The Newsletter of the IUCN/SSC Mollusc Specialist Group
Species Survival Commission • International Union for Conservation of Nature

TENTACLE

UNITAS MALACOLOGICA

Editor – Robert H. Cowie

EDITORIAL

In January 2022, Benoît Fontaine and Philippe Bouchet of the Muséum national d'Histoire naturelle (Paris) and I published a paper about biodiversity extinction entitled *The Sixth Mass Extinction: fact, fiction or speculation?* Perhaps not surprisingly, we concluded that although the current human-caused biodiversity crisis has not yet reached the level of the previous five naturally-caused mass extinction events that have generally been recognised, we are probably well into the early stages of the Sixth Mass Extinction. The paper has attracted considerable media interest.

While our conclusions addressed all of biodiversity, they were based to a great extent on extrapolations derived from our previous studies on mollusc extinctions. We estimated that 10-17% of land snails have gone extinct during the course of the current biodiversity crisis. Freshwater molluscs may have suffered a similar fate, but among marine molluscs only three are thought to be extinct and three possibly extinct.

Under several broad assumptions, we extrapolated to all known biodiversity and arrived at the depressing estimate that probably around 200,000 of the roughly 2 million known species have gone extinct as a result of human activities.

Many of the contributors to *Tentacle* are involved in valiant efforts to stop the extinction of some of the most endangered molluscs; others are involved in important field surveys to find and collect representatives of hitherto unknown molluscs, in the hope of being able to at least preserve them in museums before they go extinct. All these efforts are extremely important, but in our paper we stressed the need to collect specimens, especially of undescribed species, and deposit them in museums so that in 200, 300, 500 years or whatever, our descendents will still be able to see the spectacular diversity of what will have been lost.

Cowie, R.H., Bouchet, P. & Fontaine, B. 2022. The Sixth Mass Extinction: fact, fiction or speculation? *Biological Reviews* 97: 640-663.

Robert H. Cowie

In this issue: **click on page**

IN MEMORIAM JOHN B. BURCH (1929–2021)

From Diarmaid Ó Foighil, University of Michigan

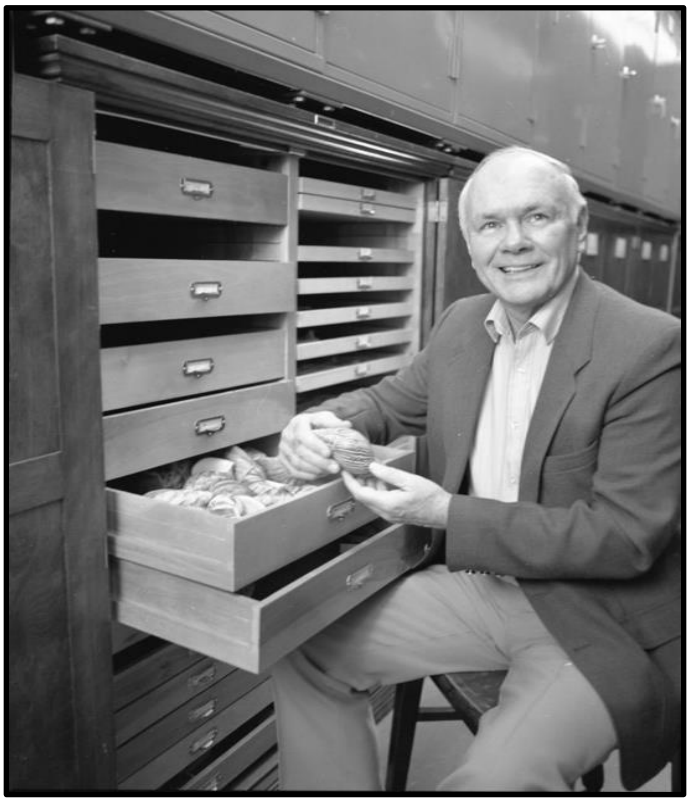

Fig. 1. John B. Burch posing with a specimen of *Lissacathina fulica* in the University of Michigan Museum of Zoology's dry mollusc collection (1990s).

We unfortunately lost a cherished colleague in 2021, the legendary malacologist John B. ("Jack") Burch. He had an extraordinary, long-lived and highly influential career in science, serving as Professor and Curator of Mollusks at the University of Michigan since 1963 (Emeritus since 2001). See below an outline of some of the highlights (details are available in his CV), as well as a summary, based partially on Jack's oral accounts (to the author) and field notes, of his remarkable 1970 Society Islands collections and their conservation research importance.

Jack had broad interests in the biology of non-marine Mollusca, especially freshwater snails, and he made numerous significant contributions to their global study. Early in his career, a major focus was the application of karyological, serological and tissue culture techniques to characterise the roles of intermediate snail hosts in the epidemiology of human schistosome parasites. One of his major immuno-cytological discoveries was the presence of cryptic diploid and polyploid (tetra/hexa/octoploid) lineages in populations of the important intermediate host *Bulinus truncates*/*tropicus* complex that were differentially susceptible to infection by human schistosome parasites. This seminal work led to years of research (supported by NIH, NSF and the World Health Organization) and international outreach, the latter involving numerous workshops on medical malacology as well as the training of scientists from a large diversity of countries. He received many honors including the Lifetime Achievement Award of the Freshwater Mollusk Conservation Society, and special recognition from the American Malacological Society, Science Society of Thailand, the Malacological Society of the Philippines and the Korean Society of Malacology.

Jack was also distinguished by his prodigious outreach and service to malacology as a discipline. One aspect of this was his exquisite guides to North American freshwater molluscs (*Freshwater Unionacean Clams of North America*, *Freshwater Sphaeriacean Clams of North America*, *North American Freshwater Snails*) and land snails (*Land Snails of The University of Michigan Biological Station Area*, *Identification of Eastern North American Land Snails*, *How to Know Eastern Land Snails*). Another was his astonishing record of founding four new malacological journals, one of which, *Malacologia*, endures. The other three are now either transformed into a new entity (*Walkerana*, now *Freshwater Mollusk Biology and Conservation*), or retired after decades of production (*Malacological Review*, *Journal of Medical and Applied Malacology*). Jack was a gregarious and generous personality, who formed life-long friendships with many of his students and colleagues, some of whom have written personal reminiscences about him – scroll down to the "Tributes to John B. Burch" link on this page to peruse them.

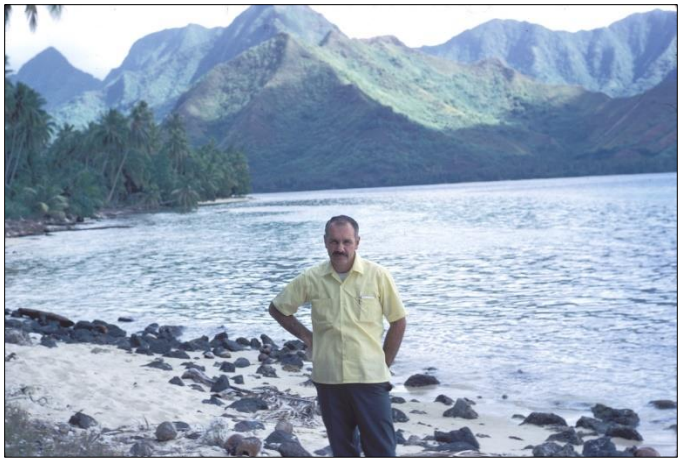

Fig. 2. John B. Burch on Tahiti in 1970. The island is composed of two peninsulas and the photo was taken on a Tahiti-Iti (the smaller peninsula) north shore beach with Tahiti-Nui (the larger peninsula) in the background.

Society Islands field collections

In 1970, Jack spent five months in the Society Islands (Fig. 2), much of it sampling endemic Partulidae, in collaboration with his good friend Yoshio Kondo (Bishop Museum, Honolulu). Their primary goal was to build on H.E. Crampton's classic work (Crampton, 1916) by publishing a monographic revision of Tahitian *Partula* species that would incorporate detailed anatomical (Kondo's specialty) and comparative immuno-taxonomic (Burch's specialty) data. The latter methodology, now obsolete, used the rabbit immune system as an indirect

biochemical assay of inferred relatedness among snail species of interest. Snail antigens, prepared by lyophilising (freeze-drying) foot tissue, were injected into rabbits and the resulting polyclonal antibodies were harvested and "tested" against antigens of other snail species to assay the comparative degree of among species cross-reactivity (stronger cross-reactivity implied closer relatedness).

Jack's collecting trip had three notable characteristics. It was quite comprehensive, for example, see his sampling map of Tahitian valleys (Fig. 3). Most of the tree snails sampled were airmailed alive to his lab in Ann Arbor for lyophilisation (Fig. 4). It occurred just 4 years prior to the fateful introduction of the rosy wolfsnail, *Euglandina rosea* (Pointier & Blanc, 1985).

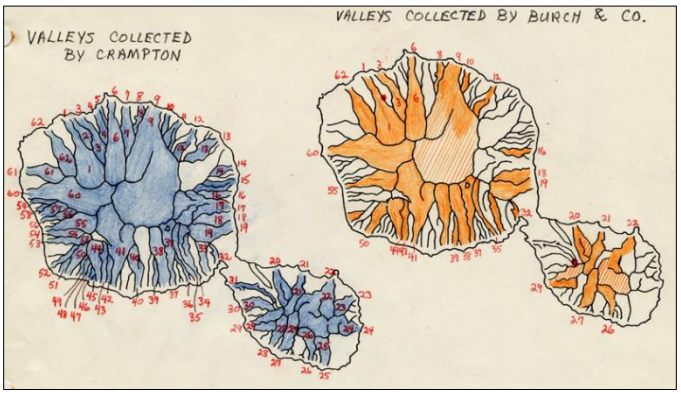

Fig. 3. Tahiti sampling maps from Burch's field notebook comparing the valleys he sampled (right) with those collected by Crampton (1916). Burch was accompanied by his University of Michigan colleague Jim Cather and by his then 14-year-old son John B. ("Jackie") Burch, Jr.

Fig. 4. Some of the many hundreds of 1970 partulid snail tissue samples lyophilised by Burch's research assistant Gene Lindsay in Ann Arbor from live, airmailed specimens.

Failed conservation intervention

There is an interesting conservation subtext to Jack's 1970 fieldwork: he had been forewarned by Yoshio Kondo about an incipient danger facing Society Island partulids. Yoshio had heard reports that the giant African land snail, *Lissachatina fulica*, had recently appeared in the archipelago. He predicted, to Jack, the following sequence of events: local agricultural scientists, spurred by horticultural losses, would reach out to colleagues in Hawaii for advice on how to control this new pest species; they in turn would claim to have the perfect biocontrol agent at hand (*Euglandina rosea*) and recommend its introduction; this would lead to the collapse and extirpation of many local endemic land snail populations, as was already occurring in Hawaii.

Yoshio requested that Jack preemptively argue against this course of action, emphasising the grave consequences for endemic Society Island snails. Jack dutifully did so. Donning his self-described "best clothes", he went to meet with Robert Millaud, *Directeur du Service de l'Agriculture*, at his office in Piara'e (Papeete, Tahiti). It did not go well. Millaud listened to Jack's argument but was unconvinced, stating that "biological control worked and that they were going to do it". Jack recalled that Millaud's last comment to him, as he was leaving, was: "What's more important, people or snails?" To modern sensibilities, that perspective may seem misguided, if not shocking, but it is important to emphasise that such views were then the norm among agricultural scientists and government officials, e.g. see the following quote from Lambert (1974), a South Pacific Commission (SPC) tropical agriculturalist:

> *The SPC has promoted - and financed - the introduction of the predators* Euglandina rosea *and* Gonaxis quadra lateralis [sic] *into New Caledonia and the New Hebrides at the request of their territorial Administrations and in collaboration with local scientists. It is conducting research aimed at discovering other predators and investigating the best combinations of those that are already known. It goes without saying that the SPC will wholeheartedly welcome and carefully examine any suggestions concerning crop protection and* Achatina *control, and will be happy to answer any requests for information.*

Kondo & Burch partulid publications

In subsequent years, Yoshio and Jack collectively published six papers based on the 1970 collections (Kondo, 1973, 1981; Kondo & Burch 1972, 1979, 1983, 1989), prior to Kondo's death in 1990. Although valuable, all of them were short contributions, and the primary goal – an integrative revisionary monograph of Tahitian *Partula* species – was never completed, although it was later mentioned as a Kondo (posthumous) & Burch manuscript "in preparation" (Cowie, 1993). A partial draft of the manuscript in Jack's files incorporated sampling, conchological and anatomical data but no immuno-taxonomic results; it appears that the extensive 1970 lyophilised material was never put to its intended use. Jack and his family had suffered a devastating personal tragedy in 1976 when his son, John B. Burch Jr. (who had accompanied him to Tahiti), died unexpectedly at the age of 20. More than one University of Michigan colleague has remarked to me that Jack "was never the same" afterwards. He and his partner Peggy Burch decided to try living in Australia in 1978 and he worked as an Australian Museum research associate until 1980 when they eventually returned to Ann Arbor. It is quite possible that Jack found it too

painful to reengage with and complete the Tahitian project. After Kondo's passing in 1990, only Jack knew about the lyophilised partulid collection sequestered safely in his lab.

"Rediscovery" of the 1970 Tahitian samples

Jack was highly social and hosted a regular Friday afternoon Australian-style POETS get-together at his favorite Ann Arbor waterhole, Good Time Charley's. He often talked about field work experiences and seemed to have sampled just about everywhere: if a remote location/island came up in conversation, he had typically been there (twice) and had a sampling story to match. From time to time he would casually mention having spent a lot of time on Tahiti but did not elaborate. That did not strike me as being particularly notable: of course he had been there, as well as in almost every major archipelago across Oceania.

Jack's reticence regarding the 1970 collection persisted until after his retirement, when we were decommissioning his laboratory. He brought up Tahiti again, while simultaneously, with a barely concealed flourish, swinging open his lab freezer door. I was completely unprepared for its contents: a fabled, largely extinct partulid radiation in lyophilised form! Once I picked my jaw off the floor, and recovered my power of speech, I told Jack that we had to work together on these specimens (despite my complete lack of experience with terrestrial snails). Part of my motivation stemmed from the pressing need many university research museums face from central administrations to justify the maintenance and growth of their research collections. Jack's 1970 samples epitomised the fundamental research and conservation value of such collections so emphatically that even the most obdurate administrator would surely see the light?

Fig. 5. Gone but not forgotten. Trevor Coote (1953-2021, on left) and Jack Burch (on right) on Mt. Marau, Tahiti in 2005.

Thus began a marvelous new line of collaborative research (a list of resulting publications is provided below). Jack's 1970 lyophilised samples proved to be highly amenable to molecular approaches. By combining them with extant captive and relict wild populations, we have been able to comprehensively address a suite of basic research and applied conservation questions pertaining to the Society Islands partulid radiation, and to Partulidae as a whole, that had previously seemed out of reach. For instance, a ground-breaking 2009 phylogenomic study, led by Amanda Haponski, firmly established the presence of five Windward Island (Moorea and Tahiti) *Partula* species complexes and, notably, all five have extant members. There is still hope!

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Lambert, M. 1974. The African giant snail, *Achatina fulica*, in the Pacific islands. *South Pacific Bulletin* 24: 35-40.

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Burch, J.B. 2007. A new species of land snail (Stylommatophora: Partulidae) from Raiatea, French Polynesia, Oceania. *Occasional Papers of the Museum of Zoology* 740: 1-8.

Lee, T., Meyer, J-Y, Burch, J.B., Pearce-Kelly, P. & Ó Foighil, D. 2008. Not completely lost: two partulid tree snail species persist on the highest peak of Raiatea, French Polynesia. *Oryx* 42: 615-619.

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Lee, T., Burch, J.B., Coote, T., Pearce-Kelly, P., Hickman., C., Meyer, J-Y. & Ó Foighil, D. 2009. Moorean tree snail survival revisited: a multi-island genealogical perspective. *BMC Evolutionary Biology* 9: 204.

Ó Foighil, D., Lee, T. & Slapcinsky, J. 2011. Prehistoric anthropogenic introduction of partulid tree snails in Papua New Guinean archipelagoes. *Journal of Biogeography* 38: 1625-1632.

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Brodie, G., Barker G.M., Pippard, H., Bick, C.S. & Ó Foighil, D. 2016. Disappearing jewels: an urgent need for conservation of

Fiji's unique partulid tree snail fauna. *Pacific Conservation Biology* 22: 249-261.
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Haponski, A.E., Lee, T. & Ó Foighil, D. 2017. Moorean and Tahitian *Partula* tree snail survival after a mass extinction: new genomic insights using museum specimens. *Molecular Phylogenetics & Evolution* 106: 151-157.
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Bick, C.S., Lee, I., Coote, T., Haponski, A.E., Blaauw, D. & Ó Foighil, D. 2021. Millimeter-sized smart sensors reveal that a solar refuge protects tree snail *Partula hyalina* from extirpation. *Communications Biology* 4, 744. [see also New York Times Trilobites article].

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NEWS

The Tony Whitten Conservation Award 2021

From the Editor

Tony Whitten (1953-2017) was an inspirational conservationist who championed biodiversity across Asia and beyond (see *Tentacle* 26). As a tribute to him, the Tony Whitten Conservation Award was established in 2019 by the Cambridge Conservation Initiative (CCI) to celebrate early career researchers from East and Southeast Asia working on any area of conservation or field biology, but especially the overlooked species and habitats that Tony was most passionate about, such as caves and karst ecosystems, and little-studied invertebrates and fishes. Winners of the 2019 awards included three working on molluscs (see *Tentacle* 28) and one of the 2020 winners also worked on molluscs (see *Tentacle* 29).

The five 2021 winners were announced in the January 2022 issue of *Oryx* (*Oryx* 56(1): 15). One of the winners was Zhe-Yu Chen, for his work on the systematics and diversity of land snails in southern China, focused on microsnails in karst areas. He has discovered 21 new taxa, including seven new genera and substantially extended the known range of genera previously thought to be restricted to South-east Asia. Zhe-Yu will put his award towards the costs of museum visits, field trips and laboratory identification of his specimens.

Zhe-Yu Chen

In addition, six highly commended young biologists were announced, including one, Harold B. Lipae, also for work on the diversity and taxonomy of microsnails in karst ecosystems, in this case those of southern Luzon, Philippines.

A new species of *Partula* described

From the Editor

In 2021, in the journal *Zookeys*, Dave Sischo and Mike Hadfield described a new species of *Partula* from the island of Rota in the Northern Mariana Islands of the western Pacific, naming it *Partula lutaensis*, for Luta, the indigenous Chamorro name for the island.

Partula lutaensis, a new partulid species from Rota, Northern Mariana Islands, described by Dave Sischo and Mike Hadfield. (Photo: D. Sischo)

The authors explain that the U.S. administered Mariana Islands, consisting of Guam in the South and the Commonwealth of the Northern Mariana Islands (CNMI) in the north, historically harboured six endemic partulid species, although half of them are now thought to be extinct. While conducting a phylogenetic assessment of *Partula gibba*, an extant tree snail with a range spanning at least seven islands across the archipelago, they discovered that what had been identified as *P. gibba* on Rota is in fact a misidentified cryptic species.

Because *P. lutaensis* has suffered population declines and has a restricted range, consisting solely of the small island of Rota, the authors highlighted the urgent need for conservation measures.

Severe climate-driven loss of native molluscs reported off Israel's coast

From: Oryx 55(3): 328, May 2021

Native mollusc populations along the coast of Israel have collapsed by ~90% in recent decades because they cannot tolerate the increasingly hot water, which raises concerns about the wider ecosystem and neighbouring regions. Scientists said the sharp decline of native cockles, whelks and other invertebrates in shallow, subtidal waters is likely to also affect other countries in the region and would continue to progress westward to Greece and beyond as global temperatures increase. The study estimates native mollusc populations have fallen to 12% of their historical species richness on sedimentary substrates, and to 5% on rocky substrates. The research team took samples at multiple points,

then compared living mollusc numbers with previous population sizes, which were estimated from empty shells found in sediment. The shortfall exceeded anything seen before. As well as stepping up protections of the still relatively pristine deep waters and tackling localised problems like pollution, the only way to address this shift is to tackle climate change by reducing emissions as soon as possible.
Sources: Proceedings of the Royal Society B 288: 20202469 (2021); The Guardian (2021)

THE ENDEMIC LAND SNAILS OF THE FERNANDO DE NORONHA ARCHIPELAGO, BRASIL

By Rodrigo B. Salvador, Daniel C. Cavallari, Carl C. Christensen, André V. L. Freitas, Marcel S. Miranda & Flávio D. Passos

Fernando de Noronha (henceforth 'Noronha') is an oceanic archipelago of volcanic origin, located ~350 km off the northeast coast of Brasil (Fig. 1). The eponymous main island was an important midway port in the Portuguese exploitation of Brasilian resources during the 16th and 17th centuries (Lins & Silva, 2013). The island was also briefly occupied by the British, French and Dutch. It also served as a prison until the mid-20th century (Pessoa, 2014).

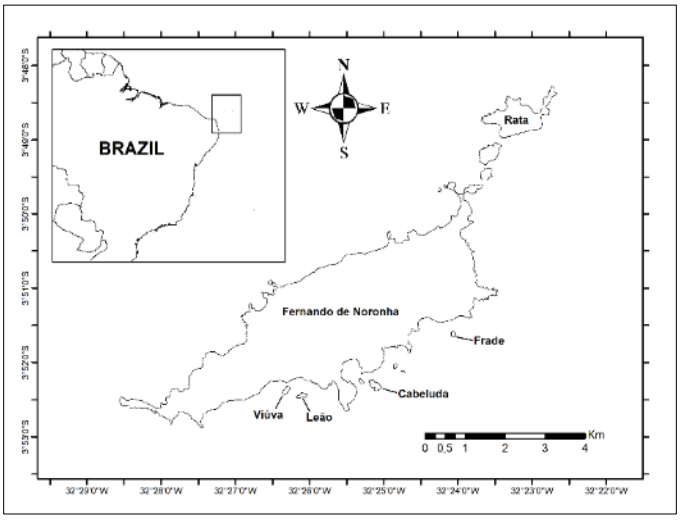

Fig. 1. Location of the Fernando de Noronha archipelago off the Brasilian coast.

Noronha still had much of its natural cover when Darwin visited it in 1832 (Darwin, 1839), but most of that had already been cut down by the end of the 19th century (Ridley, 1890). Today, most of its area is a national marine reserve and the archipelago is a UNESCO World Heritage Site (Fig. 2).

Noronha's terrestrial snail fauna is a mix of mainland species (including possibly introduced ones) and endemics. Similar to what is seen on other archipelagos around the world, Noronha's endemic species are very distinct from the rest of the Brasilian land snails.

Fig. 2. Aerial view of Noronha (source: Wikimedia Commons, GNU-FDL, 2004; CC BY-SA 3.0).

Systematics

Historically, the three endemic species from Noronha have been classified in three monospecific genera, as *Bonnanius ramagei* (Smith, 1890), *Hyperaulax ridleyi* (Smith, 1890) and *Ridleya quinquelirata* (Smith, 1890). However, all of them have recently gone through taxonomic revisions involving morphological and molecular analyses, which have resulted in some important changes.

The genus *Bonnanius* Jousseaume, 1900 is now considered a synonym of *Hyperaulax* Pilsbry, 1897 (Salvador & Cavallari, 2019). Thus, its single species is now classified as *Hyperaulax ramagei* (Fig. 3). Furthermore, molecular data on *H. ridleyi* (Fig. 4) have supported placement of *Hyperaulax* in the Odontostomidae (Orthalicoidea; Salvador & Cavallari, 2019). That analysis also suggested that *Hyperaulax* is closely related to the continental genus *Tomigerus* Spix, 1827.

Ridleya quinquelirata (Fig. 5) is the species that underwent most changes in nomenclature and classification. First, the gastropod genus *Ridleya* Ancey, 1901 was recognized as a junior homonym of the sponge genus *Ridleya* Delage & Hérouard, 1899 (Christensen, 2020). As such, a new name was proposed for the snail genus: *Ridleyconcha* Christensen, 2020.

Throughout the decades, *Ridleyconcha quinquelirata* was classified in several stylommatophoran families: Streptaxidae,

Fig. 3. *Hyperaulax ramagei*, lectotype (NHMUK 1988.6.24.163) in three views. This species was originally described as *Bulimus* (*Bulimulus*) *ridleyi* Smith, 1890.

Fig. 4. *Hyperaulax ridleyi*, lectotype (NHMUK 1888.6.27.106) in two views. This species was originally described as *Bulimus* (*Tomigerus*) *ramagei* Smith, 1890.

Fig. 5. *Ridleyconcha quinquelirata*, syntype (NHMUK 1988.6.27.135). This species was originally described as *Helix* (*Ophiogyra*?) *quinquelirata* Smith, 1890.

Endodontidae, Charopidae and Camaenidae. In a recent review based solely on conchological characters, Salvador (2019a) proposed that it belonged instead in the family Scolodontidae. A new phylogenetic study based on genetic markers has confirmed its placement in Scolodontidae, with *Ridleyconcha* as the sister taxon to *Entodina* Ancey, 1887 (Salvador, 2021).

Finally, there is a fourth possibly endemic species from Noronha, *Gastrocopta solitaria* (Smith, 1890). However, given that species of Pupilloidea have been readily introduced worldwide, a reassessment of the validity of this species is needed.

These latest morphological and molecular analyses have thus permitted revision of Noronha's endemic land snails, resulting in several advances in our knowledge of them.

Conservation

However, there are now issues regarding the conservation of these snails that need to be addressed. Freitas *et al*. (2019) recently conducted a land snail survey in Noronha, reporting on the species' distribution and abundance in the archipelago. Of a total of 20 surveyed sites on the main island, land snails were found at only three, two of them with live snails (Fig. 6) and a third where long-dead or subfossil shells of *H. ridleyi* were recovered from a dune deposit. These authors reported four land snail species on Noronha: *H. ridleyi*, *R. quinquelirata*, *Beckianum beckianum* (Pfeiffer, 1846) and *Allopeas gracile* (Hutton, 1834).

The latter two species are widespread in the neotropics, but both have been widely distributed by human commerce. *Beckianum beckianum* is believed to be native to Central and South America, though it now occurs elsewhere as well (Pilsbry, 1906–1907; Cowie, 1997). *Allopeas gracile* is now pantropical in distribution and even though a neotropical origin has been suggested (e.g. Pilsbry, 1946), its presence in the fossil and pre-modern archaeological record from Africa to the islands of Polynesia indicates an origin in the Old World tropics (Christensen & Weisler, 2013). As such, *A. gracile* has in all likelihood been introduced to Noronha, while *B. beckianum* may be considered as possibly introduced.

Fig. 6. Habitat and vegetation on the coastal lowland plains near Cacimba do Padre beach, where Freitas *et al*. (2019) found *A. gracile*, *B. beckianum*, *H. ridleyi* and *R. quinquelirata*.

Other notable introduced species in Brasil are thankfully absent from Noronha, such as the giant African snail *Lissachatina fulica* (Bowdich, 1822) and the Asian tramp snail *Bradybaena similaris* (Férussac, 1821). Freitas *et al*. (2019) hypothesised that the arid conditions of the archipelago would act as a deterrent to their establishment.

Hyperaulax ridleyi was the most abundant species reported by Freitas *et al*. (2019), while *R. quinquelirata* was restricted to a single locality (Fig. 7). Despite the good news of finding these endemics alive (and in sites with moderate to high anthropogenic disturbance), their limited distribution might be a reason for concern. Habitat destruction is considered to be the main threat to Noronha's endemic land snails, as the native forests have been widely converted to secondary vegetation over the past two centuries (Freitas *et al*., 2019).

Freitas *et al*. (2019) did not find the endemic *Hyperaulax ramagei* or the possibly endemic *Gastrocopta solitaria* in their survey. They also did not find *Rhinus pubescens* (Moricand, 1846), a mainland species that had been reported previously

Fig. 7. Left: live *H. ridleyi* found under loose bark of a live shrub. Right: live *R. quinquelirata* under dead bark on the soil.

from Noronha (Simone, 2006). As a confirmed endemic species, *Hyperaulax ramagei* is of particular interest. This species has not been found alive during any collecting efforts since the 1990s (Salvador & Cavallari, 2019). Museum specimens of *H. ramagei* that still have a well preserved periostracum typically date back to the first half of the 20th century (Salvador & Cavallari, 2019), indicating that the species was still alive back then. Either this species still survives in a very restricted range or, more likely, it has become extinct.

Of the ~700 land snail species found in Brasil, only an insignificant number has any sort of protection (Salvador, 2019b). The work done on the endemic snails of Noronha in the past few years will allow assessment of the risks that each species faces and determine their conservation status according to the IUCN guidelines (IUCN, 2012). Vulnerability to extinction is correlated with geographic range on oceanic islands, with less widespread species being the most likely to become extinct (Chiba & Roy, 2011; Chiba & Cowie, 2016). In Noronha, the two endemic land snails are only known from the main island (with museum specimens indicating their former presence on the adjacent Rata Island), which suggests they are in a very vulnerable position.

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MOLLUSCS IN THE NEW EDITION OF THE RED BOOK OF UKRAINE

By Igor Balashov

The Red Book of Ukraine is an official government document that lists the threatened species occurring in Ukraine and provides basic information on these species, threats to them and required measures for their conservation. Each species listed, under any category, is protected by law in Ukraine; killing or use of individual specimens and destruction of their

habitats leads legally to administrative fines. According to Ukrainian law, the presence of species listed in the Red Book of Ukraine is the main foundation for the creation of new protected areas. Therefore, this document is one of the main tools for practical purposes of nature conservation in Ukraine. It is also a very well-known and mostly positively accepted document among the general public in Ukraine as a result of the basic information on it having been included in school programmes for several decades.

The Red Book of Ukraine is regulated by the Law of Ukraine "On the Red Book Ukraine" (Verkhovna Rada of Ukraine, 2002; with further changes) and is published as a large book with species accounts similar to those in the IUCN Red List. Three editions have been published: in 1980, 1994 (animal volume) and 2009 (animal volume) (Sytnyk, 1980; Shcherbak, 1994; Akimov, 2009). The species are legally protected not from the date of publication of the book itself, but when the Decree of the Ministry of Ecology of Ukraine with the current list of species protected by the Red Book of Ukraine goes into effect, which normally happens several months before publication of each new edition. The list of species is revised before each edition. In the transitions some small changes to the lists are implemented, but only on rare occasions (changes are permitted to be made at any time, but such opportunities have been almost unused). According to the above mentioned Law of Ukraine (Verkhovna Rada of Ukraine, 2002), a new edition of the Red Book should be published at least every 10 years, but this frequency has never been achieved, mainly because of bureaucracy and lack of funding.

The scientific work on the Red Book is managed by the National Council on the Red Book of Ukraine, which currently is based in the National Academy of Sciences of Ukraine and consists mainly of the leading zoologists and botanists, as well as some government and academy officials. However, funding comes from the Ministry of Ecology of Ukraine and final adoption of the results is also the responsibility of the Ministry, but the link between the two structures often has not worked well. The Fourth Edition of the Red Book of Ukraine was scheduled to be published in 2019, but all attempts in 2019 and 2020 failed even though all changes to the list of protected species and the book itself were already largely prepared by the scientists. In March 2021 two decrees (separately on the animals and on the plants) from the Ministry of Ecology of Ukraine, with renewed lists of the species protected by the Red Book, were published, with the one on the animals going into effect from 12 March 2021 (Ministry of Ecology of Ukraine, 2021). The Ministry intended to publish the Fourth Edition in 2021, but the tendering process failed again.

Therefore, as of February 2022, there is no new published version of the book with species accounts, although the renewed lists of protected species are already in effect, which is the important point from the practical perspective of nature conservation.

Currently there are seven categories for the species listed in the Red Book: "Extinct", "Extinct in the wild" (in Ukraine or completely), "Endangered" (close to the IUCN CR and EN categories combined), "Vulnerable" (close to the IUCN VU category), "Rare" (close to the IUCN NT category: "species that may become vulnerable in the near future") and two categories of uncertainty: "Insufficiently known" and "Not assessed" (the latter category is hardly necessary in the opinion of many experts and exists mainly for the species listed in the previous editions the current status of which is uncertain).

Table 1. Molluscs in the 2021 Red Book of Ukraine, with the year of the edition in which they were first listed.

Species	Year	Category	Habitat
Gastropoda			
Caspia knipowitchi	2021	EN	brackish water
Euxinipyrgula lincta	1994	VU	brackish water
Marstoniopsis insubrica	2021	R	fresh water
Pomatias rivularis	2009	R	forest
Acicula parcelineata	2021	R	forest
Platyla perpusilla	2021	VU	forest
Platyla polita	2021	R	forest
Lymnaea taurica	2021	EN	steppic puddles
Ladislavella terebra	2021	VU	fresh water
Sphyradium doliolum	2021	R	forest
Argna bielzi	2021	R	forest
Pupilla alpicola	2021	EN	fen
Pupilla sterrii	2021	EN	steppe/rock
Pupilla triplicata	2021	R	steppe/rock
Vertigo moulinsiana	2021	EN	fen
Vertigo geyeri	2021	EX	fen
Vertigo angustior	2021	R	various wet
Truncatellina claustralis	2021	R	various dry
Granaria frumentum	1994	VU	steppe/rock
Chondrina arcadica	1994	R	rock
Rupestrella rhodia	2021	R	juniper/rock
Peristoma merduenianum	1994	VU	juniper/rock
Ramusculus subulatus	2021	EN	steppe/rock
Mastus bielzi	2009	R	forest
Serrulina serrulata	1994	EN	forest
Elia novorossica	2021	EN	forest
Ruthenica filograna	2021	R	forest
Macrogastra borealis	2021	R	forest
Macrogastra plicatula	2021	VU	forest
Macrogastra tumida	2021	R	forest
Clausilia pumila	2021	VU	forest
Clausilia cruciata	2021	R	forest
Vestia elata	2021	VU	forest
Pseudalinda fallax	2021	VU	forest
Discus perspectivus (Fig. 1)	2021	VU	forest
Vitrea nadejdae	2021	EN	forest
Taurinellushka babugana	2021	R	subterranean
Oxychilus kobelti	1994	VU	forest
Mediterranea inopinata	2021	VU	steppe/rock
Daudebardia rufa	2021	VU	forest
Daudebardia brevipes	2021	VU	forest
Drobacia banatica	1994	VU	forest
Arianta aethyops	2009	R	various mountain
Trochulus villosulus	1994	VU	forest
Trochulus bielzi	2009	R	forest
Plicuteria lubomirskii	2009	R	forest
Prostenomphalia carpathica	1994	VU	forest
Bivalvia			
Hypanis laeviuscula	2009	VU	brackish water
Hypanis plicata	2009	VU	brackish water
Sphaerium nucleus	2021	VU	fresh water
Unio crassus	2021	VU	fresh water
Anodonta cygnea	2021	VU	fresh water
Pseudanodonta complanata	2021	VU	fresh water
Ostrea edulis	1994	EN	marine

As of 2021 there are 1,544 species protected by the Red Book of Ukraine and 54 of them are molluscs (Table 1). This is significantly more than in the previous years. In the Third Edition (2009-2021) 20 species of molluscs were listed, in the Second Edition (1994-2009) 12 species (see Table 1), and none was listed in the First Edition. Among these 54 mollusc species 42 are terrestrial and this group is covered almost comprehensively. A major contributor to the Second (1994)

Fig. 1. Shell of *Discus perspectivus*, a species listed in the Red Book of Ukraine in 2021. (Photo: I. Balashov & K. Martynova)

and Third (2009) editions was A.A. Baidashnikov, who included 13 species of terrestrial molluscs. This number was raised to 42 in 2021 following my review (Balashov, 2016) and my submitted assessments and species accounts with co-authors (A.A. Baidashnikov, N.V. Gural-Sverlova and others).

Representation of aquatic molluscs is far less comprehensive: only 12 species are currently listed, including two brackishwater gastropods, three freshwater gastropods, two brackishwater bivalves (which sometimes occur in large freshwater reservoirs), four freshwater bivalves and one marine bivalve (Table 1). These species were rather haphazardly selected by the several contributors depending on the available data, interest in them or in some cases even availability of suitable illustrations (as this is one of the requirements for submitting a species to the Red Book of Ukraine). For most of the aquatic molluscs of Ukraine there have been no consistent published attempts to analyse their conservation statuses. In large part this is a result of the problematic taxonomy and impossibility of clearly interpreting many of the earlier published faunistic records. In the Soviet Union, and to some extent in some of the post-soviet countries, the taxonomy of aquatic molluscs was dominated by the school of Ya. I. Starobogatov, such that understanding of many species was very different from their currently recognised status, with some names not used in their original meaning. Therefore, not only were many problematic names used (e.g. nomina dubia), but also use of some names may not have referred to the taxa currently recognised as corresponding to those names, as explained by Korniushin (1998, 2002), Graf (2007) and Balashov *et al*. (2013). Many such issues with aquatic molluscs of Ukraine remain unsolved or disputed, so it is often problematic even to figure out which species occur in Ukraine, not to mention the details of their distribution and their conservation statuses.

Three species of molluscs were excluded from the Red Book of Ukraine in 2021. Two of them were excluded mainly for taxonomic reasons: "*Lymnaea clavata* Westerlund, 1885" and "*Lymnaea pachyta* Westerlund, 1885" which are either nomina dubia or refer to unrecognised taxa. The third excluded species is *Helix lucorum* Linnaeus, 1758, which was included in 2009, but it is not native to Ukraine (Korábek *et al*., 2018).

Among the aquatic molluscs of Ukraine, the most complete knowledge is of freshwater bivalves following the review by Korniushin (2002), who not only provided a checklist of species for Ukraine according to current taxonomic understanding (or close to that), but also analysed which of them should be protected in Ukraine. Korniushin (2002) assessed ten species of freshwater bivalves (seven Sphaeriidae and three Unionidae) as needing protection in Ukraine, using the categories of the Red Book of Ukraine (see above): *Euglesa lilljeborgii* (Clessin, 1886) – endangered; *Pseudanodonta complanata* (Rossmässler, 1835), *Unio crassus* Philipsson, 1788, *Euglesa pulchella* (Jenyns, 1832), *Euglesa pseudosphaerium* (Favre, 1927) – vulnerable; *Anodonta cygnea* (Linnaeus, 1758), *Odhneripisidium moitessierianum* (Paladilhe, 1866), *Euglesa personata* (Malm, 1855), *Euglesa hibernica* (Westerlund, 1894) [= *Euglesa parvula* (Clessin, 1873)] – rare; *Sphaerium solidum* (Normand, 1844) – status undetermined (but at least "rare"). In addition to these ten species *Sphaerium nucleus* (Studer, 1820), *S. ovale* (Férussac, 1807) and *Euglesa globularis* (Clessin, 1873) were listed as needing additional sudies of their conservation statuses (Korniushin, 2002). Apparently, Korniushin's intention was to submit these ten species for inclusion in the Third Edition of the Red Book of Ukraine, but, unfortunately, he died suddenly in 2004, before work on the Third Edition was started. Detailed assessments and distribution datasets were not published by him and there is still no expert in Ukraine who could provide such information for most species of Sphaeriidae. But three of the species of Unionidae were included in the 2021 edition by the group of experts based in Zhytomyr City, who had accumulated extensive data on the unionids of Ukraine (e.g. Shevchuk *et al*., 2019, 2021).

Uvaeva & Hural (2008) reviewed the distribution and ecology of Planorbidae in Ukraine (18 freshwater species) and mentioned five species as "very threatened", three as "threatened" and four as "potentially threatened" in Ukraine. The following eight species were reported as very threatened (first five) and threatened: *Planorbis carinatus* Müller, 1774, *Anisus vorticulus* (Troschel, 1834), *Gyraulus acronicus* (Férussac, 1807), *Gyraulus rossmaessleri* (Auerswald, 1852), *Gyraulus laevis* (Alder, 1838), *Anisus leucostoma* (Millet, 1813), *Gyraulus albus* (Müller, 1774), *Ancylus fluviatilis* Müller, 1774 (Uvaeva & Hural, 2008). But these species were never submitted to the Red Book.

Among the species that are listed in the IUCN Red List and occur in Ukraine, but are not listed in the Red Book of Ukraine, there are notably *Turricaspia ismailensis* (Golikov & Starobogatov, 1966) (VU), *Sphaerium rivicola* (Lamarck, 1818) (VU) and *S. solidum* (NT). Korniushin (2002) assessed *S. rivicola* as common, abundant and not threatened in Ukraine.

One freshwater species, *Anisus vorticulus*, is listed in Annex I of Resolution 6 of the Bern Convention (ratified by Ukraine), as well as in Annex II of the Habitat Directive, DD in the

IUCN Red List and mentioned as "very threatened" in Ukraine (Uvaeva & Hural, 2008), but was not assessed for the Red Book of Ukraine.

Among the 29 species of terrestrial molluscs included in the Red Book of Ukraine in 2021 most are dead wood dwellers (11), others are species of forests (7), steppes and other dry habitats (6) and wetlands (4), as well as a single subterranean species. This largely reflects the major regional environmental problems in Ukraine with forest management involving minimisation of dead wood in existing forests and afforestation in the steppes and other natural grasslands (Balashov, 2016). All species of terrestrial molluscs that are sufficiently known and of high priority for conservation in Ukraine are currently protected by the Red Book. Although there are a few species in Ukraine that correspond to the IUCN NT category (and therefore to "Rare" in the Red Book of Ukraine) and may become vulnerable in the near future, they are still omitted: *Helicopsis lunulata* (Krynicki, 1833) (Balashov *et al*., 2021), *Clausilia dubia* Draparnaud, 1805, *Truncatellina costulata* (Nilsson, 1823) (Balashov, 2016). Also, there are several terrestrial species that are insufficiently known in Ukraine to assess their conservation status, often because there is uncertainty regarding their presence in Ukraine or regarding their taxonomic status. This refers mostly to *Platyla jankowskiana* (Jackiewicz, 1979), *Oxyloma dunkeri* (Pfeiffer, 1865), *Spermodea lamellata* (Jeffreys, 1830), *Zebrina detrita* (Müller, 1774), *Cochlodina cerata* (Rossmässler, 1836), *Macrogastra ventricosa* (Draparnaud, 1801), *Balea perversa* (Linnaeus, 1758), *Tandonia kaleniczenkoi* (Clessin, 1883), *Limax bielzii* Seibert, 1873 and *Urticicola umbrosus* (Pfeiffer, 1828) (Balashov, 2016).

Consequently, it appears that the greatest challenge and the highest priority for further work on molluscs in the Red Book of Ukraine is assessing and including more freshwater species as this is a group of the highest conservation priority (Lopes-Lima *et al*., 2021), especially species of Sphaeriidae and Planorbidae that have already been reported to be threatened in Ukraine (Korniushin, 2002; Uvaeva & Hural, 2008).

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CONSERVATION STRATEGIES FOR NEW YORK STATE'S CHITTENANGO OVATE AMBER SNAIL (NORTH AMERICA)

By Emlyn B. Clark, Cody R. Gilbertson, David A. Bullis, Delaney Kalsman, Tom Hughes, Kathleen O'Brien, Robyn Niver, John Wiley & Rebecca J. Rundell

Succineid land snails are found worldwide, from riparian areas to dry landscapes on the slopes of Mauna Kea in Hawaii. Although some succineid species are familiar as greenhouse pests and accidental introductions, our most famous central New York State (USA) succineid is a narrow-range endemic detritivore, living as a single population among a scramble of rocks and vegetation in the spray zone of Chittenango Falls in Madison County, New York, not far from Lake Ontario. The Chittenango ovate amber snail ("COAS", *Novisuccinea chittenangoensis*; Fig. 1) is considered Threatened under the U.S. Endangered Species Act, and Endangered in New York State. COAS has recently been recommended for uplisting to federally Endangered status (USFWS, 2019). Saving this species from extinction requires the concerted effort and good faith of multiple partners and volunteers, the most recent work

Fig. 1. A one year-old captive-bred Chittenango ovate amber snail (COAS) crawls on its favorite substrate, sun-bleached sugar maple leaf litter. (Photo: R.J. Rundell)

Fig. 2. Chittenango ovate amber snail technician Emlyn Clark peaking inside one of our growth chambers to show the COAS terraria, which are labeled to indicate generations and hatch years. (Photo: R.J. Rundell)

of which we report here. Our approach has included developing captive breeding and field research programmes (e.g. mark-recapture, climate monitoring), invasive species removal, rock fall monitoring, educational outreach, phylogenetic research, and most recently, beginning a plan for potential translocation of captive-bred snails into satellite wild sites. We share some key insights from our comprehensive conservation research programme here, with an aim toward connecting our work (including successes and failures) with fellow members of the land snail conservation community.

Captive breeding

Breeding snails in captivity became a necessity, given the imminent danger to the species from rock falls, combined with the small wild population, numbered in the hundreds. Establishing a breeding colony for any narrow range endemic species is a daunting task, particularly when little is known about its food preferences.

Initially, we used the successful Pacific island tree snail captive colonies of Hawaiian achatinellines and French Polynesian partulids as models for our project, and set up growth chambers and terraria accordingly, using local climatic conditions recorded by data loggers at the single wild site. We chose test foods that would balance nutritional quality with replicability and ease of feeding in the captive environment. Before bringing in wild snails, we used a surrogate species (*Succinea putris*, an introduced species that also occurs at the site) to test laboratory and zoo diets along with a wide range of local wild foods, many of which were decomposed plants found at the Chittenango Falls site (Gilbertson *et al*., 2019). It soon became clear that snail diets that worked in other settings were inappropriate for COAS. This underscores an aspect of this work that is simultaneously of biological interest and conservation frustration: many land snail species, including COAS, have dietary preferences that have probably been shaped over time, and in some detail, by these species' evolution and ecology. We were finally successful in establishing captive breeding of COAS, and now have a colony of snails that well exceeds the number of individuals in the wild (Fig. 2), and, pre-COVID-19, enabled us to establish a second breeding colony at a partner organisation, the Rosamond Gifford Zoo in Syracuse, New York. Better understanding of the wild diet (i.e. certain species of leaves at a certain stage in decomposition, arranged in a precise way and re-hydrated ("leaf litter lasagna" coined by CRG) was central to this success, but it also comes at a significant cost in time, space and expertise. Dead leaves are hand-picked and sorted according to species and decomposition stage, which involves the recruitment and training of volunteers ("Snailblazers"), and keeping an eye on their work, followed by drying and storing the leaves (Fig. 3). We examine each leaf species for specific characteristics that increase the likelihood that COAS will feed on them (based on our previous feeding experiments; Gilbertson *et al*., 2019). For example, COAS prefers thin, sun-bleached, sugar maple leaves that have been collected shortly after snowmelt, yet before temperatures warm up enough for other invertebrates to feed on them. We also collect black cherry leaves in the spring, and sort them by thickness using light transparency. Thinner decomposed leaves are highly preferred (Gilbertson *et al*., 2019). Food collection is a non-trivial aspect of the project as it involves finding the right species of trees in the wild, coordinating access to field sites, training and working closely with student volunteers, and planning the leaf collections at just the right time to ensure palatability for the snails.

COAS live in the temperate zone where it is impossible for us to access their food and wild habitat during winter months. Periodically, the site can be dynamic at other times (Fig. 4). However, since we need to maintain the animals in captivity year-round, we must ensure sufficient food for snail survival and changing of terraria, even during any experimental winter dormancy periods. Indeed, the time-intensive diet portion of

Fig. 3. Our staff and student "Snailblazers" collect leaves in certain stages of decomposition, then spread them out on tarpaulins to dry or dry them in a drying oven. Leaves are then organised by species and year in bins for later rehydration and arrangement in the captive colony terraria. (Photo: R.J. Rundell)

our project raises concerns about initiating and sustaining similar conservation programmes on threatened North American and other detritivorous land snails, given the number of species in need of conservation attention. It may be impossible to deliver such a complex and specific diet to captive snails in the form of an easily mixable paste. However, given our experience with COAS, we encourage others to pursue research on the dietary preferences of endangered land snails worldwide. This is not only useful for our understanding of land snail species ecology (and potentially supporting captive breeding), but it also ultimately supports the conservation of their wild habitats.

One important aim is for the captive colony to serve as a backup in case of a stochastic event such as a rockslide. Captive-bred snails might also augment the wild population, and so we have initiated regular releases of captive-bred snails back into the wild. Whenever possible, we mark these snails so that we at least have the chance to find them again and

Fig. 4. Chittenango Falls after heavy rainfall (A) and on an average late Summer day (B). High water levels flowing over the falls can wash out the lower portions of COAS habitat and remove potential food sources. (Photos: E.B. Clark)

Fig. 5. Captive-bred COAS with a glued bee tag for identification. COAS typically live for 2-2.5 years (sometimes longer in captivity). (Photo: C.R. Gilbertson)

better understand how (or if) released COAS can survive long-term (Fig. 5). Over seven years, we have released 482 snails, 161 marked adults and 321 juveniles. We also started releasing captive-bred egg masses in 2021 (4 masses containing 212 eggs in total). We are gaining confidence in our captive release programme. For example during 2020-2021, we discovered three marked snails that had successfully overwintered, a major milestone for the project. Our approach also involves releasing previously wild-caught individuals that were brought into the lab for breeding, so that we continue to refresh our breeding stock. As our breeding colony becomes more successful, and we increase our capability of putting more snails into the wild, we continue to explore the question of how many individuals to release and when, also in consultation with other conservation biologists at SUNY-ESF with experience in vertebrate species releases. Our COAS conservation programme is unusual in that we have a species that is rare in the wild, while laying many eggs in a cluster at once, meaning that once our captive feeding, habitat and climate regime proved successful, the species became fairly abundant in captivity. This poses challenges for tracking parentage of these hermaphriditic snails in the captive colony. We have done our best to document snail parents and generations, but are beginning to investigate the genetic side of the project in more detail in order to better understand the potential differences between captive and wild COAS.

Wild site work: mark-recapture, trampling prevention, invasive plant removal, rock falls

The complete known geographic range of COAS is contained within a state park, which has been instrumental in the protection of the species. We are fortunate to have comparative data from summer 2002 to present on the state of the single wild COAS population (Campbell *et al*., 2015, USFWS, 2019). Recently, we have detected a notable decline in the species. There is no one clear reason for the decline, but rockslides have no doubt contributed. For example, in 2006 a rockslide reduced the habitat previously occupied by COAS, and decreased the estimated number of COAS from about 780

animals in 2005 to about 300 in 2008 (USFWS, 2012). By 2015 we estimated 360 wild snails, but unfortunately the population has been decreasing since then. In 2019, we estimated 76 individuals remaining. For all population estimates POPAN was used in RMARK (White & Burnham, 1999). Unfortunately, we were reminded of the possibility of new rockslides in the area during summer 2021, when we detected new fallen boulders in the COAS habitat, and instability in the rocks above the habitat. We consulted with the New York State Parks Regional Scaling Team to assess the safety of the site before we proceeeded with additional snail surveys or releases. We are also discussing the potential removal of large boulders in the area. However, there is a difficult balance to be struck between the habitat and refuge certain rocks might provide to snails, the obstruction to vegetation growth and leaf litter capture that too-large rocks might cause, and the danger to the snails that could be caused by trampling of workers and running large equipment to the site to break up and extract rocks. This is a critical aspect of the project that relies heavily on the expertise and collegiality of our group of partners to bring their knowledge and dedication to COAS, in order to help figure out a path forward. It seems there are no perfect decisions in this case, and as much as we have learned about COAS ecology, we still do not fully understand how the site supports this species and how any modification to the site could improve or worsen the chances for COAS survival.

Similar considerations must be made for plant species removal at the site, which has thus far targeted invasive species such as pale swallow-wort (PSW; *Vincetoxicum rossicum*), European dewberry (*Rubus caesius*) and buckthorn (common: *Rhamnus catharticus*; and glossy: *Frangula alnus*). Removal involves cutting and hand-pulling plants to prevent their spread into the habitat and around the park. Two of these plants, dewberry and PSW, are found inside the COAS habitat. These plants smother and prevent recruitment of COAS-preferred native plant species such as Joe Pye weed (*Eutrochium purpureum*). This is the first year of dewberry and buckthorn removal, with results yet to be seen. However, we think that the removal of PSW from the habitat may have facilitated Joe Pye weed increase in the habitat. Each year we have needed to remove fewer invasive PSW plants. Encouraging native plants to grow could increase food and shelter for COAS and help increase humidity in rocky zones. Cultivating native vegetation might also naturally hinder PSW in the habitat, which would reduce the potential for trampling the habitat or snails during our invasive species removal projects.

Trampling is an ongoing threat to COAS, especially considering its tiny geographic range. For species security reasons, we do not publicise the location of this tiny range. However, there is an unfortunate coincidence between COAS crawling sites and places that tourists, dare-devils, hikers, bathers and fishers like to frequent in summer, despite signage restricting the area because of the presence of an endangered species. Recently we have increased educational signage at the park as well as staff presence near the base of the waterfall during working hours, to deter would-be tramplers. We have also added trail-cams to try to better understand when and who the culprits are. However, since beautiful waterfalls are an eternal lure to humans and because the park is also intended as a place for visitor recreation, it remains a challenge to channel tourists away from the only place that COAS lives. The good news is that local pride and interest has grown around COAS. Thus, park staff presence is aimed not just at deterrence, but at cultivating interest and conservation concern for the species.

Geographic context for COAS and future for translocation

COAS currently resides on one side of one waterfall in central New York State. Understanding whether COAS once had a larger geographic range is important for conservation, since it suggests that other areas could receive translocated captive-bred or wild-caught snails. In order to better understand COAS's past distribution, as well as current habitat requirements, we 1) investigated putative COAS records outside its current range, and 2) determined suitabilitiy of other sites outside of the current COAS habitat.

Since the original description of COAS by Pilsbry in 1908, COAS specimens have been reported from the U.S. states of Tennessee, North Carolina, Illinois, Missouri and Iowa. If past identifications are accurate, COAS previously had a much larger range that has contracted to a single locality. This is not altogether unlikely, since all other members of the genus *Novisuccinea* have broad geographic ranges. Unfortunately, validating past COAS records is not straightforward, because succineid identification is notoriously challenging. Without anatomical data for those specimens, which are only shells, some past records might be unverifiable. To attempt to resolve these identifications, we are applying traditional as well as novel geometric morphometric techniques to examine COAS and other succineid shells. Comparing the type material of COAS and other succineid species against the unverified COAS specimens might help us reconstruct COAS's historical biogeography. Preliminary data suggest that COAS shells are not easily distinguished by eye, and thus previous records of the species outside its current range may have been mistaken. Analyses are ongoing.

Concurrently, we have been collecting field data on temperature, humidity, land snail community composition and plant community composition at other central New York sites to compare with COAS's current habitat. We are considering these sites for future translocation based on these factors. We are also documenting the presence/absence of invertebrate predators and parasitoids of COAS at potential translocation sites. Certain fly genera (Sciomyzidae and Sarcophagidae) are parasitoid specialists on snails that could affect translocation success. We are also recording salamander distributions, since these are important predators of land snails. Finally, the local establishment of the non-native harvestman *Trogulus tricarinatus*, which is a voracious predator of snails, is not yet confirmed. If present, these opilionids could have negative effects on the local malacofauna, including succineids. Fortunately, our initial results indicate that several other local waterfall sites may be appropriate for COAS translocation. We are currently developing a detailed proposal for translocation and ongoing monitoring and COAS management that could involve one or more of these sites.

Fig. 6. A local TV crew helps to publicize and celebrate the release of captive-bred COAS at Chittenango Falls State Park in Central New York State, the only known wild locality for this federally threatened North American land snail species. (Photo: R.J. Rundell)

Education is central to invertebrate conservation

We initially partnered with Syracuse's Rosamond Gifford Zoo, primarily as an avenue to explore educational outreach during the summer months, and as a site for a second breeding colony. In the past several years, educational outreach has grown into a central aspect of our COAS project, in part because so many of our staff and volunteer Snailblazers are outstanding snail ambassadors, but also because there has been so much local, regional and even national interest in this little snail. The goals of our outreach are multifarious and underscore the critical yet under-appreciated roles that our partners play in species and habitat conservation. Most importantly, however, any increased appreciation for land snails among young people and the public, whether it be through media release or a hands-on school programme, serves to broadly benefit global invertebrate conservation. At the local level, a COAS educational programme teaches a participant that the extinction crisis is in their backyard, and that they can actually play a role in turning that around. But participants also learn that even seemingly insignificant organisms are important. We have discovered that land snails are especially suited to deliver these big messages. We have also found that outreach is effective when we catch people where they are, enjoying their daily activities. This includes talking to people during their hike through Chittenango Falls State Park, while we walk to the habitat in our hard hats, and getting our SUNY-ESF undergraduates directly involved in our on-campus snail lab. Other examples of our snaily COAS outreach include: publicising snail release events at the wild site (Fig. 6); commissioning a local artist to build a "crawl-on" snail for kids at the Rosamond Gifford Zoo (Fig. 7); an Endangered Species Beer fundraiser sponsored by a local brewery (Critz Farms); leading snail-focused tabling events at Chittenango Falls State Park (connecting with 1,000 visitors in 2021); establishing a "Friends of the Chittenango Ovate Amber Snail" organisation as a special fundraising arm of the Zoo that can receive small donations; "Chitt Chat" presentations at local libraries and schools; creation of a colourful children's booklet; and creation of COAS social media pages (Instagram/Snailblazers_NY and Facebook.com/SnailblazersNY). We are continually reminded that despite any setbacks in the project, and snail numbers in the wild, any chance we have for success rests with the public that supports our conservation research and practical management actions.

We acknowledge the Rosamond Gifford and Seneca Park Zoos (New York, USA) for their continued interest in COAS. We thank the New York State Department of Environmental Conservation for permits and for water quality review upstream of the habitat. We thank K. Schulz and CIRTAS at ESF for granting the space for our captive breeding project. We thank our many student research assistants, including A. Yost, A. Whitbread, T. Daino, E. Tanski, P. Raucci, J. Bruno, W. Schofield-Broadbent, B. Hahn, C. Boolukos, A. Protus, K. Hyacinthe, S. Farnham, S. Munoz, L. Evans and T. Goggin. We also thank former University of Rochester and Seneca Park Zoo veterinarian J. Wyatt, who helped assess snail health, as well as J. Brown, B. Underwood and P. Gilbertson for their contributions. Finally, we gratefully acknowledge the longterm support of the U.S. Fish and Wildlife Service, including their funding through the Great Lakes Restoration Initiative, which has been central to the success of the project as well as the training of many students in the conservation of understudied invertebrate animals. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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Fig. 7. "Crawl-on" COAS: a sturdy all-weather endangered snail exhibit for kids in the Explorer's PlaySpace at the Rosamond Gifford Zoo in Syracuse, New York, USA. (Photo: C.R. Gilbertson)

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COLLECTING IN THE HEART OF SOUTH AMERICA: THE FRESHWATER MUSSELS OF PARAGUAY

By Cristhian Clavijo, Igor Christo Miyahira & Rebeca Carballo

Two of the most important rivers in the world, Paraná and Paraguay, run through Paraguay. Despite this, the country was ignored by most of the European scientific expeditions of the 18th and 19th centuries; this environmentally privileged position, was also hard to reach by expeditions that arrived by sea from Europe. It is noteworthy that Paraguay and Bolivia are the only two landlocked South American countries. During the 20th century, few naturalists interested in molluscs worked in Paraguay. The main existing works are an inventory of the department of Guairá (eastern region of Paraguay) by an Austrian naturalist (Schade, 1965), and a catalogue of the Paraguayan fauna made by an Argentinean researcher who lived in Paraguay in the 1970s (Quintana, 1982). The samples used by these two authors were not deposited in museums in Paraguay and they did not train resident pupils in Paraguay. The absence of historic and recent studies in Paraguay resulted in a large information gap in the heart of South America. Thus, it was necessary and urgent to obtain information from Paraguay if a proper evaluation of the whole basin was to be accomplished. The fieldwork described in this report was undertaken under the project "Conservation of freshwater bivalves of Rio de la Plata basin", funded by the Mohamed bin Zayed Foundation. The main goal of the project is to obtain updated information on freshwater mussels in the Río de La Plata basin (Clavijo & Miyahira, 2021).

For seven days the authors travelled ~2,500 km, visiting 40 locations looking for freshwater bivalves, taking advantage of the extreme drought that the country suffered (Fig. 1). In total, 18 species of the 31 previously recorded in the country

Fig. 1. A small specimen of *Castalia* sp. 'running' for its life during severe drought in the Paraguay River Basin.

(Pereira *et al*., 2014) were found. The taxonomy of freshwater mussels in South America is not well resolved (Miyahira *et al*., 2017) and these numbers may change as work progresses. Empty shells only of the rare native species *Leila blainvilliana* (Lea, 1834) were found at just one locality. The invasive species *Corbicula fluminea* (Müller, 1774) was found in most of the localities. *Limnoperna fortunei* (Dunker, 1857) and other species of the genus *Corbicula* were recorded in some localities. The massive presence of invasive species in Paraguay, as also recorded in other freshwater habitats of South America (e.g. Clavijo & Carranza 2018; Darrigran *et al*., 2020; Miyahira *et al*., 2020) may have contributed to the decline of native species richness (Fig. 2). Invasive species and habitat modifications are the main threats to freshwater bivalves in South America (e.g. Pereira *et al*., 2014; Clavijo & Carranza, 2018). The specimens obtained were deposited in the Museo Nacional de Historia Natural del Paraguay, doubling its collection of freshwater mussels.

Fig. 2. Panoramic view of Tebicuarymí River, a tributary of the Paraguay River, which supported a rich fauna of freshwater bivalves in the past, but now has been invaded by *Corbicula fluminea*.

This effort is a new beginning to advance knowledge and conservation of freshwater bivalves in Paraguay and contribute to conservation knowledge in the Río de la Plata basin more broadly. Moreover, we hope that it can also be an incentive to establish a Paraguayan team doing research on freshwater mussels. The study of the the Río de La Plata basin is an ongoing project and other parts of the basin will be investigated in the near future.

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TREE SNAILS IN SOUTH FLORIDA: ONGOING RESEARCH AND CONSERVATION CONCERNS

By Lawrence Lopez, Alície Warren, David Cook, Steve Sparks, Stefan Rhoades & Timothy Collins

In the United States, south Florida harbours four large charismatic native species of tree snails: *Liguus fasciatus*, *Orthalicus floridensis*, *Orthalicus reses* (two named subspecies) and *Drymaeus multilineatus*. Long lauded for their aesthetic beauty and noted for inspiring appreciation and affection in observers, these arboreal, pulmonate gastropods live in forested habitats composed of tropical and temperate trees and shrubs (Davidson, 1965). Studies of these tree snails have shed some light on their natural history and ecology, but much remains unknown about their behaviour and factors affecting their distribution and abundance. Furthermore, decades of development across south Florida have produced urban sprawl and ensuing elimination and fragmentation of natural habitats. In addition, some of these attractive and quite variable species have been the object of shell collectors since the 1950s and possibly before, at that time fetching US$50 or more for rare shells (Davidson, 1965). As a result of these combined factors, and others outlined below, all four of these tree snail species have suffered dramatic population declines, some of them now existing only in areas to which they have been relocated to save them from extinction (Emmel & Cotter, 1995).

Fig. 1. *Orthalicus reses reses* (Stock Island tree snail) on a wild tamarind tree (*Lysiloma latisiliquum*) in mainland south Florida. (Photo: Tim Collins)

Legal protections are in place for some of these tree snail species. *Orthalicus reses reses*, known as the Stock Island tree snail, is a state (Florida) and federally protected species (USFWS, 1978) (Fig. 1). *Liguus fasciatus*, known as a rare "gem of the Everglades", was state-listed until 2017; it is not currently listed, but maintains some protections (Davidson, 1965; FWC, 2020). *Orthalicus floridensis* and a variety of *D. multilineatus* (var. *latizonatus*) are considered "biologically vulnerable" (FWC, 2012). These conservation designations, however, are challenged by the worldwide traffic and colonisation of snail-eating land planarians (Sluys, 2016), which have already arrived in south Florida and are causing significant declines of local populations of tree snails, as they have in other parts of the world (Justine *et al*., 2015). In particular, we have found one species of land planarian known as the New Guinea flatworm (NGF) (*Platydemus manokwari*) naturalised and well established in forested "tropical hardwood or rockland hammocks" (local terms for sub- tropical upland forest habitat with very shallow organic soil and underlying or exposed oolitic limestone) (FNAI, 2010) where tree snails live, with flatworm densities between 0.2 and 3.8 individuals per square metre (unpublished data). Direct evidence of NGF predation of tree snails has been captured in photos and videos by our team (Fig. 2). Currently, local remnant populations of tree

Fig. 2. *Platydemus manokwari* (New Guinea flatworm) preying on a Florida tree snail (*Liguus fasciatus*) in a Miami-Dade County hardwood hammock. (Photo: Lawrence Lopez)

Fig. 3. The land planarian *Bipalium cf. vagum* on a hardwood hammock tree in Miami-Dade County, Florida. (Photo: Lawrence Lopez)

snails in south Florida living in county, state, federal and private lands are under predatory pressure caused by NGF (Lopez *et al*., 2021) and other invasive land planarian species recorded by our research team, such as *Bipalium cf. vagum*, another snail- and slug-eating flatworm species (Fig. 3). In addition, tree snail populations continue to be threatened by other predators (raccoons, opossums, birds, crabs, non-native herpetofauna, fire ants and rats), fires, habitat encroachment and microhabitat disturbances, hurricanes and climate change, all of which weigh heavily on dwindling populations (Smith, 1997; Forys *et al*., 2003; Giery *et al*., 2017).

Our research team is currently studying the distribution and population status of these four Floridian tree snails and that of NGF in mainland south Florida and the Florida Keys. Current surveys of these tree snail species in 18 hardwood hammock sites so far studied are preliminarily indicating higher frequency counts of *L. fasciatus*, followed by *O. floridensis*, *D. multilineatus* and *O. reses*, representing 50, 28, 20 and 2 percent of the total number of tree snails so far counted, respectively (e.g. Fig. 4). However, the distribution and abundance of these species varies widely based on a history of natural and human movements (translocations) and local habitat ecologies where some hardwood hammocks host three species of tree snails and others only one. Our preliminary NGF studies seem to indicate they are more abundant in hardwood hammocks in urban and semi-urban south Florida, reflecting in part the higher traffic of people, transport vehicles and plant nurseries (ornamental horticulture facilities) in these areas (Fig. 5). Much remains to be learned, however, about the different factors that could be implicated in determining the distribution and abundance of these non-native predatory flatworms.

Currently, many populations of tree snails live in fragmented hardwood hammocks, remnants of a once continuous forest habitat that extended throughout southeastern Florida and its Keys (with some degree of mixture with other habitats such as pine rocklands and coastal and freshwater wetlands). With highways and real estate development cutting through these forests, the ecological and habitat attributes of these now biogeographic islands are already affected by well known fragmentation impacts and consequences (Laurance *et al*., 2000), which means the conservation of these remaining

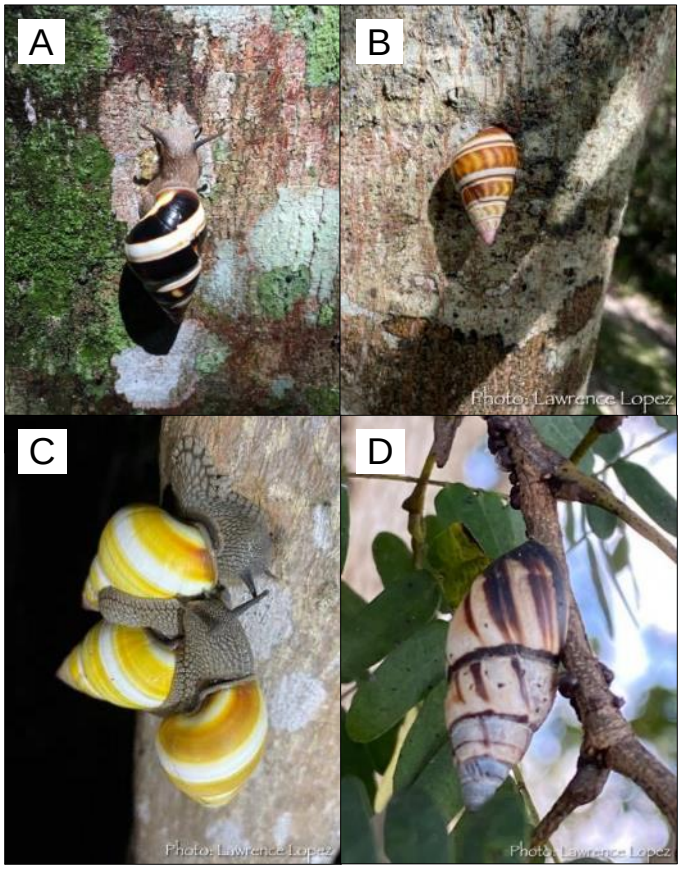

Fig. 4. A - *Liguus fasciatus* var. *castaneozonatus* on a mature hardwood hammock tree in Miami-Dade County, mainland south Florida (Photo: Tim Collins). B - *Liguus fasciatus* var. *alternatus* aestivating on wild tamarind tree (*Lysiloma latisiliquum*) in a Miami-Dade County protected hardwood hammock (Photo: Lawrence Lopez). C - Three individuals of *Liguus fasciatus* var. *roseatus* during the breeding season on a hardwood hammock tree in Miami-Dade County, Florida (Photo: Lawrence Lopez). D - *Drymaeus multilineatus* in a Miami-Dade County hardwood hammock, mainland south Florida (Photo: Lawrence Lopez)

imperiled natural areas is essential for the continued existence of tree snails in south Florida. *Liguus fasciatus* is quite variable with about 59 colourful varieties, many of them with extremely limited distributions, some of which appear to have totally vanished (Close, 2000). Now, with the invasion of NGF into south Florida, the pressure is mounting to take steps to protect these tree snails. Our goal is to assess tree snail and NGF populations and to keep state and federal agencies as well as the general public informed of research developments and recommended actions. Additionally, our research will

Fig. 5. New Guinea flatworm (*Platydemus manokwari*) exiting a Miami-Dade County hardwood hammock, moving into an adjacent agricultural grove in 2015. (Photo: Alície Warren)

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DISEASE IMPLICATED IN DECLINE OF THE THREATENED OBÔ GIANT LAND SNAIL *ARCHACHATINA BICARINATA* IN SÃO TOMÉ AND PRÍNCIPE

By Martina Panisi & Ricardo F. de Lima

The rapid decline of the Obô giant land snail *Archachatina bicarinata* (Bruguière, 1792; Fig. 1) has long been identified (Gascoigne, 1994; Dallimer & Melo, 2010; Panisi *et al*., 2020) in the oceanic islands of Príncipe and São Tomé (Democratic Republic of São Tomé and Príncipe, Central Africa), where it is endemic. The species was abundant and widespread until the mid-20th century, but it is now restricted to the most remote forests of both islands (Panisi *et al*., in press). Overharvesting, habitat loss and the introduction of the West African giant land snail *Archachatina marginata* (Swainson, 1821; Fig.1) are all possible causes for its decline, and a potential disease has also been implicated since 1994 (Gascoigne, 1994; Panisi *et al*., in press). The Obô giant land snail is listed by IUCN (Clarke & Naggs, 1996) as "Vulnerable" but a new assessment suggests an upgrade to "Endangered". The suspicion around an unidentified disease is particularly concerning, as it would have the potential to push it towards extinctions in the near future.

Apparently sick individuals have been recorded on both islands and mass mortality events have been recorded on São Tomé in recent years. In March 2021, we failed to find live Obô giant land snails at Zagaia, a remote peak covered in native forest in the São Tomé Obô Natural Park, where it used to be abundant until recently, according to monitoring reports and interviews (Fig. 2). We found nine intact dead snail shells and several fragments of old shells belonging to both juveniles and adults of the threatened species, and evidence that the introduced giant land snail had reached this location. A similar

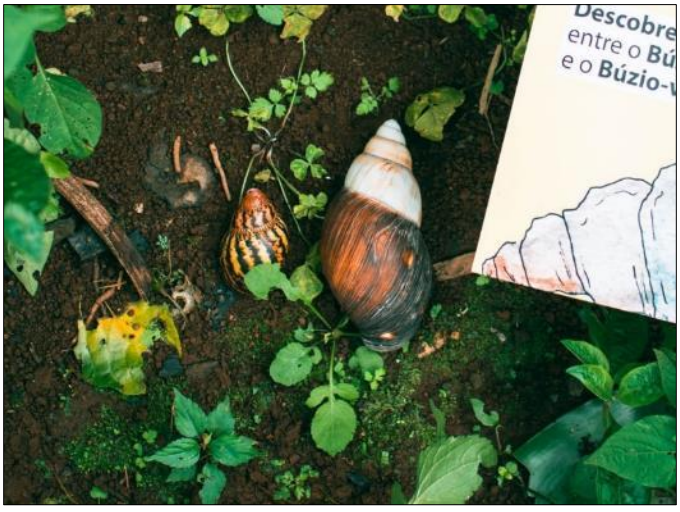

Fig. 1. Part of an educational display at the Obô giant land snail ex-situ centre in São Tomé. On the left, the invasive West African giant land snail *Archachatina marginata* (shell length ~75 mm, individuals in São Tomé and Príncipe can reach up to ~125 mm). On the right, the threatened Obô giant land snail, *Archachatina bicarinata* (sinistral, shell length ~ 160 mm). (Photo: Vasco Pissarra, Forest Giants Project/Alisei NGO).

event had been recorded in 2017, when we visited another remote location near the Cabumbé peak, where the species was also long known to occur, according to local hunters. There, we also recorded no live Obô giant land snails, but 22 freshly dead adult or near adult specimens in just 400 m^2, three of which containing eggs that were still visible (Panisi, 2017; Fig. 2). No dramatic climatic event was reported during these periods and the areas are seldom visited.

In 2019, an ex-situ breeding programme was created for the species in São Tomé to obtain information on its ecology (Panisi *et al.*, 2020), but three separate events between February and June 2020 affected the population, which was being kept in open-air cages. Fifty-eight percent of the individuals showed symptoms of a disease and most of them, including some juveniles that had been born ex-situ, eventually died.

Although there is no proof that the wild and ex-situ events are related, the snails showed similar symptoms: the individuals weigh less and present leucodermic lesions, weakened epidermis, low mobility and occasionally tuberculations in the foot. Leucodermic lesions have been described in the giant African land snail *Lissachatina fulica* (Bowdich, 1822) in their native range (Mead, 1979), and in wild and captive populations introduced in India (Raut, 1983) and on islands in the Pacific (Gerlach, 2001). A presumed disease has been attributed to *Aeromonas* spp. bacteria (Mead, 1979), and it was observed to spread easily when snail populations are dense (Raut, 1983). This may explain the mass mortality events recorded for the Obô giant land snail, which can occur at high densities in isolated forested patches (Panisi, 2017; Panisi *et al*., 2020), and help provide a possible explanation for its spectacular decline.

The spread of this disease has already been linked to the introduction of molluscs in some islands of the Pacific, where it has been suggested to help reducing the population growth of the introduced molluscs, but not necessarily affect native species (Gerlach, 2001). In São Tomé, it has been hypothesised that a disease may have been introduced in the islands together with the West African Giant Snail *Archachatina marginata* (Gascoigne, 1994), but the exact mechanisms of interaction between these two giant snail species is not well understood. Anecdotal reports of local inhabitants are consistent and seem to match our observations as well as the few written accounts regarding the reduction in the distribution of the Obô giant land snail following the spread of the introduced one (Fig. 2). Nowadays, the species are almost completely segregated in space, sometimes separated by natural barriers, such as streams (Panisi, 2017). We did not find evidence of the presence of the invasive snail in the surroundings of the freshly dead Obô giant land snail in 2017. Nonetheless, the introduced snails have also been seen showing signs of disease, such as leucodermic lesions, on both islands.

The Obô giant land snail is an iconic terrestrial mollusc that, in recent years, has been widely used as flagship for the protection of the unique malacofauna of São Tomé and Príncipe, and even for the conservation of their endemic-rich

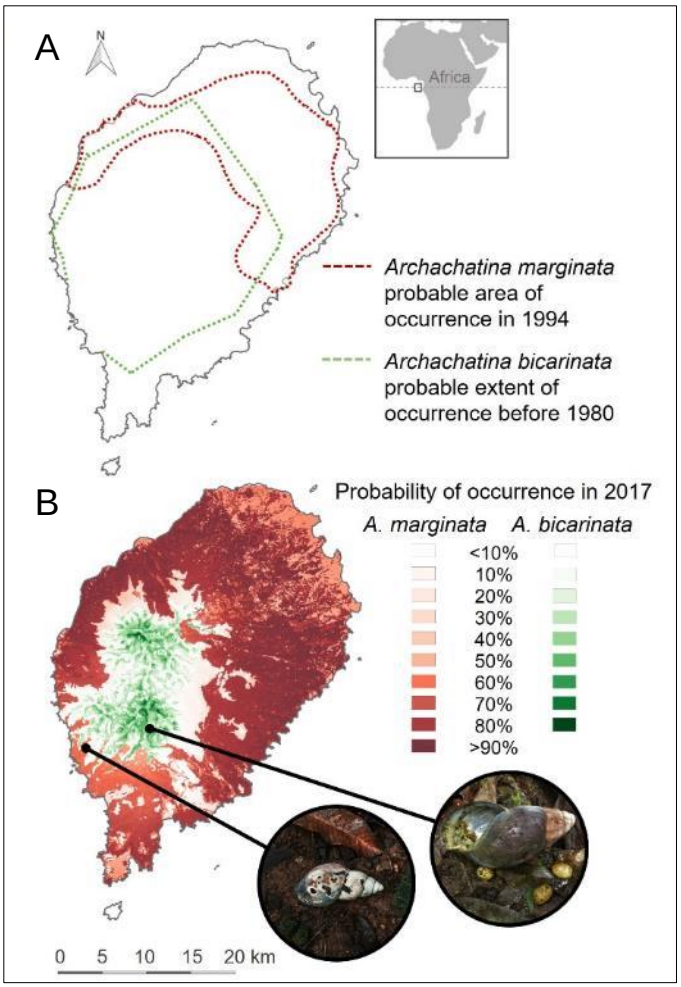

Fig. 2. Changes in the potential distribution of the Obô giant land snail *Archachatina bicarinata* and the West African giant land snail *Archachatina marginata* on São Tomé Island. A - The dotted black lines represent the probable extent of occurrence of A. *bicarinata* before 1980, based on 38 interviews of relevant stakeholders, such as eco-guides and snail harvesters (Panisi, 2017). The dotted red lines represent the estimated distribution of *A. marginata* in 1994 (Gascoigne, 1994). B - The island-wide distribution in 2017 was modelled by Panisi (2017) for both species. The black dots represent the location of Zagaia, surveyed in 2021 (left) and the area near Cabumbé peak, surveyed in 2017 (right). The inset at the top shows the location of São Tomé Island in relation to mainland Africa.

forests (Forest Giants Project, 2019; Rebelo, 2020). However, efforts have focused mostly on stopping habitat loss and harvesting, which this potential disease might prove fruitless. Thus, we urge for the need of a specialised intervention to identify the exact cause(s) of death, and assess how to prevent future declines, which probably will involve further ex-situ conservation efforts.

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IMPORTANCE OF AUTHORS' LABELS AND OTHER COLLECTION INFORMATION IN EX SITU CONSERVATION OF BIODIVERSITY

By Basudev Tripathy, Amit Mukhopadhyay & Sheikh Sajan

Ex situ conservation and preservation of biological diversity (especially endangered species) is always a challenge for conservationists and policymakers regarding development of proper management strategies (Lane, 1996; Soberón *et al*., 2000). Most of the ex situ efforts, such as in vitro tissue culture, museum collections, captive breeding, aquariums, botanical gardens and genomic databases (e.g. GenBank) render complementary services for in situ conservation and preservation and represent an insurance against extinction of endangered species. Meanwhile, ex situ conservation provides ample opportunities for governments and non-governmental organisations, research and educational institutions, individual researchers and students to contribute to the preservation of biological diversity.

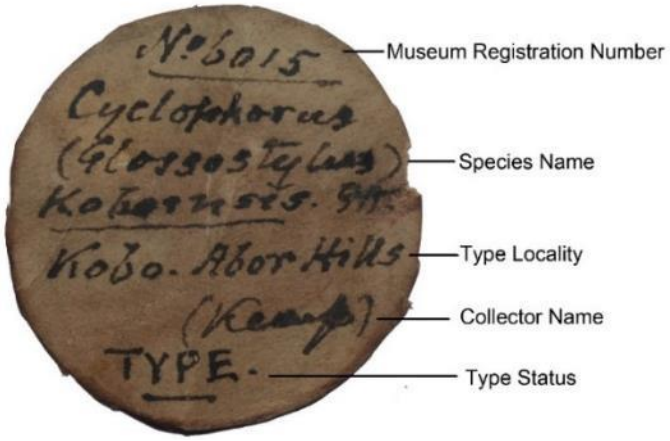

Fig 1. Label of Henry Haversham Godwin-Austen with "type" indication, registration number and other relevant information.

Taxonomy is the science of naming, describing and classifying the world's biodiversity, providing a crucial link between other branches of science. A taxonomist who describes a particular species and places it in a systematic arrangement is also actively involved in both in situ and ex situ preservation and conservation of the species as well as the specimens on which the species is described. The original labels and other information provided by the author associated with the museum specimen may include information on the species, including name, higher taxa, locality, date, habitat and other relevant information that could be used by future workers (not only taxonomists but also ecologists, climatologists and others) to study the species in situ (Tripathy & Venkitesan, 2011; Tripathy *et al*., 2019; Breure & Páll-Gergely, 2019; Sajan *et al*., 2019). Authors' labels and other documentation such as field notes (particularly for type specimens) may provide detailed information about type and other localities and could be useful for ecologists and conservationists in formulating species-specific conservation plans and preserving biological resources (Fig. 1). Such documentation could also be useful for resolving taxonomic problems, helping to pursue the history of the species and the previous and current status of the species (Naggs, 1997; Anistratenko, 2015; Sutcharit *et al*., 2015; Oliver *et al*., 2017; Tripathy *et al*., 2019; Sajan *et al*., 2019). Ex situ preservation and conservation will be hindered without the original documentation of the taxonomist(s) who described and named the species (Tripathy *et al*., 2019; Sajan *et al*., 2019). Hence, natural history museums and other national and international institutions and biodiversity repositories involved in taxonomy can play a vital role in the maintenance and preservation of the hard work of taxonomists in support of ex situ preservation (Hooper-Greenhill, 1992; Lane, 1996; Drew, 2011; Sutcharit *et al*., 2015; Ballard *et al*., 2017; Tripathy & Sajan, 2019).

The shrinkage of habitats due to anthropogenic activities, including modernisation, habitat fragmentation, urbanisation and climate change may cause rapid extinction (Fahrig, 2003;

Thomas *et al*., 2004; Román-Palacios & Wiens, 2020). Under such scenarios, the authors' labels and other information would help to ascertain the former range of the species. For example, in India, most of the species described from Chilika Lake and Chingrighata (now part of the East Kolkata Wetlands) during the British colonial period are now only known from museum collections and most of them are untraceable in in situ environments. At present most natural history museums have begun to digitise their collections and other resources (Chavan & Krishnan, 2003; Hedrick *et al*., 2020), but at the same time they should also focus on preserving original authors' labels so that future generations will still be able to explore the history of the specimens.

We thank the Director, Zoological Survey of India, for providing necessary facilities. SS is supported by a Zoological Survey of India postdoctoral research fellowship.

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STUDIES ON THE HABITAT OF *THEODOXUS PREVOSTIANUS* IN KÁCS, HUNGARY

By Sándor Ötvös & János Varga

Theodoxus prevostianus (C. Pfeiffer, 1828) is a relict protected freshwater snail species, in the Carpathian Basin (Fig. 1). Since 2002, we have been conducting studies in the Kács spring area, the only remaining natural habitat of this species in Hungary, in order to better understand its habitat requirements (Fig. 2). The only significant literature on the population of the species located in the area is the publication of Lukács (1959). The species is mentioned in some earlier malacological works (Wagner, 1937; Soós, 1943; Vásárhelyi, 1956) but no other serious studies have been carried out so far. To make up for the shortfall, we felt it was important to learn more about this undeservedly neglected and now endangered snail species. Nowadays, the only populations outside our

Fig. 1. *Theodoxus prevostianus* (C. Pfeiffer, 1828).

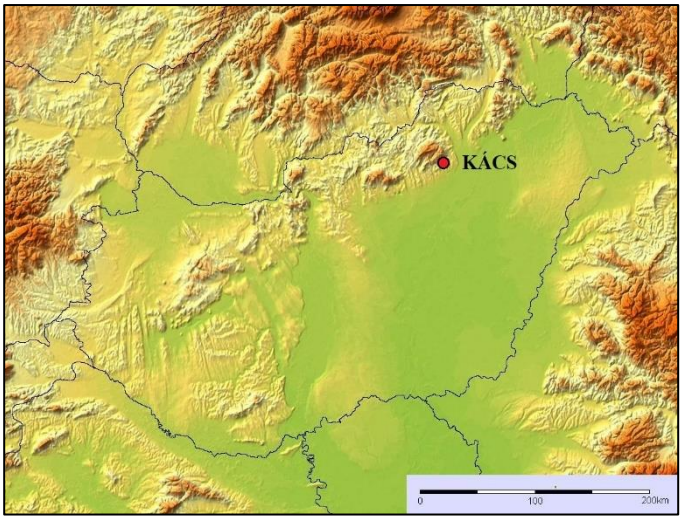

Fig. 2. Habitat of *Theodoxus prevostianus*. (Base map: pinterest.com)

sample area are found in the tepid springs of Bad Vöslau (Austria), Bad Fischau (Austria) and Bušeča Vas (Slovenia) (Fehér *et al*., 2011). It is therefore particularly remarkable that, as a result of the efforts of Hungarian malacologists, *Theodoxus prevostianus* was successfully reintroduced from the Kács Spring to its former habitat, the Sály Spring (Fehér *et al*., 2017).

As no preliminary research results were available, our initial aim was to determine the size of the population. In addition to the continuous recording of data, the environmental changes in the habitat meant that we expected to conduct a highly diverse programme of research. As the results were being evaluated, new studies and research objectives were identified.

In the Kács spring area there are two major springs (a tepid-water spring (hypothermal) and a cold-water spring) and several other springs providing low water yields. After 100 metres, the two tributaries converge and continue their course as the Kács stream (Fig. 3). During our studies carried out in 2002, *Theodoxus prevostianus* was recorded in the solid bed material of the tepid-water tributary and the first few hundred metres stretch of the Kács stream. In 2006, specific studies were carried out to explore the population. The method involved placing 25×25 cm squares of stone slabs at each of four designated test sites: 1) tepid-water spring, spring outlet, 2) cold-water spring, spring outlet, 3) confluence of the two tributaries, 4) Kács stream, 700 m below the confluence (Figs. 4, 5). The highest population density of *T. prevostianus* was found in the tepid-water spring, and a significant population was also detected at the confluence and in the Kács stream section. The total size of the Kácsi population was estimated at 3,000,000-3,200,000 individuals. We did not record the presence of the species at all in the cold spring, and below an 800 m stretch of the Kács stream its habitat also disappears completely, as the stream goes over a waterfall.

During a follow-up study in 2010 (data recording from 25 April to 17 September) we found that in the tepid-water spring, the solid bed material essential for *T. prevostianus* had disappeared, and instead the entire length of the tributary was

Fig. 3. Tepid-spring stream (left), cold-spring stream (right).

Fig. 4. Test site 1 – tepid-water spring outlet.

Fig. 5. Test site 2 – cold-water spring outlet (in the foreground) and test site 3 – confluence (in the background).

filled with sludge 30-50 cm thick (recorded in April 2010). This was due to the deposition of sediment washed into the catchment area by sudden heavy rainfall. The *T. prevostianus*

Fig. 6. Creation of artificial habitats in the Tepid-water spring.

Fig. 7. An artificial habitat patch in 2014 in the tepid-water spring.

population had been reduced by 95-99% in the tepid-water spring. A prompt and effective status assessment and a habitat restoration plan was needed. Following our method, we re-ran our stone slab study at the tepid-water spring outlet in order to obtain at least an approximate indication of the extent of the destruction. The results indicated a reduction in abundance of snails from 400-600 individuals (data recorded from 2 February to 14 May 2006) to only 15-30 on a surface of this size. The habitat reconstruction was started in the estuarine zones of the creeks flowing into the main river, which are less affected by siltation. Stones were placed in these small estuaries to provide habitat for any remaining individuals. A few individuals successfully settled on these stones, so it was considered appropriate to place large stones on the left bank of the river (20 such monitoring sites were designated), where we detected some individuals attached to the leaves of the overhanging foliage. A few weeks later, the stones were placed in the middle of the bed (Fig. 6). In 8 months, a very significant and consistent pattern of reproduction was observed on the stones, starting with an average of 25-50 individuals. In February 2011, a population of 15,000-17,000 was recorded, which also increased considerably during subsequent breeding cycles (Fig. 7). However, the original 2006 population in the tepid-water spring, which was recorded at around 800,000-1,000,000 individuals, had not regained its former size because of insufficient removal of the fine sediment from the riverbed. About 70% of the riverbed is still filled with silt.

Our main objective was to reintroduce the snails through natural means; therefore, we did not want to use a translocation approach. From 2011 onwards, continuous field observations on the development of the population have been carried out and the first revision date of the habitat reconstruction was set at 10 years (2021). The processing of the recorded data of numbers of individuals is still in progress. It is already well established that there has been a major habitat rearrangement in the *T. prevostianus* population of the springs. This is manifested in the fact that the snails have begun to populate the previously neglected cold spring progressively. This is a result of their high reproductive rates,

Fig. 8. *Theodoxus prevostianus* in the cold-water spring.

which outstripped the rate of the removal of silty bed material from the tepid-water spring to the extent that there was insufficient habitat for growth of the *T. prevostianus* population. Today, tens of thousands of individuals can be recorded in the cold-water spring (Fig. 8). The species, which used to be restricted to warm water springs, can now find suitable habitat in cold water of 14-15 °C. The occurrence in water of lower temperatures is not a recent phenomenon, as Dezső Lukács had already recorded numerous references to mass presence in cold springs in his study (Lukács, 1959). The question then arises why, in the 2006 studies, no *T. prevostianus* were found in the spring with lower water temperatures. The most probable explanation for this is that in 1972 the cold-water spring was reclaimed, and a spring house was built, the water from which is still used as a domestic water supply. It is probable that the cold-spring *T. prevostianus* population was completely extirpated by the work on the riverbed at that time, and that it then adapted exclusively to the tepid-water spring with its more favourable water temperature range. Although we have no data available on this, it can be assumed that the water treatment processes of the time were not conducive to the reintroduction of the snails

Fig. 9. The malacofauna associated with *Theodoxus prevostianus*.

either. It is for the same reason that we can speculate on the extinction of the population of *T. prevostianus* in the Sály spring, which was also reclaimed in 1974. The species has not had the opportunity to repopulate this spring, as there is only one spring outlet. It is worth noting that modern water treatment techniques are now being used in both habitats, which could greatly facilitate the reintroduction of the population. In addition to the studies on population density, we have also conducted research on the effects of water temperature on the snails and started fossil quaternary malacological studies of the Kács spring area and its immediate surroundings, the data from which are currently being processed. Also of particular importance was the study of the associated malacofauna of *Theodoxus prevostianus* (*Bythinella pannonica*, *Bythinella thermophila*, *Fagotia daudebartii*), especially with regard to the effects of the species on each other (Fig. 9).

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BAD TAXONOMY AND POOR DETECTABILITY HAS HINDERED ITALIAN *UNIO* CONSERVATION. THE CASE OF *UNIO ELONGATULUS* AND *UNIO MANCUS*: WHAT IS THEIR REAL CONSERVATION STATUS?

By Nicoletta Riccardi, Olga Aksenova, Tiziano Bo, Arthur E. Bogan, Wendell R. Haag, Ekaterina Konopleva, Duarte V. Gonçalves, Elsa Froufe, Vanessa Modesto, Vincent Prié, Ronaldo Sousa, Maria Urbańska, Simone Varandas, Ilja Vikhrev, Amílcar Teixeira & Manuel Lopes-Lima

Freshwater unionids are declining more rapidly than most other taxa because of life-history characteristics that make them more sensitive to human and natural disturbances and that reduce their ability to recover (e.g. a complex life cycle, an obligate parasitic larval stage on a suitable fish host, and limited mobility; Strayer *et al*., 2004). The alarm over this declining trend, stemming from Unionidae extinctions in North America, also extends to European species (Lopes-Lima *et al*., 2017). In Europe, the situation is exacerbated by the lack of adequate legislation for the protection of most species (e.g. Mammola *et al*., 2020). Conservation is limited to just three of the 20 currently recognised European species, while the others receive little or no attention based on the assumption that they are widespread, abundant and functional (Lopes-Lima *et al*., 2017). The neglected taxa include all the Italian species. Mediterranean mussels are of special concern, since they are affected by a wider variety of threats and require more conservation actions than non-Mediterranean species (Benson *et al*., 2021). Like other southern European countries, Italy is characterised by low freshwater mussel species richness and this, as expected, increases the importance of each species, as there is little or no redundancy within the group if a species is lost.

The genus *Unio* is represented in Italy by only two species: *Unio elongatulus*, restricted to the north of Italy and extending down the west coast of the Balkans south to Albania, and *Unio mancus*, recorded from eastern Iberia, France, Corsica,

Sardinia, Sicily and the central and southern Italian river basins (Froufe *et al*., 2017).

The two species have often been misidentified or synonymised because of taxonomic uncertainties. This has resulted in a lack of clarity concerning their conservation status and legal protection. *Unio mancus* is currently listed as Near Threatened in the IUCN Red List and is protected in Spain under the name *U. elongatulus.* However, there is no IUCN conservation assessment of *U. elongatulus* since this name has only recently been revived for the *Unio* population in Lake Maggiore (Prié & Puillandre, 2014). Nevertheless, *U. elongatulus* is protected under the Habitats Directive (Annex V) and the Bern Convention (Annex III), while *U. mancus* is not listed.

Because of these taxonomic complications, an IUCN assessment for *U. elongatulus* is urgently needed, and the assessment for *U. mancus* should be revised to include all the Italian *Unio* populations.

Knowledge of the life history traits and ecology of these species is poor, and incorrect taxonomy further complicates the compilation of such information (Froufe *et al*., 2017). Both species are habitat generalists occurring in lotic and lentic environments that range from eutrophic to oligotrophic. Like other *Unio* species, eggs and larvae are brooded for short periods (2-6 weeks) (Lopes-Lima *et al*., 2017). Glochidia are released from May to August in the form of broadcast masses in mucus strands (the authors, personal observations) and may attach to native fish of which cyprinids seem to be the primary hosts (Lopes Lima *et al*., 2017).

The current conservation status of the Italian populations of both species is unknown. Recent (2018-2021) surveys suggested an alarming decline in population number and density of both species. The decline mainly affects populations in rivers, in which these species are now extirpated from many sites where they were previously abundant. Most river habitats are degraded by morpho-hydrological changes for irrigation, energy production purposes or flood control. The increased frequency and duration of droughts further reduces the availability of permanent habitats that can guarantee the persistence of reproducing populations (Fig. 1). Habitat destruction and dewatering benefit invasive species, which are more resistant to desiccation and able to recolonize rapidly after die-offs (e.g. Bielen *et al*., 2016).

Unlike riverine populations, lake populations are persisting in most of the sites, although many show major density reduction (Riccardi, unpublished data). This difference might be explained by the stronger impact of hydrological modifications in rivers than in lakes, where water depth is probably the most important factor limiting mussel distributions (e.g. Cyr, 2020). Although in lakes the water level can vary by several metres, the shear stress, which strongly limits mussel spatial distributions, is low and almost constant. With less limiting hydrological gradients, mussels have a better chance of finding refuge areas in lakes than in rivers. Although climate-driven water level reductions are causing die-offs in lake shore areas, they do not directly affect the deeper populations.

Fig. 1. Dewatering in rivers during summer (upper left) and autumn (upper right) droughts; traces of the displacement of *Unio elongatulus* during river dewatering (lower left) and an individual that died from desiccation (lower right).

Recently, we undertook an update of knowledge of the distributions of *Unio* species in Italy. To do this we combined environmental eDNA and direct surveys. The eDNA allowed us to overcome the detectability issues resulting from stronger hydrological gradients and turbidity, which limit detectability of mussels more in rivers than in lakes and thereby introduce a bias in the qualitative-quantitative comparison of distributions. To increase the probability of locating populations we sampled water eDNA in some river stretches. Next, we physically surveyed the sites that tested positive. Unfortunately, at none of these sites have we been able to locate the mussels, despite considerable sampling effort both from the banks and by scuba diving. Given the uncertain detectability distance of eDNA, we cannot discard the possibility that the surveys were not exhaustive enough or that mussels may be buried deep in the sediments or present in lateral refuge areas, such as oxbow lakes and secondary river branches that were not selected for survey. This mismatch between indirect and direct search emphasizes that new methodologies, such as eDNA surveys, can help but not solve all difficulties in estimating mussel distributions (Prié *et al*., 2021) and determinants of these mismatches should be further investigated.

The decline trend was nevertheless apparent in our surveys, and it is particularly worrying in a Mediterranean country, like Italy, where climate shifts are expected to be pronounced. The situation is of great concern, especially because in Italy there is no real conservation policy and no funds are earmarked

even for the assessment of the conservation status of species of priority EU interest. This hinders the acquisition of up to date information on species distributions and basic demographics, essential for conservation planning. In a Europe where national action plans are highly unbalanced across countries, Italy and other Mediterranean countries are on the lower end of the distribution.

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FOUR MOLLUSC SPECIES ASSESSED BY COSEWIC IN 2020 AND 2021

By Dwayne A.W. Lepitzki & Joseph P. Carney

The COVID-19 global pandemic required all meetings of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to be online. COSEWIC is an independent body of experts that assigns conservation status to species using the IUCN criteria and recommends listing and legal protection under the Canadian Species at Risk Act (SARA; see Lepitzki & Mackie, 2013, in *Tentacle* 21, for details). Condensed assessment meetings were still held twice a year (April-May and November-December 2020 and 2021) but fewer species were assessed than was previously typical. Four of these were molluscs: one terrestrial snail, one marine bivalve and two freshwater mussels. Two of these were reassessments and two were assessed for the first time. SARA requires that at-risk species be reassessed every 10 years, or sooner if warranted. Details of the assessments of these four species, with the IUCN criteria on which their final categories were based and the date of the meeting at which they were assessed, are as follows. [Note that although COSEWIC adopted the IUCN criteria, it adjusted the names of the categories. IUCN Critically Endangered and Endangered is COSEWIC Endangered (EN below); IUCN Vulnerable is COSEWIC Threatened (TH below); IUCN Near Threatened is COSEWIC Special Concern; IUCN Least Concern is COSEWIC Not at Risk.]

Black Hills Mountainsnail (*Oreohelix cooperi*)

EN B1ab(iii)+2ab(iii), May 2021 (COSEWIC, 2021a)

Fig. 1. Black Hills Mountainsnail (*Oreohelix cooperi*), on a piece of bark, Cypress Hills Interprovincial Park, Alberta, Canada, 2018. Shells of this species are typically ~1 cm in diameter. (Photo: R.G. Forsyth)

This terrestrial snail (Fig. 1) is confined to four mountainous "sky islands" on the Great Plains of North America. In Canada it occurs only in the Cypress Hills of Alberta and Saskatchewan, an area that escaped the last glaciation that ended over 12,000 years ago and is the highest point between the Rocky Mountains to the west and, at the other end of the continent, the Torngat Mountains in Newfoundland and Labrador to the east. Originally described as *Oreohelix strigosa* var. *stantoni* Dall 1905, and thought to be endemic to the Cypress Hills, recent COI gene sequencing supports its identity as *O. cooperi* (Binney, 1858). This snail is patchily distributed and appears to be associated with a specific geological formation, the sand, silt, cobbles and conglomerates of the Cypress Hills Formation. Catastrophic wildfires, exacerbated by fire suppression and droughts associated with climate change, and introduced ground-feeding birds are the biggest threats. Indeed, western North America has recently experienced unprecedented heat waves and fires, as have other areas of the globe.

Atlantic Mud-piddock (*Barnea truncata*)

TH D2, May 2021, retained status previously assessed November 2009 (COSEWIC, 2021b)

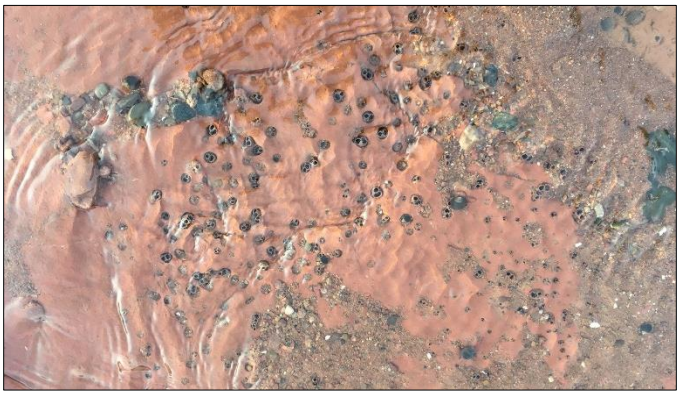

Fig. 2. Atlantic Mud-piddock (*Barnea truncata*) in their bore holes in red mudstone, Minas Basin, Nova Scotia, Canada. Their siphons can be seen. (Photo: Andrew Hebda)

This marine bivalve (Fig. 2), confined in Canada to the Minas Basin in Nova Scotia, also is dependent on a specific geological formation and bores only into red-mudstone facies. The nearest populations outside Canada are along the coasts of Maine and Massachusetts, USA. Changes in sediment deposition can bury, smother and kill the immobile adults. Increased frequency and intensity of severe storms and hurricanes due to climate change is the biggest threat; human activities that alter water flow, erosion and sediment deposition, and pollution from urban and agricultural sources also are threats. An abbreviated form of the status report was used for this reassessment.

Purple Wartyback (*Cyclonaias tuberculata*)

TH B1ab(iii)+2ab(iii), May 2021, (SARA Public Registry, 2021a; status report yet to be posted)

Fig. 3. Live adult Purple Wartyback (*Cyclonaias tuberculata*), observed during a mussel survey, southern Ontario, Canada. (Photo: Fisheries and Oceans Canada)

In Canada this long-lived, medium-sized, heavy-shelled freshwater mussel (Fig. 3) is restricted to three small to large rivers in southwestern Ontario. It prefers a substrate of cobble, gravel and sand and is believed to be extirpated from the historically occupied Detroit River and Lake Erie, both shared with the USA, because of the dreissenid mussel invasion that started in the 1980s. Threats include agricultural and urban pollution, droughts caused by climate change, continuing invasion by dreissenids and more recently an invasive fish, the Round Goby (*Eogobius melanostomus*), first detected in North America in 1990), and dredging.

Dwarf Wedgemussel (*Alasmidonta heterodon*)

Extirpated, December 2021, retained status previously assigned in 1999, 2000, 2009 (SARA Public Registry, 2021b; latest status report yet to be posted)

The 2021 Rapid Review of Classification, an even more abbreviated form of the status report, confirmed that this species is still absent from Canada but continues to be found in rivers from North Carolina to Vermont, USA, where its abundance is declining. It once occurred in a single river, the Petitcodiac, in New Brunswick that flows into the Bay of Fundy. A causeway constructed across the river in 1967/68 prevented the anadromous host fishes (probably American Shad, *Alosa sapidissima*), required to complete the mussel's life cycle, from migrating to their spawning grounds. While

the causeway is no longer fully blocking fish migration and host fishes have been observed in the river, there are no mussels present to re-establish the population.

More information on COSEWIC, including definitions of the criteria and status, can be found at the COSEWIC website. Status reports for all species assessed by COSEWIC eventually will be posted online; follow the links at the above website.

COSEWIC. 2021a. COSEWIC assessment and status report on the Black Hills Mountainsnail *Oreohelix cooperi* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 48 p.

COSEWIC. 2021b. COSEWIC status appraisal summary on the Atlantic Mud-piddock *Barnea truncata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xv p.

Lepitzki, D.A.W. & Mackie, G.L. 2013. Molluscs assessed by COSEWIC in 2012. *Tentacle* 21: 26-27.

SARA Public Registry. 2021a. Species at Risk Act species summary: Purple Wartyback (*Cyclonaias tuberculata*).

SARA Public Registry. 2021b. Species at Risk Act species summary: Dwarf Wedgemussel (*Alasmidonta heterodon*).

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CONSERVATION OF FRESHWATER MUSSELS IN EUROPE – THE CONFREMUS COST PROJECT

By Tadeusz Zając

The times when the scientist worked alone are long gone. Successful research leading to important scientific discoveries, successfully implemented in policy and/or practice, requires extensive collaboration among scientists from different countries. For this reason, the European Union (EU) long ago initiated a project known as COST (European Cooperation in Science and Technology). The project only provides funding for networking, stimulating the transfer of knowledge and technology among different European countries and their neighbourhoods, especially between new and old EU member states. At the end of 2019, we launched the CONFREMUS project "Conservation of freshwater mussels – a pan-European approach" (COST Action CA18239), which aims to integrate data on the phylogeny of European species, their diversity and abundance to identify patterns of spatial diversity and species (or populations) in need of urgent conservation action. Both for scientific and conservation purposes, it is also very important to combine knowledge about the biological characteristics of mussels with information on the features of their habitats in order to identify the processes leading to the decline of mussels or, on the contrary, those responsible for their resilience. Knowledge of the status of bivalve molluscs must be based on effective monitoring schemes developed using the best scientific knowledge. It is very important for scientists and the general public to understand the role of bivalve molluscs as providers of key ecosystem functions and services. The project will analyse the scientific horizon of freshwater mussel research and prepare a strategic programme for their protection in Europe, both to prepare specific conservation measures and to raise awareness and involvement of European societies. However, project progress has been slower than expected because of the COVID pandemic hampering activities based on face-to-face meetings. Nevertheless, we have done a lot to prepare pan-European databases, and stimulate large international teams to work on the distribution and diversity of bivalve molluscs, on the ecosystem functions and services provided by freshwater mussels, and on monitoring and research methodological standards. The period of uncertainty caused by COVID is ending: we already know how to adapt international research coordination to new conditions and how to develop new ways of communication and collaboration. Our project is constantly growing, finding new participants from the EU or neighbouring countries (over 100 scientists from the 30 countries involved). More about the project can be found on the website, cost4naiads on Facebook, and on a a new portal, www.e-mussel.eu, that will be launched soon.

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EVALUATION OF THE CONSERVATION STATUS OF BRASILIAN NON-MARINE MOLLUSCS (FRESHWATER BIVALVES)

By Sonia Barbosa dos Santos & Igor Christo Miyahira

The Chico Mendes Institute for Biodiversity Conservation (Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio) is an agency linked to the Ministry of Environment (Ministério do Meio Ambiente - MMA), which coordinates the assessment of the risk of extinction of species, periodically updating the Official National List of Endangered Brasilian Fauna Species.

The previous evaluation period, Evaluation Cycle I (Santos, Miyahira & Mansur, 2013; Santos & Carvalho, 2014; Santos *et al*., 2015; Santos & Miyahira, 2018) was closed with the publication of the last edition of the Red Book of Brasilian Endangered Fauna (ICMBio, 2018). Since 2021 we have been re-evaluating the non-marine molluscs starting with the freshwater bivalves. During the following months the evaluation of gastropods will take place.

For this Evaluation Cycle II a letter of invitation was sent by email on 4 October 2021 to the members of the Sociedade Brasileira de Malacologia (SBMa) as well as via the SBMa instagram (@malacologiabrasil) to a wide audience. The work is being coordinated by the National Center for Research and Conservation of Marine Biodiversity of the Northeast (CEPENE) of ICMBio, where the focal point for the "Assessment of the Risk of Extinction of Non-marine Mollusca Species and other taxa" is located.

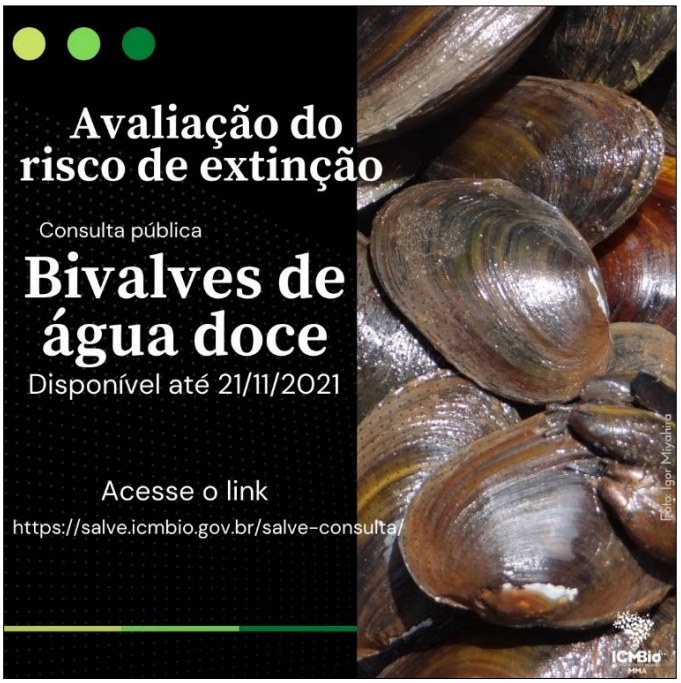

Fig. 1. ICMBio poster inviting public consultation on candidate species of freshwater bivalves for the the Brasilian Red Book.

Fig. 2. ICMBio poster announcing the evaluation workshop for candidate species of freshwater bivalves in the Brasilian Red Book.

The first phase of extensive consultation was open from 7 to 21 November 2021 (Fig. 1). During this period, specialists and the lay public were able to send contributions. We received several contributions to the SALVE system (Biodiversity Extinction Risk Assessment System), an ICMBio electronic database that allows registration of candidate species and provides access to information about them. By the end of this period, we had 40 bivalve species to be evaluated according to the IUCN categories and criteria. These contributions to SALVE were

Table 1. Brasilian freshwater mussels to be evaluated during the specialists workshop in February 2022), following public consultation organised by ICMBio. Nomenclature follows ICMBio's SALVE (Biodiversity Conservation Status Assessment System).*Synonym of *Anodontites elongata*. **Synonym of *Diplodon ellipticus*, which will be evaluated for the first time in the II Cycle. ***Synonym of *Diplodon multistriatus*.

Species	Previous Brasilian Red List (2008, 20018) categories
Anodontites crispata (Lea, 1834)	LC (2018)
Anodontites elongata (Swainson, 1823)	VU (2008) LC (2018)
Anodontites ferrarisii (d'Orbigny, 1835)	NT (2018)
Anodontites iheringi (Clessin, 1882)	EN (2008), NT (2018)
Anodontites solenidae (d'Orbigny, 1835)	VU (2008) LC (2018)
Anodontites tenebricosa (Lea, 1834)	VU (2008) LC (2018)
Anodontites trapesialis (Lamarck, 1819)	VU (2008) LC (2018)
Anodontites trapezea (Spix in Wagner, 1827)	EN (2008) LC (2018)
Anodontites trigonus (Spix in Wagner, 1827)*	LC (2018)
Bartlettia stefanensis (Moricand, 1856)	VU (2008) NT (2018)
Castalia ambigua (Lamarck, 1819)	LC (Brasil, 2018)
Callonaia duprei (Récluz, 1842)	DD (2018)
Castalia martensi (Ihering, 1981)	NT (2018)
Castalia undosa von Martens, 1827	EN (2008) LC (2018)
Cyanocyclas guahybensis Marshall, 1927	First evaluation
Diplodon caipira (Ihering, 1893)	EN (2008) DD (2018)
Diplodon dunkerianus (Lea, 1857)**	EN (2008) DD (2018)
Diplodon ellipticus Spix in Wagner, 1827	First evaluation
Diplodon expansus (Küster, 1856)***	VU (2008) DD (2018)
Diplodon fontainianus d´Orbigny, 1835	EN (2008) NT (2018)
Diplodon granosus (Bruguière, 1792)	LC (2018)
Diplodon greeffeanus (Ihering, 1893)	EN (2008) DD (2018)
Diplodon jacksoni Marshall, 1928	DD (2018)
Diplodon martensi (Ihering, 1893)	VU (2008) NT (2018)
Diplodon multistriatus (Lea, 1831)	DD (2018)
Diplodon pfeifferi (Dunker, 1848)***	EN (2008) DD (2018)
Diplodon rotundus (Spix in Wagner, 1827)	EN (2008) LC (2018)
Fossula fossiculifera (d´Orbigny, 1835)	EN (2008) LC (2018)
Haasica balzani (Ihering, 1893)	NT (2018)
Lamproscapha ensiformis (Spix in Wagner, 1827)	VU (2008) LC (2018)
Leila blainvilliana (Lea, 1834)	EN (2008) DD (2018)
Leila esula (d´Orbigny, 1835)	VU (2008) LC (2018)
Monocondylaea franciscana (Moricand, 1837)	DD (2018)
Monocondylaea paraguayana (d´Orbigny, 1835)	VU (2008) LC (2018)
Mycetopoda legumen (Martens, 1888	VU (2008) EN (2018)
Mycetopoda siliquosa (Spix in Wagner, 1827)	VU (2008) LC (2018)
Mycetopoda soleniformis (Orbigny, 1835)	DD (2018)
Rhipidodonta garbei (Ihering, 1910)	NT (2018)
Rhipidodonta iheringi (Simpson, 1914)	EN (2008) NT (2018)
Rhipidodonta koseritzi (Clessin, 1888)	CR (2008) EN (2018
Sphaerium cambaraense Mansur *et al*., 2008	First evaluation

analysed during a preparatory workshop (3 December 2021), when, together with ICMBio staff Iara Braga Sommer, Carlos Augusto Rangel and Jonatas de Arruda Francisco, we evaluated and complemented the information provided by the researchers, resulting in 37 sepeces to be evaluated (Table 1). The preparatory workshop was the first step prior to the evaluation workshop, which took place from 31 January 31 to 3 February 2022 (Fig. 2), virtually, because of COVID-19. During and following this evaluation workshop, about 15 attendants, including bivalve specialists, have been evaluating the information collected in the individual species charts to assign threat categories. The resulting list will be assessed during a validation workshop, probably in July 2022, to be published in the next edition of the Brasilian Red Book.

We emphasise the importance of the ongoing review, since the results of the Evaluation Cycle I (ICMBio, 2018) concerning freshwater mussels led to 24 species being excluded from the first list of endangered species (Amaral *et al*., 2008) because

of a lack of sufficient information according to the IUCN criteria, such that they were able to be included following Evaluation Cycle II as LC or DD (Table 1) (ICMBio, 2018). Only *Rhipidodonta koseritzi* (Clessin, 1888) (Hyriidae) and *Mycetopoda legume*n (Martens, 1888) Mycetopodidae were kept as EN (endangered).

We are grateful to our colleagues who voluntarily donate their time and the best of their efforts for the conservation of our wonderful freshwater mussels.

As previously noted, in 2022 we will begin the evaluation of non-marine gastropods. Wait for news!

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FRESHWATER MOLLUSCS IN LOTIC HABITATS OF THE WESTERN GHATS

By N.A. Aravind

Freshwater habitats occupy less than 1% of the earth's surface. However, the relative species richness per unit area in freshwater ecosystems is much higher than in marine and terrestrial ecosystems (McAllister *et al*., 1997). This small extent of habitat houses an extraordinarily high level of biodiversity (Dudgeon *et al*., 2006). Freshwater systems support various animals, plants, fungi and algae, contributing almost 10% of all species and 35% of all vertebrates described so far (Strayer & Dudgeon, 2010; Molur *et al*., 2011; Stendera *et al*., 2012). Unfortunately, anthropogenic pressures and threats have resulted in freshwater biodiversity declining at an alarming rate (Dudgeon *et al*., 2006; WWF, 2016). According to the Living Planet Index, populations of freshwater species declined more rapidly since 1970 (falling by 81%) than marine (36%) and terrestrial (38%) populations (WWF, 2016). The major gap in our knowledge in freshwater biodiversity conservation is the lack of data on species distributions and threats, especially in lotic systems of tropical regions of the world. Conservation efforts for freshwater biodiversity are also far behind those for terrestrial systems (Stendera *et al*., 2012). This is true for India, in which four of the world's 36 biodiversity hotspots occur.

Diversity and endemism

India is home to over 220 species of freshwater molluscs (Ramakrishna & Dey, 2007), of which about 60% are restricted to lotic systems. High overall biodiversity occurs in two of the four hotspots, the Western Ghats and Northeast India (part of the Indo-Burma hotspot; Myers *et al*., 2000). The Western Ghats with various habitat types, both terrestrial and freshwater, constitute a unique landscape with 35 west-flowing and five major east-flowing rivers. These river systems harbour a host of endemic species, some restricted to a very small region or a river basin, which are also threatened by anthropogenic activities. This makes the Western Ghats worthy of high conservation priority.

In the Western Ghats, 10 families and 14 genera of freshwater molluscs are reported from lotic habitats with 37 described species, and there are at least 30 more undescribed lineages (Aravind, in preparation; Fig. 1). Apart from these, there may be several other undescribed species yet to be discovered and studied in the Western Ghats. The families Littorinidae and Neritidae are predominantly marine, with two genera (*Cremnoconchus* and *Vitta*) colonising freshwater habitats in the Western Ghats. To date, *Cremnoconchus* is represented by the maximum number of described species (nine) in a genus, restricted to waterfalls and distributed between 13 and 21 °N in the Western Ghats. *Cremnoconchus* species in the central Western Ghats (defined as between 12 and 16 °N) are point endemics (known from a single location), found only in one waterfall, in contrast to the species found in the northern Western Ghats (between 16 and 21 °N), where one can see the same species in several waterfalls. South of 13 °N, *Cremnoconchus* is replaced by *Vitta* in the waterfalls. The genus *Paludomus* is the second largest genus with eight described species distributed across the Western Ghats. In *Paracrostoma* (Pachychilidae), two species, *P. martini* and *P. tigrina*, are endemic to the central Western Ghats, while *P. huegelii* is more widespread. *Vitta perottetiana* is the only known member of the family Neritidae from freshwaters of the Western Ghats. The only lotic species of Ampullariidae, *Pila saxea*, is confined to the large streams of the northern Western Ghats near Lonavala and the status of this species needs to be assessed. Several recent attempts to locate it were

Fig. 1. Representatives of the genera found in lotic systems of the Western Ghats, India. 1 - *Lamellidens*, 2 - *Parreysia*, 3 - *Indonaia*?, 4 - *Corbicula*, 5 - *Arcidopsis*, 6 - *Pseudomulleria*, 7 - *Paracrostoma*, 8 - *Pila*, 9 - *Cremnoconchus*, 10 - *Neosataria*, 11 - *Vitta*, 12 - *Paludomus*. Representatives of *Pettancylus* and *Radiatula* not illustrated.

unsuccessful and there are no recent collections of it from the region.

Among bivalves, two genera are endemic to the Western Ghats: *Pseudomulleria* (Etheridae) and *Arcidospsis* (Unionidae). Both are found in two large rivers, the Thunga and Bhadra (tributaries of River Krishna), in the central Western Ghats and are sympatric. The former is a cemented bivalve known to occur in fewer than half a dozen sites with fewer than 6,000 individuals, and all these sites are outside protected areas and next to temples or close to urban areas (Madhyastha, 2000; Aravind *et al*., 2011). Four other bivalves, *Parreysia keralaensis* (Unionidae), *Corbicula krishnae*, *C. peninsularis* and *C. annandalei* (Cyrenidae), are known only from their type localities. Hence, more studies are required to assess the current statuses of these species and their actual distributions.

Conservation status of lotic molluscs

All known freshwater mollusc species from the Western Ghats were assessed for IUCN Red List status in 2010 (Table 1). Since then, several new species have been described, and the ecology of some has been studied. Only *A. footei*, and *P. dalyi* and three species of *Cremnoconchus* are in the threatened categories (Aravind *et al*., 2011; Table 1). The distribution, population status, ecology, natural history and threats are unknown for many species, and there is a need for further studies and reassessment of conservation statuses.

Table 1. Freshwater molluscs reported from lotic systems of the Western Ghats, India, whether endemic (E) or non-endemic (NE) to the Western Ghats and with their Red List status (EN: Endangered, VU: Vulnerable, DD: Data Deficient, LC: Least Concern, NA: Not Assessed).

Class	Family	Genus/species	E/NE*	IUCN status#
Gastropoda	Littorinidae	*Cremnoconchus syhadrensis*	E	EN
		C. conicus	E	VU
		C. canniculatus	E	EN
		C. dwarakii	E	NA
		C. cingulatus	E	NA
		C. castanea	E	NA
		C. agumbensis	E	NA
		C. globulus	E	NA
		C. hanumani	E	NA
	Paludomidae	*Paludomus annandalei*	E	DD
		P. inflatus	NE	DD
		P. obesus	E	LC
		P. rotunda	E	DD
		P. tanschauricus	NE	LC
		P. sulcatus	E	DD
		P. stomatodon	E	DD
		P. neritoides	E	NA
	Neritidae	*Vitta perottetiana*	E	DD
	Pachychilidae	*Paracrostoma huegelii*	E	LC
		P. martini	E	DD
		P. tigrina	E	DD
	Ampullariidae	*Pila saxea*	E	LC
	Bithyniidae	*Neosataria evezardi*	E	DD
	Palnorbidae	*Pettancylus fivefallsiensis*	E	NA
Bivalvia	Etheridae	*Pseudomulleria dalyi*	E	EN
	Unionidae	*Arcidopsis footei*	E	EN
		Lamellidens marginalis	NE	LC
		L. corrianus	NE	LC
		Indonaia shurtleffiana	NE	LC
		Radiatula cylindrica	E	DD
		Parreysia corrugata	NE	LC
		P. keralaensis	E	NA
		P. favidens	NE	LC
	Cyrenidae	*Corbicula krishnae*	E	DD
		C. peninsularis	E	DD
		C. annandalei	E	DD
		C. striatella	NE	LC

Conservation challenges

Freshwater systems are common property resources in India and are under severe threat (Vörösmarty *et al*., 2010; Fig. 2). Waterfalls, streams and rivers are used extensively for multiple purposes including washing clothes and vehicles, bathing, dumping garbage and pollutants, and illegal water abstraction for agriculture. Also, because of urbanisation and agricultural expansion in recent times, extensive land use and land cover changes have resulted in sedimentation and pollution of rivers and streams because of run-off during the monsoon season. This has put pressure on aquatic biodiversity, including molluscs. The Western Ghats also have a high human population density for any hotspot globally, with over 420 people per km^2 (Cincotta *et al*., 2000). More than one-third of the dams in India are in the Western Ghats, primarily in the northern Western Ghats. The type locality of *C. conicus* in Mahabaleshwar in the northern Western Ghats is highly polluted, and the species is extirpated from that locality (Reid *et al*., 2013; Aravind *et al*., 2016). Similarly, the increase in the water level in the reservoir behind Thunga dam at Shimoga in the central Western Ghats has resulted in the extirpation of *Pseudomulleria dalyi* (Aravind *et al*., 2011).

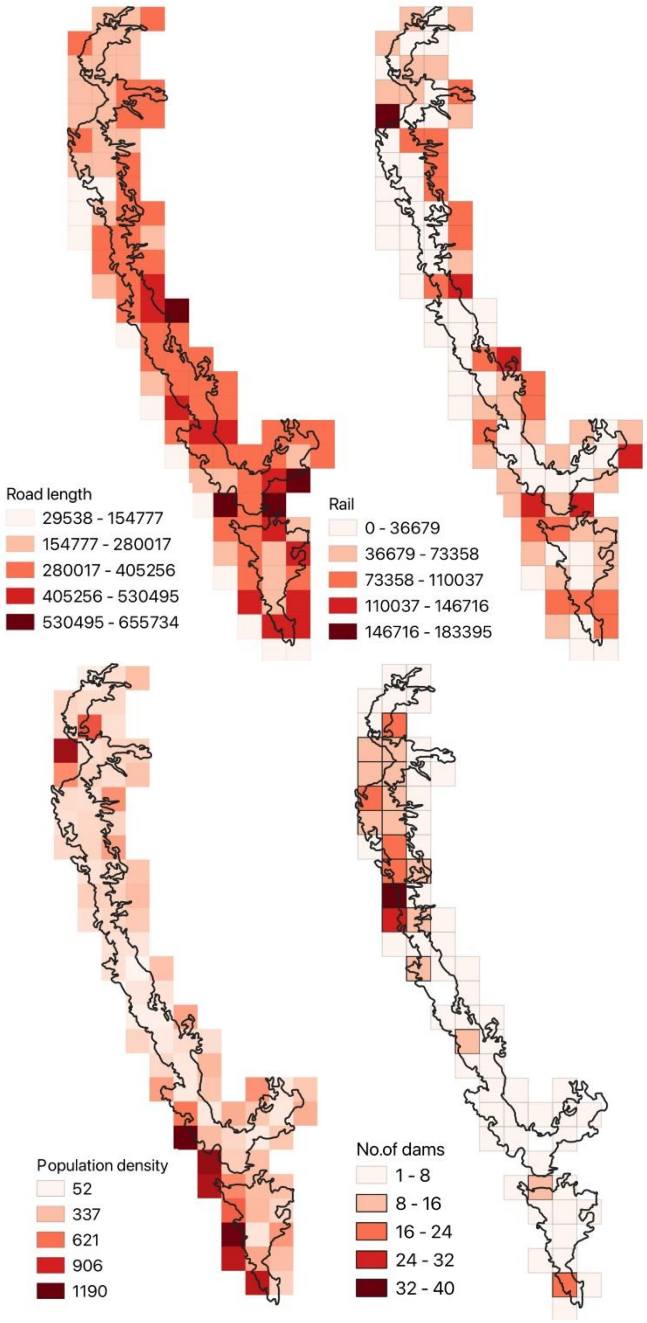

Fig. 2. Maps showing density of roads, railways, population and dams in the Western Ghats. Each grid square is half a degree.

There are several reasons for information paucity on molluscs. The lack of trained people in molluscan taxonomy and identification, lack of interest in molluscs in general, limited research funding, unavailability of type collections and authentically identified specimens in the country, and difficulty getting permission to collect in protected areas are hampering research on freshwater molluscs. Therefore, there is a need to create awareness among various stakeholders regarding the importance of molluscs in ecosystems. Also, it is high time we studied the ecology, natural history and conservation needs of freshwater molluscs in general and those of lotic systems in particular for better conservation of this imperilled group of organisms.

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VIRTUAL MALACOLOGICAL COLLECTIONS IN ARGENTINA – A TECHNOLOGY FOR ENVIRONMENTAL EDUCATION APPLIED TO THE CLASSROOM SPACE DURING AND AFTER THE PANDEMIC, AIMED AT THE CONSERVATION OF BIOLOGICAL DIVERSITY

By Heliana Custodio, Alfredo Vilches & Gustavo Darrigran

According to Dioum (1968, as cited by Lotze, 2020), "…we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught". Based on that, this study will contribute to the generation of a scientifically aware and literate society, for which specific environmental education activities will be implemented in the classroom through scientific-technological culture, as essential tools for inclusive innovation. The study will address education as a tool for society to be lucid about the crisis that biodiversity faces today (Vilches, *et al*., 2015) and scientifically literate considering that science is more than a body of knowledge, it is a way of thinking (Sagan, 1996). The focus of the study is the second most diverse zoological group in nature (molluscs) (Fig. 1). Digital resources, much expanded during the current pandemic, will be implemented to make use of didactic resources such as biological collections (BC) in general, and malacological collections (MC) in particular. For their application, accessibility and inclusion, virtual biological collections (VBC) / virtual malacological collections (VMC) accessed through PCs, tablets, mobile phones, etc. will be developed.

The importance of this project is framed in the topicality of the issue (biodiversity crisis) and the feasibility of the objectives/time ratio for its development. Design, construction and management (DCM) techniques will be used for both BC/MC and VBC/VMC. These virtual collections will be easy to access and to include in university classrooms and higher education institutes for training of natural sciences teachers. The motivations of the students and teachers regarding BC as a didactic resource, its link with the web and their evaluations will be considered. Tools will be generated for teachers on BC, DCM techniques as a resource and to ensure that, through the generation of VBC, the levels of education considered can access the BC/MC that exist in institutions that have limited access, which makes their use as a teaching resource difficult (e.g. museums; Rabanaque *et al*., 2021) (Fig. 2). Didactic recommendations will be developed regarding the use and construction of BC/MC and VBC/VMC, favouring their use as innovative strategies in the teaching of biodiversity conservation. BC/MC and information and communication technologies (ICT) will be used in the classroom (Custodio *et al*., 2019). Quantitative/qualitative analysis methodology will be applied; exploratory design.

For the use of ICT, a quick response code (QR) will be attached to the images of the corresponding mollusc specimens, which will lead to the malacological records (Darrigran *et al*., 2017),

Fig. 1. This work is based on the importance of molluscs for humans (e.g. food, aesthetics, fouling on a wide array of human infrastructure).

Fig. 2. A - The Museo de La Plata opened in 1888 and is now part of the National University of La Plata; education and scientific research are among its main goals. The malacology collection contains more than 13,000 lots, including 511 type lots. The lots are preserved in the traditional way: B - dry, C - wet, and microscope slides, as well as frozen tissue for molecular studies.

published since 2011 in an open-access digital education journal. Likewise, through this QR code, knowledge about molluscs can be expanded and updated, considering the educational level to which it is directed.

In order to implement accessible and cost-effective DCM-MC-VMC techniques, mobile phone images will be taken of batches of two Institutional Collections:

1) The didactic BC of the Biological Sciences Faculty of the National University of La Plata (UNLP).
2) The Malacological Collection of the Museum of La Plata (UNLP).

The importance of molluscs for ecosystems in general and for humanity in particular, and the importance of molluscs as a

Fig. 3. Instagram. Virtual Malacological Collection (VMC) (in preparation).

teaching resource for biology teachers in Argentina will be emphasised (Custodio *et al*., 2018).

The Tree of Life website will be used for updated BC systematics and MolluscaBase for malacological collections. Network integration is proposed (e.g. iNaturalist; Instagram - Fig. 3), with recreation of a didactic scenario and learning from e-platforms. The results of the project will provide access to the BC/MC and protocol for creating VMB/VMC.

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THE XERCES SOCIETY PETITIONS PROTECTION FOR *GONIDEA ANGULATA* (LEA, 1838) UNDER THE U.S. ENDANGERED SPECIES ACT

By Edward J. Johannes

On 18 August 2020, the Xerces Society for Invertebrate Conservation in Portland, Oregon, USA, filed a petition to have the U.S. Fish & Wildlife Service (USFWS) list *Gonidea angulata* (Lea, 1838) (western ridged mussel; Fig. 1) under the Endangered Species Act (ESA) (Blevins *et al*., 2020).

This species has been designated in Canada as a species of Special Concern because of its limited occurrence, evidence of declining populations and continued loss or degradation of suitable habitat both in Canada and the western USA (COSEWIC, 2003).

Fig. 1. Right valve of *Gonidea angulata*. Specimen from the upper Sacramento River, California. (Photo: Stephanie Clark)

The only species in the genus, *Gonidea angulata* is found across the western USA in the states of California, Oregon, Washington, Idaho and Wyoming, and in the Okanagon River drainage (a Columbia River tributary) of southern British Columbia, Canada (Fig. 2).

The distributions of all western USA mussel species were recently assessed both in California (Howard *et al*., 2015) and

Fig. 2. Range of *Gonidea angulata* in the USA and Canada. Light-blue shading (upper left) is its range in the Chehalis River drainage. Map modified from Mock *et al.*, unpublished.

Fig. 3. *Gonidea angulata* with *Juga plicifera* in the Chehalis River. (Photo: Roger Taber)

throughout their historic ranges (Blevins *et al*., 2017). All were found to have suffered significant range reductions. Blevins *et al*. (2017) found that the range of *G. angulata* had declined by 43%, the most among all western USA unionids. Howard *et al*. (2015) reported that the best populations of this species were found in the Pit River system in northern California. But even here *G. angulata* is not safe, as there have been declines and extinctions of other freshwater molluscs in this river and in adjacent river systems where *G. angulata* occurs (Johannes & Clark, 2016).

An unusual aspect of the distribution of *Gonidea angulata* is its occurrence in the Chehalis River, Washington State, and striking divergence here genetically from all other populations, based on microsatellite markers (Figs. 2, 4; Mock *et al.*, 2022). Possibly it meets the two criteria of a distinct population segment (DPS) to be considered an evolutionary significant unit (ESU) because: (1) it has been substantially reproductively isolated; and (2) it represents an important component in the evolutionary legacy of this species. It is unfortunate that the ESA, as amended in 1978, only extends the protection of DPS recognised as an ESU to vertebrates and has so far only applied this to Pacific occurring salmonids.

The Chehalis is one of several rivers in which recent large-scale die-offs of this species have been observed (Blevins *et al*., 2020). Both human-caused pollutants and climate change increasing water temperatures have been cited as possible causes for the die-offs in the Chehalis River (Blevins *et al*., 2020). An additional threat to the species, *Potamopyrgus antipodarum* (Gray, 1843) (New Zealand mudsnail), was found to be introduced in the Chehalis in 2013 (Johannes, 2013a).

Gonidea angulata is generally an inhabitant of large rivers and except for the Chehalis River is not found in coastal river drainages of Washington, Oregon or California (Fig. 2). It co-occurs in the Chehalis with *Juga plicifera* (Lea, 1838), a snail that is also an inhabitant of large rivers and that has a very limited distribution in the lower portion of the adjacent Columbia River drainage (Fig. 3). Both species' large stream preference preclude their occurrence in the Chehalis to have been as a result of small stream capture.

The Chehalis River system is also unusual in that it has at least twice the number of fish species (many of them found in the adjacent Columbia River) compared to other coastal rivers (McPhail & Lindsey, 1986). It is an underfit river (a river that is too small to have eroded the valley in which it flows), has a rather large estuary; its basin is sizable when compared to other coastal drainages (second biggest river basin in Washington State); and it has a rather broad low divide near its headwaters with the adjacent Columbia River drainage (Fig. 2).

The Columbia River may formerly have flowed through the Chehalis drainage, which would explain the geography and biogeography of this river system. Outcrops of Columbia River Flood Basalts found in this drainage also support this supposition and indicate a Miocene timing for a former Columbia River channel (Riedel & Tolan, 2013). Fossil records for both *G. angulata* and *J. plicifera* support occurrences in this region during this time (Weaver, 1942; Taylor, 1952, 1985).

On 27 July 2021, USFWS determined that the Xerces Society petition for the western ridged mussel presented substantial scientific or commercial information indicating that the petitioned actions may be warranted. As a result, the USFWS initiated a status review of this species to determine whether the action is warranted under the Act (USFWS, 2021). However, the USFWS record of listing of molluscs of the western USA, and invertebrates in general under the ESA is abysmal and does not bode well for this species. Currently, only four (formerly six; Johannes, 2019) of the 103 listed mollusc species under ESA protection are found in the range of *G. angulata*. A petition to list 32 terrestrial and freshwater molluscs (none were unionids) was filed by the Center for Biological Diversity (CBD), Portland, Oregon (Curry *et al*., 2008). This petition was later reduced by CBD to 29 molluscs (USFWS, 2011; Johannes, 2013). In one fell swoop, USFWS rejected listing all of the 14 freshwater snails on this petition (USFWS, 2012). Currently, USFWS is working on the remainder of species on this petition, all terrestrial molluscs, and has already rejected the listing of one of them (Johannes, 2020; USFWS, 2020).

I thank Stephanie Clark (Invertebrate Identification Australasia, Faulconbridge, Australia) and Roger Taber (USFWS, Lacey, Washington) for the photos used in this

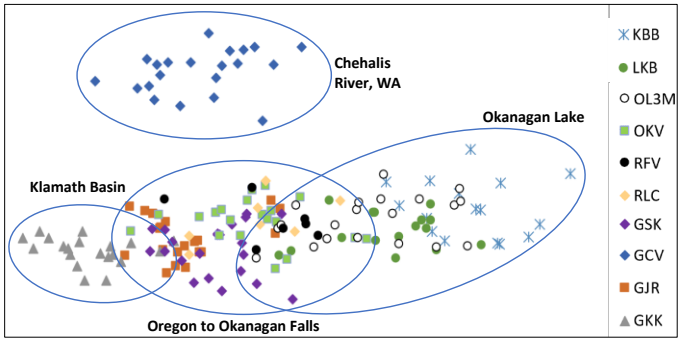

Fig. 4. Principal coordinate analysis of *Gonidea angulata* populations based on microsatellite loci. Mock *et al.*, 2022.

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ON THE LAND AND FRESHWATER MOLLUSCA OF PRAYAGRAJ AND ADJACENT AREAS OF UTTAR PRADESH, INDIA

By Sheikh Sajan, Sandeep Kushwaha & Basudev Tripathy

The River Ganga is among the most holy and largest rivers in India, flowing from Goumukh glacier in Uttarakhand to the Bay of Bengal at Ganga Sagar in West Bengal, covering 2,500 km and draining ~26% of the landmass of the country. The Ganga was also considered among the most polluted rivers of India, largely because of uninterrupted discharge of untreated domestic sewage and industrial pollutants into the river. However, with the intervention of the Government of India, through the National Mission for a Clean Ganga, there have been recent attempts to clean the Ganga and provide better habitat for the biodiversity that depends on this aquatic ecosystem.

The Prayagraj (erstwhile Allahabad) district, lies in the southern part of the state of Uttar Pradesh (Fig. 1). It has an area of 5,246 km^2 (24°47′N and 25°47′N, 81°19′E and 82°21′E), lying on the fringe of the River Ganga and

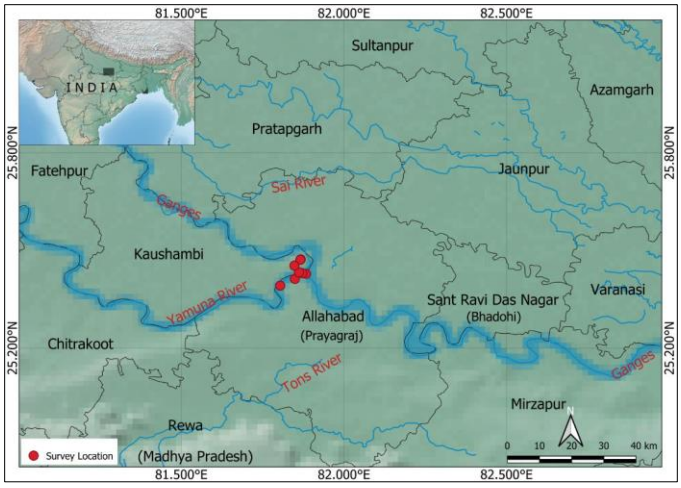

Fig 1. Map of Prayagraj (Allahabad) and adjacent areas of Uttar Pradesh, India.

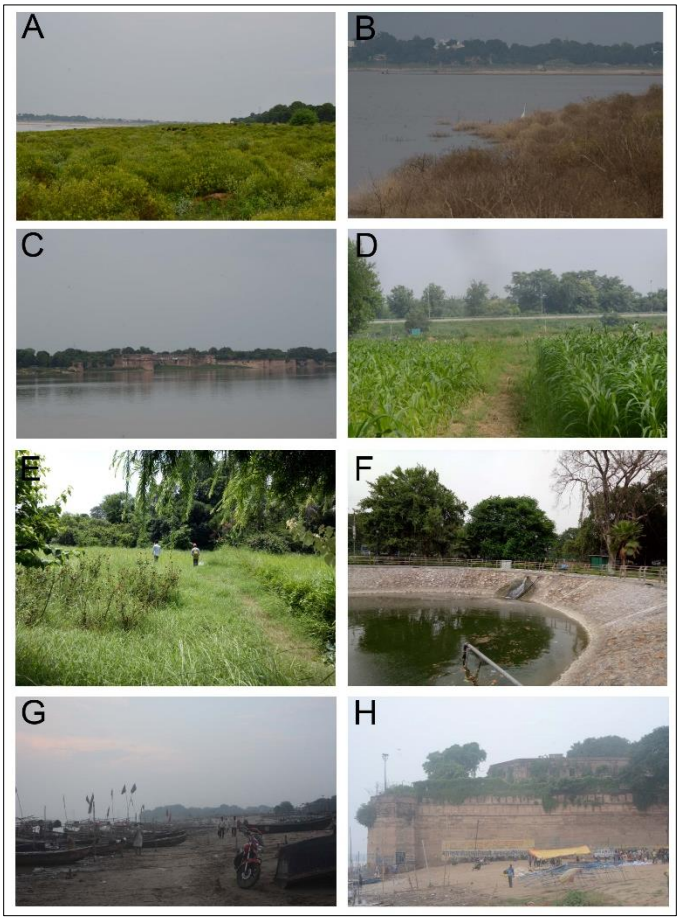

Fig 2. Sampling sites. A, B - Yamuna Ghats. C, H - Allahabad Fort. D, E - Sam Higginbottom Institute of Agriculture, Technology and Sciences campus. F - Minto Park. G - Triveni Sangam.

Fig 3. A - *Laevicaulis alte* (Férussac, 1822), B - *Macrochlamys indica* Godwin-Austen, 1908, C - *Tarebia lineata* (Gray, 1828), D - *Physella acuta* (Draparnaud, 1805), E-H - Training and field survey.

extending through part of the Gangetic plain and adjoining the Vindhyan plateau of India (Rodgers *et al*., 2000). It is surrounded by Bhadohi and Mirzapur districts in the east, Kaushambi and Banda in the west, Pratapgarh and Jaunpur in the north and Banda, bordering Madhya Pradesh, in the south. The major rivers Ganga and Yamuna and their tributaries the Tons and Sai flow through the district. The climate of the area is characterised by a long and hot summer and a fairly good period of rainfall during the monsoon, with ~975 mm during July and August. The area supports forest with the major vegetation including *Terminalia arjuna*, *T. chebula*, *Butea monosprma*, *Ziziphus nummularia*, *Z. globerrima*, *Emblica officinalis*, *Holoptelea inegrifolia*, *Madhuca indica*, *Salmalia malabarica*, *Boswellia serrata*, *Acacia catechu*, etc., and provides good habitats for non-marine molluscs.

We adopted a visual search method for collections of non-marine molluscs from various parts of the Prayagraj district and adjacent areas (Fig. 2). During the survey, all possible macro- and microhabitats along the banks of the Ganga and Yamuna rivers were thoroughly investigated (Fig. 3). Voucher specimens were collected and brought to the laboratory either in wet or dry condition for identification. The living animals were collected and preserved in 70% ethanol in the field. Land snails were identified based on the keys of Mitra *et al.* (2005), while freshwater molluscs were identified using the keys of Preston (1915), Subba Rao (1989) and Ramakrishna & Dey (2007). Classification of taxa followed WoRMS and the IUCN Red List.

Land and freshwater gastropods and bivalves were collected from forest floors along the Ganga and Yamuna rivers and from the Sam Higginbottom Institute of Agriculture, Allahabad, during field visits. In total, 35 species were identified from the collections, of which 10 are land snails and 25 are freshwater gastropods and bivalves (Table 1). The highest land snail species diversities were recorded at the Sam Higginbottom Institute of Agriculture campus (10) and the Botanical Survey of India campus (9). *Macrochlamys indica*, *Lissachatina fulica* and *Laevicaulis alte* were the most common land snails. In freshwater, 17 gastropod and 8 bivalve species were recorded, from the Yamuna Ghats, Triveni Sangam and other lentic waterbodies as well as waterbodies on the Sam Higginbottom Institute of Agriculture campus. Among the gastropods, *Filopaludina bengalensis*, *Idiopoma dissimilis*, *Mieniplotia scabra*, *Melanoides tuberculata*, *Tarebia granifera*, *Brotia costula*, *Radix rufescens*, *Gyraulus convexiusculus* and *Indoplanorbis exustus* were common all along the banks of the Yamuna and Ganga. Among the bivalves, *Lamellidens marginalis*, *Parreysia corrugata*,

Table 1. Land and freshwater Mollusca from different parts of Prayagraj and adjacent areas.

GASTROPODA (land)	
Ariophantidae	*Ariophanta interrupta* (Benson, 1834)
	Euplecta baconi (Benson, 1850)
	Macrochlamys indica Godwin-Austen, 1908
	Macrochlamys lubrica (Benson, 1852)
Achatinidae	*Lissachatina fulica* (Férussac, 1821)
	Allopeas gracile (Hutton, 1834)
	Zootecus insularis (Ehrenberg, 1831)
Succineidae	*Succinea indica* Pfeiffer, 1849
	Quickia bensoni (Pfeiffer, 1849)
Veronicellidae	*Laevicaulis alte* (Ferussac, 1822)
GASTROPODA (freshwater)	
Viviparidae	*Filopaludina bengalensis* (Lamarck, 1822)
	Idiopoma dissimilis (Müller, 1774)
Ampullariidae	*Pila globosa* (Swainson, 1822)
Bithyniidae	*Bithynia cerameopoma* (Benson, 1830)
	Bithynia pulchella (Benson, 1836)
	Gabbia orcula Frauenfeld, 1862
Thiaridae	*Mieniplotia scabra* (Müller, 1774)
	Melanoides tuberculata (Müller, 1774)
	Tarebia granifera (Lamarck, 1816)
	Tarebia lineata (Gray, 1828)
Pachychilidae	*Brotia costula* (Rafinesque, 1833)
Paludomidae	*Paludomus blanfordiana* Nevill, 1877
Lymnaeidae	*Radix rufescens* (Gray, 1822)
	Lymnaea luteola Lamarck, 1822
Physidae	*Physella acuta* (Draparnaud, 1805)
Planorbidae	*Gyraulus convexiusculus* (Hutton, 1849)
Bulinidae	*Indoplanorbis exustus* (Deshayes, 1834)
BIVALVIA	
Unionidae	*Lamellidens marginalis* (Lamarck, 1819)
	Parreysia corrugata (Müller, 1774)
	Parreysia favidens (Benson, 1862)
	Parreysia occata (Lea, 1860)
	Parreysia shurtleffiana (Lea, 1856)
Cyrenidae	*Corbicula striatella* Deshayes, 1854
Sphaeriidae	*Pisidium clarkeanum* G. & H. Nevill, 1871
	Sphaerium indicum Deshayes, 1854

Parreysia favidens, *Corbicula striatella* and *Sphaerium indicum* were common. *Laevicaulis alte* and *Allopeas gracile*, which are considered agricultural and horticultural pests (Maheshini *et al*., 2019), were recorded for the first time in the state. The worst invasive species, *Lissachatina fulica*, was also recorded from various sites (Sajan *et al*., 2018).

The ecological degradation of the Gangetic Plains of India is saddening. Mani (1974) noted, long before the biogeographical classification of India currently followed (Rodgers & Panwar, 1988), that the characteristics of the fauna today hardly give any clue to its pattern of diversity and distribution just 5,000 years ago. Biogeographically the Plain is now distinguished entirely by negative characters. Either no species became differentiated on the Plains or all have now been eliminated, as there is a most striking poverty of endemic species.

In India, 1,140 terrestrial molluscs and 218 freshwater molluscs have been described (Sajan *et al*., 2021). The state of Uttar Pradesh has 47 recorded species (3 terrestrial, 44 freshwater), which represent 15 families and 27 genera (Hegde & Venkatraman, 2014). During the present opportunistic survey, 35 species (10 terrestrial and 25 freshwater forms) belonging to 17 families and 30 genera from the district of Prayagraj and adjoining districts were recorded (Table 1).

The inland and coastal wetlands of eastern India constitute the Gangetic Plains biogeographic region, one of the key global freshwater biodiversity hotspots. Several species of fauna and flora, including threatened and endemic species are restricted to this region. The wetlands of this region provide multiple provisioning and regulatory ecosystem services and support the livelihoods of millions of people directly and indirectly. This fertile biogeographic region is also the bread basket of India with intensive agriculture and high human population density. The life, social, cultural, spiritual and economic security of the region is inseparably linked to the health of wetland ecosystems of the region. The region also faces the brunt of rapid urbanisation, industrialisation, pollution and colonisation by invasive alien species, which lead to habitat degradation and loss of wetlands. Conservation and sustainable use of wetlands through participation by multiple stakeholders, including government agencies, voluntary organisations and the general public is essential for safeguarding the ecosystem health of the wetlands.

The main conservation issue for terrestrial and freshwater molluscs is habitat fragmentation due to urbanisation and conversion of forest land into agricultural land. Moreover, the use of chemicals and pesticides, the introduction and spread of alien invasive species are also major causes of native species declines. In freshwater, urban sewage discharge and other kinds of river pollution are major issues for the mollusc fauna. During the present opportunistic survey field visits, rampant construction work that sometimes caused filling in of small pools and other aquatic habitats, contamination of the rivers with urban sewage and expansion of human habitation were observed. These activities might directly or indirectly impact the molluscan diversity of the region.

We thank the Director, Zoological Survey of India (ZSI), for providing necessary facilities. We also thank Dr. R.P. Sinha, Officer-in-Charge, Central Regional Centre of the Botanical Survey of India (BSI) for logistic support, Dr. Rajmohana K., Zoological Survey of India, and Dr. Sandeep Malhotra, Professor of Zoology, for their support. SS is supported by a ZSI Postdoctoral Research Fellowship.

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PACIFIC ISLAND LAND SNAILS

Partula conservation programme update

By Paul Pearce-Kelly

By chance I recently found a copy of the very first issue of *Tentacle* (way back in 1989), which included the first of a long line of updates on the *Partula* conservation efforts. Coincidentally 1989 also saw the first international *Partula* studbook and it is heartening that almost all the taxa listed in that first conservation breeding inventory are still in the breeding programme and enabling the species reintroduction phase of the programme to be realised (Fig. 1).

As in the last *Tentacle* update, COVID-19 loomed large as a major impediment to reintroductions, which for a second year running had to be suspended, and the hope is that they will be resumed in the latter half of 2022 under the auspices of the French Polynesian Government's Direction de l'environnement (Diren) – the Department of the Environment. Being able to resume reintroductions will hopefully increase the likelihood of realising successfully established populations, especially for the Extinct in the Wild status species. This objective is still a formidable challenge and highlights the importance of continuing reintroduction and monitoring efforts. Successes and failures will hopefully inform (and be informed by) the wider mollusc conservation efforts and challenges detailed in Diren's 2019 *'Āreho*, Natural and Cultural Heritage Seminar (see Brocherieux & Cowie, 2020, in *Tentacle* 28).

Meanwhile, the conservation breeding programme continues to manage the ex situ populations, which currently total 15 taxa. Although COVID was again a constraining factor in fully progressing the establishment of planned new participating institutions, populations were re-established at Düsseldorf Zoo and a new participating collection was established at Wild Discovery (UK). The 2021 European Endangered Species Programme (EEP) inventory is in the final stages of production and good cryopreservation progress has been realised in agreeing optimal procedures for

Fig. 1. From top: *Partula varia* reintroduction on Huahine; *P. tohiveana* dispersing into Afareaito Valley, Moorea; reintroduced *P. rosea* on Huahine; reintroduced *P. suturalis* on Moorea. (Photos: P. Pearce-Kelley)

submitting population samples into the Biobank, an initiative of the European Association of Zoos and Aquariums (EAZA), which manages the EEP.

As with any successful conservation effort, there is no question that the most vital factor is the collective endeavour of the programme's diverse collaborators, key individuals listed below. In this regard the *Partula* programme is indeed most fortunate.

Key collaborators: Sam Aberdeen, Christophe Brocherieux, Ross Brown, Mark Bushell, Paul Buzzard, Dave Clarke, Maartje de Vries, Matai Depierre, Jo Elliott, Glenn Frei, Gerardo García, Justin Gerlach, Sandra Honigs, Bob Merz, Bobbi Miller, Pete Mohan, Sarah Robinson, Claude Serra, Jamie Sincage, Ed Spevak, Christoph Schwitzer, Janos Szánthó, Miri Tatarata, Scott Wilson & Tim Woodfine.

Brocherieux, C. & Cowie, R.H. 2020. *'Āreho*, natural and cultural heritage: report of a seminar on land snail conservation, August 2019, Tahiti. *Tentacle* 28: 36-39.

Paul Pearce-Kelly, International *Partula* conservation breeding programme coordinator, Zoological Society of London, Regent's Park, London NW1 4RY, UK. ppk@zsl.org

Hawaiian land snail conservation updates

By Kenneth A. Hayes, Bonnie Derne, Chandra Earl, Jan Kealoha & Norine W. Yeung

From the earliest days of human contact, Hawaiian land snails have been on the decline, with extinction rates increasing dramatically in the last century (Régnier *et al*., 2015). This highly endemic fauna, once numbering more than 750 species, has now been reduced to fewer than 300 (Yeung & Hayes, 2018). Of the remaining species, at least one third are critically endangered and anticipated to go extinct within a decade without immediate and effective intervention.

Effective conservation requires clear objectives aimed at preserving genetic diversity, evolutionary potential and ecological functions predicated on a thorough understanding of the ecosystems and taxa targeted (Milot *et al*., 2020). Unfortunately, our knowledge of biodiversity remains largely incomplete, hampering our ability to answer questions critical for developing effective conservation plans. Although great efforts have been made to conserve some members of the Achatinellidae in Hawaii since they were first listed under the United States Endangered Species Act in 1981 (USFWS, 1981), there remain large gaps in the knowledge and understanding necessary to effectively conserve Hawaiian land snails and the ecosystems on which they and all of Hawaii's imperiled biodiversity rely.

Our team of researchers, conservationists, resource managers, cultural practitioners and volunteers has worked collaboratively over the last decade to prevent immediate extinction of dozens of endemic land snails and to understand multiple dimensions of Hawaiian land snail biodiversity needed to develop scientifically based and effective strategies for conservation and restoration. Such strategies must be based on complete and accurate identification and distributions of all taxa, along with a broader understanding of the patterns and processes that govern ecosystem dynamics. Here we provide a collective update to some of these efforts and offer additional suggestions for expanding such activities in the future. This is by no means a comprehensive list of activities and actions being undertaken on behalf of land snail conservation but is a sampling of the work with which we are involved and most familiar.

Bishop Museum captive rearing

Since the early 1980s, to slow the extinction of the Hawaiian land snail fauna, several species have been placed in captive rearing facilities as a stopgap measure to safeguard them from extinction. This was done in hopes of re-introducing individuals back into protected areas that can sustain populations. In 1981, the Oahu tree snails (*Achatinella* spp.) were federally listed as endangered under the U.S. Endangered Species Act and several other achatinellines have been added to that list in subsequent years (USFWS, 2013). Representatives of all extant listed species have been placed in captive rearing facilities supported by the U.S. Fish and Wildlife Service (USFWS), first at the University of Hawaii and more recently as part of the Hawaii Department of Land and Natural Resources (DLNR) Snail Extinction Prevention Program (SEPP) (see this issue of *Tentacle*, page 44).

Fig. 1. *Amastra cylindrica* in Bishop Museum's captive rearing programme. This is one of three species previously extinct in the wild until reintroduced into predator-proof exclosures.

At about the same time that the USFWS was listing and ramping up their captive rearing efforts for *Achatinella* species at the University of Hawaii, Dr. Daniel Chung recognised that the federal snail conservation initiatives focused only on a single genus, representing less than 6% of native Hawaiian land snail species. In the absence of federal recognition, the other 94% of Hawaiian land snails, including members of the entirely endemic family Amastridae continued to rapidly disappear, so he began manning what has become known as "conservation lifeboats". He initially began rearing several Amastridae species (Fig. 1) at his home and continued adding additional species from other families before relocating these activities to the Bernice Pauahi Bishop Museum (BPBM) in 2007. In the more than 40 years since Chung started these snail rearing efforts, he has been working to optimise captive rearing techniques and record life history data across a diversity of species, while also training a small band of dedicated volunteers. Currently at the BPBM, 11 volunteers, and a minimal part-time staff partially supported by the SEPP programme, now care for more than 11,400 snails of 24 species representing five families.

Over the last three years, individuals of three *Amastra* species believed to be extinct in the wild and only existing in the BPBM captive rearing facility were given to the SEPP captive rearing facility to provide additional security for the species. One of the species was also given to the Honolulu Zoo to increase the number of captive populations existing in separate locations. All institutions have been successful in rearing these three species to the extent that over 6,000 individuals have been off-loaded from their conservation lifeboats into predator-proof exclosures in the mountains of Oahu. In 2021, in recognition of the strong multi-institutional captive rearing partnership between BPBM, SEPP and the Honolulu Zoo,

USFWS supported this conservation effort by providing funds to upgrade and expand captive rearing facilities to increase taxonomic scope and space capacity. In addition to these facility improvements, BPBM and the Honolulu Zoo will be developing outreach exhibits and displays to educate the public about captive rearing efforts and Hawaiian land snail conservation.

Disease ecology of Hawaiian land snails: a missing piece of the conservation puzzle

Captive rearing has been a mainstay of Hawaiian land snail conservation for more than four decades. However, in this time there has been little research into the suite of associated symbionts that have substantial potential to negatively and positively influence conservation outcomes. The species we seek to conserve do not exist independently of other species (Zook, 2001; Stampar *et al*., 2010). Endangered fauna undoubtedly host a diversity of symbionts, including viruses, bacteria, fungi, protozoans and metazoans (Dimijian, 2000). Unsurprisingly, symbionts have important implications for host fitness, whether they are mutualistic gut bacteria performing essential digestive roles (Cardoso *et al*., 2012), parasitic helminths with a sub-lethal fitness cost (Morand, 1993) or pathogens causing widespread mortality in a population (De Vico *et al*., 2017; Cunningham & Daszak, 1998). Symbioses also have important implications for how ecosystems may respond to anthropogenic changes (Hom & Penn, 2021) and host-symbiont relationships may vary with host and environmental factors. For example, previously beneficial or commensal symbioses may exert fitness costs when the host is stressed (Morand, 1993). This often complex interplay between hosts, symbionts and the environment underlying disease ecology outcomes (including infection) can be conceptually modeled as the epidemiological triad, or disease triangle (Fig. 2).

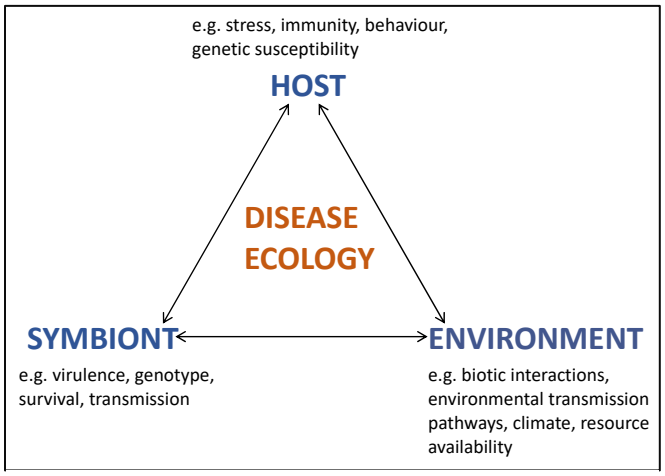

Fig. 2. Disease ecology triad illustrating the combination of interacting host, symbiont and environmental factors that influence outcomes. Adapted from Stevens (1960).

Species targeted for conservation generally face a myriad of threats and stressors, not only from the cause(s) of their decline, but also because of (hopefully) beneficial conservation interventions such as captive rearing and translocations (Northover *et al*., 2018). Captivity for example, represents a marked change in the set of environmental conditions influencing disease outcomes (Fig. 2). Understanding host-symbiont relationships provides the first step towards management that optimises host fitness, reduces disease mortalities and where appropriate saves symbionts from co-extinction. Our ability to understand these relationships are, however, severely hampered by a lack of knowledge of symbiont diversity, biology and ecology. Molecular tools such as DNA-barcoding hold great promise in helping us fill some of these knowledge gaps, such as the identification of symbionts within their hosts, their prevalence and broader ecology (Gupta *et al*., 2020).

Beyond a few studies investigating select achatinellines, we know relatively little about the biology and broader ecology of most Hawaiian land snails (Yeung & Hayes, 2018), and our knowledge concerning gastropod symbionts in Hawaii is limited to introduced parasites of public health significance (Kim *et al*., 2014). To address this gap in our knowledge and better characterize the symbionts of endangered Hawaiian land snails, a collaborative project between Hawaii's SEPP and the Bishop Museum's Malacology Research Center and Pacific Center for Molecular Biodiversity is being funded through a USFWS State Competitive Wildlife Grant. A primary objective is to identify any potential parasites and pathogens that may be negatively impacting captively reared populations. These data will also allow the characterization of symbionts in both wild and captive populations to better understand the environmental factors necessary for long term survival. The project will also yield general insights into the gut microbiome and symbionts of an array of Hawaiian land snails, and local invasive gastropods. These data will be used to develop screening tools and improved disease risk mitigation actions for conservation. Using the extensive preserved Hawaiian land snail wet tissue collection at the BPBM offers the opportunity to explore how symbiont communities vary over temporal and spatial scales in concert with the profound environmental changes and widespread extinction for this endemic gastropod fauna. The improved understanding of Hawaiian land snail symbioses will provide a stronger foundation from which to build effective conservation strategies.

Biodiversity informatics and digitisation for Pacific Island Land Snail (PILS) conservation

Biodiversity data follow a life cycle, alternating between two major stages: 1) data collection and management and 2) data analysis and synthesis. To perform novel scientific discovery, data at both stages must be correct, complete and publicly available (Michener & Jones, 2012). Unfortunately, much biodiversity data associated with Pacific Island Land Snails (PILS), such as species names, ranges and associated collection information remain unavailable, scattered and incomplete, severely limiting the development of knowledge needed for conservation efforts. In addition, many studies involving analyses of data from PILS lack proper data management and preservation (i.e. properly vouchered specimen and associated collection information) leading to

unverifiable results derived from often inaccurate species identifications, further limiting extended research potential.

To increase data discovery and preservation and scientific rigour and transparency, the BPBM Malacology Center is leading a collaborative effort with five major institutions, supported by the National Science Foundation, to mobilise and clean the valuable digital PILS resources for use by researchers, organisations, conservationists, resource managers and citizen scientists. Efforts include digitisation of previously unavailable collection events, imaging of primary type specimens, georeferencing for spatial mobilisation of the data, and scanning and linking associated literature (field notebooks, maps, ledgers, etc.) to their related specimens (Fig. 3). The project is now in the third of four years and is a little over halfway complete. All available data have been converted to Darwin Core format and major fields such as taxonomy and geography are in the process of becoming standardised and updated for ease of analysis and exploration of the data. Specimen images and literature scans are uploaded and linked as data become available. Data are publicly available online via the Pacific Island Land Snail Biodiversity Repository (PILSBRy) portal under FAIR principles and will be ingested into iDigBio as the major source of PILS data.

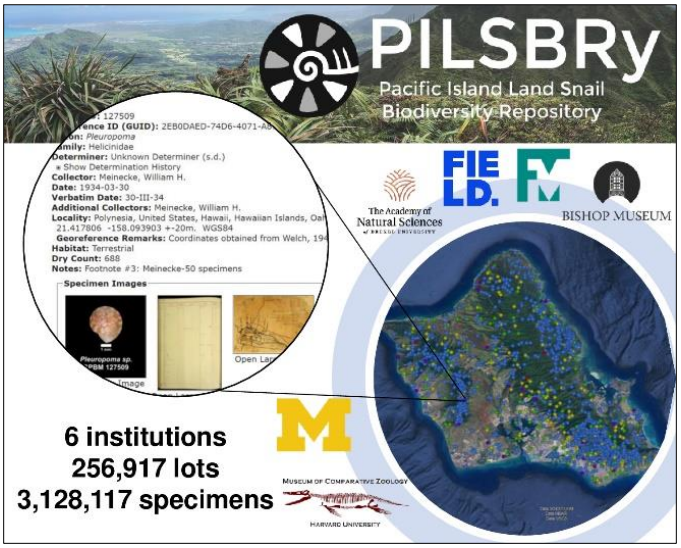

Fig. 3. PILSBRy portal developed to share all Pacific Island land snail data from at least six U.S. institutions.

Aggregating and mobilising all PILS data increases its visibility and value for asking and answering questions about large scale evolutionary processes, which are critical given the rapid rate of land snail extinction (Nelson & Ellis, 2018). Potential research emphases include assessing phylogenetic diversity for conservation, geospatial analyses using specimen locality data, and advances in ecological niche and species distribution modelling. Pacific Island Land Snail research can finally move into the big data science era, opening multiple pathways for researchers to make positive contributions to our understanding of, responses to and mitigation of the imminent extinction of these species.

Thank you to our extensive network of collaborators, funding partners and supporters. Special thanks to all those at the U.S. Fish and Wildlife Service, the Hawaii Department of Land and Natural Resources, the Bernice Pauahi Bishop Museum, the University of Hawaii, the Army Natural Resources Program, Pulama Lanai, National Tropical Botanical Garden, Hawaii Association of Watershed Partnerships, the Nature Conservancy and Puu Kukui Watershed Preserve.

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Hawaii Snail Extinction Prevention Program (SEPP)

By David R. Sischo

The Snail Extinction Prevention Program (SEPP) is a partnership recovery effort hosted by the Hawaii Department of Land and Natural Resources. Aimed at preventing the mass extinction of land snails in the Hawaiian Islands, SEPP works with a diverse array of partners and land holders across the state to directly manage snail populations and to facilitate research and conservation. SEPP has a fully staffed captive rearing facility on the island of Oahu and field biologists on Oahu and Maui. The following is a brief update on noteworthy captive rearing and reintroduction efforts.

SEPP captive rearing update

The SEPP lab currently maintains 60 distinct populations of rare and endangered land snails representing 38 species from five islands. Most of these populations no longer have wild counterparts and exist solely in captivity (Fig. 1). SEPP has faced significant logistical challenges because of the ongoing COVID-19 pandemic. However, despite it all the show must go on at the SEPP lab as the existence of species depends on it. Throughout the year staff have diligently donned PPE and worked in shifts, keeping each other safe while caring for the snails.

SEPP was awarded funds from the U.S. Fish and Wildlife Servie and the State of Hawaii to relocate and expand its captive rearing facility. After several years of planning, ground will be broken in February 2022. The new facility will be located at the Waimano State Complex in Pearl City, Oahu. The new building will be double the size of the current space, increasing the capacity for rearing snails and conducting critical research.

Multi-institution captive rearing collective

In recent years SEPP has partnered with the Malacology Department at the Bernice Pauahi Bishop Museum, which has maintained critical snail populations in captivity for many years (see previous article, page 41), and the Honolulu Zoo, which has recently partnered and has started rearing snails. In 2021, the three institutions together released over 7,000 snails

Fig. 1. *Achatinella lila* maintained in the SEPP lab. *Achatinella lila* is a tree snail endemic to the Northern Koolau Mountains of Oahu. There are only two poplations of *A. lila* known and both are extinct in the wild and now only persist inside the SEPP lab.

into protected areas on Oahu and Maui. Snail species released include *Amastra goniops*, *Amastra intermedia*, *Amastra micans* (Fig. 2), *Amastra spirizona*, *Leptachatina vitreola*, *Cookeconcha hystricella*, *Achatinella concavospira* and *Achatinella mustelina*.

The initial success of this partnership effort has gained momentum. In 2021 the captive rearing collective was awarded a Competitive State Wildlife Grant from the U.S. Fish and Wildlife Service to expand rearing efforts at all three institutions. Currently, there are over 60 populations of rare and endangered snails with no wild counterparts. Furthermore, most of these species exist solely at one single facility. The

Fig. 2. *Amastra micans* released on Oahu into habitat protected by a predator-proof fence. *Amastra micans* is thought to have gone extict in the wild over 20 years ago. Thanks to Bishop Museum Malacology staff and affiliated researchers, this species was brought back from the brink of extinction and is now maintained at the Bishop Museum and the SEPP lab, and has been released back into the wild. This is an example of how a partnership approach combining captive rearing and reintroduction can quickly stabilise species on the brink.

impetus for the project is to prioritise and split vulnerable populations between the three facilities to lower the risk of extinction by increasing both population redundancy and the capacity to generate individuals for release into the wild. Funds will go towards equipment, facility modifications and staffing. As a bonus, both the Honolulu Zoo and the Bishop Museum will have public facing exhibits allowing visitors to see these beautiful animals and to interact with keepers and lab staff.

Snail feeding ecology research

Hawaiian tree snails feed on biofilm composed of fungus, bacteria, algae, etc. on leaf surfaces. While ground dwelling snails typically eat dead and decaying leaves of native plants. To feed captive snails, native vegetation is brought into the lab on a weekly basis, and a single species of tree fungus (*Cladosporium* sp.) is cultivated on potato dextrose agar. Unfortunately, native forests are in decline across the islands, and the number of snails in captivity requires large quantities of leaves. Additionally, we suspect pathogens are occasionally introduced to the lab via the wild-collected vegetation. There is an urgent need to reduce or eliminate the collection of native vegetation, to both prevent harm to native forests and to prevent the introduction of harmful pathogens and parasites to the lab populations. To tackle this problem, we have initiated a series of studies to better understand feeding ecology, with the aim of improving snail diets and reducing the reliance on wild-collected native vegetation.

An initial study looking at the impact on egg production of *Auriculella diaphana* fed a diet consisting of native vegetation only, native vegetation and cultivated fungus, and cultivated fungus only was conducted in the SEPP lab with research partners from the University of Hawaii (Strouse *et al*., 2021). Snails fed a diet of native vegetation and fungus overwhelmingly produced more eggs than snails fed on native vegetation alone or fungus alone. Furthermore, snails fed on vegetation alone laid more eggs than snails fed on fungus alone. These results suggest that the diversity of the biofilm (as found on native vegetation) and bulk (as provided by the cultivated *Cladosporium* sp.) may be important factors for captive snail diets. Snails maintained on fungus alone were observed to spend more time aestivating than snails in other treatments, a possible stress response to a starker environment. This may indicate that the ambient environment created by vegetation encourages normal behaviour and reproduction. Similar studies will be conducted looking at other substrates, native versus non-native vegetation, as well as snails fed on other types of manufactured and or cultivated food items.

In 2021 the SEPP lab conducted feeding trials using *Amastra intermedia*, a ground-dwelling snail that feeds on dead and decaying native plants. The objective of this study was to understand the wild diet of ground-dwelling snails in the Hawaiian endemic family Amastridae so that captive diets can be further optimised.

Here we used a buffet style experiment in a feeding arena (Fig. 3). Dead leaves of native plant species, cultured fungus (*Cladosporium* sp.) on potato dextrose agar, as well as plain potato dextrose agar, were offered to the snails. Cohorts of

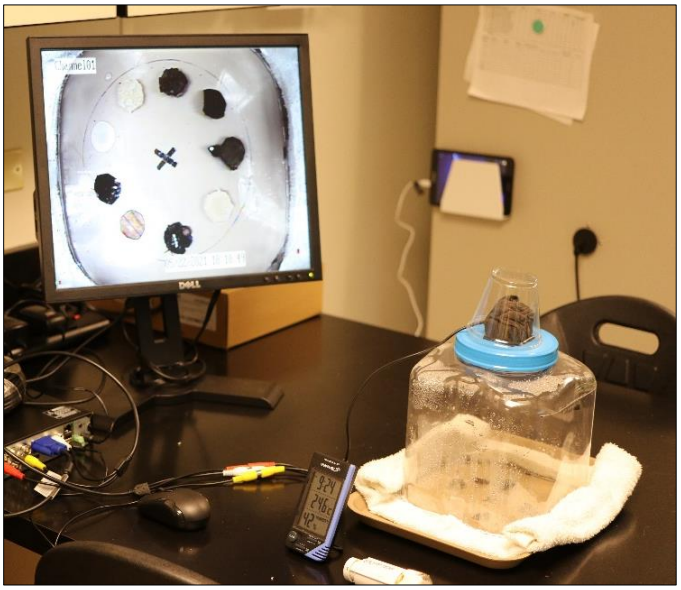

Fig. 3. Experimental setup showing feeding arena. The monitor shows food items in standardised portions.

snails were videotaped for five 24-hour trials, each with five different snails, marked to keep track of individual snail movements. We quantified the number of visits and the time spent on each food type. Results showed that snails interacted with all food items offered, indicating foraging behaviour; however, snails overwhelmingly spent the most time on native plants in the nettle family (Urticaceae), including *Pipturus albidus* and *Urera glabra.* A nutrient analysis of all leaf types offered showed that nettles have higher calcium contents than all other leaves tested. This may be one reason why snails preferentially selected nettles to eat. Further studies will attempt to replicate the nutrient profile of preferred leaves using ingredients available commercially to create and test an artificial food for ground-dwelling snails.

Predator-proof fencing

To maintain snails on the landscape, predator-proof fencing (Fig. 4) is used to protect populations with barriers that keep out all known invasive predators.

Fig. 4. A recently completed predator-proof fence on Oahu.

Currently, SEPP and multiple partners across the state, including the Army Natural Resources Program and Pulama Lanai, have constructed 11 predator-proof fence units across the islands, with two more under construction on Maui and two in the queue on Oahu. Collectively these predator-proof fences are protecting over ten species of rare and endangered snails. It is estimated that over the next decade at least 50 small fence units will be needed to conserve the diversity that is being lost across the archipelago. To optimise fence placement, SEPP is working with researchers at the University of Hawaii to model potential snail range reductions due to climate change. With this information, areas that will be suitable for snail survival are being prioritised for protection.

Many thanks to our collaborators and fuding partners at the U.S. Fish and Wildlife Service, the Hawaii Department of Land and Natural Resources, the Bernice Pauahi Bishop Museum, the University of Hawaii, the Army Natural Resources Program, Pulama Lanai and Puukukui Watershed Partnership.

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MARINE MATTERS

Field and GIS validation of oyster stocks and the reef ecosytem of Hab River Delta, Balochistan, Pakistan: a conservation approach

By Sadar Aslam, Ghazala Siddiqui, Malik Wajid H. Chan, Jamil.H. Kazmi & Nuzhat Afsar

Natural calamities (major adverse events resulting from natural process of the Earth) and human activities threaten the productivity, diversity and survival of coastal resources such as oyster reefs, emphasising the need to understand and manage coastal zones. Assessment of oyster reefs has shown that 85-91% have been lost worldwide and the remaining natural oyster populations are in fragile condition and declining to the level of extinction (Beck *et al*., 2011). The basic aim and objective of the present study was to gather baseline data for oyster reef conservation and restoration in Pakistan by carrying out field surveys and using a Global Information System (GIS) based approach to assist conservationists and future restoration practitioners at provincial, national and international levels. The main objectives to fulfill the goals of this research were divided into the following three components.

- **Spatial assessment** of conservation metrics for oyster reef restoration using GIS techniques to explore the present status focused on reef categorisation, universal metrics, habitat suitability analysis, universal environmental variables, restoration goal-based metrics, condition indices, grain size composition, oyster spat-fall determination and presence of parasites for the intertidal oyster reefs of the Hab River Delta in Pakistan.
- **Overall biodiversity** assessment on intertidal oyster reefs in the Hab River Delta over one year (seasonal data using quadrat sampling for species richness and abundance; relationships of other species with oysters and their reef structure; detailed examination of community structure and biocoenosis; identification of associated fauna and flora).
- **Pollution assessment** through heavy metals analysis to investigate the metal concentrations of seawater, sediments and oysters (two indigenous oyster species, *Magallana cuttackensis* and *M. bilineata*) by applying different pollution indices; and analysis and profiling of volatile organic compounds (VOCs), using the GC-MS technique to determine levels of organic pollutants / hydrocarbons in the two oyster species (bioaccumulation), seawater and sediments.

Because of environmental and anthropogenic factors, Pakistan only has appropriate oyster reef habitats for *M. bilineata* and *M. cuttackensis* in the Hab River Delta, Balochistan, and the results from the above three components of the study indicate an urgent need for Marine Protected Areas (MPAs) for oyster reef conservation in the Delta (Fig. 1).

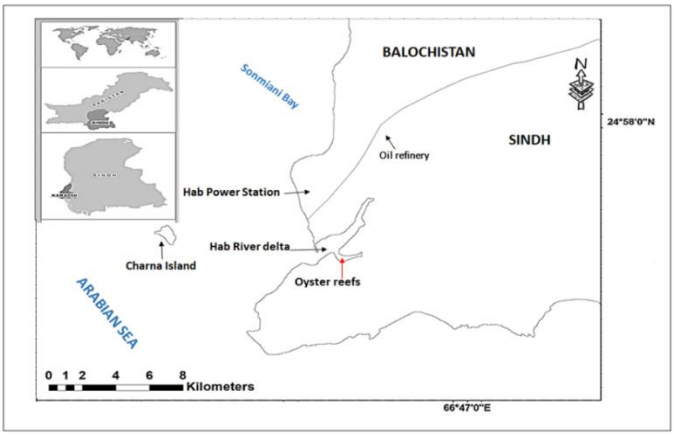

Fig. 1. Detailed map of the study area, the Hab River Delta.

Preliminary spatial assessment of oyster reefs in the Hab River Delta indicates need for MPA

Oyster reefs in Pakistan are on the verge of extinction as a consequence of environmental and anthropogenic factors. Surveys of oyster reef habitat were conducted from March 2017 to February 2018 in the Hab River Delta along the Balochistan coast. A combination of field survey and geographical information system (GIS) based approaches (reef categorisation, universal metrics and habitat suitability analysis) was adopted and universal environmental variables, restoration goal-based metrics, sounding, condition indices, grain size composition and oyster spat-fall were assessed in order to plan future oyster reef restoration efforts. The reefs were categorised into three main groups – dispersed, patch and continuous (Fig. 2) – on the basis of fragmented spatial geometry. Dispersed reefs were more numerous than continuous and patch reefs. The differences in morphometric measurements and density of oysters among reef types were statistically non-significant. Habitat suitability analysis was

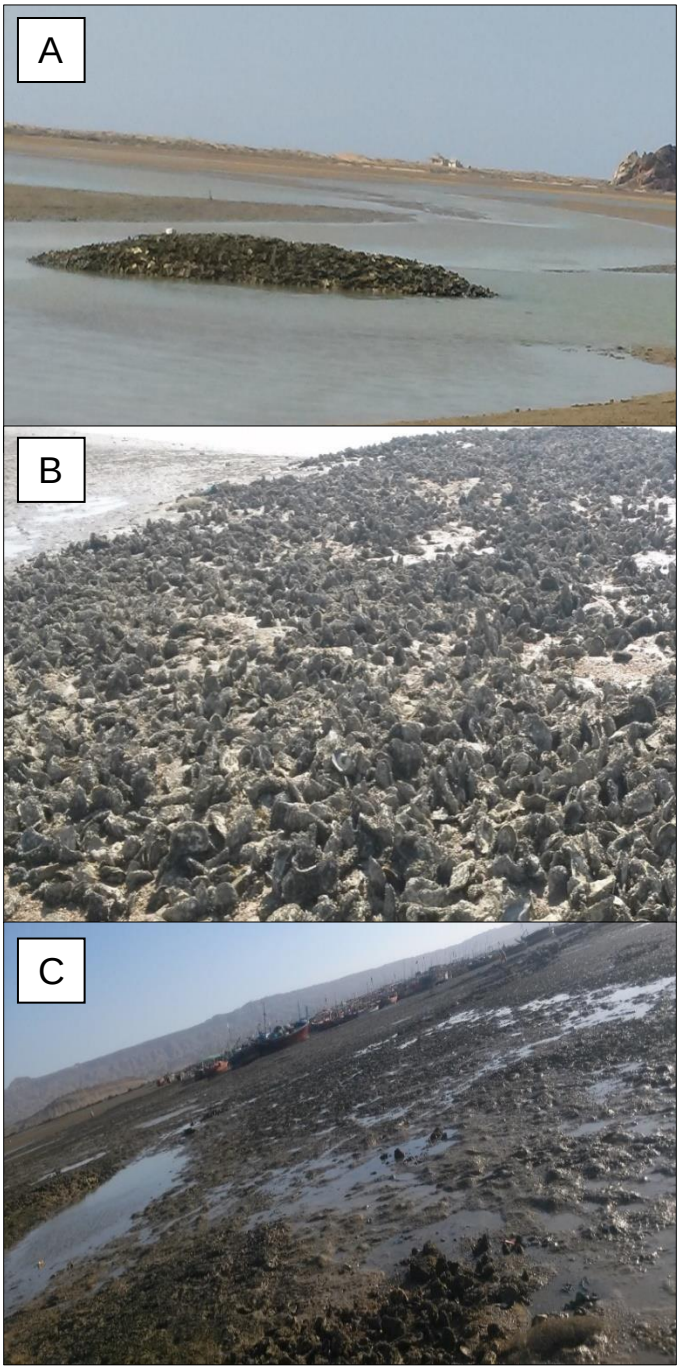

Fig. 2. Reef Categories: A – patch, B – continuous, C – dispersed.

undertaken with 'Benthic Terrain Modeler' using ArcGIS software. The moderate, positive values of the Bathymetric Position Index (BPI) of the oyster reef indicated an area of high or open slope with sea bottom (-2 to 6). The area of reef location shows high to moderate values of rugosity (0.7 to 0.9), indicating good to intermediate conditions; whereas the aspect analysis showed slope orientation in the northeast direction but mostly flat areas. The environmental and restoration goal-based metrics were favourable for oyster growth and survival. The dispersed reefs had the lowest bathymetry points compared to patch and continuous reefs. The values of the condition indices revealed non-significant difference among reef types (continuous, dispersed and patch). Fine sand was the dominant substrate (71%) followed by the silt/clay fraction (18%). The higher density and spat size were recorded in the monsoon (June to September) season. Histological examination found no parasites; however, necrosis in some tissues and mortality was observed. This study suggests that the present reefs are viable and have potential for successful restoration and may be converted into a sizeable ecological sanctuary (Aslam *et al*., 2020a).

Biodiversity assessment on intertidal oyster reefs in the Hab River Delta, with 35 new species records for Pakistan, indicates need for an MPA

This part of the study focused on the biodiversity of sessile and motile organisms using intertidal reefs of *M. cuttackensis* and *M. bilineata* for settlement space, feeding and/or refuge in the Hab River Delta. A one year (February 2017 to January 2018) field survey was carried out to investigate species diversity and abundance on the reefs and surrounding areas. Monthly samples were taken and the relative abundance of macro organisms was observed. Oysters were brought to the laboratory for detailed examination of their shells for the presence of other species. In total, 122 species were collected, with 35 new records for Pakistan. The most abundant phylum was Mollusca represented by 55 species. The overall highest biodiversity was recorded in the pre-monsoon season, decreasing in the monsoon and post-monsoon seasons. April was the month with highest number of species observed. A near-round natural pearl was discovered in the edible oyster *Magallana bilineata* (Aslam *et al*., 2019a). *Haminoea* cf. *fusca* (gastropod), *Amathia verticillata* (bryozoan), *Pseudanurida bogoyawlenskyi* (collembolan), *Fortuynia longiseta* (mite), *Ceratonereis burmensis* (polychaete)and *Peronia verruculata* (gastropod) were recorded for the first time with detailed descriptions (Aslam *et al*., 2018, 2019b,c,d, 2020b,c; Dayrat *et al*., 2020). This study provides baseline information for the management and understanding of *M. cuttackensis* and *M. bilineata* reefs and their biodiversity in the Hab River Delta. We recommend this place be designated a Marine Protected Area (MPA) under the 2010 Aichi Biodiversity Targets for the conservation of the oyster reefs and declare them as a sanctuary to preserve one of the most important marine habitats in Pakistan.

Pollution assessment of oyster reefs in the Hab River Delta revealed an urgent need for an MPA

Heavy metals are permanent pollutants that accumulate in the tissues of aquatic organisms. Bioaccumulation of these metals in aquatic animals especially in filter feeders has been considered a serious problem. In the Hab River Delta, the two indigenous oysters, *M. cuttackensis* and *M. bilineata*, are subject to heavy metal pollution because of fast growing industries and urbanisation in the area. This is the first report on heavy metal contamination in native oysters in the Hab River Delta. The heavy metal pollution status of the oyster reefs of the Delta has been assessed with respect to ten metals (Al, As, Cd, Cr, Cu, Fe, Hg, Pb, Ni and Zn) in seawater, sediments and oysters (soft tissues and shells). The results showed that concentrations of heavy metals accumulated in *M.*

bilineata were higher than those in *M. cuttackensis*. This could be one of the reasons for the small population size of *M. bilineata* at the study site. There were significant differences in their profiles among sediments, seawater and in tissues and shells of the two oyster species. A previous study also compared these metal concentrations with national and international databases by applying different pollution indices. Heavy metals in all samples were above the local environmental quality standards (NEQS-Pakistan). The high level of metal pollution, indicating alarming conditions in the Delta needs more coastal management attention (Aslam *et al*. 2020d).

Oysters are one of the most promising bioindicators for monitoring of chemical contaminants in the environment because of their habitat and filter-feeding properties. The comparative analysis and profiling by the GC-MS technique of volatile organic compounds (VOCs) in the two oyster species and the investigation of hydrocarbons / organic pollutants in seawater and sediments revealed that the area is heavily polluted and there is a need to establish a Marine Protected Area (MPA) in the Delta. This report presents a comparative study for several groups of organic compounds identified in oysters as well as seawater and sediments. Results are discussed in terms of availability of pollutants in the environment, their uptake by oysters as well as their biotransformation. The presence of PAHs in the oysters puts a new spotlight on the risk for human health from pollution of the environment. This study proved also the usefulness of oyster tissues as a bio-indicator for future research (Aslam *et al*., in press).

The present study on oyster reefs as preliminary research for restoration was a part of the PhD research work by the first author Sadar Aslam. The author is looking for a funding source for the conservation and restoration of Pakistan's native oysters. If someone is interested, please contact Sadar Aslam.

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Red Listing can protect UK Overseas Territories marine biodiversity

By Aoife Molloy & Julia Sigwart

A new project entitled "Red Listing can protect UK Overseas Territories marine biodiversity" has started with funding from the Darwin Initiative, a UK government grant scheme within the Department for Environment, Food and Rural Affairs. This project will examine the potential threats of climate change to marine molluscs from across Antarctic and Subantarctic UK Overseas Territories (OTs). It will encompass the impacts of climate change, fisheries and other anthropogenic impacts, as well as the mitigating effects of conservation measures such as Marine Protected Areas (MPAs). We are looking at marine molluscs found in three target UK OTs: Falkland Islands / Malvinas, South Georgia and the South Sandwich Islands (SGSSI), and the British Antarctic Territory (BAT), as well as species having wider ranges throughout the Southern Ocean and the coasts of South America. These molluscs will be assessed for their extinction risk using the International Union for Conservation of Nature (IUCN) Red List of Threatened Species criteria (IUCN, 2012).

Marine species remain dramatically under-represented in Red List assessments: of ~138,000 species assessed to date, only 15% are marine species (mostly fish and seabirds). Only 596 assessed marine species occur in the Southern Ocean, and many are animals with much wider ranges including whales, tuna and seabirds (IUCN, 2021). Only 79 species of marine invertebrates in the Southern Ocean have been assessed to date, with molluscs representing 59 of those. This project is an opportunity to use molluscs as an effective case study for conservation.

A lack of assessments may prevent stakeholders from understanding which species are under threat, and also which conservation measures are effective. In addition, robust assessments of climate change vulnerability could direct proposals for additional conservation priorities under predicted climate change scenarios. These are universal problems applicable globally, for all species. This new project aims to start filling assessment gaps, for the Southern Ocean, for climate change stressors and for marine invertebrates, using marine molluscs in Antarctic and Subantarctic UK OTs as a case study. However, our results will be applicable to all species in the Southern Ocean.

Red List assessments completed throughout this one year project should improve global communication about the threats faced by marine species. It will also provide a robust proxy measure of the success of existing conservation measures by comparing mollusc species with and without conservation protection. We can compare the assessed extinction risk of those that are found within the SGSSI MPA and Antarctic Treaty regions, with other species in the region that mostly range outside these protected areas. The numbers of species at different risk levels (Least Concern, Near Threatened, Vulnerable, Endangered or Critically Endangered) will be used to inform policy for conservation in the UK OTs.

As a part of this project, we are offering a free training workshop in collaboration with the IUCN Red List Unit. This offers training to anyone who would like to use Red List assessments in their work. The workshop will take place from 5-8 April, 2022, at the British Antarctic Survey offices in Cambridge, UK. The workshop is planned as an in person event in Cambridge. This training will allow others, especially those carrying out conservation projects in other UK OTs, to gain knowledge of the Red List and develop skills in applying Red List assessments to conservation efforts. Travel funding to attend the workshop is available for those working in UK OT areas. (Please email Aoife if you are interested.)
To attend the workshop, you can register at the link above.
[Unfortunately *Tentacle* was published too late for most people reading this to sign up for the workshop – Editor]

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Julia Sigwart, Senckenberg Research Institute and Natural History Museum, Frankfurt am Main, Germany. julia.sigwart@senckenberg.de

RECENT PUBLICATIONS RELEVANT TO MOLLUSC CONSERVATION

Journal of Threatened Taxa

All issues for 2021 (volume 13), and the first three for 2022 (volume 14), of the *Journal of Threatened Taxa* are available on-line now. There are some articles about molluscs.

Freshwater Mollusk Biology and Conservation

Freshwater Mollusk Biology and Conservation, formerly *Walkerana* is the on-line journal of the Freshwater Mollusk Conservation Society, based in North America. In 2021, it published two issues: volume 24, numbers 1 and 2, each with five papers. All issues are available on-line at the journal's website, with open access.

Volume 24, number 1

Christian, A.D., McMurray, S.E., McCanty, S.T., Dimino, T. & Harris, J.L. 2021. Freshwater mussel assemblages in the Black River, Missouri and Arkansas. *Freshwater Mollusk Biology and Conservation* 24: 1-6.
Mitchell, Z.A. & Schwalb, A.N. 2021. Seasonality of gamete production of *Cyclonaias* species in central Texas. *Freshwater Mollusk Biology and Conservation* 24: 7-17.
Shepard, A., McGregor, M.A. & Haag, W.R. 2021. Host fishes and life history of the round hickorynut (*Obovaria subrotunda*). *Freshwater Mollusk Biology and Conservation* 24: 18-25.
Walters, A.D., Taynor, K.N. & Berg, D.J. 2021. Genetic diversity in the threatened freshwater mussel *Lampsilis powellii*. *Freshwater Mollusk Biology and Conservation* 24: 26-33.
Gladstone, N.S., Pieper, E.B., Keenan, S.W., Paterson, A.T., Slay, M.E., Dooley, K., Engel, A.S. & Niemiller, M.L. 2021. Discovery of the Blue Ridge springsnail, *Fontigens orolibas*, Hubricht, 1957 (Gastropoda: Emmericiidae) in east Tennessee and its conservation implications. *Freshwater Mollusk Biology and Conservation* 24: 34-42.

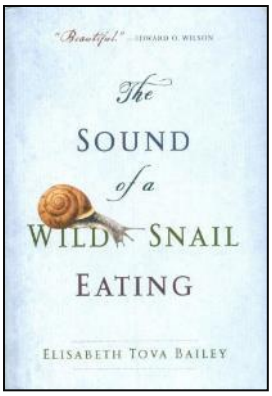
Volume 24, number 2

Key, K.N., Rosenberger, A.E., Lindner, G.A., Bouska, K. & McMurray, S.E. 2021. Riverscape-scale modeling of fundamentally suitable habitat for mussel assemblages in an Ozark river system, Missouri. *Freshwater Mollusk Biology and Conservation* 24: 43-58.
Stodola, A.P., Lydeard, C., Lamer, J.T., Douglass, S.A., Cummings, K.S. & Campbell, D. 2021. Hiding in plain sight: genetic confirmation of putative Louisiana fatmucket *Lampsilis hydiana* (Mollusca: Unionidae) in Illinois. *Freshwater Mollusk Biology and Conservation* 24: 59-86.
Whelan, N.V. 2021. Phenotypic plasticity and the endless forms of freshwater gastropod shells. *Freshwater Mollusk Biology and Conservation* 24: 87-103.
North, E. & Minton, R.L. 2021. Diversity and predicted function of gut microbes from two species of viviparid snails. *Freshwater Mollusk Biology and Conservation* 24: 104-113.
Poulton, B.C., Bailey, J., Kroboth, P.T., George, A.E. & Chapman, D.C. 2021. Invasive black carp as a reservoir host for the

freshwater mollusk parasite *Aspidogaster conchicola*: further evidence of mollusk consumption and implications for parasite dispersal. *Freshwater Mollusk Biology and Conservation* 24: 114-123.

The Sound of a Wild Snail Eating

Elisabeth Tova Bailey, original edition 2010. Algonquin Books of Chapel Hill, Chapel Hill, North Carolina, USA.



Here is my usual notice of this delightful book, which I continue to thoroughly recommend. It was originally reviewed in *Tentacle* 19 (2011). The memoir recounts the author's year-long observation of a forest snail, *Neohelix albolabris*. The original book was published in the USA in 2010, but it has been translated into various languages. For links to the publishers of these editions please see the author's website. An audiobook edition is available as a Kindle or hard CD. And there is an award winning short film adapted from it (see wildsnailfilm.org for upcoming screenings).

Film of the book available

The author informs me that the film of the book (around 15 minutes) is available for screenings to malacology and other groups and departments. Anyone interested in such a group screening for their lab or department should send an e-mail to info@wildsnailfilm.org. I have seen the film and can recommend it highly – it is as delightful and thought provoking as the book.

Other publications of interest

This is by no means a comprehensive list but simply a list of publications that I have happened to come across, additional to those mentioned elsewhere in this section. If you want to have your publications listed in the next issue of *Tentacle*, please send details to me, Robert Cowie, the editor.

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Christensen, C.C., Cowie, R.H., Yeung, N.W. & Hayes, K.A. 2021. Biological control of pest non-marine molluscs: a Pacific perspective on risks to non-target organisms. *Insects* 12: 583.

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IUCN/SSC AND MOLLUSC SPECIALIST GROUP NEWS AND ANNOUNCEMENTS

www.iucn.org/

News and information provided by Mary Seddon, chair of the Mollusc Specialist Group (MSG) of the IUCN Species Survival Commission (SSC).

SSC Mollusc Specialist Group News

IMORTANT IF YOU ARE A MSG MEMBER
Renewing your SSC MSG membership via the IUCN portal

First, many thanks to all the MSG members for your hard work over the last five years. It is valued and appreciated by the wider invertebrate conservation community as well as by IUCN members.

Members of the SSC Mollusc Specialist group are invited for a four year period, mirroring the four year cycle of the IUCN scientific programme. Each four years you need to renew your membership using the IUCN membership portal. This process took place between November 2021 and January 2022. At this point there are some members of the group who have yet to respond to the automated email requests to renew their MSG membership. In many cases this is due to their email addresses changing so their invitations went to old email addresses. Unfortunately the specialist group chairs and Red List authorities cannot assist with changes to email addresses on the system, so we may need to send a new invitation for you to register your new email in the IUCN membership portal and then join the group. We will be sending out fresh invitations so that members can be seen as official members of the IUCN, SSC and the SSC Mollusc Specialist Group. Please check your junk-mail/spam boxes for your invitation.

IUCN refocuses its structure for 2021-2024

IUCN has reviewed its programme structure and moved away from more traditional thematic programmes to develop four cross-cutting programmes that reflect the three key pillars of sustainable development – economic, social and environmental, underpinned by a fourth centre, the Centre on Science and Data (see below). IUCN expects this new programme structure to be fully operational by September 2022. Most of the SSC, and hence MSG based work lies

within the Centre for Science and Data and the Centre for Conservation Action.

The new Centre for Economy and Finance, led by Chris Buss, will work on global targets on biodiversity and climate change creating new business models and economic analysis including IUCN's work with the Global Environment Facility (GEF) and Green Climate Fund.

The Centre for Society and Governance, led by Dr Radhika Murti, works on institutional, legal and collaborative efforts aimed at empowering and protecting the rights of traditionally marginalised communities, women, Indigenous Peoples, local communities and youth. It will also work on Environmental Law and World Heritage Programmes.

The Centre for Conservation Action, led by Trevor Sandwith, will oversee IUCN's cutting-edge work on biomes, including global efforts on land, ocean and species. This Centre will apply state-of-the-art knowledge to improve conservation planning, monitoring and results.

The Centre for Science and Data, led by Dr Jane Smart, will further develop IUCN's longstanding reputation as a leading global authority with knowledge-based products such as the IUCN Red List of Threatened Species, IUCN Red List of Ecosystems, IUCN Green List of Protected Areas and IUCN Standard for Nature-based Solutions.

Convention on Biodiversity: replacing the Aichi Targets 2020-2030

IUCN has been providing evidence to inform the post-2020 Global Biodiversity Framework. This includes data compiled from the IUCN Red List, including over 8,000 mollusc species, indicating the proportion of threatened species in different biomes and regions of the world.

There have been ongoing online discussions with many partner organisations and governments, managed by the CBD Secretariat. The first draft of the post-2020 Global Biodiversity Framework (12 July 2021) builds on the zero draft discussed in February 2020. The first draft framework was reviewed again at the resumed Working Group 2020-3 session in January 2022 in Geneva, and further changes are going through a third process of consultation prior to final adoption in May 2022.

There are currently 21 targets that signatory countries will be working toward, eight of which are specifically reporting on threats to biodiversity. This includes increasing spatial planning, protecting wilderness areas, increasing proportions of protected areas for marine species, increasing the percentage areas of habitat restoration as a conservation action, controlling invasive species and increasing on the ground conservation actions for threatened species. These eight targets that are focused on threats to biodiversity are summarised as follows.

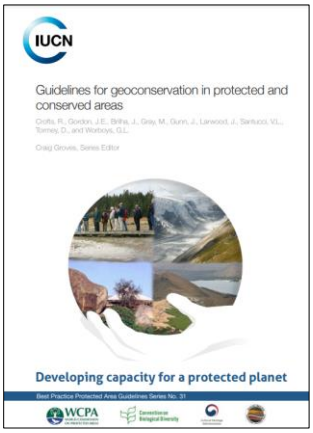
- **Target 1.** Ensure that all land and sea areas globally are under integrated biodiversity-inclusive spatial planning addressing land- and sea-use change, retaining existing intact and wilderness areas.
- **Target 2.** Ensure that at least 20% of degraded freshwater, marine and terrestrial ecosystems are under restoration, ensuring connectivity among them and focusing on priority ecosystems.
- **Target 3.** Ensure that at least 30% globally of land areas and of sea areas, especially areas of particular importance for biodiversity and its contributions to people, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.
- **Target 4.** Ensure active management actions to enable the recovery and conservation of species and the genetic diversity of wild and domesticated species, including through ex situ conservation, and effectively manage human-wildlife interactions to avoid or reduce human-wildlife conflict.
- **Target 5.** Ensure that the harvesting, trade and use of wild species is sustainable, legal and safe for human health.
- **Target 6.** Manage pathways for the introduction of invasive alien species, preventing or reducing their rate of introduction and establishment by at least 50%, and control or eradicate invasive alien species to eliminate or reduce their impacts, focusing on priority species and priority sites.
- **Target 7.** Reduce pollution from all sources to levels that are not harmful to biodiversity and ecosystem functions and human health, including by reducing nutrients lost to the environment by at least half, and pesticides by at least two thirds and eliminating the discharge of plastic waste. Countries will establish national targets/indicators aligned with this framework and progress towards the national and global targets will be periodically reviewed.
- **Target 8.** Minimise the impact of climate change on biodiversity, contribute to mitigation and adaptation through ecosystem-based approaches, contributing at least 10 GtCO2e (gigatonnes of CO_2 equivalent) per year to global mitigation efforts, and ensure that all mitigation and adaptation efforts avoid negative impacts on biodiversity.

Further details can be found at this link and more about IUCN's interventions at this link.

New tools for 2022: the Contributions for Nature Initiative

The IUCN Secretariat has begun development of a Contribution for Nature platform for members to document their intended contributions to the conservation of nature. The beta version of the Contributions for Nature platform was launched at the IUCN World Conservation Congress in Marseille on 8 September. The Contributions for Nature platform will allow IUCN members to document where they are undertaking (or planning to undertake) conservation and restoration actions. It will then overlay data for biodiversity (potential for species extinction risk reduction, drawing from the IUCN Red List of Threatened Species) and for nature-based solutions to climate change (potential for carbon sequestration, drawing from the Bonn Challenge Barometer).

IUCN Publication



Crofts, R., Gordon, J.E., Brilha, J., Gray, M., Gunn, J., Larwood, J., Santucci, V.L., Tormey, D. & Worboys, G.L. 2020. Guidelines for geoconservation in protected and conserved areas. *Best Practice Protected Area Guidelines Series* 31. IUCN, Gland, Switzerland. xii + 144 p.

This publication, initially launched in English in November 2020, is now available in French, Portuguese and German, and a Spanish version is in preparation. All available language versions are free to access and available from this link.

IUCN Red List updates 2022

These schedules may change but at present the submission and proposed publication dates are:

Submission	Proposed publication
15 April 2022	21 July 2022
9 September 2022	8 December 2022

EU Pulse Project 2022-2023

The European Union has commissioned a follow-up project for re-evaluation of the European freshwater molluscs and selected families of land snails. Since the publication of the first assessments in 2010-2011 there has been a great increase in the number of species recognised in Europe. The reassessment process will start with the freshwater bivalves at a workshop in early May 2022 in Brussels and a second workshop in September 2022 probably at a venue in central Europe. The original plans to hold workshops in eastern Europe have been amended. The taxonomic revision works to match MolluscaBase with the Red List database for European freshwater gastropods. This task is almost complete for the terrestrial gastropods and we anticipate that the reassessment work will be starting from June/July 2022 onwards. This project will create the first regional Red List Index for Mollusca, which as yet has only be implemented for birds, mammals and amphibians.

The process will:

- Update information on distribution and ecology
- Provide an opportunity to refine the maps and update with new information, possibly revising to a better quality based on point data
- Create better understanding of the impact of known threats to the species, including whether species are tolerant of disturbance, impacted by pollution, susceptible to climate change events (drought/frequency of fire)
- Generate more information on conservation actions proposed, including modification of protected areas, targeted interventions, management of invasive species and knowledge on other conservation actions for species in the same habitats that may be detrimental to the species in question.

Grants

Calls for proposals for the latest BIOPAMA Action Component grants

The Biodiversity and Protected Areas Management (BIOPAMA) Programme aims to improve the long-term conservation, sustainable use of natural resources and ecosystem services in Protected and conserved areas in African, Caribbean and Pacific countries. It provides funding opportunities to address protected and conserved areas, sustainable use of biodiversity, natural resources priorities for actions on the ground in African, Caribbean and the Pacific countries.

The BIOPAMA Action Component is a 21 million Euro grant-awarding facility managed by IUCN in the frame of the BIOPAMA Programme and financed by the European Union's 11th European Development Fund.

The main objective is to improve biodiversity conservation in priority areas through on the ground actions. It addresses key management and governance issues identified by diagnostic tools, whilst seeking co-benefits for human well-being and livelihoods, as well as for climate change mitigation and adaptation actions.

Medium Grants – 2022 – Eastern and Southern Africa Expression of Interest (EOI) closing date: 27 March 2022
Medium Grants – 2022 – Western and Central Africa EOI closing date: 10 April 2022
Medium Grants – 2022 – Pacific EOI closing date: 13 April 2022

[No doubt these closing dates have either past or are too soon for most people, but keep these grants in mind for the next round – Editor.]

Applying for grants for mollusc conservation projects: why you should add your project to the IUCN SSC Data System

In 2019 a new automated data management system was developed for reporting SSC Specialist Group members' activities within the SSC Commission. Prior to this, Specialist Groups created annual reports in Word, reflecting activities via a mix of grant project reports and, in the case of the Mollusc Specialist Group, articles in *Tentacle*, to cover the breadth of work ongoing throughout the world and acknowledge the individual projects and the funding basis for this work.

If projects are registered in the new data management system this can provide the opportunity to apply for small grants from SSC central funds that are only open to SSC Specialist Group members with registered projects; proposed projects will also be seen by the central fund-raising teams. Any project that then uploads an annual report against the planned targets should be automatically included in the annual reporting system and the project funders/sponsors would also be acknowledged.

To find out more about adding your mollusc conservation project to the SSC data management system please contact Mary Seddon – mary.molluscsg@gmail.com or Monika Böhm – mbohm@indyzoo.com

Mohamed bin Zayed grants 2019-2021

This funding source opens two to three times a year and allocates funds to practical conservation projects as well as field surveys gathering data for species assessments. Usually there will be a proportion of the funds allocated for major taxon groups including invertebrates. Recently, funding for mollusc conservation projects has ranged from $4,000 to $10,000. In any one round of awards only one project will receive the maximum funding available, most will get between $2,500 and $10,000 and not all projects will get the full amount they are seeking. Grant applications that have requests for capital items must be well supported, with the need for the equipment in terms of delivering the project aims as well as information about what will happen to the equipment at the end of the project.

The following are some examples of recent awards and completed projects funded by Mohaned bin Zayed grants.

Assisted recruitment of the critically endangered fan mussel *Pinna nobilis* in Cyprus
Project Leader: Valentina Fossati
Awarded $11,000, 5 November 2021

Searching for ghost endemic land snails species from Madeira Island (Portugal)
Project Leader: Dinarte Teixiera
Awarded $10,000, 10 January 2021

Rescuing *Microcondylaea bonellii*: a testimonial for non-iconic neglected species.
Project Leader: Nicoletta Riccardi
Awarded $6,500, 2 April 2020

Save the Forest Giants [Obô Land Snail (*Archachatina bicarinata*)]: conservation of terrestrial molluscs and native forest in a tropical island
Project Leader: Martina Panisi
Awarded: $4,950 – completed (see page 19)

Conservation of the endangered mussel *Unio crassus* in the Southern Bug River (Ukraine), which is under threat of hydrotechnical construction
Project Leader: Mikhail Son
Awarded $4,490, 23 August 2019

A Red List for molluscs from hydrothermal vents in the Indian Ocean
Project Leader: Julia Sigwart
Awarded $8,000, 30 March 2019

Successful small grant applications for mollusc projects promoted by IUCN/SSC

Examples are provided to give people an idea of the kinds of grants and amounts of funding that are available for small projects. Contact Mary Seddon – mary.molluscsg@gmail.com for more details.

Red List assessments of recently described threatened spring-snails in Morocco. SSC, ~ $3,000, 18 March 2022.

Conservation of threatened land snails *Advena campbellii* and *Mathewsoconcha belli* on Norfolk Island through pest control and predator exclusion fencing. Mohamed bin Zayed, $22,000, 19 December 2021.

Ecology and conservation of the snail *Chilina angusta*: a species of the Atacama Desert threatened of extinction. Mohamed bin Zayed, $8,000, 29 September 2021.

The last chance of saving the population of critically endangered species *Pinna nobilis* Linnaeus, 1758. Mohamed bin Zayed, $5,000, 29 September, 2021.

Preservation and recuperation of *Margaritifera margaritifera* (Linnaeus, 1758) in the Alberche River, Ávila, Spain. Mohamed bin Zayed, $5,000, 19 April 2021.

Saving Norfolk Island's critically endangered land snails through improved habitat management and captive breeding. IUCN Species Survival Commission / National Geographic Society / Fondation Segré, $49,000, 1 April, 2021.

A Survey to assess the status of the Critically Endangered, *Popenaias popeii* (Lea, 1857) (family Unionidae) in Mexico. Mohamed bin Zayed, $6,000, 29 December 2019.

Conservation of rare Mauritius endemic snails at Vallée de L'Est, Mauritius. Mohamed bin Zayed, $6,000, 25 September 2019.

Towards a regional redlist of the freshwater mussels of Sumatra and Java. Mohamed bin Zayed, $9,000, 24 September 2019.

Exploring terrestrial molluscan biodiversity in the Atewa Range Forest Reserve: a biodiversity hotspot in Ghana. Rufford Foundation, 9 August 2019.

Distribution and conservation of the endangered giant land snail (*Bertia cambojiensis*) in southern Vietnam. Rufford Foundation, 24 May 2019.

Initiating research and conservation of terrestrial molluscs in Armenia, Rufford Foundation, 2 January 2018.

Diversity, distribution and conservation status of Brunei's freshwater mussels. Rufford Foundation, 9 November 2017.

Some small grant sources

On the Edge Conservation: Red listing and action planning for evolutionarily distinct species and lineages.

Recovery of species on the brink of Extinction: IUCN Species Survival Commission (SSC) in partnership with National Geographic Society (NGS) and Fondation Segré promote this Request for Proposals (RFP) with the aim to halt further biodiversity decline by implementing IUCN SSC Species Conservation Plans for species and groups of species. [This programme is now in the process of being re-thought by National Geographic – Editor].

Rufford Grants: The Rufford Foundation awards a series of small grants and project leaders can apply for another follow-on grant on successful completion of their first grant project (value up to £6,000). Recipients of a first Rufford Small Grant will be provided with a webpage for reporting.

MEETINGS 2022

This is not a comprehensive list of mollusc and conservation related meetings but includes those for which people have sent me details and the major ones that I am generally aware of without doing a thorough search. Robert Cowie, *Tentacle* editor.

World Congress of Malacology 2022

The triennial Unitas Malacologica (UM) World Congress of Malacology (WCM) will be happening soon, hosted in Munich, Germany, during 1-6 August 2022. The theme of the meeting is "Meeting of generations" to emphasise the need for expansion of our scientific societies' reach and relevance across generations.

The plan is for the meeting to be in-person in one of Europe's most beautiful cities that will surely feature many opportunities to enjoy the city and surrounding natural attractions during the congress. Some of the field trips already planned for the middle day of the conference include half-day trips to The Botanical Garden Munich-Nymphenburg, The Paleontological Museum Munich, the Bavarian State Collection of Zoology and a full-day trip to Neuschwanstein Castle.

The deadline for early bird registration has passed, but you can still get a discount off the regular registration if you are a member of Unitas Malacologica. Abstracts are due on 15 April 2022, so there is not much time left. Additional information can be found at the WCM website. The Congress is being held in conjunction with the annual meeting of the American Malacological Society (AMS). Additional information about AMS activities at the WCM is provided below.

American Malacological Society annual meeting

The 2022 annual meeting of the American Malacological Society will take place in conjunction with the World Congress of Malacology (WCM) in Munich, Germany, during 1-6 August 2022. See above for details of the WCM.

The AMS President's Symposium will be one of the ten symposia and will focus on mollusc conservation. The symposium will feature a diverse lineup of international researchers with expertise in topics from across molluscan classes related to mollusc conservation. Our plenary speaker, Dr. Monika Böhm from the Global Center for Species Survival at the Indianapolis Zoo, USA, will kick off the symposium providing an updated picture of molluscan biodiversity and conservation. We have already lined up an impressive list of contributors, including keynote presentations by Dr. Alexandria Zieritz, University of Nottingham, UK, and Dr. Dinarte Teixeira, Institute of Forests and Nature Conservation IP-RAM, Portugal. We still have room for a few more speakers, so please sign up and contact AMS president Ken Hayes (hayes.ken@gmail.com).

On the second night of the congress the always lively and entertaining AMS auction will be held to raise funds in support of the next generation of malacologists. Following on from the highly successful virtual auction hosted last year, this year's auction will combine the best components of a virtual auction with in-person activities to facilitate broader participation and allow items to be auctioned off in person and virtually. This will allow some items to be shipped from donor locations, further reducing the costs and associated carbon footprint of those items.

The AMS Systematics Committee is also working to develop a taxonomically focused workshop that will join with an already planned workshop on "Nomenclature: rules and type species in molecular times" to be held on 6 August.

Conchologists of America 2022 convention

The 2021 CoA Convention is planned to take place in Galveston, Texas, 31 May - 4 June 2022. Additional information is available at the Convention website.

INTERNET RESOURCES

These are just a few of the many websites dealing with mollusc conservation, with molluscs and conservation in general, and available collection databases. If you would like me to include any new ones or to update any of the current ones, please send details to me, Robert Cowie, editor of *Tentacle*.

IUCN Red List

The entire *IUCN Red List of Threatened Animals* can be searched at the following address: www.iucnredlist.org

IUCN Invasive Species Specialist Group

The ISSG website includes details of the Aliens-L listserver and the ISSG newsletter, *Aliens*, published up to 2013.

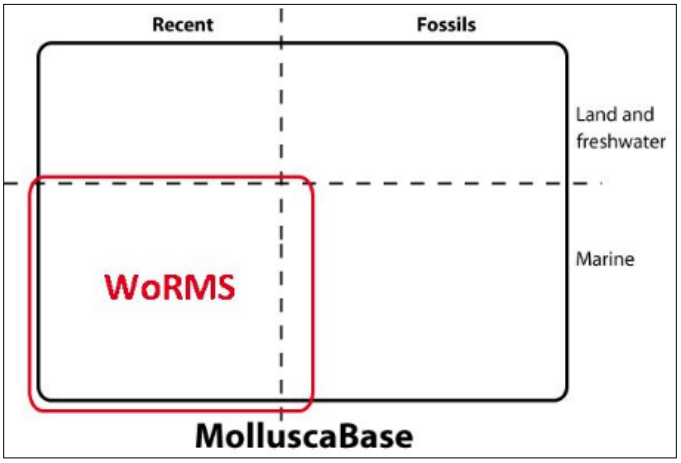
Unitas Malacologica

Unitas Malacologica (UM) is the worldwide society for malacologists and malacology. Its aim is to further the study of Mollusca by individuals, societies and institutions worldwide. UM has provided financial support for the production of *Tentacle* in the past and I urge all readers to become members. The UM website has links to many interesting and useful sources of malacological information, including all the UM newsletters, which have a lot of information complementing information in *Tentacle*. UM also makes small grants available to students for both research and travel to the triennial UM World Congress of Malacology. To become a member of UNITAS, go to its website and follow the links to the application.

Mollusca list

The MOLLUSCA listserver is an informal forum for discussions of molluscan biology. There are over 700 subscribers. You can subscribe to the list here. Once your subscription is approved, you will receive anything that is posted to the list, and be able to post to the list. To post to the list, send email to molluscalist@listserv.dfn.de. The list is now managed by Julia Sigwart of the Senckenberg Museum, Frankfurt, with David Lindberg and Gerhard Haszprunar.

MolluscaBase



MolluscaBase is a taxonomically oriented database that aims to provide an authoritative, permanently updated account of all molluscan species.

Subject to availability, the following information is provided for taxa included in MolluscaBase:

- Accepted (valid) name
- Classification (presented with a parent/child hierarchy)
- Synonyms
- Reference of original description and other relevant literature sources
- Type locality and distribution
- Stratigraphic range
- Traits (environment, feeding type, host/parasite relationship) and notes
- Images

The recent, marine component coincides with the Mollusca entries in the World Register of Marine Species (WoRMS), whereas the non-marine and fossil components are not displayed in the WoRMS interface, although the former are increasingly being added.

American Malacological Society

The homepage of the American Malacological Society carries a link to its Conservation Policy. Student research grants are available (scroll down on the homepage). Many useful links are provided on the Resources page.

Freshwater Mollusk Conservation Society

The Freshwater Mollusk Conservation Society (FMCS) is devoted to the advocacy for, public education about and conservation science of freshwater molluscs, North America's most imperiled fauna. Its website has an excellent page of links. The FMCS now publishes the journal *Freshwater Mollusk Biology and Conservation* (formerly *Walkerana*) and has all issues on-line and available, including volume 1, which includes Jack Burch's *Identification of Eastern North American Land Snails* and two-part *North American Freshwater Snails*.

Malacological Society of Australasia

The Malacological Society of Australasia is networked with the leading conservation organisations and is working with the IUCN Mollusc Specialist Group to list Australia's threatened and endangered species of molluscs. The society publishes the journal *Molluscan Research*.

Brasilian Society of Malacology

The Sociedade Brasileira de Malacologia (SBMa) welcomes malacological researchers, professionals and students, Brasilian and foreign, as well as aficionados of molluscs, having as its main objective to encourage the study of malacology, promoting knowledge of molluscs and its dissemination at all cultural levels, and taking reasonable measures to preserve the Brasilian mollusc fauna.

Conchologists of America

The homepage of the COA carries a link to a number of pages dealing with its conservation policy and conservation issues. Research grants are available.

Western Society of Malacologists

The WSM home page carries links to membership, conferences, grants, and other news.

Haus der Natur – Cismar

The Haus der Natur homepage carries a link to a page on mollusc conservation and responsible collecting, as well as other links.

The National Museum of Wales – Mollusca

The Mollusca page of the National Museum of Wales provides information on the global projects on molluscs underway based in Cardiff. The museum's Mollusca collection database is searchable.

Illinois Natural History Survey

The Illinois Natural History Survey's mollusc page has much information on the mussels of North America, with links to other mussel sites.

National Zoological Collection of India type specimens illustrated online

The Zoological Survey of India now has online information, including illustrations, for the type collections of the National Zoological Collection of India, including molluscs.

Field Museum land snails

The online database of Chicago's Field Museum mollusc collections contains information for most of its 165,000 land snail lots, including over 2,500 type lots. Freshwater lots (45,000) and most marine lots (90,000) are yet to be databased.

Museum of Comparative Zoology (MCZ) collections, Harvard University

The MCZ has migrated its legacy specimen records from multiple independent sources, including the Malacology Collection, to a single centralised database, MCZbase.

Academy of Natural Sciences, Philadelphia, Malacology Collection

The Malacology Collection database contains records related to 460,000 lots maintained in the Malacology Department.

The Natural History Museum, London

The collections database of the Natural History Museum can be searched via the Museum's Data Portal.

The Smithsonian Institution National Museum of Natural History, Washington

The Invertebrate Zoology collections, including Mollusca, can be searched online.

Florida Museum of Natural History Invertebrate Zoology Collection

The collection database, including Mollusca, can be searched online.

CLEMAM: Check List of European Marine Mollusca

The Check List of European Marine Mollusca database provides a list of taxonomic references concerning all molluscan taxa living in marine waters of Europe.

MUSSEL database project

The MUSSEL Project is an on-going study aimed at the global revision of the classification of the Unionoida, otherwise known as freshwater mussels. The two principle investigators, Daniel L. Graf and Kevin S. Cummings, combine their efforts to maintain an efficient malacological strike force equally capable of working in remote collection localities or urban mollusc collections. Toward this end, they are compiling an exhaustive database of all Recent described unionoid species and genera. This database will eventually serve as the basis for a universal synthesis and revision of freshwater mussel taxonomy.

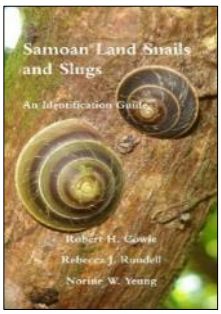
Unio listserver

Unio is an unmoderated internet listserver focusing on the biology, ecology and evolution of freshwater unionid mussels. The list is sponsored by the Florida Institute of Technology and administered and managed by Rick Tankersley (rtank@fit.edu).

Caucasian Snail Project

The Caucasian Land Snails Project is a major collaborative effort. The website is maintained by Bernhard Hausdorf, mollusc curator at the Zoological Museum, Hamburg University.

Samoan Snail Project



The Samoan Snail Project had as its goals assessing the diversity and historical decline of the native Samoan non-marine snail fauna, as a first step in its conservation. It is part of the Bishop Museum's Pacific Biological Survey. In 2017 an inexpensive illustrated paperback guide to the Samoan Islands land snail fauna was published (see *Tentacle* 26).

Hawaii Biological Survey

The Hawaii Biological Survey (based at the Bishop Museum, Honolulu) web site has searchable databases and much additional information on most Hawaiian organisms, including both indigenous (99 % endemic) and non-indigenous land and freshwater snails, endangered species, and so on.

Tropical land snail project at the Natural History Museum, London

The Tropical Land Snail Diversity site provides access to the Sri Lankan and South and South-east Asian snail projects of Fred Naggs, Dinarzarde Raheem and colleagues. There are some marvellous photos of brightly coloured snails.

Australian marine invertebrates

Overview of the Conservation of Australian Marine Invertebrates by W. F. Ponder, P. Hutchings & R. Chapman (588 p.), published in July 2002.

CITES

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The majority of information relates to mammal and bird trade, but a number of molluscs are listed in the Appendices.

Other useful links

www.manandmollusc.net/
www.staff.uni-mainz.de/lieb/Moll.html

TENTACLE – PUBLICATION GUIDELINES AND INFORMATION

Disclaimer 1: *Tentacle* is not issued for purposes of zoological nomenclature. All or any names or nomenclatural acts in it are disclaimed for nomenclatural purposes. See the *International Code of Zoological Nomenclature*, Fourth Edition, Article 8.

Disclaimer 2: Views expressed in *Tentacle* are those of the authors of individual articles. They do not necessarily reflect the views of the Editor, nor of the Mollusc Specialist Group, the Species Survival Commission or of IUCN.

Tentacle is a web-based newsletter, accessed at www.hawaii.edu/cowielab/Tentacle.htm, where all issues are available. Guidelines for submission of articles to *Tentacle*, and other related IUCN links are also on this website.

If you plan to submit something to *Tentacle*, please read the following guidelines. Carefully following the guidelines will make the life of the editor a lot easier!

Your submission **must** be **explicitly** relevant to **mollusc conservation** and the conservation relevance must be **specific to the study you are reporting**.

I usually make only editorial changes to submitted articles and in the past have accepted almost everything sent to me. However, before I accept an article I will assess whether it really includes anything **explicitly and specifically relevant to mollusc conservation** and whether any conclusions drawn are supported by the information presented. For example, **new records of non-native species and lists of non-native species will not be accepted unless there is a clear and significant relevance to mollusc conservation**. Also **reports of surveys will not be accepted unless there is a clear and specific conservation significance of the survey**. So, fully explain the specific conservation relevance in your article and be sure not to speculate too wildly. Unjustified statements (even if probably true) do a disservice to conservation as they permit our critics to undermine our overall arguments. *Tentacle*, however, is not a peer-reviewed publication and statements made in *Tentacle* remain the authors' responsibilities.

I stress that *Tentacle* is not a peer-reviewed publication. Please do not see *Tentacle* as an easy way to get your original data published without going through the rigours of peer review. ***Tentacle* is a NEWSLETTER** and so it is primarily **news items** that I want, including summaries of your ongoing studies, rather than full, data-rich reports of your research. Those reports should be submitted to peer reviewed journals. I will increasingly decline to publish articles that I feel should be in the peer-reviewed literature, especially if they are long.

There is, therefore, a **limit of three published pages**, including all text, illustrations, references, etc., for all articles that I accept for publication in *Tentacle* (though I reserve the right to make rare exceptions if I consider it appropriate).

Please make every effort to FORMAT YOUR ARTICLE, including fonts (Times New Roman), paragraphing styles, heading styles, and especially citations, in a way that makes it easy for me simply to paste your article into *Tentacle*, which is created in Microsoft Word. Please pay special attention to the format (paragraphing, fonts, font sizes, etc.) in past issues. TEMPLATES FOR ARTICLES ARE AVAILABLE – ASK ME IF YOU HAVE NOT RECEIVED ONE.

Conformance to the guidelines has improved – perhaps because of my many many reminders! But it still takes untold hours to format your submissions – please do it for me! Especially, please pay very careful attention to the format of references in the reference lists, especially punctuation – it still takes enormous amounts of time deleting commas, inserting colons, changing journal titles to italics, putting initials after not before names, deleting parentheses around dates and so on. Here are examples of how it should be done – please follow them very carefully:

Cowie, R.H., Bouchet, P. & Fontaine, B. 2022. The Sixth Mass Extinction: fact, fiction or speculation? *Biological Reviews* 97: 640-663.

Cowie, R.H., Evenhuis, N.L. & Christensen, C.C. 1995. *Catalog of the Native Land and Freshwater Molluscs of the Hawaiian Islands*. Backhuys Publishers, Leiden. vi + 248 p.

Cowie, R.H. 2011. Snails and slugs. In: *Encyclopedia of Invasive Introduced Species* (ed. Simberloff, D. & Rejmánek, M.), p. 634-643. University of California Press, Berkeley.

Please provide links to references if available.

Also note that **illustrations and tables must fit in a single column**, so make sure your maps, diagrams and tables are readable and show what you intend when they are reduced to this size. **Any text on a figure must be large enough to read**.

Metric Système International units are used throughout *Tentacle*. Please do not use miles, inches, gallons, etc.

Tentacle is published using **British English** not American English, e.g. "mollusc" not "mollusk"!

Membership of the Mollusc Specialist Group is by invitation. However, everyone is welcome to submit articles to *Tentacle* and to promote its distribution as widely as possible. Since I announce the publication of each new issue to all who are on my *Tentacle* e-mail distribution list, please keep me updated with your current e-mail address so that you do not drop off the list. I also announce the availability of each issue on the MOLLUSCA listserver (for details, see page 56 of this issue) and the Unitas Malacologica members e-mail list.

As always, I reiterate that the content of *Tentacle* depends on what you send me. So I encourage anyone with anything relevant to mollusc conservation to send me something now, and it will be included in the next issue (published once a year, usually in January-March).

IUCN SSC MOLLUSC SPECIALIST GROUP

This membership list now includes taxonomic and conservation expertises, to the extent they are known. In order to keep your details up to date, please inform the chair of the IUCN SSC Mollusc Specialist Group, Mary Seddon, and the editor of *Tentacle*, Robert Cowie, of any changes or corrections, especially regarding expertises. If there is any information you do not want to be public, please also inform us.

The list is in two parts: Official Members and Other Contributors. The former are currently listed on the IUCN official register of members of the IUCN SSC Mollusc Specialist Group. The latter are people who may have served on the Mollusc Specialist Group in the past or have provided assistance on enquiries, all of whom we acknowledge for their continued support of the work of the Group, although they are not currently listed on the IUCN official register of members.

Chair
Mary B. Seddon, Okehampton, UK. mary.molluscsg@gmail.com

Editor (*Tentacle*)
Robert H. Cowie, University of Hawaii, Honolulu, USA. cowie@hawaii.edu www.hawaii.edu/cowielab/

Name	Country	Taxonomic Expertise			Conservation Expertise								
		Marine molluscs	Freshwater molluscs	Land snails	Assessment	Survey & monitoring	Red List trainer	Habitat status & restoration	Conservation breeding	Conservation genetics	Environmental legislation	Invasive species	Wildlife trade
Official Members													
Christian Albrecht Justus Liebig University, Giessen	Germany		X		X	X				X			
David Aldridge University of Cambridge, Cambridge	UK		X			X				X		X	
Louise Allcock National University of Ireland, Galway	Ireland	X			X								
Maria Rosario Alonso Universidad de la Laguna, Tenerife	Spain			X	X								
Jose Arrebola Burgos Universidad de Sevilla, Sevilla	Spain			X	X				X				X
Thierry Backeljau Royal Belgian Institute of Natural Sciences, Brussels	Belgium	X		X	X					X		X	
Igor Balashov Schmalhausen Institute of Zoology, Kiev	Ukraine			X	X	X							
Gary Barker Landcare Research, Hamilton	Australia / New Zealand			X	X								
Gregory Barord Des Moines, Iowa	USA	X			X								
Arthur Bogan North Carolina State Museum of Natural History, Raleigh	USA		X		X	X			X				
Monika Böhm Global Center for Species Survival, Indianapolis Zoo	USA	X	X		X		X						

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		Marine molluscs	Freshwater molluscs	Land snails	Assessment	Survey & monitoring	Red List trainer	Habitat status & restoration	Conservation breeding	Conservation genetics	Environmental legislation	Invasive species	Wildlife trade
Official Members (continued)													
Ivan Bolotov Northern Arctic Federal University, Arkhangelsk	Russian Federation		X		X			X					
Prem Budha Tribhuvan University, Kathmandu	Nepal		X	X	X	X							
Viviana Castillo Servicio Agrícola y Ganadero, Santiago	Chile			X		X						X	
Chong Chen Japan Agency for Marine-Earth Science and Technology, Yokosuka	Japan	X			X	X							
Satoshi Chiba Tohoku University, Sendai	Japan			X		X			X				
Simone Cianfanelli Museo di Storia Naturale dell'Università degli Studi di Firenze	Italy		X	X	X	X			X			X	
Stephanie Clark Invertebrate Identification Australasia, Chicago, Illinois	USA		X		X	X							
Cristhian Clavijo Museo Nacional de Historia Natural, Montevideo	Uruguay		X		X	X							
Mary Cole East London Museum	South Africa			X	X	X							
Robert H. Cowie University of Hawaii, Honolulu, Hawaii	USA		X	X	X	X						X	
Kevin Cummings Illinois Natural History Survey, Champaign, Illinois	USA		X		X	X							
Gustavo Darrigran Museo de La Plata	Argentina	X	X		X							X	
Ivaylo Dedov Institute of Biodiversity and Ecosystem Research, Sofia	Bulgaria		X	X	X	X							
Zoltán Fehér Hungarian Natural History Museum, Budapest	Hungary		X	X	X	X		X					
Junn Kitt Foon Australian Museum, Sydney	Australia / Malaysia			X	X	X							
António Frias Martins Universidade dos Açores, Ponta Delgada	Portugal (Azores)	X		X	X	X							
Gerardo Garcia Chester Zoo	UK			X					X				
Olivier Gargominy Muséum national d'Histoire naturelle, Paris	France			X	X	X							
Daniel Geiger Santa Barbara Museum of Natural History, California	USA	X			X	X							
Jürgen Geist Technische Universität München, Freising	Germany		X		X	X			X				

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Official Members (continued)													
Dilian Georgiev University of Plovdiv	Bulgaria		X	X	X	X							
Justin Gerlach, University of Cambridge	UK/Seychelles			X	X	X							
Mohammed Ghamizi Muséum d'Histoire Naturelle de Marrakech, Marrakech	Morocco		X	X	X	X		X	X				
Ronaldo Gomes de Sousa University of Minho, Braga	Portugal		X		X	X		X	X	X		X	
Benjamin Gomez-Moliner Universidad de Pais Vasco, Vitoria	Spain			X	X	X							
Daniel Graf University of Wisconsin, Wisconsin	USA		X		X	X			X				
Klaus Groh Büro Groh, Bad Dürkheim	Germany	X	X	X	X	X							
Diego Gutierrez Gregoric Museo de La Plata	Argentina		X		X	X			X				
Michael G. Hadfield University of Hawaii, Honolulu, Hawaii	USA			X									
Jason Hall-Spencer University of Plymouth	UK	X						X					
Kenneth A. Hayes Bishop Museum, Honolulu, Hawaii	USA		X	X	X	X							
Dai Herbert National Museum of Wales, Cardiff	UK / South Africa	X		X	X	X							
Auke-Florian Hiemstra Naturalis Biodiversity Center, Leiden	Netherlands	X				X							X
Isabel Hyman Australian Museum, Sydney	Australia			X	X	X			X				
Mayu Inada Ministry of the Environment, Chichijima	Japan			X		X			X				
Paul Johnson Alabama Aquatic Biodiversity Center, Marion, Alabama	USA		X		X				X				
Umit Kepabci Mehmet Akif Ersoy University, Burdur	Turkey		X	X	X	X							
Michael Klutzinger North Lakes, Queensland	Australia		X		X								
Frank Köhler Australian Museum, Sydney	Australia		X	X	X	X							
Andrew Kough John G. Shedd Aquarium, Chicago	USA	X				X			X				X
Charles Lange National Museums of Kenya, Nairobi	Kenya		X	X	X								
Dwayne Lepitzki Wildlife Systems Research, Banff	Canada		X		X	X		X					

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Official members (continued)													
Marco Neiber Universität Hamburg	Germany		X	X	X	X							
Jeff Nekola Masaryk University, Brno	Czech Republic / USA			X		X							
Eike Neubert Naturhistorisches Museum, Bern	Switzerland			X	X	X							
Christine Ngereza National Museums of Tanzania, Dar es Salaam	Tanzania			X	X	X							
Vincent Nijman Oxford Brookes University, Oxford	UK	X											X
Ayu Nurinsiyah Museum Zoologicum Bogoriense, Bogor	Indonesia			X	X	X							
Mac Elikem Nutsaokor Kwame Nkrumah University of Science and Technology, Kumasi	Ghana			X	X	X							
Kristiina Ovaska Royal British Columbia Museum and Biolinx Environmental Research Ltd., Victoria	Canada			X	X	X		X	X				
Barna Páll-Gergely Centre for Agricultural Research, Budapest	Hungary			X	X	X							
Somsak Panha Chulalongkorn University, Bangkok	Thailand			X	X	X							
Christine Parent University of Idaho, Moscow, Idaho	USA/Galapagos			X	X	X							
Paul Pearce-Kelly Zoological Society of London	UK			X		X			X				X
Kathryn Perez University of Texas Rio Grande Valley, Edinburgh, Texas	USA		X	X	X	X		X					
Howard Peters University of York	UK	X			X								X
John Pfeiffer Smithsonian National Museum of Natural History, Washington, DC	USA		X		X	X				X			
Winston F. Ponder Australian Museum, Sydney	Australia												
Vincent Prié Muséum national d'Histoire naturelle, Paris	France		X		X	X		X		X	X		
Canella Radea National and Kapodistrian University of Athens	Greece		X		X	X							
Nicoletta Riccardi Institute of Ecosystem Study, Verbania Pallanza	Italy		X		X	X		X	X		X		
Ira Richling Staatliches Museum für Naturkunde Stuttgart	Germany		X	X	X	X				X			
Rodrigo Salvador Museum of New Zealand Te Papa Tongarewa, Wellington	New Zealand / Brasil		X	X	X	X			X				

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Official members (continued)													
Sonia B. dos Santos Universidade do Estado do Rio de Janeiro, Rio de Janeiro	Brasil		X			X							
Menno Schuilthuizen Naturalis Biodiversity Center, Leiden	Netherlands			X		X				X			
Mary B. Seddon Okehampton	UK	X	X	X	X	X	X				X		
Julia Sigwart Senckenberg Research Institute and Natural History Museum, Frankfurt am Main	Germany	X			X	X					X		
Ioan Sîrbu Lucian Blaga University of Sibiu	Romania		X		X	X		X				X	
David Sischo Department of Land and Natural Resources, State of Hawaii, Honolulu, Hawaii	USA			X				X	X				
Rajko Slapnik Agencija Republike Slovenije Okolje, Ljubljana	Slovenia		X	X	X								
Peter Tattersfield Bakewell, Derbyshire.	UK			X	X	X		X			X		
Dinarte Teixeria Instituto das Florestas e Conservação da Natureza, Madeira	Portugal (Madeira)			X	X	X	X						
Elin Thomas Queen's University Belfast, Portaferry	UK	X			X	X					X		
Kostas Triantis National and Kapodistrian University of Athens	Greece			X	X	X							
Do Van Tu Institute of Ecology and Biological Resources, Hanoi	Viet Nam		X		X	X							
Dirk Van Damme Destelbergen	Belgium		X		X	X							
Jackie Van Goethem Royal Belgian Institute of Natural Sciences, Brussels	Belgium	X		X		X							
Ilya Vikhrev N. Laverov Federal Center for Integrated Arctic Research, Arkhangelsk	Russian Federation		X		X	X				X			
Maxim Vinarksi Saint Petersburg State University	Russian Federation		X		X	X				X			
Ted von Proschwitz Göteborg Natural History Museum	Sweden		X	X	X	X							
Thomas von Rintelen Museum für Naturkunde, Berlin	Germany		X		X	X							
Norine Yeung Bishop Museum, Honolulu, Hawaii	USA			X	X	X		X	X				
Tadeusz Zajac Institute of Nature Conservation, Krakow	Poland		X		X	X			X				
Alexandra Zieritz University of Nottingham	UK		X		X	X			X				

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Other contributors													
Jonathan Ablett, Natural History Museum, London	UK	X		X									
Takahiro Asami Shinshu University, Matsumoto	Japan			X									
Ruud Bank, University of Groningen	Netherlands		X	X									
Rudiger Bieler Field Museum, Chicago	USA	X											
Philippe Bouchet Muséum national d'Histoire naturelle	France	X	X	X									
Khadija Boulaassafer Cadi Ayyad University, Marrakech	Morocco												
Bram Breure Naturalis Biodiversity Center, Leiden	Netherlands			X									
Gilianne Brodie University of the South Pacific	Fiji			X	X								
David Clarke Zoological Society of London	UK			X					X				
Robert Cameron University of Sheffield	UK			X	X	X							
Jay Cordeiro Boston	USA		X		X								
Willy De Mattia Natural History Museum Vienna	Austria			X	X								
Mark Etherbirdge Environment and Natural Resources	Bermuda			X					X				
Hiroshi Fukuda Okayama University	Japan	X											
Terrence Gosliner California Academy of Sciences, San Francisco, California	USA	X											
Owen Griffiths BioCulture Mauritius	Mauritus			X	X								
Nova Hanson Memorial University of Newfoundland	Canada	X			X								
Joseph Heller Hebrew University, Jerusalem	Israel		X	X	X	X							
Jasna Lajtner University of Zagreb	Croatia		X		X	X							
Charles (Chuck) Lydeard Morehead State University, Morehead	USA		X	X									
Maria Cristina Dreher Mansur Museu de Ciências e Tecnolo, Porto Alegre	Brasil		X	X									
Ristiyanti M. Marwoto Research and Development Centre for Biology, Bogor	Indonesia		X	X									

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Other contributors (continued)													
Paula M. Mikkelsen Paleontological Research Institution, Ithaca	USA	X											
Hugh Morrison Australian Sea Shells P/L	Australia	X			X								X
Richard Neves Virginia Tech, Blacksburg, Virginia	USA		X						X				
Diarmaid Ó Foighil University of Michigan	USA		X	X	X					X			
Timothy A. Pearce Carnegie Museum, Pittsburg	USA		X	X									
Shane Penny Fisheries, Department of Industry, Tourism and Trade, Northern Territories	Australia	X	X										
Vladimir Pešić University of Montenegro	Montenegro		X	X	X								
Guido Poppe Conchology Inc, Cebu	Philipinnes	X			X								X
Barry Roth San Francisco, California	USA			X									
David Robinson USDA/APHIS/PPQ, Academy of Natural Sciences, Philadelphia	USA			X									
Rebecca J. Rundell State University of New York, Syracuse	USA			X									
John Stanisic Queensland Museum, South Brisbane	Australia			X									
Jaap J. Vermeulen National Botanic Garden, Singapore	Singapore			X									
Peter Ward University of Washington, Seattle	USA	X											
Anton (Ton) J. de Winter Nationaal Natuurhistorisch Museum, Leiden	Netherlands			X									
Min Wu Nanjing University	China			X									
Xiaoping Wu Nanchang University	China		X										
Nicolas Zuel, Ebony Forest Ltd	Mauritius			X	X	X		X