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The Asian market of frogs as food for humans during COVID-19. Risk and consequences for public health

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Summary

Amphibians are currently facing a global extinction crisis and trade has been identified as a major driver in this decline. Also amphibian trade is known to facilitate the geographic spread of pathogens. Frogs and frog legs are widely regarded as culinary treats in most regions of the world, including Europe, United States, Asia and Australia. The closures of the Asian animal markets due to the COVID-19 pandemic will have important economic and social repercussions worldwide. There is fear of a return to the illegal and incorrectly controlled frogs market.

Key Words

COVID-19, Asia, Amphibians, Wildlife trade.

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Introduction

In December 31, 2019, hospitals reported a cluster of cases with pneumonia of unknown cause in Wuhan, Hubei, China, attracting great attention nationally and worldwide (Wang et al., 2020). On January 1, 2020, Wuhan public health authorities shut down the Huanan Seafood Wholesale Market, where wild and live animals were sold, due to a suspected link with the outbreak. At the time, state-run Xinhua News Agency reported that it was being closed for renovations. On January 7, 2020, researchers rapidly isolated a novel coronavirus (SARS-CoV-2, previously referred to as 2019-nCoV) from confirmed infected pneumonia patients. Real-time reverse-transcriptase polymerase chain reaction (Real-time RT-PCR) and next-generation sequencing were used to characterize it. The number of RT-PCR-confirmed cases has increased rapidly. On January 30, 2020, the World Health Organization (WHO) declared COVID-19 (as it would be officially known as of February 11) to be a Public Health Emergency of International Concern (PHEIC) and declared an epidemic (Jiang et al., 2020). On March 11, WHO stated that COVID-19 can be characterized as a pandemic, due to the rapid increase in the number of cases outside China. In fact, in March 2020, the center of the pandemic moved to Europe, then later shifting to the USA in April. At the moment, November 28, 2020, there are 61,877.685 people infected in the world and 1,447.246 dead ones.

As of now, SARS-CoV-2 is considered the seventh coronavirus that infects humans. The other coronaviruses (CoVs) include HKU1, NL63, OC43, 229E, SARS-CoV, and MERS-CoV. SARS-CoV and MERS-CoV are zoonoses and have resulted in high mortality outbreaks in the last two decades, while the others are usually associated with mild upper-respiratory tract illnesses (Tiwari et al., 2020; Wei et al., 2020), and sometimes leading to complicated disease when occurring in immunocompromised individuals (Tiwari et al., 2020; Villamil-Gomez et al., 2020). Before this event that changed our lifestyle and also conditioned food choices, the Wuhan market was one of the most important centers for the sale of animals used as human food and there they sell, in addition to seafood and other objects, animals like birds (chickens, pheasants), bats, hedgehogs, marmots, frogs and snakes, as well as organs from rabbits and other animals (Ralph et al., 2020). Cages with animals that had been captured in the wild or bred in captivity - many of them lethargic, sick

and dying with open wounds caused during their capture and transportation - were stacked on top of each other. Many species of wild animals are crowded together under unhygienic and stressful conditions and frequently slaughtered on the premises, providing ideal circumstances for the spread of zoonoses (Humane Society International, 2020). In China, the wildlife sector enjoys numerous privileges. Chinese authorities issued a special national law in 1989, the Wildlife Protection Law (WPL), later revised and integrated in 2006, but despite this law, the trade in wildlife for human consumption is still a big deal. Many farmers raise frogs to sell them at wet markets and restaurants, especially in Guangdong province in southern China, where frogs are a popular delicacy. But on January 26, China announced a national ban on wildlife trade in response to the coronavirus pandemic, suddenly stopping all breeding activities. A month later, China's top legislative body went further, banning all food and related trade in wild land animals - be they wild or captive bred - effective immediately, warning that offenders would be severely punished. Many of the roughly 14 million people involved in wildlife breeding are based in poor rural areas that were heavily reliant on the industry. If the market isn't phased out smoothly, experts warn the ban could cause severe side effects as breeders go bankrupt or try to continue selling on the black market. The Chinese government has announced that it is fully committed to enforcing the ban on reducing the risk of future pandemics. As with the SARS crisis of 2003, scientists believe that coronavirus originated from bats and was transmitted to humans through an intermediate host: although pangolins were among the first animals suspected (Andersen et al., 2020), the real intermediate remains still to be determined. In lab experiments, cats, fruit bats, ferrets, rhesus macaques and hamsters have been shown to be susceptible to SARS-CoV-2.

On February 3, Chinese President Xi Jinping ordered officials to crack down on markets that sell animals illegally and eliminate the "bad habit of overeating wildlife". In the days following the president's speech, government officials launched a massive inspection campaign targeting wet markets and restaurants known for selling exotic animals (Zhang et al., 2020). By February 27, approximately 350,000 locations had been inspected and 39,000 animals seized, according to the National Forestry and Grassland Administration. Prior to this ban, the government had enthusiastically promoted the breeding of wild animals, considering it an excellent method of reducing poverty in rural communities. The Chinese National Forestry Office has named wildlife that breeds the industry in its five-year plan for 2011–2015, while the central government has included it in its 2018 rural revitalization strategy. A surprisingly huge number of frogs (hundreds of millions of individuals) are consumed in the EU and USA every year and a large part of these animals come from Asia (Warkentin et al., 2009; Altherr et al., 2011). The sustainable use of natural resources is a strong political argument to preserve biological diversity (CBD, 2008). However, overexploitation of these resources is also one of the major threats to the conservation of nature (Cowlishaw, 2005; CBD, 2008). For example, overexploitation is mentioned as one of the reasons for the worldwide amphibian decline (Stuart et al., 2004, 2008). Amphibians are currently facing a global extinction crisis (Stuart et al., 2004; Gascon et al., 2007; Corey & Waite, 2008; Wake & Vredenberg, 2008; Warkentin et al., 2009; Carpenter et al., 2014) and trade has been identified as a major driver in this decline (Gibbons et al., 2000). To supplement the higher demand for frogs, and to counteract the effects of over-harvesting, some countries have introduced frog farming.

DISCUSSION

The international trade in frogs' legs has increased substantially over the last thirty years. The increased exports are evidently due to a higher demand for frogs' legs in the consuming countries and were made possible by better freezing techniques and improved transport facilities within the countries of export. Islam forbids the consumption of frogs, but allows their collection, breeding and sale. Frog meat is considered as haraam (non-halal) according to mainstream Islamic dietary laws. Frog meat is not halal as frogs, together with ants, bees, and seabirds, are animals that should not be killed by Muslims. This haraam status has caused controversy in Demak, Indonesia, where the authorities urged the swikee (frog legs soup) restaurant owners not to associate swikee with Demak city, since it would tarnish Demak's image as the first Islamic city in Java, and also opposed by its inhabitants that mainly follow Shafi'i school that forbids the consumption of frogs. Within Islamic dietary law there are some debates and differences about the consumption of frog legs. The mainstream Islamic madhhab of Shafi'i, Hanafi and Hanbali strictly forbids the consumption of frogs, but according to the Maliki School, only the green frog commonly found in rice fields may be eaten, while other species, especially those with blistered skin, are considered to be unclean. So the economic importance

of frog meat derives mainly from foreign trade. The number of frogs killed is much higher than indicated by export figures, because many frogs are dead on arrival at the processing plants and cannot be exported. In Indonesia, for example, forty to fifty per cent more frogs are killed than exported because of the "lack of export quality" (IUCN, 1986). The markets of the most important Asian countries are analyzed below.

The Bangladesh market

The major export markets for frozen frog legs during 1991–1992 were USA (92.03%), Belgium (4.49%) and Canada (3.48%). In Bangladesh a ban on the collection of *R. tigerina*, *R. hexadactyla* end *R. limnocharis* was imposed in 1982, 1983 and 1984 from 15 April to 15 May. The ban was annulled on 10 May 1984. However, it had been widely ignored and frogs were collected and kept in holding tanks for export after the end of each yearly export ban. In 1985 Bangladesh re-established an export ban to run from 15 April to 15 July (IUCN, 1986). Bangladesh has permanently banned export of frogs' legs in 1989 in order to preserve the environment.

The Indian market

All species of *Rana* are protected in India under the 1972 Wildlife Protection Act. Collectors and processors have to obtain licenses from regional offices which also have to control the quantities caught. In 1984 India established an export quota of 4.000 t and reduced this to 2.500 t in 1985 (IUCN, 1986). At the fifth meeting of the Conference of the Parties to CITES, held in Buenos Aires, Argentina, in April-May 1985, the delegation of India said that their Government was considering further reduction of the quota over the next few years or even an export ban for some years. The proposal presented at that meeting by Germany to list *R. tigerina* and *R. hexadactyla* on Appendix II of CITES, was adopted in the light of growing concern over the plight of frogs in Asia (IUCN, 1986). Prior to this important regulation, severe exploitation had resulted in the collapse of many wild frog populations in this country. In turn, the decline of these species has resulted in a dramatic increase in the use of pesticides, due to an explosion of insects and other agricultural pests previously controlled by frogs. According with Pandian & Marian, 1986 a ban on the frog export from India would mean the loss of not only a revenue of 10 million US dollars/annum but also the jobs for 0-16 million villagers. India has permanently banned export of frogs' legs in 1987.

The Indonesian market

Indonesia is one of the world's largest exporters of frogs' legs for consumption as food (Niekisch, 1986; Martens, 1991; Schmuck, 2000). Several frog farming ventures have been started in Indonesia, using exotic *Lithobates catesbeianus*, but have mostly failed, probably due to disease-related issues. Currently the majority of the frogs are caught in natural habitat on the island of Java - predominantly the Crab-eating Frog *Fejervarya cancrivora* (75%), and the Giant Javan Frog *Limnonectes macrodon* (19%). Local hunters collect frogs in wetlands at night, using torches and nets or spears, and the catches are transported by intermediaries to the cities (Kusrini, 2005). While the greater number of frogs taken is for local consumption, the available data show increasing numbers of frogs' legs have been exported from Indonesia over time – from around 28 t in 1969, rising to around 5600 t in 1992 and then declining to around 3800 t in 2002. A strong increase in exports after 1985 corresponded with the ban in that year of exports of edible frogs from India and Pakistan – formerly the principal exporters of frogs' legs (Kusrini & Alford, 2006). In total, some 36 jurisdictions imported frogs' legs from Indonesia from 1969 to 2002. Ten of these were in Asia (China, East Timor, Hong Kong, Japan, Malaysia, Pakistan Singapore, South Korea, Taiwan and Vietnam,); two in the Middle East (Bahrain and Egypt); 14 were in Europe (Austria, Belgium and Luxembourg, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, and the UK); four were in Latin America and the Caribbean (Brazil, Ecuador, Mexico, and Bahamas); two in North America (USA and Canada) and at least four in Pacific countries (Australia, Papua New Guinea, New Caledonia and other countries in Oceania). Europe was the major importer of Indonesian frogs' legs (83.2% of the total exported), with Belgium and Luxembourg as the principal destination (47.6%), followed by France (27.6%) and the Netherlands (21%). Export to Europe tended to fluctuate but increased dramatically after 1985 (Kusrini & Alford, 2006). While Indonesia is presently the dominant exporter for frogs' legs, there is controversy as to which species are in trade. According to Kusrini (2005) the majority of frogs are caught in Java, with the Asian brackish frog accounting for 75% and the giant Javan frog for 19% of takes. These data conflict with what was identified in exports to the EU. According to that data the Indonesian frogs' legs shipments to the EU include four species: giant Asian river frogs, Asian brackish frogs, common pond frogs, and giant Javan frogs. However, biochemical analysis (enzyme analysis) identi-

fied all imported specimens as Asian brackish frogs (Veith et al., 2000). This false labeling may not be intentional but simply indicates that the traders and exporters are not able to identify the frog species in trade (Kusrini & Alford, 2006; Veith et al., 2000; Altherr et al., 2011). This reveals two serious problems: first, that reliable monitoring and sustainable management of trade is extremely difficult, especially for shipments of frozen legs; second, enormous enforcement problems may arise if only trade in individual frog species is managed by CITES or other measures due to look-alike issues and since it is difficult, without genetic testing, to distinguish prepared frog legs by species (Altherr et al., 2011).

The Malaysia market

Commercial culture of the American bullfrog *Lithobates catesbeianus* in Malaysia is thought to have begun in the early 1980s. With the use of Taiwanese techniques on feeding, stocking and disease prevention, bullfrog farming has become a profitable industry. Currently there are also schools to educate new frog farmers. One of these schools is the Sepang Today Aquaculture Centre started in 1996. The school is located about 30 km from the Kuala Lumpur International Airport. It is owned and managed by Mr. Khoo Eng Wah who has a biology degree from Nanyang University of Singapore and a postgraduate diploma in fisheries from the University of Singapore.

For the past 3–4 years of its existence, the school has trained hundreds of aquaculture farmers and investors from different parts of the world. Some of them, as he mentioned, come from Saudi Arabia, Seychelles, Brunei, Colombia, China, Taiwan, Indonesia, and Malaysia (Dagoon, 2000). Currently, the domestic market absorbs most of Malaysia's annual frog meat production. Domestic prices are higher than those offered by exporters. While exporters want just legs, local restaurants buy the whole carcass. Bullfrog meat has fine texture and pleasant taste. Low in fat (0, 5%), it is rich in protein and provides a good balance of amino acids. These characteristics appeal to health-conscious consumers. Dressed bullfrog (beheaded, skinned, gutted, and digital extremities cut off) weighs 70% of its live weight. Legs account for 60% of dressed carcass weight. Processing of frogs is similar to that of poultry. The final product is packed in polythene bags, individually quick-frozen and stored in a cold room at -23°C. Various useful by-products can be obtained from frog processing.

Tanned frog skin yields leather. Fat reserves in the frog's abdominal cavity are processed into cosmetic oil. Dried and ground offal from frog processing may be used in the manufacture of pet feed (Dagoon, 2000).

The Cambodian market

Frog consumption among local people in Cambodia is widespread, and many communities still depend on collecting frogs to either supplement their limited protein intake or generate additional income (Allen et al., 2008). Throughout Cambodia, frogs are collected as a food source, and at some time or other, most species are probably gathered for human consumption. Rural communities living near forests will opportunistically utilize frog protein, especially the larger species, such as riverine ranids and the spine-glanded mountain frog *Quasipaa fasciculispina*. This type of collecting, although it may be responsible for localized depletion of certain species, is potentially of minimal threat to native amphibian populations. Of greater concern is the wholesale collecting of the larger species found in agricultural landscapes that constitute the bulk of frogs harvested in Cambodia (Neang, 2010). A total of six frog species were reportedly harvested on a regular basis for local consumption and trade. In decreasing order of reported volume, the species collected were as follows: Rugulose frog *Hoplobatrachus rugulosus,* paddy frog *Fejervarya limnocharis*, truncate-snouted frog *Glyphoglossus molossus*, Asian bullfrog *Kaloula pulchra*, Kokarit frog *Rana lateralis*, and black-spined toad *Bufo melanostictus.* Generally, the common species of frogs – with the exception of tree frogs – are collected by local people as a protein supplement. Large volumes of frogs are caught after the first heavy rain of the wet season, when some species emerge after a six-month aestivation period. During that time, both skinned and live *Hoplobatrachus* are on trays or in large bowls for sale in the local markets countrywide. *Fejervarya limnocharis* are widely collected by some individuals for consumption but are not as valuable as *Hoplobatrachus* because of their smaller size. As frogs are abundant during only a short period of the year they are highly prized by locals, middlemen and restaurants (Neang, 2010). The price of frogs varies depending on a variety of factors: season, species, size, and the locations where the frogs are sold. The price in collection localities is relatively low. Local traders set prices depending on the availability of frogs. Each trader can expect to make a profit per kilogram of around 1,000-2,000 riel (US$ 0.25–0.50). The chance of making a profit depends entirely on the quantity of the supply for that season or year. While collectors usually get a set price, the retail sellers in the markets can bargain with customers and make a bit more profit. The live paddy frogs are delivered fresh to the markets and then fried which preserves them

for at least a month before they are out of stock. One kilogram of fried frogs costs 70,000–90,000 riel (US$18–23).

The Chinese market

In China, 39 species of ranid frogs are already negatively impacted by utilization, with twelve of these species in rapid decline (Carpenter et al., 2007). Fortunately, in recent years the domestic demand for frogs as food has significantly changed. While frogs' legs were considered a fashionable food choice in the 1990s resulting in large-scale frog production, demand has decreased as frogs have been replaced by high value seafood. Approximately a dozen frog farms are producing American bullfrogs and other frog species, but the farms have experienced technical problems, impairing operations (Teixeira et al., 2001). Nevertheless, several native species, including the East Asian bullfrog (*Hoplobatrachus rugulosus*), Eurasian marsh frog (*Pelophylax ridibundus*), Chinese brown frog (*Rana chensinensis*), and Eastern golden frog (*Pelophylax plancyi*), are still exploited for local and regional consumption (Altherr et al., 2011). *H. rugulosus* is the preferred species, thanks to its appetizing and nutritious meat (Ding et al., 2015), many of the Chinese farms have raised this frog since the 1980s (Zhan & Yang, 2012). *H. rugulosus* farms have received attention from the scientific community for breeding systems (Tang et al., 2020) given that growth, development and sexual differentiation of amphibians are influenced by temperature and steroid hormone level. These farms should consider the production efficiency and economic efficiency with different sexes of frogs, and it is known that sex ratio bias induced by temperature has a high practical value, but the economic efficiency is not as good as that induced by hormones (Fu, 2010). However, hormone residues are harmful, and it is worth considering whether non-sterol aromatase inhibitors can be used instead of hormones (Tang et al., 2020). Chytridiomycosis has also been reported from introduced bullfrogs (wild, farmed, and market-sold) in Yunnan province, as well as in native amphibians, suggesting that farmed and escaped bullfrogs may present a major threat to native species by carrying disease as well (Bai et al., 2010).

The Korean market

Lithobates catesbeianus was first introduced into the Republic of Korea in 1959 by Jinhae National Fish Farm to be produced as a potential alternative food source (Kim, 1972; Oh & Hong, 2007; National Institute of Ecology, 2014; Park et al., 2014; Groffen et al., 2019). However, none of the individuals survived due to the absence of appropriate farming protocols (National Institute of Ecology, 2014). The first research on captive breeding in Korea was conducted with individuals imported in 1971 by the director of the Natural History Museum from Ewha Womans University, with the purpose of researching alternative food sources (Kim, 1971a, b, 1975; Oh & Hong, 2007). A total of 30,000 individuals were raised in laboratory and their value as meat source was explored as a potential solution to the protein shortage ongoing in Korea at that time. One of the first recorded outdoor captive breeding attempts was conducted in 1973, by two middle school teachers in Chuncheon, Gangwon Province. Within three years of importing two breeding pairs of *L. catesbeianus* from the United States of America, the farmed population was composed of 450 adults and 30,000 tadpoles (Donga, 1976). The successful breeding of *L. catesbeianus* was widely publicized and lead to a boom in captive farming of the species, with additional individuals being imported from Japan as early as 1973 and distributed to all Korean provinces (Kim, 1975; Shim et al., 2005; Oh & Hong 2007). Until recently, *L. catesbeianus* individuals were regularly released to the wild, principally from Buddhist temples during ceremonies (Liu et al., 2012). While the frequency of these religious ceremonial releases has significantly decreased, it is still regarded as a promoter of invasive population establishment (Liu et al., 2012).

The Lao PDR market

Fish, frogs, turtles, snails and other aquatic animals provide more than 50% of the animal protein consumed by the population in the Lao PDR and are of critical importance to national food security (MOPI, 2010). However in this country there are no large farms capable of exporting farmed frogs.

The Taiwan market

The American Bullfrog was introduced into Taiwan from the United States via Japan in 1924 and 1951 (Hsu & Liang, 1970). In April 1985, the Government of Taiwan issued a warning to restaurants, consumer and retailers not to buy bullfrogs, as checks by the Department of Health on frogs for sale at market had led to the discovery that some frogs were carrying typhoid of the bacterium *Vibrio parahaemolyticus* (IUCN, 1986). Also the native amphibians are at risk of infection by *B. dendrobatidis*. Taiwan's subtropical climate also creates a suitable environment for the growth of this pathogen

(Schloegel et al., 2009). Only recently a research programme aimed at the cultivation of *Lithobates catesbeianus* was then established (FAO, 2010).

The Thai market

In the early 1990s Thai farmers also began culturing frogs, and American bullfrog (along with *Hoplobatrachus tigerinus*, a species native to Southeast Asia) became a popular culture species, technically supported by Chulalongkorn University (FAO, 2010). In Thailand, most of the frogs are consumed locally, with only the surplus exported to neighboring countries (Hong Kong, Singapore, and Malaysia) and to Europe. In the period between the years 1981–1984, over 6 million rugulose frogs *Hoplobatrachus rugulosus*, presumably caught from the wild, were exported from Thailand to Hong Kong (Wai-Neng Lau et al., 1999). Farming has become popular recently due to progress in developing feeding techniques (Teixeira et al., 2001). The fresh markets in Thailand are a real attraction for tourists and offer a unique experience to foreign travelers. To get to know the Thai lifestyle, visiting a fresh market in Bangkok is a must. Life in Thai communities revolves around the fresh market. Among the stalls of fresh products and animated carts full of raw materials, there are the best restaurants and street food vendors in the neighborhood.

The Honk Kong market

Hong Kong is one of the major world centers for the global amphibian trade, largely due to its strong transport and economic links with mainland China and many other countries, its open trading policy, economic success and high demand for wildlife consumption (Lau et al., 1995). The trade of amphibians as food in Hong Kong has been largely dominated by Chinese frogs *Hoplobatrachus rugulosus* of Southeast Asia e Mainland China (Lau et al., 1995). In addition, Hong Kong is also a transit port for the Chinese goods intended for international markets (Lau et al., 1995). Hong Kong, together with Singapore and Malaysia are the main destinations for shipments of frogs from Thailand (Teixeira et al., 2001). In 1994, Hong Kong alone imported 6 million East Asian frogs from Thailand (Lau et al., 1995; Altherr et al., 2011).

The Singapore market

Wet markets in Singapore have a very strong and ancient tradition. The term "*wet markets*" is derived from the markets' wet floors which are caused by the melting of ice used to ensure the freshness of seafood sold and by stall holders who routinely clean their stalls by spraying them with water. The term "wet markets" came into common usage in the early 1970s when the Singapore government used the term to distinguish these markets from air-conditioned "supermarkets" that had become popular with the opening of Fitzpatrick's supermarket in Orchard Road in 1958. Wet markets meet the basic needs of Singaporeans and are a source of livelihood for their stall holders. They have also become a common ground for Singapore's ethnically diverse population to interact and bond, and contribute to Singapore's vibrant community heritage (National Heritage Board, 2013). American bullfrogs are almost exclusively the frogs sold in these markets. The Singapore Food Agency (SFA) has stated that slaughtering of live turtles, frogs and eels in markets and food stalls is allowed provided that the vendors of stalls meet the requirements of the public environmental Health Act, which covers food safety and hygiene. The NEA and Singapore Food Agency (SFA) issued a joint advisory with sanitation and hygiene guidelines to stallholders in all 114 hawker centres and wet markets on Jan 29 in light of the coronavirus situation. Public spaces in wet markets are cleaned every four hours, once a day. The tables, used and unused, are cleaned every two hours, as well as the toilets, which are cleaned with a chlorine-based disinfectant every two hours. The disinfectant has been added to the hand soap solutions provided in wet markets and will be constantly topped up with detergents. In Singapore, the availability of living bullfrogs in the market for food uses has caused the escape or the deliberate release in nature, increasing the number of alien species in the national territory (Tin Hui & Kelvin, 2010). The species was first imported into Singapore and observed to be sold as food in the 1980's (Ng & Lim, 2010; Ng & Yeo, 2012). The first recorded individuals in the wild were from Upper Peirce Reservoir in 1989 (Lim, 1989, as *Rana catesbeiana*).

The Vietnamese market

In Viet Nam, a variety of frog species are consumed as traditional food, including Gunther's amoy frog (*Hylarana guentheri*), large-headed frog (*Limnonectes kuhlii*), Asian greenback frog (*Odorrana livida*), common pond frog, East Asian bullfrog, giant spiny frog (*Quasipaa spinosa*), and spiny frog (*Quasipaa verrucospinosa*). In urban restaurants, East Asian bullfrogs are sought after as a delicacy (Truong, 2000). Import documentation for frogs' legs from Viet Nam did not indicate the species name on all of the entries reviewed from 1996 to 2002. Most

commercial invoices from Viet Nam indicated the product simply as frogs' legs or frozen frogs' legs. Beginning in 2003, the species name *Rana tigerina*, or *Hoplobatrachus tigerinus*, began to be indicated on some of the commercial invoices and Viet Nam was issuing CITES export permits for this species. Once the Scientific Authority of Viet Nam was advised by the Nomenclature Committee of CITES that the species concerned is *H. rugulosus*, and that *H. tigerinus* (included in CITES Appendix II) does not occur in Viet Nam, Viet Nam began to use the scientific name *Hoplobatrachus rugulosus* and continues to issue export permits (non-CITES) for this species. All of the permits issued by Viet Nam indicate that the *H. rugulosus* exported from the country is captive reared (Gerson, 2012).

The Japanese market

Lithobates catesbeianus was first introduced to Japan by a professor of Tokyo Imperial University (now University of Tokyo) around 1918 (Okada, 1927). The frog was already well integrated into the Japanese herpetofauna in 1958–1959, about 40 years after its introduction. *Lithobates catesbeianus* is permanently established at least in the plains of Kanto and Kansai, the two largest flat regions of Japan, and many local people recognize it as a "*food frog*". Studies reveal that it can adversely affect native anuran species such as the endangered porous short-legged frog through predation and food competition. The removal of bullfrogs, along with other invasive alien species, is highly recommended for the conservation of local vertebrates (Hirai, 2004). Studies reveal that *L. catesbeianus* populations that expand in rice fields prefer microhabitats with deep waters; habitat management to reduce immigration of bullfrogs can help prevent the spread of this invasive species (Minowa et al., 2008). A recent death of the ranavirus *L. catesbeianus* lasted from September to October 2008 in a 1000 m^2 pond in western Japan. Wild infected populations of *L. catesbeianus* pose a serious threat to Japanese amphibians (Une et al., 2009). Fortunately, *B.d.* does not appear to have introduced infected populations of *L. catesbeianus* and no death has been reported from chtridiomycosis (Garner et al., 2006). In a western part of Ichinoseki, Iwate prefecture, bullfrogs from North America have been spotted in storage tanks in agricultural areas since the 2000s. They ate wrinkled frogs and other indigenous species in the forests of the villages, causing a drastic drop in their populations. Normally hundreds of wrinkled frogs can be found in a single pond. Researchers from the University of Tokyo said that only a few American frogs in the same pond can almost eliminate wrinkled frogs. Kubogawa Iihatobu Shizen Saisei Kyogikai, an organization of citizens who works to revive the natural environment in the area, began exterminating American frogs in the ponds of the basins in late June.

When members used nets to dig a pond, they caught over 200 American frogs in 10 minutes, but only a few wrinkled frogs. Due to the damage done by this alien frog, import, transport and keeping of American Bullfrog are prohibited in Japan by the Invasive Alien Species Act (Dontchev & Matsui, 2016).

CONCLUSIONS

Several authors have noted that commercial exchange of live amphibians for food, pets, and laboratory animals may be adversely influencing wild populations by direct harvesting or through the spread of disease (Oza, 1990; Veith et al., 2000; Weldon et al., 2004; Schlaepfer et al., 2005; Fisher & Garner, 2007; Picco & Collins, 2008; Schloegel et al., 2009; Gratwicke et al., 2010). Two major pathogens of concern in the amphibian trade are iridoviruses, such as *Ranavirus* spp., and the amphibian chytrid fungus *Batrachochytrium dendrobatidis* (Schloegel et al., 2009). Both pathogens can be deadly to their hosts; however, although *Ranavirus* is associated with amphibian die-offs, like many other diseases it generally does not lead to the extinction of the host (Collins & Crump, 2009). *B.d.*, on the other hand, is an unusual example of a disease that is a primary cause of extinction (Skerratt et al., 2007). In fact, *B.d.* has been listed as a likely threat in 94 cases out of the 159 extinct and potentially extinct species listed in the 2008 Global Amphibian Assessment (IUCN, 2009). There are several hypotheses about how *B.d.* has spread around the world, but the trade in amphibians for food, bait, pets, zoos, and laboratory animals has been identified as the most likely mode of spread (Garner et al., 2006; Picco & Collins, 2008; Garner et al., 2009; Kriger & Hero, 2009; Schloegel et al., 2009; Gratwicke et al., 2010). The World Organization for Animal Health (OIE) has declared chytridiomycosis a "notifiable disease" and implemented food-related policies recommending (1) removal of infectious parts (skin and feet) prior to export and (2) that member countries should have the opportunity to declare *B.d.*-free nations or geographic zones within a country (OIE, 2009). Also the United Nations Food and Agriculture Organization (FAO), which promotes the breeding of frogs and claimed that the vast majority of exchanges

occur with frozen frog legs, a declaration supported by Warkentin et al. (2009), describes the practices which potentially deny the transmission of the disease within this type of trade (Crayon, 2009). FAO provides assistance to farmers on how to humanly send a frog, remove the skin, wash the legs in chlorinated water and freeze the legs 15 ± 2 °C for storage and transportation (Crayon, 2009), anything that potentially removes or at least reduces the possible threat of disease transmission through this type of trade (Carpenter et al., 2014). As *B.d.* is an infectious pathogen of the skin, it is unlikely that skinned frog legs would pose any major risk. In addition to *B.d.*, *Salmonella* is also a potential problem. Frog legs generally enter the kitchen as a frozen raw product that will be cooked first than be consumed. Generally, this cooking terminal kills all *Salmonella* organisms that could be present and the consumption of frog legs do not subject the consumer to a possible case of salmonellosis, provided that the legs were not overcooked or had not been recontaminated. However, if *Salmonella* bacteria were on the surfaces of this raw product, the food the contact surfaces could become contaminated and in turn could contaminate the foods that do not receive further heat treatment before consumption (Andrews et al., 1977). Emerging infectious diseases are dominated by zoonoses originating mainly in wildlife. They represent a significant burden on global economies and public health, in particular when these diseases become pandemics. Their emergence is largely driven by socio-economic, environmental and ecological factors. Currently, there are some vaccines against COVID-19, but are not widespread. There is a hot debate on whether a sufficient number of people develop protective antibodies after having been exposed naturally to SARS Cov-2 in order to obtain herd immunity, before a vaccine will be available (de Sadeleer & Godfroid, 2020). The long period of closure of many businesses, caused by this pandemic, led to great economic losses globally. Some farms specializing in frog legs are real companies and provide work for dozens of families in some areas of Asia where there are great economic difficulties. In some cases, however, these are small family-run farms that sell their products locally. While not encouraging the production of frog meat for food use, it cannot be ignored that this activity is a source of sustenance for thousands of families in the world, especially in the Asian continent. A protracted stop of these activities for months can almost certainly lead to an illegal frog legs market. Breeding, slaughter and sell this type of meat illegally and without veterinary supervision can be very dangerous to public health and be a potential vector of deadly amphibian pathogens.

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