

CONTRIBUTION TO THE KNOWLEDGE OF NON-MARINE AQUATIC MOLLUSCAN FAUNA (GASTROPODA, BIVALVIA) OF PAG ISLAND (CROATIA)

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This paper presents the results of a malacological survey of Pag Island, which is among the largest islands of the Croatian coast, and is situated in the northern Adriatic Sea. Altogether 13 species of aquatic non-marine molluscs (12 gastropods, 1 bivalve) were found at 39 sites in 2009–2011. Three recorded species, *Hydrobia acuta*, *Myosotella myosotis*, *Ecrobia ventrosa*, inhabit brackish waters while the other species are freshwater molluscs. The occurrence of *Pseudamnicola conovula*, a mollusc endemic in several Croatian islands, was confirmed. *Kerkia kareli*, a species described in 2014, which inhabits phreatic waters, was found at three sites. Results of this research were compared with previous investigations and also with aquatic molluscan assemblages of other Croatian islands.

Key words: Mollusca, Gastropoda, Bivalvia, *Kerkia kareli*, *Pseudamnicola conovula*, Pag Island, Croatia, faunistics

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Rad predstavlja rezultate malakološkog istraživanja otoka Paga, jednog od najvećih hrvatskih otoka smještenog u sjevernom dijelu Jadrana. Tijekom perioda 2009–2011 na 39 lokaliteta zabilježeno je 13 vrsta slatkovodnih mekušaca (12 puževa, 1 školjkaš). Tri zabilježene vrste, *Hydrobia acuta*, *Myosotella myosotis* i *Ecrobia ventrosa*, nastanjuju bočate vode, a ostale vrste pripadaju slatkovodnim mekušcima. Potvrđena je prisutnost vrste *Pseudamnicola conovula*, endemskog mekušca nekoliko hrvatskih otoka. *Kerkia kareli*, vrsta opisana 2014. godine, koja nastanjuje vode freatika, nađena je na tri lokaliteta. Rezultati ovog istraživanja uspoređuju se s prošlim istraživanjima te s faunom vodenih mekušaca drugih hrvatskih otoka.

Ključne riječi: Mollusca, Gastropoda, Bivalvia, *Kerkia kareli*, *Pseudamnicola conovula*, otok Pag, Hrvatska, faunistika

INTRODUCTION

Pag is the fifth-largest island of the Croatian coast situated in the northern part of the Adriatic Sea. Aquatic molluscs of this island are poorly known. Land gastropods of Pag Island were recently studied by FISHER *et al.* (2000) and REISCHÜTZ & REISCHÜTZ (2005). Four sites in which non-marine aquatic molluscs occur are mentioned in FISHER *et al.* (2000) and one is given in REISCHÜTZ & REISCHÜTZ (2005), with records of *Bithynia tentaculata*, *Ventrosia cissana*, *Adrioinsulana conovula*, *Acroloxus lacustris*, *Stagnicola fuscus*, *Gyrarulus crista*, *Myosotella myosotis* and *Truncatella subcylindrica*. FISHER *et al.* (2000) also adduced older papers with several notes about aquatic gastropods e. g. FRAUENFELD (1863)

and BRUSINA (1866). RADOMAN (1973, 1977, 1983) mentioned the occurrence of only two hydrobioid snails from this island. *Ventrosia cissana* was recorded from brackish habitats, while *Adrioinsulana conovula* was found in several springs. SZAROWSKA (2006) published a record of *Adrioinsulana conovula* in a spring in Zubovici. On the base of a comparative study of the genus *Pseudamnicola*, this author found that there is no reason for distinguishing the genus *Adrioinsulana* and that *A. conovula* belongs to *Pseudamnicola* (SZAROWSKA *et al.*, 2006) and name *Pseudamnicola conovula* is also used in this paper. During faunistic research of this island, a new species was found in phreatic waters, which was described as *Kerkia kareli* (BERAN *et al.*, 2014) and its occurrence is also mentioned in this paper. The main aim of this research was to provide an inventory of aquatic non-marine molluscs inhabiting the island.

MATERIAL AND METHODS

Data were obtained from field surveys conducted in the summers of 2009, 2010 and 2011 and in winter 2011. Non-marine aquatic (freshwater, brackish) molluscs were studied only. Altogether 39 sites in which aquatic molluscs occur were studied: springs, wells, small (temporary) pools, marshes and ditches, a small lake (Veliko Blato) and also brackish canals and lakes. The main sampling method used for field research was washing vegetation or sediments using a metal sieve (a kitchen strainer, diameter 20 cm, mesh size 0.8 mm) combined with collections by hand after examination of the surfaces of plants, stones, wood and artificial materials (e.g. plastic bags and bottles). These methods were used in the case of this research, while wells were studied using this sieve on the

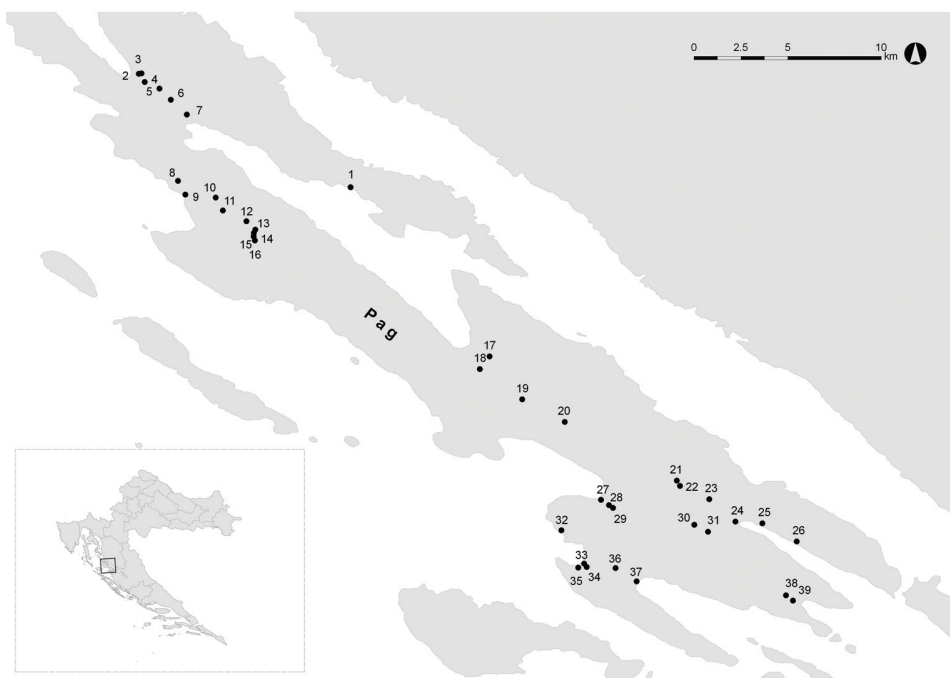


Fig. 1. Map of Pag Island with sites under study. Drawn by M. Dolejš.



Fig. 2. Veliko Blato (site No. 2). All photos by author.



Fig. 3. A spring in the valley near the west edge of Kolan (site No. 13).

end of a 2.5–3 m long stick. Aquatic molluscs were classified using various shell characteristics, or else were dissected and then identified using their copulatory organs if identification based solely on the shell was impossible. Specimens for dissection were killed in hot water and then fixed in 70% ethanol. Selected material of shells and killed specimens in 70% ethanol is deposited in author's collection.

STUDY AREA

Pag is a Croatian island in the north of the Adriatic Sea. It is the fifth-largest island of the Croatian coast, and the one with the longest coastline. This island belongs to the north-Dalmatian archipelago and it extends northwest-southeast along the coast, forming the Velebit channel. The island has an area of 285 km². It is around 60 km long (from northwest to southeast), and between 2 and 10 km wide. The southwestern coast of the island is low (Pag Bay with the large Caska Cove), and the north-western is steep and high. Most of the island is rocky and only smaller areas are covered with Mediterranean shrubs (ZÁBSKÝ *et al.*, 2011). The southeast of the island contains shallow lake, Veliko Blato (Fig. 2), and extensive marshes, Malo Blato. Other freshwater habitats consist of wells, springs (Fig. 3), small and temporary canals or brooks, pools and marshes. Brackish habitats contain small lakes (Fig. 4), lagoons, pools and canals (Fig. 5) especially in the lowest parts of the island.

LIST OF INVESTIGATED SITES

Data in the list are as follows: site number, geographical co-ordinates (<http://www.google.cz/>), name of the nearest settlement, description of the site, date of investigation. Sites are depicted in Fig. 1.

- 1 – 44°31'07"N, 14°59'38.8"E, Metajna, a small spring and a brook about 20 m from the sea northwest of Metajna, 2.7.2011;
- 2 – 44°34'13.7"N, 14°53'36.1"E, Stara Novalja, a well next to the church south of Stara Novalja, 31.12.2011;
- 3 – 44°34'13.1"N, 14°53'36.6"E, Stara Novalja, a large spring (pool) next to the church south of Stara Novalja, 31.12.2011;
- 4 – 44°33'56.2"N, 14°53'42"E, Stara Novalja, a temporary pool ca 500 m south of the church on the south edge of Stara Novalja, 31.12.2011;
- 5 – 44°33'44.6"N, 14°53'50.9"E, Novalja, a watering hole ca 1 km north-west of the road Novalja – ferry, 5.7.2011;
- 6 – 44°33'27.9"N, 14°54'20.1"E, Novalja, a watering hole near the local road ca 500 m north-west from the road Novalja – ferry, 5.7.2011;
- 7 – 44°33'16.4"N, 14°54'38"E, Caska, a small temporary ditch next to the road Novalja – Caska, 31.12.2011;
- 8 – 44°31'13.1"N, 14°54'52"E, Gajac, Kolanjsko Blato (brackish shallow lake) near Gajac (Fig. 4), 13.7.2010;
- 9 – 44°30'51"N, 14°54'56.9"E, Gajac, an outflow from Kolanjsko Blato (brackish shallow lake) near Gajac, 13.7.2010;
- 10 – 44°30'32.4"N, 14°56'12.5"E, Kolan, small pools in a dry stream of brook in fields, meadows and pastures south of Kolanjsko Blato, 12.7.2010;
- 11 – 44°30'23"N, 14°56'12.8"E, Kolan, small pools in a dry stream of brook in fields, meadows and pastures between Kolan and Kolanjsko Blato, 31.12.2011;
- 12 – 44°29'58.5"N, 14°57'02"E, Kolan, a new well in a valley north-west of Kolan, 31.12.2011;
- 13 – 44°29'49"N, 14°57'11.5"E, Kolan, a well and a spring in fields in a valley near the west edge of Kolan (Fig. 3), 13.7.2010, 29.12.2011;



Fig. 4. Kolanjsko Blato (brackish shallow lake) near Gajac (site No. 8).



Fig. 5. A brackish canal next the road Dinjiška – Povljana (site No. 24)

14 – 44°29'48"N, 14°57'06.5"E, Kolan, a small well in a valley near the west edge of Kolan, 31.12.2011;

15 – 44°29'45.3"N, 14°57'05.7"E, Kolan, a pool ca 200 m west of the spring in the valley on the west edge of Kolan, 13.7.2010;

16 – 44°29'43.6"N, 14°57'07"E, Kolan, an old well in valley ca 300 m west of Kolan, 31.12.2011;

- 17 – 44°26'10"N, 15°04'01.3"E, Pag, a canal along salt fields next the road, 7.7.2010;
- 18 – 44°25'47.5"N, 15°03'41"E, Pag, Veliki Izvor (spring) next to Stari Grad Pag, 2.7.2011;
- 19 – 44°24'54.5"N, 15°04'57.1"E, Pag, a brackish canal along the western bank of Solana Pag, 2.7.2011;
- 20 – 44°23'59.8"N, 15°06'14.3"E, Gorica, a brackish canal along the western bank of Solana Pag, 2.7.2011;
- 21 – 44°22'49.8"N, 15°08'56.6"E, Stara Vas, a spring next to the road north-west of Stara Vas, 1.7.2011;
- 22 – 44°22'27.3"N, 15°09'10.1"E, Stara Vas, a small area of wetland north-west of Stara Vas, 1.7.2011;
- 23 – 44°22'22"N, 15°09'38"E, Stara Vas, a small spring in meadow next to the road Pag – Dinjiška, 12.7.2010;
- 24 – 44°21'55.2"N, 15°10'03.3"E, Dinjiška, a canal next to the road Dinjiška – Povljana (Fig. 5), 7.7.2010;
- 25 – 44°21'46.3"N, 15°10'46.7"E, Dinjiška, a canal next to the road Ražanac – Pag near Dinjiška, 7.7.2010;
- 26 – 44°20'42"N, 15°12'50"E, Dinjiška, a spring next to the road Miškovići – Dinjiška, 1.7.2011;
- 27 – 44°22'10.4"N, 15°06'51.4"E, Povljana, a canal in Malo Blato next to the road Povljana – Pag, 7.7.2010;
- 28 – 44°22'03.5"N, 15°07'1.6"E, Povljana, a canal in Malo Blato 300 m from the sea, 7.7.2010;
- 29 – 44°22'0.7"N, 15°07'06.4"E, Povljana, the wetland Malo Blato north-east of Povljana, 1.7.2011;
- 30 – 44°21'38.8"N, 15°08'48"E, Povljana, a northwestern part of Veliko Blato, 7.7.2010;
- 31 – 44°21'32"N, 15°09'25.3"E, Povljana, a northern part of Veliko Blato (Fig. 2), 7.7.2010;
- 32 – 44°21'13.4"N, 15°05'46.2"E, Povljana, a brackish pool next to the sea on the north-west edge of Povljana, 29.12.2011;
- 33 – 44°20'33"N, 15°06'31"E, Povljana, two wells ca 100 m from St. Nicholas, 4.7.2011;
- 34 – 44°20'31"N, 15°06'44.3"E, Povljana, an old well next to the local road ca 400 m east of St. Nicholas, 4.7.2011, 29.12.2011;
- 35 – 44°20'21"N, 15°06'24"E, Povljana, two ditches ca 400 m south of St. Nicholas, 4.7.2011;
- 36 – 44°20'14.5"N, 15°07'10"E, Povljana, a well next to the road to St. Martin, 4.7.2011;
- 37 – 44°19'46.5"N, 15°07'54.4"E, Povljana, marshes next to the sea in Stara Povljana, 4.7.2011;
- 38 – 44°19'23.1"N, 15°12'16"E, Vlašići, marshes 800 m from the sea in Vlašići, 4.7.2011;
- 39 – 44°19'13.6"N, 15°12'25.2"E, Vlašići, saline marshes in the bay in Vlašići, 4.7.2011;

RESULTS

Altogether 13 species of aquatic non-marine molluscs (12 gastropods, 1 bivalve) were found at 39 sites at Pag Island. A list of molluscs found at particular sites and their densities are shown in Tab. 1.

Tab. 1. List of aquatic molluscs recorded at studied sites. x – few specimens, xx – scattered occurrence, xxx – abundant occurrence, (x) – old shells.

Species	Site No.																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Gastropoda	1																				
<i>Bithynia tentaculata</i> (Linnaeus, 1758)																					
<i>Kerkia kareli</i> (Beran, Bodon & Cianfanelli, 2014)												xxx	x								
<i>Ecrobia ventrosa</i> (Montagu, 1803)							xxx	xxx	xxx								xxx		xxx		xx
<i>Hydrobia acuta</i> (Draparnaud, 1805)																					
<i>Pseudamnicola conovula</i> (Frauenfeld, 1863)												xxx	x		xxx			xxx			
<i>Acroloxus lacustris</i> (Linnaeus, 1758)																					
<i>Galba truncatula</i> (O. F. Müller, 1774)	xx			x	x		xx				xxx					x					
<i>Stagritcola fuscus</i> (C. Pfeiffer, 1821)		x	xxx																		
<i>Anisus spirorbis</i> (Linnaeus, 1758)					xx	x				x			xx	xxx	xxx						
<i>Gyraulus crista</i> (Linnaeus, 1758)																					
<i>Ancylus fluviatilis</i> O. F. Müller, 1774										x			xx								
<i>Myosotella myosotis</i> (Draparnaud, 1801)																	x				
Bivalvia																					
<i>Pisidium casertanum</i> (Poli, 1791)													xx			xx					
Number of species	1	1	1	1	2	1	1	1	1	2	1	1	5	2	1	3	2	1	1	1	1

Species	Site No.																Σ			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		37	38	39
Gastropoda	21								xx	x	x									4
<i>Bithynia tentaculata</i> (Linnaeus, 1758)														xxx						3
<i>Kerkia kareli</i> (Beran, Bodon & Cianfanelli, 2014)				xxx	xxx														x	8
<i>Ecrobia ventrosa</i> (Montagu, 1803)							xx	xx				xxx								3
<i>Hydrobia acuta</i> (Draparnaud, 1805)						xxx														6
<i>Pseudamnicola conovula</i> (Frauenfeld, 1863)	xxx																			2
<i>Acroloxus lacusiris</i> (Linnaeus, 1758)								xx	xx	x										16
<i>Galba truncatula</i> (O. F. Müller, 1774)	x	x	xxx			x								xx	xx	xxx	x	x		6
<i>Stagnicola fuscus</i> (C. Pfeiffer, 1821)									x	xxx	x									8
<i>Anisus spirorbis</i> (Linnaeus, 1758)													xx		xxx					4
<i>Gyraulus crista</i> (Linnaeus, 1758)									x	x	x									2
<i>Ancylus fluviatilis</i> O. F. Müller, 1774																				3
<i>Myosotella myosotis</i> (Draparnaud, 1801)							x	x												
Bivalvia																				
<i>Pisidium casertanum</i> (Poli, 1791)	xx																			3
Number of species	3	1	1	1	1	2	2	5	4	4	3	1	2	2	2	1	1	1	1	

Many other sites which looked suitable for aquatic molluscs, e. g. several small pools next to the road Novalja – Lun, were also visited but yielded no records and are not mentioned. Most of the sites with positive occurrences of aquatic molluscs were inhabited by only one or two species (Tab. 1). As many as four or five species were recorded at only four sites. The richest and also the most extensive freshwater habitats are Malo Blato (extensive marshes) and Veliko Blato (small permanent and shallow lake). *Bithynia tentaculata*, *Acroloxus lacustris*, *Stagnicola fuscus* and *Gyraulus crista* were found at both sites (loc. 28–31). Snails *B. tentaculata*, *A. lacustris* and *G. crista* were documented only from these localities while *S. fuscus* was found at other two sites, the well and the large spring near Stara Novalja (loc. 2 and 3). In the canal between Malo Blato and Adriatic Sea (loc. 28) these species were recorded together with *Myosotella myosotis* and *Hydrobia acuta* which inhabit brackish waters. The determination of the second species is preliminary due to the existence of cryptic species without any anatomical differences among the taxa of *Hydrobia sensu stricto* (WILKE *et al.*, 2000) and the absence of genetic data from the population of this island. Both *M. myosotis* and *H. acuta* were found at three sites. *Ecrobia ventrosa* is the most widespread snail in brackish water such as small lakes, lagoons and canals on Pag Island and was recorded at 8 sites.

Another rich freshwater site was the spring near Kolan where five species, *Kerkia kareli*, *Pseudamnicola conovula*, *Anisus spirorbis*, *Ancylus fluviatilis*, *Pisidium casertanum* were recorded. Snail *K. kareli*, a new species that inhabits phreatic waters, was found during this research and was described from two wells and one spring on Pag Island (BERAN *et al.*, 2014). *Pseudamnicola conovula* was found at six sites, springs or wells. *Ancylus fluviatilis* was recorded only at this locality and a few specimens were also found in pools in a dry temporary brook several hundred metres from that site while *Anisus spirorbis* is one of the most often recorded species and was found at 8 sites. *Pisidium casertanum* was the only species of Bivalvia documented on Pag Island that inhabits springs at 3 studied sites. The most common species *Galba truncatula* was found at 16 sites, and in 9 of them was the only aquatic mollusc.

Nearly half (6) of the recorded species are molluscs with an extensive distribution range (Holarctic, Palaearctic, Euro-Siberian). The other 5 molluscs are species common in a large part of Europe. Only two species, *Kerkia kareli* and *Pseudamnicola conovula*, are molluscs known from restricted areas. *Kerkia kareli* was known only from phreatic waters on Pag Island (BERAN *et al.*, 2014) but was also found on Rab Island in 2013 (BERAN *et al.*, 2014). *Pseudamnicola conovula* is considered an endemic species of several islands (Pag, Cres, Krk, Rab) and the adjoining coast (RADOMAN, 1983).

DISCUSSION

Before this research 8 aquatic molluscs were known to occur on Pag Island. All these species except the widespread brackish *Truncatella subcylindrica* were recorded in 2009–2011. RADOMAN (1983) described from brackish waters the species *Ventrosia cissana* (Radoman, 1983) which was later also mentioned by FISHER *et al.* (2000). At present, this taxon is considered only as a synonym of the common and widespread species *Ecrobia ventrosa*. Dissection of material from 8 sites were considered to reveal only the occurrence of *E. ventrosa*.

With findings of only 13 species of non-marine molluscs on an island with an area of 285 km² it might seem that the aquatic molluscan fauna of Pag Island is poor; however, the richness or poverty of the molluscan assemblages corresponds with character of the

Tab. 2. Comparison of aquatic non-marine molluscs of researched islands: BOLE, 1958 (Krk), RADOMAN, 1983 (Krk, Brač, Korčula), ŠTAMOL & POJE 1998 (Susak); REISCHÜTZ & REISCHÜTZ, 1999 (Vis), REISCHÜTZ & REISCHÜTZ, 2000 (Mljet), REISCHÜTZ *et al.*, 2002 (Korčula), BERAN (unpublished records) (Brač), this paper (Pag).

Island	Brač	Korčula	Krk	Mljet	Pag	Susak	Vis
size (km ²)	394,6	276	405,8	100,4	284,6	4	90,3
distance from mainland (km)	6	1	1	6	2	68	43
number of brackish species	3	2	0	2	4	0	2
number of freshwater species	3	3	10	1	10	0	0

island. No permanent stream exists in the island, and most of the freshwater habitats consist of artificial wells, springs or small and temporary pools, the small lake Veliko Blato and the extensive marshes Malo Blato. On the other hand, a comparison with known aquatic non-marine molluscan fauna of other Croatian islands showed that the molluscan assemblages of Pag Island are among the richest or at least the best known (Tab. 2). Terrestrial snail fauna was studied more often and in greater detail than the non-marine molluscs of the same islands (e. g. ŠTAMOL & VELKOVRH, 1995; ŠTAMOL, 1995; ŠTAMOL & KLETEČKI, 2005) and it is not possible to compare the aquatic molluscan assemblages of Pag Island with other Croatian islands.

CONCLUSIONS

The research into aquatic non-marine molluscs of Pag Island surprisingly documented the occurrence of 13 species including one rare endemic species *Pseudamnicola conovula*, while another species, *Kerkia kareli*, was described from this island. The first mentioned species might have been affected especially by man-made changes of springs and the second by pollution of phreatic waters. Comparison with aquatic molluscan fauna of other Croatian islands shows that the molluscan assemblages of Pag Island are among the richest or at least the best known. Because aquatic molluscs of many Croatian islands are poorly known, the results of research into Pag Island are a precondition for a continuation of the study of non-marine aquatic molluscs of other Croatian islands.

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