First record of a feral breeding population of the exotic apple snail *Pomacea diffusa Blume*, 1957 from the Mumbai region.

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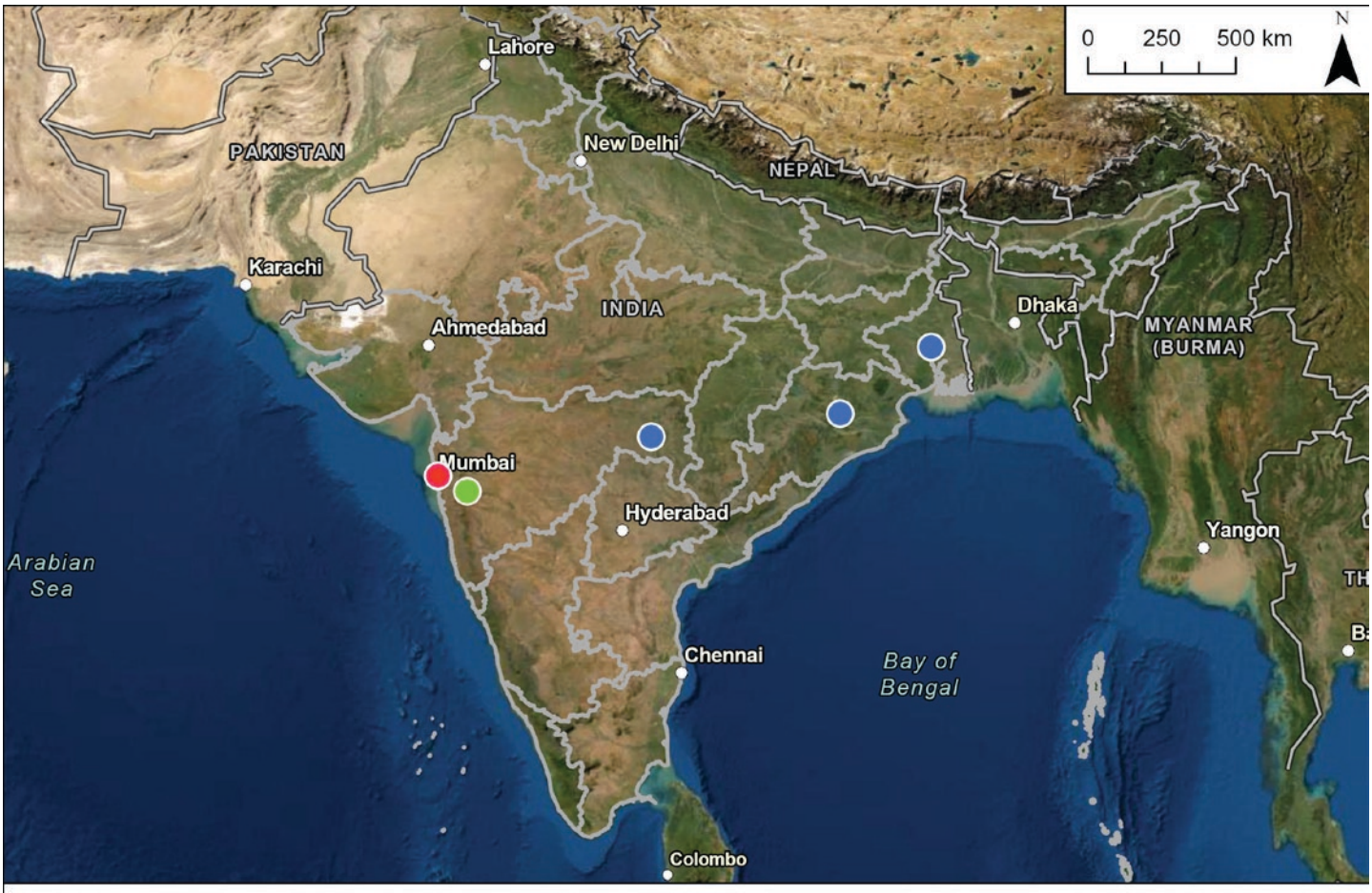
The Ampullariidae, J. E. Gray, 1824 are a diverse group of pantropical freshwater snails, with nine extant genera namely: *Pila* Röding, 1798 (Asia and Africa); *Pomacea* Perry, 1810 (southern South America, to southeastern USA, and the Caribbean islands in the far west of the Atlantic); *Marisa* Gray, 1824, *Pomella* Gray, 1847, *Felipponea* Dall, 1919, and *Asolene* d'Orbigny, 1838 (South America); Afropomus Pilsbry & Bequaert, 1927, Lanistes Montfort, 1810, and Saulea Gray, 1867 (Africa).

Popularly termed 'apple snails', they reach their highest diversity in South America, and play vital roles in the freshwater bodies they inhabit, creating an integral link between aquatic and terrestrial food chains. They can also be keystone species, in some of the ecosystems they inhabit, especially in important wetland biomes such as the Florida Everglades, the Llanos of Venezuela, and the Pantanal of central South America, (Berthold, 1991; Cowie et al., 2006 ; Donnay & Beissinger, 1993 ; Ebenman & Jonsson, 2005 ; Tanaka et al., 2006 ; K. A. Hayes et al., 2008, *as cited in* Kenneth A. Hayes et al., 2009).

In East Asia, native ampullariids occur in India, the basin of the Ganges, Sri Lanka, Thailand, Myanmar, Malaysia, and the islands of the Malay Archipelago, as far east as Bali and the Celebes and northwards to the Philippines (Baonan & Pagulayan, 2006).

Figure 1



Data sources: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, FAO, NOAA, SOI, and the GIS User Community. Basemap imagery © 2021 DigitalGlobe.

In India, the family is represented by the Genus *Pila* Röding, 1798, in the plains, and the somewhat controversial sub-genus *Turbinicola* Annandale & Prashad, 1921, in hill-streams (Prashad 1925, as cited in Baonan & Pagulayan, 2006; The Apple Snail Website: https://www.applesnail.net/content/species/pila_ampullacea.htm).

Amongst the non-native apple snails, only a single species, *Pomacea diffusa* Blume, 1957, has been recorded from the country thus far, from the states of Odisha and West Bengal in Eastern India, and Maharashtra in Western India. In the latter state, feral populations have been observed (and collected) in the Tadoba Andhari Tiger Reserve, in Chandrapur district, with a captive population recorded breeding in private aquaria in Kaspate Vasti, Wakad, in the city of Pune, Pune district (Raut & Aditya, 1999, in Pati & Sharma, 2013) (Figure 1).

The present report of a feral population from the city of Mumbai, in the Mumbai suburban district, is the first record of the species from the Mumbai region.

Specimens were found inhabiting the drainage system of the Kurla neighbourhood, in East Mumbai (19°04'01.2"N 72°53'09.6"E). The entire population consisted of the popular 'golden morph' (brightly colored yellow-orange specimens) of the species, prevalent in the aquarium trade, which is also the most likely source of feral populations of the species across its known distribution range within the country. (Figures 2*a*-*2*e).

The snails were first spotted being offered for sale by a local fish store, in Eastern Mumbai. Upon further inquiry, the proprietor, who was unaware of their South American origin, revealed that they were locally

Figure 2a

Figure 2b

Figure 2c

Figure 2d

Figure 2e

collected, and further added that the species has been seasonally harvested from local waters, and offered for sale in aquarium stores across Mumbai, from time to time, for many years.

A total of five specimens were maintained in the principal author's home aquaria for further observation, over a period of six months (Aug 2020-Feb 2021) where they displayed a distinct preference for prepared fish feed with high algae content, and also dead plant and animal matter. Living plants were not consumed.

Identification was based on the following morphological traits unique to the species, namely, apex (spire) is distinctly raised, possessing 5 to 6 sharply 'stepped' whorls, with square shoulders, and non-channelled sutures angled at almost 90˚ (Perera & Walls 1996; Bronson 2002, in Collier et. al 2011). Aperture (shell opening) is oval in shape, and the umbilicus deep. The species is also known as the 'spike-topped apple snail' on account of the aforementioned raised spire (Cowie et. al 2006, Rawlings et. al 2007) (Figures 3*a*-3*c*).

It should be noted that all records of P. *bridgesii* from India, and indeed the world, as an introduced

Figure 3a- Shell of 'Golden Morph' Pomacea diffusa, dorsal

Figure 3b- Shell of 'Golden Morph' Pomacea diffusa, ventral.

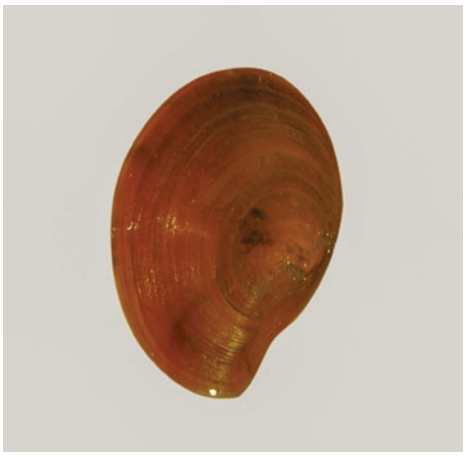


Figure 3c - Operculum

species, likely refer to *P. diffusa*, which was originally considered a subspecies of *P. bridgesii*, but has since been elevated to species. Additionally, *P. diffusa* has a much wider distribution, through much of the Amazon basin, as compared to *P. bridgesii*, which is restricted in range to Bolivia, and the western Amazon basin. *P. diffusa* is also the third most widely introduced species in the world, and has been introduced in India, Sri Lanka, Australia, and parts of the USA. (Raut & Aditya, 1999; Pati & Sharma, 2013; Cowie & Thiengo, 2003, Cowie et al., 2006, Rawlings et al., 2007, Hayes et al., 2008, 2009, Pain, 1960, Rawlings et al., 2007, Hayes et al., 2008; *in Joshi et. al, 2017*).

P. diffusa largely feeds on decaying organic matter, and algae, ignoring living plant tissue, and is therefore not considered a threat to aquatic plants, or cultivated crops such as rice (Morrison 2010; Wong et al. 2010, in Collier et. al 2011), unlike the much larger *P. canaliculata* (Lamarck, 1819), also offered in the aquarium trade, which is notorious for the damage it causes to rice paddy farming systems across Asia (Halwart, 1994), and displays a propensity for preying on amphibian eggs (Karraker & Dudgeon, 2014).

P. diffusa has also been observed preying on eggs of the ram-horn snail *Indoplanorbis exustus* (Deshayes, 1834) in captivity - a known disease vector, contributing to the spread of schistosomiasis, fascioliasis and amphistomiasis in domestic animals, and humans (Malek and Cheng 1974; Chen et al. 1986; Biswas 1991, in Aditya & Raut, 2002). This behavior, along with reports of the species readily incorporating animal carcasses (a behavior also observed by the principal author in his home aquaria), and live worms in its diet, in addition to a primary diet of aufwuchs [biofilm coating rocks and other surfaces, under water], raise concerns of similar behavior when introduced to ecosystems outside of its native range, which might result in competition with native species for comparable resources, even though potential direct, and indirect impact on habitats, and native species remains largely unknown, and requires further research (Rawlings et. al, 2007, Collier et. al, 2011).

Raghavan et. al, 2013, called for the aquarium pet trade in India to be regulated, especially in lieu of the unregulated export of threatened freshwater fish, while also noting that many international aquarium trade organizations advocated environmentally responsible practices, while condemning the collection of endangered species as bad for the industry (even if they have not been widely acknowledged). The authors of the present note earnestly support this point of view, while also echoing the sentiments expressed by Maceda-Veiga et al. 2016, in that while the aquarium hobby has certainly impacted habitats, species and ecosystems adversely, primarily through overcollection, and the introduction of alien species, it has also contributed to the conservation of several species of freshwater fish, and their habitats, and that dedicated, conscientious aquarists can aid conservation efforts by engaging in scientific research, public outreach campaigns, as well as in-situ, and ex-situ conservation programmes for native species, both nationally, and on a global scale.

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