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THE INFLUENCE OF LAND USE MANAGEMENT ON THE ECOLOGICAL STATE OF DEAD ARMS OF THE RIVER HÁRMAS-KÖRÖS

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ABSTRACT: The studies were carried out on 14 deadarms of River Hármas-Körös. The total length of deadarms involved in the studies was 74 kms and the water surface was 517 hectares. Long-term prognoses relating to the ecological state of deadarms depend on the previous exploitation and planned exploitation in the future.

The main goals of the present research were the following:

- The classification of deadarms on the basis of chosen parameters (the mode and the intensity of water change, the massiveness of the sediment, redox potential, land use management, ichthyofauna).
- The determination of the current state of degradation of given deadarms.

The results of present research can be employed successfully when planning the ecological reconstruction of deadarms or shallow lakes. The establishment of more detailed prognoses relating to the ecological state of these water ecosystems could have direct effects on their modes of exploitation.

Keywords: deadarms, deposit, nutrient, redox potential,

INTRODUCTION

The deadarm ecosystems have a strong effect on micro-climate and water balance of their immediate surrounding. At the time of river regulation the regular water supply of deadarm ecosystems broke off, as they were cut off the rivers and remained on the external side of the protection dikes. As a result the ecological conditions of these deadarms became very sensitive. Through the alteration of the local biotop, irreversible processes may be induced in these ecosystems even in the case of the least environmental changes caused by an antropogenic effect.

Hungary located in the Carpathian Basin is poor of natural waters. The major water ecosystems of the country consist of the rivers of the Great Plain all deriving from beyond the country's borders. The morphology of the river system had significantly changed due to river regulations (Pálfai, 2002). Before the river regulations the lenght of the riverbed because of numerous bends was four times longer than the actual. The river gradient was very low, 15 mm/1 km, hence the river bed due to the large quantity of suspended matter was silted up significantly (Gallacz, 1986). River regulations took place in the second half of the 19th century. When planning the cut-off of bends and the straightening of the river the main aspect was flood hazard reduction by draining water as quickly as possible. At this period 24% of the country's area was endangered by floods (Somogyi, 2000).

During the engineering works ecological aspects were ignored, since it was still not understood that straightening the riverbed did not reduce the flood hazard, but placed it to lower sections.

In the south-east part of Hungary the branches of river Körös collect the water of a 28,000 km^2 watershed area, about half of which comes from a mountaineous area. Before the river regulation this water flooded a nearly 35,000 km^2 area during the high-flood periods. Afterwards it was collected in the river Tisza. The floating and dissolved nutrients of flooding water were deposited mostly on the flooded fields. Out of seasons of high flood, the rivers settled the nutrient-rich deposit in the very meandering bends of the rivers. These bends were cut off the river during the river regulation and deadarms occurred. At present from the 44 deadarms made at the time of river regulation, only 36 remained (Pálfai, 2001). Total length of these deadarms 143 kms and 1100 has of water surface, but 90 % is on the so-called dry-side of the dikes, isolated from the original riverbed. These ecosystems function as shallow lakes at present.

There is an obvious relationship between the nutrient level of water and sediment of deadarm ecosystems and the method of utilization of the surrounding areas. The water and sediment of these ecosystems are loaded by the different quality nutrients and toxic materials of the surrounding areas which were changed as a result of the intensive agriculture, industrial activities and the increasing tourism. As a result of the water and eolic erosion, the allochtonous materials access to deadarms by the water coming from the watershed area, the erosion of the dykes, the precipitation, the different plant residues and finally by the industrial and communal sewages which are the most harmful for them. The quality and quantity of allochtonous materials are also variable based on the differences occurring in the immediate vicinity of the

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given deadarm ecosystem. This is the reason for the phenomenon that significant difference may occur between the ecological conditions of different age and morphometry ecosystems.

PURPOSE OF ANALYSES

The studies were carried out on 14 deadarms of river Hármas-Körös. The total length of deadarms involved in the studies was 74 kms and the water surface are was 513 has (Tab. 1. Fig. 1.). Based on the method of water supply one parapotamon, foure paleopotamon and nine semipaleopotamon deadarms were analyzed.

The purpose of the study was to carry out a comparative analysis of the deadarm ecosystems of different land use. The studied deadarms are situated in recreation areas, urban areas and areas cultivated with intensive agricultural technology. The analyses were carried out focussing on the sediment. The reason for it was the fact that the earlier similar comparative analyses tried to characterize the ecological conditions of the given ecosystem only by analyzing the momentary water quality. The main purpose of our studies was to investigate the effect of utilization method of the surrounding areas on accumulation of sediment, and the chemical processes going on in the sediment. The direct effect of immediate vicinity on quality of water was studied on the basis of characteristics of accumulation of organic carbon, nitrogen and phosphorus. Then the redox environment were utilized to identify the scale of deterioration of ecological conditions.

Table 1.

Morphometria of the deadarm ecosystems of river Hármas-Körös

o.n.	Name of deadarm	Lenght/km/	Width /m/	Area /ha/	Depth/m/	Number of		Number of measurement	
						profils	sampling point	ORP	Nurient / C,N,P/
Parapotamon deadarm									
1	Aranyosi	1,6	60	10	4	3	15	30	3
Areas cultivated with intensive agricultural technology									
2	Kecsegészugi	1,3	50	7	2,9	1	5	10	1
3	Németzugi	2	60	12	2	1	5	10	1
6	Félhalmi	9	44	40	2,7	9	45	90	9
5	Harcsás	3	90	27	2,3	2	10	20	2
4	Halásztelek	2,4	90	22	2,8	2	10	20	2
Urban areas									
9	Révzugi	1	65	6	2,3	1	5	10	1
7	Álomzugi	2,8	80	22	1,5	6	30	60	6
8	Hantoskerti	2,3	60	14	2,5	3	15	30	3
10	Csókási	1,2	46	6	2	1	5	10	1
Recreation areas									
13	Bónomzugi	2,2	50	11	1,5	1	5	10	1
14	Templomzugi	2	51	10	1,7	2	10	20	2
11	Kákafoki	30,2	71	207	2,2	20	100	200	20
12	Túrtő	13,3	90	119	2,2	6	30	60	6
Total :		**74,3**		**513**		**58**	**290**	**580**	**58**

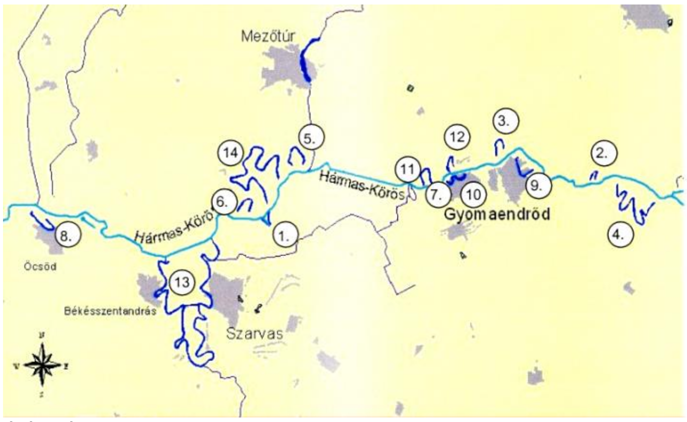

Fig. 1 Location of the studied deadarms

MATERIAL AND METHODS

The sediment was analyzed in fiftyeight profils of studied deadarm. The architecture of sediment was measured in five points within each profil. For the laboratory analyses a sample was taken from the middle of the riverbed. The studies were carried out 1992 and 2006 in autumn season. In the sampling periods the temperature of the sediment was between 14 - 16°C. The analyzed profils were selected very carefully considering the differences originating from the different lengths of deadarms.

Measurements of sediment accumulation

The deepness of soft and hard sediment layers was measured by a 3 meters long sediment sampler having a centimeter scale on one side and ended in a 20 cms diameter disk. Inside the cylinder there was a steel stick with a conical end which was pushed down at the time of sampling. Both in the soft and in the hard sediment the sampler was pushed into the sediment with a medium pressing force while it stopped.

Nutrient content of sediment

The total nitrogen and phosphorus contents of sediment were determined by the destructive method based on application of sulphuric acid and peroxyde (Felföldy, 1987). The organic matter content of the sediment was determined after a 3.5 hours long annealing on 500°C. The organic carbon content was calculated from the quantity of the organic matter.

Their relative mass rates were defined on the basis of the laboratory data (C/N, N/P, C/P). Based on the photosynthesis formula the theoretical mass rates of N, P and C were determined. According to Felföldi (1981) in the primer production one mole phosphorus transaction with 16 moles nitrogen and 106 moles carbon.

$$nCO_2 + 2nH_2A \xrightarrow{h*v} (CH_2O)_n + nH_2O + 2nA$$

After converting the mole rate to mass rate, it became possible to determine the „ideal" amount of nitrogen and carbon in relation to phosphorus in a given water ecosystem.

$$N_{ideal} = P_{real} \times 7,24 \text{ (mg/g)}$$

$$C_{ideal} = P_{real} \times 41.1 \text{(mg/g)}$$

Redox environment of sediment

The redox potential of sediment was determined at the sampling place by a pH/mV/temperature meter of type Cole-Parmer 59002-60 in a sample taken from the middle of the sampling section.

When evaluating the decomposition manner of the organic matter the following criteria were taken into consideration: values under – 140 mV as anaerobic, in the range from – 140 to + 325 mV as facultative anaerobic, form+ 325 mV as aerobic (Jorgensen, 1989).

Statistical analysis

Cluster Analysis (CA) is the collection of such algorithms that enable the grouping of objects investigated in a cluster. Cluster Analyses are employed at the exploration phase of the investigations with the aim of separating standardised groups. This method is used to define the groups of those characteristics or entities that are the most similar to each other (Neff and Marcus, 1980).

In ecological research most commonly the UPGMA (Unweighted pair-group method using arithmetic averages) method is applied (Sneath and Sokal, 1973). In this method the distance between the two aggregations is calculated by the average distance between all pairs of objects in the two different clusters (Sokołowski, 2003). The development of clusters happens on the basis of the distance between the objetcs in the polynominal space. As the unit of similarity the euclidean distance was applied. For the analysis 27 factors were considered.

The equality of the distribution of factors investigated in dead arms was controlled with the Gaussian distribution, with the Kołmogorov-Smirnov test. The discriminant analysis was employed to select that group of environmental factors that enable the separation of investigated dead arms the most. The average values of the first principal components determined by the Principal component analysis (PCA) served to prepare the dendogram presenting the mutual distance between the dead arms (cluster analysis, euclidean distance, Ward's method).

RESULTS AND DISCUSSION

The water/sediment rate was used as a basis for the comparative analyses of sediment accumulation (Table 2.). Based on these analyses it was concluded that the deepness of sediment had been fairly high in the dead arms located in agricultural areas. In average it was equal to the height of water column. In the dead arms located within the towns the deepness of sediment was higher than that of the water column. If the value of W/S index is higher, then the deepness of the water exceeds the thickness of the sediment layer. If it is lower than 1, then it shows the significant sedimentation of the dead arm. The highest values were measured at the Parapotamon dead arm (Fig. 2.). These values were the lowest in paleopotamon dead arms located in urban areas (Fig. 4.) and were remarkably lower than values measured in semipalopotamon dead arms with partial water exchange (Fig. 3.).

Table 2.

Sediment accumulation and water/sediment rate

o.n	Name of deadarm	Water depth /m/	Soft sediment /cm/	Hard sediment /cm/	W/S index
1	Aranyosi	332 (97÷595)	37 (5÷74)	168 (71÷240)	1.54 (1,12÷2,.24)
Areas cultivated with intensive agricultural technology					
2	Kecsegészugi	164	53	177	0,71
3	Németzugi	223	56	203	0,86
4	Félhalmi	254 (191÷309)	28 (20÷35)	157 (150÷165)	1,37 (1,08÷1,66)
5	Harcsás	233 (215÷250)	30 (18÷40)	112 (100÷124)	1,54 (1,52÷1,55)
6	Halásztelek	285 (279÷290)	28 (25÷31)	149 (145÷152)	1,61 (1,59÷1,64)
Urban areas					
7	Révzugi	86	59	167	0,38
8	Álomzugi	140 (127÷148)	60 (42÷81)	187 (110÷227)	0.59 (0,49÷0,82)
9	Hantoskerti	166 (143÷178)	67	139 (120÷176)	0,83 (0,59÷0,95)
10	Csókási	116	44	47	1,27
Recreation areas					
11	Bónomzugi	194	58	150	0,93
12	Templomzugi	223 (196÷250)	47 (36÷57)	153 (107÷198)	1,18 (0,84÷1,52)
13	Kákafoki	251 (173÷348)	31 (5÷99)	197 (92÷350)	1,26 (0,64÷3,28)
14	Túrtő	215 (175÷245)	30 (18÷40)	95 (54÷123)	1,80 (1,34÷2,72)

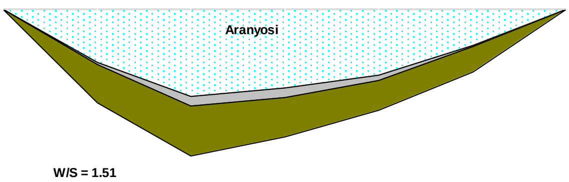

Fig. 2 Water and sediment rate – parapotamon deadarm

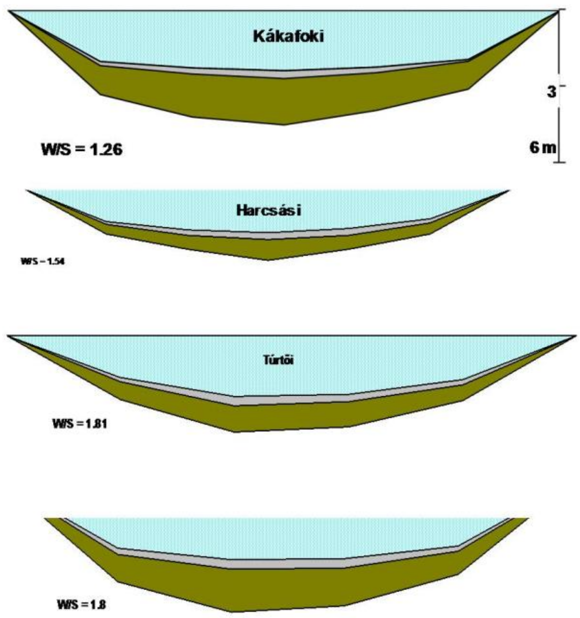

Fig. 3.1 Water and sediment rate – semipaleopotamon deadarms

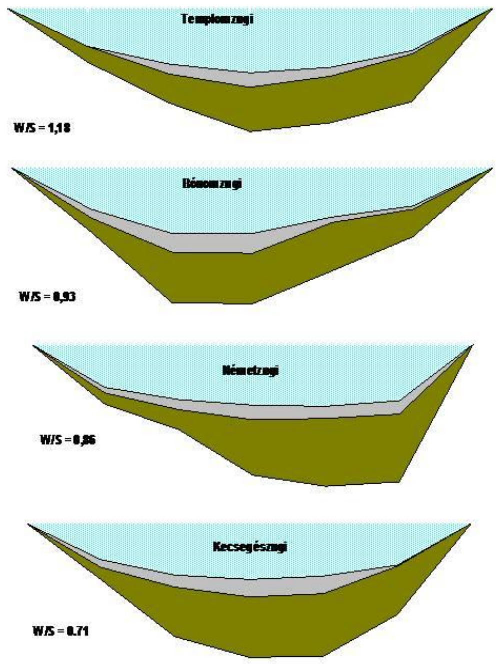

Fig. 3.2 Water and sediment rate – semipaleopotamon deadarms

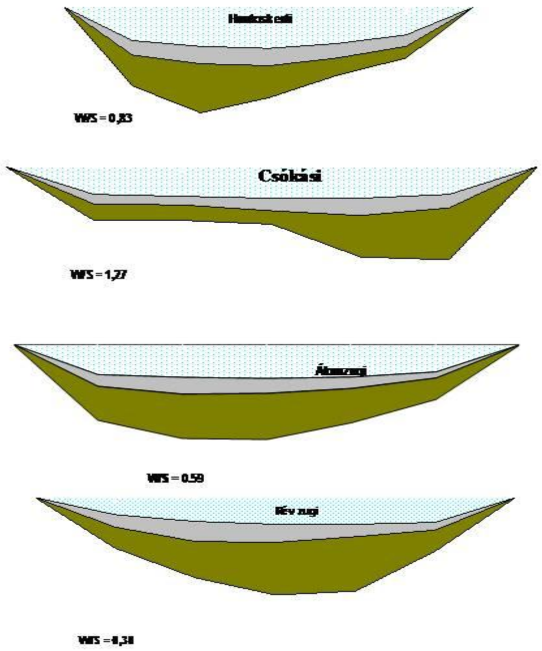

Fig. 4 Water and sediment rate – paleopotamon deadarms

The results of nutrient analyses are shown in Table 3. Based on these it can be stated that mostly in the urban areas the total nitrogen content compared to the phosphorus was magnitude higher. To ensure comparability the ideal content of nitrogen and carbon in relation to phosphorus were calculated. According to these it can be concluded that the relative nutrient surplus did not depend on the mode of exploitation of surrounding areas but primarily on the intesity of water exchange. The examined dead arms can be rated into three groups on the basis of the relative mass rates:

Group 1 – the real proportion of nitrogen compared to the phosphorus content is lower than the ideal proportion - Álomzugi, Halásztelki, Félhalmi i Túrtői.

Group 2 – the real proportion of nitrogen compared to the phosphorus content is a bit higher than the ideal proportion - Aranyosi, Kákafoki i Harcsási

Group 3 – the real proportion of nitrogen compared to the phosphorus content is two times higher than the ideal proportion Németzugi, Bónomzugi, Templomzugi, Kecsegészugi Hantoskerti, Csókási, i Révzugi. (Table 4.).

Table 3.
The results of nutrient analyse

o.n	Name of deadarm	Organic C [mg/g]	Total N [mg/g]	Total P [mg/g]
1	Kákafoki	35,43 (16,55÷52,5)	1,1 (0,29÷2,41)	0,85 (0,03÷3,127)
2	Aranyosi	62,67 (36÷96,75)	1,6 (0,57÷2,86)	0,78 (0,33÷1,56)
3	Félhalmi	43,95 (36,65÷51,75)	1,81 (0,43÷3,45)	0,9 (0,29÷0,67)
4	Álomzugi	53,57 (18,4÷81,14)	2,49 (1,68÷3,81)	0,9 (0,29÷0,67)
5	Halásztelek	37,38 (35,5÷39,25)	3,45 (3,36÷3,54)	1,83 (1,8÷1,86)
6	Túrtő	54,7 (32,85÷118,75)	5,98 (2,98÷15,59)	1,36 (0,99÷2,03)
7	Hantoskerti	49,5 (44,55÷53,15)	11,86 (9,83÷12,88)	0,77 (0,65÷0,88)
8	Bónomzugi	40,05	12,23	0,56
9	Templomzugi	39,68 (36,35÷43)	12,39 (12,36÷12,42)	0,67 (0,65÷0,69)
10	Harcsás	56,75 (38,35÷75,15)	13,07 (7,35÷20,75)	0,95 (0,86÷1,04)
11	Németzugi	38,2	14,04	0,59
12	Csókási	59	16,2	0,75
13	Révzugi	78,5	18,19	1,26
14	Kecsegészugi	90,6	19,49	0,96

Table 4.
Real and ideal rates of nutrient analyses

o.n.	Name of deadarm	C/N	N/P	C/P
		real/ideal	real/idea	real/ideal
1	Álomzugi	4,21 (1,79÷7)	0,52 (0,34÷0,93)	2,48 (0,72÷5,97)
2	Félhalmi	8,34 (2,27÷17,52)	0,34 (0,08÷0,59)	1,87 (1,18÷4,34)
3	Halásztelki	1,91 (1,86÷1,95)	0,26 (0,25÷0,27)	0,5 (0,46÷0,53)
4	Túrtő	1,75 (1,86÷1,94)	0,57 (0,37÷1,06)	0,95 (0,72÷1,02)
5	Aranyosi	9,23 (4,58÷17,16)	1,4 (0,16÷3,75)	7,22 (2,66÷17,15)
6	Kákafoki	9,4 (1,54÷22,81)	1,15 (0,02÷9,33)	5,53 (0,35÷32,51)
7	Harcsási	0,78 (0,64÷0,92)	1,97 (1,18÷2,76)	1,42 (1,08÷1,76)
8	Csókási	0,64	2,99	1,91
9	Révzugi	0,76	2,00	1,52
10	Bónomzugi	0,58	3,02	1,74
11	Németzugi	0,48	3,29	1,58
12	Kecsegészugi	0,872	2,81	2,3
13	Templomzugi	0,56 (0,52÷0,61)	2,56 (2,48÷2,64)	1,45 (1,28÷1,61)
14	Hantoskerti	0,75 (0,61÷0,95)	2,2 (1,55÷2,74)	1,59 (1,47÷1,98)

The redox environment was facultatively anaerobic or anaerobic in both three groups. The classification of studied dead arms on the basis of the average redox potential values measured during the two periods are summarised in Table 5. Results show that in paleopotamon dead arms the redox environment improved. In the case of dead arms located in areas cultivated with agricultural technology this can be explained with the reduction of artificial manure use – Kecsegészugi, Németzugi and Bónomzugi. It did not change in the case of dead arms bounded at one bank by urban areas - Templomzugi, Hantoskerti and Révzugi. It deteriorated remarkably in the Álomzugi dead arm laden with communal wastewater, and in the Harcsási dead arm surrounded by areas cultivated with intensive agricultural technology. Except for the water-stressed Halásztelki dead arm, the redox environment improved also in semipaleopotamon dead arms with intense water exchange.

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Table 5.

The redox environment and trend of changes int he sediment

Nazwa starorzecza	Average value ORP [mV]		Clasification		Trend os changes
	1992	2006	1992	2006	
paleopotamon deadarms					
Harcsási	61	107	1	7	+
Álomzugi	50	-59	2	8	-
Templomzugi	-16.5	65,5	3	4	+
Hantoskerti	-104	-21	4	5	+
Bónomzugi	-110	38	5	3	+
Németzugi	-129	73	6	2	+
Kecsegészugi	-171	79	7	1	+
Révzugi	-185	-153	8	6	+
semipaleopotamon deadarms					
Halásztelki	116	87	1	4	-
Túrtői	66	105	2	3	+
Kákafoki	61	124	3	2	+
Félhalmi	-50	179	4	1	+

As the individual analysis of abiotic factors failed to answer what had direct effects on the environmental state of the dead arms in question, a statistical analysis was performed on the basis of the gathered data.

According to the Cluster analysis out of the 27 measured parameters on the 0,05 significance level only 11 differed significantly. Based on the results of Principal component analysis dead arms can be rated into four main groups. The first group included Kákafoki (K), Halásztelki (H) and Túrtői (I) dead arms marked with red colour. The second group involved Félhalmi (L) dead arm marked with a green line. The third group consisted of the Álomzugi (A) dead arm marked with a blue line. Dead arms Templomzugi (D), Harcsási (J), Bónomzugi (C), Hantoskerti (E) and Németzugi (F) showing strong similarity belonged to the forth group (Figure 5.).

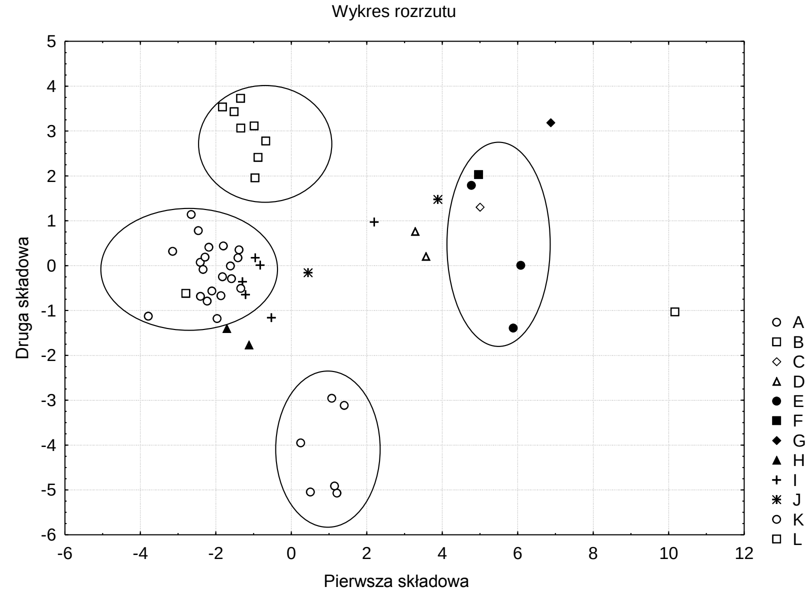

Fig. 5 Scatter diagram with results of principal component analysis

Since the fit of clusters was not adequate a discriminant analysis was applied to select factors enabling the exact grouping of dead arms. As a result of the discriminant analysis it was possible to separate three factors out of those selected by PCA analysis.

Table 6.

Summary of discriminant analysis

variables	Lambda Wilk's	Particle	F	Level p
Real total N [mg/g] 1992	0,016	0,279	12,893	0,000
ORP 2006	0,013	0,346	9,451	0,000
ORP 1992	0,016	0,278	13,002	0,000

The cluster analysis was repeatedly performed with the help of the three variables selected in the discriminant analysis. This confirmed the strenght of discriminant of the selected variables and made possible the accurate differentiation of dead arms (Figure 6.). The first group included next deadarms: Félhalmi (L2-L3-L4-L5-L6-L7), Kákafoki (K10-K14-K7, K6-K18-K17-K13-K4), (Harcsás (J2), Tűrtői (I-I3-I5-I6-I4-I2), Halásztelki (H2), Kákafoki (K15-K12, K5-K9-K8-K2), Templomzugi (D2), Álomzugi (A6-A5-A4), Hantoskerti (E3-E2), Álomzugi (A3-A2).

The second group involved part of Kákafoki deadarm near areas cultivated with intensive agricultural technology (K19-K16-K11, K20-K3). The third group consists. First part of Kákafoki deadarm near water inflow (K1). The forth group. involved Túrtői (I1-L1), Németzugi (F), (Bónomzugi (C), Kecsegészugi (G), Hantoskerti (E1), Révzugi (B), Harcsási (J1), Halásztelki (H1) and Templomzugi (D1) deadarms.

It enabled the separation of four main clusters, for which the euclidean distance was 16.

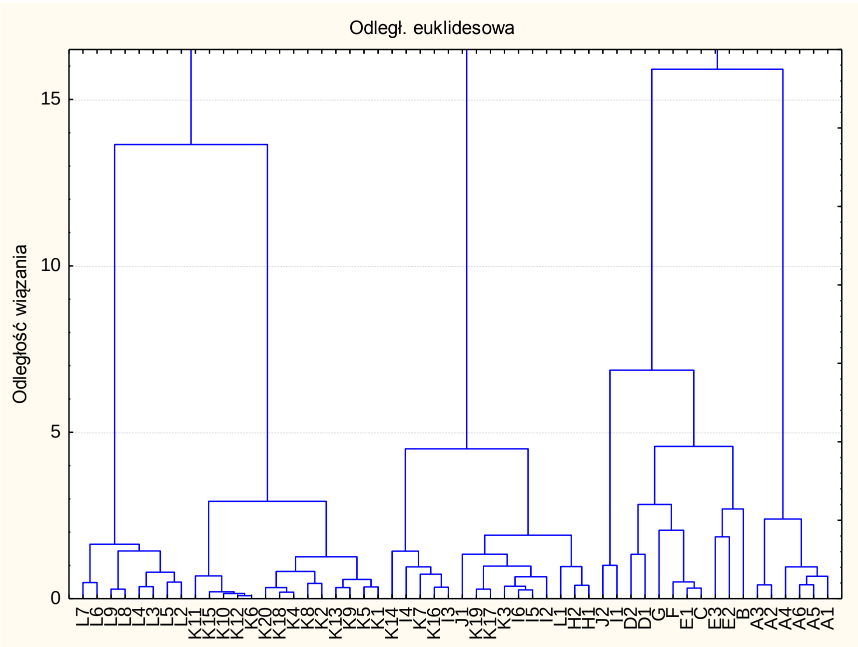

Fig. 6 Dendogram of discriminant analysis

CONCLUSION

The investigated dead arms were categorised into different groups (parapotamon, plaeopotamon and semipaleopotamon) not only on the basis of their morphologic characteristics, but also based on their manner of water exchange.

Particular dead arms differed primarily in certain physico-chemical parameters.

Antrophogenic effects negatively affected their ecological state.

Statistical analysis of data showed that the most important abiotic factor differentiating dead arms is the total nitrogen level and the redox potential of sediment.

Probably, it is possible to characterise the environmental state of dead arms quickly on the basis of these factors. The periodic measurement in a few years' interval of the total nitrogen level and the redox potential of sediment in dead arms enables the establishment of trends in the changes taking place in water environment.

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