.41	98.99	80.00	98.75	99.20	69.57	96.67	97.94
41.77	92.68	91.98	52.38	96.28	94.91	49.25	94.62	94.16	80.49	98.58	99.25	82.50	98.90	99.47	71.74	96.91	98.23
43.04	93.13	92.40	53.97	96.49	95.26	50.75	95.04	94.53	82.93	98.76	99.50	85.00	99.06	99.70	73.91	97.15	98.50
44.30	93.52	92.79	55.56	96.70	95.59	52.24	95.35	94.88	85.37	98.94	99.74	87.50	99.22	99.93	76.09	97.39	98.76
45.57	93.91	93.17	57.14	96.91	95.91	53.73	95.66	95.21	87.80	99.12	99.96	90.00	99.37	100.15	78.26	97.62	99.01
46.84	94.30	93.52	58.73	97.13	96.21	55.22	95.97	95.53	90.24	99.29	100.17	92.50	99.53	100.36	80.43	97.86	99.25
48.10	94.62	93.86	60.32	97.34	96.50	56.72	96.17	95.83	92.68	99.47	100.38	95.00	99.69	100.56	82.61	98.10	99.47
49.37	94.94	94.19	61.90	97.45	96.78	58.21	96.38	96.12	95.12	99.65	100.57	97.50	99.84	100.75	84.78	98.34	99.68
50.63	95.20	94.50	63.49	97.55	97.04	59.70	96.59	96.39	97.56	99.82	100.75	100.00	100	100.93	86.96	98.57	99.88
51.90	95.46	94.80	65.08	97.66	97.29	61.19	96.79	96.65	100.00	100.00	100.93				89.13	98.81	100.08
53.16	95.72	95.09	66.67	97.77	97.53	62.69	97.00	96.91							91.30	99.05	100.26
54.43	95.98	95.36	68.25	97.87	97.76	64.18	97.21	97.15							93.48	99.29	100.44
55.70	96.24	95.62	69.84	97.98	97.98	65.67	97.41	97.38							95.65	99.52	100.61
56.96	96.50	95.88	71.43	98.09	98.19	67.16	97.62	97.60							97.83	99.76	100.77
58.23	96.76	96.12	73.02	98.19	98.39	68.66	97.83	97.81							100.00	100.00	100.93
59.49	96.95	96.35	74.61	98.30	98.59	70.15	97.93	98.02									
60.76	97.15	96.58	76.19	98.40	98.78	71.64	98.04	98.22									
62.03	97.34	96.80	77.78	98.51	98.96	73.13	98.14	98.41									
63.29	97.54	97.00	79.37	98.62	99.13	74.63	98.24	98.59									
64.56	97.67	97.21	80.95	98.72	99.30	76.12	98.35	98.77									
65.82	97.80	97.40	82.54	98.83	99.46	77.61	98.45	98.94									
67.09	97.93	97.59	84.13	98.94	99.62	79.10	98.55	99.10									
68.35	98.06	97.77	85.71	99.04	99.77	80.60	98.66	99.26									
69.62	98.19	97.95	87.30	99.15	99.92	82.09	98.76	99.42									

70.89	98.31	98.12	88.89	99.26	100.06	83.58	98.86	99.57									
72.15	98.44	98.28	90.48	99.36	100.19	85.07	98.97	99.71									
73.42	98.57	98.44	92.06	99.47	100.33	86.57	99.07	99.85									
74.68	98.70	98.60	93.65	99.57	100.46	88.06	99.17	99.98									
75.95	98.77	98.75	95.24	99.68	100.58	89.55	99.28	100.11									
77.22	98.83	98.89	96.83	99.79	100.70	91.04	99.38	100.24									
78.48	98.90	99.04	98.41	99.89	100.82	92.54	99.48	100.37									
79.75	98.96	99.17	100.00	100.00	100.93	94.03	99.59	100.49									
81.01	99.03	99.31				95.52	99.69	100.60									
82.28	99.09	99.44				97.01	99.79	100.71									
83.54	99.16	99.56				98.51	99.90	100.82									
84.81	99.22	99.68				100.00	100.00	100.93									
86.08	99.29	99.80															
87.34	99.35	99.92															
88.61	99.42	100.03															
89.87	99.48	100.14															
91.14	99.55	100.25															
92.41	99.61	100.35															
93.67	99.68	100.46															
94.94	99.74	100.56															
96.20	99.81	100.65															
97.47	99.87	100.75															
98.73	99.94	100.84															
100.00	100.00	100.93															