Is the international frog legs trade a potential vector for deadly amphibian pathogens?

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There have been surprisingly few analyses of how the international trade in amphibians for food affects the conservation status of this group. We analyzed information from the UN Commodity Trade Statistics Database and found that, by volume, Indonesia supplied nearly half of the animals entering the world's US$40 million per year international frog legs trade, and that – collectively – France, Belgium, and the US imported more than 75% of all frog legs traded internationally. Nonetheless, a close examination of available information from 1996 through 2006 revealed that most countries throughout the world participated in the frog legs trade at some level. These extensive international amphibian trade networks could facilitate the spread of pathogens, including *Batrachochytrium dendrobatidis*, which has been identified as a threat connected with the disappearance and possible extinction of over 90 amphibian species around the world. Given the size and extent of the international trade in frog legs, we advocate for the rigorous implementation of clear policies regulating the domestic and international movement of amphibians for food.

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The overexploitation of wildlife for food (Figure 1), bush meat, wildlife-based medicines, and pets threatens wild animal and plant populations around the world (Sodhi *et al.* 2004; Karesh *et al.* 2005; Worm *et al.* 2006; Gratwicke *et al.* 2008). Many open-access harvesting models are unsustainable and overexploitation arises from a "tragedy of the commons" situation, whereby several individuals acting in their own self-interest destroy a shared, limited resource in the short term, even when it is not in their long-term interests (Hardin 1968; Ludwig *et al.* 1993). While it is conceivable that the twin goals of biodiversity conservation and profit can be met if harvests were sustainably managed (Smith 1981; Child 1996), the spread of pathogens is a major indirect effect of the international wildlife trade that also needs to be considered in ecological risk assessments (Karesh *et al.* 2005). Lack of knowledge has hindered our ability to make sound conservation policy recommendations on the extent and effects of the global trade in amphibians (Carpenter *et al.* 2007). 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 and Garner 2007; Picco and Collins 2008; Schloegel *et al.* 2009).

Two major pathogens of concern in the amphibian trade are iridoviruses, such as *Ranavirus* spp, and the amphibian chytrid fungus *Batrachochytrium dendrobatidis* (Bd; 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 and Crump 2009). Bd, on the other hand, is an unusual example of a disease that is a primary cause of extinction (Skerratt *et al.* 2007). In fact, Bd 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 Bd 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 and Collins 2008; Garner *et al.* 2009; Kriger and Hero 2009; Schloegel *et al.* 2009).

In a nutshell:

- Few people realize the size and scope of the international trade in frog legs
- Trade of live or unskinned, unfrozen frogs is a possible mechanism for the spread of the deadly amphibian chytrid fungus, *Batrachochytrium dendrobatidis*, which has been implicated in "enigmatic declines" of amphibian species around the world
- Implementation and enforcement of some key amphibian trade policies are recommended as a cost-effective conservation tool to mitigate disease risks associated with the trade

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International trade in amphibians for food

Although consuming amphibian legs is familiar to many people as a culinary curiosity, the global extent of the

international trade is unknown, especially in relation to large-bodied ranid frog species that are indiscriminately harvested for food (Carpenter *et al.* 2007). The IUCN estimates that overharvesting is a serious threat, affecting 40% of the 54 declining true frog species in the family Ranidae (Stuart *et al.* 2004). The most comprehensive source of data documenting the global extent of the international trade in amphibians for food is the UN Commodity Trade Statistics Database, but this information remains largely unsynthesized and uninterpreted, and is poorly studied by the amphibian conservation community. One exception is a recent paper by Warkentin *et al.* (2009), which uses these data to quantify and describe the recent history of the international frog legs trade. They advocate for a wild-harvest certification scheme to prevent imminent amphibian population collapses, drawing comparisons with global fisheries collapses. We use this database to characterize the global extent of the international trade in frog legs for food and review the potential disease risks arising from this trade.


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Figure 1. *Frogs are a common treat in many Asian countries. Photo taken in a street market in Jakarta, Indonesia (May 2008).*

We downloaded publicly available, raw amphibian trade data for all countries from the UN Commodity Trade Statistics Database (http://comtrade.un.org/db). We only used information available for the period 1996–2006, because import/export data prior to this time were patchily collected and contained discrepancies, and more recent data were not available at the time of this analysis.

From 1996 through 2006, more than 100 000 metric tons of frog legs were imported from both wild and farmed sources, at a net value approaching half a billion US dollars (Figure 2). Interestingly, there were no clear global increases or decreases in average import volumes (total kilograms) or average price per kilogram over this 11-year period, suggesting fairly stable levels of international supply and demand (Figure 3). One kilogram of frog legs earned an average of US$3.83 (exported) and US$4.17 (imported) over this period. Considering that a kilogram of export-quality frog legs requires 10 to 40 individual animals (Kusrini and Alford 2006), this translates to approximately 100 to 400 million animals per year, originating predominantly in Indonesia (Figure 2). What was particularly interesting was the enormous global extent of the trade, with most countries around the world participating in the trade at some level (Figure 4). It is unclear what proportion of imported frogs are sourced from the wild versus farmed animals, but the importance of farmed frogs appears to be growing, particularly in South America and Asia (FAO 2005–2009). According to the FAO fisheries database (http://faostat.fao.org), there has been a dramatic increase in amphibian production from frog farms since 2003, and these operations focus mainly on American bullfrogs, *Lithobates catesbeianus*, a known Bd carrier (Mazzoni *et al.* 2003). In 2006, around 75 000 tons of amphibians were produced on farms, as opposed to about 8000 tons of wild-caught amphibians. If these data are reliable, it means that between 0.8 and 3.2 billion frogs are consumed by people each year.

These numbers are cause for concern in terms of the sustainability of this harvest. There are many anecdotal accounts indicating that the demand for frogs as food has severely depleted some wild populations of amphibians, including the edible frog *Pelophylax esculenta* complex in Europe (Carpenter *et al.* 2007), the Chinese edible frog *Hoplobatrachus rugulosus* (Carpenter *et al.* 2007), the Indus Valley bullfrog *Hoplobatrachus tigerinus* (Abdulali 1985), the goliath frog *Conraua goliath* from West Africa (Sabater-Pi 1985), and the California red-legged frog *Rana draytonii* (Jennings and Hayes 1985). Despite these declines, there are no recorded cases of amphibian extinction caused by collection for food (Collins and Crump 2009), and some species, such as the crab-eating frog (*Fejervarya cancrivora*) on Java in Indonesia, can withstand high off-take. Modeling has suggested that harvests of 100 to 500 million individuals annually could actually be sustainable (Kusrini 2005). Given the growing importance of aquaculture to supply frog legs to global markets (FAO 2005–2009), we argue that the risk of disease spread through poorly regulated amphibian trade is probably an even greater risk to amphibian biodiversity than the direct population effects of overharvesting.

Potential vector of disease

Indonesia is the world's largest source of frog leg exports (Figure 2). While several frog farming ventures have

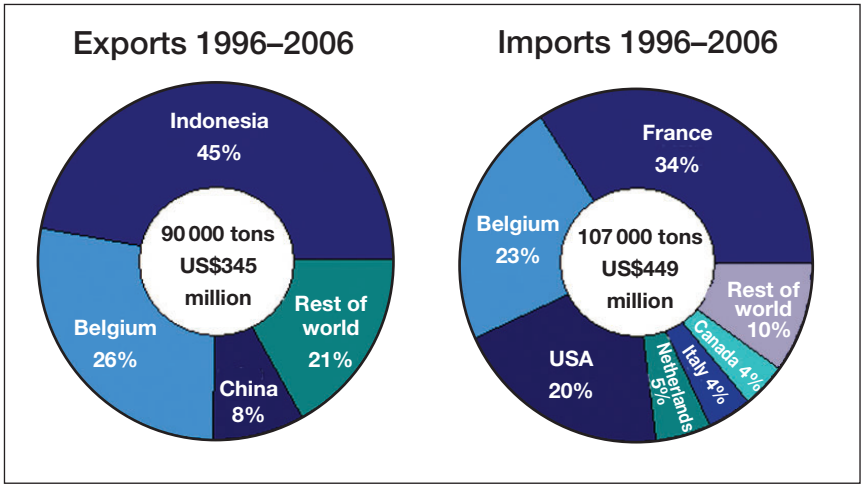

Figure 2. *Global importers and exporters of frog legs (1996–2006). Data from the UN Commodity Trade Statistics Database.*

been started in Indonesia, using exotic *Lithobates catesbeianus*, they have mostly failed, probably resulting from disease-related issues; most of the frogs now sourced from Indonesia are therefore probably wild-caught (Kusrini and Alford 2006). Local hunters harvest frogs in wetlands at night, using torches and hand-nets or spears, and their catch is transported by middlemen to the cities (Kusrini 2005). Some are sold alive in domestic markets, while high-quality, larger animals are sold to the 22 registered seafood export companies. Here, the animals are butchered and then the legs are removed, skinned, and chilled or frozen for export and international shipping (Kusrini and Alford 2006). There is no effort in Indonesia (or in other countries) to monitor this food source for disease pathogens. The recent discovery of Bd in two ranid frog species on the island of Java (Kusrini *et al.* 2008) raises two urgent issues in relation to amphibian trade. First, the within-country transport of live, infected frogs could rapidly spread Bd to naïve populations of Indonesia's vast and diverse amphibian fauna, as seen in the case of pathogen pollution resulting from the live trade of amphibians for bait in the US (Picco and Collins 2008). Second, without sufficient controls on sourcing and processing of harvested frog legs, Bd could potentially be transported to importing countries where Bd has not yet been detected but that are intimately involved in the commercial frog legs trade network, such as Vietnam, Malaysia, Thailand, and Madagascar. (See www.spatialepidemiology.net/bd for the most up-to-date global Bd distribution.)

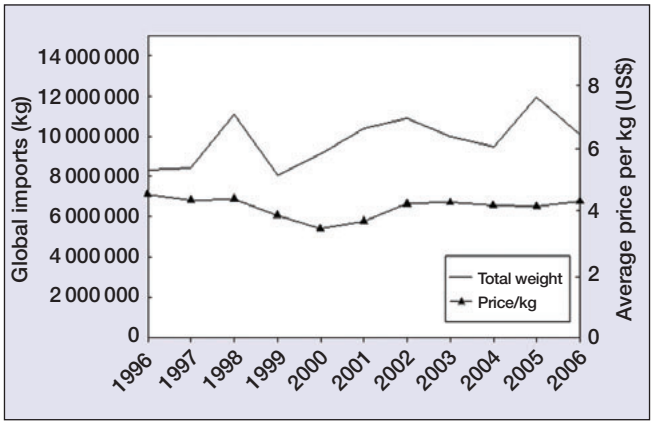

Figure 3. *Trends in average global prices of frog legs and total volumes imported. Data from the UN Commodity Trade Statistics Database.*

For this reason, the World Organisation for Animal Health (OIE) has recently 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 Bd-free nations or geographic zones within a country (OIE 2009a). As Bd is an infectious pathogen of the skin, it is unlikely that skinned frog legs would pose any major risk. While there have been no published studies demonstrating whether Bd can survive freezing on dead animals, Bd cultures are inactivated by freezing unless cryoprotectants are used (J Longcore and L Schloegel pers comm). Tests on free-living soil chytrids found that species of free-living Rhizophydiales, to which Bd belongs, did not recover from incubation at –15°C (Gleason *et al.* 2008). Therefore, the practice of transporting skinned, frozen frog legs already used by many source countries should not be considered a major risk to the international spread of this pathogen. However, where live amphibians, or chilled, unfrozen, unskinned legs are being transported, these could act as potential Bd vectors. Each year, Indonesia issues live export permits for around 28 000 individual frogs belonging to about 40 species (Anonymous 2008). A recent study of the trade in live amphibians coming into three major cities in the US found that over 5 million frogs were imported each year (Schloegel *et al.* 2009). These frogs primarily originated from Taiwan, Brazil, Ecuador, and China, and 62% of them were carriers of Bd, while 8.5% carried *Ranavirus* (Schloegel *et al.* 2009).

Conclusions

The direct value of amphibians for food is substantial, and trade and consumption occur worldwide. The topic has received some attention from global regulatory bodies, such as the Convention on International Trade in Endangered Species (CITES), created in 1973 to address the contribution of trade to overharvesting pressure (CITES 2009). However, CITES has paid little attention to the amphibian trade in recent decades. A total of 16 species are on Appendix I, which prohibits almost all trade, and 98 species are on Appendix II, which allows trade so long as it is regulated and non-detrimental to the species' survival prospects. However, no new CITES

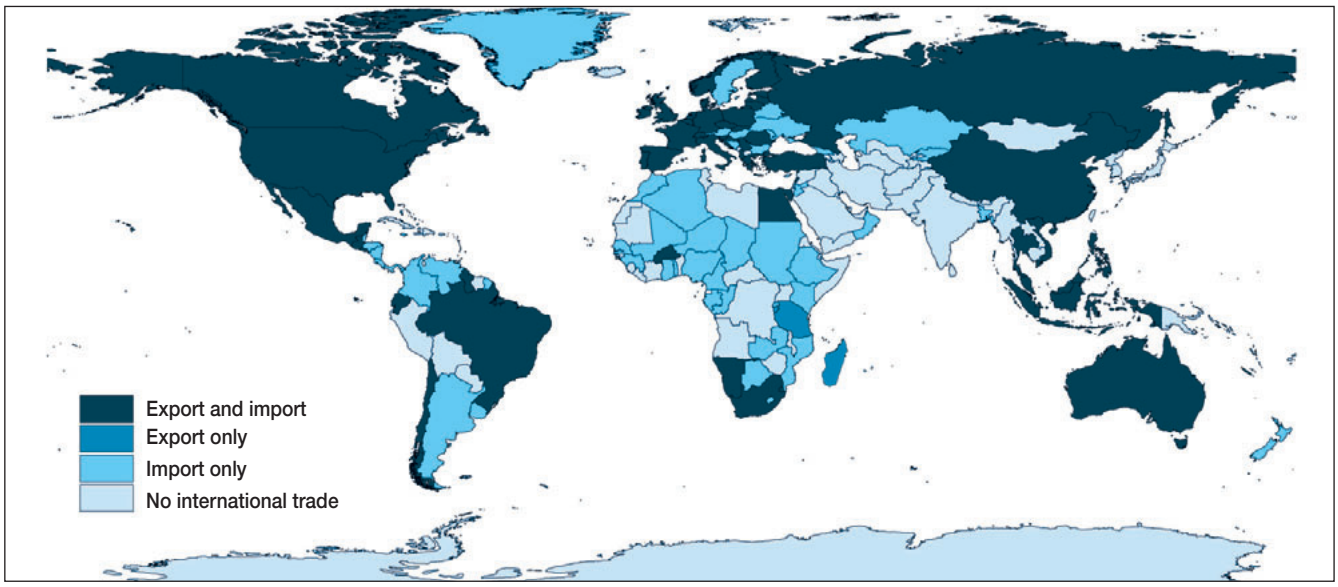

Figure 4. *Global extent of the trade in frog legs (1996–2006). Data from the UN Commodity Trade Statistics Database.*

amphibian regulatory listings have occurred since 1989, with the exception of two taxa from Madagascar: one genus (*Mantella*) in 2000 and one species (*Scaphiophryne gottlebei*) in 2003, neither of which were attributable to the frog legs trade (UNEP–WCMC 2009). Most CITES amphibian listings have resulted from pet-trade pressure rather than the frog legs trade.

More CITES listings could help reduce the impact of this trade. Species currently under consideration for CITES listings, due at least partially to impacts of the frog legs trade, include *Limnonectes blythii*, *Limnonectes macrodon*, *Limnonectes magnus*, *Calyptocephallela gayi* (Chile), and *Pelophylax shqipericus* (Albania and Montenegro; US FWS 2009).

The amphibian trade has received recent attention from the OIE. The OIE, which is the body created to reduce the risk of zoonotic diseases such as anthrax, bovine spongiform encephalopathy (mad cow disease), and foot and mouth disease, recently developed a set of recommendations specifically focused on preventing the further spread of Bd and *Ranavirus*. While the OIE policies are promising, they are only recommendations. Since adoption by OIE of its recommended Bd and *Ranavirus* standards in May of 2008, there has been little indication of any follow-up action, either by the OIE itself or by member countries (OIE 2009b). For example, the US, a major frog legs importer, has not adopted the OIE Bd standard as a regulation governing amphibian imports. Petitions were recently filed with the US Departments of Agriculture and Interior, formally requesting that the agencies adopt the OIE standard (Defenders of Wildlife 2009). Until the amphibian import trade is regulated by these agencies, no legal mechanism exists in the US that would mandate the rejection of imports even of known Bd-infected specimens.

We recommend that the following steps be taken to manage the risks to amphibian populations posed by international trade of frog legs for food:

- Exporters and importers should only permit the trade of skinned, frozen frog legs. Any trade in live animals or fresh, unskinned frog legs presents a substantial risk of the spread of Bd; imports under these circumstances should comply with OIE recommendations. (It is unclear whether these recommendations would be effective in preventing the spread of ranaviruses.)
- Countries should adopt the OIE recommendations as mandatory laws, in order to effectively reduce the risks of the frog legs export and import trade.
- The distribution of Bd in source countries should be carefully monitored, especially on frog farms, and additional measures recommended by the OIE should be taken to prevent the spread of the pathogen within a country. In the case of Indonesia, for example, simple policy restrictions could be implemented to prevent the transport of live amphibians between islands.
- Allowance for harvesting wild amphibians should be preceded by adequate data on life history, range, abundance, and maximum sustainable yield for that species, followed by quotas and monitoring to ensure that take rates are not exceeded. CITES should afford protections to species detrimentally impacted by this trade.

The total direct value of imported frog legs globally may appear large (at least US$40 million annually); when factoring domestic consumption in the countries of origin into account, this figure is likely to be around 2–7 times this amount (Kusrini and Alford 2006). However, this total direct value is fairly small when compared with US$42 billion for global fish and US$26 billion for global beef importation (UN 2007). The question therefore arises: are the financial benefits and the potential ecological damage of shipping 10 000 tons of frog legs around the world each year worth the ecological risks for a limited (albeit widespread) consumer base? If the answer is yes, then individual exporting (and importing) countries

should be prepared to mitigate those threats through adequately enforced regulation, and exporters should price their product to include the costs of managing these risks.

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