REPTILES & AMPHIBIANS

Emerging Community Reports of the Highly Invasive American Bullfrog (*Lithobates catesbeianus*) in Hong Kong

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A broad range of fauna has been transported anthropogenically by accident or intentionally (Eskew et al. 2020; Bezerra-Santos et al. 2021). Amphibians are increasingly popular in the global pet trade, generating appeal from their distinctiveness and reduced space requirements compared to most traditional companion animals (Mohanty and Measey 2019). The pet trade plays an important role in non-native species reaching new environments, either from owners abandoning pets (Stringham and Lockwood 2018; Lockwood et al. 2019) or animals escaping (Liu and Li 2009; Mo and Oliver 2020). It has been documented that the trade in live amphibians as pets is associated with the majority of amphibian introductions outside their native range (Kraus 2009). A number of invasive populations of amphibians are also associated with cargo and luggage stowaways (Kraus and Campbell 2002; García-Díaz and Cassey 2014; Mo 2017; Hong et al. 2022). In many parts of Asia, captive animals are also released by members of the public as part of a Buddhist act believed to build spiritual merit (Agoramoorthy and Hsu 2005; Chan 2006; Ng and Lim 2010; Gilbert et al. 2012; Liu et al. 2012).

Exotic herpetofauna are freely traded in Hong Kong, a special administrative region of China (Mo 2020). This has enabled herpetofauna such as the Red-eared Slider (*Trachemys scripta elegans*) and possibly other non-native chelonians to proliferate in local urban ponds and waterways (Lau et al. 2000; Mo 2019a). Other herpetofauna introduced to Hong Kong include the Tokay Gecko (*Gekko gecko*; Romer 1951), Brook's House Gecko (*Hemidactylus brookii*; Romer 1977) and the Chinese Water Dragon (*Physignathus cocincinus*; Mo 2019b). The establishment of populations of invasive herpetofauna raises concerns for potential ecological impacts such as competition with native species (Polo-Cavia et al. 2011) and biological impacts such as pathogen transmission (Garner et al. 2006; Liu et al. 2013; Kolby et al. 2014; Meyer et al. 2015; Zhang et al. 2022). Similarly, the live plant trade is believed responsible for the introduction of the Greenhouse Frog (*Eleutherodactylus planirostris*) to Hong Kong (Lee et al. 2016), while the wholesale availability of live amphibians in the local pet trade facilitates an ongoing risk of further amphibian introductions.

The American Bullfrog (*Lithobates catesbeianus*), native to eastern North America (Ficetola et al. 2007a), is a large amphibian, reaching 500 g in mature females. The species is a general carnivore (Leivas et al. 2012; Liu et al. 2015) and exhibits a high degree of environmental plasticity, colonizing anthropogenic and modified habitats such as artificial ponds, canals, and culverts (Rubbo and Kiesecker 2005; Maret et al.

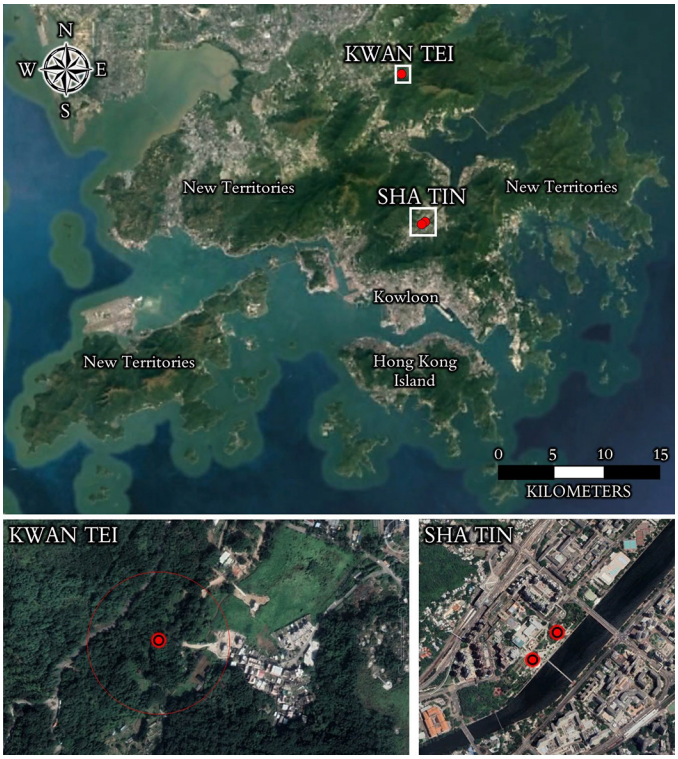

Fig. 1. Locations of three community reports of American Bullfrog (*Lithobates catesbeianus*) observations in Sha Tin and Kwan Tei, with inset maps showing topography and surrounding land uses. The geographic coordinates for the Kwan Tei observation were attributed to positional accuracy of 122 m, which is shown in the inset map by the red radius.

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2006). This adaptability has enabled American Bullfrogs to spread and establish invasive populations elsewhere in North America, including the western United States of America, Canada, Mexico, Cuba, the Dominican Republic, and Jamaica (Govindarajulu et al. 2006; Luja and Rodríguez-Estrella 2010; Nelson and Piovia-Scott 2022; South American countries including Argentina, Brazil, Uruguay, Venezuela, and Colombia (Giovanelli et al. 2008; Laufer et al. 2008; Barrasso et al. 2009; Nori et al. 2011); European countries including Italy, the Netherlands, Belgium, and France (Ficetola et al. 2007b; Johovic et al. 2020); and Asian countries including China, South Korea, and Japan (Li et al. 2011; Kang et al. 2019; Lin et al. 2019). As a result, it is considered among the world's 100 worst invasive species (Lowe et al. 2000; D'Amore 2012).

Established populations of the American Bullfrog have yet to be found in Hong Kong although the species has long been naturalized in mainland China (Cheng and Feng 2004; Wu et al. 2005; Yiming et al. 2006; Bai et al. 2012). We queried observations of American Bullfrogs in Hong Kong on the online biodiversity database iNaturalist (California Academy of Sciences and the National Geographic Society 2021), an application that gathers crowdsourced spatiotemporal data on observations of organisms or evidence of their presence (such as tracks, nests, or skeletal material) through registered application users uploading photographs of their observations from the field. The photographs enabled us and other application users to review the observations and verify species identifications.

As of 1 October 2022, there were three reported observations of American Bullfrogs in Hong Kong in the iNaturalist application (Fig. 1). In all cases, adult individuals were observed. The first two observations were made by the same application user four days apart in December 2018 (Table 1). Both observations occurred in Sha Tin Park, an 8-ha public recreational park situated along the Shing Mun River, eastern New Territories. Based on photographs lodged in the application, the American Bullfrogs were adult specimens inhabiting the shallow part of a clear waterbody. The third observation was an adult specimen reported by a different application user in a natural or agricultural area in the vicinity of the Hok Tau Village, Kwan Tei, northern New Territories. The positional accuracy of the geographical coordinates reported (122 m) was too broad to determine the exact land use of the site where the American Bullfrog was observed. However, the photograph in the application also shows a shallow part of a clear waterbody. This third and most recent observation occurred on 1 May 2020 (Table 1), 29 months prior to the preparation of this research note.

Fig. 2. Juvenile American Bullfrogs (*Lithobates catesbeianus*) available for sale in one of five pet shops in Hong Kong that were selling these frogs. Photograph by M. Mo.

During October 2016, we documented species being sold by retailers at Tung Choi Street, Mong Kok, which is Hong Kong's largest pet market (Chan and Sadovy 2000; Sung et al. 2021). Of the 21 pet shops visited, we found 12 retailers that sold live amphibians. Five of these shops sold juvenile American Bullfrogs. In all cases, the bullfrogs were displayed to prospective customers in an open-topped box at the front of the shop, each containing several hundred individuals (Fig. 2). Considering the commercial distribution of these numbers of American Bullfrogs, it is not inconceivable that this amphibian could become an invasive species in Hong Kong in the future. The present global invasiveness of the American Bullfrog (Ficetola et al. 2007a,b; Johovic et al. 2020) highlights the need for caution. Appropriate preventative measures could include legislation prohibiting the sale and private keeping of species with known patterns of invasiveness.

Information from online biodiversity databases has provided a means for early detection of a number of potentially and confirmed invasive species, particularly in recent times (Mo 2019b; Pawson et al. 2020; Werenkraut et al. 2020; Mesaglio and Callaghan 2021; Mo and Mo 2022). Community reports of American Bullfrog observations in

Table 1. Summary of reported American Bullfrog observations in Hong Kong.

Record identity	Observer	Observation date	Latitude	Longitude	Positional accuracy	Locality
19189997	B. Leung	24 December 2018	22.381095	114.191109	15 m	Sha Tin
19250341	B. Leung	27 December 2018	22.379852	114.190084	15 m	Sha Tin
44856256	P. Ng	1 May 2020	22.502026	114.172386	122 m	Kwan Tei

Hong Kong further demonstrate the value of community science as a pathway for documentation of exotic animal incursions. This information repository provided a preliminary dataset in the absence of established research programs dedicated to the subject. Despite the small sample size, the dataset has important implications for biosecurity and environmental management, especially if further observations of American Bullfrogs emerge in the future. We therefore recommend periodic monitoring of community reports of American Bullfrog observations in Hong Kong to detect potential clustering of reports and evidence of potential establishment.

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