

NON-INDIGENOUS FROGS IN SINGAPORE

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ABSTRACT. — The statuses of the non-indigenous frogs in Singapore are reviewed. Out of the 28 species of anurans known in Singapore, four are non-indigenous: *Hylarana guentheri* (Boulenger), *Kaloula pulchra* Gray, *Lithobates catesbeianus* (Shaw), and *Microhyla fissipes* Boulenger. The introduction pathways of the frogs are discussed, along with their status, distribution, impacts, and management issues with regard to Singapore.

INTRODUCTION

There are at least 28 species of anuran amphibians known in Singapore (Baker & Lim, 2012; Leong & Lim, 2011), of which 10 are threatened (Lim, 2008). While the most common threat is habitat loss (Brook et al., 2003; Baker & Lim, 2012), native anurans may also be potentially threatened by an increasing number of non-indigenous anuran species. There are currently four such species in Singapore, i.e., *Hylarana guentheri* (Boulenger), *Kaloula pulchra* Gray, *Lithobates catesbeianus* (Shaw), and *Microhyla fissipes* Boulenger (Baker & Lim, 2012; Leong & Lim, 2011). The increase in non-indigenous species (NIS) of anurans follows the general trend of growing introductions in Singapore (Yeo & Chia, 2010).

Despite the similarity in that trend, the introduction pathways of anuran NIS appear to be unique among the non-indigenous aquatic vertebrates here. While the pet trade has been linked to the introductions of many freshwater fishes (Ng & Tan, 2010) and reptiles (Ng & Lim, 2010) into Singapore freshwater habitats, there does not seem to be as strong a connection with the pet trade for anurans (see later: Introduction pathways under *Lithobates catesbeianus*). Only one amphibian species, White's tree frog (*Litoria caerulea*) from Australia and New Guinea, can legally be sold as a pet in Singapore (Agri-Food & Veterinary Authority Singapore, 2011), but it has not been recorded outside of pet shops. The anuran NIS that have been recorded in Singapore are known or suspected to have been introduced via various other pathways.

The introduction pathways of the four non-indigenous anurans in Singapore will be discussed here, along with their status, distribution, impacts, and management issues in the country. The native ranges are not explicitly presented because of the lack of data on historical distributions, and the possibility of unrecorded human-mediated introductions occurring in the past (Scalera, 2007). Nonetheless, possible native ranges are indicated using the available literature.

SPECIES ACCOUNTS

Family Microhylidae

Kaloula pulchra Gray, banded bull frog

Fig. 1

Diagnosis. — *Kaloula pulchra* has a stocky, rough-skinned body, and a characteristically thick, light-brown to orange band extending from behind the eyes down each side of the body (Berry, 1975). *Kaloula pulchra* has a snout-vent length (SVL) of up to 75 mm and feeds on insects (Baker & Lim, 2012). The species is largely terrestrial, and found in freshwater habitats in both natural forests and built-up areas (Berry, 1975; Baker & Lim, 2012).

Geographical distribution. — *Kaloula pulchra* was first described from China and is widely distributed from southern China and Taiwan, northeastern India and Bangladesh, throughout Indochina, down south to the Malay Peninsula and Singapore, and Sumatra, Borneo, Sulawesi, and the Philippines (Frost, 2011). Its true native range is unclear, but as early as the late 1800s, it was already found almost exclusively in the big towns in southern regions of Peninsular Malaysia (Boulenger, 1912). It may even have been introduced first to Singapore, before spreading north into the southern regions of the Malay Peninsula (Tweedie & Harrison, 1970).



Fig. 1. An adult *Kaloula pulchra* of about 70 mm SVL recorded on the banks of Jurong Lake on 8 Jul.2008. (Photograph by: Ng Ting Hui).

Local introduction and current status. — The species was noted to have spread quickly after it first appeared in Singapore in the 1880s (Flower, 1896). It is well-established in Singapore and is a widespread and common species throughout the island, from coastal areas to forests of the Central Catchment Nature Reserve (CCNR) (Baker & Lim, 2012).

Introduction pathways. — Lim & Chou (1990) suggested that *Kaloula pulchra* was introduced into Singapore accidentally via cargo being transported into Singapore from Peninsular Malaysia or from Thailand. However, anecdotal accounts from locals in the late 1800s attributed its introduction to a single person who brought the species into the country (Flower, 1896). The validity of this account cannot be verified. If it were true, one plausible reason for the introduction may have been as a food source. It is currently not sold for food, but it could have been possible in the past. *Kaloula pulchra* appears to be comparable in size to one of two common food species of anurans (*Fejervarya cancrivorus* and *Limnonectes blythii*) in Malaysia a few decades ago. The crab-eating frog, *Fejervarya cancrivorus* grows to 50–75 mm SVL (Berry, 1975, as *Rana cancrivora*) and is also known to be collected for food in some countries (Lue et al., 2004).

Impacts. — Although it has been present for more than 100 years in Singapore, and is also found in forested areas, *Kaloula pulchra* does not appear to have had any obvious impact on native fauna.

Management information. — The apparent lack of environmental impact and its preference for urbanised habitats places *Kaloula pulchra* at low risk of becoming an invasive organism in Singapore. Also, it is usually very difficult to eradicate long-established species, especially when the species has spread extensively (Simberloff, 2003).

Microhyla fissipes Boulenger, East Asian ornate chorus frog

Fig. 2

Diagnosis. — *Microhyla fissipes* is smooth-skinned, and has a reddish or greyish olive dorsum, with a dark, wavy marking extending from between the eyes and widening towards the posterior (as *Microhyla ornata* in Berry 1975). *Microhyla fissipes* has a maximum SVL of 25 mm and is an insectivore (Baker & Lim, 2012). It was previously considered a junior synonym of *Microhyla ornata* (Duméril & Bibron) (e.g., in Flower, 1896; Berry, 1975). However, a recent phylogenetic analysis using mitochondrial DNA showed that there are at least two distinct lineages—the South Asian *Microhyla ornata*, and the Southeast and East Asian *Microhyla fissipes* (see Matsui et al., 2005). *Microhyla fissipes* has been found in forests, grassland, agricultural land, and urban areas (Flower, 1896; Berry, 1975; Lau et al., 2008).



Fig. 2. A mating pair of *Microhyla fissipes* (each about 20 mm SVL) in a puddle at Pulau Tekong on 4 Apr.2006. (Photograph by: Norman T-L. Lim).

Geographical distribution. — The species was first described from southern Taiwan, and is distributed across southern and central China, Taiwan, Thailand and Indochina, and through the Malay Peninsula to Singapore (Frost, 2011). It has also been recorded from one locality in Sumatra, Indonesia (Lau et al., 2008). *Microhyla fissipes* was only recently recorded in the southern regions of Peninsular Malaysia (Grismer & Pan, 2008), whereas it was previously only known from the northern regions (Boulenger, 1912; Berry, 1975; as *Microhyla ornata*). Thus, the native range may have extended only to the northern regions of Peninsular Malaysia, with no known records of it from the central regions.

Local introduction and current status. — The species was first recorded in Singapore from young secondary forests of Pulau Tekong on 3 Aug.2005 (Lim et al., 2006; Baker & Lim, 2012). The first record included adult as well as larval specimens (Lim et al., 2006), which indicates that the species has established self-sustaining populations in Singapore. However, there have been no records or evidence of breeding since, and it has not been recorded from any other locality in Singapore. It is currently categorised as a restricted and rare species in Singapore (Baker & Lim, 2012).

Introduction pathways. — The locality from which *Microhyla fissipes* was recorded was previously a village (Lim et al., 2006) before Pulau Tekong was converted into a military training area, and has since become a secondary forest (Baker & Lim, 2012). The species could have been accidentally introduced via importation of plants or transportation of cargo onto the island.

Impacts. — Two supposedly native microhylids—*Microhyla butleri* and *Microhyla heymonsi*—are similar in size to *Microhyla fissipes* and are also insectivores (Baker & Lim, 2012). However, their preferred habitats range widely from urban to suburban and rural areas, and disturbed forests (Baker & Lim, 2012). Hence, the introduced microhylid should not pose a high level of competitive threat to its native congeners, especially given its highly restricted distribution in Singapore at the moment. Furthermore, all three species do occur sympatrically on Pulau Tekong with no obvious negative effects.

Management information. — With no known impacts on syntopic amphibians and limitation to one locality on an off-shore island, *Microhyla fissipes* has a very low risk of becoming invasive in Singapore. Since it is a recent introduction, and with Singapore presently the southern-most extremity of its range, ecological and genetic studies should be carried out on the local population to investigate its origins and the possibility of it spreading here (and from Singapore to other areas).

Family **Ranidae**

Hylarana guentheri (Boulenger), Günther's frog
Fig. 3

Diagnosis. — *Hylarana guentheri* is pale-brown dorsally, and has dark brown sides, prominent dorso-lateral folds, and a large, white-ringed tympanum (Leong & Lim, 2011). *Hylarana guentheri* generally grows to 80 mm SVL (Leong & Lim, 2011). This species is a human commensal, and is usually found in open swampy habitat (Leong & Lim, 2011). Populations are reported to have declined in some parts of China owing to habitat loss and overharvesting, but it is not a threatened species because it remains common in its range and breeds easily even in human-modified habitats (Lue et al., 2009). The presence of this species in Singapore was recently discussed in detail by Leong & Lim (2011).

Geographical distribution. — The species was originally described from Xiamen in southern China, and is distributed from southern China to central Vietnam (Frost, 2011). It has also been introduced to Guam (Christy et al., 2007), and recently, Singapore (Leong & Lim, 2011).

Local introduction and current status. — *Hylarana guentheri* is a widespread but uncommon species in Singapore (Baker & Lim, 2012). The calls of this species were heard from as early as 1997, but its occurrence was only confirmed visually with a specimen collected in 2008 (Leong & Lim, 2011). It was previously only recorded from the southwest (Jurong Bird Park and Jurong Central Park), and the northwest (Sungei Buloh Wetland Reserve and Lim Chu Kang area) regions of Singapore (Leong & Lim, 2011). Leong & Lim (2011) had proposed that the species was most likely established in the Lim Chu Kang area, and this was confirmed with the discovery of tadpoles in an aquatic plant nursery on 11 Jan.2012 (W. F. Ang, pers. comm.). One example (ZRC. 1.12481, male, SVL: 70.6 mm) was collected from a newly known locality on 28 Feb.2012—ornamental ponds on the grounds of a hospital in Yishun, in north-central Singapore. There may be a self-sustaining population in this locality as many individuals were seen and heard calling among the vegetation of the ponds. The barking calls of this species were also heard coming from a man-made floating platform of aquatic plants, on a storm-water retention pond immediately adjacent to the hospital.

Introduction pathways. — Leong & Lim (2011) postulated that the species could have been introduced accidentally as tadpoles with food or ornamental fish, or as adults hidden amongst ornamental plants, as there are plant nurseries and ornamental and aquaculture facilities in Lim Chu Kang. Its presence at the Jurong Bird Park could also be owed to it hitch-hiking on ornamental plants or as tadpoles with fishes brought into the park. This theory is further enhanced by the discovery of its latest locality in Yishun, because the individuals there were found in ponds which are heavily planted with ornamental aquatic plants and also contain various ornamental fishes. These are viable pathways, as the import of food fish from East Asian countries has been linked to the introduction of this species to Guam (Christy et al., 2007).



Fig. 3. An adult *Hylarana guentheri* of about 70 mm SVL at an aquatic plant nursery at Lim Chu Kang Lane 8 on 11 Jan.2012. (Photograph by: Ang Wee Foong).

Impacts. — *Hylarana guentheri* has toxic skin secretions that is known to be lethal to other frogs in enclosed areas (see Leong & Lim, 2011), but this impact has yet to be recorded in the wild. Nonetheless, predatory animals like native snakes may be at risk of being poisoned if they ingest this frog, as it was in the case of the toxic invasive cane toad (*Rhinella marina*) in Australia (as *Bufo marinus* in Shine, 2010). *Hylarana guentheri* has also been found to be a host of the parasitic roundworm, *Angiostrongylus cantonensis* (Lv et al., 2008), which causes the potentially lethal angiostrongyliasis in humans, mainly when intermediate hosts of this parasite (e.g., freshwater snails, crustaceans, and frogs) are consumed raw or undercooked (Alicata, 1991; Lv et al., 2008). Although the capture and consumption of these freshwater animals are not commonly practised in urban Singapore, the recreational use of some reservoirs for water sports may expose users to contact with raw water and the risk of accidental ingestion of the vectors or waters contaminated by parasites, should this species spread to these reservoirs. The species currently does not pose a threat to rare native species, as it is mostly confined to man-made habitats (where native species are uncommonly found) and appears to be rare at the Sungei Buloh Wetland Reserve.

Management information. — While *Hylarana guentheri* is currently found in urban habitats and may not likely pose a serious risk, it is worth examining the three disjunct populations using ecological studies and molecular methods. This would help elucidate the origins of the introduced population in Singapore, and contribute to a better overall understanding of introduction pathways. Such directed studies may in turn allow for improved management of non-indigenous anurans in Singapore. The toxicity of its skin secretions to potential native predators should also be studied, and the individuals found in the wild here should be screened for *Angiostrongylus cantonensis* to accurately assess the future impacts of this species.

***Lithobates catesbeianus* (Shaw), American bull frog**

Fig. 4

Diagnosis. — *Lithobates catesbeianus* has a large tympanum, and a reticulated pattern across its body, with a pale green to dark olive dorsum, and a pale underside (Global Invasive Species Database, 2009). *Lithobates catesbeianus* is the largest among the four alien anuran species in Singapore, with a maximum SVL of 200 mm. This species can be found in habitats ranging from natural (e.g., lakes and swamps) to artificial (e.g., reservoirs) water bodies (Adams et al., 2003). The tadpoles consume algae, while the adults feed opportunistically on various prey organisms including crayfish, insects, frogs, and other vertebrates (Pryor, 2003; Hirai, 2004). This is the only non-indigenous anuran found in Singapore that is on the IUCN's list of 100 World's Worst Invasive Species (Lowe et al., 2004).

Geographical distribution. — The American bull frog was described in 1802 and was found in localities like South Carolina and Virginia in eastern United States of America (USA) (Frost, 2011). It is currently distributed in the New World from northern Canada and eastern USA, and central and south Mexico (Frost, 2011). *Lithobates catesbeianus* is likely to be native only to eastern USA, and has been introduced to a few localities in western USA (Adams et al., 2003).



Fig. 4. An adult *Lithobates catesbeianus* of about 200 mm SVL at the fishing grounds of Lower Peirce Reservoir on 20 Jan.2009. (Photograph by: Ng Ting Hui).

It has also been introduced to more than 40 other countries worldwide, including Belgium, Cuba, France, Indonesia, Italy, Japan, Korea, Malaysia, the Netherlands, Spain, Puerto Rico, Singapore, Thailand, and Taiwan (Global Invasive Species Database, 2009; Frost, 2011).

Local introduction and current status. — The species was first imported into Singapore and observed to be sold as food in the 1980's (Ng & Lim, 2010). The first recorded individuals in the wild were from Upper Peirce Reservoir in 1989 (Lim, 1989, as *Rana catesbeiana*). Presently, *Lithobates catesbeianus* has been recorded from five out of the 17 reservoirs in Singapore (Ng & Lim, 2010), and individuals have been observed in core areas of Bukit Timah Nature Reserve (BTNR) and streams at the edge of the CCNR (D. J. J. Ng, pers. comm.). Although it is categorised as a widespread and common species (Baker & Lim, 2012), we have known it to be common only at two urban reservoirs—Bedok Reservoir and Jurong Lake (N. T-L. Lim, pers. comm.). All other records were either of one individual or suspected batches of recently released individuals, including the ones at BTNR and the CCNR. The species does not appear to be breeding in the wild as no eggs or tadpoles have been recorded to date (Ng & Lim, 2010), although it is apparently being successfully bred locally in captivity (see below).

Introduction pathways. — While *Litoria caerulea* is the only amphibian that can legally be sold as a pet in Singapore, there are no equivalent restrictions placed by the Agri-Food & Veterinary Authority Singapore on species that are bred and sold as food. *Lithobates catesbeianus* is mostly imported into Singapore by the Jurong Frog Farm (C. Wan, pers. comm.) and live frogs are widely sold in markets and restaurants (some frogs at the farm also breed in the concrete holding pens [C. Wan, pers. comm.]). Juveniles of the species are commonly sold in pet shops as feed for predatory ornamental fishes. The first record of *Lithobates catesbeianus* found in the wild in Singapore was of a few dead frogs and one live individual at the banks of Upper Peirce Reservoir (Lim, 1989). This indicated that its most likely pathway of spread is through intentional release by people. Local records have mostly been of individual adults or groups of juveniles. Owing to the ease of buying live *Lithobates catesbeianus*, these records were likely a result of releases by religious devotees seeking to gain spiritual merit or were unwanted bait discarded by anglers (Ng & Lim, 2010). The species does not appear to be breeding outside the frog farm as no eggs or tadpoles have been recorded to date (Ng & Lim, 2010).

Impacts. — The ecology of the the American bull frog in Singapore is not well understood, and so far no ecological studies have been published on this topic. However, it is considered a highly invasive species in many other parts of its introduced range as it has been recorded to be a carrier of the deadly fungus *Batrachochytrium dendrobatidis*, a predator of native species, and a competitor of native species (Global Invasive Species Database, 2009). The possible impacts of *Lithobates catesbeianus* in Singapore are mostly disease transmission and predation, especially since many native species are much smaller than the bullfrog (19 out of 24 native species are under 100 mm SVL, see: Baker & Lim, 2012). For a few similarly large native species (e.g., *Limnonectes malesianus*, *Limnonectes blythii*), however, competition from the American bull frog is another possible impact that needs to be considered. As the species seems to be breeding in the Jurong Frog Farm with no human assistance (Ng & Lim, 2010), there is a chance that it might be able to establish breeding populations in the wild, especially given the high propagule pressure (Lockwood et al., 2005). That being said, sustained and frequent releases into habitats like BTNR and the CCNR alone may be sufficient to introduce large enough numbers to threaten native species, which are mainly found in the forests and streams of the CCNR (Baker & Lim, 2012). Large-scale releases of the frogs may result in pollution of the aquatic habitats that they are released into (e.g., reservoirs or streams), if the frogs are diseased or die en-masse for insufficient food resources to support them.

Management information. — Owing to its history of being an invasive species elsewhere, *Lithobates catesbeianus* should be treated as having a high risk of becoming invasive in Singapore as well. The prevalence of intentional releases should be addressed to prevent a constant introduction of individuals into sensitive areas like the CCNR. Effective enforcement of regulations that ban the release of animals in nature reserves and wide-reaching public education is necessary to prevent such releases. The National Parks Board (NParks) has an outreach programme, with activities intensifying close to Vesak Day, involving rangers and volunteers who patrol various sites around the CCNR reservoirs to discourage people from releasing animals (National Parks Board, 2009). Also, the reservoirs should be studied and monitored for the occurrence of established populations of this species.

DISCUSSION AND CONCLUSIONS

Kaloula pulchra was the sole anuran NIS for almost a century. However, in a relatively short span of time, three other species have been introduced within the past 20 years. A handful of native species in Singapore are regarded as human commensals. They include the Asian toad (*Duttaphrynus melanostictus*), the four-lined tree frog (*Polypedates leucomystax*), the dark-sided chorus frog (*Microhyla heymonsi*), the painted chorus frog (*Microhyla butleri*), the green paddy frog (*Hylarana erythraea*), the field frog (*Fejervarya limnocharis*), and the crab-eating frog (*Fejervarya cancrivorus*). These are found largely in urban and disturbed habitats and clearings, but rarely within the forest (Flower, 1896; Baker & Lim, 2012). Although they are currently considered to be indigenous fauna, we cannot discount the

possibility that they might have been introduced through early human settlement in Singapore and became naturalised prior to the arrival of the British (and the beginning of faunal records for the island) in 1819. Therefore, long-term monitoring and in-depth studies of the anurans (including native species) are necessary for effective management and conservation efforts. These would also contribute to more successful public education to reduce intentional releases of NIS, especially those that are potentially invasive.

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