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OSTRACODA OF THE EEMIAN INTERGLACIAL AT KRUKLANKI IN NE POLAND

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Abstract

The assemblage of lacustrine ostracods found in the Eemian Interglacial sediments at Kruklanki (Masurian Lake District, northeastern Poland) contains 18 species belonging to 13 genera. The most dominant species are *Candona neglecta* Sars, 1887, *Limnocytherina sanctipatricii* (Brady et Robertson, 1869), *Limnocythere inopinata* (Baird, 1843) and *Candona candida* (O.F. Müller, 1776). *Cyclocypris serena* (Koch, 1838), *Ilyocypris decipiens* Masi, 1905, *Pseudocandona insculpta* (G.W. Müller, 1900) and *Leucocythere mirabilis* Kaufmann, 1892 are recorded for the first time from the Eemian of Poland; the latter two species are also new for the Eemian lacustrine deposits of Europe. The ecological requirements of the recognised ostracod species as well as their geographic ranges in the Quaternary of Europe are summarised. Based on these data, past habitat type is estimated as a deeper littoral of a lake with reasonably cold, well-oxygenated and calcium-rich waters. The present state of knowledge of the Eemian ostracods from Poland is reviewed and their comparison with the Eemian ostracod assemblages from Europe is briefly given. Comparison of the ostracod faunal assemblage from Kruklanki with those from other Eemian sites in Poland enables to establish and describe one general type of ostracod assemblages characteristic for lacustrine littoral in this interglacial.

Key words: NE Poland, Eemian Interglacial, lacustrine chalk, ostracods

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INTRODUCTION

Ostracods, together with pollen and floral macroremnants as well as diatom flora (Bacillariophyta), Cladocera and, to a lesser degree, different groups of insects, are among the most important sources of our knowledge on the climatic changes and the succession of the inland aquatic ecosystems during the Quaternary (Löffler 1986b, Carbonel *et al.* 1988, De Deckker 1988, Delorme 1989, Holmes 1992, Namiotko 1995, 1998, Griffiths, Holmes 2000). The last interglacial, *i.e.* the Eemian, was similar to the Holocene in its biotic and abiotic characteristics; most of the Eemian species are found alive today. There are, however, differences mainly due to the human influence in the Holocene ecosystems. Therefore, research on the evolution of these ecosystems is valuable for the studies on the biodiversity changes in general.

In spite of the quite abundant occurrence of the Eemian deposits throughout Europe, especially those of the lake origin, ostracods of the Eemian "palaeolakes" are neither adequately recognised in Poland nor in other European countries. At present, about 50 sites of the Eemian limnic deposits of various types are known to contain remains of ostracods, however, in a number of cases this fauna is rather superficially described.

The main aims of this paper were:

a) detailed faunistic and zoocoenological analysis of the Eemian ostracod assemblage from the lacustrine chalk from Kruklanki;

b) palaeoecological interpretation of the environment of the studied assemblage;

c) comparison of the studied ostracod assemblage with others so far known from the Eemian limnic deposits from Poland.

PRESENT KNOWLEDGE OF THE EUROPEAN NON-MARINE OSTRACODA FROM THE EEMIAN INTERGLACIAL DEPOSITS

According to Griffiths's catalogue (1995) of European (except the former Soviet Union) freshwater Quaternary Ostracoda, there are 33 sites (excluding Poland) from six countries with Eemian ostracods recorded. With 13 Polish sites (Table 1, Fig. 1), there exist at least 46 sites from where 117 Eemian non-marine ostracod species are known. Unfortunately, no such summary data for the former Soviet Union are available. The above mentioned data concern mostly the sites of well established Eemian age and ostracods identified to the species level.

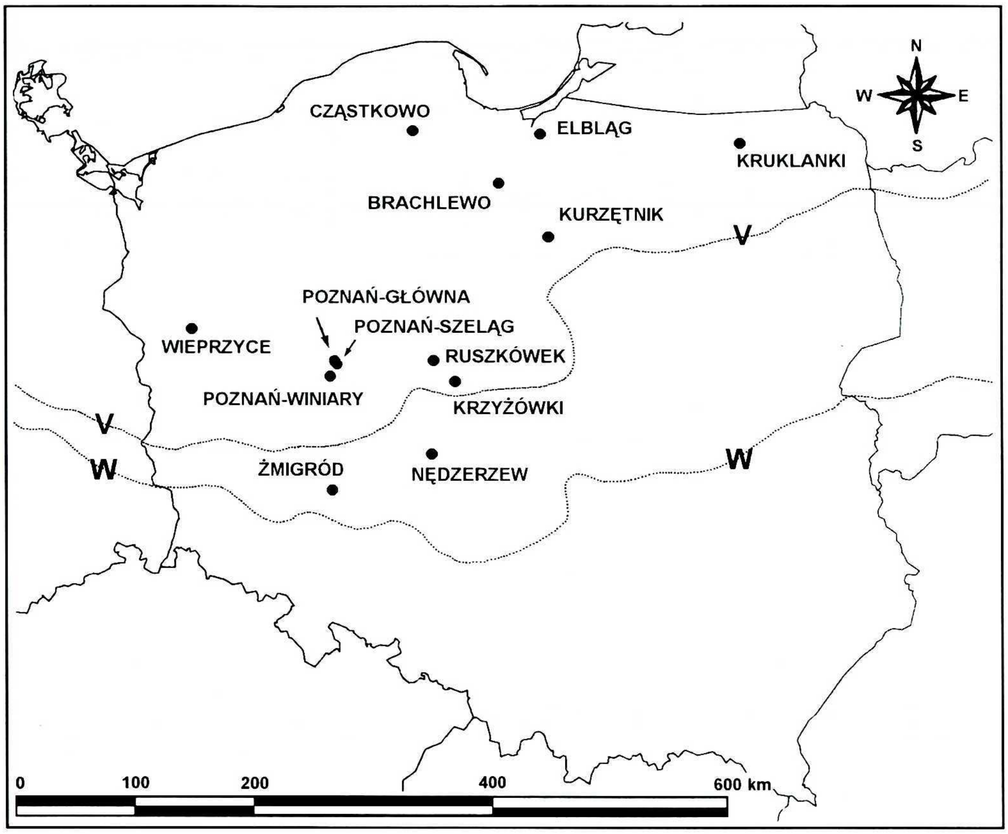


Fig. 1. Localities of the Eemian Interglacial in Poland from which non-marine Ostracoda were recorded, with the maximum ranges of the Vistulian Glacial (V) and the Warta Glacistadial (W) (glacial ranges after Lindner, 1992).

The state of knowledge on the Eemian ostracods in Europe varies from country to country (Griffiths 1995). They are best recognised in Germany, where in 20 sites (43% of all listed European sites) 105 ostracod species has been recognised (90% of the Eemian ostracod species known from Europe). Remarkably, the diversity of the Eemian ostracods found in Germany is comparable to those living there today, *i.e.* 126 species (Meisch 2000). Poland, with 13 sites recognised so far (28% of all Eemian sites from Europe) and 45 ostracod species (38% of all species from Europe) ranks the second. From the United Kingdom 25 Eemian ostracod species from nine sites are known. As 90 non-marine ostracod species are recorded in this country today (Meisch 2000), fossil fauna, similarly as in Poland, seems to be inadequately recognised. Beside the countries mentioned above, Eemian non-marine ostracods are known only from a few sites in southern Europe, with 21 distinguished species in total.

The vast majority of the 117 Eemian non-marine ostracod species lives in Europe today (Griffiths 1995). Only 20 species (17%) went extinct, most probably in the late Quaternary. At the same time two species changed their zoogeographical ranges: *Fabaeformiscandona rawsoni* (Tressler) recently occurs in the Nearctic Region, while *Vestalenula paglioli* (Pinto et Kotzian) – in the Neogaea.

The Eemian Interglacial has the best known non-marine ostracod fauna of all Pleistocene interglacials. However, the number of recognised species is barely a quarter of all non-marine species living in Europe today (cf. Löffler, Danielopol 1978).

Among the most common Eemian ostracod species, occurring in about half of the 46 European sites, are *Darwinula stevensoni* (Brady et Robertson) (28 sites), *Candona candida* (O.F. Müller) (26 sites) and *Candona neglecta* Sars (24 sites); they are also quite common in recent ecosystems. Further 14 species (12% of the total number) are known from 10–22 sites. The remaining 100 species (85% of all) were recorded in less than 10 sites; 41 of these species (35% of all) are known from single sites only.

Interestingly, some of the recently parthenogenetic species (*e.g. Limnocythere inopinata* (Baird) and *Candona candida*) changed their mode of reproduction: their males are more frequently reported in the Eemian than in modern assemblages.

A BRIEF HISTORICAL REVIEW OF STUDIES ON NON-MARINE OSTRACODA FROM THE EEMIAN INTERGLACIAL IN POLAND

So far, Eemian non-marine ostracods of Poland have been known from 13 sites and comprised 45 species (Fig. 1, Table 1).

The earliest paper concerning fresh-water ostracod species from the Eemian inland deposits in Poland is that by Hucke (1912). Among 12 Late Quaternary German sites, Hucke (1912) mentioned also Wieprzyce (then Wepritz in German) situated now in Polish territory near Gorzów Wielkopolski in the Toruń-Eberswald Pradolina (Ice Marginal Channel). In the sandy marls of lacustrine origin Hucke (1912) recognised five ostracod species, of which the determination of poorly preserved *Herpetocypris reptans* Baird, was tentative.

Only one more paper on the Eemian ostracods from Poland was published before the World War II (Grochmalicki 1931). That author identified 12 limnic ostracod species from marly sediments of the Poznań-Szeląg locality. A revised taxonomic study of this ostracod assemblage (Sywula, Pietrzeniuk 1989) allowed to distinguish there 21 species in total and to make it one of the best known Eemian ostracod assemblages from Poland.

In the 1960s two papers mentioned the Eemian Interglacial ostracods from Poland (Brodniewicz 1965, 1966), however both papers focused mostly on molluscs. The first paper (Brodniewicz 1965) described the Eemian marine fauna from Brachlewo near Kwidzyn (Lower Vistula Valley), where among ostracods, only *Cyprideis torosa* (Jones) was identified. The latter paper (Brodniewicz 1966) concerned the fresh-water deposits from Kurzętnik near Nowe Miasto Lubawskie, in the Chełmno-Dobrzyń Lake District. That site yielded *Cyclocypris laevis* (O.F. Müller) and *Candona s.l.* Baird. The taxonomic structure of the fauna (mostly molluscs) from Kurzętnik allowed Brodniewicz (1966) to suggest its lacustrine or oxbow-lake origin of highly eutrophic conditions.

Skompski (1973) reported seven fresh-water as well as some brackish-water and marine ostracod species from silty deposits from the environs of Elbląg. Since marine ostracods are most probably reworked, and the taxonomic position of juveniles assigned to *Candona rostrata* Brady et Norman is dubious (see Sywula, Pietrzeniuk 1989), only 6 fresh-water species from that site are included in Table 1. Skompski (1983) also recorded Eemian ostracods while studying molluscs from the river/lake sediments cored near Żmigród (close to Trzebnica in the Milicz-Głogów Depression). In re-examination of that material by Sywula and Pietrzeniuk (1989), two ostracod species have been distinguished.

Kociszewska-Musiał (1987) listed 12 limnic Eemian ostracod species from Kruklanki near Giżycko (Masurian Lake District). More detailed elaboration of this ostracod assemblage is the subject of the present paper.

In 1989 there appeared "Atlas of guide and characteristic fossils" (Sywula, Pietrzeniuk 1989), which seems to be, so far, the most comprehensive source of knowledge on the taxonomy as well the biostratigraphy of the Polish ostracods. For the Eemian Interglacial, there are given new data for three sites, *i.e.* Poznań-Główna (lacustrine sediments), Poznań-Winiary (deposits of a spring complex) and Nędzerzew near Kalisz in the Southern Great Poland Lowland (lacustrine deposits). Nędzerzew and Poznań-Główna together with above mentioned Poznań-Szeląg, are the most species-rich sites of the Polish Eemian (cf. Table 1).

Quite abundant Eemian fauna was also found in a core from Ruszkówek near Konin (the Great Poland Lake District) (Kozydra, Skompski 1995). Ostracods are represented there by 14 species, including *Scottia tumida* (Jones), previously believed extinct at the end of the Mazovian Interglacial. Ostracods determined only to the generic rank are not listed in Table 1. The petrographic, palynological and faunistic analyses allowed suggesting that this fauna lived in a stagnant lake water.

Another Eemian limnic ostracod assemblage (15 species) is mentioned by Szałamacha and Skompski (1999) from Krzyżówki near Koło (Southern Great Poland Lowland). This assemblage was interpreted as living in a shallow, stagnant-water and richly vegetated pond-like water-body.

The newest data concerning the limnic Pleistocene ostracods of Poland (excluding the Baltic area), are those published by Krzymińska and Jurys (2001) from Cząstkowo near Kościerzyna (Southern Pomeranian Lake District). The U-Th studies indicate that these deposits are younger (<110,000 and <130,000 years ago) than previously supposed. This site, with seven ostracod species, might thus be of Eemian age.

The ostracods of the last interglacial are also known from Grabówka, Lower Vistula Valley (Sywula, Pietrzeniuk 1989); however they are not identified at the species level, so this site is not listed in Table 1.

In summary, the Eemian non-marine ostracods in Poland are derived mostly from lacustrine deposits. Such deposits occur in seven sites (Cząstkowo, Kruklanki, Nędzerzew, Poznań-Główna, Poznań-Szeląg, Ruszkówek and Wieprzyce). The sediments of small, overgrown ponds are characteristic for 3 sites (Kurzętnik, Krzyżówki and Żmigród). The remaining sites may be classified as representing spring (Poznań-Winiary), marine (Brachlewo) and mixed – marine/fresh-water environments (Elbląg-Bażantarnia).

Like in the other European countries, the most ubiquitous species of Eemian limnic ostracods in Poland are *Candona candida*, *C. neglecta* and *Darwinula stevensoni* (present in 8 or 9 sites) as well as *Fabaeformiscandona protzi* (Hartwig), *Herpetocypris reptans* and *Metacypris cordata* (7 sites). Altogether they represent 13% of the Polish Eemian limnic ostracod species. 21 species are moderately common, while 18 species are known from single sites only. Four species: *Fabaeformiscandona fragilis* (Hartwig), *F. lapponica* (Ekman), *"Candoniella" subellipsoida* Sharapova and *Potamocypris negadaevi* Zubovich have not been recorded in the European Eemian deposits outside Poland, yet (not considering the former USSR).

GEOGRAPHICAL LOCATION AND GEOLOGICAL AND PALAEONTOLOGICAL SETTING OF KRUKLANKI SITE

The Kruklanki site (at the Kruklanki village) is situated close to Giżycko, in the Masurian Lake District, NE Poland, nearly 120 m a.s.l. (21° 56' 00" E, 54° 5' 44" N). It is located in the valley of Górna Sapina River, near the southern bank of the lake Gołdapiwo (Fig. 2A).

Exploitation at the gravel pit in Kruklanki began in the 1950s, and hydrogeological boreholes made in the 1960s provided geological characteristics of the Kruklanki environs (Kociszewska-Musiał 1987). According to that author, the Kruklanki pit is situated in a latitudinal subglacial channel, filled with gravel and sands (Fig. 2B), formed at the end of the Warta Stadial of the Middle-Polish Glaciation. However, in the last stage of the deglaciation and in the cataglacial stage of the Eemian, strong river erosion probably took place

Table 1

Distribution of non-marine Ostracoda recorded from the Eemian Interglacial deposits in Poland
BRA – Brachlewo (Brodniewicz 1965); CZA – Cząstkowo (Krzymińska, Jurys 2001); ELB – Elbląg-Bażantarnia (Skompski 1973, Sywula, Pietrzeniuk 1989); KRZ – Krzyżówki (Szałamacha, Skompski 1999); KUR – Kurzętnik (Brodniewicz 1966); NED – Nędzerzew (Sywula, Pietrzeniuk 1989); P-G – Poznań-Główna (Sywula, Pietrzeniuk 1989); P-S – Poznań-Szeląg (Grochmalicki 1931, Sywula, Pietrzeniuk 1989); P-W – Poznań-Winiary (Sywula, Pietrzeniuk 1989); RUS – Ruszkówek (Kozydra, Skompski 1995); WIE – Wieprzyce (Hucke 1912); ZMI – Żmigród (Skompski 1983, Sywula, Pietrzeniuk 1989); KRU – Kruklanki (A – Kociszewska-Musiał 1987, B – present study)

No.	Species	BRA	CZA	ELB	KRZ	KUR	NED	P-G	P-S	P-W	RUS	WIE	ZMI	KRU		Σ
														A	B	
1	*Darwinula stevensoni* (Brady et Robertson, 1870)			+	+		+	+	+		+	+		+	+	8
2	*Candona angulata* G.W Müller, 1900						+									1
3	*Candona candida* (O.F. Müller, 1776)		+		+		+	+	+	+	+	+		+	+	9
4	*Candona neglecta* Sars, 1887		+	+	+			+	+	+	+			+	+	8
5	*Candona weltneri* Hartwig, 1899				+		+	+[1]	+[1]							4
6	*Fabaeformiscandona alexandri* (Sywula, 1981)							+	+							2
7	*Fabaeformiscandona fabaeformis* (Fischer, 1851)								+						+	2
8	*Fabaeformiscandona fragilis* (Hartwig, 1898)						+									1
9	*Fabaeformiscandona hyalina* (Brady et Robertson, 1870)		+				+									2
10	*Fabaeformiscandona lapponica* (Ekman, 1908)								+[2]							1
11	*Fabaeformiscandona levanderi* (Hirschmann, 1912)				+			+			+					3
12	*Fabaeformiscandona lozeki* (Absolon, 1973)							+	+							2
13	*Fabaeformiscandona protzi* (Hartwig, 1898)		+		+		+	+	+		+			+	+	7
14	*Pseudocandona albicans* (Brady, 1864)				+[3]				+[4]	+[4]	+[3]					4
15	*Pseudocandona compressa* (Koch, 1838)				+		+	+	+		+			+	+	6
16	*Pseudocandona insculpta* (G.W. Müller, 1900)														+	1
17	*Pseudocandona lobipes* (Hartwig, 1900)						+									1
18	*Pseudocandona marchica* (Hartwig, 1899)						+	+	+							3
19	*Pseudocandona rostrata* (Brady et Norman, 1899)								+[2]							1
20	*'Candoniella' subellipsoida* Sharapova, 1961		+		+						+					3
21	*Candonopsis kingsleii* (Brady et Robertson, 1870)						+									1
22	*Cryptocandona vavrai* Kaufmann, 1900		+							+						2
23	*Paracandona euplectella* (Robertson, 1889)						+									1
24	*Cyclocypris globosa* (Sars, 1863)						+			+						2
25	*Cyclocypris laevis* (O.F. Müller, 1776)					+	+	+	+	+				+	+	6
26	*Cyclocypris ovum* (Jurine, 1820)				+		+	+	+		+				+	6
27	*Cyclocypris serena* (Koch, 1838)														+	1
28	*Ilyocypris bradyi* Sars, 1890									+	+			+[5]		2
29	*Ilyocypris decipiens* Masi, 1905														+	1
30	*Ilyocypris gibba* (Ramdohr, 1808)			+								+	+[6]			3
31	*Ilyocypris inermis* Kaufmann, 1900									+						1
32	*Herpetocypris reptans* (Baird, 1835)						+	+	+	+		+[7]	+	+	+	7
33	*Psychrodromus olivaceus* (Brady et Norman, 1889)									+						1
34	*Heterocypris salina* (Brady, 1868)				+[8]											1
35	*Scottia pseudobrowniana* Kempf, 1971									+						1
36	*Scottia tumida* (Jones, 1850)										+					1
37	*Cypridopsis hartwigi* G.W. Müller, 1900							+[9]								1
38	*Cypridopsis vidua* (O.F. Müller, 1776)						+	+	+	+					+	5
39	*Potamocypris negadaevi* Zubovich, 1976										+					1

Table 1 (continued)

No.	Species	BRA	CZA	ELB	KRZ	KUR	NED	P-G	P-S	P-W	RUS	WIE	ZMI	KRU		Σ
														A	B	
40	*Potamocypris producta* (Sars, 1924)						+[10]									1
41	*Potamocypris similis* G.W. Müller, 1900						+							+	+	2
42	*Potamocypris zschokkei* (Kaufmann, 1900)									+[11]						1
43	*Leucocythere mirabilis* Kaufmann, 1892														+	1
44	*Limnocythere inopinata* (Baird, 1843)				+		+	+	+					+	+	5
45	*Limnocythere stationis* Vávra, 1891						+									1
46	*Limnocytherina sanctipatricii* (Brady et Robertson, 1869)				+[12]			+[12]	+[12]		+[12]			+[12]	+	5
47	*Metacypris cordata* Brady et Robertson, 1870			+	+		+	+	+		+	+				7
48	*Cyprideis torosa* (Jones, 1850)	+		+	+											3
49	*Cytherissa lacustris* (Sars, 1863)		+	+				+	+					+	+	5
Total number of species at site		1	7	6	15	1	22	19	21	13	14	5	2	12	18	

Remarks: 1 – as *Candona weltheri* var. *obtusa* G.W. Müller, 1900; 2 – identification dubious; 3 – as *Candoniella albicans* (Brady); 4 – as *Candona parallela* G.W. Müller, 1900; 5 – here referred to *I. decipiens* (cf. Discussion in this paper); 6 – as *Ilyocypris* sp. in Skompski (1983) and as *Ilyocypris biplicata* (Koch) in Sywula, Pietrzeniuk (1989); 7 – as *Cypris reptans* Baird; 8 – as *Cyprinotus salinus* (Brady); 9 – as *Cypridopsis brincki* Petkovski; 10 – originally described as *Potamocypris* aff. *comosa* Furtos (redetermination as *P. producta* by Pietrzeniuk, see Griffiths 1995); 11 – as *Potamocypris foxi* Sywula; 12 – as *Limnocythere sanctipatricii* Brady et Robertson. All species of the genera *Fabaeformiscandona* and *Pseudocandona* in this table were originally ascribed to the genus *Candona* s.l.

at that area. This erosion was followed by deposition of either lacustrine or ancient river bed sediments, *i.e.* fine-grained sands and silts with silty gyttja and intercalations of lacustrine chalk. Such sediments occur at the bottom part of the outcrop and are referred to as the Bed 1 (Fig. 2C). The lacustrine chalk of the Bed 1 contains numerous mollusc shells and valves (rarely carapaces) of ostracods. These limnic deposits of the Eemian Interglacial are overlain by two distinct beds of fluvioglacial sandy-gravel sediments of the last glacial (Vistulian) (Fig. 2C). The Bed 2 consists of cross-bedded and poorly segregated sediments (mostly sands with gravel), as supposed result of the strong erosion of the neighbouring slopes of a high plain. The horizontally bedded sandy-gravel deposits represent the topmost Bed 3 (Fig. 2C).

In the lacustrine chalk of the Bed 1, Kociszewska-Musiał (1987) found numerous molluscs and ostracods. Shells of gastropods and bivalves were markedly damaged chemically (corroded), biologically (perforated) and/or mechanically (crushed).

Ostracods, quite common and in many cases well preserved as valves, were preliminarily determined by J. Szczechura, and assigned to 13 taxa (*Candona neglecta* Sars, *C. candida* (O.F. Müller), *C. ?protzi* Hartwig, *C. compressa* (Koch), *Cyclocypris ?laevis* (O.F. Müller), *Potamocypris* cf. *similis* G.W. Müller, *Cytherissa lacustris* (Sars), *Darwinula stevensoni* (Brady et Robertson), *Ilyocypris bradyi* Sars, *Limnocythere inopinata* (Baird), *Limnocythere sanctipatricii* Brady et Robertson, *Cypridopsis* sp. and *Erpetocypris reptans* (Baird)). One of those taxa, *Cypridopsis* sp. is not listed in Table 1.

According to Kociszewska-Musiał (1987), this lacustrine chalk was deposited in a shallow, marginal part (presumably seasonally drying) of a lake or in an old river-bed, in the temperate climate, similar to that recently prevailing in the area.

MATERIAL AND METHODS

All of the ostracod material for the present study (*i.e.* closed carapaces, separate valves and their larger fragments) was extracted from a sample of about 220-g dry sediment (140 cm^3 in volume). Ostracods were identified under a stereomicroscope at magnification of 14×, 28× or 56×, with reference to the papers by: Sywula (1974), Absolon (1978), Meisch (1984), Danielopol *et al.* (1990), Griffiths *et al.* (1993), Griffiths, Holmes (2000), and Meisch (2000). The collection of modern non-marine ostracods of Poland housed at the University of Gdańsk, Department of Genetics and Cytology was of considerable assistance, too.

In the palaeozoocoenological analysis of the ostracod assemblage from Kruklanki, a series of indexes and methods was involved:

A. The number of species in the assemblage (s).

B. The abundances of various ostracod remains and their proportions.

For each determined taxon the closed carapaces (C) as well as the left (L) and right (R) valves were counted separately for adults (ad.) and juveniles (juv.). In case of species having distinct sexual dimorphism, adult counts were also distinguished by sex.

The total abundance of *i*-th taxon (N_i) was expressed as the sum of the carapace number and the number of more numerous (left or right) valves of both adults and juveniles.

The total abundance of ostracods in the assemblage (N) was the sum of all the N_i values.

The ratio between left and right valves (L/R) of the most abundant species was tested statistically by the chi-square (χ^2) test at a significance level of P = 0.05, assuming a binomial distribution (a simple ratio 1:1). For (L+R) > 200 the formula $\chi^2 = (L-R)^2 / (L+R)$, while for $25 < (L+R) \leq 200$, $\chi^2 =$

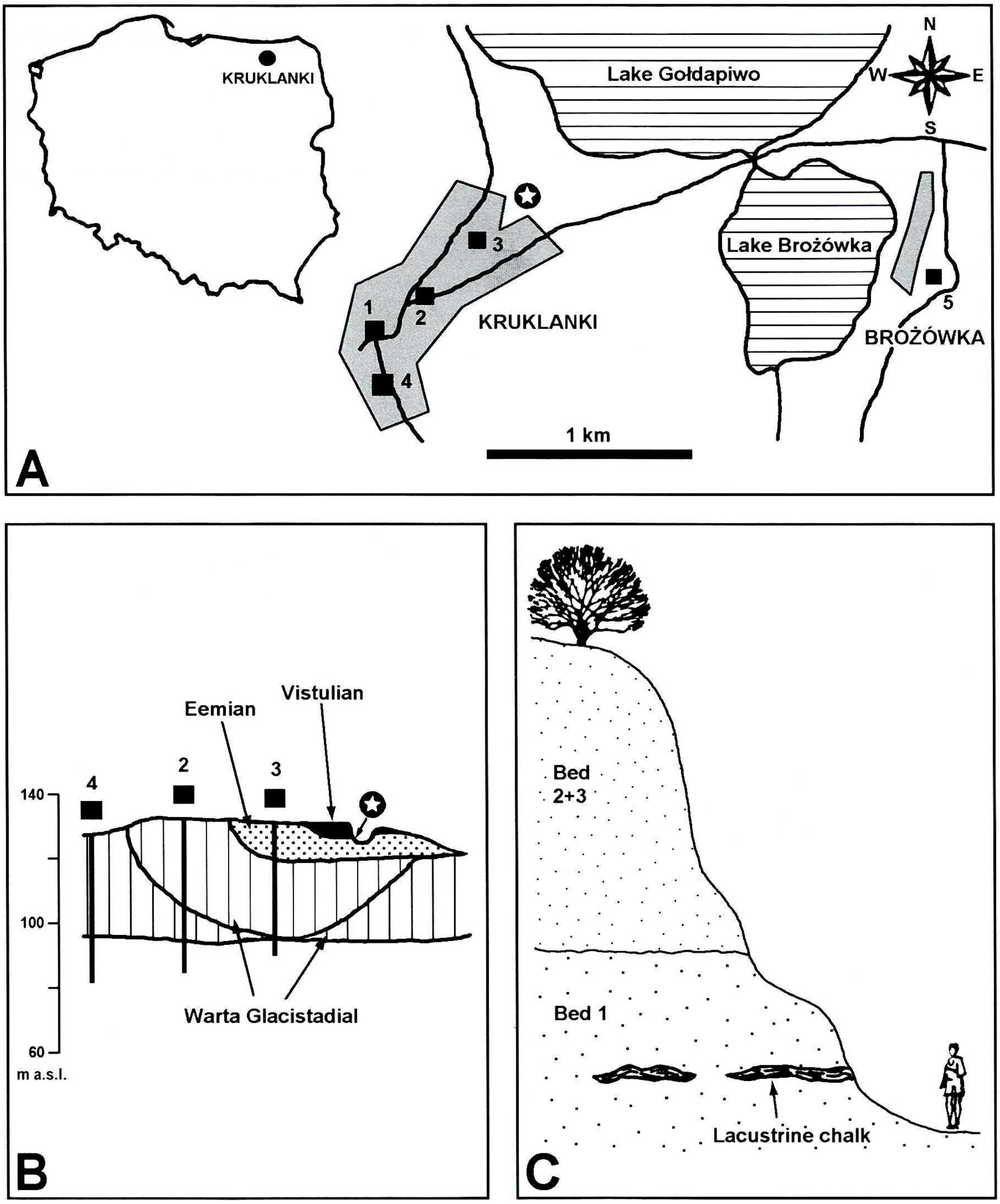


Fig. 2. A. Sketch map of Kruklanki vicinities showing location of the gravel pit (white star) and five boreholes (black squares) (after Kociszewska-Musiał, 1987, simplified); **B.** Geological cross-section through the vicinities of the gravel pit at Kruklanki (after Kociszewska-Musiał, 1987, simplified); **C.** Section of the gravel pit at Kruklanki (orig. after Kociszewska-Musiał, 1987).

$[(L-R)-1]^2/(L+R)$ was used (Sokal, Rohlf 1981). The equilibrium between L and R could indicate undisturbed (post-) sedimentary conditions (Oertli 1971).

For sexually dimorphic and reasonably abundant ($N_i \geq 25$) species the sex ratio (SR) was expressed as a number of females per male.

C. Domination (D_i).

Relative proportion of i-th species abundance was expressed in percent $D_i = (N_i / N) \times 100\%$. Basing on the D_i values, the species were assigned to one of the following classes of domination: dominants, influents or recedents. This assignment was facilitated by the analysis of partial dominance curve (Clarke 1990). This method involved ordering domination values of ranked species, from the most to the least dominant. The dominance of the second most dominant species was computed over the remainders after removal of the most dominant species. By such a successive removal, the dominances of the following species were computed.

D. Species diversity (H') and evenness (J) (Heip *et al.* 1988).

These values were defined by Shannon's and Pielou's indexes:

$$H' = -\sum_{i=1}^{s} (N_i/N)\ln(N_i/N)$$

and

$$J = H'/H_{max}, \text{ where: } H_{max} = \ln s.$$

For the comparison of the assemblage from Kruklanki with those from the other Eemian Polish sites the following methods were employed:

A. Similarity between assemblages (S_J).

Since for the majority of the analysed assemblages only species list was available without the data on abundances, the Jaccard's coefficient was chosen (Heip *et al.* 1988):

$$S_J = [a / (a + b + c)] \times 100\%,$$

where: a – number of species present in both assemblages, b (c) – number of species present in the first (second) assemblage and not in the second (first) assemblage.

B. Techniques designed to group assemblages.

Using the similarity values, groups of assemblages were searched for, such that assemblages within a group were more similar that were assemblages in different groups. Two different approaches were used: classification by hierarchical agglomerative clustering with group average linking UPGMA (Sneath, Sokal 1973) and ordination by multi-dimensional scaling technique MDS (Ludwig, Reynolds 1988). Both the UPGMA dendrogram and the two-dimensional MDS plot were produced with Statistica (StatSoft) programme.

RESULTS

General review of the material

The studied material consists of 2448 valves and 7 complete carapaces representing 18 ostracod species, belonging to six families. The valves are well preserved (only in some cases slightly deformed), and rather abundant in the sediment (nearly 4080 valves per 100 cm^3 and nearly 2500 valves per 100 g of dry sediment). Beside the complete (or only slightly damaged) remains, numerous small fragments occur (mostly juvenile valves), which cannot be precisely identified. Particularly poorly preserved are juveniles of Limnocytheridae, Darwinulidae and Ilyocyprididae (in each case they constitute less than 14% of the abundance of individual taxa), while those of Candonidae appear more resistant (for *Candona candida* and *C. neglecta* the proportions of juveniles count 82% and 84%, respectively).

Of the studied valves and carapaces, 13 valves could be determined to the subfamily level only (*ca* 0.5% of the total number) and 36 only to the genus level (nearly 1.5% of the total number).

The most abundant species is *Candona neglecta*, nearly 34% of the total, while only one or two valves of *Leucocythere mirabilis* Kaufmann, *Cypridopsis vidua* (O.F. Müller) and *Cyclocypris serena* (Koch) were found.

Among the 18 recognised species, 11 are known as the amphigonic forms. For those most abundant, and having particularly distinct sexual dimorphism (*Limnocytherina sanctipatricii* (Brady et Robertson), *Ilyocypris decipiens* Masi and *Candona neglecta*), the sex ratio (SR) has been calculated. In all cases, females predominate, however in *I. decipiens* this bias is the least displayed. Of the remaining 7 species, known to be parthenogenetic today, for four of them the males are unknown, whereas for *Limnocythere inopinata*, *Cytherissa lacustris* and *Candona candida*, the populations with (rare) males are sporadically reported from some areas (Meisch 2000). Thus, it is worth mentioning, that among the 403 adults of *L. inopinata* from Kruklanki two male valves were found.

Systematics and autecology

The following description of the recognised ostracod species conforms the taxonomic system and nomenclature of Meisch (2000). For each taxon the number of various remains (valves, carapaces), including their sex assignment as well as ontogenetic stage, is given. For each taxon, the list describes its ecological distribution with the environmental preferences, especially for the lacustrine conditions. The classification of the freshwater biotopes was adapted mainly from Husmann (1970). Ecological tolerance of each species is also indicated for the temperature (oligo-, meso-, polithermophilic or thermoeuryplastic), oxygen content (polioxyphilic or oxyeuryplastic), calcium content (meso-, polititanophilic or titanoeuryplastic), water dynamics (oligo-, mesoreophilic or rheoeuryplastic), salinity (oligo- or mesohalophilic) and pH (see also Table 5). All these data were collected mostly from Sywula (1974), Namiotko (1996) and Meisch (2000). The species are also characterised according to their geographical and stratigraphical distributions. In this respect, beside the papers quoted above, the NODE (Non-marine Ostracod Distribution in Europe) database housed at the University of Greenwich in the UK appeared useful, too (details in: www.gre.ac.uk/directory/earthsci/ostracod/Index.htm). Some additional papers, however, not yet included to NODE (Skompski 1989, Lindner *et al.* 1991, Skompski, Ber 1999, Sywula 2000, Sywula, Jędryczkowski 2000 and Wysocka *et al.* 2000) were also taken into account.

The geographical range of the ostracod species is referred to the zoogeographical regions of the world, while their recent distribution in Poland is considered using regionalisation after the Catalogus Faunae Poloniae (Catalogue of the Polish Fauna) published by the Institute of Zoology of the Polish Academy of Sciences. The Quaternary stratigraphical range is described using Lindner's (1992) division of the Quaternary in Poland: Podlaski (Augustowski) Interglacial = Günz/Mindel = Cromerian; Mazovian Interglacial = Lower Mindel/Riss = Holstein *s.s.*; Odranian Glacial = Lower Riss = Saale 1+2 = Drenthe; Lubawski Interglacial = Middle Riss = Rügen; Eemian Interglacial = Riss/Würm; Vistulian Glacial = Würm = Weichselian.

All the species listed below belong to the order Podocopida Sars, 1866 and suborder Podocopina Sars, 1866. Within the suborder Podocopina, the systematics of the analysed species is as follows.

Infraorder: Darwinulocopina Sohn, 1988
Superfamily: Darwinuloidea Brady et Norman, 1889
Family: Darwinulidae (Brady et Robertson), 1889
Genus: *Darwinula* Brady et Robertson, 1885

Darwinula stevensoni (Brady et Robertson, 1870)

Material – 27 L, 8 R, females only, and 1 L, 3 R juv., Fig. 3: 10.
Autecology – recorded mainly in lakes (from littoral, where the most common, to profundal, where being exceptionally rare; maximum depth reported – 84 m in Lake Turkana, Kenya, but that report could refer to empty carapaces drifted from shallower bottom – Griffiths, Butlin 1994) and in small, permanent, non-lacustrine water-bodies of different types, rarely or occasionally also in potamal, stygal, temporary water-bodies and mesohaline waters (salinity up to 15‰). Thermoeuryplastic, oxyeuryplastic (but requires high oxygen content for development of the early juveniles retained in the brood pouch), probably titanoeuryplastic, oligorheophilic and mesohalophilic.
Geographical distribution – cosmopolitan (except Antarctic and Oriental Regions).
Stratigraphical range – Middle Oligocene to Recent.
Recent distribution in Poland – Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Western Sudetes Mts., Bieszczady Mts.
Quaternary stratigraphical range in Poland – Augustów (Podlaski) Interglacial, Mazovian Interglacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Infraorder: Cypridocopina Jones, 1901
Superfamily: Cypridoidea Baird, 1845
Family: Candonidae Kaufmann, 1900
Subfamily: Candoninae Kaufmann, 1900
Genus: *Candona* s.l. Baird, 1845

Candona candida (O.F. Müller, 1776)

Material – 31 L, 36 R, females only, and 139 L, 163 R, 1 C juv., Fig. 4: 17, 18.
Autecology – ubiquitous species; in lakes it occurs from littoral (mainly) down to profundal (maximum depth reported – 311 m); found also in mesohaline waters (salinity up to 5.8‰). Oligothermophilic (but tolerates broad range of temperature), oxyeuryplastic, titanoeuryplastic, rheoeuryplastic, oligo-mesohalophilic and acidoeuryplastic (pH 5.0–13.0).
Geographical distribution – Holarctic (rather rare in southern parts).
Stratigraphical range – Upper Pliocene to Recent.
Recent distribution in Poland – Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Mazovian Lowland, Lower Silesia, Upper Silesia, Little Poland Highland, Lublin Highland, Roztocze/Sandomierz Lowland, Western Sudetes, Eastern Sudetes, Western Beskids Mts., Bieszczady Mts., Pieniny Mts., Tatra Mts., "Western Prussia".
Quaternary stratigraphical range in Poland – Mazovian Interglacial, Odranian Glacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Candona neglecta Sars, 1887

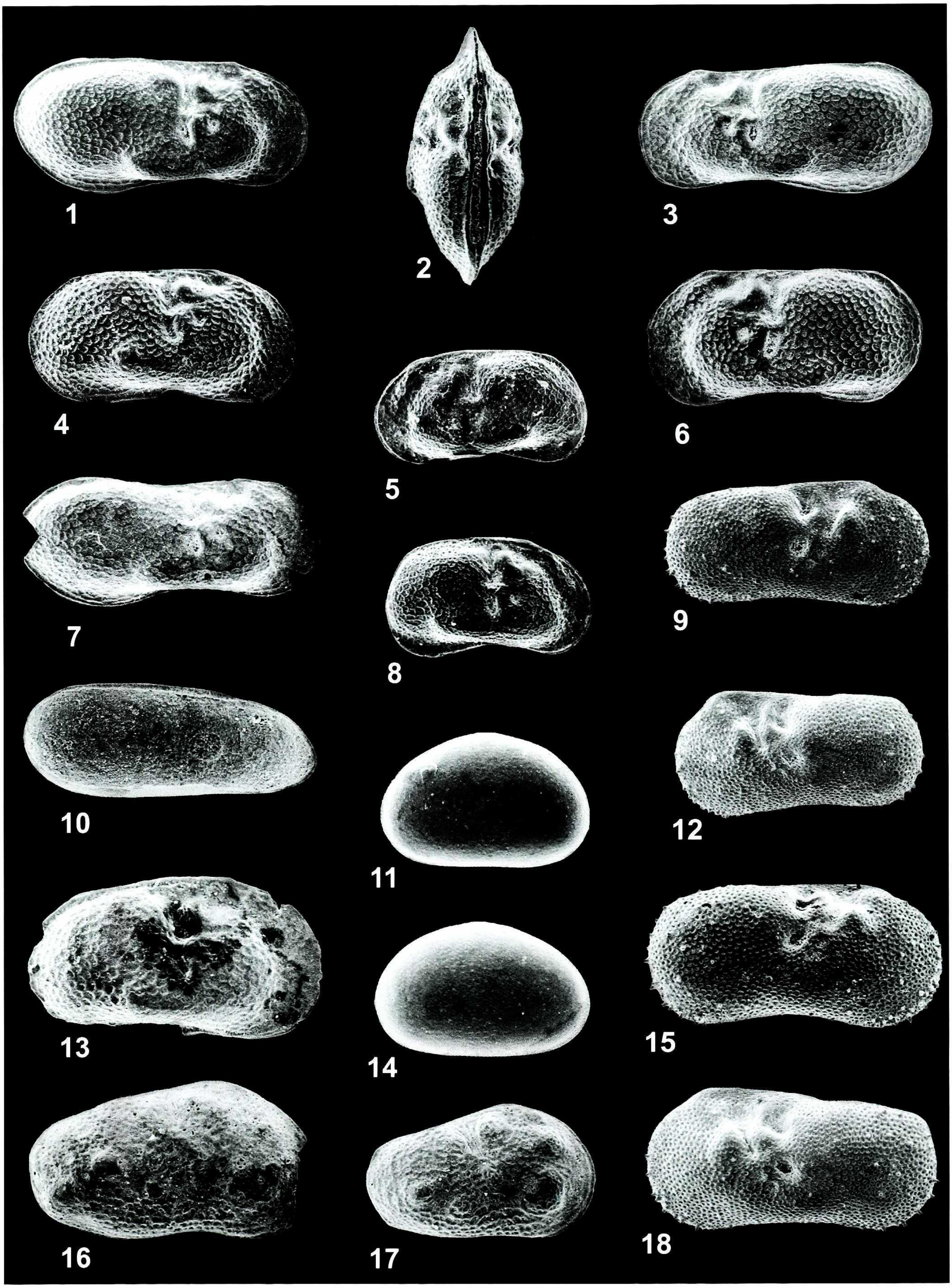
Material – 40 L, 60 R females, 3 L, 12 R males, and 336 L, 384 R juv., SR = 5.0 : 1, Fig. 4: 13, 14, 16.
Autecology – ubiquitous species; in lakes it occurs from littoral down to the deepest profundal (maximum depth reported – 311 m); reported also from saline waters (salinity up to 20‰). Oligothermophilic (but reported from the range 0.2 to 20.0°C of the water temperature), oxyeuryplastic, politanophilic, oligo-mesorheophilic, mesohalophilic and pH-euryplastic.
Geographical distribution – Holarctic.
Stratigraphical range – Pleistocene to Recent.
Recent distribution in Poland – Baltic Sea, Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Białowieża Forest, Lower Silesia, Upper Silesia, Western Sudetes Mts., Western Beskids Mts., Bieszczady Mts., Pieniny Mts.
Quaternary stratigraphical range in Poland – Podlaski (Augustów) Interglacial, Mazovian Interglacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Genus: *Fabaeformiscandona* Krstić, 1972

Fabaeformiscandona fabaeformis (Fischer, 1851)

Material – 1 R female and 1 R juv., Fig. 4: 7.
Autecology – inhabits lakes (maximum depth reported – 3 m), small permanent non-lacustrine water-bodies of different types, temporary water-bodies, rithral (seldom), krenal (seldom) and mesohaline waters (salinity up to 8.1‰). However, it prefers muddy, swampy and usually rich in organic detritus bottom of small temporary water-bodies. Mesothermophilic, probably oxyeuryplastic, titanoeuryplastic (or polititanophilic), oligorheophilic, mesohalophilic and pH-euryplastic.
Geographical distribution – Holarctic.
Stratigraphical range – Miocene to Recent.
Recent distribution in Poland – Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great

Fig. 3. Eemian Ostracoda of the assemblage from Kruklanki. 1–4, 6 – *Limnocytherina sanctipatricii* (Brady et Robertson): 1 – R male, 2 – C male, 3 – L male, 4 – R female, 6 – L female, × 60; 5, 7, 8 – *Limnocythere inopinata* (Baird): 5 – L female, 7 – R male, 8 – R female, × 60; 9, 12, 15, 18 – *Ilyocypris decipiens* Masi: 9 – R male, 12 – L male, 15 – R female, 18 – L female, × 50; 10 – *Darwinula stevensoni* (Brady et Robertson): L female, × 70; 11, 14 – *Cyclocypris ovum* (Jurine): 11 – L ad., 14 – R ad., × 80; 13 – *Leucocythere mirabilis* Kaufmann: R female, × 65; 16, 17 – *Cytherissa lacustris* (Sars): 16 – damaged R female, 17 – R juv., × 60. Specimens 1, 3–9, 11–18 are shown from the outer lateral side. Specimen 2 is shown from dorsal side, while 10 from inside.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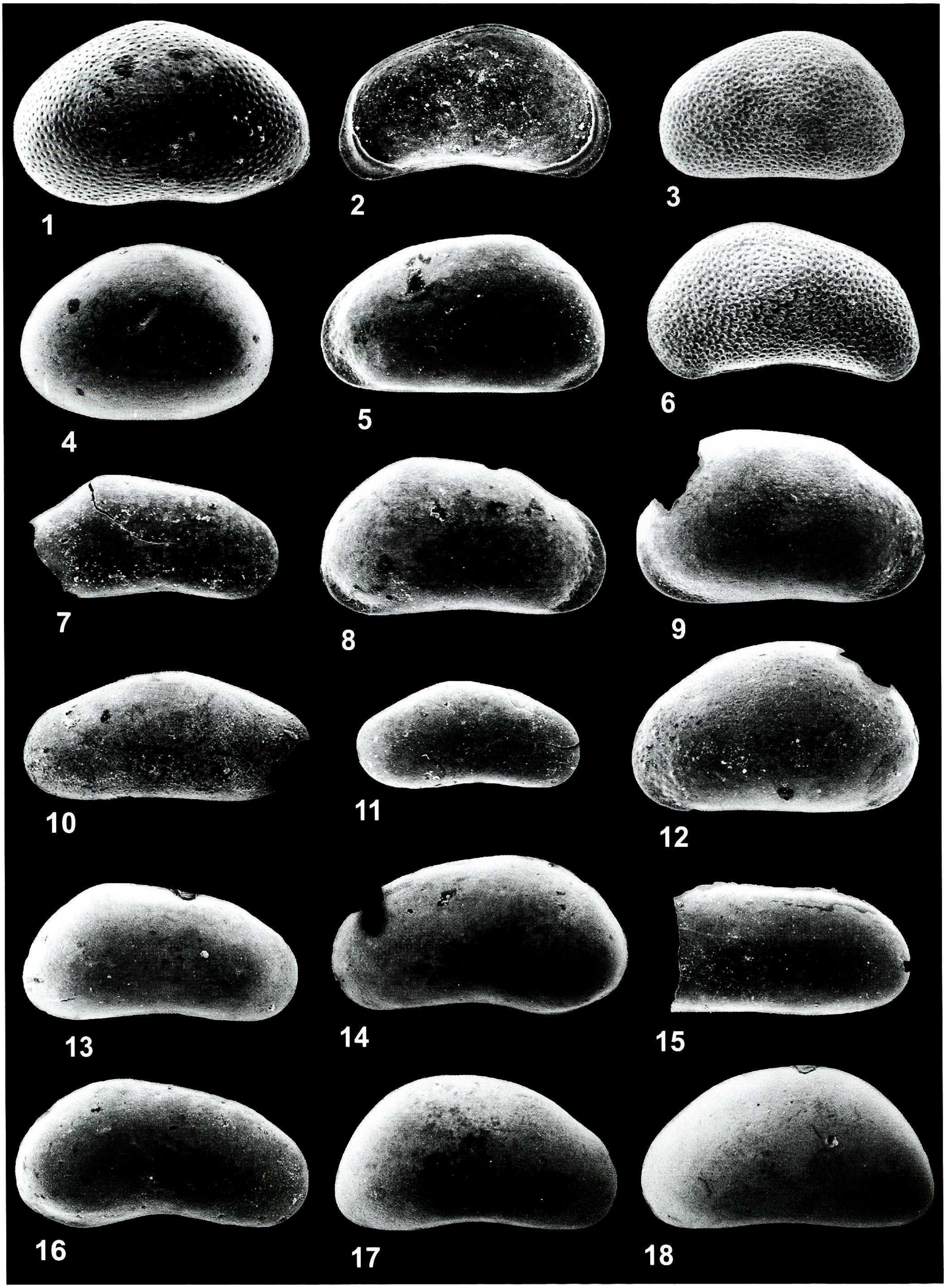
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Poland-Kujawy Lowland, Białowieża Forest, Roztocze/Sandomierz Lowland, Western Beskids Mts.
Quaternary stratigraphical range in Poland – Eemian Interglacial, Holocene.

Fabaeformiscandona sp. ex gr. *fabaeformis* (Fischer, 1851)

Material – 4 L, 5 R juv.
Remarks – most likely these valves represent *F. fabaeformis* but their more exact identification to the species rank was hardly possible.

Fabaeformiscandona protzi (Hartwig, 1898)

Material – 3 L, 1 R females, 1 L, 1 R males, and 3 L, 8 R juv., Fig. 4: 10, 11.
Autecology – occurs in lakes (from shallow zones down to the greatest depths; maximum depth recorded – 63 m, but abundance to peak at about 20 m), small permanent non-lacustrine water-bodies of different types, potamal and occasionally found in oligo-mesohaline waters (salinity up to 5.8‰). It seems that the species prefers environments of lacustrine origin and related to them oxbow lakes and ponds. Oligothermophilic but can withstand a wide range of water temperature, oxyeuryplastic in Europe, distinctly polioxyphilic in Northern America, titanoeuryplastic, mesorheophilic, mesohalophilic and pH-euryplastic.
Geographical distribution – northern part of Nearctic Region and European part of Palaearctic Region.
Stratigraphical range – Lower Pleistocene to Recent.
Recent distribution in Poland – Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Little Poland Highland, Western Sudetes Mts.
Quaternary stratigraphical range in Poland – Mazovian Interglacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.
Remarks – identification of two right juvenile valves uncertain.

Genus: *Pseudocandona* Kaufmann, 1900

Pseudocandona compressa (Koch, 1838)

Material – 6 L, 2 R ad., Fig. 4: 5, 8.
Autecology – reported from lakes (from littoral down to sublittoral, where found only occasionally; maximum depth recorded – 20 m), small permanent non-lacustrine water-bodies of different types, temporary water-bodies, krenal (seldom) and mesohaline waters (salinity up to 8.4‰). Prefers small swampy, temporary water-bodies, originated in the very shallow coastal zone of lakes. Mesothermophilic, oxyeuryplastic, meso-polititanophilic, oligorheophilic, oligo-mesohalophilic and pH-euryplastic.
Geographical distribution – Holarctic (North American records needs a corroboration).
Stratigraphical range – Pliocene to Recent.
Recent distribution in Poland – Baltic Sea, Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Białowieża Forest, Western Beskids Mts., Pieniny Mts., Tatra Mts.
Quaternary stratigraphical range in Poland – Mazovian Interglacial, Odranian Glacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Pseudocandona insculpta (G.W. Müller, 1900)

Material – 2 L, 2 R ad., Fig. 4: 9, 12.
Autecology – found in littoral zone of lakes, small permanent, non-lacustrine water-bodies of different types, temporary water-bodies, potamal and seldom in brackish waters. Prefers shallow, muddy and rich vegetated small water-bodies. Mesothermophilic, meso-polititanophilic, oligorheophilic and (?) oligohalophilic.
Geographical distribution – European Subregion of Palaearctic.
Stratigraphical range – Middle Pleistocene to Recent.
Recent distribution in Poland – Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Białowieża Forest.
Quaternary stratigraphical range in Poland – Odranian Glacial, Vistulian Glacial, Holocene.

Pseudocandona sp. ex gr. *compressa* (Koch, 1838)

Material – 13 L, 14 R juv.
Remarks – unequivocal identification of these juvenile valves to the species rank was impossible. Most likely, they represent *Pseudocandona compressa* (Koch) and/or *P. insculpta* (G.W. Müller).

Subfamily: Cyclocypridinae Kaufmann, 1900
Genus: *Cyclocypris* Brady et Norman, 1889

Cyclocypris laevis (O.F. Müller, 1776)

Material – 3 L ad., Fig. 4: 4.
Autecology – a ubiquitist, not found only in stygal. In lakes it occurs mainly in littoral, being rare in greater depths (maximum depth reported – 84 m). It was found also in mesohaline waters (salinity up to 8.4‰). Thermoeuryplastic, oxyeuryplastic, meso-polititanophilic or titanoeuryplastic, mesor-

Fig. 4. Eemian Ostracoda of the assemblage from Kruklanki (cont.). 1 – *Cypridopsis vidua* (O.F. Müller): R female, × 80; 2, 3, 6 – *Potamocypris similis* (G.W. Müller): 2 – L female, 3 – R female, 6 – L female, × 85; 4 – *Cyclocypris laevis* (O.F. Müller): L ad., × 80; 5, 8 – *Pseudocandona compressa* (Koch): 5 – L ad., 8 – R ad., × 60; 9, 12 – *Pseudocandona insculpta* (G.W. Müller): 9 – R ad., 12 – L ad., × 60; 7 – *Fabaeformiscandona fabaeformis* (Fischer): damaged R female, × 50; 10, 11 – *Fabaeformiscandona protzi* (Hartwig): 10 – R female, 11 – R juv., × 50; 13, 14, 16 – *Candona neglecta* Sars: 13 – R female, 14 – L male, 16 – R male, × 45; 15 – *Herpetocypris* aff. *reptans* (Baird): damaged R female, × 32; 17, 18 – *Candona candida* (O.F. Müller): 17 – R female, 18 – L female, × 50. Specimens 1, 3–18 are shown from the outer lateral side, while 2 from inside.

heophilic, mesohalophilic and pH-euryplastic (found in acidic waters of pH < 5). One of the most common non-marine ostracod species with wide tolerance limits (*e.g.* recorded in waters containing 30 mg H_2S dm^{-3}).
Geographical distribution – Holarctic.
Stratigraphical range – Miocene to Recent.
Recent distribution in Poland – Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Masovian Lowland, Podlasie, Białowieża Forest, Lower Silesia, Upper Silesia, Little Poland Highland, Roztocze/Sandomierz Lowland, Western Sudetes Mts., Western Beskids Mts., Bieszczady Mts., Pieniny Mts., "Western Prussia".
Quaternary stratigraphical range in Poland – Mazovian Interglacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Cyclocypris ovum (Jurine, 1820)

Material – 8 L, 8 R ad. and 2 L, 1 R juv., Fig. 3: 11, 14.
Autecology – a ubiquitist as *C. laevis*, occasionally found also in stygal, but on the contrary to *C. laevis* not recorded in potamal and rhitral. In lakes it occurs from littoral (mainly) down to profundal, where being rare (maximum depth reported – 70 m). Recorded also from slightly mesohaline waters (salinity up to 6.4‰). Thermoeuryplastic, oxyeuryplastic (one of the most tolerant species towards oxygen depletion), titanoeuryplastic, rheoeuryplastic, mesohalophilic and pH-euryplastic. It is suggested that *C. ovum* actually comprises several closely related and morphologically indistinguishable forms with narrower ranges of ecological valency.
Geographical distribution – Holarctic.
Stratigraphical range – Miocene to Recent.
Recent distribution in Poland – Baltic Sea, Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Białowieża Forest, Lower Silesia, Upper Silesia, Little Poland Highland, Roztocze/ Sandomierz Lowland, Western Sudetes Mts., Western Beskids Mts., Bieszczady Mts., Pieniny Mts.
Quaternary stratigraphical range in Poland – Mazovian Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Cyclocypris serena (Koch, 1838)

Material – 1 R ad.
Autecology – inhabits lakes (from littoral down to profundal, where being rare; maximum depth reported – 84 m), small permanent non-lacustrine water-bodies of different kinds and occasionally also temporary water-bodies, potamal, rhitral, krenal and stygal. Oligothermophilic (but recorded in a wide range of water temperature: 2.2–30.0°C), oxyeuryplastic, polititanophilic or titanoeuryplastic and oligo-mesoreophilic.
Geographical distribution – Holarctic.
Stratigraphical range – Lower Pleistocene to Recent.
Recent distribution in Poland – Pomeranian Lake District, Masurian Lake District, Western Beskids Mts., Tatra Mts., "Western Prussia".
Quaternary stratigraphical range in Poland – Odranian Glacial, Vistulian Glacial, Holocene.

Family: Ilyocyprididae Kaufmann, 1900
Subfamily: Ilyocypridinae Kaufmann, 1900
Genus: *Ilyocypris* Brady et Norman, 1889

Ilyocypris decipiens Masi, 1905

Material – 18 L, 26 R females, 20 L, 18 R males, and 3 L, 7 R juv., SR = 1.3 : 1, Fig. 3: 9, 12, 15, 18.
Autecology – recorded in lakes (from littoral, where the most abundant, down to sublittoral-profundal; maximum depth reported – 6 m), small permanent non-lacustrine water-bodies of different kinds (where being common) as well as occasionally in temporary water-bodies, potamal, rhitral, krenal, stygal and oligohaline waters (salinity up to 2.2‰). It prefers littoral zone of lakes, ponds and other small water-bodies. Polithermophilic, probably titanoeuryplastic, rheoeuryplastic and oligohalophilic. One of the rare and poorly known species.
Geographical distribution – Palaearctic Region.
Stratigraphical range – Pleistocene to Recent.
Recent distribution in Poland – Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland.
Quaternary stratigraphical range in Poland – Holocene.

Family: Cyprididae Baird, 1845
Subfamily: Herpetocypridinae Kaufmann, 1900
Genus: *Herpetocypris* Brady et Norman, 1899

Herpetocypris aff. *reptans* (Baird, 1835)

Material – 1 R ad., damaged, and 1 L, 1 R + 3 L or R juv., Fig. 4: 15.
Autecology – found in lakes (from littoral zone down to sublittoral, where being rare; maximum depth reported – 15 m), small permanent non-lacustrine water-bodies of different kinds as well as occasionally in temporary water-bodies, potamal, rhitral, krenal, stygal and mesohaline waters (salinity up to 6.0‰). It prefers small water-bodies with muddy and richly vegetated bottom and similar habitats in shallower coastal zones of lakes. Thermoeuryplastic, meso-polititanophilic or titanoeuryplastic, mesorheophilic, mesohalophilic.
Geographical distribution – cosmopolitan (except the Antarctic Region).
Stratigraphical range – Pleistocene to Recent.
Recent distribution in Poland – Masurian Lake District, Great Poland-Kujawy Lowland, Upper Silesia, Little Poland Highland, Roztocze/Sandomierz Lowland, Western Sudetes Mts.
Quaternary stratigraphical range in Poland – Mazovian Interglacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.
Remarks – these valves were too badly fragmented for full determination.

Subfamily: Cypridopsinae Kaufmann, 1900
Genus: *Cypridopsis* Brady, 1867

Cypridopsis vidua (O.F. Müller, 1776)

Material – 2 R females, Fig. 4: 1.
Autecology – a ubiquitist. In lakes it occurs in littoral zone (common) and rarely in profundal (maximum depth reported – 72 m); in saline waters found up to salinity of 8.0‰. Prefers permanent water-bodies with muddy bottom and rich vegetation (phytophile). Polithermophilic (but recorded in a wide range of water temperature: 0.2–36.0°C), oxyeuryplastic or rather polioxyphilic, titanoeuryplastic, mesorheophilic and oligohalophilic.
Geographical distribution – almost cosmopolitan (Holarctic and Neotropical Region).
Stratigraphical range – Lower Pleistocene to Recent.
Recent distribution in Poland – Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Mazovian Lowland, Białowieża Forest, Little Poland Highland, Western Sudetes Mts., Eastern Sudetes Mts., Western Beskids Mts., Bieszczady Mts., Tatra Mts., "Western Prussia".
Quaternary stratigraphical range in Poland – Mazovian Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Genus: *Potamocypris* Brady, 1870

Potamocypris similis (G.W. Müller, 1912)

Material – 28 L, 23 R, females only, Fig. 4: 2, 3, 6.
Autecology – poorly known species. Reported from littoral zone of lakes and from ponds down to the depth of 6 m as well as sporadically from brackish waters.
Geographical distribution – European Subregion of Palaearctic.
Stratigraphical range – Pleistocene to Recent.
Recent distribution in Poland – Baltic Littoral Region.
Quaternary stratigraphical range in Poland – Eemian Interglacial, Holocene.

Infraorder: Cytherocopina Gründel, 1967
Superfamily: Cytheroidea Baird, 1850
Family: Limnocytheridae Klie, 1938
Subfamily: Limnocytherinae Klie, 1938
Genus: *Limnocythere* Brady, 1867

Limnocythere inopinata (Baird, 1843)

Material – 198 L, 201 R, 1 C females, 1 L, 1 R males, and 2 L, 1 R juv., Fig. 3: 5, 7, 8.
Autecology – found in lakes (from littoral down to profundal, where not common; maximum depth reported – 15 m), small permanent non-lacustrine water-bodies of different kinds, potamal, stygal and mesohaline waters (salinity up to 6.7‰). Prefers shallow zone of lakes. Polithermophilic, probably polioxyphilic, titanoeuryplastic, rheoeuryplastic and mesohalophilic.
Geographical distribution – Holarctic and single sites in the Ethiopian Region, where it has been probably introduced.
Stratigraphical range – Pleistocene to Recent.
Recent distribution in Poland – Baltic Sea, Baltic Littoral Region, Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, Little Poland Highland, Western Sudetes Mts., Western Beskids Mts. Single male specimens were recorded only in Lake Ślesińskie near Konin in Great Poland-Kujawy Lowland (Sywula 1977).
Quaternary stratigraphical range in Poland – Podlaski (Augustów) Interglacial, Mazovian Interglacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene. Males were found at two sites of the Eemian Interglacial – Nędzerzew and Poznań-Szeląg (Sywula, Pietrzeniuk 1989) as well as in subrecent (historical) sediment of the Lake Wigry (Namiotko 1992).

Genus: *Limnocytherina* Negadaev-Nikonov, 1967

Limnocytherina sanctipatricii (Brady et Robertson, 1869)

Material – 205 L, 205 R, 3 C females, 48 L, 48 R males, and 9 L, 4 R juv., SR = 4.3 : 1, Fig. 3: 1–4, 6.
Autecology – inhabits lakes (from littoral, where not numerous, down to the greatest depths; maximum depth reported – 250 m), small permanent non-lacustrine water-bodies of different kinds (rare) and oligohaline waters (salinity up to 3‰). It prefers profundal of oligo-/mesotrophic lacustrine habitats. Oligo-mesothermophilic and probably polioxyphilic.
Geographical distribution – northern parts of Nearctic Region and European Subregion of Palaearctic.
Stratigraphical range – Pleistocene to Recent.
Recent distribution in Poland – Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland, "Western Prussia".
Quaternary stratigraphical range in Poland – Lubawski Interglacial, Eemian Interglacial, Holocene.

Limnocytherinae Klie, 1938 indet.

Material – 6 L, 7 R. juv. and ad.
Remarks – valves of these (mainly) juvenile specimens were markedly damaged, thus their specific identification was not possible. Most likely, they represent *L. sanctipatricii*.

Genus: *Leucocythere* Kaufmann, 1892

Leucocythere mirabilis Kaufmann, 1892

Material – 1 R, 1 C, females only, Fig. 3: 13.
Autecology – found almost exclusively in lakes (sublittoral-profundal; maximum depth reported – 68 m); there are also single records from brackish waters of the Baltic Sea (salinity up to 3‰) and from one ditch on the Isle of Corfu, Greece. Prefers a deeper bottom (minimum depth – 12 m) of cold, oligo-mesotrophic postglacial lakes. Oligothermophilic and polioxyphilic.
Geographical distribution – Palaearctic: European, Mediterranean and East Asian Subregions.
Stratigraphical range – (? Middle Pleistocene) Last Glacial to Recent.

Recent distribution in Poland – Lake Drawsko and Żerdno in the Pomeranian Lake District.
Quaternary stratigraphical range in Poland – Holocene.

Family: Cytherideidae Sars, 1925
Genus: *Cytherissa* Sars, 1925

Cytherissa lacustris (Sars, 1863)

Material – 4 L, 8 R, females only, and 6 L, 8 R juv., Fig. 3: 16, 17.
Autecology – inhabits lakes (from littoral, where not common, down to profundal; maximum depth reported – 220 m) and occasionally – small permanent non-lacustrine waterbodies (mainly in the northern parts of its geographical range) and oligohaline waters (salinity up to 1.5‰). Prefers deeper bottom (maximum densities peaked at 12–40 m) of cold oligo-mesotrophic postglacial lakes. Oligothermophilic (but tolerates a wide range of annual water temperature) and polioxyphilic.
Geographical distribution – Holarctic. Males present only in Lake Baikal.
Stratigraphical range – Pliocene to Recent.
Recent distribution in Poland – Pomeranian Lake District, Masurian Lake District, Great Poland-Kujawy Lowland.
Quaternary stratigraphical range in Poland – Podlaski (Augustów) Interglacial, Mazovian Interglacial, Odranian Glacial, Lubawski Interglacial, Eemian Interglacial, Vistulian Glacial, Holocene.

Table 2

Basic zoocoenological characteristics of the Eemian ostracod assemblage from Kruklanki

Species	Abundance (N_i)	Domination (D_i)	Domination class
Candona neglecta	456	34.44	(eu-) dominant
Limnocytherina sanctipatricii	272	20.54	dominant
Limnocythere inopinata	205	15.48	dominant
Candona candida	200	15.11	dominant
Ilyocypris decipiens	53	4.00	influent
Darwinula stevensoni	30	2.27	recedent
Potamocypris similis	28	2.11	recedent
Pseudocandona compressa	17	1.28	recedent
Cytherissa lacustris	16	1.21	recedent
Fabaeformiscandona protzi	12	0.91	recedent
Cyclocypris ovum	10	0.75	recedent
Fabaeformiscandona fabaeformis	7	0.53	recedent
Pseudocandona insculpta	5	0.38	recedent
Herpetocypris aff. *reptans*	5	0.38	recedent
Cyclocypris laevis	3	0.23	recedent
Leucocythere mirabilis	2	0.15	recedent
Cypridopsis vidua	2	0.15	recedent
Cyclocypris serena	1	0.08	recedent
Σ	1324	100.00	
Shannon index (H')		1.860	
Pielou Index (J)		0.644	

Synecology

Zoocoenological characteristics of the ostracod assemblage from the Eemian lacustrine chalk of Kruklanki

The obtained material appeared to be rich (both qualitatively and quantitatively; s = 18, N = 1324) and relatively well preserved, hence it enabled zoocoenological analysis of the ostracod assemblage. The abundances (N_i) and dominations (D_i) of each species were given in Table 2. In this analysis the valves identified as Limnocytherinae indet. were treated as *Limnocytherina sanctipatricii*, whereas those of *Fabaeformiscandona* sp. ex gr. *fabaeformis* – as *Fabaeformiscandona fabaeformis*. The juveniles belonging to *Pseudocandona* ex gr. *compressa* were assigned to two species, *i.e. P. compressa* and *P. insculpta* based upon the same ratio as that counted between the unequivocally determined adults of these two species.

Each species was assigned to the class of domination (Table 2) after portraying the domination values for all species as the partial dominance curve (Fig. 5). The assemblage was predominantly composed of four dominant species: *Candona neglecta* (recognised as eudominant), *Limnocytherina sanctipatricii*, *Limnocythere inopinata* and *Candona candida*, augmented by one influent – *Ilyocypris decipiens*. In addition, 13 species were assigned to the recedents, from which *Darwinula stevensoni* and *Potamocypris similis* were distinguished by their relatively high dominations.

Although the total number of species in the assemblage was high, about 90% of the valves belonged to five species only (four dominants and one influent). Thus, species diversity (H') and evenness (J) could be considered relatively moderate (Table 2).

Significance levels for the differences between the number of the left and right valves (L/R) of the most abundant species were presented in Table 3. In each case probability was well above $P > 0.05$, hence the null hypothesis that there was no difference between L and R was not rejected. The binomial model appeared then applicable.

Comparison with other sites

From among 12 Polish sites (except Kruklanki) with records of the Eemian ostracods, eight were selected for comparison with Kruklanki: Cząstkowo, Krzyżówki, Nędzerzew, Poznań-Główna, Poznań-Szeląg, Poznań-Winiary, Ruszkówek and Wieprzyce. Three other sites (Brachlewo, Kurzętnik and Żmigród) were omitted due to the poverty of their ostracod fauna (compare Table 1). The material from Elbląg as containing both marine and freshwater species was also excluded from this analysis.

A matrix of the Jaccard similarity values (S_J) is shown in Table 4. Two-dimensional MDS ordination of these assemblages is presented in Fig. 6, whereas their agglomerative clustering by the UPGMA method in Fig. 7.

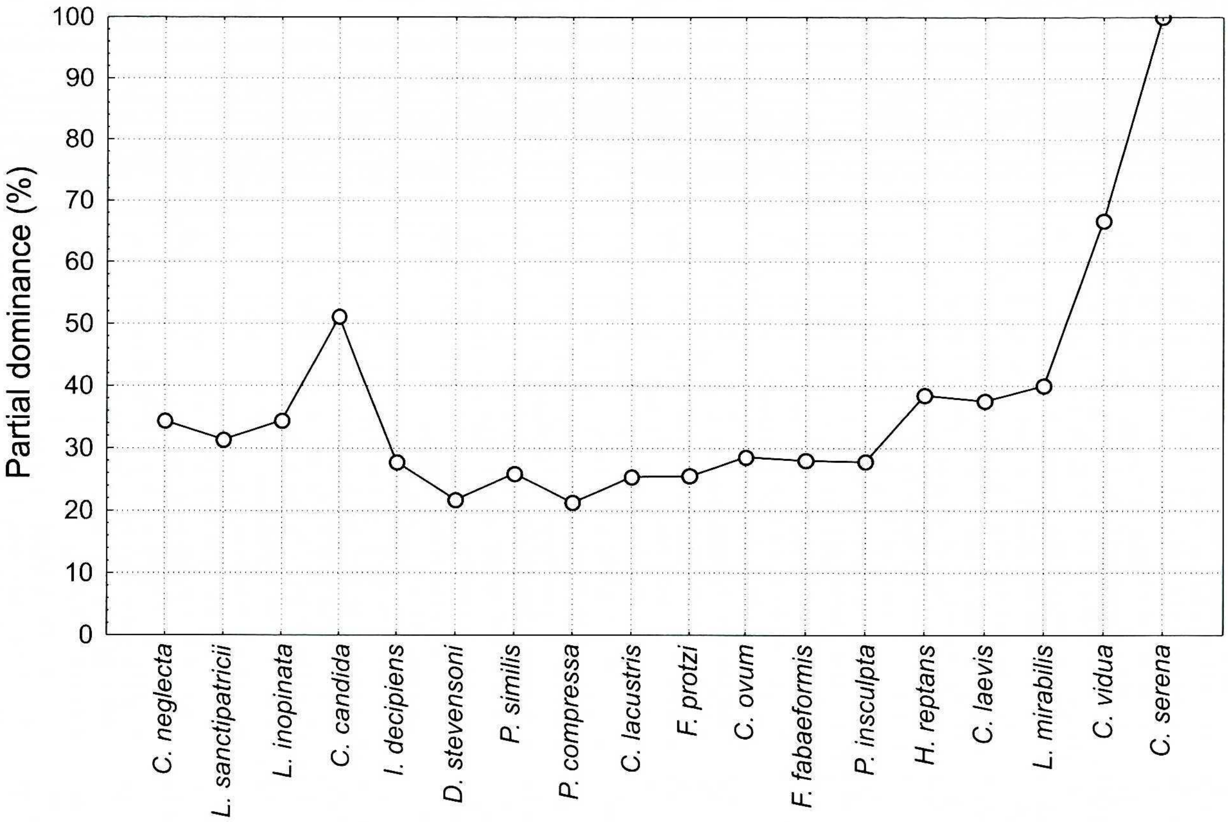

Fig. 5. Partial dominance curve for the non-marine Eemian ostracod assemblage from Kruklanki (full species names in Table 2).

Because clusters are reasonably sharp and the MDS stress low, an agreement of the classification with the ordination method was nearly excellent. In both the dendrogram and the MDS plot (Fig. 6 and 7) a group of six assemblages: Kruklanki, Krzyżówki, Nędzerzew, Poznań-Główna, Poznań-Szeląg and Ruszkówek can be distinguished (average similarity between them amounted to $S_J \pm SD = 41\% \pm 13\%$), which is separated by 25% similarity cut-off from three other assemblages (Cząstkowo, Poznań-Winiary and Wieprzyce) greatly differing from one another. The S_J values between any pair of these three assemblages as well as between any of them and any one from the group of six mentioned above, do not exceed 25% (Table 4). The Kruklanki assemblage is the most similar to those from Poznań-Szeląg ($S_J = 50\%$) and Poznań-Główna ($S_J = 48\%$), both representing lacustrine environment (Fig. 7, Table 4).

Table 3

Significance levels (P) for the differences between number of the left and right valves (L/R) of the most abundant ostracod species from Kruklanki (χ^2 – chi square statistic)

Species, sex or stage	L:R	χ^2	P
Limnocythere inopinata females	198 : 201	0.023	0.881
Limnocytherina sanctipatricii f.	205 : 205	0.000	1.000
Limnocytherina sanctipatricii m.	48 : 48	0.000	1.000
Darwinula stevensoni females	27 : 8	3.240	0.072
Ilyocypris decipiens females	18 : 26	1.841	0.175
Ilyocypris decipiens males	20 : 18	0.026	0.871
Candona candida females	31 : 36	0.537	0.464
Candona candida juv.	139 : 163	1.907	0.167
Candona neglecta females	40 : 60	3.610	0.057
Candona neglecta juv.	336 : 384	3.200	0.074
Pseudocandona sp. ex gr. *compressa* juv.	13 : 14	0.000	1.000
Potamocypris similis females	28 : 23	0.314	0.575

DISCUSSION

Comparison with the previous study on ostracods from Kruklanki

Kociszewska-Musiał (1987) listed 13 Eemian ostracod species from the lacustrine chalk from Kruklanki, including one determined as *Cypridopsis* sp., and a few other taxa only tentatively determined at the species level. Most of those preliminary identifications were confirmed by the present study so their taxonomic position was established (cf. Table 1).

Bad preservation of specimens referred by Kociszewska-Musiał (1987) to *Herpetocypris reptans* is a reason to assign them here to *Herpetocypris* aff. *reptans*, since it is not excluded that they represent another species of this genus. *Cypridopsis* sp. mentioned by Kociszewska-Musiał (1987) is referred here to *Cypridopsis vidua*.

The present study allowed to distinguish six additional species, *i.e. Fabaeformiscandona fabaeformis*, *Pseudocandona insculpta*, *Cyclocypris ovum*, C. *serena*, *Leucocythere*

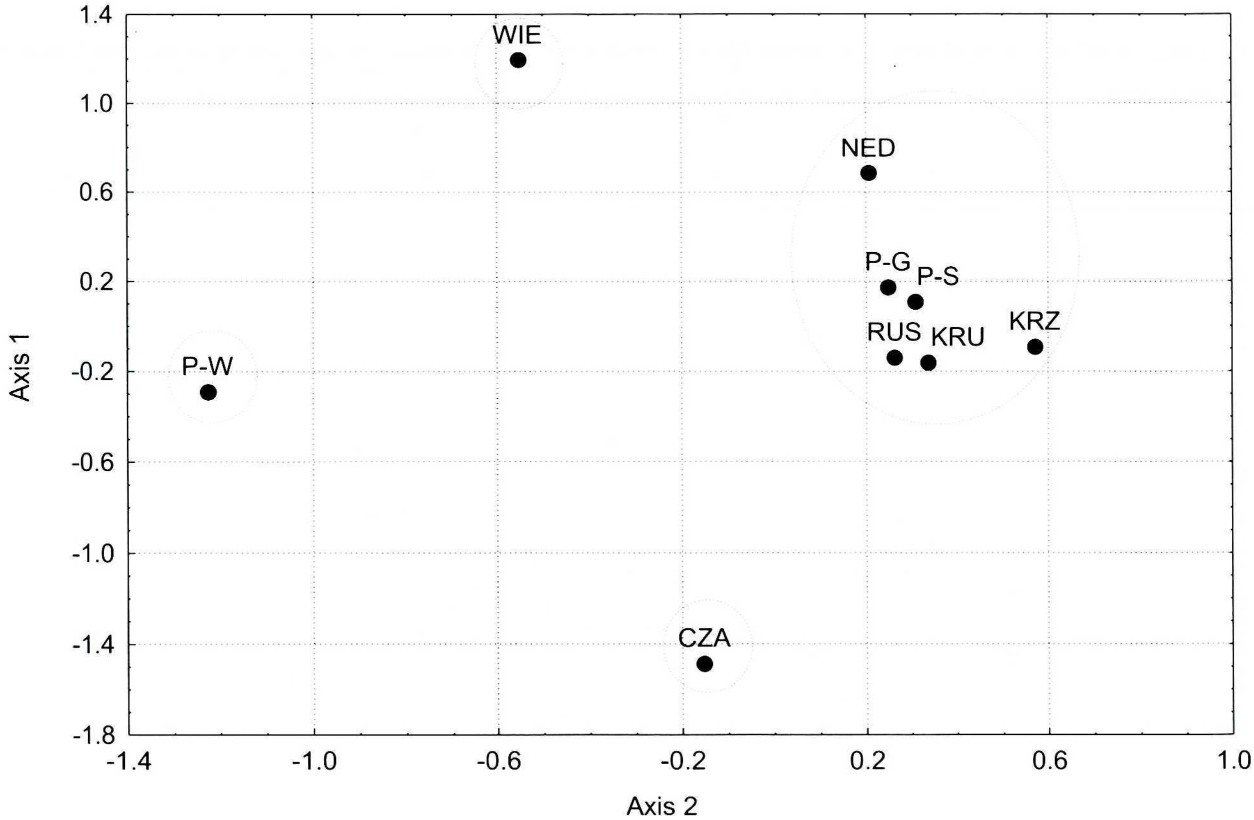

Fig. 6. Two-dimensional MDS ordination of Eemian non-marine ostracod assemblages from nine Polish sites based on coefficients obtained using the Jaccard index of similarity (Stress = 0.081). The 25% similarity threshold has been shown with dashed line (CZA = Cząstkowo, KRU = Kruklanki, KRZ = Krzyżówki, NED = Nędzerzew, P-G = Poznań-Główna, P-S = Poznań-Szeląg, P-W = Poznań-Winiary, RUS = Ruszkówek, WIE = Wieprzyce).

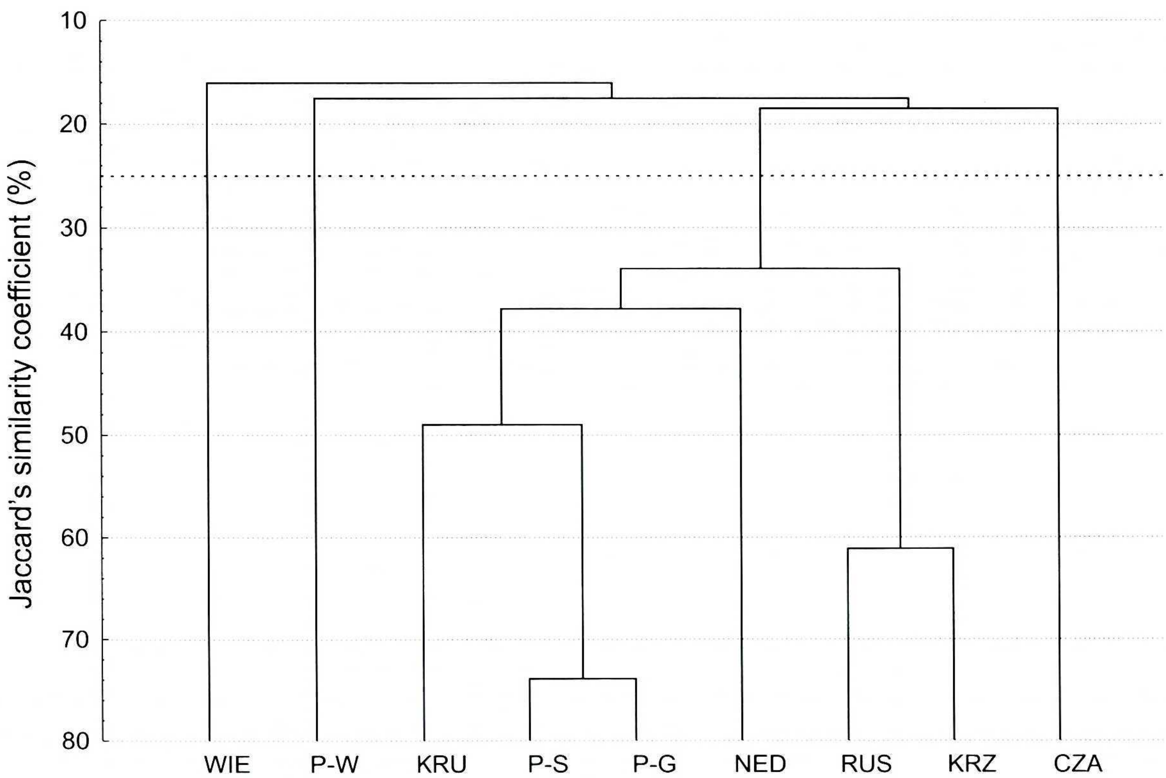

Fig. 7. Dendrogram UPGMA showing the results of the cluster analysis of Eemian non-marine ostracod assemblages from nine Polish sites based on coefficients obtained using the Jaccard index of similarity. Four groups of sites have been separated by 25% similarity cut-off (abbreviations of the site names as in Fig. 4).

Table 4

Lower triangular matrix showing values of the Jaccard similarity S_J (%) between each pair of nine assemblages of non-marine Eemian ostracods from Poland (CZA – Cząstkowo, KRU – Kruklanki, KRZ – Krzyżówki, NED – Nędzerzew, P-G – Poznań-Główna, P-S – Poznań-Szeląg, P-W – Poznań-Winiary, RUS – Ruszkówek, WIE – Wieprzyce)

	CZA	KRU	KRZ	NED	P-G	P-S	P-W	RUS	WIE
CZA	×								
KRU	19.05	×							
KRZ	22.22	32.00	×						
NED	11.54	33.33	27.59	×					
P-G	18.18	48.00	47.83	41.38	×				
P-S	16.67	50.00	44.00	38.71	73.91	×			
P-W	17.65	19.23	12.00	16.67	18.52	21.43	×		
RUS	23.53	28.00	61.11	20.00	37.50	34.62	17.39	×	
WIE	9.09	15.00	17.65	17.39	20.00	18.18	12.50	18.75	×

mirabilis and *Ilyocypris decipiens*. The latter species may correspond to *I. bradyi* mentioned by Kociszewska-Musiał (1987). Both these *Ilyocypris*-species differ in their lateral outlines as well as in other morphological details. The lack of distinct knobs on the carapace surface of *I. decipiens* from Kruklanki makes them similar to *I. decipiens* f. *almi* described by Sywula (1968) from the brackish Lake Blatnitsa, close to the Black Sea coast in Bulgaria. However, Petkowski (1958) found coexisting specimens of *I. decipiens* both having knobs and lacking them.

According to Meisch (2000), the carapaces of males and females of *I. decipiens* from northern France, Germany and Luxembourg are similar, as far as their shape and size are considered. In the Hiller's (1972) opinion, however, based on the populations of this species from northern Germany, females are somewhat larger than males. Since there are distinct two classes of size among the specimens assigned to *I. decipiens* from Kruklanki, the smaller ones are treated here as males.

The present state of knowledge of the Eemian ostracods from limnic sediments of Poland

About 60% of the ostracod species from Kruklanki are quite common species in the Eemian ostracod assemblages in Poland; they occur in at least five of the 13 known sites. *Fabaeformiscandona fabaeformis* and *Potamocypris similis* should be considered rare species. The former was found earlier in Poznań-Szeląg only, while *P. similis* – exclusively in Nędzerzew. The new ostracod species for this interglacial in Poland are *Pseudocandona insculpta*, *Cyclocypris serena*, *Ilyocypris decipiens* and *Leucocythere mirabilis*. Thus, 49 Eemian ostracod species are known from Poland today (cf. Table 1).

At least four species found in Kruklanki (*C. serena*, *F. fabaeformis*, *I. decipiens* and *P. similis*) should be considered very rare in the Eemian fresh-water sediments in Europe (excluding former USSR). *Cyclocypris serena* is known so far from seven sites from Germany: Burgtonna, Taubach and Parkhöhlen in Thüringen (Diebel, Pietrzeniuk 1977, 1978a,b, 1984), Eurach in Bayern (Ohmert 1979), Gröbern in Sachsen-Anhalt (Fuhrmann, Pietrzeniuk 1990b), Klein Klütz Höved in Mecklenburg-Vorpommern (Griffiths 1995) and Schönfeld in Brandenburg (Pietrzeniuk 1991). *Fabaeformiscandona fabaeformis,* besides Poznań-Szeląg locality in Poland, is also known from four sites from Germany: Ascherslebener See in Sachsen-Anhalt (Mania 1967), Derwitz in Brandenburg (Diebel, Pietrzeniuk 1975) and in the above-mentioned Parkhöhlen and Taubach in Thüringen. *Potamocypris similis* outside Poland was reported in the Eemian deposits from two German sites only: Gröbern and Parkhöhlen, both listed above. Finally, records of *Ilyocypris decipiens* come from Gröbern and Neumark-Nord (Fuhrmann, Pietrzeniuk 1990a,b) in Germany and from Coston in Great Britain (Griffiths 1995).

Two species from Kruklanki, *Pseudocandona insculpta* and *Leucocythere mirabilis*, are new for the Eemian Interglacial of Europe (excluding former USSR). *Pseudocandona insculpta*, is not rare in the Quaternary deposits of Europe. It is known from a dozen or so sites in six countries, from Holocene, Late Glacial, Mindel/Riss (Holstein) Interglacial and Lower Pleistocene. The age of the two sites, one from Hungary and one from the former Yugoslavia, is determined only as Pleistocene (without more detailed stratigraphical data, Griffiths 1995). Since the stratigraphical range of this species starts at the lower Pleistocene, its further occurrences in the Eemian deposits (besides Kruklanki) seem highly probable. *Leucocythere mirabilis* is rare, both as a recent and as a fossil form. It is known as a subfossil species from five recent Polish lakes (Namiotko 1996) but also from the Quaternary of Europe, *i.e.* mostly of the end of the Late Glacial and Holocene. The Holocene sites occur in the Austrian lakes: Attersee (Löffler 1983a), Mondsee (Danielopol *et al.* 1993), Halleswiessee (Danielopol *et al.* 1990) and Traunsee (Löffler 1983b), as well as in the Swiss lakes Brienzer See and Thuner See (Danielopol *et al.* 1990). The Late Glacial sediments comprising *L. mirabilis* have been found in the Schalkenmehrener Maar, a German lake of a volcanic origin (Scharf 1993), and in two Swiss lakes – Neuchâtel (Schwalb *et al.* 1994) and Lobsigensee (Löffler 1986a). Moreover, some specimens from Elster (Middle Pleistocene) deposits of Süssenborn near Weimar in Germany, referred by Diebel and Pietrzeniuk (1969) to *Limnocythere baltica* Diebel, should in fact be assigned to *Leucocythere* cf. *mirabilis* (cf. Danielopol *et al.* 1990). Thus, the last record may extend the actual stratigraphical range of the discussed species.

Inerestingly, two male valves of *Limnocythere inopinata* were found in Kruklanki. Today, males of this species are extremely rare, being confined to single sites only in six European countries (Meisch 2000). The bisexual populations, with males approximately as abundant as females, are known from Greece (Griffiths, Horne 1998), Macedonia (Petkowski 1959), Turkey (Gülen 1985), China (Yin *et al.* 1999) and North America (Delorme 1971), from where they are referred to *Limnocythere sappaensis* Staplin. In the Quaternary deposits, especially in the Eemian, the occurrence of *L. inopinata* males is more frequent (seven sites).

Zoocoenological analysis of the ostracod assemblage from Kruklanki and palaeoenvironmental reconstruction

Validity of any palaeozoocoenological analysis and palaeoenvironmental reconstruction depends on a knowledge of the taphonomy of the sample. In the material studied there were no significant differences between numbers of the left and right valves (L/R) of the most abundant species (Table 3). It suggests no post-mortem sorting of the disarticulated valves in an environment of slow sedimentation, that was indicated by the low value of carapace-to-valve ratios for the most common species. The percentages of the adult valves in both dominant *Candona*-species (16–18%) indicate *in situ* preservation of these taxa as well as suggest low energy conditions (Holmes 1992). On the other hand, the numbers of juveniles of two remaining dominants (*Limnocytherina sanctipatricii* and *Limnocythere inopinata*) were low (6% and 1%, respectively), suggesting some taphonomic sorting. In the simplest interpretation, past wave activity or fluctuations of the lake level might have transported away the smallest valves after death of ostracods. However, plenty of very small valve fragments of juvenile limnocytherids reflected possible post-mortem disturbance. Counting of such badly fragmented remains and determining the stage of a given species within the sample was not possible. Susceptibility of ostracod valves to mechanical break in depositional environment as well as during sampling and sample processing varies with species. It seems that weakly calcified valves of juvenile limnocytherids (comparing with those of juvenile candonids) are more susceptible to mechanical damage. Hence, high adult-to-juvenile ratios in both *L. inopinata* and *L. sanctipatricii* could just reflect a great number of broken (not counted) juvenile valves. Similar differences in adult-to-juvenile ratios between candonids and limnocytherids were also recorded by Namiotko (1996) in several subfossil ostracod assemblages from deep lake habitats in northern Poland. In conclusion, there is only a little (or no) evidence of post-mortem reworking, hence the ostracod assemblage from Kruklanki is thought to be deposited *in situ* and palaeoenvironmental reconstruction may be valid. This is in disagreement with Kociszewska-Musiał (1987) who suggested that only molluscs were deposited *in situ* there, whereas ostracods might have been drifted by wave activity into a sheltered "bay-head beach" (where the sample has been collected from). Actually, number of broken mollusc shells recovered from the same sediment bed may indicate mechanical action related to water dynamics. Very rich associations of allochthonous mollusc shells and much debris are often found on the littoral fringe.

18 ostracod species recovered from Kruklanki (Table 2), make this site one of the most species-rich in the Polish Eemian. Only the assemblages from Nędzerzew, Poznań-Główna and Poznań-Szeląg contain slightly more species (Table 1). The Shannon's index (Table 2) shows that the species diversity of the Kruklanki assemblage was not low (H' = 1.86), nevertheless since four dominant species (*Candona neglecta*, *C. candida*, *Limnocytherina sanctipatricii* and *Limnocythere inopinata*) accounted for 86% of the abundance, the species evenness (J = 0.64) was rather moderate. Beside four dominants, only one distinct influent was distinguished – *Ilyocypris decipiens*, the species still poorly known ecologically and not very common. Of 13 recedents, two species (*Darwinula stevensoni* and *Potamocypris similis*), encompass 50% of the total number of all recedents' valves. The recedents include also *Cytherissa lacustris* and *Leucocythere mirabilis*, good bioindicators of the profundal and sublittoral zones of cold, deep and oligo- to mesotrophic lakes.

The species composition of the Kruklanki assemblage indicates undoubtedly lacustrine environment. It corresponds well with the sediment type from which the ostracods were recovered (lacustrine chalk) and with composition of mollusc fauna found in the same bed (Kociszewska-Musiał 1987). All of the 18 ostracod species are known from modern lakes, although the extent of their association to lacustrine environments is diverse. Two recedents, *i.e. L. mirabilis* and *C. lacustris*, are almost obligate lacustrine species. Species preferring lakes (but sometimes being found in other ecosystems) include: *L. inopinata*, *L. sanctipatricii*, *D. stevensoni*, *F. protzi*, *P. similis* and to lesser extent *I. decipiens*, *F. fabaeformis*, *P. compressa*, *P. insculpta*, *C. serena* and *H. reptans*. The remaining five species are rather eurytopic and capable to occupy a range of niches.

Considering preferences for water depth, within the dominants one can find typically deep-water species (*L. sanctipatricii*), species characteristic for the lacustrine littoral zone (*L. inopinata*) as well as forms highly eurytopic in terms of depth preferences but very often dominant in the profundal zone (*Candona neglecta* and *C. candida*). One must emphasise however, that all these four dominant species are known to occur at depths of >15 m. Nevertheless, in the Kruklanki assemblage as a whole, the typical profundal-dwelling species (*C. lacustris*, *L. mirabilis* and *L. sanctipatricii*) were outnumbered by those most frequently associated with the shallower parts of lakes. This latter group was composed of 12 species, only three of which (*F. fabaeformis*, *P. insculpta* and *P. similis*) however, have never been found in deeper limnic waters (Table 5). With both, the species composition and the species-abundance relations, the Kruklanki assemblage appears as a littoral one of a comparatively large lake. Ecological tolerances for water dynamics (Table 5) as well as scarcity of strongly phytophilic species (except *Cypridopsis vidua* with very low domination value) indicate deeper littoral (sublittoral) below the limit of rooted plants rather than shallow waters with littoral vegetation and presence of wave activity. In addition, contrary to the shallow littoral bottom, sublittoral sediments of not much eutrophic lakes usually contain more autochthonous organics and silty inorganics, and such a type of sediment is preferred by *Cytherissa lacustris* (as documented by Geiger 1993), present in the assemblage from Kruklanki.

Some more information on a range of past environmental conditions can be also derived from individual species preferences for water temperature, dissolved oxygen and calcium content (Table 5). The examined assemblage lived in a relatively cold water (10 oligothermophilic species, two dominants included), *i.e.* either at greater depths or in cool stages of the Eemian when average air temperatures were lower than in the climatic optimum, and even neritic lacus-

Table 5

Ecological preferences of the ostracod species ordered by decreasing value of their domination in the assemblage from Kruklanki

Species	Water depth			Water temperature			Oxygen content in water			Calcium content in water			Water velocity		
	L	SL	P	oligo-	meso-	poli-	oligo-	meso-	poli-	oligo-	meso-	poli-	oligo-	meso-	poli-
				thermophilic			oxyphilic			titanophilic			rheophilic		
				←thermoeuryplastic→			←oxyeuryplastic→			←titanoeuryplastic→			←rheoeuryplastic→		
C. neglecta	■	■	■	■			■	■	■			■	■	■	
L. sanctipatricii	░	■	■	■	■				■		?			?	
L. inopinata	■	■	░			■			■	■	■	■	■	■	■
C. candida	■	■	■	■			■	■	■	■	■	■	■	■	■
I. decipiens	■	░	░			■		?		■	■	■	■	■	■
D. stevensoni	■	░	░	■	■	■	■	■	■	■	■	■	■		
P. similis	■				?			?			?			?	
P. compressa	■	■			■		■	■	■		■	■	■		
C. lacustris	░	■	■	■					■			?		?	
F. protzi	■	■	■	■			■	■	■	■	■	■		■	
C. ovum	■	░	░	■	■	■	■	■	■	■	■	■	■	■	■
F. fabaeformis	■				■		■	■	■	■	■	■	■		
P. insculpta	■				■			?			■	■	■		
H. reptans	■	░		■	■	■		?			■	■		■	
C. laevis	■	░	░	■	■	■	■	■	■		■	■		■	
L. mirabilis		■	■	■					■		?			?	
C. vidua	■	░	░			■	■	■	■	■	■	■		■	
C. serena	■	░		■			■	■	■			■	■	■	

Water depth: L – littoral, SL – sublittoral, P – profundal

■ – main zone of species' occurrence; ░ – minor (uncommon) zone of species' occurrence

trine waters could not get warm in summers. The presence of four polioxyphilic species and six meso- to polititanophilic species indicates waters which were well oxygenated (>3 mg O_2 dm^{-3}) and enriched with Ca^{++} (>18 mg Ca^{++} dm^{-3}), of typical chemistry of modern inland waters in the temperate Europe.

Comparison of the Kruklanki ostracod assemblage with other ostracod assemblages from the Eemian Interglacial in Poland

Comprehensive zoocoenological analysis of the Eemian ostracod fauna of Poland, would require comparison of species composition as well as species-abundance relations of the analysed assemblages. Since abundances of different species were known only from Kruklanki and (partly) from Cząstkowo, getting a full picture was not possible. So, the following analysis was based on binary (presence/absence) information only.

The similarity matrix (Table 4), the UPGMA dendrogram (Fig. 7) and the MDS plot (Fig. 6) revealed high similarity of six littoral assemblages (Kruklanki, Krzyżówki, Nędzerzew, Poznań-Główna, Poznań-Szeląg and Ruszkówek) while the remaining three assemblages (Cząstkowo, Poznań-Winiary and Wieprzyce) were clearly different from the cluster of the six as well as from each other.

The large offset of the assemblage from Poznań-Winiary is not surprising since it was retrieved from spring deposits (Sywula, Pietrzeniuk 1989). This offset is mainly produced by the presence of *Cryptocandona vavrai*, *Psychrodromus olivaceus*, *Scottia pseudobrowniana*, *Potamocypris zschokkei* and *Ilyocypris inermis* (Table 1).

The assemblage from Wieprzyce was recovered from sandy marls (Hucke 1912), which could indicate its lacustrine origin. Therefore, its separation from the cluster of six littoral assemblages may be striking. The most distinctive species of Wieprzyce is *Ilyocypris gibba*, which prefers small permanent or temporary water-bodies or shallow parts of lakes (Sywula 1974). This species was not recorded in any littoral assemblage, thus the average similarity between Wieprzyce and the littoral assemblages was only $S_J \pm SD = 18\% \pm 2\%$. However, the assemblage from Wieprzyce contains five species only and it was the least species-rich of all the analysed assemblages (Table 1).

The assemblage from Cząstkowo is broadly characteristic to lake profundal, in terms of species composition as well as domination structure (Krzymińska, Jurys 2001). The species distinctly dominant are *Cytherissa lacustris* (D = 60–70%) and *Candona neglecta* (D = 20–30%), both occurring frequently in profundal zones of the oligo-mesotrophic lakes in the northern Poland (assemblages 'B' and 'E' in Namiotko 1998). Such low trophy environments are indicated by: (a) low content of organic matter in sediment (9–25%), (b) high values of Secchi's disc visibility in summer (2.7–6.4 m), (c) high O_2 concentration at the lake bottom (5.0–6.9 mg O_2 dm^{-3}), (d) low content of phosphates (0.01–0.10 mg PO_4^{-3} dm^{-3}) near the bottom during summer stagnation period, (e) low phytoplankton biomass and (f) low chlorophyll-*a* concentration in surface waters during summer (0.1–0.5 mg dm^{-3} and ca. 5.5 mg dm^{-3}, respectively) (Namiotko 1998). The separate location of this assemblage on the MDS plot and UPGMA dendrogram resulted from the presence of *Fabaeformiscandona hyalina* and *Cryptocandona vavrai*, the species very rare in the other analysed assemblages.

The species consistently prominent, and responsible for clustering of the assemblages from Kruklanki, Krzyżówki, Nędzerzew, Poznań-Główna, Poznań-Szeląg and Ruszkówek included: *Candona candida*, *Fabaeformiscandona protzi*, *Pseudocandona compressa*, *Cyclocypris ovum*, *Darwinula stevensoni* (present in all assemblages) and *Candona neglecta*, *Limnocythere inopinata*, *Limnocytherina sanctipatricii*, *Metacypris cordata* (present in five assemblages). According to the source data, all these assemblages represented lacustrine environments.

The cluster of the littoral assemblages was not perfectly "cohesive". This is not surprising in a set of samples representing various biotopes of the lake littoral *sensu lato*, regarding depth zonation as well as continuous natural evolution of lake basin. Deeper littoral (sublittoral) ostracod assemblages in the recent postglacial lakes often have almost completely different species composition than those of swampy, shallow vegetated bodies temporarily formed in the lacustrine supralittoral zone. The assemblages from Kruklanki, Poznań-Główna and Poznań-Szeląg forming the "core" of the littoral cluster appear to correspond to sublittoral, whereas the assemblage from Nędzerzew represents either the shallow, swampy or boggy littoral, or small stagnant pool on a lake shore (permanent or temporary) where ordinary waves of calm weather seasons could produce dampness of the ground. This was evidenced by the presence of *Paracandona euplectella*, *Pseudocandona lobipes*, *Fabaeformiscandona fragilis* and *Limnocythere stationis*, and also by the absence of *Cytherissa lacustris*, *Fabaeformiscandona lozeki* and *Limnocytherina sanctipatricii*.

The environments of Krzyżówki and Ruszkówek, the sites of the high similarity of assemblages ($S_J = 61\%$), were described as shallow, richly vegetated lentic water-bodies (Szałamacha, Skompski 1999 and Kozydra, Skompski 1995, respectively). Besides eight common species, present in the remaining six littoral assemblages too, to the high similarity between these two assemblages contributed also "*Candoniella" subellipsoida* (species unknown ecologically and probably conspecific with juveniles of *Candona neglecta*), *Fabaeformiscandona levanderi* and *Pseudocandona albicans*. Two halophilic species strongly associated with salty coastal and inland waters (*Cyprideis torosa* and *Heterocypris salina*) in Krzyżówki could suggest that this water-body was either in receipt of (surface) brackish water run-off or was situated on the waterfowl migration route. On the other hand, *Scottia tumida* and *Potamocypris negadaevi* (both fossil species) as well as *Ilyocypris bradyi* were good discriminators for the assemblage from Ruszkówek (Table 1).

Basing on the six littoral assemblages (Kruklanki, Krzyżówki, Nędzerzew, Poznań-Główna, Poznań-Szeląg and Ruszkówek) one is able to characterise an ostracod taxocenose typical for the lacustrine littoral zone *sensu lato* of the Eemian Interglacial in Poland. This coenological unit may be identified by the nine key species: *Candona candida*, *Fabaeformiscandona protzi*, *Pseudocandona compressa*, *Cyclocypris ovum*, *Darwinula stevensoni*, *Candona neglecta*, *Limnocythere inopinata*, *Limnocytherina sanctipatricii* and *Metacypris cordata*.

Providing examples of information that ostracods can yield, this study should promote the use of these animals in Quaternary research. Although ostracods are still less routinely studied than other fossils, they have excellent potential as palaeoenvironmental indicators. Any new site of the Eemian Interglacial with non-marine ostracods will be extremely valuable for more comprehensive survey of the ostracod fauna of this interglacial.

SUMMARY

1. From lacustrine chalk of the Eemian Interglacial at Kruklanki (NE Poland) ca. 2450 non-marine ostracod valves belonging to 18 species have been recovered.

2. The results of the previous study on ostracods from Kruklanki (Kociszewska-Musiał 1987) have been revised. Rich material allowed for identification of five new species in this site.

3. For each taxon its ecological distribution, environmental preferences as well as its geographical and stratigraphical ranges have been given.

4. Ilyocypris decipiens and *Cyclocypris serena* have been found for the first time in Polish while *Leucocythere mirabilis* and *Pseudocandona insculpta* in European (excluding the former USRR countries) Eemian sediments.

5. The assemblage from Kruklanki has been characterised zoocoenologically. Four dominant species *Candona neglecta*, *Limnocytherina sanctipatricii*, *Limnocythere inopinata* and *Candona candida* accounted for 86% of the total abundance.

6. Palaeoenvironmental reconstruction has been derived from the perceived autecology of individual species. It was documented that the Kruklanki assemblage lived in deeper littoral (at the limit of rooted plants) of a comparatively large lake with cold, well oxygenated and calcium rich waters.

7. Both, classification by UPGMA method and ordination by MDS technique of nine Polish Eemian ostracod assemblages revealed a discrete cluster of six assemblages. They represent one taxocenose typical for the lacustrine littoral *sensu lato* of the Eemian Interglacial, which may be identified by nine key species: *Candona candida*, *Fabaeformiscandona protzi*, *Pseudocandona compressa*, *Cyclocypris ovum*, *Darwinula stevensoni*, *Candona neglecta*, *Limnocythere inopinata*, *Limnocytherina sanctipatricii* and *Metacypris cordata*.

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