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ON THE HYPOTHESIS OF UNIQUENESS OF THE BALTIC HERRING (*CLUPEA HARENGUS MEMBRAS*) CATCHES ON THE BASIS OF POLYCHLORINATED BIPHENYLS CONTENT EVALUATIONS

Abstract. Complex sortings on the basis of the content of chlorinated hydrocarbons (polychlorinated biphenyls (PCB) and chlorinated pesticides (p,p'DDE; p,p'DDD; p,p'DDT, and lindan)) and morphological parameters of Baltic herring proved statistically important only in terms of PCB. The studies on pesticides revealed only weak statistical connections. The morphological parameters (length, age, sex) and fat content in herring's muscle tissue, used on the sorting, should be considered as a basis for statistical classification according to the catching time and place. Thus every catch (or population) of Baltic herring is unique, and the parameters of different catches (populations) cannot be described as a single array.

Key words: PCB, DDT, Baltic herring, Baltic Sea.

Let us proceed from the conception of regularity as something inevitable, indispensable, persistent, and recurrent in the field of natural phenomena. This kind of approach considers a cast of a regular die as a model of an irregular process and the related state as minimally predictable. As soon as the die proves slightly damaged, the result of the cast becomes weakly predictable in comparison with the ideal state. At the other end of the scale, composed on the bases of the pair of the categories *random-inevitable*, we find an utterly defective die which after every cast will stop at one and the same facet. The experiment comprising such a die may be treated as a model of a highly predictable process. As an analogy, very many processes taking place in the living nature should be treated as weakly predictable processes. The research into these processes is characterized by an abundance of experimental or observation data. However, by increasing the accuracy on single measurements over a certain boundary, no additional information will be obtained. Here the analogy between the impossibility in terms of the construction of perpetuum mobile and finding the formulas for success in stochastic games is revealed. And, also, in mathematical processing of observation data, only relatively simple methods will prove effective, since in dividing the objects into many classes, some of these classes may contain very few objects and the distinction between the classes may prove unreliable. Below, the state corresponding to random and indispensable realization of events will be used as a measure. In a greater detail, the potentials of the method have been discussed in Lukki (1987).

Mathematical Treatment

Further we are going to deal with some scientific terms in a wider sense. Thus, we shall call an event any statement applying to a certain study object, and a measurement is an assemblage of procedures which either confirms or refutes the occurrence of the event under consideration.

The studied data base comprised the parameters obtained by measuring 188 herring specimens. The catches were carried out in different Baltic Sea areas in 1976 and 1977.

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Table 1

Sorting of Baltic herring in the 1976 and 1977 catches, %

Years	R_1				R_2			
	V_1		V_2		V_1		V_2	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
1976	9.09	32.73	1.82	54.54	0.00	0.00	0.00	1.82
1977	5.26	6.01	6.01	12.78	30.83	3.01	20.30	15.79

Note: the figures show the percentage of herring which fell into the interval subjected to sorting during the succeeding sortings.

Table 2

Sorting of Baltic herring in the two catching areas, %

Areas	R_1							
	V_1				V_2			
	P_1		P_2		P_1		P_2	
	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
Nõva	3.80	5.06	5.06	5.06	0.00	2.53	2.53	11.39
Toila	0.00	0.00	0.00	0.00	5.56	5.56	11.10	0.00

Areas	R_2							
	V_1				V_2			
	P_1		P_2		P_1		P_2	
	C_1	C_2	C_1	C_2	C_1	C_2	C_1	C_2
Nõva	20.25	15.19	1.27	3.80	0.00	6.33	2.53	15.19
Toila	20.37	3.70	0.00	0.00	35.19	5.56	12.96	0.00

See note to Table 1.

Herring's age, length, sex, percentage of fat, content of PCB, summary DDT, p,p'DDE, p,p'DDD, p,p'DDT, and lindan in the muscle tissue (Roots, Peikre, 1981; Роотс, Пейкре, 1978) were measured.

The following events were differentiated:

V_1 — the age of the herring $\leqslant 3$ years, $V_2 = \overline{V}_1$. The probability of the events with the index 2 is calculated using the formula $p(V_2) = 1 - p(V_1)$, where $p(V_1)$ is the probability of the event with the index 1;

P_1 — the length of the herring $\leqslant 17.4$ cm, $P_2 = \overline{P}_1$;

S_1 — male herring, $S_2 = \overline{S}_1$;

R_1 — fat content of the herring $\leqslant 11.2\%$, $R_2 = \overline{R}_1$;

C_1 — PCB content in the herring's muscle tissue $\leqslant 0.20$ mg/kg, $C_2 = \overline{C}_1$;

D_1 — summary DDT content in the herring's muscle tissue $\leqslant 0.19$ mg/kg $D_2 = \overline{D}_1$;

L_1 — lindan content in the herring's muscle tissue $\leqslant 0.0040$ mg/kg $L_2 = \overline{L}_1$.

Primarily, the boundary between the events of the same type was chosen as close as possible to the median of the division of a corresponding parameter, including all the 188 Baltic herring.

The sortings were carried out according to the catching time, catching place, R_1/R_2, V_1/V_2, P_1/P_2, and C_1/C_2. Other sortings did not yield statistically important results.

Table 3

Data on the co-occurrence m, m^+ of the events at the Nõva herring catching area in 1977 (below the main diagonal, probabilities are given)

	V_1	S_1	P_1	R_1	L_1	D_1	C_1	E^+_1	D^+_1	T^+_1	
V_1	**47**	18 21.42	31 19.63	23 23.80	21 20.82	24 22.61	19 12.49	28 24.39	26 23.80	23 23.20	m m^+
S_1	0.054	**36**	14 15.04	13 18.23	15 15.95	18 17.32	9 9.57	16 18.68	18 18.23	21 17.77	m m^+
P_1	$4 \cdot 10^{-8}$	0.162	**33**	11 16.71	16 14.62	15 15.87	12 8.77	16 17.13	17 16.71	15 16.29	m m^+
R_1	0.170	0.011	0.006	**40**	19 17.72	22 19.24	10 10.63	27 20.76	20 20.25	23 19.75	m m^+
L_1	0.182	0.164	0.149	0.152	**35**	16 16.84	12 9.30	17 18.16	17 17.72	14 17.28	m m^+
D_1	0.149	0.170	0.167	0.084	0.167	**38**	10 10.10	32 19.72	32 19.24	33 18.76	m m^+
C_1	$5 \cdot 10^{-4}$	0.194	0.052	0.191	0.079	0.200	**21**	11 10.90	10 10.63	9 10.37	m m^+
E^+_1	0.047	0.087	0.158	0.004	0.156	$2 \cdot 10^{-8}$	0.200	**41**	27 20.76	29 20.24	m m^+
D^+_1	0.110	0.178	0.179	0.177	0.170	$5 \cdot 10^{-9}$	0.191	0.004	**40**	29 19.79	m m^+
T^+_1	0.180	0.063	0.152	0.062	0.061	$4 \cdot 10^{-11}$	0.159	$7 \cdot 10^{-5}$	$3 \cdot 10^{-5}$	**39**	

$N_1 = 79$

The results are presented in Tables 1 and 2. The data obtained in 1977 by studying the herring from two different catching areas (two different populations of the herring in the Gulf of Finland: Nõva and Toila, situated respectively in the west and east parts of the Gulf of Finland) are presented separately. New boundaries of the pairs of events were determined:

V_1 — the herring's age $\leqslant 3$ years, $V_2 = \overline{V}_1$;
P_1 — the herring's length $\leqslant 16.9$ cm, $P_2 = \overline{P}_1$;
S_1 — male herring, $S_2 = \overline{S}_1$;
R_1 — the herring's fat content $\leqslant 13.4\%$, $R_2 = \overline{R}_1$;
L_1 — lindan content in the herring's muscle tissue $\leqslant 0.0033$ mg/kg, $L_2 = \overline{L}_1$;
D_1 — summary DDT content in the herring's muscle tissue $\leqslant 0.17$ mg/kg, $D_2 = \overline{D}_1$;
C_1 — PCB content in the herring's muscle tissue $\leqslant 0.17$ mg/kg, $C_2 = \overline{C}_1$;
E^+_1 — p,p'DDE content in the herring's muscle tissue $\leqslant 0.079$ mg/kg, $E^+_2 = \overline{E}^+_1$;
D^+_1 — p,p'DDD content in the herring's muscle tissue $\leqslant 0.049$ mg/kg, $D^+_2 = \overline{D}^+_1$;

Table 4

Data on the co-occurrence m, m^+ of the events at the Toila herring catching area in 1977 (below the main diagonal, probabilities are given)

	V_1	S_1	P_1	R_1	L_1	D_1	C_1	E^+_1	D^+_1	T^+_1
V_1	**13**	4 4.57	13 8.19	2 5.78	9 7.46	9 6.74	11 10.59	9 6.50	7 6.74	7 m 5.78 m^+
S_1	0.247	**19**	10 11.96	10 8.44	10 10.91	9 9.85	16 15.48	9 9.50	8 9.85	8 m 8.44 m^+
P_1	$8 \cdot 10^{-4}$	0.120	**34**	13 15.11	17 19.52	20 17.63	25 27.70	21 17.00	20 17.63	17 m 15.11 m^+
R_1	0.014	0.153	0.111	**24**	16 13.78	14 12.44	17 19.56	13 12.00	16 12.44	10 m 10.67 m^+
L_1	0.161	0.197	0.083	0.105	**31**	22 16.07	23 25.26	19 15.50	21 16.07	17 m 13.78 m^+
D_1	0.093	0.200	0.093	0.152	0.001	**28**	21 22.81	23 14.00	25 14.52	18 m 12.44 m^+
C_1	0.311	0.274	0.044	0.059	0.083	0.129	**44**	20 22.00	21 22.81	21 m 19.56 m^+
E^+_1	0.074	0.215	0.018	0.186	0.036	$8 \cdot 10^{-7}$	0.109	**27**	21 14.00	14 m 12.00 m^+
D^+_1	0.246	0.131	0.093	0.034	0.006	$5 \cdot 10^{-9}$	0.129	$1 \cdot 10^{-4}$	**28**	17 m 12.44 m^+
T^+_1	0.185	0.219	0.129	0.203	0.046	0.002	0.172	0.121	0.010	**24**

$N_2=54$

T^+_1 — p,p'DDT content in the herring's muscle tissue $\leqslant 0.030$ mg/kg, $T^+_2=\bar{T}^+_1$.

Summary DDT = p,p'DDT + 1.1 (p,p'DDE + p,p'DDD).

Tables 3, 4, and 5 present data on the co-occurrence of the events. Above the main diagonal the first row presents the measured number of the co-occurrence of events; the second row shows the most probable number of the events' co-occurrence, if the events were random and independent. Let us denote them by m $(s_i;\ s_j)$ and m^+ $(s_i;\ s_j)$. The latter is calculated from the formula:

$$m^+(s_i,\ s_j)=\frac{n(s_i)\cdot n(s_j)}{N};$$

where n (s_i) and n (s_j) denote the number of the events s_i and s_j, respectively, and N is the total number of the objects studied.

Below the main diagonal the probability of random occurrence of the measured number of s_i and s_j is:

$$p(s_i,\ s_j)=\frac{C^{n(s_j)-m(s_i,\ s_j)}_{N-n(s_i)}\ C^{m(s_i,\ s_j)}_{n(s_i)}}{C^{n(s_j)}_{N}}.$$

Table 5

Data on the co-occurrence of the events at the Nõva and Toila herring catching areas in 1977 (below the main diagonal, probabilities are given)

	V_1	S_1	P_1	R_1	L_1	D_1	C_1	E^+_1	D^+_1	T^+_1		$p(N_1N_2s_i)$
V_1	60	22	44	25	30	33	30	37	33	30	m	$3.64\cdot10^{-5}$
		24.81	30.23	28.87	29.77	29.77	29.32	30.68	30.68	28.42	m^+	
S_1	0.086	55	24	23	25	27	25	25	26	29	m	0.071
			27.71	26.47	27.29	27.29	26.88	28.12	28.12	26.05	m^+	
P_1	$1\cdot10^{-6}$	0.060	67	24	33	35	37	37	37	32	m	0.008
				32.24	33.25	33.25	32.74	34.26	34.26	31.74	m^+	
R_1	0.056	0.067	0.002	64	35	36	27	40	36	33	m	0.110
					31.76	31.76	31.28	32.72	32.72	30.32	m^+	
L_1	0.138	0.101	0.137	0.074	66	38	35	36	38	31	m	0.047
						32.75	32.26	33.74	33.74	31.26	m^+	
D_1	0.074	0.139	0.115	0.047	0.027	66	31	55	57	51	m	0.128
							32.26	33.74	33.74	31.26	m^+	
C_1	0.135	0.113	0.047	0.046	0.088	0.125	65	31	31	30	m	$2.45\cdot10^{-10}$
								33.23	33.23	30.79	m^+	
E^+_1	0.012	0.077	0.088	0.006	0.102	$4\cdot10^{-14}$	0.10	68	48	43	m	0.140
									34.77	32.21	m^+	
D^+_1	0.100	0.106	0.088	0.073	0.047	$7\cdot10^{-17}$	0.0102	$3\cdot10^{-6}$	68	46	m	0.139
										32.21	m^+	
T^+_1	0.119	0.082	0.137	0.090	0.137	$3\cdot10^{-12}$	0.133	$1\cdot10^{-4}$	$1\cdot10^{-6}$	63		0.120

$N_1+N_2=133$

In Table 5, the probabilities that the measured events (in figures presented on the main diagonal in Tables 3 and 4) are of random distribution in measured ratios between catching areas are separately shown on the right hand side. These probabilities are calculated from the formula:

$$p(N_1,\ N_2,\ s_i)=\frac{C^{n_1(s_i)}_{N_1}\cdot C^{n_2(s_i)}_{N_2}}{C^{n_1(s_i)+n_2(s_i)}_{N_1+N_2}},$$

where s_i is the event for which the probability is calculated and the subindices of n and N denote the area (1 — Nõva and 2 — Toila).

Conclusions

The results obtained provide a basis for the hypothesis about the uniqueness of herring populations (there are 14 herring populations around the Baltic Sea (Ojaveer, 1969)). This means that in the future studies one has to consider that the data obtained on the objects in different times and from different areas cannot always be treated as a unitary data bank. Any statistical differentiation and analysis of objects can be successful only if all the objects in the set have an equal state with respect to the characteristics not included in the study. The analysis of the material shows that for combined events both the catching time and place are of consequence.

Complex sortings on the basis of the content of polychlorinated biphenyls and morphological parameters proved statistically important only in terms of PCB. The studies on pesticides revealed only weak statistical connections. An expected strong connection was revealed between the summary DDT content and that of its metabolites. The morphological parameters *R*, *V*, and *P* used on the sorting should be considered as those obligatory on herring's chemical analyses, since they serve as a basis for statistical classification according to the catching time and place.

The accuracy of measurements cannot serve as a limiting factor on elucidating statistical regularities. In view of this express studies are also possible.

REFERENCES

Lukki, T. 1987. Maastike eristamisest neil paiknevate objektide kooseksisteerimise analüüsi alusel. In: Looduskasutusest ja keskkonnakaitsest künkliku pinnamoega maastikul. Tallinn, 132—135.

Ojaveer, E. 1969. Räim — Läänemere heeringas. — Eesti Loodus, 4, 232—234.

Roots, O., Peikre, E. 1981. The study of the Baltic Sea zooplankton pollution with chlorinated pesticides and polychlorinated biphenyls during the 10-th cruise of the R/V "Aju-Dag". In: The Investigation and Modelling of Processes in the Baltic Sea, II. Tallinn, 131—137.

Роотс О., Пейкре Э. 1978. О содержании полихлорированных бифенилов и хлорорганических пестицидов в рыбах Балтийского моря. — Изв. АН ЭССР. Хим., 27, 3, 193—196.

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