

LITERATURE REVIEW OF TERRESTRIAL SNAIL RESEARCH FOR SEVERAL CROATIAN ISLANDS

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A review of the malacological literature established the number and type of papers containing data on the terrestrial malacofauna of the Croatian islands Cres, Susak, Dugi otok, Kornat, Brač, and the archipelagos of Telašćica Nature Park and Kornati National Park. The total number of taxa of terrestrial snails and their localities on each analysed island and archipelago was also established. The thoroughness of the investigation of these islands and archipelagos was assessed according to the number of snail taxa and localities listed, and to the representation of small snail species. This allows for an assessment of the knowledge of their malacofauna and the determination of priority islands and archipelagos for future research on terrestrial snails.

Key words: literature data, terrestrial gastropods, islands, Croatia

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Pregledom malakološke literature ustanovljen je broj i vrsta radova u kojima se nalaze podaci o kopnenoj malakofauni hrvatskih otoka Cresa, Suska, Dugog otoka, Kornata, Brača, te otočja Parka prirode »Telašćica« i Nacionalnog parka »Kornati«. Također je utvrđen ukupno poznati broj svojiti i nalazišta na svakom istraženom otoku i otočju. Na temelju broja vrsta puževa i lokaliteta koja se navode kao nalazišta puževa, te na temelju zastupljenosti malih vrsta puževa ocijenjena je sustavnost radova koji obrađuju proučene otoke i otočje. To je omogućilo ocjenu poznavanja njihove malakofaune i određivanje prioritetenog otoka i otočja u potrebi istraživanja kopnenih puževa.

Ključne riječi: literaturni podaci, kopneni puževi, otoci, Hrvatska

INTRODUCTION

The study of the fauna of a region is tied to field study and/or a review of the literature data. Literature data, if recent, comprehensive and based on systematic research conducted using modern and accepted methods can provide an adequate knowledge of the fauna of an area. Systematised faunal studies from early research periods allow for the comparison of fauna then and now, and for an interpretation of the differences. Knowing the fauna also allows for further research, such as research on threats, distributions, zoogeography of the species and biodiversity of the area.

In researching terrestrial snails to date, the first author has primarily focused on island fauna. In this process, a review of literature data gave information about the types of works containing faunal data, just how systematically an area was investigated, what kind of species are within and the chronological changes in the characteristics of the works, data on localities and species. In this paper, the literature relating to the terrestrial snail fauna of five large eastern Adriatic islands in Croatia

(Cres, Susak, Dugi otok, Kornat and Brač), and the archipelagos of Telašćica Nature Park and Kornati National Park were examined in detail. The first author has conducted systematised studies of the terrestrial snail fauna of these islands and archipelagos, and has published results for the majority of these areas (ŠTAMOL, 1986, 2004; ŠTAMOL & VELKOVHR, 1995; ŠTAMOL & POJE, 1998; ŠTAMOL & KLETEČKI, 2005), while the publication of results of field studies of the island Kornat and other islands of Kornati National Park is in preparation. The aim of this study was to give a chronological overview of papers providing data on the terrestrial malacofauna of the analysed islands and archipelagos, to compare those data that can indicate their attractiveness and accessibility, and to assess the systematics of malacofauna research in the past and, based on these data, to give a final assessment of the knowledge of their malacofauna. In addition to providing a detailed analysis of the data from these islands and archipelagos, a very short overview of the research into Croatian islands is given.

METHODS OF PROCESSING LITERATURE DATA

Papers containing data on terrestrial gastropods are considered those works in which one or more taxa (species and/or subspecies) of terrestrial snails are listed, either with the scientific name, or with the common name, if this can undoubtedly be associated with recognised species or subspecies. Papers with data associated with an island are those works which list localities on that island where terrestrial snails are present or even where the entire island is noted.

The malacological literature data for five islands (Cres, Susak, Dugi otok, Kornat and Brač) were analysed in detail (hereinafter: analysed islands), and for the entire archipelago of Telašćica Nature Park, which includes 18 islands, islets and crags, and for the entire archipelago of Kornati National Park, which includes 87 islands, islets and crags (hereinafter: analysed islets or analysed archipelagos).

The detailed analysis included:

- the chronological course of the works with data on terrestrial malacofauna of analysed islands and islets,
- the number of papers listing malacofauna data of the analysed island and islet
- the number of localities of snails in papers for an analysed island or islet,
- the number of snail species in papers for an analysed island or islet,
- representation of small snail species in papers for an analysed island or islet,
- representation of the types of papers with malacological literature data for an individual island or islet.

For the sake of comparing the level of research conducted on an island, papers and snails were grouped according to certain criteria. Even though the analysed islands differ by size and by the number of species and subspecies of their malacofauna, it can still be considered acceptable for these criteria to be used in grouping papers based on the number of species and finding sites on an island in order to define how systematic the research was.

A) Grouping papers

1. according to the number of localities on an island listed in a paper as a site of terrestrial snails in five categories.

- papers listing the island as a snail site;
 - papers listing 1 locality on the island;
 - papers listing 2 to 5 localities;
 - papers listing 6 to 10 localities;
 - papers listing more than 10 localities.
2. according to the number of species of terrestrial snails on the island listed in the paper in five categories:
- papers listing 1 species;
 - papers listing 2 to 5 species;
 - papers listing 6 to 10 species;
 - papers listing 11 to 20 species;
 - papers listing more than 20 species of terrestrial snails for the investigated island.
3. according to the type of paper in six categories:
- general papers (lists, catalogues and the faunas of parts of Europe, Europe and beyond);
 - systematic (papers covering systematic groups: family, genus and more rarely, species);
 - papers describing a new taxa;
 - bibliographic papers and lists of collections;
 - faunistic papers covering larger or smaller sections of the Adriatic coast;
 - faunistic papers of the respective island.

B) Grouping snails

According to the size of the shell of the adult individual:

- large: shell of the adult individual larger than 10 mm;
- medium: shell of the adult individual from 5–10 mm;
- small: shell of the adult individual smaller than 5 mm

C) Chronological overview

For the analysed islands, the following was shown:

- percentage representation of size classes of snails of an individual island in 50 year periods;
- number of total known snail species on an individual island by decade;
- number of total known localities for a given island by decade;
- number of papers concerning terrestrial malacofauna of the island by decade.

The graphical depiction of the three latter data show how the number of papers in a given decade contributed to an increase in the study (in terms of increase in the number of localities and increase in the number of species) of the malacofauna of an island, and shows the total number of known species and researched localities on a given island.

D) Defining the attractiveness and accessibility of an island

The attractiveness of the island is indicated in part by the number of papers concerning terrestrial snails for that island. Islands that are more interesting to malacologists were visited more often, as seen by the larger number of papers. The number of papers also depends on the accessibility of the island, and so more isolated islands, though attractive, were visited less often and there are fewer papers concerning them.

E) Defining how systematised the research was

The number of localities with snail finds, number of snail species, representation of small snail species, and the representation of the types of papers in the literature of an island give an idea of the degree of systematisation of the research on the analysed islands, islets and archipelagos.

Papers listing only the island in question, or just one locality on the island (and those listing up to five localities) as snail sites certainly indicate a lack of systematised study. The existence of exclusively such papers indicates that these islands have been insufficiently studied. Yet the domination of such papers need not indicate that the research was ultimately non-systematised, as only one, proper and thorough paper is needed for the fauna of an area to be investigated to a satisfactory level.

Papers recording only one or a small number of species for larger islands are not systematised studies given the overall malacofauna of the island in question. The domination of papers with a small number of species indicates that non-systematised malacofauna papers dominate the literature for that island, however, as for the localities, this need not confirm an ultimate lack of thorough research of that island.

The malacofauna of individual island is not thoroughly investigated in general and systematic papers (monograph of the genus or family), in the former due to the broad scope, and in the latter due to the small number of species investigated. The opposite should be malacofauna papers for a given island (»island papers«). A larger number of »island papers« in the literature of an island in comparison to the number of such papers in the literature of another island should indicate the greater research of the former.

The percent representation of snail size category indicates that sampling was systematised. From experience, we know that small snail species make up at least 30 % of the snail fauna on the larger Croatian islands. A substantially smaller or no representation of small species in the literature of an island indicates non-systematised collecting, and is usually the consequence of the method of collecting individual snails, which was virtually the only method used in older papers. The review of the percent representation of snail size classes by 50 year periods of an analysed island indicates changes in systematization of collecting practices, and the percent representation of size classes in the first half of the 21st century, i.e. today, indicates the current state of systematised research of island malacofauna.

RESULTS AND DISCUSSION

1. History of research of the terrestrial malacofauna of the Croatian Adriatic islands

The first written records of malacological research of Croatian Adriatic islands date back to the first half of 19th century. According to the available literature, the oldest paper containing data on the presence of terrestrial snails on Croatian islands was that by Paul PARTSCH (1826): »Bericht über das Detonations Phänomen auf der Insel Meleda bey Ragusa«. According to his paper and others from the 19th century, it could be concluded that research into the terrestrial snails of the Croatian Adriatic islands took place incidentally during that period. These studies covered only several

of the larger islands, and the number of species listed for a given island per paper is small, usually 1–2 taxa. For the majority of terrestrial snails, there is no information about their distribution on the island, while for a small number of species very little information is provided about their distribution on the island. This is due to the rare listing of island localities. Knowledge of the ecology of the recorded species indicates that the research did not encompass all habitats, and the habitats investigated were not uniformly processed. Data are found in general malacological papers (faunas, catalogues and lists) for the Palaearctic, Europe or other broader regions.

In the first half of the 20th century, attempts were made to conduct more systematised research into certain islands, e.g. Mljet (ROGENHOFER, 1908; STURANY, 1908), Dugi otok and Kornat (KUŠČER, 1930, 1930a). However, either due to the fact that field teams did not contain a malacologist, and/or due to different and less successful sampling methods than those used today, and/or due to poor accessibility, these works did not give a comprehensive overview of the island malacofauna, or of its island distribution. A similar case is with the research conducted somewhat later on the island of Krk (BOLE, 1958).

In the second half of 20th and early 21st centuries, research into individual systematic groups became more vigorous and, as a result, data are provided on the presence of given species on the islands through the description of new taxa (e.g. PINTÉR & RIEDEL, 1973; PINTÉR & SZIGETHY, 1973) and in monographic examinations of genera and families (BOLE, 1974; NORDSIECK, 1969, 1970, 1970a; BOETERS *et al.*, 1989; SUBAI, 1980, 2002; SLAPNIK & OZIMEC, 2004). In the late 1970s, the first author of the present paper and her co-workers (colleagues Z. Godec, B. Jalžić, E. Kletečki, S. Leiner, S. Muštra, J. Mužinić, F. Perović, M. Poje, G. Sušić, N. Tvrtković, F. Velkovrh, S. Vujčić-Karlo, M. Vuković, husband F. Štamol and daughter S. Šlezak) began systematised field research of the terrestrial snails of the Croatian islands. These studies results in a more or less doubling of the number of taxa known for an individual island and/or new knowledge of the distribution on the islands and the general distribution range of the taxa (ŠTAMOL, 1986, 1997, 2004; ŠTAMOL & VELKOVRH, 1995; ŠTAMOL & MUŽINIĆ, 1998; ŠTAMOL & POJE, 1998; ŠTAMOL *et al.*, 1999; ŠTAMOL & KLETEČKI, 2005), and the description of species new to science (ŠTAMOL, 1995; ŠTAMOL & SLAPNIK, 2002). Recent systematised studies by Austrian malacologists, father and son, Peter and Alexander Reischütz, occasionally with colleagues, into the islands of Vis (REISCHÜTZ & REISCHÜTZ, 1999), Mljet (REISCHÜTZ & REISCHÜTZ, 2000), Pag (FISCHER *et al.*, 2000; REISCHÜTZ & REISCHÜTZ 2005) and Korčula (REISCHÜTZ *et al.*, 2002) have given the first comprehensive fauna overview of these islands, judging by the method and results, and the systematised research by German malacologist Klaus KITTEL (2002) further completed knowledge to date about the malacofauna of Brač.

The small islands were less often studied than the large islands, and there are only two papers aimed at revealing the malacofauna of small islands. One paper (STURANY, 1915) covered the malacofauna of several southern Dalmatian islets and several islets around Lošinj. The second paper (KUŠČER, 1930) is the result of research of the Yugoslav Academy of Science and Arts from 1925–1927 in the area of Dugi otok and Kornat which included only 9 islets in this region. Judging by the results of these papers, the islets and crags included in the study were, for the most part, not studied systematically.

2. History of research into the terrestrial malacofauna of analysed islands and archipelagos

2.1. History of research into the terrestrial malacofauna of the island of Cres

In the second half of the 19th century, German malacologist Oscar BÖTTGER (1878, 1879) published papers on the door snail family. This paper gives information on the presence of two such species on Cres, the first data on terrestrial snails on the island. German malacologists Ludovik Pfeiffer and Stefan Clessin in »Nomenclator heliceorum viventium...« list a third taxon for Cres (PFEIFFER & CLESSIN, 1881). Trieste zoologist Adolf Stossich, alone and with son Michel, conducted natural history research along the Croatian coast in the second half of the 19th century. Though there are no data concerning their research on Cres, in his study »Contribuzione alla fauna malacologica terrestre e fluviatile del territorio di Trieste ed in parte delle località contermini«, STOSSICH (1899) records two taxa for the island of Cres: one species of door snail previously known to exist on Cres and one unreported species, an endemic snail of the subgenus *Chilostoma* (*Liburnica*). Eight years later, Adolf Stossich's widow Ersilia STOSSICH (1907) published a collection catalogue in the desire to acquaint the public with her late husband's large collection of molluscs. The catalogues list two species of terrestrial snails for the island of Cres. Polish malacologist Antoni WAGNER (1925) reported fourth species of door snails for Cres in his work on the snails of the genus *Delima*. Hungarian malacologist János WAGNER (1932) in »Weitere Mitteilungen über die Molluskenfauna von Abbazia und Umgebung« published the list of snail species collected on Cres by A. Plöbst. This was the first paper with data for a given locality on the island of Cres, and listed 12 species of terrestrial snails, only one of which had previously been recorded for the island. German malacologist Hartmut NORDSIECK (1969, 1970) conducted systematic studies of the snails of the genera *Delima* and *Chondrina* and recorded Cres as a site for *Delima* taxa, and two localities on Cres as localities for *Chondrina*. A somewhat broader contribution to the knowledge of the malacofauna of Cres was given by Dragutin and Renata Rucner, who collected 13 species of terrestrial snails in the forest vegetation fauna at 3 localities (RUCNER & RUCNER, 1971). Systematic papers followed by Peter SUBAI (1980) (Germany), Adolf RIEDEL (1983) (Poland) and Boeters and co-workers (BOETERS *et al.*, 1989) (Germany). Each of these papers lists one taxon for Cres, with sparse data on its distribution on the island, of only one locality. One year later, the first author of this paper together with Serbian malacologist Božana Jovanović published a paper on the distribution of the snails of the genus *Pomatias* in the territory of the former Yugoslavia (ŠTAMOL & JOVANOVIĆ, 1990). The data were based on a review of the literature, and private and museum collections, including the General Collection of Recent Molluscs of the Croatian National History Museum in Zagreb. The island of Cres made up a significant part of the collection and, thanks to this, the study listed a large number (31) of Cres localities for *Pomatias elegans* (O. F. Müller, 1774). In the faunistic study by Austrian malacologist Christa FRANK (1991), in which Cres is listed as one of the sites of field research on the Adriatic coast, the author lists 23 taxa of terrestrial snails for 5 Cres localities. Four years later, the first author of this paper and Slovenian malacologist France Velkoverh published the results of their own field studies and gave a critical review of the literature data on the terrestrial snails of the islands of Cres and Lošinj (ŠTAMOL & VELKOVERH, 1995). They listed 70 taxa for 70 localities for the island of Cres. This is, to date, the most systematised malacological

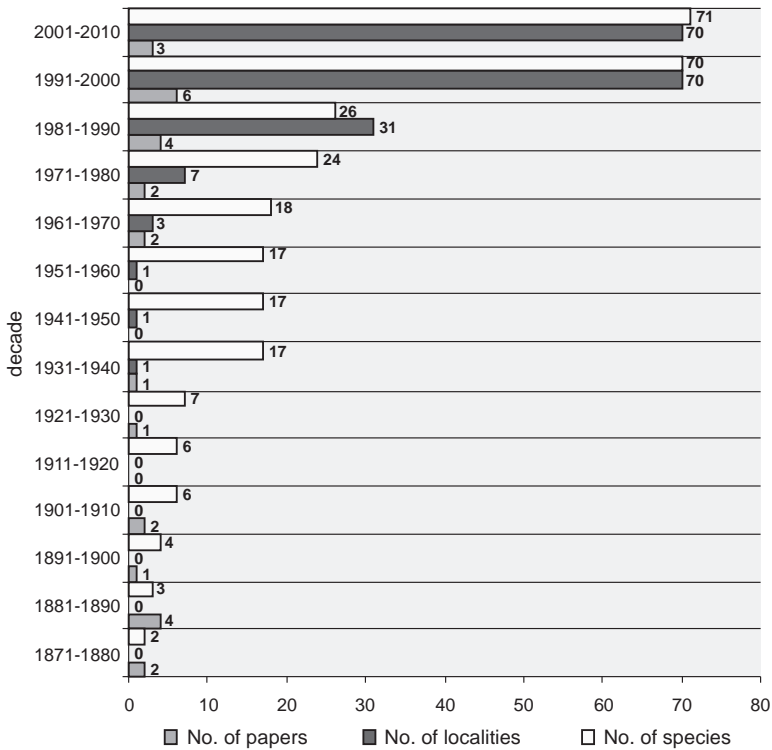


Fig. 1. Number of papers in decade, total number of known species of terrestrial snails and their localities on the island of Cres by decade.

study of this island. Unfortunately, there was a »citation« of non-existent data from this paper on the species *Paralaoma servilis* (Shuttleworth, 1852) for Cres by German malacologists Gregor SCHMITZ (1999: 38) and Hartwig SCHÜTT (2005: 158), which originally pertained to the island of Lošinj. Slovenian malacologist Rajko Slapnik and Croatian biospeleologist Roman Ozimec examined the distribution of terrestrial cave

Tab. 1. Overview of the number of papers with malacological data for an individual island (No. of P), number of terrestrial snail taxa (No. of sp) and their localities (No. of L) on a given island according to the literature data, percent representation of snails smaller than 5 mm in the fauna of the analysed island (% small) according to the literature data, and percent representation of papers listing only one species of terrestrial snail (% 1 sp), or one narrow locality and/or only a given island as the site of terrestrial snails (% 1 L).

island	No. of P	No. of sp	No. of L	% small	% 1 sp	% 1 L
Cres	28	71	70	38	61	78
Susak	12	23	7	30	8	83
Dugi	21	45	92	40	62	76
Kornat	2	12	1	0	50	100
Brač	48	53	43	40	52	73

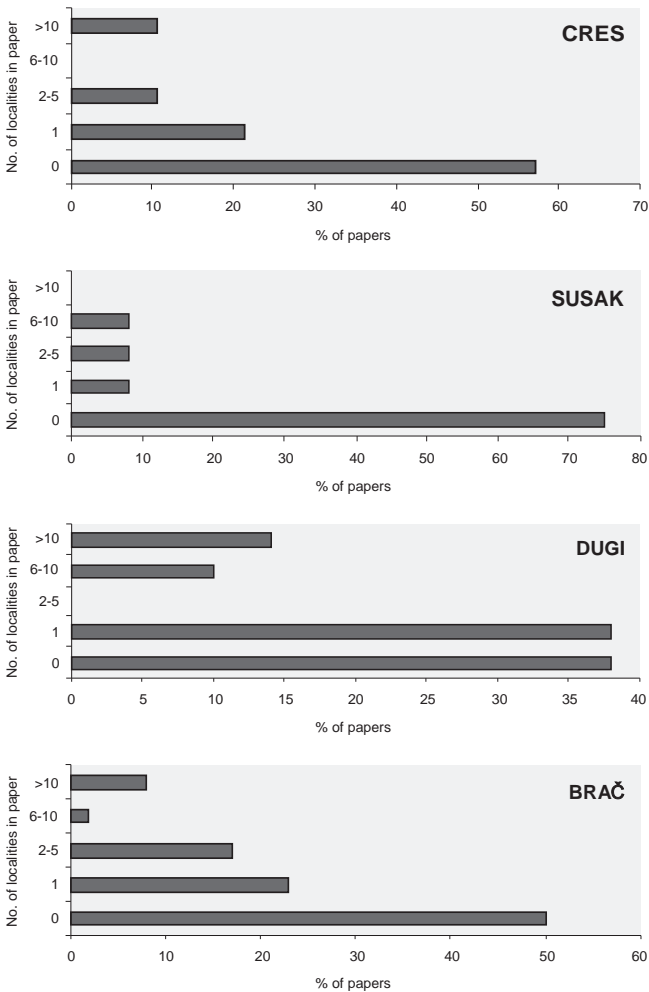


Fig. 2. Percent representation of papers listing 1, 2 to 5, 6 to 10, more than 10 localities of the island in question, or only the island (0) for its terrestrial snails.

snails of the genus *Zospium* in Croatia and listed one species in Čampari cave on Cres (SLAPNIK & OZIMEC, 2004). Accordingly, a total of 71 species of terrestrial snails were reported for the island of Cres in 28 papers (Fig. 1, Tab. 1).

A review of the papers shows that 79 % of papers list only one locality or generally list the island of Cres as a site for terrestrial snails (Fig. 2). This indicates the predominance of non-systematised studies of Cres, which is confirmed by the large number of papers listing only one species for Cres (61 %) (Fig. 3). This is due to:

- the existence of only one faunistic paper (4 % of papers) that systematically investigates the terrestrial snails of the island of Cres (ŠTAMOL & VELKOVRH, 1995) (Fig. 6);
- the existence of only one paper which, among papers listing only one or a small number of snail taxa for Cres, gives a detailed record of the distribution

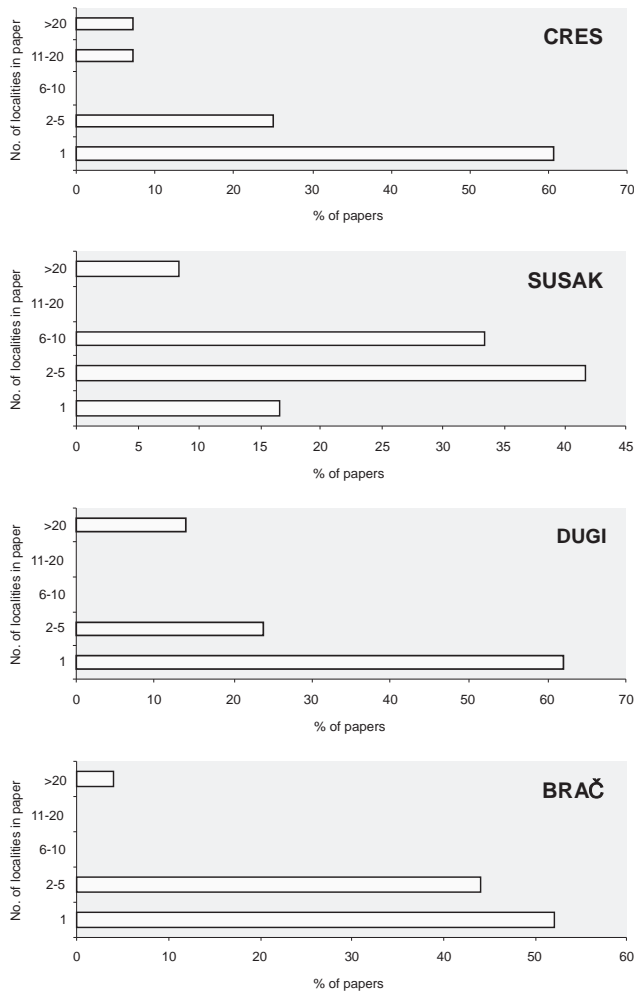


Fig. 3. Percent representation of papers listing 1, 2 to 5, 6 to 10, 11 to 20, more than 20 species of terrestrial snails for the island in question.

of the taxon on the island (31 localities on Cres for one species) (ŠTAMOL & JOVANOVIĆ, 1990);

- the predominance of systematic papers investigating families, genera or species that are represented on Cres with one or a small number of taxa, and their distribution on the island has not been thoroughly researched (13 papers or 46 %: BÖTTGER, 1878, 1879; WESTERLUND, 1901; WAGNER, 1925; NORDSIECK, 1969, 1970; SUBAI, 1980; RIEDEL, 1983; BOETERS *et al.*, 1989; RIEDEL, 1998; SCHMITZ, 1999; SUBAI, 2002; SLAPNIK & OZIMEC, 2004) (Fig. 6);
- a high representation of general papers investigating the fauna of parts of Europe, Europe or broader regions in which Cres is only mentioned in passing (6 papers or 21 %: KOBELT, 1881; PFEIFFER & CLESSIN, 1881; WESTERLUND, 1884, 1890; FRANK, 1992; SCHÜTT, 2005) (Fig. 6);

- within malacofaunistic papers of the eastern Adriatic coast (5 papers or 18 %) (Fig. 6), those investigating Cres in passing, as a poorly studied area (STOSSICH, 1899; WAGNER, 1932; RUCNER & RUCNER, 1971) or not even as an area but only citing literature data (GRAACK, 1989) dominate, with only one paper in which Cres is investigated in greater detail (FRANK, 1991);
- among papers giving lists of mollusc collections and lists of literature data (3 papers or 11 %) (Fig. 6), those in which Cres is mentioned in passing predominate, either because the island was not the main geographical area of the collection (STOSSICH, 1907), or because Cres was not even included in the collection and the island was only listed in the citation of literature data on the distribution of the taxa in the investigated collection (FRANK, 2000).

Thanks to the only systematic malacofaunistic paper for the island of Cres (ŠTAMOL & VELKOVRH, 1995), the number of terrestrial snail species known for the island was doubled (from 33 taxa to 70 taxa), the number of Cres localities of terrestrial snails was increased from 41 to 70, and much was learned about the distribution of snails on Cres. This was the result of field studies that included all the main macrohabitats and many microhabitats at a large number of localities, and the collection methods ensured the representation of all size classes of snails (Fig. 7).

2.2. History of research of the terrestrial malacofauna of the island of Susak

Due to the distinctive geological structure of the island of Susak, it has long attracted naturalists who were primarily interested in resolving the issue of the origin of the Pleistocene sand layers. The abundant representation of snails in the soil was often reported as proof of marine or freshwater origin of the deposits. The layers showed mixing of recent and fossil material, which the authors often incorrectly gave an »age« status. Based on a critical review of the literature data from ŠTAMOL & POJE (1998), the works are listed that we assume record the recent snails of Susak. Austrian professor Josef Roman LORENZ (1859) in »Skizzen aus der Bodulei und den benachbarten Küsten...« was the first to report recent species of terrestrial snails for Susak, with a total of 9 taxa. That is a relatively large number, more than one-third of the recent species known on the island today. Italian botanist from Trieste, Mutilus H. TOMMASINI (1862) wrote that the abundance of snails on Susak was an important source of food for the island's inhabitants, referring primarily to the two largest snail species on the island, *Cornu aspersum* (O. F. Müller, 1774) and *Eobania vermiculata* (O. F. Müller, 1774). Tommasini deems that the consumption of snails contributed to maintaining herbivorous »pest« species of snails in such population sizes that allowed for the cultivation of vegetables and fruit. Almost a century later, Croatian geographer Vladimir BLAŠKOVIĆ (1957) also reported two species of snails eaten by the locals, without mentioning the names of the snails. Italian naturalist and archaeologist, Carlo MARCHESETTI (1882) from Trieste, reported four recent terrestrial snail species, one of which was new to Susak. He was assisted in the determination of the material by malacologist Adolfo Stossich, also from Trieste, and by Oscar Böttger from Germany. Croatian naturalist Dragutin Hirc visited the island in 1903 and 1912, and he published the results of his research, with a detailed list of literature citations, in 1914 (HIRC, 1914). This is the first paper to list more detailed localities on Susak. While collecting flora, he also collected molluscs, but did not find any new species for this island. Rudolf STURANY (1915), a malacologist from Vienna in »Beiträge zur Naturgeschichte der Scoglien und kleine-

ren Inseln Süddalmatiens« noted two taxa of terrestrial snails for Susak that were collected in 1907 and 1908 by his colleague, lepidopterologist Egon Galvagni. Polish malacologist Antoni WAGNER (1924, 1925) studied the genus *Delima* and noted one species for this island. In a discussion of the stratigraphy of the island of Susak, Serbian geologist Jelena MARKOVIĆ-MARJANOVIĆ (1966) reported 6 recent taxa, one of which was new to Susak. Croatian geologist Andrija Bognar and colleagues listed three recent snail taxa (BOGNAR *et al.*, 1983, 1989). Unlike the majority of these authors, whose objective was to study the fossil malacofauna of Susak, in 1983 Wolfgang Graack from Germany studied the island's recent malacofauna, and published the results six years later (GRAACK, 1989). During a one-day excursion, he found 10 recent species, two of which were new to Susak. Almost ten years later, in an attempt to systematically study the fossil and recent terrestrial malacofauna of Susak, Croatian palaeontologist and malacologist Marija Poje and the first author of this paper critically reviewed the literature data and data from field studies on the recent and fossil malacofauna of Susak (ŠTAMOL & POJE, 1998). They concluded, based on research conducted at 7 localities on Susak including the main snail macrohabitats and microhabitats of the island, that there are 23 recent species present on the island. Of this, 10 were new snail taxa for Susak. Among them, 7 belong to the group of snails with a shell less than 5 mm, i.e. all the small snails of Susak were found for the first time during this research (Fig. 7).

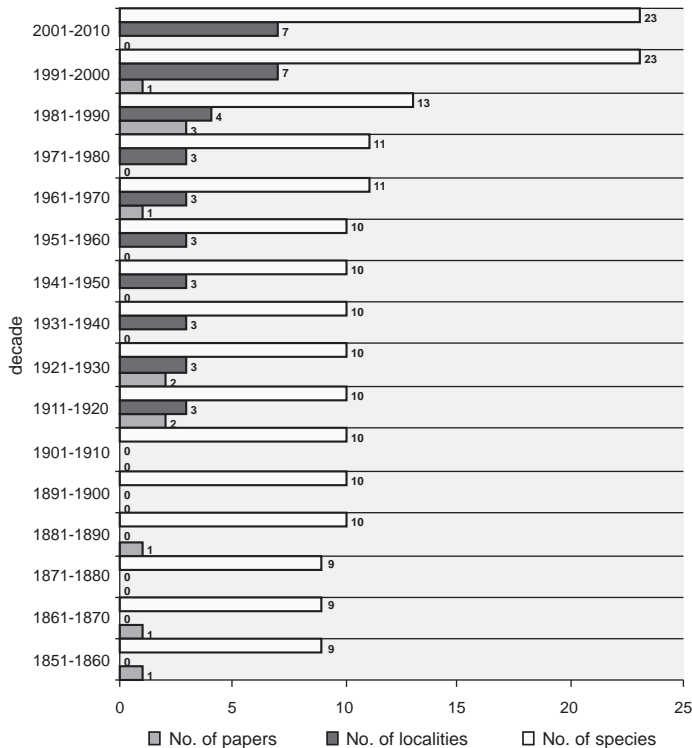


Fig. 4. Number of papers in decade, total number of known species of terrestrial snails and their localities on the island of Susak by decade.

According to the findings to date in 12 papers, 23 species of recent snail species were recorded for the island of Susak (Fig 4, Tab. 1). Among the papers, those in which the recent malacofauna is not thoroughly investigated predominate, for in the majority of papers (59 %), up to 5 species of snails were recorded (Fig. 3), and the localities where the fauna was collected were not defined in 75 % of papers (Fig. 2). This is due to the following:

- the predominance of non-malacological papers, i.e. geological, palaeontologist, floristic and other papers, in which recent gastropods are mentioned only in passing, often as fossils (7 papers: LORENZ, 1859; TOMMASINI, 1862; MARCHESETTI, 1882; HIRC, 1914; MARKOVIĆ-MARJANOVIĆ, 1966; BOGNAR *et al.*, 1983, 1989) (Fig. 6);
- systematic papers in which a genus is investigated that is represented on Susak with one species, and its distribution on the island is not defined (2 papers: WAGNER, 1924, 1925) (Fig. 6);
- malacofaunistic papers of the eastern Adriatic coast with non-systematised investigation of Susak (2 papers): in one paper, the island of Susak was not the main area of investigation (STURANY, 1915), while in the second, though it was the area of investigation, the research covered only one locality (GRAACK, 1989) (Fig. 6);
- the existence of only one paper which systematically investigated the recent malacofauna of Susak (ŠTAMOL & POJE, 1998) (Fig. 6).

2.3. History of research of the terrestrial malacofauna of the island of Dugi otok

The first data on the terrestrial snails of Dugi otok were given by Hungarian zoologist Eduard Albert BIELZ (1865) in his systematic list of snails of the Austrian Empire, in which one species was listed for one locality on Dugi otok. It was only after three decades that new data were provided by skilled Polish malacologist Antoni WAGNER (1897). In his monograph of the genus *Cochlostoma*, he listed one species for Sali. The same species for the same locality was recorded by Croatian naturalists Spiridion BRUSINA (1907) and Dragutin HIRC (1910). New data were provided by curator of the natural history museum in Vienna Rudolf STURANY (1915) who, in the investigation of the malacofauna of small southern Dalmatian islands, also listed 3 species of snails for Sali. Some ten years later, Antoni WAGNER (1924, 1925) published the results of his research into the family Clausiliidae. Here we find the first data on the presence of door snails on Dugi otok, with 3 species of the genus *Delima* and 1 species of the genus *Charpentieria*. In the period from 1925–1927, the Yugoslav Academy of Science and Arts conducted the first systematic natural history investigation of Dugi otok, Kornat and the surrounding islets. Terrestrial gastropods were studied by Slovenian malacologist Ljudevit Kuščer. The published results (KUŠČER, 1930, 1930a) indicate that 14 localities on Dugi otok were examined for malacofauna and 21 species of terrestrial snails were recorded. Papers followed that primarily cited or further processed older data (NORDSIECK, 1969; ILIJANIĆ & STOŠIĆ, 1972; RIEDEL, 1979; MAASSEN, 1985; ŠTAMOL & JOVANOVIĆ, 1990; FRANK, 1991, 2000). During the initial biological research of submarine caves, terrestrial flora and fauna of the outer cliffs of Telaščica Nature Park, conducted in 1989 by the Croatian Natural History Museum in Zagreb, led by Nikola Tvrtković in cooperation with Boris Sket from the Faculty of Biotechnology of the University of Ljubljana and Ivo Trinajstić from the Faculty of Forestry of the University of Zagreb, unusual terrestrial

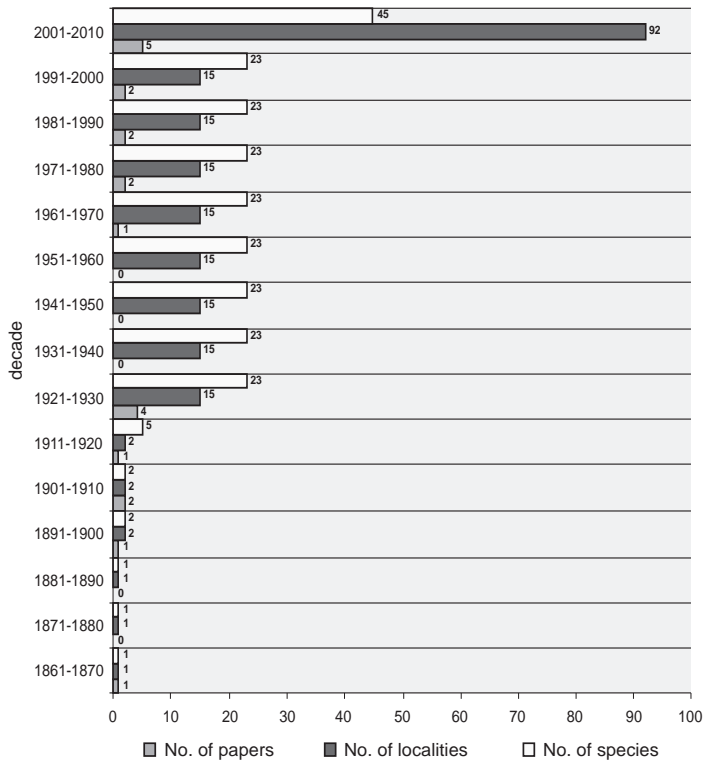


Fig. 5. Number of papers in decade, total number of known species of terrestrial snails and their localities on the island of Dugi otok by decade.

snails were collected from two localities. This stimulated the first author of this paper to conduct more thorough research of the terrestrial malacofauna of Dugi otok, which she carried out in 1995–1996 with the assistance of the staff of the Croatian Natural History Museum, and which resulted in the description of new species and a new subgenus to science, *Delima (Dugiana) edmibrani* Štamol & Slapnik, 2002 (ŠTAMOL & SLAPNIK, 2002), which was soon after cited (NORDSIECK, 2002). In 2003, Telašćica Nature Park financed the project entitled »Inventory of terrestrial snails of Telašćica Nature Park« which was conducted by the Croatian Natural History Museum under the first author’s leadership. Fifty-four localities within the park were investigated, and 38 taxa recorded (ŠTAMOL, 2004). ŠTAMOL & KLETEČKI (2005) published the results of a critical review of literature data and systematised field studies of the whole of Dugi otok, which included another 37 localities outside the park. Forty-five species were recorded for the whole of Dugi otok (Fig. 5, Tab. 1). The find of several rare and interesting species was soon cited by Italian malacologist Willy DE MATTIA (2006).

According to the knowledge to date, there are 21 papers providing data on the terrestrial snails of Dugi otok (Tab. 1). In 76 % of these papers, only one locality on Dugi otok or merely Dugi otok is listed as the locality of terrestrial snails (Fig. 2). Also, the majority of papers (62 %) list only one species of snail for Dugi otok,

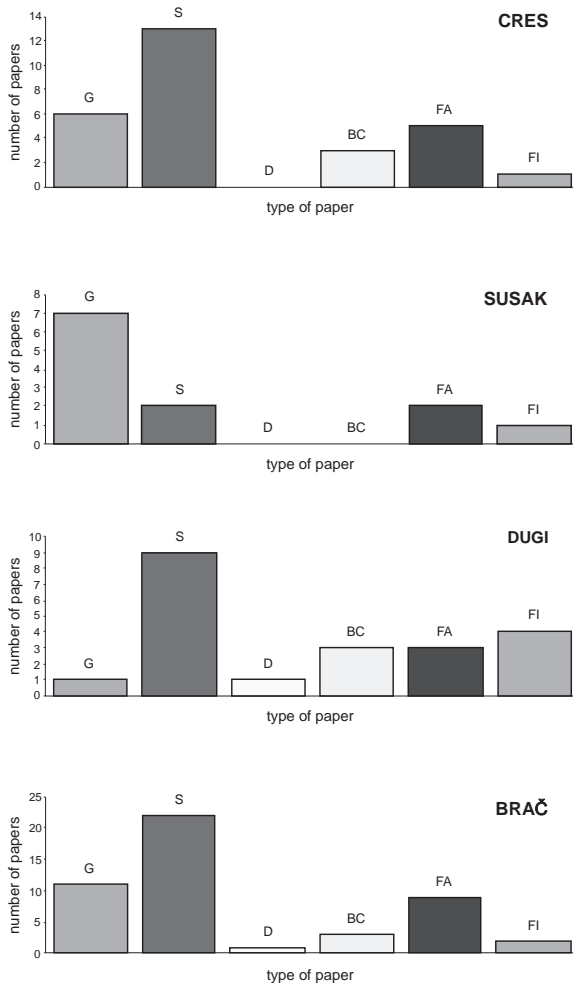


Fig. 6. Representation of types of papers for the islands of Cres, Susak, Dugi otok and Brač: G – general; S – systematic; D – papers describing new snail taxa; BC – bibliographic and collection lists; FA – faunistic studies of larger or smaller sections of the Adriatic coast; FI – faunistic studies of the island in question

followed by papers (24 %) listing 2–5 species (Fig. 3). This is due to the small number of malacofaunistic papers on Dugi otok (only 4 papers or 19 %: KUŠČER, 1930, 1930a; ŠTAMOL, 2004; ŠTAMOL & KLETEČKI, 2005) i.e. to the predominance of other papers which are (Fig. 6):

- general papers: a list of species of a broader area in which Dugi otok is mentioned only in passing (BIELZ, 1865);
- systematic papers investigating groups which are represented with one or a small number of species on Dugi otok (WAGNER, 1897; HIRC 1910; WAGNER, 1924, 1925; NORDSIECK, 1969; RIEDEL, 1979; MAASSEN, 1985; NORDSIECK, 2002; DE MATTIA, 2006);

- papers which are lists of private and/or museum collections, in which the material of terrestrial snails from Dugi otok is not a significant part of the collections, either geographically or systematically (ILIJANIĆ & STOŠIĆ, 1972; ŠTAMOL & JOVANOVIĆ, 1990; FRANK, 2000);
- faunistic papers of larger areas of the eastern Adriatic coast in which Dugi otok was not the main area of study (BRUSINA, 1907; STURANY, 1915; FRANK, 1991);
- a paper with a description of a new taxon in which the accompanying malacofauna was not listed (ŠTAMOL & SLAPNIK, 2002).

One malacofaunistic paper on Dugi otok, despite being the result of systematised research, but having characteristics of just an extended abstract, lists only two species and one locality for Dugi otok (KUŠČER, 1930a). As stated above, the first complete study of Dugi otok was conducted from 1925–1927 at 14 localities, and 21 species were found that, together with the two species mentioned in the older literature but unconfirmed in this study, total 23 species (Fig. 5). The next systematised study of the whole of Dugi otok (ŠTAMOL & KLETEČKI, 2005) included 92 localities, which is 6.5 times more than in the first study. The number of species was doubled. This was due to more modern collection methods for terrestrial snails, which included all size classes of snails (Fig. 7) and all or the majority of macro- and micro-habitats.

2.4. History of research of the terrestrial malacofauna of the island of Kornat

Due to the lack of permanent human settlements, paucity of roads and lack of traffic connections, the island of Kornat has been poorly researched malacologically. It seems almost unbelievable that there are only two papers providing data on the terrestrial snails of this island (Tab. 1). One is the work of Hungarian malacologist Eduard Albert BIELZ (1865) who in »Systematisches Verzeichniss der Land- und Süßwasser-Mollusken des österreichischen Kaiserstaate« listed one species. The second paper (KUŠČER, 1930) is the result of natural history research by the Yugoslav Academy of Science and Arts conducted on Dugi otok and Kornat in 1925 and 1926. This paper states that the collection of terrestrial snails on this large island took place on only two days, and that only one locality (Toreta) was defined as a finding site (Tab. 1). A total of 11 species in 60 individuals was confirmed. This indicates the lack of systematic study of the terrestrial malacofauna of Kornat, and among the analysed islands in this literature review of the history of malacologist research, Kornat is the most poorly studied.

2.5. History of research into the terrestrial malacofauna of the archipelago of Telašćica Nature Park

ŠTAMOL (2004) published the results of research into the terrestrial malacofauna of the archipelago of Telašćica Nature Park conducted in 2003. On 18 islets and crags, 32 localities with terrestrial snails were defined. A total of 24 taxa were found, with a maximum of 18 species and minimum of 4 species of terrestrial snails on one islet.

Unfortunately, from KUŠČER (1930) it is not possible to ascertain whether the toponym »Gvozdjenjak« (which likely corresponds to the present day toponym »Gozdenjak«) relates to the bay or islet of the same name, and accordingly the data from ŠTAMOL (2004) remain the only data on the malacofauna of the islets and crags of Telašćica Nature Park.

2.6. History of research into the terrestrial malacofauna of the islets and crags of Kornati National Park

German zoology professor and esteemed malacologist Edmund Adolph ROSS-MÄSSLER (1836, 1842) in the volumes of his famous »Iconographie der Land-und Süßwasser-Mollusken...« reported one species of door snail in 1836 for »Scolia in Dalmatien« and another species in 1842 for »Scoglia in Dalmatien«. From German malacologists Adolf Zilch and his collaborators (ZILCH *et al.*, 2002), we learn that »Scolia in Dalmatien«, or »Scoglia in Dalmatien« is the *locus typicus* for two species of terrestrial snails. In the journal »La Dalmazia«, an unfinished list of the terrestrial snails of Dalmatia was published in three parts in 1846, entitled »Conchiliologica« (first and third part) and »Conchiglie dalmatae« (second part) (ANONYMOUS, 1846, 1846a). It is here that two species are listed for »scogli di Zara«. The best known Croatian malacologist Spiridion BRUSINA (1866) in »Contribuzione pelle Fauna dei molluschi dalmati« reports *Theba pisana* (O. F. Müller, 1774) for »scogli di Zara«. Ljudevit KUŠČER (1930) wrote that the collection of the Zagreb museum contained the snail *Cerņuella virgata* (Da Costa, 1778) from the Zadar islands (»Ostrovi«). German malacologist Hartmut NORDSIECK (1969) lists Kornati as the area of distribution of two species of door snails. Unfortunately, the concepts of the Zadar islands, or »Scoglia in Dalmatien«, »Scolia in Dalmatien«, »scogli di Zara«, »ostrovi«, and even of »Kornati« are undefined, as the data cannot be specified to any particular group of islands or individual island with any certainty, and regardless of their historical interest, they cannot be considered. Accordingly, Kuščer's data (KUŠČER, 1930) pertaining to the islets Trbuh (=Mali Obručan), Obručan, Mrtvac, Levrnaka, Borovnik and Purara, are the first and only data on the existence of terrestrial snails on the islets and crags of Kornati National Park. These six islets were included in the previously mentioned research by the Yugoslav Academy of Science and Arts in 1925 and 1926. Here, a total of 9 taxa of terrestrial snails were recorded, the majority on Obručan (4 taxa), and the fewest on the largest of the investigated islets, Levrnaka (only one taxon). Judging by the dates of the research (only two days), by the number of investigated islets (less than one-tenth of the islets), by the number of species found per islet (from 1 to 4), by the total number of terrestrial snail species found on the archipelago and the fact that not a single small species was recorded among them, it can be concluded that the islets of Kornati National Park have not been systematically studied.

Due to the existence of the homotonym »Smokvica«, the door snail *Delima amoena smokvicensis* A. J. Wagner, 1915 listed in the paper by Rudolf STURANY (1915), originating from the southern Dalmatian islet of Smokvica near Lastovo, was incorrectly interpreted by WAGNER (1924: 113; 1925: 51) to be a resident of the Kornati islet Smokvica, which was later cited by NORDSIECK (1969: 282). The error was brought to light by ZILCH *et al.* (2002: 210), and the new position adopted by NORDSIECK (2002: 32).

2.7. History of research of the terrestrial malacofauna of the island of Brač

The first data on the terrestrial snails of Brač date back to the mid 19th century. These can likely be attributed to Austrian animal collector and trader Ludwig Parreyss of Vienna, who undertook many trips to Croatia, first in 1823, and in Dalmatia for the first time in 1825 (SATTMANN, 1986). He cooperated with many of the top malacologists of his time, to whom he sold molluscs. He also published lists

of his collections, which served for trading. A publication from an unknown year entitled »Arten –Verzeichnis der Gattung *Clausilia* Drp. & Rssm., welche sich in d. Sammlung d. L. Parreyss zu Wien befinden« (PARREYSS, ?), which we assume to be published prior to 1842, represents the first data on the existence of terrestrial snails of Brač, listing two door snail taxa. Parreyss' material likely made it to German malacologist Emil Adolph Rossmässler who listed one taxon for Brač (ROSSMÄSSLER, 1842, 1856). German coleopterologist and malacologist Heinrich Carl Küster visited Dalmatia and Montenegro in 1841 and 1842. In February 1842, he visited the island of Brač and recorded three species of terrestrial snails (KÜSTER, 1842), while in »Systematisches Conchylien Cabinet« he listed three new species for Brač (KÜSTER & PHILIPPI, 1844–62; KÜSTER, ?). In the previously mentioned unfinished list of the terrestrial snails of Dalmatia which was published in the journal »La Dalmazia«, an anonymous author reported four species for Brač (ANONYMOUS, 1846, 1846a). Italian malacologist Pelegrino STROBEL (1854) listed 5 species of terrestrial snails for Brač that were collected by Cristoforo Bellotti in 1853 during his travels through Dalmatia. In further works, the data of the presence of door snails on Brač were repeated, without listing detailed localities that could undoubtedly be on this island. The first specific localities, undoubtedly from Brač, were listed by Polish malacologist Antoni WAGNER (1906). He listed two localities on the island for two species new to Brač. The first relatively serious natural history research of the island was carried out by the Vienna Natural History Society in July 1912 (ROGENHOFER, 1914). Unfortunately, the field team did not include a malacologist, and the papers published by members of the team provide only data of two taxa of terrestrial snails in Činjadra cave (WETTSTEIN, 1914). In that same year, Czech speleologist Karel Absolon made his first visit to the island, and his second visit in 1917. He found a total of 6 taxa in the caves of Brač, three of which should have been new to science (ABSOLON & KSENNEMANN, 1942). Two were described by Antoni WAGNER (1914), and the description of the third was never published. A significant contribution to the knowledge of the terrestrial malacofauna of this island was given in the papers by German Hartmut Nordsieck who described a species new to science of the genus *Delima* from the western part of the island of Brač (NORDSIECK, 1969), and a species new to science from the genus *Medora* from the eastern part of the island (NORDSIECK, 1970a). That same year, he published the precise locality of the species *Chondrina spelta* (H. Beck, 1837) on Brač (NORDSIECK, 1970). Nordsieck's data for Brač are the result of his field studies conducted in April 1969. Papers by Hungarian László PINTÉR (1972) and Slovenian Jože BOLE (1974) tell that Slovenian malacologist Ljudevit Kuščer was in Brazgova (or Bazgava) pit on Brač, and a part of the collected material was processed in these papers. Dutchman Wim M. J. Maassen visited Brač, and the gastropods he collected were processed by the collector (MAASSEN, 1978, 1978a) and by German Peter SUBAI (1980). In the late 1970s, the first author of this paper began her research of the terrestrial snails of Brač, and she published the main results of a critical literature review and her field work in 1986 (ŠTAMOL, 1986), with later supplements for the genus *Medora* (ŠTAMOL, 1987, 1989). In these papers, ŠTAMOL reported 46 species, 43 of which were terrestrial snails found by the author during her own field studies at 27 localities, while for 3 troglobiont species she cited literature data. The next systematised malacofaunistic paper on Brač was written by German Klaus KITTEL (2002), who in June 2001 found 7 new species on Brač.

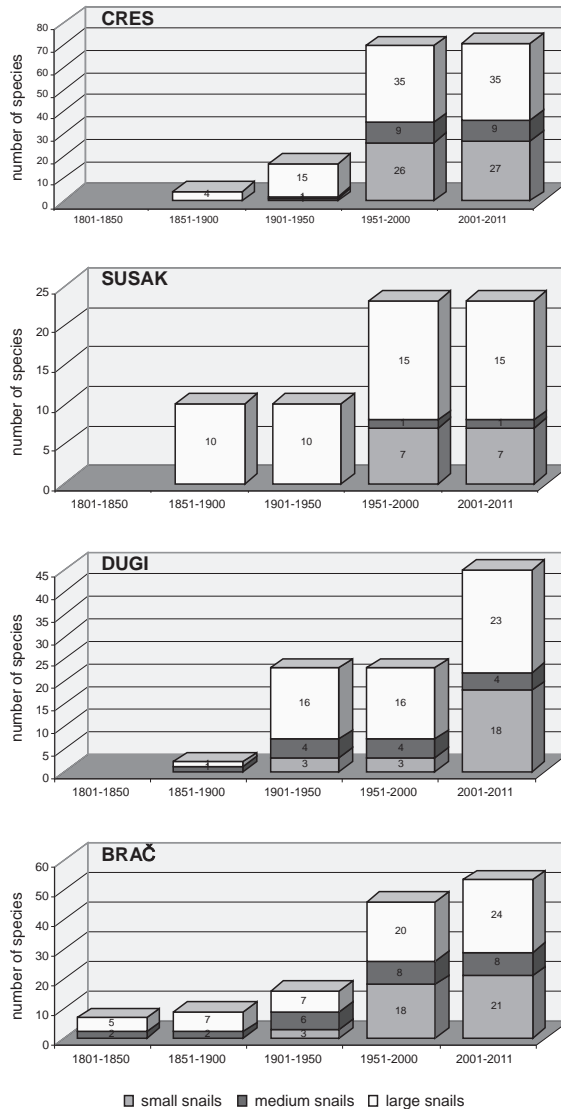


Fig. 7. Representation of large (larger than 10 mm), medium (from 5–10 mm) and small (less than 5 mm) terrestrial snail species of the islands of Cres, Susak, Dugi otok and Brač in the malacological literature by 50 year periods.

From the research conducted to date, there are 48 papers listing 53 species of terrestrial snails for the island of Brač (Fig. 8, Tab. 1). There is a predominance of papers mentioning a small number of species (96 % of papers list up to 5 snail taxa) (Fig. 3) and papers listing merely the name of the island (50 % of papers) or only one locality on the island (23 % of papers) as a finding site (Fig. 2). This indicates the dominance of non-systematised studies in the research of terrestrial malacofauna of Brač, which is due to:

- the predominance of systematic papers in which the family and genera investigated are represented on Brač with only one or a small number of species, and their distribution on the island was not thoroughly researched in the majority of papers (22 papers or 46 %: CHARPENTIER, 1852; SCHMIDT, 1868; BÖTTGER, 1878, 1879; WAGNER, 1906, 1918, 1924, 1925; ABSOLON & KSENNEMANN, 1942; BERBEROVIĆ, 1963; NORDSIECK, 1969, 1970, 1970a; PINTÉR, 1972; BOLE, 1974; MAASSEN, 1978; PINTÉR & SZIGETHY, 1979; SUBAI, 1980; ŠTAMOL, 1987, 1989; SUBAI, 2002; SLAPNIK & OZIMEC, 2004) (Fig. 6);
- a high representation of general papers in which the malacofauna of larger parts of Europe, all of Europe or even broader areas is investigated (11 papers or 23 %: ROSSMÄSSLER, 1842; KÜSTER, ?; KÜSTER & PHILIPPI, 1844–1862; ROSSMÄSSLER, 1856; BIELZ, 1865; WESTERLUND, 1884, 1890; WAGNER, 1914, 1927; JAECKEL, 1954; JAECKEL *et al.*, 1957) (Fig. 6);
- faunistic papers of larger or smaller parts of the Adriatic coast in which the Brač malacofauna was not systematically investigated (9 papers or 19 %: KÜSTER, 1842; ANONYMOUS, 1846, 1846a; STROBEL, 1854; BRUSINA, 1866; KÜSTER, 1870; WETTSTEIN, 1914; WAGNER, 1939; MAASSEN, 1978a) (Fig. 6);

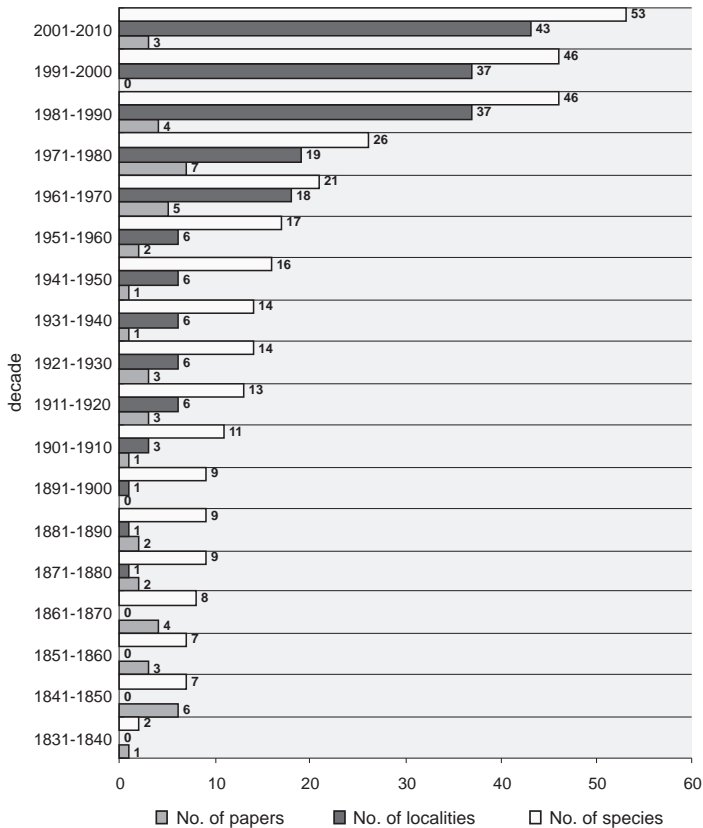


Fig. 8. Number of papers in decade, total number of known species of terrestrial snails and their localities on the island of Brač by decade.

- lists of collections or bibliographic papers (3 papers or 6 %) which list only Brač (PARREYSS, ?) or one narrow locality as finding site (ZILCH, 1977), or 15 localities but for only one species (ŠTAMOL & JOVANOVIĆ, 1990) (Fig. 6);
- a paper describing a new taxon outside the area of Brač, in which the island is only mentioned in passing (one paper or 2 %: BERBEROVIĆ, 1964) (Fig. 6);
- poor representation of the malacofaunistic papers of Brač (only two such papers or 4 %: ŠTAMOL, 1986; KITTEL, 2002) (Fig. 6).

However, both thorough papers on the terrestrial malacofauna of this island were published in the last 30 years, using collection methods that include all size classes of snails, and so it can be assumed that despite the relatively small number of research localities on Brač (Tab. 1), its terrestrial malacofauna has been relatively well studied.

CONCLUSION

According to the knowledge to date, it appears that the oldest paper listing species of terrestrial snails for Croatian islands was published in 1826, with data for the island Mljet (PARTSCH, 1826).

A review of the literature data on terrestrial snails of the analysed islands (Cres, Susak, Dugi otok, Kornat, Brač) presented here shows that the oldest data are those for the island of Brač (Figs. 1, 4, 5, 8), one paper the authors assume to predate 1842, and the second from 1842. Also, according to the knowledge to date, Brač has the highest number of papers with data on terrestrial snails (Brač: 48; Cres: 28; Dugi otok: 21; Susak: 12), and the island of Kornat the fewest, only two (Tab. 1). The number of papers is the result of many factors, of which attractiveness for researchers and accessibility are the most significant. The very small number of papers for the island of Kornat is primarily a result of its poor accessibility.

In comparing the types of papers with malacological data for the analysed islands, it is evident that general and systematic papers are highly represented, making up more than 60% of all papers for the majority of the islands (Susak: 75 %; Brač: 69 %; Cres: 67 %; Dugi otok: 48 %) (Fig. 6). In such papers, the malacofauna of individual islands has not been systematically investigated, in general papers due to the general topics of these works, and in systematic papers because the investigated genus or family is most often represented on the island with one or a few species. However, it should be stressed that the systematic papers, though almost always listing a very small number of species, can give a large number of island localities if the distribution range of the taxon with a broad range on the island was thoroughly investigated. However, this is rare, and the result of the dominance of general and systematic papers is that many of the papers show other two indicators of non-systematised study: more than half the papers list only a few (up to 5) species for a given island (Brač: 96 %; Cres: 86 %; Dugi otok: 86 %; Susak: 59 %) (Fig. 3) and \pm two-thirds of the papers list only one locality on the island and/or the island itself as a finding site for terrestrial snails (Susak: 83 %; Cres: 78 %; Dugi otok: 76 %; Brač: 73 %) (Fig. 2, Tab. 1). Thus it appears that the literature is dominated by papers reporting incomplete investigations of the malacofauna of the analysed islands. However, each of these analysed islands has at least one paper, and at most four, in which the malacofauna of the island takes central stage (Fig. 6), and this can then be considered a malacofaunistic paper of the island in question. This is not a guarantee

that a comprehensive investigation was made of the island, as the systematics of the »island papers« depends on the field research methods (distribution and number of studied localities and habitats, collection methods) and the manner of presenting the results. Snail collection methods in the past 40 years have included snails of all sizes, and therefore more recent malacofaunistic papers have significantly increased the number of species, thanks primarily to the discovery of small snails (Fig. 7). On the other hand, modern and fast transport connections have made thorough research of larger areas possible in a shorter period of time. Therefore, the island of Kornat is undoubtedly the least investigated island among the islands analysed here; there is only one malacofaunistic paper concerning Kornat, from the first half of the 20th century, in which old collection methods were used over only two days of field work, and not a single small snail species was found (Tab. 1). The remaining islands have, for the most part, been satisfactorily investigated. Among them, Dugi otok could be the most systematically researched island thanks to recent investigations that looked at some 90 locations, the most of the islands analysed here (Figs. 1, 4, 5, 8, Tab. 1) and on the Croatian Adriatic islands in general. Of the analysed archipelagos, Telašćica Nature Park has been systematically researched as sampling was conducted using modern methods on a variety of habitats and localities on all the islets (ŠTAMOL, 2004), unlike in Kornati National Park for which there are data for only 9 taxa on 6 of a total of 87 islets (KUŠČER, 1930).

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SAŽETAK

Literaturni pregled istraženosti kopnenih puževa nekih hrvatskih otoka

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Pregledom literature o kopnenoj malakofauni otoka Cresa, Suska, Dugog otoka, Kornata, Brača te otočja Parka prirode »Telašćica« i Nacionalnog parka »Kornati« uočeno je da prevladavaju djela u kojima se nesustavno obrađuju kopneni puževi tih područja. Nesustavna su zato jer i) navode malo (do 5) vrsta puževa što čini 1/14 (Cres) – 1/5 (Susak) kopnene malakofaune otoka, ii) navode malo lokaliteta (samo 1 lokalitet ili sam otok) kao nalazišta puževa, iii) uopće ne navode male vrste (one čija kućica odrasle jedinke je manja od 5 mm) ili ih je spomenuto puno manje spram većih vrsta. Posljedica je to dominacije i) fauna, kataloga, popisa vrsta širih područja Evrope, Evrope ili čak i većih područja u kojima su navedeni otoci ili otočje samo usputno spomenuti s uglavnom malim brojem vrsta i malim brojem otočnih nalazišta, ii) sistematskih radova čije interesne skupine i jesu zastupane na otocima s jednom ili malim brojem vrsta. Svi navedeni otoci i otočja imaju barem jedan rad u kojem je njihova kopnena malakofauna imala centralni značaj, pa bi bilo za očekivati da su svi sustavno istraženi. Ipak, sustavnost je ovisila o metodama sabiranja puževa, te broju i rasporedu mjesta uzorkovanja, i načinu izlaganja rezultata. Sustavnost sabiranja povijesno se povećavala te današnji rezultati govore o cca 30 % zastupanosti malih vrsta u fauni otoka, dok u prošlosti male vrste ili uopće nisu bile sabirane ili su činile neznatni dio poznate malakofaune. Otok Brač ima najviše djela s malakološkim podacima (48), a otok Kornat najmanje (samo 2) što je prvenstveno posljedica nenaseljenosti i slabe prometne povezanosti otoka Kornata. Što se tiče sustavnosti istraživanja, otoci Cres, Susak, Dugi otok i Brač, te otočje PP »Telašćica« su sustavno istraženi. Otok Kornat, te cjelokupno otočje NP »Kornati« nisu sustavno istraženi. Otok Kornat ima zabilježeno samo 12 vrsta i jedan lokalitet, a otočje NP »Kornati«, ako izumemo otok Kornat, ima podatke za ukupno 9 svojiti na 6 otočića. Tako je ovaj pregled literature ukazao i na nužnost istraživanja kornatskog područja.