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MOLLUSCAN ASSOCIATIONS WITH THE CLAUSILIID *ALINDA BIPLICATA* (MONTAGU, 1803) (GASTROPODA: PULMONATA: CLAUSILIIDAE) IN FLOODPLAIN FORESTS AT THE NORTH-EASTERN EDGE OF ITS RANGE

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ABSTRACT: We quantified the mollusc assemblage composition in eight riverine forests inhabited by the door snail *Alinda biplicata* (Montagu) in Central Poland where it occurs at the north-eastern border of its distribution range. In each location, eight random 0.25 m^2 plots were quantitatively sampled from a 400 m^2 core area that was searched for additional species. A total of 54 species were found, composed of 46 terrestrial snails and slugs, six freshwater gastropod and two clam species. Abundances ranged from 220 to 4,400 ind.m^{-2} per location, with a maximum of 2,200 individuals per plot. The number of taxa ranged from 17 to 34 per location and from 3 to 23 per plot. *A. biplicata* occurred in each randomly sampled plot. The highest number of co-occurrences with *Alinda* was found for *Carychium tridentatum* and *Nesovitrea hammonis*. Additionally, forest-specific, wetland-specific and even dry habitat-specific snails can use the same patch of microhabitat. The lack of narrow ecological specialisation in *A. biplicata* may favour its presence in man-made habitats where it is sometimes considered an invasive native gastropod. The species list included invasive *Arion vulgaris* and some other species with a mainly West European distribution, such as *Oxychilus draparnaudi*, *O. alliarius*, *Arion rufus*, *Cepaea nemoralis* and *C. hortensis*. The eastern borders of the native ranges of these species reach into the western part of Poland but in the sampled region they seem to be recent arrivals. Our results indicate that "western" (Atlantic) faunal elements benefit from more balanced microclimate in wet floodplain forests, which possibly reduces macroclimatic constraints at their distribution border.

KEY WORDS: alder forest, Clausiliidae, diversity, Gastropoda, land snails, Mollusca, stream

INTRODUCTION

Alinda biplicata (Montagu, 1803) is a clausiliid inhabiting humid floodplain forests, woody successions, sometimes parks and gardens, and other shaded habitats (KERNEY et al. 1983). It usually lives on the ground, but often climbs tree trunks and occasionally can be found on exposed rocks and old walls (WIKTOR 2004). The species reaches its north-eastern distribution border in Poland: in the lowlands it does not cross the Vistula river, while in the Carpathians it reaches to the Wisłoka river valley (RIEDEL 1988). The limited distribution of the species to the east probably is linked to some climatic factor such as the January isotherm of –2°C, which crosses Poland almost longitudinally and runs through its central part (vicinity of Łódź).

In the region of Łódź, *A. biplicata* was previously known from only two sites (PIECHOCKI 1963, 1966), but it recently was found in abundant populations in several floodplain forests (SULIKOWSKA-DROZD 2010, and unpublished).

The mollusc assemblage composition of some of these sites has not yet been studied quantitatively, thus we aimed at quantifying the malacocoenoses and intended to analyse species co-occurring with *A. biplicata* at the small spatial scale. Additionally, we wished to define the ecological requirements of the species found in riverine forest in Central Poland.

METHODS

STUDY AREA

The study was conducted in the vicinity of Łódź (Łódź Upland), in the area adjacent to the main watershed between the Vistula and the Odra rivers (Fig. 1). We selected floodplain forests inhabited by *Alinda biplicata*. European alder (*Alnus glutinosa*) was the characteristic tree species in all forests, with admixture of *Acer platanoides*, *A. pseudoplatanus*, *A. negundo*, *Quercus robur*, *Betula pendula*, *Carpinus betulus*, *Ulmus laevis* and *Picea abies* at some locations. All sites were located at the upper courses of streams (0.5–3 m wide) that are tributaries of the Bzura River (Wrząca, Czarnawka, Moszczenica) and the Ner River (Łódka). The selected riparian forests are irregularly inundated, usually after local rainfall in the summer. Additionally, they tend to have moist areas from local groundwater discharge. Two of the locations are protected as nature reserves, namely "Grądy nad Moszczenicą" and "Polesie Konstantynowskie".

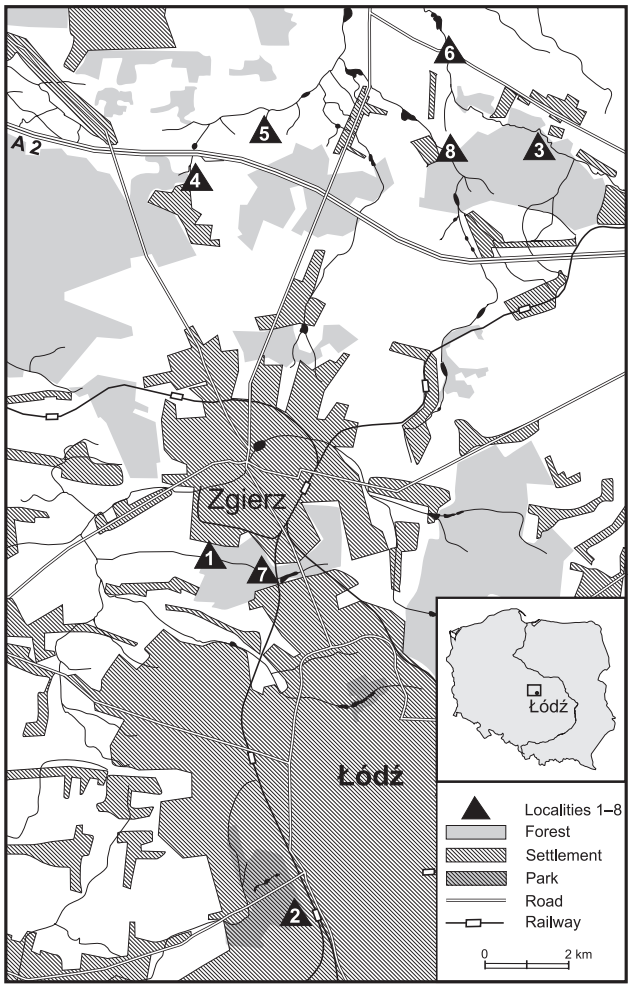

Fig. 1. Geographic position of the studied locations: 1 – Szczecińska, 2 – Polesie Konstantynowskie, 3 – Grądy nad Moszczenicą, 4 – Rosanów, 5 – Dzierżązna, 6 – Wola Branicka, 7 – Helenówek, 8 – Czarnawka

We recorded the local habitat characteristics in terms of the average breast height diameter of trees, the amount of deadwood per hectare and soil pH. We additionally estimated the cover of the tree, shrub, herb and moss layer (to the nearest 5%) and identified tree species. The habitat characteristics are presented in Tables 1–4.

SAMPLING

Sampling was performed in spring and early summer 2010. We considered one quadrat of 20 m × 20 m per location, as suggested for land snail forest sampling by CAMERON & POKRYSZKO (2005). In each of the eight locations, we took substrate samples, such as decaying herbs and leaf litter, from eight random plots to quantify alpha diversity and density of the molluscs. Each plot covered an area of 50 cm × 50 cm (0.25 m²), thus a total of 2 m² were sampled at each site. Only living specimens were counted. We additionally collected molluscs from tree trunks and fallen logs within the location. These species were added to the species list of the location (the beta diversity), but not to assemblage density calculations.

The identification of molluscs followed KERNEY et al. (1983), WIKTOR (2004), GLÖER & MEIER-BROOK (2003) and PINCEEL et al. (2004). Taxonomic placement followed WELTER-SCHULTES (2012) but based on NORDSIECK (2007) we used for our focal clausiliid the generic name *Alinda* instead of *Balea*. Authorities for species names are given in Tables 1–4. The distribution ranges of some species were classified as "western" according to the maps in KERNEY et al. (1983), WIKTOR (2004) and WELTER-SCHULTES (2012). We also adopted the classification of mollusc species into ecological groups proposed by LOŽEK (1964) and

Table 1. Habitat characteristics, list of molluscs and their abundance in localities 1 (Szczecińska) and 2 (Polesie Konstantynowskie). Grey fields indicate the presence of the species at the locality but not in the quantitative samples

Location no.	1								2							
Location name	Szczecińska								Polesie Konstantynowskie							
Sampling date	2010.05.15								2010.05.20							
Dominant tree species	*Alnus glutinosa*								*Acer platanoides, Alnus glutinosa*							
Canopy layer %	40								60							
Bush/herb/moss cover %	90/30/30								70/70/30							
Deadwood volume (m^3/ha)	90.2								47.8							
Mean soil pH	4.7								4.4							
Coordinates	19.39612°E; 51.83495°N								19.41713°E; 51.75874°N							
Subsample	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Galba truncatula (O. F. Müller, 1774)	4	0	0	0	0	0	1	0	–	–	–	–	–	–	–	–
Bathyomphalus contortus (Linnaeus, 1758)	2	0	0	0	0	0	1	0	–	–	–	–	–	–	–	–
Carychium minimum O. F. Müller, 1774	68	0	0	0	0	0	22	1	–	–	–	–	–	–	–	–
Carychium tridentatum (Risso, 1826)	25	0	0	0	9	17	12	0	0	0	0	0	1	3	1	0
Succinea putris (Linnaeus, 1758)	20	0	0	0	0	2	8	0	–	–	–	–	–	–	–	–
Cochlicopa lubrica (O. F. Müller, 1774)	5	6	0	8	2	7	7	1	0	0	1	0	4	1	0	0
Cochlicopa nitens (M. von Gallenstein, 1848)	2	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–
Vallonia pulchella (O. F. Müller, 1774)	1	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–
Acanthinula aculeata (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	0	0	0	0	0	0	1	2
Columella edentula (Draparnaud, 1805)	1	0	0	0	0	0	1	1	–	–	–	–	–	–	–	–
Vertigo pusilla O. F. Müller, 1774	–	–	–	–	–	–	–	–	0	0	0	0	0	0	0	1
Alinda biplicata (Montagu, 1803)	45	19	36	42	26	29	52	4	22	7	7	11	4	45	24	20
Punctum pygmaeum (Draparnaud, 1801)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Discus rotundatus (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	11	3	16	16	7	10	16	14
Vitrea crystallina (O. F. Müller, 1774)	1	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–
Zonitoides nitidus (O. F. Müller, 1774)	12	0	0	0	0	0	26	0	–	–	–	–	–	–	–	–
Oxychilus draparnaudi (H. Beck, 1837)	3	0	0	6	0	5	6	0	–	–	–	–	–	–	–	–
Oxychilus alliarius (J. S. Miller, 1822)	0	0	0	0	0	2	0	25	0	0	6	3	3	3	0	0
Aegopinella pura (Alder, 1830)	7	0	0	11	1	1	8	0	13	12	4	8	2	1	3	0
Nesovitrea hammonis (Strøm, 1765)	1	13	0	15	21	29	0	2	0	1	6	3	15	19	3	2
Nesovitrea petronella (L. Pfeiffer, 1853)	0	0	0	0	0	3	0	0	–	–	–	–	–	–	–	–
Limax maximus Linnaeus, 1758	0	0	0	1	0	0	0	0								
Malacolimax tenellus (O. F. Müller, 1774)	0	0	0	0	0	0	0	0								
Limacidae juv. non det.	0	0	0	0	0	0	0	0								
Deroceras laeve (O. F. Müller, 1774)	0	0	0	0	0	0	0	0								
Arion rufus (Linnaeus, 1758)	–	–	–	–	–	–	–	–								
Arion vulgaris Moquin–Tandon, 1855									–	–	–	–	–	–	–	–
Arion fuscus (O. F. Müller, 1774)	0	0	2	0	0	0	0	0								
Arion circumscriptus Johnston, 1828	0	2	0	0	0	0	0	0	–	–	–	–	–	–	–	–
Fruticicola fruticum (O. F. Müller, 1774)	5	6	5	13	30	40	17	0	0	0	3	0	1	1	0	3
Trochulus hispidus (Linnaeus, 1758)	14	5	4	1	7	0	9	0								
Monachoides incarnatus (O. F. Müller, 1774)	0	0	0	5	4	4	1	1	10	1	0	0	0	0	0	0
Perforatella bidentata (Gmelin, 1791)	1	0	0	3	0	1	0	0	–	–	–	–	–	–	–	–
Arianta arbustorum (Linnaeus, 1758)	–	–	–	–	–	–	–	–	3	4	9	5	18	6	2	2
Cepaea nemoralis (Linnaeus, 1758)	0	0	0	0	5	0	0	2	5	3	0	0	0	8	0	3
Cepaea hortensis (O. F. Müller, 1774)									–	–	–	–	–	–	–	–
Helix pomatia Linnaeus, 1758									–	–	–	–	–	–	–	–
Number of species per subsample	19	6	4	10	9	12	14	8	6	7	8	6	9	10	8	8
Number of individuals per subsample	219	51	47	105	105	140	171	37	64	31	52	46	55	97	52	47
Number of species (total)								29								17
Number of individuals per 1 m^2								438								222

Table 2. Habitat characteristics, list of molluscs and their abundance in localities 3 (Grądy nad Moszczenicą) and 4 (Rosanów). Grey fields indicate the presence of the species at the locality but not in the quantitative samples

Location no.	3								4							
Location name	Grądy nad Moszczenicą								Rosanów							
Sampling date	2010.05.29								2010.06.05							
Dominant tree species	*Acer pseudoplatanus, Quercus robur, Betula pendula, Alnus glutinosa*								*Alnus glutinosa, Acer platanoides, Acer pseudoplatanus, Betula pendula*							
Canopy layer %	50								60							
Bush/herb/moss cover %	50/80/10								60/80/0							
Deadwood volume (m^3/ha)	42.6								10.1							
Mean soil pH	5.0								4.2							
Coordinates	19.49841°E; 51.92278°N								19.38737°E; 51.91544°N							
Subsample	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Carychium minimum O. F. Müller, 1774	0	0	12	0	0	5	2	5	0	0	0	0	0	0	0	7
Carychium tridentatum (Risso, 1826)	13	7	10	1	0	42	21	16	0	0	0	1	0	0	33	66
Cochlicopa lubrica (O. F. Müller, 1774)	5	1	11	1	3	15	12	7	0	0	28	24	0	0	0	23
Cochlicopa lubricella (Rossmässler, 1834)	–	–	–	–	–	–	–	–	28	15	0	0	21	33	17	4
Acanthinula aculeata (O. F. Müller, 1774)	9	12	2	11	2	6	1	16	36	12	19	2	4	9	55	8
Columella edentula (Draparnaud, 1805)	1	1	0	1	0	2	0	3	–	–	–	–	–	–	–	–
Vertigo pusilla O. F. Müller, 1774	3	0	1	3	2	0	0	1	40	78	22	24	20	29	11	7
Vertigo substriata (Jeffreys, 1833)	–	–	–	–	–	–	–	–	6	4	1	1	3	6	10	17
Ruthenica filograna (Rossmässler, 1836)	0	1	4	4	12	15	10	10	–	–	–	–	–	–	–	–
Alinda biplicata (Montagu, 1803)	15	20	35	45	17	26	15	9	47	43	15	43	15	12	15	23
Punctum pygmaeum (Draparnaud, 1801)	1	15	3	3	1	3	2	1	50	35	90	83	109	84	23	2
Discus rotundatus (O. F. Müller, 1774)	86	90	25	14	7	2	0	33	0	0	0	0	0	0	8	21
Vitrea crystallina (O. F. Müller, 1774)	7	0	52	7	7	43	26	9	–	–	–	–	–	–	–	–
Vitrea contracta (Westerlund, 1871)	–	–	–	–	–	–	–	–	0	0	0	0	0	0	4	2
Euconulus fulvus (O. F. Müller, 1774)	1	0	4	3	0	2	0	0	0	0	0	0	0	0	0	6
Zonitoides nitidus (O. F. Müller, 1774)	0	0	3	2	1	8	3	0	0	0	0	0	0	0	0	2
Oxychilus alliarius (J. S. Miller, 1822)	5	0	0	0	0	0	0	4	0	0	1	1	0	0	2	8
Aegopinella pura (Alder, 1830)	27	37	21	25	8	24	5	23	0	2	6	4	1	0	36	2
Nesovitrea hammonis (Strøm, 1765)	2	12	16	14	6	18	15	12	13	10	15	21	31	34	27	39
Nesovitrea petronella (L. Pfeiffer, 1853)	0	0	0	0	0	0	1	0	–	–	–	–	–	–	–	–
Vitrina pellucida (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	11	27	5	15	11	5	7	2
Limax cinereoniger Wolf, 1803									–	–	–	–	–	–	–	–
Malacolimax tenellus (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	0	0	0	1	0	0	0	0
Limacidae juv. non det.	–	–	–	–	–	–	–	–	0	0	0	1	0	0	1	1
Arion fuscus (O. F. Müller, 1774)	0	0	1	2	0	1	0	0	–	–	–	–	–	–	–	–
Fruticicola fruticum (O. F. Müller, 1774)	4	5	0	1	0	3	3	0	–	–	–	–	–	–	–	–
Trochulus hispidus (Linnaeus, 1758)	–	–	–	–	–	–	–	–	0	0	0	1	0	0	0	0
Monachoides incarnatus (O. F. Müller, 1774)	10	5	1	5	2	0	1	3	0	0	2	0	1	0	1	0
Perforatella bidentata (Gmelin, 1791)	4	3	9	16	11	9	6	10	–	–	–	–	–	–	–	–
Cepaea nemoralis (Linnaeus, 1758)	–	–	–	–	–	–	–	–	1	0	0	1	1	0	4	0
Helix pomatia Linnaeus, 1758	1	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–
Number of species per subsample	17	13	17	18	13	17	15	16	9	9	11	15	11	8	16	18
Number of individuals per subsample	194	209	210	158	79	224	123	162	232	226	204	223	217	212	254	240
Number of species (total)								23								22
Number of individuals per 1 m^2								679.5								904

Table 3. Habitat characteristics, list of molluscs and their abundance in localities 5 (Dzierżązna) and 6 (Wola Branicka)

Location no.	5								6							
Location name	Dzierżązna								Wola Branicka							
Sampling date	2010.06.10								2010.06.16							
Dominant tree species	*Alnus glutinosa*								*Alnus glutinosa, Ulmus laevis, Acer negundo, Quercus robur*							
Canopy layer %	60								60							
Bush/herb/moss cover %	40/60/20								40/80/5							
Deadwood volume (m^3/ha)	7.9								3.9							
Mean soil pH	5								3.9							
Coordinates	19.41244°E; 51.92548°N								19.4755°E; 51.9418°N							
Subsample	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Carychium minimum O. F. Müller, 1774	5	5	0	0	0	0	0	9	–	–	–	–	–	–	–	–
Carychium tridentatum (Risso, 1826)	2	0	3	40	0	6	8	61	5	21	10	26	12	0	0	1
Succinea putris (Linnaeus, 1758)	3	0	1	0	0	0	0	1	11	31	16	49	21	3	0	3
Cochlicopa lubrica (O. F. Müller, 1774)	1	4	2	11	1	12	7	10	0	23	13	47	16	12	7	20
Acanthinula aculeata (O. F. Müller, 1774)	0	1	0	0	1	0	0	0	2	11	3	2	24	105	40	65
Columella edentula (Draparnaud, 1805)	0	0	1	0	0	0	0	0	0	3	0	2	9	23	0	2
Vertigo pusilla O. F. Müller, 1774	–	–	–	–	–	–	–	–	4	0	0	1	2	18	20	36
Vertigo substriata (Jeffreys, 1833)	1	2	1	2	0	1	0	1	0	0	0	0	0	0	1	0
Ruthenica filograna (Rossmässler, 1836)	–	–	–	–	–	–	–	–	0	2	1	0	2	15	7	12
Alinda biplicata (Montagu, 1803)	2	4	13	22	55	31	26	49	64	72	48	75	85	72	80	56
Punctum pygmaeum (Draparnaud, 1801)	0	0	1	1	0	0	0	4	1	0	2	1	1	4	9	6
Vitrea crystallina (O. F. Müller, 1774)	0	3	7	22	0	25	18	32	0	10	3	54	2	2	0	7
Euconulus fulvus (O. F. Müller, 1774)	0	0	1	0	0	0	0	2	0	1	0	0	0	5	6	13
Zonitoides nitidus (O. F. Müller, 1774)	4	12	6	1	0	30	5	18	0	3	0	0	1	2	11	9
Oxychilus alliarius (J. S. Miller, 1822)	3	0	22	11	3	0	12	3	–	–	–	–	–	–	–	–
Aegopinella pura (Alder, 1830)	0	0	2	0	0	0	0	1	8	31	21	23	115	145	67	71
Nesovitrea hammonis (Strøm, 1765)	0	18	7	8	14	26	1	10	26	14	17	28	12	28	40	60
Vitrina pellucida (O. F. Müller, 1774)	0	0	0	1	1	1	1	1	1	0	0	5	0	8	3	5
Deroceras laeve (O. F. Müller, 1774)	0	0	0	1	0	1	1	1	–	–	–	–	–	–	–	–
Arion rufus (Linnaeus, 1758)	–	–	–	–	–	–	–	–	0	2	0	0	1	0	0	0
Arion fuscus (O. F. Müller, 1774)	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Arion circumscriptus Johnston, 1828	–	–	–	–	–	–	–	–	0	1	0	0	2	0	0	0
Fruticicola fruticum (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	0	2	1	1	4	1	0	0
Monachoides incarnatus (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	4	4	1	6	6	7	2	5
Perforatella bidentata (Gmelin, 1791)	–	–	–	–	–	–	–	–	27	44	25	32	67	40	54	21
Helix pomatia Linnaeus, 1758	–	–	–	–	–	–	–	–	0	0	0	1	1	0	0	0
Number of species per subsample	9	8	13	11	7	9	9	15	11	17	13	16	19	18	14	17
Number of individuals per subsample	22	49	67	120	76	133	79	203	153	275	161	353	383	491	347	392
Number of species (total)								18								23
Number of individuals per 1 m^2								374.5								1,277.5

Table 4. Habitat characteristics, list of molluscs and their abundance in localities 7 (Helenówek) and 8 (Czarnawka). Grey fields indicate the presence of the species at the locality but not in the quantitative samples

Location no.	7								8							
Location name	Helenówek								Czarnawka							
Sampling date	2010.06.28								2010.07.03							
Dominant tree species	*Alnus glutinosa, Picea abies*								*Alnus glutinosa*							
Canopy layer %	50								40							
Bush/herb/moss cover %	30/95/15								20/80/10							
Deadwood volume (m³/ha)	27.9								8.6							
Mean soil pH	6.7								6.2							
Coordinates	19.40967°E; 51.83294°N								19.47465°E; 51.92038°N							
Subsample	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Platyla polita (W. Hartmann, 1840)	0	3	4	51	86	1	9	31	–	–	–	–	–	–	–	–
Galba truncatula (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	1	0	0	1	1	0	0	1
Stagnicola palustris agg. (juv.)	57	101	71	5	0	20	5	0	0	0	1	0	0	0	1	0
Aplexa hypnorum (Linnaeus, 1758)	0	6	190	1	0	4	0	0	–	–	–	–	–	–	–	–
Anisus leucostoma (Millet, 1813)	50	120	683	29	14	10	3	2	1	0	0	1	0	0	0	0
Bathyomphalus contortus (Linnaeus, 1758)	–	–	–	–	–	–	–	–	1	0	0	1	0	2	1	1
Gyraulus rossmaessleri (v. Auerswals, 1852)	0	0	99	0	0	0	0	0	–	–	–	–	–	–	–	–
Carychium minimum O. F. Müller, 1774	21	114	18	93	171	73	85	39	41	7	32	8	7	16	21	0
Carychium tridentatum (Risso, 1826)	16	14	0	68	98	22	67	43	21	19	20	7	7	15	27	62
Succinea putris (Linnaeus, 1758)	18	21	56	30	37	21	43	43	38	16	25	41	23	34	25	34
Cochlicopa lubrica (O. F. Müller, 1774)	15	23	10	23	45	22	31	23	13	8	7	14	5	13	10	12
Cochlicopa nitens (M. von Gallenstein, 1848)	14	10	3	25	9	7	8	10	–	–	–	–	–	–	–	–
Vallonia costata (O. F. Müller, 1774)	9	10	2	47	87	22	53	99	–	–	–	–	–	–	–	–
Vallonia pulchella (O. F. Müller, 1774)	0	7	0	1	2	5	6	1	–	–	–	–	–	–	–	–
Columella edentula (Draparnaud, 1805)	2	2	0	2	7	1	2	1	34	14	2	4	4	2	6	0
Vertigo pusilla O. F. Müller, 1774	–	–	–	–	–	–	–	–	0	0	0	0	1	0	0	0
Ruthenica filograna (Rossmässler, 1836)	–	–	–	–	–	–	–	–	0	0	0	2	0	0	1	1
Alinda biplicata (Montagu, 1803)	78	211	44	364	475	207	340	281	55	71	13	44	31	19	14	47
Punctum pygmaeum (Draparnaud, 1801)	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0
Discus rotundatus (O. F. Müller, 1774)	–	–	–	–	–	–	–	–	1	0	0	0	0	0	0	0
Vitrea crystallina (O. F. Müller, 1774)	3	2	1	43	47	5	59	51	39	38	8	43	17	21	15	19
Euconulus praticola (Reinhardt, 1883)	1	1	0	0	0	1	2	0	–	–	–	–	–	–	–	–
Zonitoides nitidus (O. F. Müller, 1774)	56	30	38	97	69	51	63	61	60	32	68	77	24	45	51	40
Oxychilus draparnaudi (H. Beck, 1837)	0	0	0	2	0	0	0	0	–	–	–	–	–	–	–	–
Oxychilus alliarius (J. S. Miller, 1822)									–	–	–	–	–	–	–	–
Aegopinella pura (Alder, 1830)	2	0	0	6	3	0	0	0	–	–	–	–	–	–	–	–
Nesovitrea hammonis (Strøm, 1765)	16	23	5	30	24	36	19	13	4	6	2	12	3	10	8	19
Nesovitrea petronella (L. Pfeiffer, 1853)	18	21	5	11	11	34	8	11	13	24	3	11	2	8	4	0
Vitrina pellucida (O. F. Müller, 1774)	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0
Limax cinereoniger Wolf, 1803	–	–	–	–	–	–	–	–								
Deroceras laeve (O. F. Müller, 1774)	0	0	0	1	0	0	0	0	–	–	–	–	–	–	–	–
Arion rufus (Linnaeus, 1758)	–	–	–	–	–	–	–	–								
Arion vulgaris Moquin-Tandon, 1855	1	0	0	0	0	0	0	0	–	–	–	–	–	–	–	–
Arion fuscus (O. F. Müller, 1774)									–	–	–	–	–	–	–	–
Fruticicola fruticum (O. F. Müller, 1774)	2	8	3	7	36	12	19	15	5	14	13	12	8	9	12	34
Trochulus hispidus (Linnaeus, 1758)	1	0	0	6	6	5	9	17	–	–	–	–	–	–	–	–
Pseudotrichia rubiginosa (Rossmässler, 1838)	4	7	6	8	11	9	21	21	2	1	0	0	1	0	0	0
Monachoides incarnatus (O. F. Müller, 1744)	–	–	–	–	–	–	–	–	2	0	0	0	0	1	0	4
Perforatella bidentata (Gmelin, 1791)	1	2	2	1	2	1	4	3	1	1	0	7	4	0	5	16
Cepaea nemoralis (Linnaeus, 1758)	–	–	–	–	–	–	–	–	0	0	0	0	0	0	0	2
Helix pomatia Linnaeus, 1758									0	0	0	0	0	0	0	1
Pisidium casertanum casertanum (Poli, 1791)	12	45	54	0	0	20	0	0	–	–	–	–	–	–	–	–
Pisidium personatum Malm, 1855	325	411	944	12	7	234	5	1	–	–	–	–	–	–	–	–
Number of species per subsample	23	23	20	25	22	24	23	21	19	13	12	16	15	13	17	15
Number of individuals per subsample	722	1,192	2,238	963	1,248	823	862	767	333	251	194	285	138	195	203	293
Number of species (total)							34									27
Number of individuals per 1 m²							4,407.5									948

modified by ALEXANDROWICZ (1987). This was restricted to snails and clams, because slugs were not always classified on the species level.

STATISTICS

ANOVA with Tukey HSD post-hoc test was used to compare the number of mollusc species and densities per plot among locations. A further comparison between locations was performed using the diversity estimators Chao1 and Chao2. When compared to the actual number of species found, these two indices provide an estimation of the completeness of sampling based on the number of species found only as one or two individuals, or in only one or two plots, respectively. Chao1 and Chao2 were recently suggested for forest gastropods by CAMERON & POKRYSZKO (2005). Chao1 and Chao2 values were calculated for each location separately in EstimateS, Version 8.2.0 (COLWELL 2006).

Species relative abundance and frequency of occurrence were also calculated from the plot data. At each site four most abundant terrestrial species (*A. biplicata* excluded) were classified as four top dominants, then Pearson correlation coefficients of their abundance and abundance of *A. biplicata* per plot were calculated in Statistica, Version 10.

RESULTS

SPECIES RICHNESS

At the eight studied localities, we found a total of 54 species. Of these, 39 were terrestrial snails and seven species were slugs. Freshwater molluscs were represented by six gastropod species and two clam species. At a single locality the total number of mollusc taxa varied two-folds, from 17 to 34 species (number of land snails ranged from 14 to 25; Tables 1–4). Within the 0.25 m^2 plots, a total of 52 species were recorded. The number of taxa per plot ranged from 3 to 23 (Fig. 2). Additional sampling by visual search in each locality revealed a few species which were not found within the eight plots. These species were added to the data in Tables 1–4. The values for Chao1 and Chao2 (Table 5) suggest that the species richness in some locations might be substantially higher than recorded in the eight forest floor plots.

ABSOLUTE AND RELATIVE ABUNDANCE OF SPECIES

The abundance of mollusc assemblages revealed by quantitative sampling ranged from 222 to 4,407 ind.m^{-2} per location (only live individuals were counted). The highest mollusc density per plot (0.25 m^2) was 2,238 individuals, the lowest density was 22 (Fig. 2). The abundance of *A. biplicata* per plot ranged from 2 to 475 individuals. The average density of its population estimated from plots ranged from 70 ind.m^{-2} to 1,000 ind.m^{-2} at a location.

In each location, *A. biplicata* was among most abundant species with the relative abundance above 10%. The extreme values of its relative abundance reached 28% at location 1 (Szczecińska). Other terrestrial species predominating in the assemblages (four top dominants) are listed in Table 6. No species was found in more than five out of eight sites as one of the top dominants. *Carychium tridentatum* and

Table 5. Species richness recorded at the eight localities and species richness estimation (Chao1 and Chao2 bias–corrected formula) based on the eight replicates covering a total area of 2 m^2 per location

Locality	Number of species in quantitative samples (8 × 0.25 m^2)	Total number of species, including qualitative samples	Chao1	Chao1 (95% conf. limits)	Chao2	Chao2 (95% conf. limits)
Szczecińska	26	29	26.6	26.1–33.1	30.1	26.8–46.4
Polesie	14	17	14	14	14.3	14.0–19.4
Grądy	22	23	23	22.1–36.3	22.4	22.0–29.4
Rosanów	22	22	22.5	22.0–30.3	24.9	22.4–41.6
Dzierżązna	18	18	18	18	18	18.0–19.1
Wola Branicka	23	23	23.5	23.0–31.3	23.2	23.0–27.3
Helenówek	31	34	32	31.1–41.7	35.4	31.7–59.5
Czarnawka	25	27	26.2	25.1–35.1	27.2	25.3–40.2

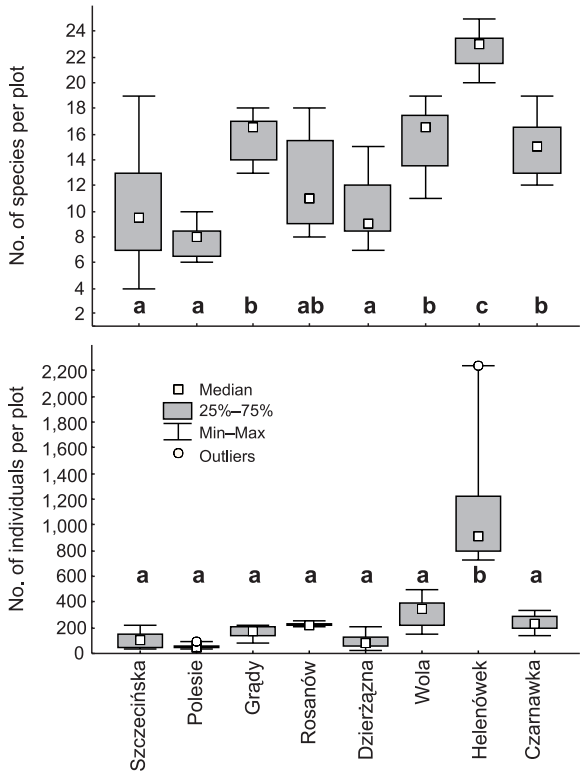

Fig. 2. Comparison of mollusc species numbers and densities per plot (n=8 per location) at different sites. Shared letters indicate no significant difference between locations (ANOVA with the Tukey post-hoc test)

N. hammonis were the only species in top four in sites and present in all remaining localities. Considering all mollusc taxa also *Anisus leucostoma* and *Pisidium personatum* reached relative abundance above 10% at a single location (Helenówek). Abundance of *A. biplicata* per plot was positively correlated with the number of individuals of *Carychium tridentatum, C. minimum, Zonitoides nitidus, Vitrea crystallina, Nesovitrea hammonis, Succinea putris, Fruticicola fruticum,* but not with the number of *Aegopinella pura, Discus rotundatus, Punctum pygmaeum, Vertigo pusilla* and *Perforatella bidentata* (Table 6).

FREQUENCY OF OCCURRENCE

The focus species, *A. biplicata*, occurred in all sampled plots (frequency of occurrence = 100%). The high constancy was found also for *N. hammonis* (60/64 plots; 94% of constancy), *Cochlicopa lubrica* (81%) and *C. tridentatum* (69%). Among species which were rarely found within the plots harbouring *A. biplicata,* some taxa reached high abundance (Tables 1–4). This mostly concerns freshwater snails and bivalves, such as *Anisus leucostoma, Aplexa hypnorum, Gyraulus rossmaessleri, Pisidium personatum, P. casertanum,* but also terrestrial snails such as *Platyla polita* and *Cochlicopa lubricella*.

Table 6. Fauna associated with *A. biplicata*. Relative abundances calculated for terrestrial gastropods alone

Species	Number of sites in which the species was in the "top four"	Relative abundance (%), if in the "four top" species of the site								Number of sites with the species	Number of plots with the species	Correlation between the abundance of the species and abundance of *A. biplicata* per plot (r Pearson)
		Sites										
		1	2	3	4	5	6	7	8			
C. tridentatum	5	7.2		8.1		16.0		6.2	9.4	8	44	0.66; p<0.000
N. hammonis	5	9.3	11.0		10.5	11.2	8.81			8	64	0.27; p=0.036
Z. nitidus	3					10.1		8.8	21.0	7	36	0.64; p<0.000
Ae. pura	3		9.7	12.5			18.8			7	39	n.s.
V. crystallina	3			11.1		14.3			10.6	6	36	0.52; p<0.000
C. minimum	2	10.4						11.6		6	26	0.86; p<0.000
A. aculeata	2				8.0		9.9			5	28	n.s.
D. rotundatus	2		21.0	18.9						4	18	n.s.
P. pygmaeum	1				26.0					8	31	n.s.
F. fruticum	1	13.3								6	37	0.44; p<0.000
S. putris	1								12.5	5	29	0.53; p<0.000
P. bidentata	1						12.2			5	33	n.s.
V. pusilla	1				12.8					5	21	n.s.
V. costata	1							6.2		1	8	0.89; p<0.000
A. arbustorum	1		11.0							1	8	n.s.

HABITAT PREFERENCES

The assemblages were composed of species that were classified as indicator species of several different habitats (Fig. 3). Typical forest dwellers (group 1), woodland species (group 2) and wetland species (group 9) were represented by several taxa, while eurytopic species (group 7) predominated in terms of species richness (Fig. 3A). The ecological groups had a similar distribution in terms of the numbers of individuals (Fig. 3B), but here, clams such as *P. personatum* (lotic habitats, group 12), were additionally highly abundant.

WEST EUROPEAN ZOOGEOGRAPHICAL ELEMENTS

We found six species that have their distribution ranges confined to Western or Western and Central Europe. These occurred in species pairs from the same genus, namely: *Oxychilus draparnaudi*, *O. alliarius*, *Arion rufus*, *A. vulgaris*, *Cepaea hortensis* and *C. nemoralis*. Of these species, *O. alliarius* and *C. nemoralis* occurred most frequently (at 6 and 4 locations, respectively) whereas *C. hortensis* was only found in a single location. The number of "western" species per location ranged from one to five. Three species or more were found at Szczecińska, Polesie and Helenówek localities. The relative abundance of the "western" species was higher than 5% at Szczecińska, Polesie and Dzierżązna, mostly because *O. alliarius* reached high densities (see Tables 1–4).

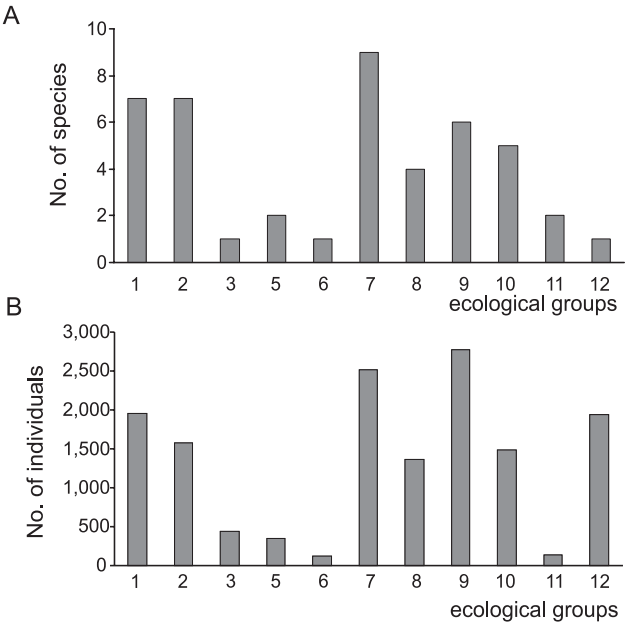

Fig. 3. Distribution of shelled molluscs of various ecological groups within the studied sites (*A. biplicata* excluded): A – number of species, B – number of individuals. Preferred habitats according to LOŽEK (1964), modified by ALEXANDROWICZ (1987): 1 – typical forest; 2 – different shaded habitats, 3 – very humid forests; 5 – open habitats of various classes of humidity; 6 – open, dry habitats; 7 – open or shaded habitat, medium humidity; 8 – open or shaded habitat, high humidity, 9 – very wet habitats, swamps, inundated areas; 10 – small, temporal water bodies; 11 – lakes, ponds; 12 – brooks and rivers

DISCUSSION

SPECIES RICHNESS AND COMPOSITION

The riparian alder forests harbouring *A. biplicata* appear to be rich in terms of species numbers (17–34 species per 400 m^2) but it is partly the effect of including the freshwater gastropods and clams co-occurring with land snails in swamps. The number of terrestrial shelled species, here 14–25, is below the richness reported for Polish lowland forests (17–35 species) (CAMERON et al. 2010). Regionally rare species such as *Platyla polita*, *Cochlicopa nitens*, *Nesovitrea petronella* and *Ruthenica filograna* were recorded, even though forest habitats are fragmented in the vicinity of Łódź (Fig. 1).

Our sampling design probably underestimated the species richness in some locations. For example, the number of terrestrial species found at Grądy nad Moszczenicą (23 species) was below values previously recorded by SULIKOWSKA-DROZD (2010) from the whole area of this nature reserve (34 species). The discrepancy may be at least partly associated with the heterogeneity of mesohabitat conditions within the reserve area, but diversity estimators also indicate that the randomly sampled total of 2 m^2 of forest floor did not cover total species richness within the location.

We found a surprisingly high number of species that have the cores of their distribution ranges in Western Europe and reaching as far as the western part of Poland with their native ranges (distribution maps published in KERNEY et al. (1983), WIKTOR (2004) and WELTER-SCHULTES (2012)). For example *O. draparnaudi*, *C. nemoralis* and *C. hortensis* were regarded as the Atlantic zoogeographic elements and in Central Poland inhabit only man-made habitats (RIEDEL 1988). According to RIEDEL & WIKTOR (1974), *Arion rufus* occurs in natural habitats in Western Poland and its native range should not reach the area of our study. Its population in Łódź was probably established by introduction in the 1960s (SULIKOWSKA-DROZD 2007). Similarly, the natural distribution of *O. alliarius* is confined to the influence of oceanic climate (RIEDEL 1988). At present,

the species occurs in several localities in Łódź and its vicinity (Piechocki 1963, Sulikowska-Drozd 2011, this study). We found also the major invasive slug in Europe – *A. vulgaris*, previously mistakenly recognised as *A. lusitanicus* (Welter-Schultes 2012). The first record of this slug from Poland dates back to the 1990s (Kozłowski & Kornobis 1995) and from Łódź to 2007 (Soroka & Kałuski 2011). Here, we found these alien species in semi-natural floodplain forests indicating that they are able to establish populations outside cities in Central Poland and may potentially be spread further along truck roads and rivers.

All these species might be regarded in Central Poland as recent arrivals from the west. It is likely that the mild microclimatic conditions in the moist floodplain forests mimic the lack of extreme cold conditions in the Atlantic Bioregion of Europe (e.g. Metzger et al. 2005) and thus support the presence of these snails and slugs. The microclimate of all the locations is influenced by both the river and groundwater discharge. It is known that high soil moisture and rich vegetation can buffer daily and annual temperature amplitudes (Geiger et al. 1995, and references therein). We suppose that the reduced cold and heat stress in floodplain forest might favour the presence of *A. biplicata* at the border of its distribution area. Similarly, *Cepaea* occurred in groundwater discharge areas in post-glacial Northern Europe (Jaeckel 1949), indicating that microhabitat use can ameliorate macroclimatic constraints.

Our results indicate the existence of some zoogeographical gradient in Central Poland where several species reach the easternmost distribution limit, probably in connection to the increasing continentality of climate. This was suggested by Pokryszko & Cameron (2005: p. 123, fig. 5) who calculated the similarity of land snail faunas across Europe. The malacocoenoses of Central Poland have ca. 40% similarity (Nei index) to westernmost localities in Ireland and 20–30% similarity to malacocoenoses of the Carpathians, while Ireland is more distant. Malacocoenoses located more to the east at the same latitude seem to have more affinity to the Carpathian fauna.

HABITAT PREFERENCES OF *A. BIPLICATA*

The 100% frequency of occurrence of *A. biplicata* within the studied plots suggests a wide tolerance of this clausiliid for light and moisture conditions, at least in the studied type of forest habitat. The study shows that *A. biplicata* has viable populations that can reach high densities (up to 1,000 ind.m^{-2}), especially if sampled in late spring/early summer when the reproduction peak of the species occurs (Sulikowska-Drozd et al. 2013). *Alinda biplicata* is accompanied by eurytopic species, but also by forest-specific, wetland-specific and occasionally even by dry habitat-specific species. High abundance of *A. biplicata* in the riverine forests may favour its spreading not only along rivers but also to adjacent drier habitats.

The lack of narrow microhabitat specialisation may favour the presence of *A. biplicata* in man-made habitats. According to Kerney (1999) and Welter-Schultes (2012), *A. biplicata* was introduced several hundred years ago in southern England, where it lived in ground litter at the river banks, commonly associated with human rubbish, and has also been successfully introduced to gardens. Spreading of *A. biplicata* on a local scale was recently recorded in NW. Germany (Kobialka et al. 2009). The number of occupied grids increased in Northrhine-Westphalia during the last decade(s) so it has been suggested that the species is an invasive native gastropod. Laboratory observation of its breeding biology revealed that *A. biplicata* overcomes environmental fluctuations by intrauterine egg retention and viviparity and possesses other life history traits of a good coloniser (Maltz & Sulikowska-Drozd 2012).

Assemblages of land snails and slugs occurring in riparian forests have been sampled by different authors, both from montane (Dyduch-Falniowska & Tobis 1989, Sulikowska-Drozd & Horsák 2007) and lowland rivers (Čejka 1999, 2005, Čejka et al. 2008, Kappes et al. 2007). According to Čejka et al. (2008), the ecological factor with the highest influence on mollusc species composition in floodplain forests is humidity, which is partly linked to flood frequency. At the scale of microhabitats, however, the co-occurrence of floodplain molluscs is still poorly understood and needs to be studied in more detail.

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