THE INTERNET-BASED SOUTHEAST ASIA AMPHIBIAN PET TRADE

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Polypedates otilophus © BROOBAS/CC BY-SA 4.0

Amphibians, as a class, are the most threatened vertebrates on the planet, with 41% of species threatened with extinction. Southeast Asian amphibian species in particular have been impacted by a high rate of habitat loss, and overharvesting for consumption, traditional medicine, and the pet trade has placed further pressure on populations. Collection for the pet trade is a threat to many amphibian species but is notoriously difficult to quantify. Here we use internet and social media surveys to quantify online availability and demand for the pet trade of Southeast Asian amphibian species. We found postings for 59 Southeast Asian amphibians, comprised of 53 anurans and six caudates. Of these, only five species are included in a Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix. The geographic origin of postings was more challenging to determine in social media postings than in internet postings. Internet postings came primarily from domains or self-described posts associated with the United Kingdom, the Czech Republic, the United States, Russia, and Germany. We highlight several species groups which would benefit from further conservation action such as CITES listing, to improve monitoring and curb overharvesting.

Amphibians are the most threatened vertebrate class on earth, with an estimated 41% of species threatened with extinction (IUCN, 2019). Major threats include habitat loss and fragmentation, pollution, introduced species, disease, and collection from the wild (Martel *et al*., 2014; Pratihar *et al*., 2014; Sy, 2018; IUCN 2019). A known threat to many amphibians is the harvest to supply the global pet trade (IUCN, 2019). For example, the trade in live amphibians and reptiles for the United States from 2001–2009 was estimated to be in the millions of individuals (Herrel and van der Meijden, 2014).

In 2015, the IUCN SSC Amphibian Specialist Group (ASG) updated the Amphibian Conservation Action Plan (ACAP). The ACAP provides a framework for global amphibian conservation, and its thematic working groups have identified priorities and actions to address specific challenges in their respective theme (Wren *et al*., 2015). The Trade & Policy Working Group of the ASG identified the "Evaluation of the life history and/or reproductive traits of commonly traded 'captive bred' species to determine whether commercial-scale breeding is likely" as a priority, which helped guide the development of this study.

Southeast Asia has the planet's highest deforestation rates, and habitat loss continues to be the greatest threat facing amphibians in this region (Sodhi *et al*., 2004; Miettinen *et al*., 2011; Coleman *et al*., 2019). Deforestation, climate change, pollution, and harvesting for the pet, meat, and traditional medicine trades have created an impending crisis for this species group (Rowley *et al*., 2010; Pratihar *et al*., 2014). Furthermore, amphibian species richness in Southeast Asia is greatly underestimated, and there are likely undescribed threatened species (Diesmos *et al*., 2004; Stuart *et al*., 2006; Mahony *et al*., 2018). Trade-focused research has centred on frogs and frog legs for human consumption (Warkentin *et al*., 2009; Gratwicke *et al*., 2010; Altherr *et al*., 2011); however, the potential threat of the pet trade to Southeast Asian amphibians has garnered little attention (Herrel and van der Meijden, 2014; Rowley *et al*., 2016; Yuan *et al*., 2018), despite being largely unregulated and a known driver of population declines in a number of species (IUCN, 2019).

Lack of trade data is challenging, especially for species that are not listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), as their trade is unregulated in their countries of origin. Country-level export data are generally non-existent or not publicly available for Southeast Asian countries, although some countries (e.g. Indonesia) do have quota systems. However, internet-based e-commerce has been documented for numerous taxa, including amphibians (e.g. Auliya, *et al*., 2016; Kaczmarski and Kolenda, 2018; Sung and Fong, 2018; Sy, 2018), and internet surveys can be used to quantify availability and demand (Tapley *et al*., 2011; Rowley *et al*., 2016; Phassaraudomsak and Krishnasamy, 2018).

Using the internet and social media, this study sought to investigate 1) the identity and number of Southeast Asian amphibian species in the online wildlife trade, 2) where possible, their geographical provenance and origin (wild or captive-bred), and 3) their life histories.

METHODS

Web surveys have been used to quantify amphibians in the pet trade (United Nations Environment Programme/World Conservation Monitoring Centre (UNEP-WCMC), 2008; Tapley *et al*., 2011; Rowley *et al*., 2016). For this study, 20 websites for dealers or groups specialising in herpetofauna in the United States and Europe and relevant posts on a large social media website were surveyed (see Table 1). Surveys were conducted using standard English and scientific terms and the Google search engine. Scientific names of popular Southeast Asian species combined with the keywords "buy" or "sale" were used as search criteria. A first reference list was compiled from the "Review of Non-CITES Amphibia Species that are Known or Likely to be in International Trade" (UNEP-WCMC, 2008) and through communication with hobbyists and researchers. Some websites were no longer available in the period between compiling the first reference list and our surveys, highlighting the ephemeral nature of the online trade. Posts on the social media website were found through searches using the scientific names of amphibians popular in mainland Southeast Asia and through communication with hobbyists and researchers. *Amphibian Species of the World* (Frost, 2019) was used as a taxonomic reference.

Posts could include a standing list, or one or more individuals. Evidence of availability (sale offers) and demand ("in search of" or "ISO" posts) of Southeast Asian amphibians was collated for two time periods: (1) posting dates from 1st January 2015 to 30th June 2016, collected April–July 2016, and (2) posting dates from 1st January 2017 to 30th June 2018 collected October–November, 2018. Both supply and demand were understood as evidence for demand for the amphibian species in question, as wildlife trade supply is driven and counterbalanced by demand.

Assessment of evidence of Captive Breeding (following the CITES definition of animal specimens produced in a controlled environment and having produced a second generation (F2) or subsequent generation (F3, F4, etc.) in a controlled environment; and being demonstrably managed reliably to produce second-generation offspring in a controlled environment) was based on advertisements listing animals as "CB" (captive bred) and announcements/documentation of successful reproduction in social media posts. It must be noted, however, that collecting conclusive evidence of captive breeding was challenging because of the difficulty in verifying such claims. Surveys tracked species, not individual animals.

Table 1. List of websites surveyed for posts 1st January 2015–30th June 2016 and 1st January 2017–30th June 2018.

No.	Website	Domain location	Status	
			2015–2016	2018
1	WWW.EUROFAUNA.COM	Europe	active	active
2	WWW.SALAMANDERLAND.AT	Austria	inactive	inactive
3	WWW.ANIMALFARM.CZ	Czech Republic	active	active
4	WWW.LAFERMETROPICALE.COM	France	active	inactive
5	WWW.REPTILICA.DE	Germany	active	inactive
6	WWW.TERRARISTIK.COM	Germany	active	active
7	WWW.AZIENDANATURAVIVA.COM	Italy	active	active
8	WWW.CAUDATA.NL	Netherlands	redirects	redirects
9	WWW.TERRARIUMONLINE.COM	Spain	inactive	inactive
10	WWW.DRAGOREPTILE.COM	Spain	inactive	inactive
11	WWW.AMPHIBIAN.CO.UK	UK	inactive	active
12	WWW.EXOTIC-PETS.CO.UK	UK	active	active
13	WWW.EXOTICPETS.CO.UK	UK	active	active
14	WWW.REPTILESPLUS.CO.UK	UK	?	active
15	WWW.DARTFROG.CO.UK	UK	active	active
16	WWW.KINGSNAKE.COM	USA	active	active
17	WWW.BACKWATERREPTILES.COM	USA	active	active
18	WWW.NATUREBOXPETEMPORIUM.COM	USA	active	active
19	WWW.JOSHSFROGS.COM	USA	active	active
20	WWW.LLLREPTILE.COM	USA	active	active

CITES (2016) and The IUCN Red List of Threatened Species ("IUCN Red List", IUCN, 2019) were searched to determine the international legal framework and the global extinction risk of species identified in internet surveys.

Life history traits influencing reproductive modes (arboreal, terrestrial, fossorial, aquatic) were evaluated and each species was assigned a number representative of its reproductive mode as per Haddad and Prado (2005).

LEGISLATION

Legislation and trade controls for the live export of amphibians vary among countries in the region, with the exception of species listed in the CITES appendices. Country-specific regulations are not easily accessible, and few species of amphibian native to the region are listed in the CITES appendices: only *Hoplobatrachus tigerinus*, which occurs in parts of Myanmar, and newts in the genus *Paramesotriton* and *Tylototriton*. However, it is important to note that both *Paramesotriton* and *Tylototriton* are recent additions to CITES and perhaps because of this, and their importation ban in the United States (U.S. Fish & Wildlife Service, 2016), there are no records of their legal trade in the CITES database.

Hoplobatrachus tigerinus is harvested for food and is an unlikely (non-charismatic) target species for the pet trade.

The most frequently posted amphibian species on the internet trade, *Theloderma corticale*.

Table 2. Southeast Asian amphibian species in the internet pet trade in Europe and the United States; study period: 1st January 2015–30th June 2016 and 1st January 2017–30th June 2018.

Anura		Offers/requests: Internet		Offers/requests: Social media		IUCN status	Mode*	Captive breeding evidence	CITES listing
Genus	Species	2015–16	2017–18	2015–16	2017–18				
Bombina	*microdeladigitora*		3		2	Not Evaluated	1	No	No
Duttaphrynus	*melanostictus*	3	6			Least Concern	1	No	No
Fejervarya	*limnocharis*	1	1			Least Concern	2	No	No
Glyphoglossus	*guttulatus*	1	2			Least Concern	1	No	No
Hoplobatrachus	*rugulosus*		1			Least Concern	1	No	No
Hyla	*chinensis*	1	2			Least Concern	1	No	No
Hylarana	*erythraea*	2	1			Least Concern	1	No	No
Hylarana	*picturata*		1			Least Concern	2	No	No
Hylarana	*signata*	1	1			Least Concern	2	No	No
Hylarana	spp.	1	1			Varies	Varies	No	No
Ingerophrynus	*galeatus*		1			Least Concern	2	No	No
Kaloula	*baleata*	1	1			Least Concern	1	No	No
Kaloula	*pulchra*	3	4			Least Concern	1	No	No
Kurixalus	*appendiculatus*				1	Least Concern	26	Yes	No
Leptobrachium	*guangxiense*	1				Not Evaluated	1	No	No
Leptobrachium	*hasseltii*	1	1			Least Concern	2	No	No
Limnonectes	*malesianus*	1	1			Near Threatened	1	No	No
Megophrys	*montana*	1	1			Least Concern	24	No	No
Megophrys	*nasuta*	3	6	11	8	Least Concern	24	Yes	No
Microhyla	*annamensis*		1			Vulnerable	1	No	No
Microhyla	*berdmorei*		1			Least Concern	1	No	No
Microhyla	*butleri*		1			Least Concern	1	No	No
Microhyla	*fissipes*		1	1		Least Concern	1	No	No
Microhyla	*pulchra*	1	1			Least Concern	1	No	No
Micryletta	*inornata*		1			Least Concern	1	No	No
Nyctixalus	*pictus*	1	2	2	2	Near Threatened	26	No	No
Occidozyga	*lima*	1	2			Least Concern	1	No	No
Odorrana	*livida*		1			Data Deficient	2	No	No
Phrynoidis	*asper*	1	2	1		Least Concern	1	No	No
Polypedates	*leucomystax*	3	7		6	Least Concern	33	Yes	No
Polypedates	*otilophus*	4	9	5	24	Least Concern	33	Yes	No
Pulchrana	*signata*		1			Least Concern	2	No	No
Rentapia	*hosii*	3	3	3		Least Concern	2	Yes	No
Rhacophorus	*annamensis*	3	1		1	Least Concern	33	Yes	No
Rhacophorus	*dennysi*	2	2	2	8	Least Concern	33	No	No
Rhacophorus	*feae*	2	2		1	Least Concern	33	No	No
Rhacophorus	*nigropalmatus*			1		Least Concern	33	No	No
Rhacophorus	*norhayati*		1			Not Evaluated	33	No	No
Rhacophorus	*pardalis*	1	1			Least Concern	33	No	No
Rhacophorus	*prominanus*		1		4	Least Concern	33	Yes	No
Rhacophorus	*reinwardtii*	2	4		1	Near Threatened	33	No	No
Staurois	*guttatus*	1	2			Least Concern	1	No	No
Theloderma	*asperum*	4	4	1	1	Least Concern	26	Yes	No
Theloderma	*bicolor*	2	2	1		Endangered	26	Yes	No
Theloderma	*corticale*	4	20	2	4	Least Concern	26	Yes	No
Theloderma	*gordoni*	2	1			Least Concern	26	Yes	No
Theloderma	*horridum*				6	Least Concern	26	Yes	No
Theloderma	*laeve*	2	1			Data Deficient	26	No	No
Theloderma	*licin*			1		Least Concern	26	No	No
Theloderma	*palliatum*	2	1		1	Endangered	26	Yes	No
Theloderma	*rhododiscus*	2				Near Threatened	26	No	No
Theloderma	*ryabovi*	2	1		4	Endangered	26	Yes	No
Theloderma	*stellatum*	3	1		5	Least Concern	26	Yes	No

Table 2 (continued). Southeast Asian amphibian species in the internet pet trade in Europe and the United States; study period: 1st January 2015–30th June 2016 and 1st January 2017–30th June 2018.

Caudata		Offers/requests: Internet		Offers/requests: Social media		IUCN status	Mode*	Captive breeding evidence	CITES listing
Genus	Species	2015–16	2017–18	2015–16	2017–18				
Laotriton	*laoensis*	1		5	15	Endangered	1	Yes	No
Paramesotriton	*deloustali*				1	Least Concern	2	No	II
Tylototriton	*asperrimus*	3	1		2	Near Threatened	4	No	II
Tylototriton	*shanorum*		1		3	Vulnerable	1	No	II
Tylototriton	*verrucosus*		1	2	18	Least Concern	1	No	II
Tylototriton	spp.		1	2	1	Varies	Varies	No	II

* Mode = Reproductive mode as per Haddad and Prado (2005).

RESULTS

A total of 59 Southeast Asian amphibian species comprising 53 anurans and six caudates were identified in the pet trade (Table 2). Eleven species (18.6%) are listed by the IUCN Red List as Endangered (EN), Vulnerable (VU) or Near Threatened (NT); five are either Not Evaluated (NE) or Data Deficient (DD) and all others are assessed as Least Concern (LC). However, many LC species comprise species complexes (i.e. phylogenetically close taxa that are morphologically nearly indistinguishable), requiring updated conservation assessments (Tapley *et al*., 2018). Of all species found in our surveys, only five (all Caudata) were listed in CITES, all in Appendix II.

Species were identified to genus only for *Hylarana*, *Paramesotriton* and *Tylototriton* on some websites. There was an increase in the number of species and individuals in the genera *Microhyla*, *Paramesotriton*, *Theloderma* and *Tylototriton* between the two study periods (Table 2).

Potential instances of captive breeding were identified for 16 of the 59 species (27.1%). Species claimed to be captive bred were *Kurixalus appendiculatus*, *Megophrys nasuta*, *Rentapia hosii*, *Polypedates leucomystax*, *Polypedates otilophus*, *Rhacophorus annamensis*, *Rhacophorus prominanus*, *Theloderma asperum*, *Theloderma bicolor*, *Theloderma corticale*, *Theloderma gordoni*, *Theloderma horridum*, *Theloderma palliatum*, *Theloderma ryabovi* and *Theloderma stellatum*. *Laotriton laoensis* was also identified as being captive bred.

In many cases captive breeding was partially supported on social media as posted photographs documenting breeding facilities, adults in amplexus, eggs, and juveniles (with the caveat that they would need in-situ verification to be corroborated).

Of the 20 websites that were surveyed four were no longer active, one changed websites, one redirected to a nuisance site in both 2016 and 2018, one had no amphibians and another one had no Southeast Asian amphibians. Of the remaining websites, one was a classifieds site and the others companies with internet domains corresponding to the United States, United Kingdom, and the Czech Republic.

A total of 189 website posts were recorded for Southeast Asian amphibians. Countries with the greater number of posts (with the exception of the classifieds site, which showed postings from different countries, other domains were assumed to represent country of registration) were the United Kingdom (n=45), Czech Republic (n=33), United States (n=25), Russia (n=12) and Germany (n=10). Only one website reported country of origin, with Viet Nam, Indonesia, and China listed as places of origin for the website's listings.

The most frequently posted species were *Theloderma corticale* (n=24), *Polypedates otilophus* (n=13), *P. leucomystax* (n=10), *Megophrys nasuta* (n=9) and *Theloderma asperum* (n=8).

A total of 160 posts were recorded on the social media website. However, because of the cryptic nature of the site it was challenging to gauge origin of supply and demand for the majority of posts, so these were not particularly informative in this regard.

Six reproductive modes were recorded, with the most common being Mode 1 (eggs and exotrophic tadpoles in lentic water, n=22), followed by Mode 26 (eggs and exotrophic tadpoles that develop in water-filled cavities, n=13) and Mode 33 (arboreal foam nest; hatchling tadpoles drop into ponds or streams, n=10).

DISCUSSION AND CONCLUSIONS

The transitory nature of many websites and social media posts means that these surveys are only a snapshot in time. Although Southeast Asian amphibians are neither the most colourful nor the most popular species, their trade may still pose a threat to wild populations.

Over a tenth of listings were Asian newts. Demand for Caudata did not appear to be coming from a single country. For example, posts from the internet survey came from the Czech Republic, Germany, Italy, United Kingdom and the United States; however, it is difficult to tell whether this might also reflect a site bias. Posts on the social media site did not, for the most part, advertise country of origin. Large numbers of Asian newts are known to be collected for the pet trade, presenting a major threat to wild populations (Rowley *et al*., 2016).

Particularly worrisome are the morphologically cryptic genera *Paramesotriton* and *Tylototriton*, making identification challenging (Rowley *et al*., 2016). The demand for these species appears to be increasing over time (Table 2). Demand for the Lao Newt, *Laotriton laoensis*, threatened primarily by collection for the pet trade (IUCN SSC Amphibian Specialist Group, 2017a), increased three-fold in the social media website, which could reflect a decrease in the availability of this species and/or greater demand.

Rhacophorid frogs were common in the pet trade, particularly the genus *Theloderma*: 11 species were recorded, representing over 42% of known species in this genus. Of note, *Theloderma bicolor*, *T. palliatum* and *T. ryabovi* are all globally Endangered (van Dijk *et al*., 2004; Rowley *et al*., 2010; IUCN SSC Amphibian Specialist Group, 2017a,b,c). These results echo the findings of Altherr *et al*. (2020), where *Theloderma asperum*, *T. corticale* and *T. ryabovi* were found to be among the 100 most traded amphibians in Germany, in addition to other frequently posted rhacophorids such as *Polypedates otilophus* and *P. leucomystax*.

While some posts announced captive breeding, based on the information provided it was very difficult to determine if laundering was taking place. Declarations of Captive Bred animals supported by photos documenting one or more aspects of breeding (amplexus, eggs, tadpoles) were assumed to be legitimate, but still difficult to verify.

There were six reproductive modes represented in our sample, with three common modes: eggs and tadpoles developing in lentic water, eggs and tadpoles developing in water-filled cavities, and arboreal foam nests where tadpoles drop into bodies of water. Presumed evidence of captive breeding was most often recorded for *Theloderma* spp., all of which have eggs and tadpoles developing in water-filled cavities. This reproductive mode, requiring small bodies of still water, is easier to facilitate under captive conditions, potentially leading to greater success at captive reproduction.

With increased globalisation there is also increased movement and subsequent threat of wildlife diseases, as evidenced by the COVID-19 pandemic. Amphibian populations worldwide have been severely affected by the amphibian chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*) (Daszak *et al*., 2003; Olson *et al*., 2013). First identified in the late 1990s, *Bd* spread has been linked to the amphibian pet trade (Fisher and Garner, 2007; Garner *et al*., 2009; Peel *et al*., 2012). Research suggests that *Bd* originated in East Asia and that intercontinental transmission is ongoing (O'Hanlon *et al*., 2018). The more recently discovered salamander chytrid fungus, *Batrachochytrium salamandrivorans* (*Bsal*), also appears to have originated in East Asia and has spread through Europe via the pet trade, driving declines in wild Fire Salamander *Salamandra salamandra* populations (Martel *et al*., 2014; Spitzen-van der Sluijs *et al*., 2016). *Bsal* has so far only been known to cause disease in salamander populations, but has been found on Small-webbed Fire-bellied Toads *Bombina microdeladigitora* imported into Germany from Viet Nam, meaning it could be vectored by anurans (Nguyen *et al*., 2017). Other pathogens have been documented in widely traded amphibian species, including Mycobacteria and ranavirus (e.g. Suykerbuyk *et al*., 2007; Gilbert *et al*., 2013).

***Tylototriton verrucosus*, one of the more regularly encountered salamander species appearing in online posts in this study.**

RECOMMENDATIONS

Based on the results and insights gained over the course of this study, the following recommendations are offered:

1. In order to reduce pet trade pressures on wild amphibian populations, trade regulations and monitoring must be improved, inclusive of monitoring of the online trade. Ideally, trade movements of all amphibian species would be documented internationally, which would help control the spread of pathogens such as fungi, viruses and bacteria, and help protect the living communities of other ecosystems.
2. Implementing a global process such as that recommended above would take time, so in the shorter to medium term we suggest that governments who allow the importation of amphibians create a process that allows reporting of number and species involved. CITES listings would allow for better regulation of the Southeast Asian amphibian trade, especially for the most traded species. Except for species in the genus *Tylototriton* (Appendix II listing), none of the other frequently posted species are listed in any of the CITES appendices.
3. Determining the legality of trade at the regional level was challenging. The development of legal frameworks and publicly available mechanisms (e.g. databases) that allow for the identification of illegally taken wildlife within the region would help the monitoring process.
4. For every amphibian that makes it to the pet trade, there are many more that do not. From the point of harvest to the commercial point of sale there are several steps in between (including temporary housing and various transportation routes and conditions), all multiple stressors that can take an enormous toll on individual animals, to the point of mortality. Although this aspect was outside the scope of our study, we consider that documenting mortality through the supply chain is something that needs the consideration of authorities and responsible providers and hobbyists alike.
5. Identification by experts is key, so forging formal agreements between government agencies and institutions capable of assisting with identification would be beneficial.
6. Given the overriding threat of the pet trade to the monotypic and highly endemic Lao Newt *Laotriton laoensis* (Phimmachak *et al*., 2012; IUCN SSC Amphibian Specialist Group, 2017a; Stuart *et al*., 2014; Rowley *et al*., 2016), and the continued demand for the species detected on social media, we recommend an assessment for a CITES listing for the species.
7. Standardised biosecurity protocols, which could include screening and quarantine for imported amphibians, would help reduce disease spread. Such monitoring would allow a greater understanding of the nature and scale of amphibian trade, as well as identifying species in need of CITES listing. In instances where species are highly threatened and endemic to one country, detailed studies and/or an Appendix III listing may warrant consideration. IT-based approaches also show promise in increasing the range and scope of monitoring efforts in online trade (Di Minin *et al*., 2018).
8. All relevant parties, including lawmakers and hobbyists, need to be educated on the dangers posed by pathogens and the need for sustainable options for legal trade while limiting or eliminating trade in species which cannot support it. Development of documentation spelling out pet trade consumer responsibility would help inform the hobbyist community of the impacts of their choices. Globally-scoped umbrella organisations could create outreach programmes via social media and support for species study and monitoring. Smaller organisations can be engaged on a regional or local scale.
9. Based on the nature of internet posts, the verification of countries of posting, origin, and claims of captive breeding was challenging. We recommend further investigation to identify mechanisms that may allow such claims to be verified.

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***Hyla chinensis*, a species of tree frog, was encountered in trade, although there was no evidence of captive breeding.**