Eating Frogs to Extinction

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Amphibians appear particularly vulnerable to global change as the world enters its sixth mass extinction event (Wake & Vredenburg 2008). Because of their roles as important prey and predators, susceptibility to water-soluble toxins through permeable skin, and a life history that straddles aquatic and terrestrial environments, amphibians are good indicators for environmental degradation and community stability in the face of the major drivers of species loss (Semlitsch 2003). Although the causes of amphibian declines are diverse and interactive (Brook et al. 2008; Sodhi et al. 2008), individual mechanisms include habitat loss (Alford & Richards 1999); environmental contamination (Boone & Bridges 2003); global climate change (Kiesecker et al. 2001); disease and pathogens (Daszak et al. 2003); spread of invasive species (Kats & Ferrer 2003); and overharvesting (Schlaepfer et al. 2005). Here we address the latter category, which, although frequently associated with amphibian declines (Semlitsch 2003), has been poorly quantified (Collins & Storfer 2003; Carpenter et al. 2007). Specifically, we summarize global trade patterns in frogs' legs over a 20-year period and focus on harvesting in Indonesia. We also highlight the need for certification of wild-harvested animals entering international trade to improve monitoring capacity and to aid development of sustainable-harvest strategies.

Amphibians, and frogs in particular, make a substantial contribution to the gastronomy of several cultures. From the school cafeterias of France to dinner tables across Asia and in haute cuisine restaurants throughout the world, frogs' legs are on the menu (Patel 1993; Lau et al. 1997; Jensen & Camp 2003). Based on the United Nations' Commodity Trade Statistics Database (United Nations Statistics Division 2008) the major frogs' legs importing countries are France, the United States, Belgium, and Luxembourg, and there has been an overall increase in global trade during the past 20 years (Fig. 1). Among exporters, Indonesia is the largest, followed by China, Belgium, and Luxembourg (the latter two are transshipment points). The database reflects international trade only (not harvest for local consumption) and import numbers are incomplete for the late 1980s and early 1990s (Fig. 1), but they fill an identified deficiency in worldwide trade data (Schlaepfer et al. 2005). Previous estimates of trade volumes put the import of amphibians for food into the United States at 4000 t from 1998 through 2002, or about 12% of the global market (Veith et al. 2000; Schlaepfer et al. 2005). By contrast, the European Union imported over 6000 t of frogs' legs in 1990 and over 9700 t in 1999, with the majority of this market belonging to Belgium, Luxembourg, and France (Patel 1993; Teixeira et al. 2001). Demand in Asia supports local consumers and markets predominated by Singapore, Hong Kong, and Malaysia (Kusrini & Alford 2006).

The frogs' legs market has shifted from seasonal harvest for local consumption to year-round global trade. Markets in the United States and France were initially supplied by domestic harvest to serve a seasonal demand, but overexploitation led to decline or loss of commercial stocks (Carpenter et al. 2007). By the time these local sources disappeared, improved food-freezing technology enabled international markets to be tapped for North American and European demand, most notably in Asia where overexploitation again occurred. India and Bangladesh became major exporters of frogs' legs beginning in the 1950s, producing >4000 *t*/year over the next 30 years (Niekisch 1986; Pandian & Marian 1986). Legal trade in frogs was banned by India in 1987 because of concerns over inhumane killing and loss of natural control of agricultural pests (Pandian & Marian 1986) and because

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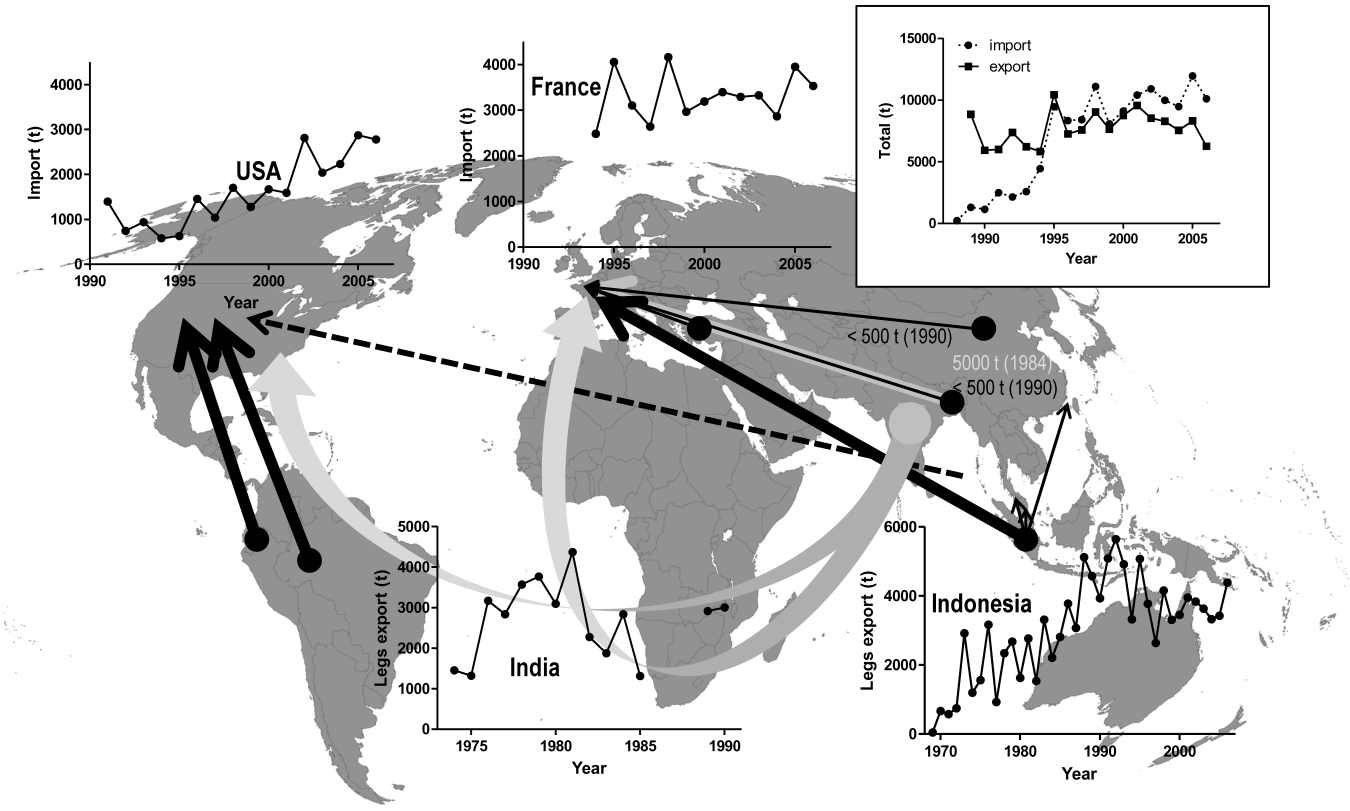

Figure 1. Distribution and time series of import and export data for frogs (mainly legs) of commercial importance (sources: Oza 1990; Patel 1993; Teixeira et al. 2001; Schlaepfer et al. 2005; Daszak et al. 2006; Kusrini & Alford 2006; United Nations Statistics Division 2008) (light gray arrows, past [pre-1987] source and destination pathways; dark gray arrows, contemporary pathways, including trade from Ecuador and Brazil to the United States, from "Asia" to the United States (dashed arrow), from Indonesia to Europe, Hong Kong, and other countries in South East Asia, and from Turkey, China, and Bangladesh to Europe. Also shown are the time series of import data from 1991–2006 and 1994–2006 for the United States and France, respectively; time series of export tonnage for India from 1974–1985, with estimates of illegal harvest weight for 1989–1990; export time series for Indonesia from 1969–2006; and time series of total world import and export of frogs (whole or body parts) from 1988–2006. Point data (export tonnage for specific years) are also given for China (1990) and Bangladesh (1984, 1990).

several harvested species were listed under Appendix II of the Convention on International Trade in Endangered Species (CITES) (Niekisch 1986) (although illegal harvest in India continued after 1987; Fig. 1). Subsequently, Indonesia became one of the primary global exporters of frogs' legs (Teixeira et al. 2001; Kusrini & Alford 2006).

Indonesia's frog harvest supplies large export and domestic markets through an expanding industry that employs thousands of people year-round (Kusrini & Alford 2006). Although the export market is substantial, reaching a high of 5600 *t* in 1992 and then declining slightly since (Fig. 1), the domestic Indonesian market accounts for 2 to 7 times this volume (Kusrini & Alford 2006). Favored exports are the crab-eating frog (*Fejervarya cancrivora*), giant Javan frog (*Limnonectes macrodon*), and the introduced (farmed) American bullfrog (*Rana catesbeiana*); along with these species, the grass frog (*F. limnocharis*) is also sold locally (Kusrini & Alford 2006). Striking morphological similarity among various large-bodied ranid frogs (genera *Fejervarya* and *Limnonectes*) and the existence of cryptic species complexes (Bickford et al. 2007) among those commercially harvested, suggest that many other species may be regularly harvested but misidentified. Monitoring and management of harvested populations requires, first and foremost, accurate species identification; yet, high error rates are likely. This accounting may be further complicated because frogs destined for export are skinned and only frozen legs are shipped. Veith et al. (2000) found that shipments to Belgium from Indonesia declared as the four species listed above were in fact all *F. cancrivora*. Proper resource management, essential for conservation and to ensure a stable livelihood and food supply for local harvesters and their communities, is difficult because fundamental data relevant to the management and conservation of frogs in Indonesia are lacking.

Overexploitation in the seas has caused a chain reaction of fisheries collapses around the world as humans move from one location and species to another (Pauly et al. 1998). This global experience should motivate better management of other exploited wild populations. Although Kusrini and Alford (2006) suggest that the Indonesian harvest might be sustainable, they estimate that between 31 and 160 million frogs were killed annually for export from 1989 through 1998. Thus, harvesters appear to be following the same pattern for frogs as for marine fisheries: initial local collapses in Europe and North America followed by population declines in India and Bangladesh and now potentially in Indonesia. Will the extinction dominos continue to fall? Six million Chinese edible frogs (*Hoplobatrachus rugulosus*) were shipped from Thailand to Hong Kong in 1 year (Lau et al. 1997), and there is evidence of possible increased capture of wild frogs in Thailand, China, Taiwan, Vietnam, and Mexico (Teixeira et al. 2001; Carpenter et al. 2007 United Nations Statistics Division 2008).

Although captive rearing of frogs has been proposed to protect populations from overharvest (Hardouin 1997; Carpenter et al. 2007), wildlife farming does not alleviate pressure on wild populations for all taxa (Bulte and Damania 2005), and farming of American bullfrogs in Indonesia has been unsuccessful (Kusrini & Alford 2006). Thus, the continued importance of the wild-harvest industry for Indonesia and other nations (Teixeira et al. 2001; Kusrini & Alford 2006) suggests that the absence of essential data to monitor and manage the wild harvest is a large concern. Characteristics such as rapid growth, early maturation, and high fecundity may enable some amphibians to withstand high exploitation rates, but body-size selection and the efficiency and timing of harvest relative to life-history stage could reduce a particular population's capacity to recover (Jennings et al. 1999). To estimate sustainable harvest rates, it is essential that high-quality, species-specific population size (e.g., habitat-specific density ranges), and demographic (e.g., survival via tagging, breeding frequency, longevity) data be collected so that population viability analyses and harvest models can be developed.

Some species' demographic characteristics may be difficult to measure, but basic mark-recapture tagging, density surveys, and captive rearing to estimate growth and reproductive potential are achievable in the short term. At the very least, species (perhaps even morphospecies; Bickford et al. 2007) identification and capture location data for all frogs harvested would enhance the capacity of the industry to determine effort, harvest ratios and total takes for species across their ranges. With greater information on approximate wild population size, replacement rates (productivity less natural mortality), and harvesting intensity, harvest models may indicate the long-term prospects for population persistence under various management scenarios (e.g., Otway et al. 2004).

The broad thrust of our recommendation for more and better data on harvested populations echoes that put forward most recently by Schlaepfer et al. (2005) and Carpenter et al. (2007). We suggest that the absence of a regulatory framework to police international trade, in combination with insufficient financial backing to support the current formal trade-monitoring structure (i.e., CITES), have limited progress in response to these calls for action. Thus, we propose that a mandatory certification process for the harvest of wild frog's legs be established. Because most frog exports are skinned body parts, it will be necessary to develop a mechanism to monitor numbers and certify species identification of exported products at processing points. Likewise a reporting system, coupled with the demonstration of local population sustainability similar to that used for wild-harvested and ranched crocodiles under CITES regulations (Thorbjarnarson 1992), would be needed to indicate a harvested frog's origin, species, and associated population's conservation status. This is a step beyond previous calls for action to manage better the harvest of wild amphibian populations, and it would likely be costly to implement and monitor. Nevertheless, such a program would greatly enhance our monitoring and harvest-modeling capacity by providing a structure for the collection of necessary demographic data, which would in turn promote development of a sustainable frog-harvesting industry. It is the moral duty and responsibility of importing, developed countries to assist with such a program's implementation because many frog-exporting countries lack the necessary institutional capacity and financial resources.

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