Chapter 16
Conservation of the Lymnaeidae

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Abstract Like many other groups of freshwater Mollusca, the lymnaeid snails are prone to extinction, the main cause of which is currently habitat degradation. Unfortunately, only a modest portion of species of this species have been assessed from the conservationist's point of view, and the available information on distribution, ecology, and population trends of many of the assessed species is not enough to determine their current conservation status. The chapter deals with the state of the art of lymnaeid conservation and reviews the existing advances and challenges in the field. A quantitative analysis of the patterns of a rarity among the Lymnaeidae, based on the available IUCN assessments of their conservation status, is presented. A single case of a presumed rarity at the global scale (*Myxas glutinosa*) is reviewed and discussed. The article provides a brief overview of the eight shortfalls "impairing knowledge and conservation of freshwater molluscs" (Lopes-Lima et al., Hydrobiologia 848(11–12):2831–2867, 2021), with discussion of their application to protection and conservation of the lymnaeid snails.

It is a very well-known fact that the conservationists' efforts have historically been biased toward the protection of the so-called charismatic species of animals, i.e. a group of taxa, which easily get public attention (McKinney 1999; Clark and May 2002; Colléony et al. 2017; Delso et al. 2021). This group includes, according to Skibins et al. (2017, p. 157), primarily those creatures that are "cute and cuddly, or exotic and alluring" (or, following an alternate rating, "Rare, Endangered, Beautiful, Cute, Impressive, and Dangerous"; see Albert et al. 2018). In other words, these charismatic taxa belong to relatively large vertebrates (especially mammals, birds, and reptiles) and are characterized by either increased attractivity to laymen or high media coverage, or both (Albert et al. 2018; Berti et al. 2020; Mammola et al. 2020).

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The issue of how to increase the attention of decision-makers and the public to the lesser-known and less charismatic groups of animals, including most taxa of insects and many groups of relatively unseen and "non-attractive" invertebrates, forms a hot challenge for conservation biology. These relatively neglected animal groups are especially prone to what was called "quiet extinction" (Eisenhauer et al. 2019), and the disappearance of their members often is almost unnoticed by both the scientific community and the public (Régnier et al. 2009, 2015; Cowie et al. 2017). Freshwater mollusks, with the probable exception of some species popular among aquarists, also belong to animals relatively unknown to the public that results in insufficient effort to protect them, including the lack of legislative measures.

Nevertheless, the scientific and public awareness of the problem is continuously increasing, and, during several last decades, a special field of malacology, *conservation malacology*, has formed. Special publications stressing the need for the protection of freshwater snails and bivalves started to appear around a century ago (for example, in Poland, see Poliński 1927; Urbański 1932). Already in these pioneering works, a significant idea was developed: the protection of molluscan communities as a whole (and their habitats) is a much more effective conservation measure than the protection of an individual molluscan species. A body of publications concerning various aspects of freshwater mollusks conservation is today growing increasingly, and, during the last 25 years, a series of valuable review studies on this subject have appeared (see Bouchet et al. 1999; Lydeard et al. 2004; Perez and Minton 2008; Régnier et al. 2009, 2015; Johnson et al. 2013; Cowie et al. 2017, 2022; Lopes-Lima et al. 2017, 2018, 2021; Ferreira-Rodríguez et al. 2019; Böhm et al. 2021; Neubauer and Georgopoupou 2021; Neubauer et al. 2021; and references therein). These studies demonstrate very high extinction rates for freshwater Mollusca as well as an urgent need for the sound taxonomy of this group, the lack of which hampers the efforts made by conservationists. The deficiency of reliable knowledge of other aspects of freshwater malacology (distribution, abundance, ecology and competition, and current population trends) is also evident (Lopes-Lima et al. 2021).

The Lymnaeidae have very rarely (if any) been an object of conservation efforts and research related to it. Most representatives of the family remain virtually neutral in relation to protective measures, whereas some of the pond snails (e.g., the dwarf pond snail, *Galba truncatula*) were subjected to eradicative rather than protective actions (see Zhadin and Pankratova 1931; Rondelaud 1978; Rondelaud and Vareille-Morel 1994; Tunholi et al. 2017).

In this review article, I try to outline the current state of the Lymnaeidae conservation at a global scale and discuss some perspectives for further work in this direction.

The world's most authoritative data source in animal conservation is the IUCN Red List of Threatened Species, which is accessible through the website (https://www.iucnredlist.org/) and is updated steadily. Despite its title, it contains not only truly threatened taxa but also widespread and abundant species, whose survival raises no concern (the so-called least concern species, or LC). Each animal species, included in this list, is classified as belonging to one of the following basic categories

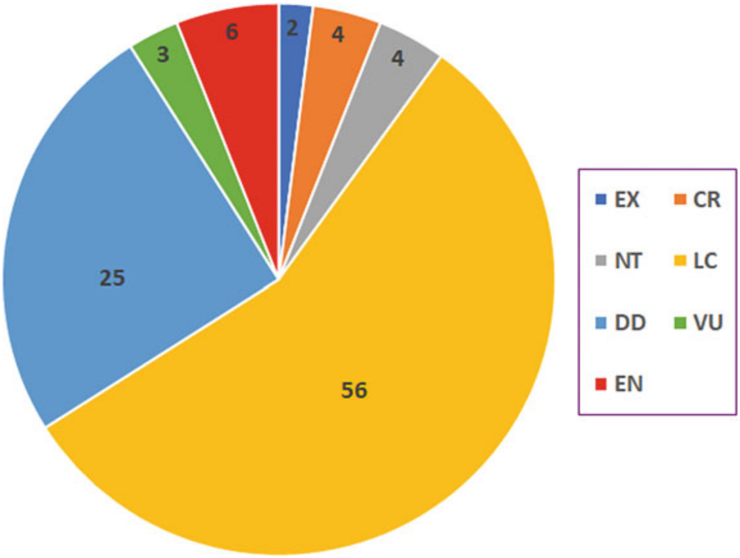

Fig. 16.1 Extinction risk in the Lymnaeidae (based on 100 Red List conservation assessments). See text for the abbreviations. The numbers correspond to number of lymnaeid species belonging to each conservation category

(in addition to LC): EX—extinct; EW—extinct in the wild; CR—critically endangered; EN—endangered; VU—vulnerable; NT—near threatened; DD—data deficient. The latter category contains species the information about which is too scarce to make a conservation assessment. The assessment of the conservation status of species and their placement in a certain Red List category are being made using a set of criteria, including the number of known locations, the current population trend, the known threats, existing protective efforts, etc. The data that are currently available for the taxon across its entire global range form the basis for the assessment (see https://www.iucnredlist.org/assessment/process for more detail).

As of 30 September 2021, the IUCN Red List database includes 100 lymnaeid species, which constitutes, roughly, 2/3 of the global species richness of this family. Most assessed species have been classified as belonging to LC ($n = 56$) and DD ($n = 25$) categories (Fig. 16.1). According to these data, only 19% of recent lymnaeid species are threatened by extinction or extinct. The high proportion of DD species among the Lymnaeidae is by no means surprising. Many species of pond snails have attracted too little attention from conservationists and ecologists, and little is known about their current distribution, abundance, and population trends. The high proportion of DD species is characteristic for the freshwater Mollusca as a whole (Lopes-Lima et al. 2021): for example, the percentage of these species in freshwater Gastropoda is as high as 40.8 (Böhm et al. 2021). The two lymnaeid species considered extinct by the IUCN Red List are *Galba vancouverensis* F.C. Baker, 1939 and *Hinkleyia pilsbryi* (Hemphill, 1890), both endemic to North America.

The numbers discussed above may give an impression that the Lymnaeidae are not seriously threatened at a global scale, and no urgent actions to protect them are needed. However, I must add some cautionary notes to this discussion to show that the overall picture, as it is seen from an analysis of the IUCN Red List, may be quite misleading, or at least is somewhat biased.

First of all, the 100 species represented in the IUCN database form, in fact, less than 2/3 of the global richness of the Lymnaeidae. A survey of the included species made by a systematist will show that a portion of the pond snail species assessed to the day, are not valid, being junior synonyms of other taxa. I can mention such species as *Omphiscola reticulata*, *Lymnaea carelica*, *L. maroccana*, or *Radix lilli* as examples of this. None of them is currently accepted by experts in the field (see MolluscaBase 2021). Furthermore, the number of extinct species seems to be a bit underestimated. For example, the species *Stagnicola utahensis* (Call, 1884), the thickshell pond snail, endemic to Utah, USA, is considered extinct by the North American conservationists (Johnson et al. 2013), whereas IUCN Red List categorizes it as "critically endangered." The taxonomic status of *Radix arachleica* (Kruglov & Starobogatov, 1989) included in CR category needs to be elucidated. Probably, this snail, thought to be endemic to the Arakhlei Lake in Transbaikalia (south Siberia, Russia), is a synonym of another widespread species—the genetic information required to check its validity is still unavailable (Vinarski, unpublished data).

Given that a substantial portion of the actual lymnaeid diversity remains not evaluated, there are all reasons to consider the situation with conservation of the pond snails family far from being clear, and substantial efforts are required to fulfill the gap between the actual knowledge and the information currently provided by the IUCN website. I should like to make it clear that the critical remarks toward the current state of the IUCN Red List presented above do not mean I underrate the efforts which the experts involved in the process of assessment of species' conservation status are being made. Their work is extremely important in the "Sixth Extinction" epoch and should be praised as very urgent. I must admit that the practitioners of the IUCN Red List assessments fully realize that the data, available today from the IUCN Red List, need a serious update, and some actions are undertaken now to actualize this information (David Allen, pers. comm.). Hopefully, the quality of taxonomic and conservation information concerning lymnaeid snails provided by the IUCN website will increase in the nearest future.

Let us proceed to a survey of the lymnaeid conservation status at the level of the world's continents and ecoregions. The primary data for this survey was taken from a series of IUCN regional assessment projects covering territories of Europe (Cuttelod et al. 2011), Pan-Africa (Darwall et al. 2009), Western Ghats (Molur et al. 2011), and Indo-Burma (Köhler et al. 2012). These data were checked and updated using the IUCN website. For North America (the USA and Canada excluding Mexico) I used the data represented in Johnson et al. (2013) though the conservation categories used in the latter publication do not fully coincide with those of IUCN (see below).

The IUCN assessments data show that the percentage of lymnaeid species threatened with extinction varies drastically from region to region (Table 16.1).

Table 16.1 Red List status of lymnaeid species by region[a]

Region	No. of species	IUCN category							% threatened
		EX/ RE[b]	CR	EN	VU	NT	LC	DD	
Europe	20	0	0	2	0	2	13	3	10.0
Mediterranean	10	0	0	3	0	1	4	2	40.0
Pan-Africa	7	1	0	3	0	0	3	0	66.6
North Asia	27	0	1	0	0	1	20	5	7.4
West and Central Asia	19	0	0	1	0	0	16	2	5.3
Indo-Burma	19	0	0	0	1	0	11	4	5.2
Western Ghats	4	0	0	0	0	0	2	2	0.0
Oceania	7	0	0	0	1	0	6	0	14.3

[a]The primary data for this table were taken from a series of IUCN publications (Darwall et al. 2009; Molur et al. 2011; Cuttelod et al. 2011; Köhler et al. 2012) as well as from the IUCN Red List website

[b]RE (regionally extinct) denotes species disappeared from a particular region but survived in the other parts of its range

Table 16.2 Conservation status of the North American lymnaeid species assessed by AFS and IUCN

Authority	No. of species	Conservation status (category)							% threatened
AFS	60	*X*	*Xp*	*E*	*T*	*V*	*CS*	*U*	61.7
		2	8	13	8	6	23	0	
IUCN	42	*EX/RE*	*CR*	*EN*	*VU*	*NT*	*LC*	*DD*	19.0
		2	2	2	1	1	27	7	

Different parts of the same continent (e.g., Europe, Asia) may demonstrate different portions of threatened and not threatened (LC, DD) species.

The system of conservation categories developed by the AFS Endangered Species Committee (AFS = the American Fisheries Society) and used by Johnson et al. (2013) resembles that of the IUCN; below I list these seven categories and propose their probable correspondences to the IUCN categories: X (EX)—extinct; Xp (EW/CR)—probably extinct; E (EN)—endangered; T (VU)—threatened; V (NT)—vulnerable; CS (LC)—currently stable; U (DD)—unknown. Table 16.2 contains a comparison between two series of assessments of the conservation status of the North American lymnaeids made independently by the AFS and IUCN experts. As the table shows, the percentages of the threatened pond snail species provided by the two organizations are dramatically different, with the AFS estimate being much more "pessimistic" than that of IUCN. Most probably, such a disparity reflects some substantial differences between the assessment procedures realized by IUCN and AFS. This numerical discrepancy, in my opinion, gives a good illustration of the current uncertainty of the conservation status of the Lymnaeidae at the global scale (see above).

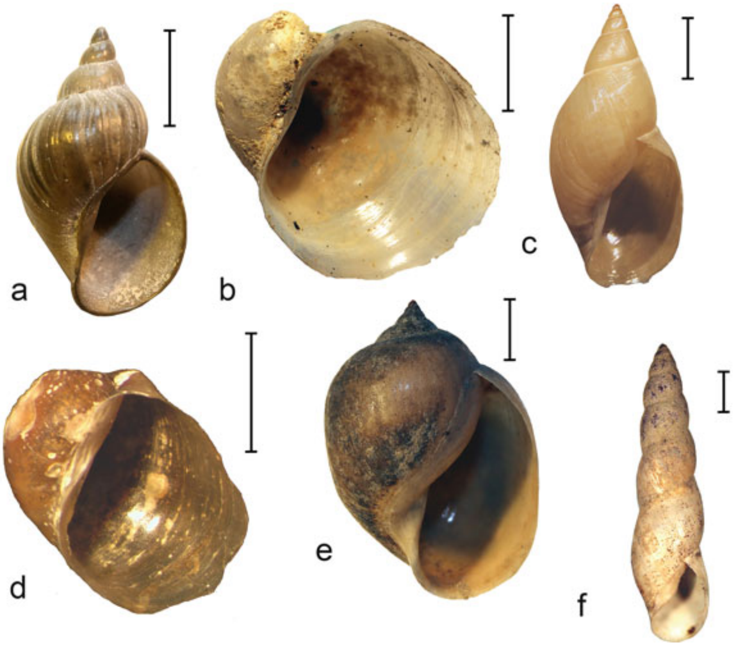

Fig. 16.2 Shells of some lymnaeid species with conservation status other than LC or DD. (**a**) *"Stagnicola" idahoensis* (CR). USA, Idaho, Bear Lake (NHMW). (**b**) *Radix pinteri* (EN), the holotype. North Macedonia, Prespa Lake (SMF). (**c**) *Stagnicola montenegrinus* (NT). Montenegro, Skadar lake, Karuč (LMBI). (**d**) *Erinna newcombi* (VU). USA, Hawaii, Henda River (NHMUK). (**e**) *Racesina ovalior* (VU). India, Calcutta (NHMUK). (**f**) *Omphiscola glabra* (NT). UK, Dewsbury (NHMUK). The global extinction risk is given according to IUCN Red List of Threatened Species. Scale bars 2 mm (**d, f**), 5 mm (**a–c**, **e**). Museum acronyms: LMBI—Laboratory of Macroecology and Biogeography of Invertebrates, Saint-Petersburg State University, Russia; NHMUK—Natural History Museum of the United Kingdom, London; NHMW—Natural History Museum of Vienna, Austria; SMF—The Naturmuseum Senckenberg, Frankfurt am Main, Germany

What is common in the lymnaeid species considered threatened (EX, EN, VU, and NT categories) by the IUCN (Fig. 16.2)? What properties do they share?

Foremost, the vast majority of the threatened pond snails are very narrowly distributed, being sometimes found in a very restricted area only. For example, *Lantzia carinata* (CR) is known from a single locality, i.e. from a waterfall at or near the type locality on Réunion (Van Damme 2016). The ranges of *Stagnicola utahensis* (CR), *S. idahoensis* (EN) are confined to a single state of the USA (Utah and Idaho, respectively). Two lymnaeids classified as endangered (*Radix pinteri* and *R. skutaris*) are endemics to the great ancient lakes of Balkans (south Europe). *Kutikina hispida* and *Erinna newcombi* (both VU) are endemics to islands (Tasmania and Hawaii, respectively). Not surprisingly, the high extinction risk in this family is related mainly to the narrow range and a low number of localities. Such properties of the species make them extremely prone to extinction, since the chances of the total or partial degradation of their habitats are especially high. Among the threatened

Fig. 16.3 Living specimens of *Myxas glutinosa* (left) and the general view of their habitat (right)—Russia, Chelyabinsk City, the Miass River. The photo was taken on 16.09.2009. The shell of the largest snail in this picture is 11.5 mm height. Photo: Olga S. Shishkoedova. After Vinarski et al. (2013), with modifications

lymnaeid species, only two, *Acella haldemani* in North America and *Omphiscola glabra* in Europe, are characterized by relatively vast ranges; both species are classified as NT by IUCN Red List, and no of the two is in imminent danger of extinction.

A substantial portion of the threatened lymnaeids belongs to monotypic or very small genera and subgenera (*Acella*, *Erinna*, *Fisherola*, *Kutikina*, *Lantzia*, *Omphiscola*) which may indicate, though indirectly, that the ecological specialization and phylogenetic distinctness may enhance the extinction risks within the Lymnaeidae. In other words, members of more speciose, widespread, and (presumably) ecologically plastic lymnaeid genera are less susceptible to extinction.

However, even those pond snail species that are not considered threatened by the IUCN Red List may, in fact, be of great conservation interest being endangered at either country or region levels. Some of such species are still qualified as LC or DD by the IUCN Red List, which requires urgent attention. Below, a single example is discussed in detail to illustrate this.

Myxas glutinosa (O.F. Müller, 1774), the glutinous pond snail (Fig. 16.3), is widespread in Europe, except for its northern and southern parts (Welter-Schultes 2012). This species' range also includes Western and some parts of Central Siberia (Prozorova and Sharyi-ool 1999; Kruglov 2005; Andreeva et al. 2010; Vinarski et al. 2013). *M. glutinosa* has been assessed as a data deficient species by the IUCN at the global scale, whereas the European Red List of Non-marine Molluscs (Cuttelod et al. 2011) lists it as LC, which was considered a surprising decision by some authors (Welter-Schultes 2012; Vinarski et al. 2013; Mouthon and Vimpère 2014).

Historically, the glutinous pond snail has been recorded from 25 European countries and Kazakhstan (Falkner et al. 2001; Hubendick 1951; Lazareva 1968; Glöer 2002, 2019; Vinarski et al. 2013). The current situation of this species in each country of occurrence is summarized below (in alphabetical order).

Austria *M. glutinosa* was listed in the malacofauna of this country by Klemm (1960), who recorded it for Lower Austria and East Tirol. Now this species is considered extinct in Austria (Falkner et al. 2001; Welter-Schultes 2012).

Belarus Layenko (2012) is the most recent monograph on the Belarus aquatic malacofauna. The author cites three localities in Belarus where *M. glutinosa* was found between 2005 and 2008. No data on the abundance of this mollusk in Belarus are provided in this book, and the current status of the glutinous snail there remains unclear. San'ko (2007) recorded shells of *M. glutinosa* from the Holocene deposits of Belarus.

Belgium Adam (1960) mentions this species for several parts of the country; no information of the current state of *M. glutinosa* in Belgium is accessible.

Bulgaria Neither Hubendick (1951) nor Welter-Schultes (2012) included Bulgaria in the range of *M. glutinosa*, however, in 1994 this snail was discovered in the Skomlya River situated in the northwestern part of this country (Hubenov 2007; Georgiev 2014). This location is, possibly, the southernmost finding of *M. glutinosa* in Europe. There is no other data on the distribution and abundance of the glutinous snail in Bulgaria, but it seems highly likely that this species is extremely rare there.

The Czech Republic Ložek (1955) mentioned several regions of this country where the species had been living in the middle of the past century. However, *M. glutinosa* was rare in the Czech Republic already 150 years ago (Beran 2002), and today it is recognized as extinct (Welter-Schultes 2012; Horsák et al. 2013). In the second half of the twentieth century, there were no reliable findings of *M. glutinosa* in the Czech Republic (Flasar 1998; Beran 2002; Horsák et al. 2013).

Denmark This country is the type locality of *M. glutinosa*, which was described from the environs of Copenhagen (see Vinarski and Kantor 2016 for details). Mandahl-Barth (1949) characterizes it as a rare species for Denmark. According to Welter-Schultes (2012), since 1949 there were no reliable findings of *M. glutinosa* in Denmark.

Estonia Except for some old data (Schlesch 1942; Zhadin 1952), almost nothing is known about the abundance and distribution of *M. glutinosa* in Estonia. Since this snail is relatively common in the Pskov Region of Russia, which is adjacent to the territory of Estonia, it may be assumed that the snail is still present in the malacofauna of the latter.

Finland The historical recordings of this species in the country have been made from different regions, including a single locality situated at 69° N (Luther 1901; Carlsson 2000). Luther (1901) classified *M. glutinosa* as a common species in Finland. According to Welter-Schultes (2012), *M. glutinosa* occurs only in the southern part of Finland, where around 20 lake populations of this snail are known. On the other hand, Carlsson (2000, p. 105) noted that the glutinous snail in Finland "seems to have a stronghold" and has not been listed as an endangered species. Carlsson (2000) found this species in 4 lakes of 51 visited on the Åland Islands.

France Mouthon and Vimpère (2014) have recently reviewed the current state of *M. glutinosa* in France. Their data shows the "dramatic regression" of this snail in France during the last century. Since 1950, *M. glutinosa* inhabits only 6 departments, instead of 30 departments where its occurrence was recorded in old literary sources.

Germany German malacologists of the nineteenth—first half of the twentieth centuries recorded *M. glutinosa* from various areas of their country and, as a rule, did not consider it rare (Clessin 1884; Geyer 1927; Ehrmann 1933). Although Goldfuss (1900) mentioned that the glutinous snail is rare, he nevertheless listed about a dozen habitats of this species from Central Germany. Currently, *M. glutinosa* has become extremely rare throughout the country and is included in the Red Data Books of almost all federal states of Germany (Glöer 2015) where it is ranked exclusively as an extinct (category 0) or endangered (category 1) species.

Ireland In this country, the glutinous snail has been recorded mainly in the central part of the island, but is rare everywhere and occurs only sporadically. In the second half of the twentieth century, there was a sharp decline in the number of populations of the species. So, if in the 1970s, it was quite common in a number of places (Kerney 1999), then from 1985 to 2002 there was not a single reliable finding of living individuals of *M. glutinosa* in Ireland (Beckmann 2006). On the other hand, judging from the Kerney (1999), Holyoak (2005), and Beckmann (2006) information, the glutinous snails are still to be found in Ireland, and it is estimated that Ireland maintains up to 50% of the global population of *M. glutinosa* (Byrne et al. 2009).

Kazakhstan A few localities of the glutinous pond snail were identified in some regions of western (Smirnova 1967), northern, and central Kazakhstan (Lazareva 1968; Frolova 1984; Vinarski et al. 2013). The author of this work collected *M. glutinosa* in October 2002, from the Ulkendamdy stream, located in the central part of the country (Kostanay District). In 2012, a new finding of this snail from central Kazakhstan (Akmola Region, Kulanutpes stream in the Nura river drainage basin) was reported, which represents the southernmost locality of *M. glutinosa* in Asia (Krainyuk 2012). In total, around 10 localities of this species have been discovered in Kazakhstan during the last 60 years (Smirnova 1967; Lazareva 1968; Krainyuk 2012; Vinarski et al. 2013). In 1968, Lazareva (1968) reported the abundance of *M. glutinosa* in the Tobol River floodplain equal to 36 ind/m^2; unfortunately, both the current state of these populations and the population trends are unknown.

Latvia *Myxas glutinosa* is listed as a rare and protected species in the recent checklists of the Latvia malacofauna (Rudzīte et al. 2010, 2018). However, the current abundance estimates and population trends of the glutinous snail in Latvia are unknown.

Lithuania Zettler et al. (2005) discussed some recent findings of *M. glutinosa* in this Baltic country and concluded that "it appears that this species finds relatively good life conditions in Lithuania" (Zettler et al. 2005, p. 38). In 2004, the snail was found here in three locations, in one of which it reached high abundance (Zettler et al. 2005).

Moldova *Myxas glutinosa* has been recorded in Moldova in the Dniester River (Balashov et al. 2020); no data on its current abundance and population trends are available.

The Netherlands Like in many other European countries, the population of *M. glutinosa* in the Netherlands has experienced a pronounced decline in the last half of the twentieth century (Gittenberger et al. 2004). Welter-Schultes (2012) reports (without a reference) a 90% decline in the Netherlands since 1960. Today, the species is patchily distributed in this country, being found mainly in its central part.

Norway According to Økland's (1990) data, the species is very rare in Norway. It was first discovered in the waterbodies of this country in the middle of the twentieth century, and at the end of the century lived in three lakes on the southeastern coast.

Poland Before World War II, this snail was not rare in Poland (Feliksiak 1939), but the situation has quickly become much worsened, and some prominent Polish workers on freshwater snails, including Maria Jackiewicz (1920–2018), had never found living specimens of *M. glutinosa* (Szarowska and Falniowski 2006). Nevertheless, the most recent monograph on the Polish freshwater Mollusca states that the glutinous snail in Poland is "fairly common in the Pomeranian and Mazurian lakelands, in the Wielkopolsko-Kujawska and Mazovian Lowlands"; it is absent from the mountains (Piechocki and Wawrzyniak-Wydrowska 2016, p. 115). Unfortunately, no quantitative estimates of the species abundance and population trends have been provided by the authors. Arguably, *M. glutinosa* is now among the rarest freshwater Gastropoda species of the Polish fauna (Szarowska and Falniowski 2006).

Romania Grossu (1955) mentioned this species from a few localities of this country. However, later on, the author (Grossu 1987) excluded *M. glutinosa* from the Romanian malacofauna explaining that the previous record was a result of misidentification. Nonetheless, the presence of this snail in adjacent Bulgaria indicates that *M. glutinosa* can be living in Romania but is so extremely rare that it is overlooked both by professional malacologists and amateur naturalists.

Russian Federation In Russia, numerous localities of this snail have been discovered during the last half of the past century, mainly from the northern part of European Russia, including Karelia and the Pechora River basin (Sokolova 1965; Leshko 1998). In particular, Sokolova (1965) lists as many as 26 large lakes and rivers of the Republic of Karelia where the glutinous snails occurred in the mid-twentieth century. Though I am not aware of the recent studies which deal with the abundance and distribution of *M. glutinosa* in European Russia, it seems likely that the snail is still more or less common in some parts of Karelia and adjacent areas (Ivan Nekhaev, pers. communication), in the Pskov Region (Dmitry Palatov, pers. communication) as well as in the Pechora River basin (Leshko 1998). The southernmost recently discovered locality of *M. glutinosa* in European Russia lies, possibly, in the eastern part of the Moscow Region (Dmitry Palatov, pers. communication), whereas the northernmost locality is situated in the Kola Peninsula, at 68° 51′N, i.e. north of the Polar circle (Nekhaev 2021). The southern boundary of the species' range in European Russia needs to be clarified. The presence of this species in the Urals and Siberia has been documented by various authors (Mozley 1936; Ioganzen 1951; Gundrizer 1979; Prozorova and Sharyi-ool 1999; Kruglov 2005; Khokhutkin et al. 2009; Vinarski et al. 2013). It is very rare and sporadically distributed in Western Siberia (Vinarski et al. 2013), whereas in central Siberia, its presence in the Tuva Republic and the Lower Yenisei basin is known (Gundrizer 1979; Prozorova and Sharyi-ool 1999). The single record of the glutinous snail from the Lena River basin (Yakutia) made in the 1960s (Belimov 1969) remains enigmatic and, most likely, was based on a misidentification. *Myxas glutinosa* is not included in the last edition of the Red Data Book of Russia and thus is not protected at the federal level. However, recently this species was listed in the Red Data books of the Omsk and Chelyabinsk regions.

Slovakia Hubendick (1951) included this country into the range of *M. glutinosa*. Nevertheless, no data on its occurrence in Slovakia are given in faunistic monographs published during the last 70 years (Ložek 1955; Lisický 1991; Horsák et al. 2013). Both the past and present status of the glutinous snail in Slovakia remains, thus, totally unclear.

Spain *Myxas glutinosa* was once recorded for the northeastern part of this country (the Pyrenees) [Jeffreys 1862]. It is unclear if the glutinous snail still occurs in Spain; at least Welter-Schultes (2012) does not include Spain in the range of *M. glutinosa*.

Sweden Only seven localities of the glutinous snail are known in Sweden, all situated in the southern part of the country (Nilsson et al. 1998; Welter-Schultes 2012). *M. glutinosa* is included in the national Red List of threatened invertebrates (von Proschwitz 1997).

Switzerland Included in the range of *M. glutinosa* by Hubendick (1951). No recent data on the presence of the glutinous snail here is available.

Ukraine The most recent data on the occurrence and ecology of the glutinous snail in this country have been summarized by Stadnichenko (2004, 2006). These data are based on observations made by the author during the 1960–early 2000s. According to Stadnichenko, *M. glutinosa* is distributed throughout the entire Ukraine territory, but the specific data on the abundance of *M. glutinosa* are absent from the monographs quoted above. It can be assumed that in Ukraine the species has not yet become as rare as it happened in neighbouring Poland, however, some more recent research has revealed the apparent decline of the glutinous snail in different regions of the country. For instance, a survey of the malacofauna of the Zhytomir Region did not reveal *M. glutinosa* there (Zhitova et al. 2006) although, according to A.P. Stadnichenko (2004), about 40 years ago the species occurred in this area.

The United Kingdom Jeffreys (1862, p. 102) characterized this snail as "a local species [in Britain] although abundant where it occurs" and considered it neither especially rare nor declining. Today's naturalists qualify *M. glutinosa* as the "Britain's rarest freshwater snail" (Willing et al. 2014, p. 673). Notably enough, already 85 years ago, Boycott (1936) was, essentially, of the same opinion. This species was feared to be completely extinct of all its British location before it was rediscovered in 1998 in a single lake in North Wales (Willing et al. 2014). For more details on the past and present distribution of the glutinous snails in the UK, see Boycott (1936), Whitfield et al. (1998), and Kerney (1999). The latest record in North Ireland is dated 1900 (Welter-Schultes 2012).

There are no historical data on the occurrence of the glutinous snail in Croatia, Greece, Hungary, Iceland, Italy, Portugal, Serbia, Slovenia, and some other European countries, and, most probably, their territories should not be included in the native range of this snail. An anecdotal report of this species from Syria (Turton 1857) can, evidently, be rejected as based on a misidentification.

This detailed survey shows that in most European states lying within its historical range, *M. glutinosa* has either became extinct or is experiencing strong population decline accompanied by the decrease in the number of known localities. Regrettably, the current information on the status of this snail in some countries is unavailable, which means that no national monitoring programs are working in these areas. The case studies on ecology, distribution, and abundance of *M. glutinosa* are very scarce [see Carlsson (2000) and Willing et al. (2014) for an example of a much-needed study of this kind].

The general conclusion from the above survey of the available data is that since the 1900s, *M. glutinosa* has been experiencing a steady decline throughout its entire range and the future survival of this species cannot be secured unless its habitats are protected. One of the most urgent measures is to change its IUCN category from DD/LC to VU or EN.

The causes of the global decline of the species are rather obscure. There is no common agreement among researchers on some important points of the species ecology, and sometimes contradictory statements are issued. Many researchers have reported data on the low tolerance of *M. glutinosa* to different environmental factors. For example, it is registered to be susceptible to biodegradable pollution (Mouthon and Charvet 1999) and sensitive to eutrophication (Whitfield et al. 1998; Donohue et al. 2009) as well as to a high degree of the water's hardness (Beriozkina et al. 1980). Zhadin (1952), on the contrary, believes *M. glutinosa* inhabits dystrophic lakes and oxygen-deficient waterbodies. Carlsson (2001) and Briers (2003) mentioned the species among calcephile mollusks that do not inhabit calcium-deficient waterbodies. Moreover, *M. glutinosa* is not tolerant to low values of ambient pH (Salazkin 1969; Berezina 2001).

Some of these alleged causes of decline can however be ruled out. Namely, the lymnaeid species *Lymnaea ovata* (Drapanaud, 1805) [= *Ampullaceana balthica* in the current nomenclature] that is not considered to be rare has equal with *M. glutinosa* range of pH tolerance, 6.0–9.0 (Berezina 2001). According to the data of Vinarski et al. (2013), collected in June 2010, the water salinity also does not limit the glutinous snail distribution. In the South Urals, it inhabits waterbodies where salinity varies from 90 to 593 ppm. Furthermore, Carlsson (2001) found *M. glutinosa* in eutrophic habitats in the Åland Islands; therefore, its alleged intolerance to eutrophication (Whitfield et al. 1998) may be ruled out. A recent finding of *M. glutinosa* in a polluted area of a large industrial city of Chelyabinsk, South Urals, Russia (see Vinarski et al. 2013; Fig. 16.3) affirms that this species is not critically dependent on the purity of water.

At last, the rarity of *M. glutinosa* may be partially explained by some peculiarities of its life cycle. Feliksiak (1939) and Willing et al. (2014) reported that this species lives only one year (until spring) and in the summer season only juvenile individuals occur. Due to their small sizes, the juveniles can be overlooked by collectors to give the impression of the absence of this species in a waterbody. Special efforts are needed to learn if this assumption is true.

Some authors believe habitat destruction must be considered the most important cause of the global decline of this species (e.g., Welter-Schultes 2012).

Lymnaeidae belong to Hygrophila, a group of freshwater molluscs that, in general, are less prone to extinction than gill-breathing snails classified within Caenogastropoda (Neubauer and Georgopoupou 2021). Nonetheless, the list of actual and potential factors threatening the survival of the lymnaeid snails (and other aquatic pulmonates) at a global scale is rather long. It includes a number of factors such as extensive farming, water pollution, acidification of snail environment, destruction or degradation of inland waterbodies, invasion of alien species of mollusks and other animals (non-indigenous species of fish, aquatic macroinvertebrates).

Recently, Lopes-Lima et al. (2021) have summarized the eight major shortfalls "impairing knowledge and conservation of freshwater molluscs," each named in honor of a prominent scientist in the field of ecology, biodiversity, or biological conservation (Box 16.1). The statement made by the authors (Lopes-Lima et al. 2021, p. 2832), that "our basic knowledge of [freshwater Mollusca] is still highly incomplete, which hampers the development and implementation of effective and timely conservation strategies for these rapidly disappearing animals" is surely be applied to the family Lymnaeidae. Though the lymnaeid snails form one of the most well-studied families of freshwater molluscs, much scientific work is left to be done in order to improve the efficacy of conservation efforts on this taxon.

Box 16.1 The Eight Major Shortfalls Impairing Knowledge and Conservation of Freshwater Molluscs*

Title	Brief description	Eponym
Linnaean	Knowledge gaps in taxonomy of a studied group	Carl Linnaeus (1707–1778), the founder of modern biological systematics
Wallacean	Deficiency of geographical distribution data for many species	Alfred R. Wallace (1823–1913), co-discoverer of the natural selection principle, an outstanding biogeographer
Prestonian	Lack of knowledge on the abundance of species and its population dynamics in space and time	Frank W. Preston (1896–1989), author of pioneering works on species commonness and rarity
Darwinian	Lack of knowledge about the tree of life and evolution of lineages, species, and traits	Charles R. Darwin (1809–1882), the founder of modern evolutionary theory
Raunkiaeran	Lack of knowledge about ecologically relevant species traits	Christen Raunkiaer (1860–1938), one of the founders of modern plant ecology, the creator of an influential plant life-form classification
Hutchinsonian	Knowledge gaps in abiotic tolerances of particular species of a studied group, including their life histories, functional roles and responses to habitat changes	George E. Hutchinson (1903–1991), who established the modern concept of the ecological niche
Eltonian	Lack of knowledge about interactions among species or among groups of species	Charles S. Elton (1900–1991), the pioneer of the concept of food chains and food webs; also known as an early student of biological invasions
Ostromian	Lack of knowledge about the application and effectiveness of conservation assessments, methods, funding, and policies	Elinor Ostrom (1933–2012), author of ground-breaking works on common resources governance, and its impacts on biodiversity management and policies

*After Hortal et al. (2015) and Lopes-Lima et al. (2021)

Let us discuss, one by one, the eight major shortfalls delineated by Lopes-Lima et al. (2021) as applied to the Lymnaeidae conservation.

1. *Linnaean Shortfall*. Despite the substantial advancements of the lymnaeid taxonomy made during the last 10–20 years, a large number of questions remain unresolved. The validity of a large fraction of nominal species and genera of recent lymnaeid snails has yet to be reassessed using molecular techniques, and,

until this is done, a significant portion of hitherto described taxa will be classified as "taxa inquirenda" (see MolluscaBase 2021). Among the objective causes of such a situation, one can mention the inadequacy of original descriptions published 150–200 years ago, the loss of the type specimens, and the destruction of the type localities which prevents the sampling of topotypic specimens. The synonymy rate in the Lymnaeidae is one of the highest among all families of freshwater Mollusca (Lopes-Lima et al. 2021). On the other hand, several papers aiming to lower the degree of taxonomic uncertainty in Lymnaeidae have recently appeared. Some of these papers focused on discussion of the type materials of previously described species, usually with high-quality illustrations (i.e., Sitnikova et al. 2014; Vinarski 2016), whereas others provide the "integrative" reassessment of nominal species introduced by taxonomists in the past, which may result either in their synonymization (e.g., Vinarski et al. 2016, 2021; Aksenova et al. 2017) or, sometimes, in the re-establishment of old names long considered be synonyms (e.g., Mahulu et al. 2019).

2. *Wallacean Shortfall*. This shortfall, as applied to the lymnaeid snails, seems to be relatively relaxed. On my personal estimate, the state of our knowledge on the range and peculiarities of distribution of many species of pond snails varies from excellent to satisfying. Distribution maps are available for many species and many continents (see, for example, Hubendick 1951; Clarke 1973; Welter-Schultes 2012; Glöer 2019). Of course, we still are dealing with only a rough picture illustrating the wide-scale distribution patterns of the lymnaeid snails. What is urgently needed is small-scale research that would map localities of different lymnaeid species within the relatively restricted areas, e.g. provinces, river basins, state regions. Examples of such maps exist in some West- and Central European countries (e.g., Lisický 1991; Flasar 1998; Gittenberger et al. 2004) and they may be indispensable for the conservation measures applied within a particular country. The further progress of GIS technologies and the development of online occurrences databases (like GBIF—Global Biodiversity Information Facility) will, probably, help to ameliorate the Wallacean Shortfall (see Lopes-Lima et al. 2021 for more details on this subject).
3. *Prestonian Shortfall*. Comparing with the previous one, this shortfall is much more demanding. For most lymnaeid species, we lack any reliable and updated data on their abundance and current population dynamics. Exceptions are species of particular practical interest (such as the dwarf pond snail, *Galba truncatula*; see Relf et al. 2011; Charlier et al. 2014; Jones et al. 2021), some invasive taxa (e.g., *Pseudosuccinea columella*), or species/populations attracting a specific interest from conservationists (e.g., *Myxas glutinosa* in Llyn Tegid, North Wales; see Willing et al. 2014). The deficiency of such data explains a high fraction of lymnaeid species categorized as DD by the IUCN experts, which, in itself, constitutes a serious hamper for effective conservation planning and activities. Such a situation is by no means unique for the Lymnaeidae, and it characterizes the state of our knowledge of almost every genus or family of freshwater Mollusca (Lopes-Lima et al. 2021). Some newly developed methodologies, such as environmental DNA (eDNA) analysis, are thought to be useful in making

the study of the abundance of freshwater snails easier and more efficient. There are some examples of eDNA surveys applied to the study of economically important lymnaeid species (Davis et al. 2020; Jones et al. 2021; Rathinasamy et al. 2021). The use of this promising methodology for the surveys of rare and threatened species of the family will be quite desirable.

4. *Darwinian Shortfall*. The evolution and phylogeny of the Lymnaeidae have been extensively studied during the last 100–120 years, by both paleontologists and neontologists. It was possible because lymnaeid shells are vastly represented in many paleontological collections, and their evolutionary history can be traced back to the Jurassic. By the start of the molecular revolution in the lymnaeid taxonomy which took place around 1997, an impressive body of phylogenetic facts and hypotheses had been accumulated, and the extensive use of molecular information is currently helping to integrate all these data in a comprehensive integrated picture. Though many questions are still left open, the last 15–20 years have witnessed a great advance in this field, and there is little doubt that, within the next several years, the phylogenetic relationships between the majority of recent genera, subgenera and, to a lesser extent, species will be elucidated more or less satisfyingly. In my opinion, there are no serious obstacles for the tree of life for the recent Lymnaeidae to be built to the end of the current decade based on the multi-omics approach; the evolutionary relationships between many extinct lymnaeid taxa will, apparently, remain problematic much longer.
5. *Hutchinsonian Shortfall*. The lymnaeid snails, many of which belong to the most widely distributed, abundant, and conspicuous species of freshwater snails, have attracted naturalists since long ago. Some of the lymnaeids (e.g., *Galba truncatula* and *Lymnaea stagnalis*) were studied ecologically in many regions of the world and during many decades. The abiotic tolerances of the European Lymnaeidae have been discussed in many publications (Boycott 1936; Fromming 1956; Russell-Hunter 1978; Beriozkina and Starobogatov 1988; Økland 1990, etc.). Analogous information is available for some of the representatives of the family inhabiting other continents (e.g., Lynch 1965; Hunter 1975; Monzon et al. 1993; Abdul Aziz and Raut 1996) but, in general, these data are prone to geographic bias (i.e., species of “exotic” faunas are understudied as compared with species of West and Central Europe and North America). As for the lymnaeid species of conservationists’ interest, the data on their abiotic interactions are extremely scarce, and the lack of relevant information constrains the measures toward the protection of these molluscs. One of the possible ways to ameliorate the Hutchinsonian Shortfall is the realization of expansive laboratory trials, which may provide useful information on the abiotic tolerances of particular lymnaeid species.
6. *Raunkiaeran Shortfall*. Almost all that was said about the previous shortfall can be applied to this one. As compared with taxonomy and distribution, the ecological traits of the Lymnaeidae, including the parameters of their life cycles, are relatively poorly studied. Though some species of this family have long served as model objects for both field observations and laboratory trials and these data can be cautiously extrapolated to the other lymnaeid species, the state of our

knowledge on the biological and ecological traits of the endangered pond snails remains dissatisfying. Once again, it is typical for other groups of freshwater Mollusca, and the Lymnaeidae only exemplify this widespread situation.

7. *Eltonian Shortfall*. Not surprisingly, most of the available data on the biotic interactions of the Lymnaeidae was obtained from studies on *Galba truncatula*, *Austropeplea tomentosa*, and a handful of other lymnaeid species acting as the intermediate hosts for parasitic Trematoda. The details of the host–parasite relationships in these biotic systems have been profoundly studied, whereas the other sorts of biotic interactions such as predation, competition, and facilitation have been even less researched. Numerous pond snail species are almost unknown in this respect.
8. *Ostromian Shortfall* was originally defined as "a lack of knowledge about the application and effectiveness of conservation assessments, methods, funding, and policies" (Lopes-Lima et al. 2021, p. 2848). The existing gap between the taxonomy of the pond snails and their conservation assessment within the IUCN Red List framework is discussed above. In many countries, for example in Russia, freshwater Mollusca, including the lymnaeids, are underrepresented in the regional Red Data books (Grebennikov and Vinarski 2009), whereas in other (e.g., Germany) the members of this family are present in all regional lists of endangered animals (see Glöer 2015 for review). In general, the global lack of conservation knowledge about the Lymnaeidae, which constitutes the Ostromian Shortfall, can be considered substantial and worrying. The deficiency of taxonomic, phylogenetic, and especially ecological information about the recent pond snails is the main cause of this. The Ostromian Shortfall cannot be ameliorated until the other seven shortfalls are overcome.

The general conclusions which can be made from the facts and discussion presented above are as follows.

- The Lymnaeidae suffer globally from the same conservation shortfalls as most other families of freshwater gastropods and bivalves. The high rate of uncertainty in the available taxonomic and ecological information has resulted in a high fraction of species that are categorized as "data deficient" and thus belong to the "dark matter" of biological conservation.
- The lack of ecological information on the rare and endangered species of the pond snails is today more essential for conservation planning than the existing gaps in our knowledge on the systematics, phylogeny, and distribution of the family. The reliable data on current abundance and population dynamics are unavailable for most lymnaeid species in most continents and regions. The global shortage of taxonomists, field ecologists, and conservationists working with freshwater Mollusca (including Lymnaeidae) is the main cause of this situation.
- A prominent geographic bias characterizes the available data on the rare and endangered lymnaeid species, when taxa of European and North American distribution being, in general, much more studied than those of Africa, Asia, South America, and other continents (with probable exception to Australia).

- Considering that it may take a long time to fill gaps in available knowledge about concrete species of pond snails in need of protection, it would be more rational to put more attention on the conservation of specific habitats of freshwater fauna, rather than particular species of molluscs. This will allow better use of available limited resources, including financial ones, and optimize efforts to conserve freshwater communities as a whole. At the same time, it is necessary to develop special programs for the monitoring and protection of those species of pond snails that were classified in the categories with the highest risk of extinction (CR, EN), and to provide measures for the reintroduction of the endangered species into those parts of their ranges where they have become extinct by now.

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