The mollusc fauna of the Lobau (Nationalpark Donau-Auen, Viennese part) over time – past, presence and future perspectives

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The mollusc fauna of the Lobau, a forest and floodplain area of the National Park Donau-Auen, which is situated in large part within the municipal borders of Vienna (Austria), underwent several changes since the Danube regulation around 1870. After the regulation, many side arms, oxbow lakes, and backwaters, which were originally running waters, became stagnant water bodies. This reduced the habitat quality of formerly frequent species typical for Danubian flowing water, like *Theodoxus danubialis* or *Anodonta cygnea*. This first impact triggered the increase of mollusc species specialized on still water and swamp habitats. However, even this habitat type was, after some time, affected negatively by human influences. River regulation and the construction of a hydroelectric power station reduced the downstream transport of gravel and, therefore, triggered the drawdown of the groundwater level. Eventually, climate change and extreme weather events led to unfavourable hydrological conditions including complete desiccation of oxbow lakes and wet reed beds. Single observations confirmed the presumed negative impact on the mollusc fauna of the Lobau. Here we present the results of a survey performed in the years 2020 and 2021 in the Viennese part of the Lobau. We compared the results with data compiled from the literature from the early 20th century to 2019 and found a severe decrease in species numbers. Altogether 127 species (66 land snails, 38 aquatic snails and 23 mussels) were recorded in the investigated area up to this day. Of these, 121 species were found until 2019, while 6 others were recorded after 2019 for the first time (3 of them invasive species). The number of species found in the present survey (2020/2021) was only 86, out of which 63 were found alive and 23 were recorded as empty shells. Especially unionid mussels, some freshwater snails, and wetland species typical for Danubian forests like *Trochulus striolatus danubialis* and *Pseudotrichia rubiginosa* were missing. A loss of occurrences was registered for *Anisus vorticulus*, a species listed in Annex II of the Habitats Directive of the European Commission. On the other hand, several introduced molluscs have become more common in this protected area. More intense dotation of freshwater, which is long overdue, particularly for the Lower Lobau, could stabilise the hydrological situation and preserve or even improve at least the remaining freshwater and wetland fauna including the FFH species *Anisus vorticulus*.

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Die Molluskenfauna der Lobau im Wiener Teil des Nationalparks Donau-Auen erfuhr nach der Donauregulierung um 1870 mehrere Veränderungen. Als Folge der Regulierung wurden viele der ehemals durchflossenen Seitenarme und Altarme zu stehenden Gewässern. Dies hatte einen negativen Einfluss auf ehemals häufigere Arten, welche zur typischen Gewässerfauna der Donau gehören, wie z. B. *Theodoxus danubialis* oder *Anodonta cygnea*. Andererseits wurden dadurch seltene Arten der Verlandungszonen und stehenden Gewässer stark gefördert. Aber auch diese waren nach einiger Zeit durch anthropogene Faktoren negativ beeinflusst: Flussbauliche Maßnahmen und die Errichtung von Wasserkraftwerken in den flussaufwärts gelegenen Teilen der Donau reduzierten den Geschiebetrieb stark, was zu einer Eintiefung des Flussbetts und zum Absinken des Grundwasserspiegels führte. Zusätzlich beeinträchtigten zunehmende Trockenheit und Extremwetterereignisse die Situation der Gewässer in der Lobau. Der vermutete negative Einfluss auf die Molluskenfauna der Lobau wurde durch Einzelbe-

obachtungen bestätigt. Hier präsentieren wir die Ergebnisse der Erfassung der Molluskenfauna im Wiener Teil der Lobau, die in den Jahren 2020 und 2021 durchgeführt wurde. Wir vergleichen die Ergebnisse mit einer Zusammenstellung früherer Daten, vom frühen 20. Jahrhundert bis 2019, zum Gebiet und diskutieren die Entwicklung sowie die Trends für die Zukunft. Ein drastischer Rückgang an Arten wurde festgestellt. Bis 2022 wurden im Untersuchungsgebiet insgesamt 127 Arten registriert (66 Landschnecken-, 38 Wasserschnecken-, 23 Muschelarten). Von diesen wurden 121 Arten bis zum Jahr 2019 nachgewiesen, wohingegen sechs weitere Arten (darunter drei invasive Arten) erst nach 2019 im Gebiet gemeldet wurden. Im Zeitraum der Studie (2020/2021) betrug die Zahl der Arten lediglich 86, wovon 63 Arten lebend gefunden und 23 nur als Leerschalen registriert wurden. Besonders Großmuscheln und einige Wasserschnecken, aber auch typische Landschnecken der regelmäßig überfluteten Auenbereiche, wie z. B. *Pseudotrichia rubiginosa* und *Trochulus striolatus danubialis*, konnten nicht mehr nachgewiesen werden. Für *Anisus vorticulus*, eine Art, die im Anhang II der Fauna-Flora-Habitat-Richtlinie gelistet ist, wurde ein Verlust an Vorkommen verzeichnet. Andererseits breiten sich zunehmend eingeschleppte Arten im Gebiet aus. Eine lang überfällige, intensivere Dotation einiger Altarme, insbesondere der Unteren Lobau, könnte die Situation stabilisieren und zumindest die Bestände der noch verbliebenen ursprünglichen Molluskenfauna, darunter auch die FFH II Art *Anisus vorticulus*, erhalten oder sogar verbessern.

Keywords: Lobau, Vienna, Austria, Mollusca, Gastropoda, Bivalvia, Danubian river floodplain, drought.

Introduction

The Lobau is a partially dammed floodplain forest in the Southeast of Vienna which extends partly into Lower Austria. It is protected by the Ramsar Convention and by the Habitats Directive of the European Commission and it is part of the National Park Do-

Fig. 1: The Kühwörter Wasser: since the Danube regulation the only direct connection of the Lobau to the river. – Abb. 1: Das Kühwörter Wasser: seit der Donauregulierung die einzige direkte Verbindung zum Hauptstrom.

Fig. 2: Stagnant water bodies accompanied by reeds and softwood forests increased after the Danube regulation. – Abb. 2: Nach der Donauregulierung kam es zu einer Zunahme stehender Gewässer, welche von Röhricht und Weichholzauen begleitet werden.

Fig. 3: Steppe vegetation on former coarse Danube gravel. – Abb. 3: Trockenrasenvegetation auf ehemaligem grobem Donauschotter, die sogenannten „Heißländen".

Fig. 4: Prolonged ongoing drought in recent years afflicted small water bodies as well as semiaquatic areas. – Abb. 4: Lang anhaltende Trockenheit beeinträchtigte in den letzten Jahren sowohl Kleingewässer als auch semiaquatische Bereiche.

nau-Auen, established in 1996. Until the regulation of the Danube, it was a system of connected flowing side arms, oxbow lakes and old arms. Eventually, only a small connection to the main river via the Schönauer Schlitz in Lower Austria was left providing waterflow of floods, albeit as backflow from the Danube downstream of the Lobau (Fig. 1). These changes triggered the formation of new habitats, such as different types of still waters accompanied by periodically flooded softwood forests and reeds (Fig. 2) as well as dry steppe areas on former coarse Danubian gravel (Fig. 3), in Austrian literature called "Heißländen" (Schratt-Ehrendorfer 2000). In the last years, ongoing drought (Fig. 4) and possible measures to reduce its negative effects were the major subject of interest in this area. The present study deals with the historical development and the current situation of the mollusc fauna of the Viennese part of the Lobau.

The history of malacological research in the Lobau began comparably late. The first reliable report was given by Reischütz & Stojaspal (1971), who gave records of *Microcolpia daudebartii acicularis* together with accompanying water molluscs from two spots in the Lobau. The first comprehensive, systematic research on molluscs in the whole Lobau area started with Reischütz (1973), who was the first to give a reliable overview on species occurring in the Viennese floodplain areas, which also included the Lobau. This report is the base for all subsequent research in this area. Later on, Frank (1986, 1988, 1989) gave a comprehensive overview of older reports on molluscs in the Danube valley and Austria in general. Besides that, the works of Klemm (1974), Stojaspal (1978) and Reischütz (1986)

also touched the investigated area. Around the 1990s results of increasing drought of the former oxbow lakes came into focus, and a survey resulting in two studies carried out by Wittmann (1994 a, b) also treated the whole area. Unfortunately, the latter two studies are impaired by inadequate sampling methods and to some extent wrong identifications so that only few parts of those results are useful for further analysis (see Reischütz & Reischütz 2014 for more details). Nevertheless, they were the first pointing out the endangering of aquatic molluscs by ongoing drought. After 2000, research was focused on the impact of water discharge on the increasingly dry oxbow lakes as well as on special research concerning distribution of rare species (Duda & Fischer 2007; Fischer et al. 2009; Duda & Sattmann 2010; Duda 2013, 2018) and possible positive effects of supply of external water (Funk et al. 2009; Reckendorfer et al. 2012, 2013). In summary, the main problem in the Lobau area was the continuing lack of water during the last 20 years.

In the years 2020 and 2021 a mapping project was carried out which focused on occurrences of molluscs within the areas of rural development in Vienna (Duda et al. 2022). The area investigated included five regions within Vienna, among them the Danubian floodplains including the Lobau in the southeast of the city. In the present report, we present the newly achieved results of our 2020/21 survey for the Lobau. Together with a compilation of all previous data on the region, the results allow describing the development throughout the last decades.

The focus of this current report was on the following tasks:

1. Report on the composition of the mollusc fauna within the Viennese part of the Lobau.
2. Reconstruct transformations of the spectrum of mollusc species, specifically considering species with protection status as well as invasive species, and to evaluate general trends for the future.
3. Discuss measures to conserve and protect typical faunal elements.
4. Discussion and evaluation of the long-term development of selected species with high protection value (Viennese Nature Protection Directive, European Habitats Directive), as well as of species typical for Danubian river forests as defined by Čejka (2022).

Material and Methods

Concerning a reconstruction of the situation before the Danube regulation, no direct data were available for the Lobau. The potential inventory of the mollusc fauna of the area was extrapolated from Fischer & Müller (1996), who investigated a subfossil site in Kaiserebersdorf (channels of the Schwechat river, a tributary of the Danube) situated nearby on the right side of the Danube, and Pišút et al. (2021), who investigated soil layers of different age at the Devín gate, about 40 km downstream of Vienna. Concerning more recent data, we followed two approaches: in the first step, historical data on the Viennese part of the Lobau published in various studies and articles (Reischütz & Stojaspal 1971; Reischütz 1973; Stojaspal 1978; Frank 1986, 1988, 1989; Funk et al. 2009; Fischer et al. 2009; Duda & Sattmann 2010; Reckendorfer et al. 2012, 2013; Duda 2013, 2018) were compiled and – wherever possible – localized. Concerning the studies of Wittmann (1994 a, b), only selected data from these studies were used due to some doubts regarding identifications (see also Reischütz & Reischütz 2014). The main source of current data was obtained during the fieldwork of the project "Molluscs of the rural areas in Vienna", trying to cover also formerly investigated collecting sites to allow comparisons of the results. In total, 61 sites

were inspected from 20.05.2020 to 09.06.2020 and from 12.03.2021 to 19.12.2021. Both aquatic and terrestrial molluscs were collected with qualitative methods including hand catching, scooping and sieving of substrate (litter and soil samples). Species were recorded, and it was registered, whether they were found alive and/or dead and metadata (date, time, area, sampling site, coordinates, sea level, coordinates, vegetation types and landscape structures) were noted and recorded in a database. Selected samples (altogether 113) of the 2020/2021 project were transferred to the Mollusca Collection of the Natural History Museum Vienna and are inventoried under NHMW-MO-113705.

Additional recent findings of groundwater molluscs within the area were donated by Christian Griebler (University of Vienna) in 2022.

To compare and evaluate species assemblages over longer time periods, species numbers of the whole area (old records as well as those made in the course of the project "Molluscs of the rural areas in Vienna") were categorised in three time periods: before 1999, 2000–2019, 2020–2021.

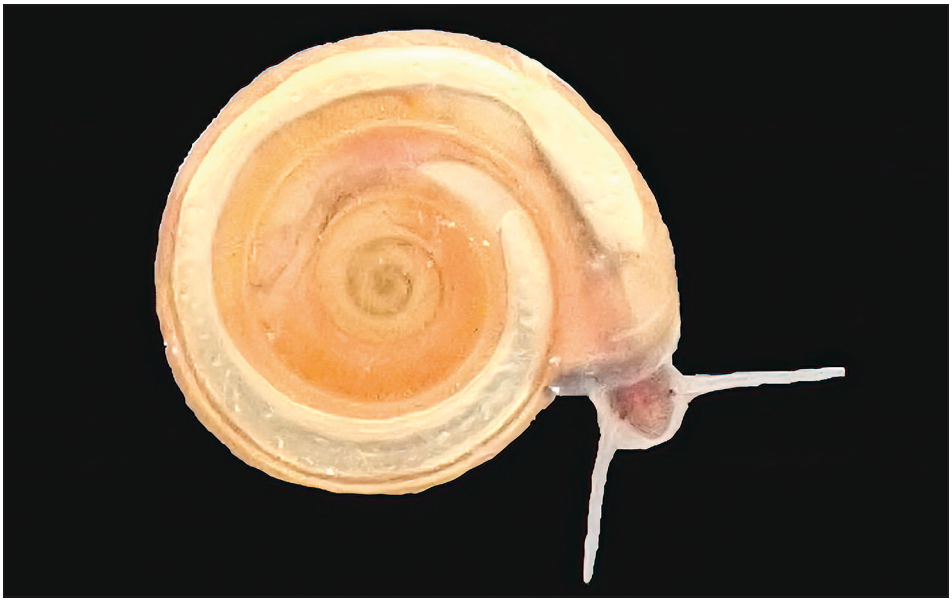

Fig. 5: *Anisus vorticulus*, the only extant species listed in Annex II of the Habitats Directive of the European Commission for the Lobau. – Abb. 5: *Anisus vorticulus,* die einzige im Anhang II der FFH-Richtlinie gelistete Art, die in der Lobau noch vorkommt.

Anisus vorticulus (Fig. 5) was considered in particular, as it is the only species which had undergone more or less continuous evaluation over time (Wittmann 1994b; Fischer et al. 2009) and was monitored in previous studies (Duda 2013, 2018). Therefore, old and new records of this species provided the basis for a more detailed evaluation of its range development over time.

Concerning nomenclature and taxonomic order (in Tab. 1), we follow Reischütz & Reischütz (2022), respectively WoRMS (2023).

Tab. 1: Mollusc species found in the Viennese part of the Lobau since Reischütz & Stojaspal (1971). Subspecies are listed for those species, of which the nominate subspecies does not occur in the investigated area. FFH: Species listed in the Annex II of the Habitats Directive of the European Commission, RL: species listed at least as "Near Threatened" in the Red List of Austrian molluscs, V: species listed in the Viennese Nature Protection Ordinance, In: invasive species, L: species found living: E: species only found as empty shell. 0: species not found at all. Remarks: [1] Both species cannot be exactly taxonomically assigned, [2] determination insecure, only empty shells found, [3] taxonomy insecure, [4] before 2000 according to Klemm (1974), [5] before 2000 according to Wittmann (1994a), [6] nomenclature insecure, [7] before 2000 according to Wittmann (1994a), [8] insecure if in Viennese or Lower Austrian part of the Lobau before 2000; * number of species not recorded at all (out of the 126 species recorded between 1972–2021; irrespective of alive or dead). – Tab. 1: Molluskenarten, welche im Wiener Teil der Lobau seit Reischütz & Stojaspal (1971) nachgewiesen wurden. Unterarten sind dort angegeben, wo im Untersuchungsgebiet nicht die Nominatform vorkommt. FFH: Art im Anhang II der FFH-Richtlinie der Europäischen Kommission gelistet, RL: Art mit einem Gefährdungsgrad von zumindest "Near Threatened" in der Roten Liste der Weichtiere Österreichs angeführt, V: Art in der Wiener Naturschutzverordnung angeführt, In: invasive Art, L: Art lebend nachgewiesen, E: Art nur als Leerschale nachgewiesen, 0: Art nicht nachgewiesen. Anmerkungen: [1] Diese beiden Arten können derzeit taxonomisch nicht eindeutig zugeordnet werden, [2] Bestimmung unsicher, basiert nur auf Leerschalen, [3] taxonomische Zuordnung unsicher, [4] Nachweis vor 2000 nach Klemm (1974), [5] Nachweis vor 2000 nach Wittmann (1994b), [6] Nomenklatur unklar, [7] Nachweis vor 2000 nach Wittmann (1994b), [8] unklar, ob Nachweise vor 2000 im Wiener oder Niederösterreichischen Teil der Lobau erfolgten; * Anzahl nicht nachgewiesener Arten (von den 126 Arten die im Zeitraum 1972 bis 2021 nachgewiesen wurden; lebend oder als Leerschale).

Species (altogether 126 species)		**until 1999**	**2000–2019**	**2020–2021**
Gastropoda (aquatic)				
Neritidae				
Theodoxus danubialis danubialis (C. Pfeiffer, 1828)	RL	L	0	0
Viviparidae				
Viviparus acerosus Bourguignat, 1862	RL	L	L	E
Viviparus contectus (Millet, 1813)	RL, V	L	L	L
Melanopsidae				
Microcolpia daudebartii acicularis (A. Férussac, 1823)	RL	L	0	E
Bithyniidae				
Bithynia tentaculata (Linnaeus, 1758)		L	L	L
Tateidae				
Potamopyrgus antipodarum (Gray, 1843)	In	0	L	L
Hydrobiidae				
Hauffenia danubialis (Haase, 1993)	RL	0	0	L
Bythiospeum aff. *geyeri* (Fuchs, 1925)[1]	RL?	L	0	L
Bythiospeum aff. *pfeifferi* (Clessin, 1890)[1]	RL?	0	0	L
Lithoglyphidae				
Lithoglyphus naticoides (C. Pfeiffer, 1828)	RL	E	0	0
Valvatidae				
Valvata cristata O. F. Müller, 1774		0	L	L
Valvata piscinalis piscinalis O. F. Müller, 1774		L	L	L
Acroloxidae				
Acroloxus lacustris (Linnaeus, 1758)		L	L	L
Lymnaeidae				
Galba truncatula (O. F. Müller, 1774)		L	L	L

Species (altogether 126 species)		until 1999	2000–2019	2020–2021
Stagnicola turricula (Held, 1836)	RL	L	L	L
Stagnicola corvus (Gmelin, 1791)		L	L	L
Lymnaea stagnalis (Linnaeus, 1758)		L	L	L
Radix auricularia (Linnaeus, 1758)		L	L	L
Ampullaceana balthica (Linnaeus, 1758)		L	L	L
Ampullaceana cf. *lagotis* (Schrank, 1803)[2]		0	0	E
Peregriana labiata (Rossmässler, 1835)[3]		L	L	L
Physidae				
Aplexa hypnorum (Linnaeus, 1758)	RL	L	L	L
Physella acuta (Draparnaud, 1805)	In	L	L	L
Planorbidae				
Ancylus fluviatilis O. F. Müller, 1774		0	L	0
Ferrissia californica (Rowell, 1863)	In	0	L	E
Anisus leucostoma (Millet, 1813)		L	0	0
Anisus septemgyratus (Rossmässler, 1835)		0	L	0
Anisus spirorbis (Linnaeus, 1758)	RL	L	L	L
Anisus vortex (Linnaeus, 1758)	V	L	L	L
Anisus vorticulus (Troschel, 1834)	FFH, RL	L	L	L
Gyraulus albus (O. F. Müller, 1774)		L	L	L
Gyraulus cf. *parvus* (Say, 1817)[3]	In	0	L	L
Gyraulus crista (Linnaeus, 1758)		L	L	L
Planorbis planorbis (Linnaeus, 1758)		L	L	L
Planorbis carinatus O. F. Müller, 1774		L	L	L
Hippeutis complanatus (Linnaeus, 1758)	RL	L	L	L
Segmentina nitida (O. F. Müller, 1774)	RL	0	L	L
Planorbarius corneus (Linnaeus, 1758)	V	L	L	L
Gastropoda (terrestrial)				
Ellobiidae				
Carychium minimum O. F. Müller, 1774		L	L	L
Carychium tridentatum (Risso, 1826)		L	L	E
Succineidae				
Succinella oblonga (Draparnaud, 1801)		L	0	E
Succinea putris (Linnaeus, 1758)		L	L	L
Oxyloma elegans (Risso, 1826)		L	L	L
Cochlicopidae				
Cochlicopa lubrica (O. F. Müller, 1774)	RL	L	L	L
Cochlicopa lubricella (Porro, 1838)		L	E	E
Cochlicopa nitens (M. Gallenstein, 1848)	RL	L	L	0
Valloniidae				
Vallonia costata (O. F. Müller, 1774)		L	L	L
Vallonia pulchella (O. F. Müller, 1774)		L	L	L
Pupillidae				
Pupilla muscorum (Linnaeus, 1758)	RL	L	L	E
Vertiginidae				
Vertigo alpestris Alder, 1838[4]		L	E	0
Vertigo antivertigo (Draparnaud, 1801)	RL	0	L	L

Species (altogether 126 species)		until 1999	2000–2019	2020–2021
Vertigo pygmaea (Draparnaud, 1801)		0	L	L
Chondrinidae				
Granaria frumentum (Draparnaud, 1801)	RL, V	L	L	L
Truncatellinidae				
Columella edentula (Draparnaud, 1805)		0	L	0
Truncatellina cylindrica (J. Férussac, 1807)	RL	0	E	L
Enidae				
Chondrula tridens (O. F. Müller, 1774)	RL	E	0	0
Clausiliidae				
Cochlodina laminata (Montagu, 1803)		L	L	L
Macrogastra ventricosa (Draparnaud, 1801)		0	E	0
Clausilia dubia (Draparnaud, 1805)		0	E	E
Clausilia pumila (C. Pfeiffer, 1828)		L	L	L
Laciniaria plicata (Draparnaud, 1801)		L	0	0
Alinda biplicata (Montagu, 1803)		L	L	0
Ferussaciidae				
Cecilioides acicula (O. F. Müller, 1774)	RL	E	E	E
Punctidae				
Punctum pygmaeum (Draparnaud, 1801)		0	E	0
Gastrodontidae				
Aegopinella nitens (Michaud, 1831)		L	L	L
Perpolita hammonis (Ström, 1765)		0	L	0
Zonitoides nitidus (O. F. Müller, 1774)		L	L	L
Pristilomatidae				
Vitrea crystallina (O. F. Müller, 1774)		L	E	E
Vitrea subrimata (Reinhardt, 1871)		L	0	0
Oxychilidae				
Oxychilus cellarius (O. F. Müller, 1774)		L	0	0
Oxychilus draparnaudi (H. Beck, 1837)		0	E	L
Milacidae				
Tandonia budapestensis (Hazay, 1880)	In	L	0	L
Zonitidae				
Aegopis verticillus (A. Férussac, 1819)[5]	V	L	0	0
Vitrinidae				
Eucobresia diaphana (Draparnaud, 1805)		L	0	0
Semilimax semilimax (J. Férussac, 1802)		L	0	0
Vitrina pellucida (O. F. Müller, 1774)		L	0	E
Limacidae				
Limax maximus Linnaeus, 1758		L	0	L
Agriolimacidae				
Deroceras agreste (Linnaeus, 1758)		L	0	0
Deroceras laeve (O. F. Müller, 1774)		0	L	L
Deroceras reticulatum (O. F. Müller, 1774)		L	L	0
Euconulidae				
Euconulus alderi (J. E. Gray, 1840) 6		0	L	L
Euconulus fulvus (O. F. Müller, 1774)		L	0	0

Species (altogether 126 species)		until 1999	2000–2019	2020–2021
Arionidae				
Arion distinctus Mabille, 1868		L	0	0
Arion fasciatus (Nilsson, 1823)		L	0	0
Arion fuscus (O. F. Müller, 1774)		L	L	0
Arion silvaticus Lohmander, 1937		0	L	0
Arion vulgaris Moquin-Tandon, 1855[7]	In	L	L	L
Geomitridae				
Helicopsis striata (O. F. Müller, 1774)	RL	L	0	0
Xerolenta obvia (Menke, 1828)		L	L	L
Hygromiidae				
Hygromia cinctella (Draparnaud, 1801)	In	0	0	E
Monachoides incarnatus (O. F. Müller, 1774)		L	L	L
Euomphalia strigella (Draparnaud, 1801)		L	0	0
Pseudotrichia rubiginosa (Rossmässler, 1838)	RL, V	L	L	E
Monacha cantiana (Montagu, 1803)	In	0	0	L
Monacha cartusiana (O. F. Müller, 1774)	RL, V	L	L	0
Petasina unidentata (Draparnaud, 1805)		L	E	L
Trochulus hispidus (Linnaeus, 1758)		L	L	0
Trochulus striolatus danubialis (Clessin, 1874)	RL, V	L	L	E
Urticicola umbrosus (C. Pfeiffer, 1828)		L	L	L
Camaenidae				
Fruticicola fruticum (O. F. Müller, 1774)		L	L	E
Helicidae				
Arianta arbustorum (Linnaeus, 1758)		L	L	E
Cepaea hortensis (O. F. Müller, 1774)		L	L	L
Caucasotachea vindobonensis (C. Pfeiffer, 1828)		L	L	L
Helix pomatia Linnaeus, 1758		L	L	L
Bivalvia				
Unionidae				
Anodonta anatina (Linnaeus, 1758)	RL	L	L	L
Anodonta cygnea (Linnaeus, 1758)	RL, V	L	L	0
Sinanodonta woodiana (I. Lea, 1834)	In	0	L	E
Unio crassus Philipsson, 1788[8]	FFH, RL	L	0	0
Unio pictorum (Linnaeus, 1758)	RL, V	L	E	E
Unio tumidus Philipsson, 1788[8]	RL, V	L	0	0
Cyrenidae				
Corbicula fluminea (O. F. Müller, 1774)	In	0	L	E
Sphaeriidae				
Euglesa casertana (Poli, 1791)		0	L	L
Euglesa henslowana (Sheppard, 1825)		L	0	0
Euglesa lilljeborgii (Clessin, 1886)		L	0	0
Euglesa nitida (Jenyns, 1832)		L	L	0
Euglesa milium (Held, 1836)		0	L	L
Euglesa obtusalis (Lamarck, 1818)		L	L	E
Euglesa subtruncata (Malm, 1855)		L	L	L
Euglesa supina (A. Schmidt, 1850)		L	0	0

Species (altogether 126 species)		until 1999	2000–2019	2020–2021
Odhneripisidium moitessierianum (Paladilhe, 1866)		0	L	0
Musculium lacustre (O. F. Müller, 1774)	V	L	L	L
Sphaerium corneum (Linnaeus, 1758)		L	L	L
Sphaerium nucleus (S. Studer, 1820)		0	L	L
Sphaerium ovale (A. Férussac, 1807)		0	L	0
Sphaerium rivicola (Lamarck, 1818)	V	L	0	0
Dreissenidae				
Dreissena polymorpha (Pallas, 1771)	In	L	L	E
Dreissena bugensis (Andrusov, 1897)	In	0	0	E
Summary species numbers				
Number of species recorded living		91	82	63
Number of species recorded only as empty shell		5	11	23
Number of species not recorded*		31	34	41

Results

Species recorded

In total, 127 species of molluscs (66 land snails, 38 aquatic snails and 23 mussels) could be reported up to date in the investigated area. Of these, 121 species were found until 2019, while six (three of them invasive species) were recorded after 2019 for the first time. During the present survey (2020/2021), only 86 of the former recorded 121 species of molluscs were found, only 64 of them alive; among those were 28 species of land snails, 29 aquatic snails and 7 mussels. In addition, 23 species were found as empty

Tab. 2: Sampling sites with records of living *Anisus vorticulus* 1992–2020. 1: sampling site inspected, record of living *A. vorticulus*; 0: sampling site inspected, no record of *A. vorticulus*: 1?: record according to Wittmann 1994a; #: sampling site not inspected in the respective year, * this locality was not inspected any more as it was dry since 2018. – Tab. 2: Standorte mit Nachweis von lebenden *Anisus vorticulus* 1992–2020. 1: Standort untersucht, Nachweis von lebenden *A. vorticulus*; 0: Standort untersucht, kein Nachweis von *A. vorticulus*; 1?: Nachweis der Art gemäß Wittmann 1994a; #: Standort nicht untersucht in diesem Jahr; *: Dieser Standort wurde nach seiner Austrocknung 2018 nicht mehr untersucht.

Sampling site	Before 2000	2007	2010	2013	2018	2020
Mühlleitner Furth	0	0	1	1	1	1
Gothenwasser	#	0	#	1	1	1
Gothenwasser II	#	#	#	#	#	1
Mühlwasser	#	#	#	#	1	1
Kaiserlacken	0	1	0	0	0	#*
Küniglтraverse	#	#	1	#	#	0
Panozzalacke S	#	#	0	#	#	1
Fasangartenarm	#	#	#	#	#	1
Gänshaufentraverse	#	0	0	1	0	0
Oberleitner Wasser	1?	#	#	#	#	1
Hausgraben	1?	#	#	#	#	1
Gr. Eberschütt	#	#	#	#	#	1
Gr.-Kl. Eberschütt	#	#	#	#	#	1

shells (13 land snails, four aquatic snails, six mussels). In Table 1 the results are summarised, together with a compilation of previous data in the periods before 1999 and 2000/2019.

Among the aquatic molluscs detected alive, there were three species of groundwater snails: *Bythiospeum* aff. *geyeri*, *B.* aff. *pfeifferi* and *Hauffenia danubialis*. The two *Bythiospeum* forms differ in shell shape and size and could not be clearly identified to species level.

Of the two species listed in Annex II of the Habitats Directive of the European Commission (FFH species: *Unio crassus* and *Anisus vorticulus*), only *Anisus vorticulus* could be found, whereas *Unio crassus* was not even found as empty shells. Concerning *Anisus vorticulus*, long-term data of the occurrence indicated a loss at three of nine sites, where this species had been recorded so far (Tab. 2). Four additional sites that had not been investigated for this species in the past, evidenced a recent occurrence.

Of the 29 species listed at least as "Near threatened" in the red list of Austrian molluscs, 13 were recorded alive, seven as empty shells and nine could not be detected anymore. Of the 13 species listed in the Viennese Nature Protection Ordinance five were found alive, three as empty shells and five could not be detected anymore.

Twelve invasive species were recorded in the present survey (2020–2021), six of those species alive (Tab. 1).

Comparisons with historical data

Considering the time before the end of the study in 2021 – starting with the beginning of research in the Lobau by Reischütz and Stojaspal (1971) and old evidence listed up by Frank (1986) beginning with the 1930s – altogether 127 species of molluscs had been recorded, among them 66 species of land snails, 38 aquatic snails and 23 mussels (Tab. 1).

Comparing the number of species detected in the present survey (period 3: 2020–2021) with the data of the first two periods indicates a severe decrease. Of 86 species, 63 were found alive, while 23 were recorded only as empty shells. Out of the 108 species detected alive in at least one of the first two periods, 39 species could not be detected alive anymore in 2020 and 2021.

Of the 12 invasive species, three were recorded for the first time in the period 2020–2021, five from 2000–2019, while further four were already known for period 1 (before 1999).

Concerning a long-term trend, it becomes apparent that in the first two periods the number of molluscs reported (summarising living individuals and empty shells) was rather stable (96 and 93) and decreased in the recent survey by ~10 % (86 species recorded). The loss of species appears even more drastic, if species are considered which were documented for the first time in 2020–2021. Two of the three hydrobioid spring snail species mentioned above were not recorded during the two earlier periods, but for the first time in the present project (because groundwater snails have not been surveyed consistently in the first two periods). The same applies to three invasive species, which were detected only in the period 2020–2021. Regarding only species detected alive, this decline also appears severe: 91 and 82 species, respectively, were found alive in the first two periods, while only 64 were recorded alive in 2020–2021, which is a decrease of about 25 %. When omitting the three newly detected species recorded alive (Tab. 1) for the calculation, the number decreases to 61.

Discussion

Historical development

Concerning species composition over time, it can be assumed that the very original mollusc fauna of the study area before the regulation of the Danube mainly consisted of water molluscs of slow-flowing rivers and connected side arms and oxbow lakes, e.g., snails like *Microcolpia daudebartii acicularis*, *Theodoxus danubialis* and *Viviparus acerosus* and, as typical mussel species, *Unio crassus*, *Unio pictorum*, and *Anodonta cygnea*. Results of subfossil faunas presented by Fischer & Müller (1996) and Pišút et al. (2021) also point in this direction, showing that these more rheophilous species had been much more frequent in the unregulated Danube and its side arms. After the regulation, habitats changed due to the transformed hydrological situation. The number of silent water bodies and periodically flooded softwood forests and reeds increased (Fig. 2) and dry steppe areas formed on former coarse Danubian gravel (Fig. 3). The steppe spots developed into a regionally important thermophilous land snail fauna, e.g., *Granaria frumentum* and *Caucasotachea vindobonensis*. The above-mentioned aquatic species – except *Theodoxus danubialis* – kept on surviving, possibly because of the still existing connection to the main river. In the now increasing number of standing water bodies a rich aquatic mollusc fauna developed, including nowadays rare and protected animals, like *Viviparus contectus*, *Aplexa hypnorum* and *Anisus vorticulus*. Furthermore, the periodically flooded area provided habitats for species endangered in Austria (Reischütz & Reischütz 2007), especially *Pseudotrichia rubiginosa* (Fig. 6) and *Trochulus striolatus danubialis*.

Fig. 6: *Pseudotrichia rubiginosa*, a hygrophilous land snail, was not found living since 2013 in the investigated area. – Abb. 6: *Pseudotrichia rubiginosa*, eine hygrophile Landschnecke, wurde seit 2013 nicht mehr im Untersuchungsgebiet gefunden.

Nevertheless, the new aquatic and semi-aquatic mollusc fauna has also become threatened in the long term. River regulations and the construction of a hydroelectric power station reduced the transport of gravel downstream and therefore triggered the lowering of both river and groundwater level. In addition to the lack of natural or artificial floodings, climate change and extreme weather events led to extremely unfavourable hydrological conditions including complete desiccation of oxbow lakes and wet reed beds.

Five expected species – the aquatic snail *Theodoxus transversalis* (C. Pfeiffer, 1828), the land gastropods *Arion rufus* (Linnaeus, 1758) and *Vallonia enniensis* (Gredler, 1856), *Vallonia excentrica* Sterki 1893, as well as the unionid mussel *Pseudanodonta complanata* (Rossmässler, 1835) – were historically not recorded in the investigated area. However, it can be assumed that they once occurred here, since they were documented in similar habitats nearby (Reischütz 1973; Fischer & Müller 1996) and had already disappeared when research began in the study area. This applies in particular for *Pseudanodonta complanata*: A subfossil empty shell of this species was accidentally found by C. Schmutz at a public bathing place in a river arm just a few meters outside the investigated area in 2020 (voucher at collection Reischütz). Besides, Fischer (2022) reports on recent empty shells of this mussel just a few kilometres east of the investigated area. Concerning *Vallonia excentrica*, its recent finding in other areas of the Viennese Danubian floodplains (Duda et al. 2022) support the assumption that they might have been overlooked in the Lobau so far.

Development since the 20th century

The results of the survey 2020–2021 compared to those of former periods indicate that a high number of molluscs have vanished in recent years. Furthermore, three new invasive species of land gastropods were recorded. The slug *Arion vulgaris* has inhabited the investigated area since at least the 1990s and is now one of the most frequent species in the Lobau. Moreover, *Hygromia cinctella* and *Monacha cantiana* were found at two sites in 2020–2021, and it can be assumed that these two species will also spread soon. The decrease in species numbers becomes apparent from Table 1 and was exemplified by various comparisons in the Results section. An additional trend may be emphasised here: The proportion of species found alive decreased considerably during the three periods. While in period 1 only 6 % of species were found only as dead shells, this proportion was 13 % in period 2 and 37 % in period 3 (2020–2021) (see Tab. 1).

It could be argued that the general results regarding species numbers are biased due to big differences between the periods examined here (before 1999, 2000–2019, 2020–2021). Among land snails, this might apply to single species, especially *Monacha cartusiana* and the slugs *Arion distinctus*, *Arion fuscus* and *Arion silvaticus*, as they were mainly found around 2010 in unpublished data concerning the inner dam, an area, which has been represented by just one sample site in the period of 2020–2021. Apart from that, the lack of recent living records of *Pseudotrichia rubiginosa*, *Trochulus striolatus danubialis* and *Arianta arbustorum* is alarming. All three species should be abundant in a classic softwood river forest, as indicated by Čejka (2022). *Pseudotrichia rubiginosa* was constantly recorded at one sample site by the first author from 2007 to 2013. During this time, it could easily be found even by visual search without inspecting soil samples or other efforts. Yet, since 2013, only corroded empty shells were found, despite the addition of more experienced methods like sieving and analysing detritus. The last time *Trochulus striolatus danubialis* was found alive (one juvenile specimen determined by the first author), was by Recken-

dorfer (2013). In our 2020–2021 survey, just one empty shell was found in detritus from the bottom of an oxbow lake. Even more striking is the fact that no living specimens of *Arianta arbustorum* could be found. In contrast to the above-mentioned species, it is neither endangered (Reischütz & Reischütz 2007) nor protected in Austria and should be frequently found in moist areas. In the present study, only empty shells at one locality could be found. The lack of such a common species in a habitat where it should occur in masses is indeed an alarming signal. The same applies to the common species *Trochulus hispidus*, which could not be found in the current survey, despite intense search. *Deroceras agreste* disappeared very likely shortly after the report of Reischütz (1973). The flatland populations of this species got extinct due to habitat degradation, as reported by Reischütz & Reischütz (2007). Long drought periods afflicting semi-aquatic habitats are the reason for the extinction of all these species (Fig. 4).

The recordings of water snails and mussels can be interpreted in a similar way. Concerning the original aquatic fauna of rivers and connected oxbow lakes, *Theodoxus danubialis* was already extinct at the survey of Reischütz (1973), *Lithoglyphus naticoides*, *Unio crassus* and *Unio tumidus* likely became extinct soon after that report. *Microcolpia daudebartii acicularis*, *Viviparus acerosus* and *Anodonta cygnea* could at least survive until the end of the 20th century, but presently are obviously extinct in the area. Of the first two species, subfossil shells can still be found. Among the water snails, only for *Anisus vorticulus* detailed data on their occurrence (former and present occurrences) exist, indicating that it lived at least in 13 spots within the Lobau (assuming that it also occurred in former times in the 4 newly discovered sites during this investigation). In three of the already known sample sites, it could not be found anymore (since 2018) and obviously became extinct. All of these sites were situated in the "Untere Lobau".

These extinctions were caused in all cases by the exsiccation of water bodies. It can be assumed that this is an ongoing process, as at least two of the sampling sites of *Anisus vorticulus* (Gothenwasser, Mühlleitner Furt) were desiccated in 2018, but the species kept on surviving in the moist soil of the water bodies. More intense drought periods in the future could lead to the extinction of this species also there. Similar tendencies can be assumed for all water molluscs living preferably in small water bodies in the Lobau. For freshwater mussels, even more drastic decreases can be assumed. For members of the Sphaeriidae, which are quite small and not easy to identify, an unnoticed decrease or even extinction appears likely. Particularly dramatic is the case of native unionid mussels, only one of five species – *Anodonta anatina* – could be found alive in 2020–2021, and from another one – *Unio pictorum* just old empty shells were found. Among the mussels, the highest part of invasive species was found: 4 out of 23 species. Fresh empty shells of the invader *Sinanodonta woodiana* were found in the southeast of the investigated area, near the border of Lower Austria. This fits the results of Fischer (2018), who investigated the same water body during the drought period on the nearby Lower Austrian side and found this species to be the most abundant together with *Corbicula fluminea*. In addition, both invasive Dreissenidae – *Dreissena bugensis* and *D. polymorpha* – were found in several oxbow lakes.

For the three spring snail taxa no assessment of potential threats could be made. Moreover, comparative data are needed for an exact taxonomic assignment of the two forms of *Bythiospeum* sp. The taxonomic situation for the whole genus is not fixed yet, and it should be considered that the number of species in *Bythiospeum* might be reduced soon (see also Richling et al. 2017).

In contrast to the degradation of aquatic habitats, the snails of dry steppe habitats (e.g. *Truncatellina cylindrica*, *Pupilla muscorum*, *Caucasotachea vindobonensis*) currently do not seem to be threatened. On several meadows, landscape management measures are applied to avoid intrusion of shrubs and trees, which is necessary, as ongoing pedogenesis (Schratt-Ehrendorfer 2000) would lead to denser and even forest-like vegetation. Thus, species dependent on dry steppe habitats benefit from such management activities. The only species that became extinct due to more dense vegetation over the time is *Helicopsis striata,* a highly sensitive and endangered species of steppe and dry grassland. Among the other thermophilous species, *Caucasotachea vindobonensis* even seems to spread outside of dry and open habitats into reeds and forests. This could also be interpreted as a consequence of the ongoing drought.

Parts of the current desiccation of aquatic and semiaquatic habitats were already predicted by Margl (1973), who investigated the plant societies in this area. During the last years this process was triggered by long-lasting droughts. The only way to absorb the worst effects of ongoing drought and climate change on the mollusc fauna of the Lobau would be to supply more water than currently provided. In particular, the southeastern part of the area, the Lower Lobau ("Untere Lobau"), which presently receives no additional water, is most threatened. For molluscs, the optimal conditions would be clean water that is not too cold and fast-flowing. At least the still occurring freshwater fauna with high conservation value like *Anisus vorticulus* could be stabilized. Besides that, also other plant and animal species would benefit from such measures. In addition, one or the other species thought to be extinct could recover or recur in the Viennese part of the Lobau. Therefore, an important future task is to assess the mollusc fauna of the Lower Austrian part of the Lobau, as some of the species no longer detected in the Viennese part might still occur there. In any case, a more constant monitoring concept should be established. This monitoring should include qualitative and quantitative aspects, to get information on long-term fluctuations of the mollusc fauna in relation to water level development and/or management.

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