

ISSN 2633-996X



BRITISH HERPETOLOGICAL SOCIETY REPORTS

No. 5, June 2025

**AMERSHAM MEETING REPORT 2024
CONSERVATION, CAPTIVE BREEDING AND
FIELDWORK**

Edited by Simon Townson



FRONT COVER: Captive bred pair of *Salamandra salamandra bernardezi*. Photograph by Simon Townson.

Contents

A preliminary herpetofaunal survey of Mount Po Ma Lung, north-west Vietnam Luan Thanh Nguyen, Benjamin Tapley, Daniel Kane, Tuyet-Dzung Thi Tran & Jodi J.L. Rowley	1–4
Understanding human-snake coexistence in India: Insights from Goa Shaleen Attre	5–8
Mitigating the impact of climate change in sea turtle reproduction: developing the evidence base for clutch-splitting as a low-cost management tool Leo Clarke, Nelson Semedo, Diana Nadine Semedo & Samir Martins	9–13
Observations of human-herpetofauna coexistence issues in the Neotropics John Rowland	14–16
Malagasy amphibians; competing drivers and their impacts on conservation progress Angus I. Carpenter	17–22
Breeding fire salamanders, with reference to both <i>Salamandra salamandra</i> and <i>Salamandra algira</i> David Garthwaite	23–27

A preliminary herpetofaunal survey of Mount Po Ma Lung, north-west Vietnam

Luan Thanh Nguyen¹, Benjamin Tapley^{2*}, Daniel Kane², Tuyet-Dzung Thi Tran¹ & Jodi J.L. Rowley^{3,4}

¹Asian Turtle Program of Indo-Myanmar Conservation, R.1301, CT1 Bac Ha C14 Building, To Huu Str., Nam Tu Liem Dist., Hanoi, Vietnam

²Zoological Society of London, Regent's Park, London, NW1 4RY, UK

³Australian Museum Research Institute, Australian Museum, 1 William St, Sydney, NSW, 2010, Australia

⁴Centre for Ecosystem Science, School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney NSW 2052, Australia

*Corresponding author e-mail: ben.tapley@zsl.org

The Hoang Lien Range in north-west Vietnam is home to more than 80 amphibian species (Tapley et al., 2017a) and the reptile fauna is comprised of at least 19 families (Uetz et al., 2024). The amphibians and reptiles of the Hoang Lien Range have been subject to formal scientific study for nearly 100 years (e.g. Bourret, 1937; Ohler et al., 2000) and reptiles and amphibians that are new to science continue to be described,

many within the last decade (e.g. Hoang et al., 2016; Matsui et al., 2017; Tapley et al., 2017b; 2018; 2020a; Kropachev et al., 2019; Nguyen et al., 2021, Kane et al., 2023; Nguyen et al., 2024b; Okabe, 2024) and it is likely that there will be further descriptions of species that are new to science, particularly in parts of the Hoang Lien Range that are yet to be surveyed for their herpetofauna.

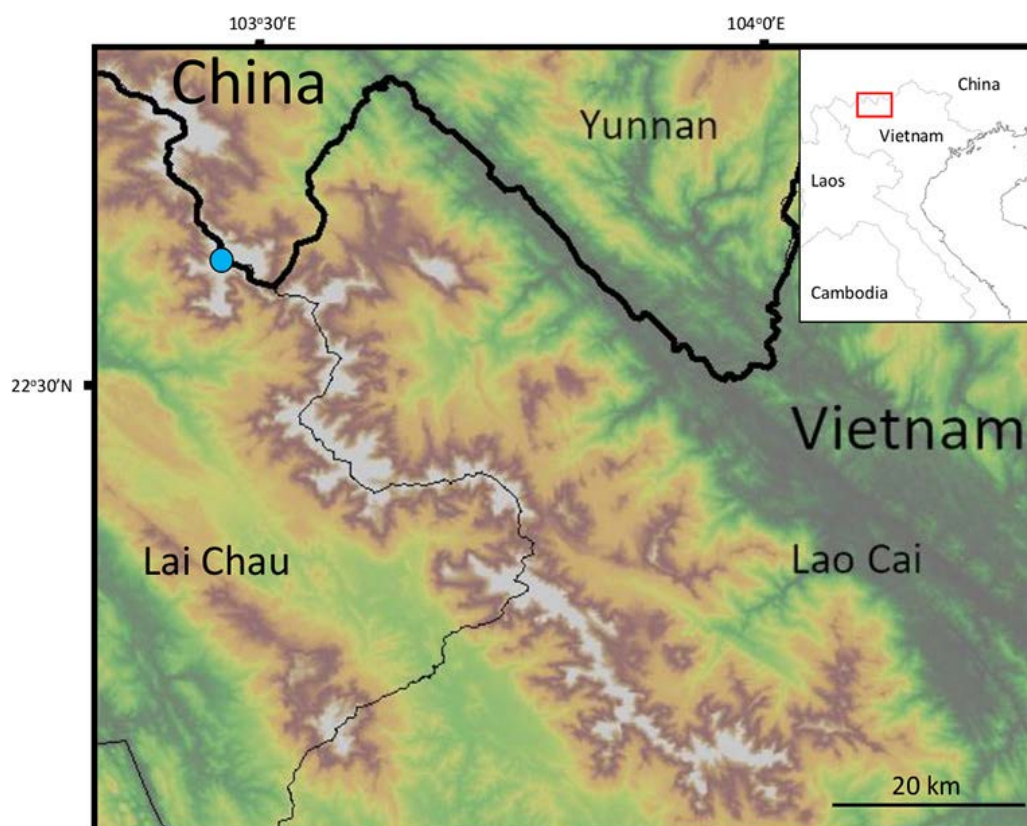


Figure 1. The Hoang Lien Range in north-west Vietnam. Blue circle shows the location of the survey sites on Moun Po Ma Lung. Pale grey areas indicative of higher elevation, dark green indicative of lowest elevation.

Table 1. Amphibians encountered during the nine day survey of Mount Po Lung.

Family	Genus	Number of species
Bufonidae	<i>Duttaphrynus</i>	1
Dicroglossidae	<i>Fejervarya</i>	1
	<i>Nanorana</i>	1
Megophryidae	<i>Oreolalax</i>	2
	<i>Leptobrachium</i>	1
	<i>Leptobrachella</i>	3
	<i>Atympanophrys</i>	1
	<i>Boulenophrys</i>	2
Ranidae	<i>Xenophrys</i>	1
	<i>Amolops</i>	1
	<i>Odorrana</i>	3
Rhacophoridae	<i>Theloderma</i>	1

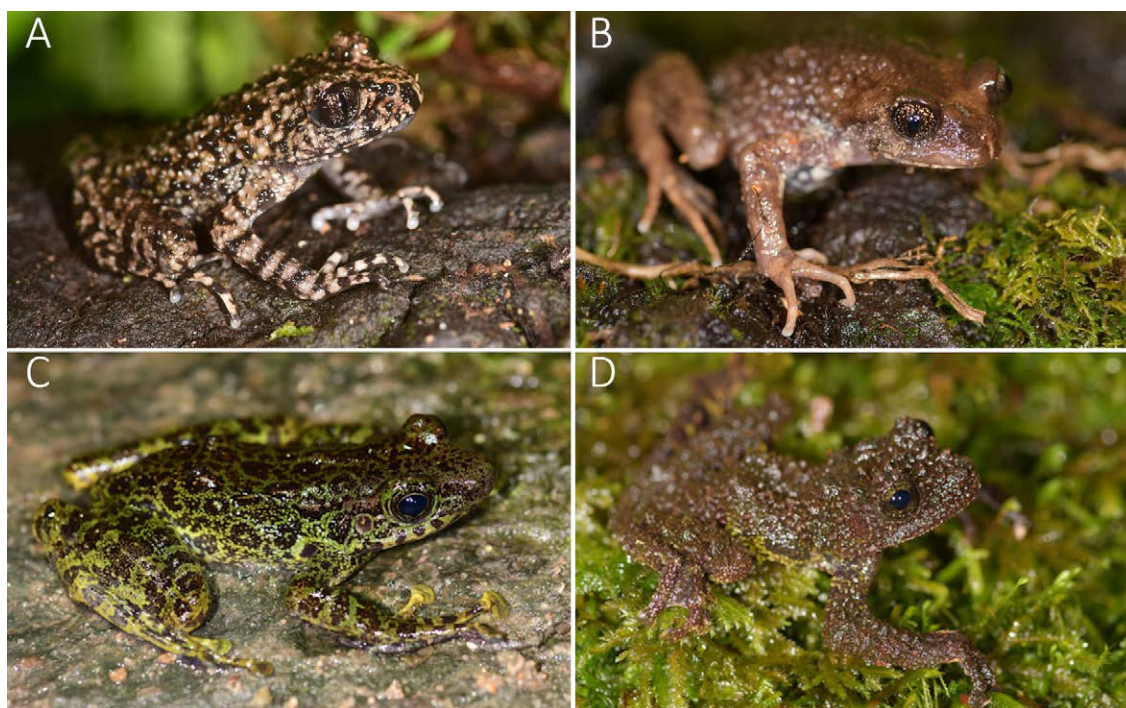
Some of these newly described species from the Hoang Lien Range are highly threatened. Botsford's leaf-litter frog *Leptobrachella botsfordi* and Sterling's toothed toad *Oreolalax sterlingae* were described as from the same high elevation stream site on Mount Fansipan in 2013 (Nguyen et al., 2013; Rowley et al., 2013). Shortly after their description, both species were assessed as Critically Endangered, as the only site that they were known to occur was increasingly threatened by habitat loss and pollution associated infrastructural developments for tourism (IUCN

Table 2. Reptiles encountered during the nine day survey of Mount Po Lung.

Family	Genus	Number of species
Agamidae	<i>Acanthosaura</i>	1
Gekkonidae	<i>Hemidactylus</i>	1
Colubridae	<i>Hebius</i>	1
	<i>Pseudoxenodon</i>	1
Viperidae	<i>Ovophis</i>	1
	<i>Protobothrops</i>	1
	<i>Trimeresurus</i>	1

SSC, 2021a; 2021b). Subsequently, *O. sterlingae* was recorded at another site 20 km to the north on Mount Pu Ta Leng (Tapley et al., 2020b), as a result it was reassessed as Endangered (IUCN SSC, 2021a). Recently, *L. botsfordi* was recorded from Mount Nam Kang Ho Tao 23.4 km south-east of the closest reported location of the species on Mount Fansipan (Nguyen et al., 2023).

There is still a knowledge deficit regarding the true range of *L. botsfordi* and *O. sterlingae* and there are several unsurveyed sites where habitats may be suitable. In August 2023 we undertook the first ever herpetological survey of Mount Po Ma Lung, in Lai Chau Province, north-west Vietnam on the China-Vietnam border (Fig. 1). Mount Po Ma Lung is the 7th highest

**Figure 2.** A. *Oreolalax adelphos*, B. *Oreolalax sterlingae*, C. *Odorrana chapaensis*, D. *Theloderma bicolor*.

mountain in Vietnam. This site is not under any formal protection and is managed by the local commune. A nine day survey across an elevation gradient from 818 m a.s.l. to 2,967 m a.s.l. was undertaken. The primary aim of this survey was to detect the presence of *L. botsfordi* and *O. sterlingae*. Visual encounter surveys were undertaken by a team of experienced researchers during the day and at night, focusing on riparian habitats. Voucher specimens and tissue samples were collected to verify the presence of species.

A total of 18 amphibian and seven reptile species were encountered during the survey (Tables 1 & 2; Fig. 2). There was a particularly diverse assemblage of frogs of the family Megophryidae. The most notable finding was a population of *Oreolalax* which was described as new to science as *Oreolalax adelphos* (Nguyen et al., 2024a; Fig. 2A). *Oreolalax sterlingae* was also encountered at elevations above 2,550 m a.s.l. (Fig. 2B). This represents a 25.5 km range extension to the north-west for this range restricted threatened species (Nguyen et al., 2024). Work to identify the remaining species encountered during the survey is ongoing and the full findings shall be published at a later date.

This survey was short in duration, and it is likely that we did not detect many species that are present on Mount Po Ma Lung. Future surveys should be undertaken at other times of the year to coincide with the activity periods of other species that could be present and much greater survey effort of Mount Po Ma Lung is warranted.

Acknowledgements

We extend our thanks to the Forest Protection Department of Phong Tho District and the Phong Tho Border Office and Ban Lang Police Office for supporting this work. Luan Thanh Nguyen extends special thanks to Chao Van Dat, Ly Manh Ha and Hoang Van Hung (Vietnam National University of Forestry) and local porters from Ban Lang Commune (Lai Chau) for assistance in the field. Ethical approval was granted by the Zoological Society of London's ethics committee (project ZFP1). The field work was generously supported by the British Herpetological Society. Field equipment was partly supported by IDEA WILD for Luan Nguyen.

References

Bourret, R. (1937). Notes herpétologiques sur L'Indochine Française. XIV. Les batraciens de la collection du Laboratoire des Sciences Naturelles de l'Université. Descriptions de quinze espèces ou

- variétés nouvelles. Annexe au Bulletin Général de l'Instruction Publique 1937, 5–56. [in French]
- IUCN SSC Amphibian Specialist Group (2021a). *Oreolalax sterlingae*. The IUCN Red List of Threatened Species 2021: e.T76491633A87995169. <https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T76491633A87995169.en>. Accessed on 21 November 2024.
- IUCN SSC Amphibian Specialist Group (2021b). *Leptobranchella botsfordi*. The IUCN Red List of Threatened Species 2021: e.T73727195A87994974. <https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T73727195A87994974.en>. Accessed on 21 November 2024.
- Kane, D., Tapley, B., La, T.V. & Nguyen, L.T. (2023). A new species of the genus *Rhabdophis* Fitzinger, 1843 (Squamata: Colubridae) from the Hoang Lien range, northwest Vietnam. *Zootaxa* 5343, 101–125.
- Kropachev, I.I., Orlov, N.L., Ninh, H.T. & Nguyen, T.T. (2019). A new species of *Rhacophorus* genus (Amphibia: Anura: Rhacophoridae: Rhacophorinae) from Van Ban District, Lao Cai Province, northern Vietnam. *Russian Journal of Herpetology* 26, 325–334.
- Matsui, M., Ohler, A., Eto, K. & Nguyen, T.T. (2017). Distinction of *Gracixalus carinensis* from Vietnam and Myanmar, with description of a new species. *Alytes* 33, 25–37.
- Nguyen, L.T., Tapley, B., Nguyen, C.T., Van Luong, H. & Rowley, J.J. (2021). A new species of *Leptobranchella* (Anura, Megophryidae) from Mount Pu Ta Leng, northwest Vietnam. *Zootaxa* 5016, 301–332.
- Nguyen, L.T., Rowley, J.J.L. La, T.V. & Tapley, B. (2023). Notes on the oviposition sites of Botsford's leaf-litter frog (*Leptobranchella botsfordi*) and a significant range extension for the species. *Herpetology Notes* 16, 103–109.
- Nguyen, L.T., Tapley, B., Kane, D., yet-Dzung, T.T., Cui, J. & Rowley, J.J.L. (2024a). A new *Oreolalax* (Anura: Megophryidae) from the Hoang Lien Range, northwest Vietnam. *Zootaxa* 5514, 501–524.
- Nguyen, T.T., Nguyen, H.H., Ninh, H.T., Le, L.T.H., Bui, H.T., Orlov, N., Hoang, C.V. & Ziegler, T. (2024b). *Zhangixalus thaoae* sp. nov., a new green treefrog species from Vietnam (Anura, Rhacophoridae). *ZooKeys* 1197, 93–113.
- Nguyen, Q.T., Phung, T.M., Le, M.D., Ziegler, T. & Böhme, W. (2013). First record of the Genus *Oreolalax* (Anura: Megophryidae) from Vietnam with description of a new species. *Copeia* 2013, 213–222.
- Ohler, A., Marquis, O., Swan, S. & Grosjean, S.T. (2000). Amphibian biodiversity of Hoang Lien Nature Reserve (Lao Cai Province, northern Vietnam) with description of two new species. *Herpetozoa* 13(1/2), 71–87.

- Okabe, S., Motokawa, M., Koizumi, Y., Nguyen, T.Q., Nguyen, T.T. & Bui, H.T. (2024). A new species of the genus *Scincella* (Squamata: Scincidae) from Mount Fansipan, Hoang Lien Son Range, northwestern Vietnam. *Zootaxa* 5537, 407–423.
- Rowley, J.J., Dau, V.Q. & Nguyen T.T. (2013). A new species of *Leptolalax* (Anura: Megophryidae) from the highest mountain in Indochina. *Zootaxa* 3737, 415–428.
- Tapley, B., Cutajar, T., Mahony, S., Nguyen, C.T., Dau, V.Q., Nguyen, T.T., Luong V.H. & Rowley, J.J.L.L. (2017b). The Vietnamese population of *Megophrys kuatunensis* (Amphibia: Megophryidae) represents a new species of Asian horned frog from Vietnam and southern China. *Zootaxa* 4344, 465–492.
- Tapley, B., Rowley, J.J.L., Nguyen, C.T. & Luong, H.V. (2017a). A conservation action plan for the amphibians of the Hoang Lien Mountain range. <http://www.amphibians.org/wp-content/uploads/2017/03/An-action-plan-for-the-amphibians-of-the-Hoang-Lien-Mountain-Range-2017-2021.pdf>. Accessed on 9 January 2023.
- Tapley, B., Cutajar, T., Mahony, S., Nguyen, C.T., Dau, V.Q., Luong, A.M., Le, D.T., Nguyen, T.T., Nguyen, T.Q., Portway, C., Luong, H.V. & Rowley, J.J.L. (2018). Two new and potentially highly threatened *Megophrys* Horned frogs (Amphibia: Megophryidae) from Indochina's highest mountains. *Zootaxa* 4508, 301–333.
- Tapley, B., Cutajar, T., Nguyen, L.T., Portway, C., Mahony, S., Nguyen, C.T., Harding, L., Luong, H.V. & Rowley, J.J. (2020a). A new potentially Endangered species of *Megophrys* (Amphibia: Megophryidae) from Mount Ky Quan San, north-west Vietnam. *Journal of Natural History* 54, 2543–2575.
- Tapley, B., Nguyen, L.T., Portway, C., Cutajar, T., Nguyen, C.T., Luong, H.V., Kane, D., Harding, L. & Rowley, J.J.L. (2020b). A point endemic no more; a range extension for *Oreolalax sterlingae* (Nguyen et al., 2013) in Bat Xat District, Lao Cai Province, northern Vietnam. *Herpetology Notes* 13, 497–500.
- Uetz, P., Freed, P., Aguilar, R. & Hošek, J. (2024). The Reptile Database. Available from: <http://www.reptile-database.org>. Accessed on 24 May 2024.

Understanding human-snake coexistence in India: Insights from Goa

Shaleen Attre

Durrell Institute of Conservation and Ecology, School of Natural Sciences, University of Kent, Canterbury, Kent CT2 7NR, UK

Introduction

Snakebites pose a significant public health challenge, especially in tropical countries like India, which accounts for a staggering 45,000 to 58,000 deaths annually (Suraweera et al., 2020). Despite these figures, much remains unknown about the broader impacts of human-snake conflict (HSC), including the mortality of domestic animals and the number of snakes killed in fear or retaliation. This article explores the complexities of snakebite management and mitigation in India, with a focus on findings from my ongoing doctoral research conducted in Goa.

The scale of the problem

Globally, snakebites claim 81,000 to 138,000 human lives annually, leaving over 400,000 people with permanent disabilities (Gutiérrez et al., 2017; Williams et al., 2019). Recognising the severity of this issue, the World Health Organisation declared snakebite envenomation a Neglected Tropical Disease in 2017 (WHO, 2018). India, home to over 285 snake species, with nearly 20% being venomous (Whitaker, 1978; 2006; Whitaker & Martin, 2015), bears the brunt of this crisis. Currently polyvalent

anti-venom is produced from the venom of four snakes known as the ‘Big Four’: spectacled cobra *Naja naja*, common krait *Bungarus caeruleus*, Russell’s viper *Daboia russelii* and saw-scaled viper *Echis carinatus* (Whitaker & Martin, 2015). However, official data on snakebite-related deaths often excludes non-human impacts, such as livestock and domestic animal losses. There is also no count on the killing of snakes out of fear, ignorance or retaliation, many of which are harmless and non-venomous.



Figure 1. Bamboo pit viper



Figure 2. Checkered Keelback with eggs

Challenges in snakebite mitigation

Efforts to mitigate snakebite deaths are hindered by numerous factors. A significant issue is the tendency for many snakebite victims to turn to faith healers or traditional medicine rather than seeking professional medical care. This is largely due to a lack of awareness regarding the correct procedures after a snakebite, and the widespread belief that snakebites are curses, not medical emergencies (Malhotra et al., 2021). The delay caused by consulting faith healers or applying unscientific remedies, such as burning the bite site or using herbal treatments, worsens the victim's condition and delays access to effective treatment (Price, 2017).



Figure 3. Cobra bite after several years

Another major barrier is the logistical difficulty in reaching hospitals that are properly equipped to treat snakebites. In rural or remote areas, hospitals with trained personnel or the necessary anti-venom and medical facilities are scarce, forcing many people to seek treatment at private hospitals. However, anti-venom can be prohibitively expensive in these private facilities, making it unaffordable for many families. As a result, patients often resort to faith healers as a cheaper, but ultimately ineffective, alternative (Bhargava et al., 2020; Malhotra et al., 2021). Moreover, the efficacy of anti-venom varies significantly by region and is often limited to treating bites from the Big Four species (Sirur et al., 2022; Whitaker & Martin, 2015). This leaves victims of bites from other venomous snakes with little recourse for effective treatment. Misconceptions and a lack of accurate information about snakes, combined with limited availability of anti-venom in nearby hospitals, can increase the danger these reptiles pose to humans and vice versa (Bawaskar, 2014).

Why Goa?

Goa presents a unique case study area for studying human-snake interactions. Despite being one of India's smallest states, it has a relatively low



Figure 4. Juvenile Spectacled cobra rescued in shopping bag



Figure 5. Juvenile Whitaker's boa

snakebite mortality rate in humans compared to neighbouring states like Karnataka and Maharashtra. From 2019 to 2021, Goa recorded 3,346 snakebite cases with 27 fatalities, a stark contrast to the higher death tolls in its larger neighbours. The state was chosen for this study due to its size and the preliminary data being gathered from local consultants, which led to the hypothesis that Goa's unique geographical, demographic and socio-economic characteristics have helped it to mitigate snakebite mortality (Sawaiker, 2021). These factors have enabled the state to successfully promote human-snake coexistence, despite the concurrent presence

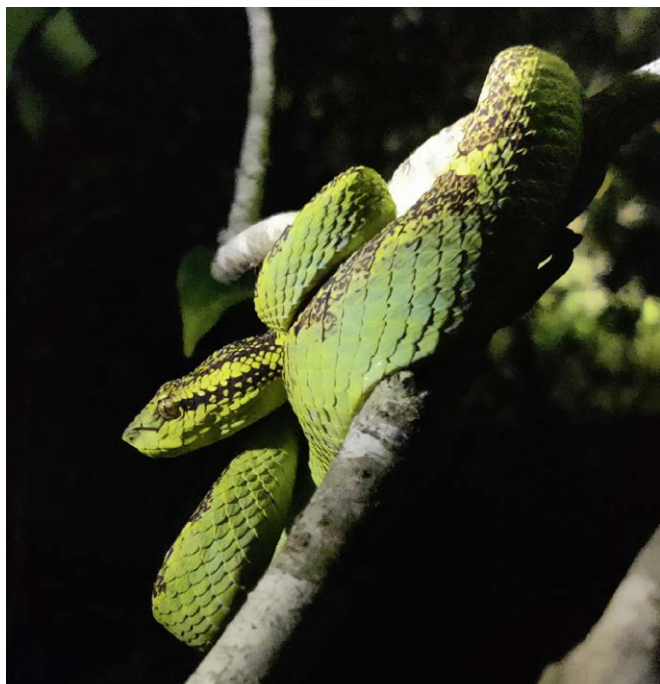


Figure 6. Malabar pit viper

of threats to snake populations, including infrastructure development, climate change, deforestation, and urbanisation (TERI, 2015; Talule & Naik, 2014).

My research aimed to understand the factors contributing to Goa's lower mortality rates while identifying effective strategies for mitigating HSC. This involved qualitative and quantitative data collection, including interviews to understand attitudes and perceptions, studying domestic animal mortality due to snakebites, analysing snake rescue records along with human snakebite data.

Findings and recommendations

The study highlighted several key factors contributing to Goa's relatively low snakebite mortality. Community-led initiatives emerged as a cornerstone in promoting coexistence between humans and snakes. Awareness campaigns and first-aid training workshops, often spearheaded by communities, have been instrumental in dispelling myths about snakes and educating communities about safe practices. By rejecting traditional medicine and adopting scientifically proven methods, communities in Goa have demonstrated how collective action can drive meaningful change.

The availability of accessible healthcare, including hospitals equipped with anti-venom,



Figure 7. Release of juvenile Russell's viper

ambulance services and trained medical professionals, has also been pivotal in saving lives. Emergency response systems, such as 24/7 helplines and a dedicated network of rescuers supported by the Forest Department, play a critical role in reducing human-snake encounters and preventing retaliatory killings of snakes.

However, snake rescues can be a double-edged sword. While they help mitigate conflict and reduce unnecessary snake deaths, the risks associated with unchecked handling and improper or unnecessary translocation of snakes highlight the need for stringent protocols and proper training and accountability for rescuers.

Despite these successes, Goa faces significant challenges, particularly from rapid, unchecked urbanisation, especially with an increase in the influx of immigrants. Expanding development increases the likelihood of human-snake interactions, underscoring the importance of outreach efforts targeted at both local and immigrant populations unfamiliar with local wildlife. Increased education about snake identification and correct actions following a snakebite is crucial for these groups.

Additionally, more research is needed to understand the socio-economic and mental health impacts of snakebites, as well as the scale of domestic animal deaths caused by snakebites or snake predation. Such data will enable the development of more holistic mitigation strategies.

Implications for conservation and coexistence

The findings from Goa underscore the power of community-led initiatives in fostering coexistence. Awareness campaigns that involve

local leaders, coupled with accessible medical care and robust emergency response systems, can significantly reduce snakebite mortality while promoting harmony between humans and snakes. When communities take ownership of coexistence strategies, they not only protect themselves but also contribute to the conservation of snake populations.

However, the ecological risks associated with snake rescues emphasise the need for balanced approaches that do not inadvertently harm snake populations. Rescue efforts must be guided by ethical practices to ensure both human safety and ecological integrity.

Conclusion

Snakebites are not just a medical emergency but a complex socio-ecological issue that requires multifaceted solutions. By addressing healthcare gaps, dispelling myths, promoting coexistence through community action and implementing responsible rescue practices, it is possible to reduce the toll of snakebites on both humans and snakes. The Goa model serves as a testament to how small, community-driven initiatives can lead the way in mitigating human-wildlife conflict, offering hope for similar efforts across India and beyond.

References

- Bawaskar, H.S. (2014). Snake bite poisoning: A neglected life-threatening occupational hazard. *Indian Journal of Critical Care Medicine*, 123–124. Doi: 10.4103/0972-5229.128698. PMID: 24701058; PMCID: PMC3963191.
- Bhargava, S., Kumari, K., Sarin, R. & Singh, R. (2020). Call for accurate statistical data to solve snakebite conundrum in India. *Asian Pacific Journal of Tropical Medicine* 13, 141.
- Gutiérrez, J.M., Calvete, J.J., Habib, A., Harrison, R.A., Williams, D. & Warrell, D.A. (2017). Snakebite envenoming. *Nature Reviews Disease Primers* 3, 17063. Doi: 10.1038/nrdp.2017.63.
- Malhotra, A., Wüster, W., Owens, J.B., Hodges, C.W., Jesudasan, A., Ch, G., Kartik, A., Christopher, P., Louies, J., Naik, H., Santra, V., Kuttalam, S.R., Attre, S., Sasa, M., Bravo-Vega, C. & Murray, K.A. (2021). Promoting co-existence between humans and venomous snakes through increasing the herpetological knowledge base. *Toxicon X* 12. Doi: 10.1016/j.toxcx.2021.100081.
- Price, L. (2017). Animals, governance and ecology: Managing the menace of venomous snakes in colonial India. *Cultural and Social History* 14(2), 201–217.
- Sawaiker, R.U. (2021). Conservation of biodiversity through scientifically validated and well-participated people's biodiversity registers in Goa, India. *Asian Journal of Conservation Biology* 10, 159–161.
- Sirur, F.M., Balakrishnan, J.M. & Lath, V. (2022). Hump-nosed pit viper envenomation in western coastal India: A case series. *Wilderness and Environmental Medicine* 33, 399–405. Doi: 10.1016/j.wem.2022.08.006.
- Suraweera, W., Warrell, D., Whitaker, R., Menon, G., Rodrigues, R., Fu, S.H., Begum, R., Sati, P., Piyasena, K. & Bhatia, M. (2020). Trends in snakebite deaths in India from 2000 to 2019 in a nationally representative mortality study. *eLife* 9, e54076.
- Talule, D.C. & Naik, G.R. (2014). Impacts of indiscriminate mining on agriculture and biodiversity in the state of Goa in India. *Universal Journal of Agricultural Research* 2(6), 211–215. Doi: 10.13189/ujar.2014.020605.
- TERI (2015). The Energy and Resources Institute. Directions, Innovations, and Strategies for Harnessing Action for Sustainable Development in Goa. New Delhi.
- Whitaker, R. (1978). *Common Indian snakes: A field guide*. Macmillan India Limited.
- Whitaker, R. (2006). Snakebite management in India: Current challenges. *The Madras Crocodile Bank Trust Bulletin* 4(3), 12–18.
- Whitaker, R. & Martin, G. (2015). Diversity and distribution of medically important snakes of India. In: *Clinical Toxinology in Asia Pacific and Africa*. 115–136 pp. Gopalakrishnakone, P., Faiz, A., Fernando, R., Gnanathasan, C.A., Habib, A.G. & Yang, C.-C. (Eds.). Dordrecht: Springer Netherlands. Doi: 10.1007/978-94-007-6386-9_16.
- WHO (2018). Snakebite envenoming: A neglected tropical disease. World Health Organisation Report, 1–9.
- Williams, D.J., Faiz, M.A., Abela-Ridder, B., Ainsworth, S., Bulfone, T.C., Nickerson, A.D., Habib, A.G., Junghanss, T., Fan, H.W., Turner, M., Harrison, R.A. & Warrell, D.A. (2019). Strategy for a globally coordinated response to a priority neglected tropical disease: Snakebite envenoming. *PLoS Neglected Tropical Diseases* 13(2), e0007059.

Mitigating the impact of climate change in sea turtle reproduction: developing the evidence base for clutch-splitting as a low-cost management tool

Leo Clarke¹, Nelson Semedo², Diana Nadine Semedo² & Samir Martins²

¹School of Environmental Sciences, University of Liverpool, UK

²BIOS.CV, Boa Vista, Cabo Verde, SA

For sea turtles, like all reptiles, environmental temperature influences numerous life-history stages (Böhm et al., 2016; Ihlow et al., 2012). Temperature-dependent sex determination (TSD), in particular, has been highlighted as a cause for concern in much of the scientific literature regarding the conservation biology of sea turtles in a changing climate. The temperature during the second trimester of incubation, also known as the thermosensitive period, determines the sex of hatchlings (Standora & Spotila, 1985). Lower temperatures (26–28 °C) result in a higher percentage of males produced, and higher temperatures (30–34 °C) yield predominantly female hatchlings (Booth, 2017). Higher nest temperatures due to global climate change are already causing heavily female-biased hatchling sex ratios (Hays et al., 2014; 2017; Laloë et al., 2014; Tanner et al., 2019) and reduced hatching success (Montero et al., 2018; Tomillo et al., 2012). Thus, conservation managers are considering what mitigation techniques are available.

Nest temperatures are further exacerbated by metabolic heat generated as the eggs develop (Broderick et al., 2001; Zbinden et al., 2006; Gammon et al., 2020), reaching up to 2.5 °C in the thermosensitive period (Gammon et al., 2020). There is evidence that a novel, low-cost technique of halving an incubating sea turtle clutch size (clutch-splitting), thereby reducing the number of eggs and thus the amount of metabolic heat generated by the nest, can reduce overall nest temperatures relative to whole control clutches in an experimental conservation hatchery setting, demonstrating potential to improve hatch success and balance primary sex ratios (Clarke et al., 2021). This work aimed to investigate the effectiveness of the technique in the natural nesting environment of the endangered loggerhead turtle *Caretta caretta* for the first time and to collect additional data to



Figure 1. Hatchling loggerhead turtles heading for the surf.

understand the factors that influence metabolic heating of incubating sea turtle clutches.

The work was carried out on Boa Vista Island, part of the Cabo Verde archipelago in the eastern Atlantic Ocean off West Africa. Cabo Verde supports more than 95% of the loggerhead's nesting activity in the entire eastern Atlantic (Marco et al., 2012). Data collection was carried out on Joao Barrosa beach within the Reserva Natural de Tartaruga, across two field trips in August and September 2023, in collaboration

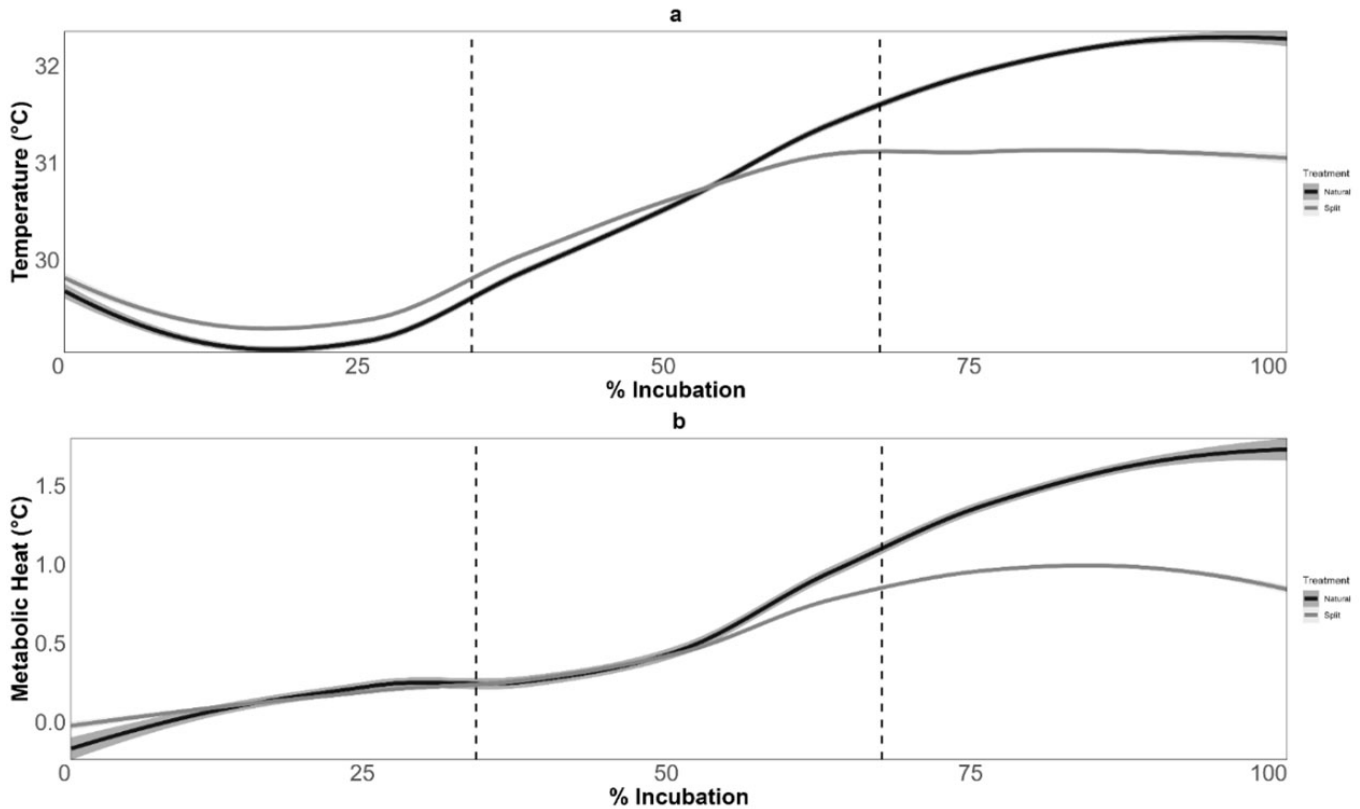


Figure 2. **a)** Incubation temperature, and **b)** metabolic heat profiles across incubation period for natural (black line, $n = 4$) and split (grey line, $n = 5$) nests, represented by a LOESS smoothing function fitted to data from nests that successfully incubated.

with BIOS.CV, a local NGO. We placed HOBO Onset Pendant UA-001-64 temperature data loggers (TDLs) in 19 loggerhead *C. caretta* nests. Nests were allocated to two treatments: control clutches ($n = 9$), which were left to incubate naturally, and split clutches ($n = 10$). In split clutches, half of the eggs were removed from the egg chamber during oviposition. An additional TDL was buried at nest depth 1 metre from the original nest at the same beach elevation, to monitor sand temperatures and to allow the calculation of metabolic heating of the nest. The elevation relative to chart datum was calculated using Finite Element Solution (FES) global tide dataset. After 60 days nests were monitored for hatching every two hours. Nests were excavated at least 48 hours after hatching to remove any hatchlings that had not emerged from the nest and to assess hatching success.

Of the 19 nests included in the study, eight nests hatched successfully. The failure of the remaining clutches to hatch was likely due to exceptionally high tides during August 2023 which left many nests on Joao Barrosa beach inundated for prolonged periods (E. Silva, pers.

comm.), and unseasonably high rainfall. Of nests that incubated successfully, nest temperatures increased gradually in the first trimester of incubation, and more rapidly in the second and third stages as embryonic development occurs (Fig. 2a). The temperature curve begins to plateau in the final stages as embryos complete development (Fig. 2a). The same trend is evident in MH profiles (Fig. 2b). Thermal profiles of both treatments diverged between natural and split clutches as incubation progresses (Fig. 2b). In the final third of incubation results indicated an almost 1 °C difference in mean nest temperatures between treatments (natural: 31.98 ± 0.57 vs split: 31.15 ± 0.37 °C) and mean MH in natural clutches 0.5 °C higher than in split clutches (1.49 ± 0.58 vs 0.99 ± 0.21 °C). Despite these trends, treatment comparisons of nest temperature and MH showed no significant differences across the whole of the incubation period, nor in any trimester individually, however. Despite this lack of statistical significance, split clutches nonetheless appeared to show lower MH overall and a trend towards lower MH in the final third. Our results show that MH of incubating *C. caretta* clutches can approach 0.5 °C in the

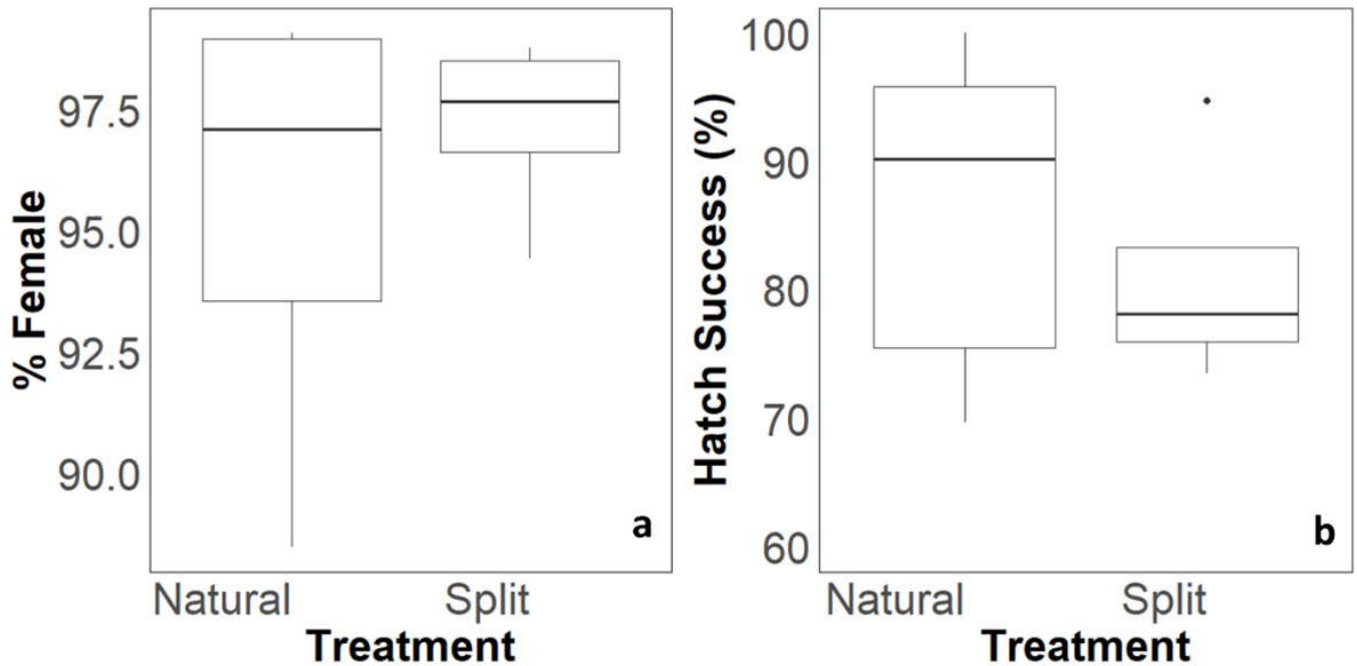


Figure 3. a) Mean modelled proportion of female hatchlings, and b) hatch success in natural and split nests in 2023. Boxplots show the interquartile range whilst the horizontal line represents the median value. Whiskers indicate the range of the data and data points indicate statistical outliers.

thermosensitive period of development and in excess of 1 °C in the final stages of incubation.

The best-fitting models applied to metabolic heat data included nest depth, elevation and clutch size as predictor variables. Only elevation and clutch size showed a significant effect, with greater elevations associated with less MH, and a positive effect of clutch size on the magnitude of MH. The best-fitting model fitted to data on MH in the middle third of incubation retained only nest elevation as a predictor variable, which again revealed a significant negative influence on the amount of MH produced in the thermosensitive period. The models fitted to overall MH and MH in the final third of incubation both included nest depth and elevation as explanatory variables, although only elevation had a significant effect and only in the model fitted to MH in the final third, with higher elevations associated with less MH during this period.

Modelled hatchling sex ratios were similar in both natural and split clutches, with mean proportions of female hatchlings >95% in both treatments (Fig. 3a). Higher proportions of females were produced at lower beach elevations (Fig. 4). Whilst mean hatching success was lower in split clutches than natural clutches (Fig. 3b), model outputs indicate no significant

treatment difference, likely due to low sample size and high variability in the data. We did not detect an effect of clutch-splitting as an effective management intervention in reducing

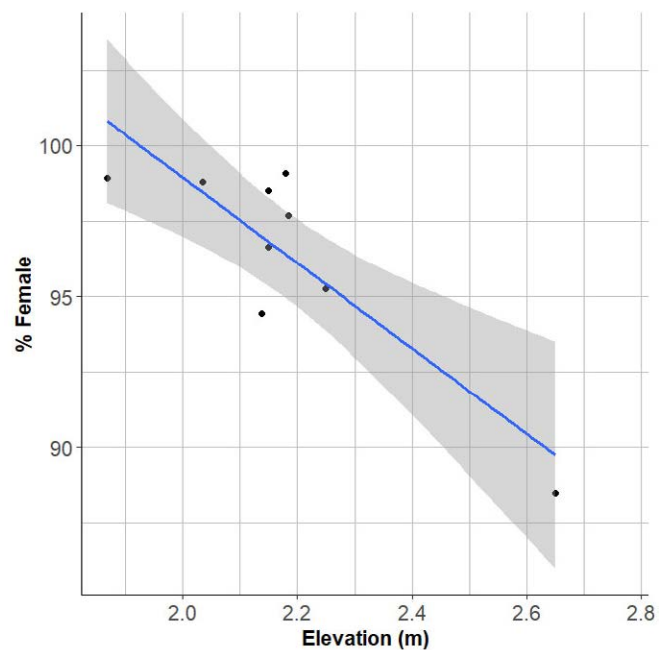


Figure 4. The relationship between hatchling sex ratios (% female) and nest elevation (m) ($F_{1,7} = 20.59$, $R^2 = 0.71$, $p = 0.003$).

the magnitude of MH produced by incubating *C. caretta* nests and in doing so reducing overall nest temperatures and female-bias in primary hatchling sex ratios. However, the failure of eleven nests to hatch due to prolonged tidal inundation and heavy rain markedly reduced our sample size and thus the statistical power of our analyses. Yet, despite the high variability in our data, the observed trends in nest temperatures and MH throughout incubation in nests that did incubate successfully provide some insight and suggest that split clutches may generate less MH and incubate at cooler temperatures compared to natural clutches, despite the lack of a statistically detectable effect. This is particularly evident when considering overall MH and in the final third of incubation.

We found no difference in the proportion of female hatchlings produced and in fact clutches from each treatment produced >95% female hatchlings. Clutches in both treatments thus incubated at high temperatures above the pivotal temperature approaching complete feminisation. This suggests that ambient temperatures during the study period were particularly high and may have contributed to the lack of successful development of a number of nests (Howard et al., 2014). The high sex ratios we observed might be interpreted as of concern for future population viability although fieldwork was conducted in the warmest months of the nesting season and temporal variability across the nesting season will likely create more balanced primary sex ratios overall.

We found a negative relationship between nest elevation and metabolic heat and the proportion of female hatchlings. Sand moisture content is both negatively correlated with beach height and a strong driver of nest thermal properties. Eggs in cooler, wetter nests at lower elevations typically demonstrate slower embryonic development and increased male hatchling production (Sifuentes-Romero et al., 2018), a signal that we did not observe in our nest temperatures or MH profiles, nor in the proportion of females being produced. Our responses to nest elevation contrary to that reported in other literature may be an artifact of our small sample size, or the relatively small range of elevations across which nests were monitored. Greater beach slope and elevation has been shown to represent preferential nesting habitat with higher survival probability (Wood & Bjørndal, 2000). Our results suggest that in such preferred nesting areas at higher elevations MH may be reduced compared to lower elevations.

The loss of several nests limits the conclusions that can be drawn with any certainty from our results, although trends in MH and temperature profiles provide some indication that clutch-splitting may be effective, despite the lack of statistically detectable results and any elicited change in hatchling sex ratios. Fieldwork was carried out during the hottest part of the nesting season, which meant that all nests produced >95% female hatchlings, combined with our reduced sample size, thus potentially limiting the potential for any change in sex ratios to be detected. In fact, it suggests that during this time of year the method may be less effective in altering sex ratios. Nonetheless, the technique may prove effective at other times in reducing nest temperatures away from the upper thermal limit, towards which it appears they may be incubating. Given the remaining uncertainty around the rate and magnitude to which sea turtles can adapt to mitigate the effects of global temperature increases, clutch-splitting may provide an alternative and low-cost management intervention for conservation managers.

Acknowledgements

This work was gratefully funded by the British Herpetological Society. Fieldwork was supported by the staff of BIOS.CV.

References

- Böhm, M., Cook, D., Ma, H., Davidson, A.D., García, A., Tapley, B., ... & Carr, J. (2016). Hot and bothered: using trait-based approaches to assess climate change vulnerability in reptiles. *Biological Conservation* 204, 32–41.
- Booth, D.T. (2017). Influence of incubation temperature on sea turtle hatchling quality. *Integrative Zoology* 12(5), 352–360.
- Broderick, A.C., Godley, B.J. & Hays, G.C. (2001). Metabolic heating and the prediction of sex ratios for green turtles (*Chelonia mydas*). *Physiological and Biochemical Zoology* 74(2), 161–170.
- Clarke, L.J., Elliot, R.L., Abella-Perez, E., Jenkins, S.R., Marco, A., Martins, S. & Hawkes, L.A. (2021). Low-cost tools mitigate climate change during reproduction in an endangered marine ectotherm. *Journal of Applied Ecology* 58(7), 1466–1476.
- Gammon, M., Fossette, S., McGrath, G. & Mitchell, N. (2020). A systematic review of metabolic heat in sea turtle nests and methods to model its impact on hatching success. *Frontiers in Ecology and Evolution* 8, 556379.
- Hays, G.C., Mazaris, A.D. & Schofield, G. (2014). Different male vs. female breeding periodicity helps mitigate offspring sex ratio skews in sea turtles. *Frontiers in Marine Science* 1, 43.

- Hays, G.C., Mazaris, A.D., Schofield, G. & Laloë, J.O. (2017). Population viability at extreme sex-ratio skews produced by temperature-dependent sex determination. *Proceedings of the Royal Society B: Biological Sciences* 284(1848), 20162576.
- Howard, R., Bell, I. & Pike, D.A. (2014). Thermal tolerances of sea turtle embryos: current understanding and future directions. *Endangered Species Research* 26(1), 75–86.
- Ihlow, F., Dambach, J., Engler, J.O., Flecks, M., Hartmann, T., Nekum, S., ... & Rödder, D. (2012). On the brink of extinction? How climate change may affect global chelonian species richness and distribution. *Global Change Biology* 18(5), 1520–1530.
- Montero, N., Ceriani, S.A., Graham, K. & Fuentes, M.M. (2018). Influences of the local climate on loggerhead hatchling production in North Florida: Implications from climate change. *Frontiers in Marine Science* 5, 262.
- Santidrián Tomillo, P., Saba, V.S., Blanco, G.S., Stock, C.A., Paladino, F.V. & Spotila, J.R. (2012). Climate driven egg and hatchling mortality threatens survival of Eastern Pacific leatherback turtles. *PLoS ONE* 7(5), e37602.
- Sifuentes-Romero, I., Tezak, B.M., Milton, S.L. & Wyneken, J. (2018). Hydric environmental effects on turtle development and sex ratio. *Zoology* 126, 89–97.
- Standora, E.A. & Spotila, J.R. (1985). Temperature dependent sex determination in sea turtles. *Copeia* 711–722.
- Tanner, C.E., Marco, A., Martins, S., Abella-Perez, E. & Hawkes, L.A. (2019). Highly feminised sex-ratio estimations for the world's third-largest nesting aggregation of loggerhead sea turtles. *Marine Ecology Progress Series* 621, 209–219.
- Zbinden, J.A., Margaritoulis, D. & Arlettaz, R. (2006). Metabolic heating in Mediterranean loggerhead sea turtle clutches. *Journal of Experimental Marine Biology and Ecology* 334(1), 151–157.

Observations of human-herpetofauna coexistence issues in the Neotropics

John Rowland

Durrell Institute of Conservation and Ecology, School of Natural Sciences, University of Kent, Canterbury, Kent CT2 7NR, UK

The Neotropics, encompassing Central and South America and the Caribbean, harbours incredible biological diversity, supporting approximately 50% and 32% of the world's amphibian and reptile species respectively (Urbina-Cardona, 2008). The Neotropics support such a diverse array of species thanks to the wide variety of habitats found within the region, from vast swathes of primary tropical rainforests supporting amphibians found nowhere else on Earth, to sandy Atlantic and Pacific coastlines providing suitable areas for female sea turtles to return to land and nest. Amphibians and reptiles perform vital roles in Neotropical ecosystems as both predators and prey, as well as providing ecosystem services to humans living throughout the region, such as controlling pest populations and providing sources of protein (Valencia-Aguilar et al., 2013). However, the shared environments of humans and herpetofauna also lead to significant coexistence challenges, including conflicts arising from fatal injuries from reptile bites, turtle egg poaching and habitat encroachment (Nyhus, 2016; Pheasey et al., 2021). Here, I will briefly describe two socio-herpetological observations I have made during ecological research trips to Costa Rica and the Peruvian Amazon, and provide examples of human-herpetofauna coexistence issues arising where human society and wildlife habitat overlap.

When discussing Neotropical herpetology, the minds of many are instantly drawn to the variety and elusive beauty of snakes inhabiting the rainforests of Central and South America. A particularly notable group of snakes in human-herpetofauna coexistence discussions is the *Bothrops* genus, known worldwide for the potency of their venom and their readiness to shelter in human settlements (Resiere et al., 2020). Members of this genus cause more snakebites than any other group in the region (da Silva et al., 2023). This has led to a strong aversion to snakes in general being commonplace across Neotropical America due to the threat



Figure 1. *Bothrops asper* in Costa Rica. This snake was living under the accommodation of the author.

of physical harm and death, with hunters in some regions indiscriminately persecuting *Bothrops* snakes whenever they are encountered (Mendonça et al., 2014). A vivid memory of mine from the Peruvian Amazon is walking with an indigenous community member and discussing his hatred of snakes, and him showing me the scar from a *Bothrops atrox* bite he suffered many years before, permanently changing his and his family's perception of snakes (and any creature resembling a snake, such as the electric eel (*Electrophorus* sp.)). *Bothrops atrox* is responsible for most of the snakebites in the Amazon, with rural and agricultural workers, children, and people with lower socioeconomic statuses facing greater coexistence issues with the species due to higher exposure (da Silva et al., 2023). In the short time I was stationed in the forests near the Caribbean coast of Costa Rica, I had several encounters with *Bothrops asper*, with a subadult individual returning daily to rest beneath my accommodation building during the day. This is far from an unusual incident, as human settlements provide dry, rodent-populated microhabitats favoured by the species, which is notorious for its defensive tendencies and readiness to strike. In Costa Rica, *B. asper* causes 90% of snakebites and the majority of



Figure 2. *Bothrops asper* contained in a perspex tube ready to be translocated from a human settlement.



Figure 3. View over Tortuguero, Costa Rica, displaying the overlap between human settlement and primary rainforest habitat.

fatal accidents (Solórzano, 2022), with deep social and psychological impacts for local rural residents (Millán-González, 2023).

As mentioned above, I have spent a short time based near the Caribbean coast of Costa Rica, at the Caño Palma Biological Station, situated in the Barro Colorado Wildlife Refuge. The location of this research station has largely been determined by another example of a human-herpetofauna coexistence issue – illegal turtle egg poaching. The issue is of such severity and importance in this part of the Neotropics that it warrants the majority of the attention from an entire research station, to try and prevent sea turtle population declines at the hands of egg collectors. On Costa Rica’s Atlantic Coast, there are three species of sea turtle that return to land and nest: the green *Chelonia mydas*, the hawksbill *Eretmochelys imbricata* and the leatherback *Dermochelys coriacea*. Despite the legal protection, each of these species are directly harvested for their eggs, meat or carapace, for direct consumption or decorative purposes (Mejías-Balsalobre et al., 2021). On the beaches monitored by Caño Palma, nest poaching caused 12.5% and 21% nest loss in hawksbill and leatherback turtles respectively between 2006 and 2019, and a 1.1% nest loss in the green turtles, on account of their much greater abundance (Pheasey et al., 2021). Turtle eggs and meat are not vital sources of nutrition for either the poachers or eventual consumers, with the primary driver of this activity instead being the procurement of illegal drugs by marginalised members of society (Pheasey et al., 2023), highlighting

how human-herpetofauna coexistence issues can be driven by social inequalities in human communities. I engaged in several casual conversation with local poachers during beach survey work in Costa Rica, who all appeared largely unaware of the negative consequences of their activities, possibly demonstrating the fact that education levels among poachers in this region are low (Pheasey et al., 2023). Notably, during one conversation, we had returned a data logger that we had previously placed in a green sea turtle nest, to monitor climatic variables, that had been discovered during a nest poaching event. Community-based programmes are desperately needed in areas with high poaching rates, in order to provide alternative employment opportunities, and deter and prevent narcotics-driven turtle poaching from persisting.

The examples of human-herpetofauna coexistence issues highlighted in this article underscore the complex interaction between biodiversity conservation and socioeconomic factors in the Neotropics. Species such as *Bothrops* snakes and the green, hawksbill and leatherback turtles illustrate the significant challenges faced by both wildlife and local communities when their habitats and livelihoods overlap. In the case of snakebites, the lack of adequate healthcare infrastructure and educational outreach exacerbates human-herpetofauna coexistence issues and negative perceptions, while the poaching of turtle eggs demonstrates how social inequalities and illicit activities drive unsustainable exploitation. There is no one-size-fits-all approach to addressing



Figure 4. The author and colleagues burying a bamboo mesh above a green sea turtle nest, to prevent predation from stray dogs.

complex and deep-rooted human-wildlife coexistence issues, such as those highlighted in this article. Community-based conservation approaches are required to develop programmes aimed at fostering coexistence over conflict, prevention over retaliation, and the provision of alternative livelihoods over destructive exploitation, ensuring a future where both human communities and herpetofauna can thrive together.

References

- Mejías-Balsalobre, C. et al. (2021). Local community perceptions of sea turtle egg use in Tortuguero, Costa Rica. *Ocean & Coastal Management* 201, 105423.
- Mendonça, L.E.T. et al. (2014). Caatinga Ethnoherpetology: Relationships between herpetofauna and people in a semiarid region of northeastern Brazil. *Amphibian and Reptile Conservation* 8(1), 24–32.
- Millán-González, R. et al. (2023). *Bothrops asper* bite and post-traumatic stress disorder in Costa Rica: Report of two cases. *Toxicon* 231, p. 107199.
- Nyhus, P.J. (2016). Human–wildlife conflict and coexistence. *Annual Review of Environment and Resources* 41(1), 143–171.
- Pheasey, H. et al. (2021). Quantifying illegal extraction of sea turtles in Costa Rica. *Frontiers in Conservation Science* 2, p. 705556.
- Pheasey, H. et al. (2023). Motivations and sensitivities surrounding the illegal trade of sea turtles in Costa Rica. *Ecology and Society* 28(4), 15.
- Solórzano, A. (2022). *Serpientes de Costa Rica: Distribución, Taxonomía e historia Natural*. 2nd. ed. Topografía e imprenta LIL SA.
- da Silva, W.R.G.B. et al. (2023). Who are the most affected by *Bothrops* snakebite envenoming in Brazil? A clinical-epidemiological profile study among the regions of the country. *PLoS Neglected Tropical Diseases* 17(10), e0011708.
- Resiere, D. et al. (2020). *Bothrops* snakebite envenomings in the Amazon region. *Current Tropical Medicine Reports* 7(2), 48–60.
- Urbina-Cardona, J.N. (2008). Conservation of Neotropical herpetofauna: research trends and challenges. *Tropical Conservation Science* 1(4), 359–375.
- Valencia-Aguilar, A. et al. (2013). Ecosystem services provided by amphibians and reptiles in Neotropical ecosystems. *International Journal of Biodiversity Science, Ecosystem Services & Management* 9(3), pp. 257–272.

Malagasy amphibians; competing drivers and their impacts on conservation progress

Angus I. Carpenter

Institute of Science & Environment, University of Cumbria, Ambleside campus, Cumbria, LA22 9BB, UK

Email: carpenter.angus@gmail.com; angus.carpenter@cumbria.ac.uk

Setting the scene

Madagascar is one of the oldest and largest islands in the world and also one of the biologically richest places on earth (Goodman, 2022). However, Madagascar faces considerable conservation issues; for example, over 71% of its land has been converted to agriculture while over 71% of its population live below the poverty line (CIA, 2024). Madagascar's human population size is predicted to approach 60 million by 2050 (UN, 2022) and extreme weather events, both droughts and cyclones that hit Madagascar are increasing in frequency and intensity resulting in deaths, displacement and insecurity. While severe localised food insecurity also resulted from the extreme weather events, and slow economic recovery, revenue from forest resources was 4.34% of national GDP (CIA, 2024). Furthermore, Madagascar's political and institutional structures lack robustness in their ways of working, thus, leaving opportunities for illicit behaviours; for example, CITES (2024) requirement to suspend commercial trade of specimens of *Diospyros* spp. and *Dalbergia* spp. from Madagascar in 2022. Within country scenarios exacerbated these situations. For example, in 2020, Madagascar's environment minister, Ms Raharinirina stated that Madagascar's 144 protected areas (PAs) were a failure for conservation and that PAs needed to be more people-centric (Mongabay, 2020). While, in 2021, the U.S. Agency for International Development (USAID) launched a program aimed at undermining illegal wildlife trafficking and the corruption that helps it flourish (USAID, 2021). Yet, in 2024 alone, Thailand itself returned nearly 1000 endangered lemurs and tortoises to Madagascar that had been confiscated from the illegal wildlife trade (BBC, 2024), highlighting how rife the illicit trade in fauna from Madagascar still remains.

Trade in Madagascar's amphibians

Madagascar's amphibians have had a long association with the wildlife trade having been consistently exploited for the international pet trade (Carpenter et al., 2005; 2014; 2022; Rabemananjara et al., 2007; Carpenter & Robson, 2008; Carpenter & Andreone, 2023a; 2023b). Madagascar has 365 species of amphibians formally recognised with many more species awaiting formal description (Fig. 1, Goodman, 2022; Carpenter & Andreone, 2023a). However, there were 313 species listed on the IUCN Red List (2024) with 6.7% categorised as Critically Endangered, 26.2% Endangered and 14.1% Vulnerable, and pretty much all of those species reported with declining populations (Fig. 2).

Hence, there have been several studies investigating conservation action planning (Carpenter et al., 2007; Andreone et al., 2008), socio-bioeconomic models (Carpenter & Robson, 2008) and alternative income sources (Carpenter & Andreone, 2023b) for Madagascar's amphibians. These conservation actions are set against the background of the wider conditions cited previously.

Build a suitable model

In recent years, knowledge of the ecology and breeding biology of Madagascar's amphibians has increased rapidly. For example, for many species we now have robust information on the distribution and population localities, their breeding strategies and fecundity (CITES Secretariat, 2008; Goodman, 2022). To the extent where it is possible to develop sustainable harvest models (Andreone et al., 2021). Additionally, robust information exists on both (1) the trade and financial structures operating within this trade and (2) the levels and trends of the trade (Carpenter & Andreone, 2023b). Furthermore, we also have detailed enough information on the seasonal activities

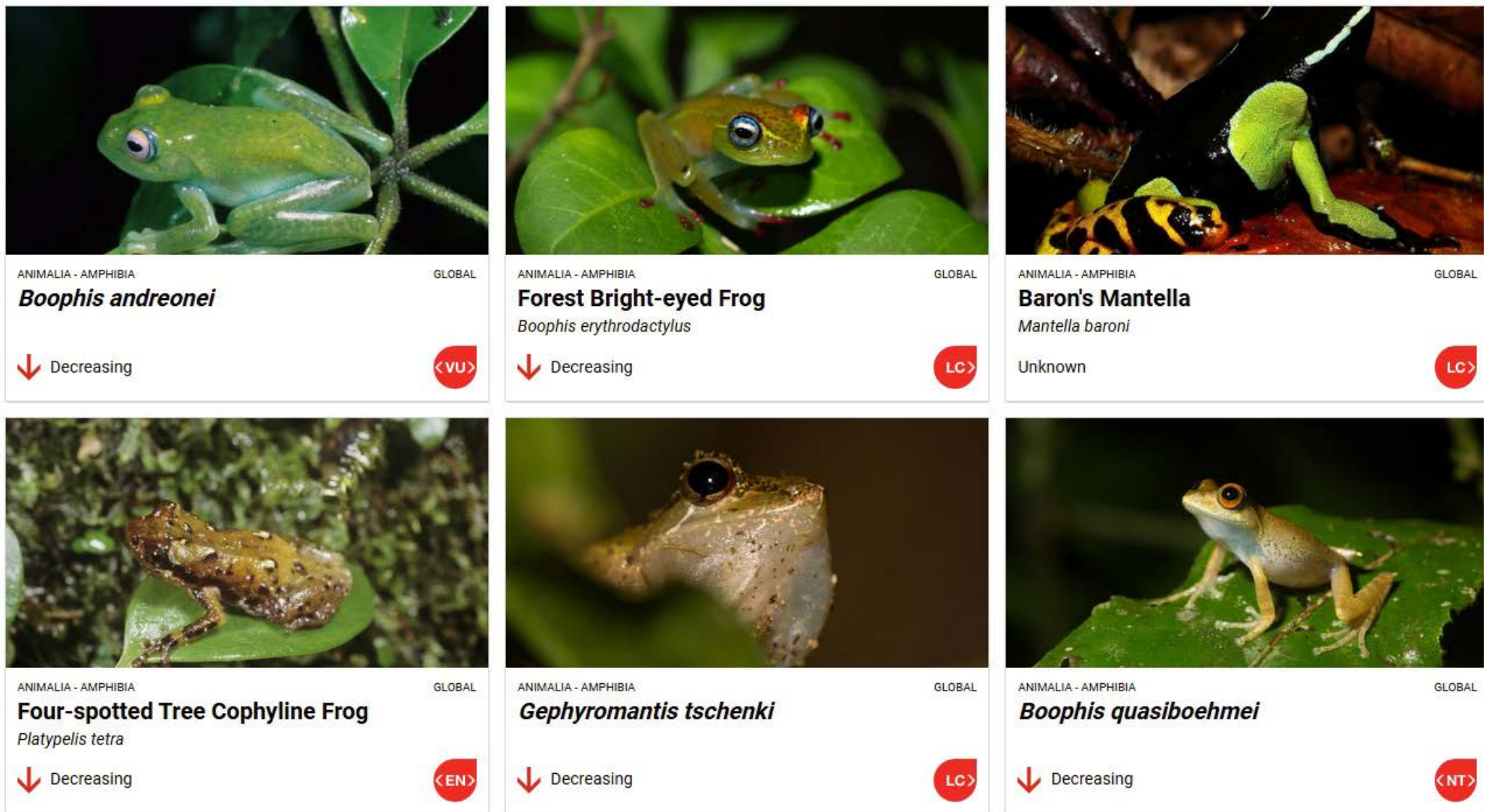


Figure 1. A random selection of the Malagasy amphibian community, highlighting the declining population levels for 5 of the 6 species shown (Source: IUCN Red List, 2024).

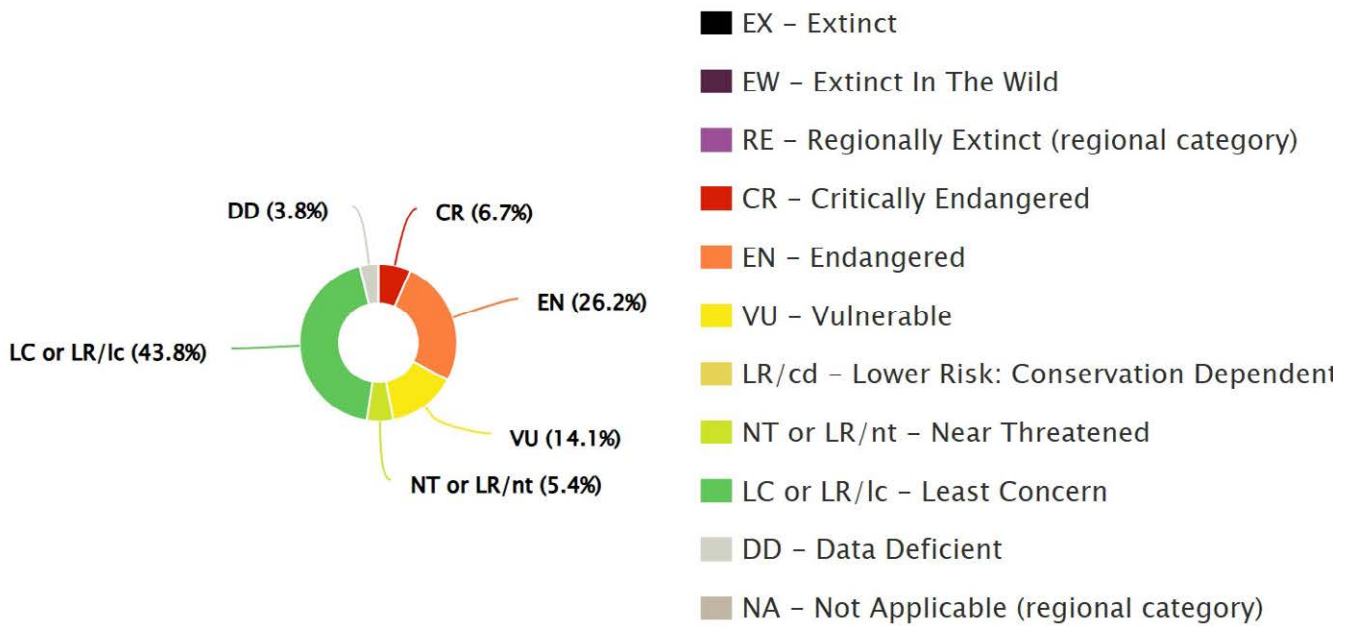


Figure 2. The number of amphibians (n=313) from Madagascar reported under each of the IUCN Red List categories (Source: IUCN Red List, 2024).

and income sources and values for local communities in some localities (Carpenter & Robson, 2008; Carpenter & Andreone, 2023b). These multiple datasets all combine to allow the building of bio-economic models that provide local communities with enhanced income from non-timber forest products (NTFPs) to mitigate deforestation at sites. As long as the supply of the resource stays connected to the habitat, such practices can provide conservation benefits with sustainable local income opportunities. A potential win/win scenario.

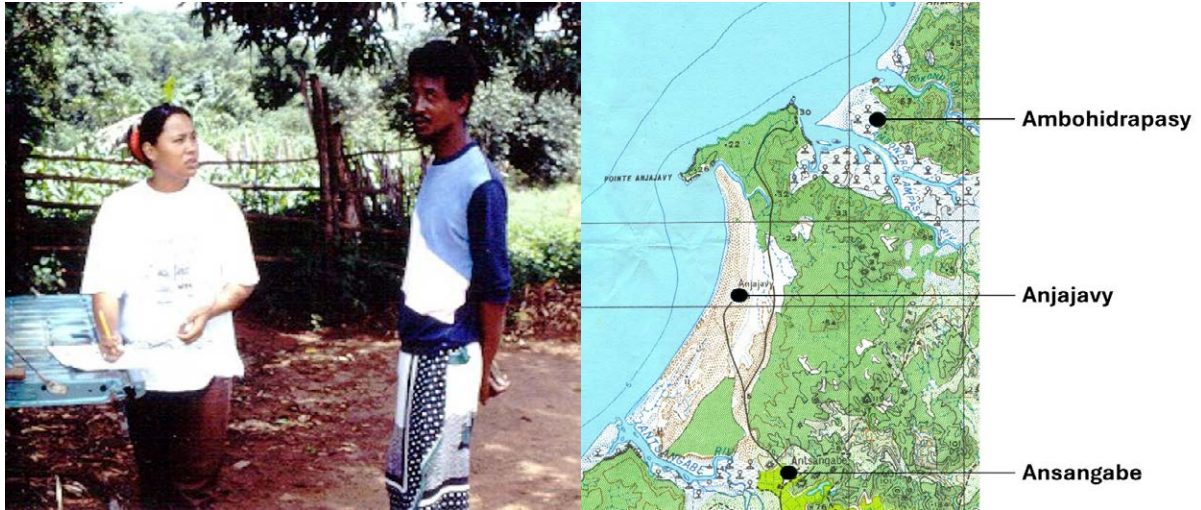
The resource: habitat disconnect

As stated previously, the trade in Madagascar’s amphibians has a long history, the driver for which has been the international pet (and zoo) trade. Hobbyists from all over the world have constantly demanded amphibians from Madagascar, as the trade review papers reported (see section “Trade in Madagascar’s amphibians”). However, as the trade reviews also reported, the demand from Madagascar has witnessed a slight declining trend in overall numbers of individuals while expanding the number of species being traded. Specifically, including novel species not previously traded and often only recently formally described (Carpenter & Andreone, 2023b). On Madagascar, conservation actions have included the maintaining in captivity and captive breeding of multiple species of amphibian, which has made great advances in recent years; most notably at the Association

Mitsinjo’s breeding facility (Edmonds et al., 2012; Rakotoarisoa et al., 2024). The drivers for securing ark populations for species often being chytrid fungus and habitat destruction, which are constant conservation issues on Madagascar. However, hobbyists and zoological organisations in the US, Europe and other global localities have been able to both sustain and captively breed populations of Malagasy amphibians too. Often resulting in breeding more individuals than a centre requires, that are then distributed to other localities (Murphy & Gratwicke, 2017; Browne et al., 2018). This has the possibility of leading to the alternative supply of Malagasy amphibians sourced from within non-native countries, which has the implications on Madagascar of disconnecting the supply of amphibians away from the country and removing these species as a valuable resource for local people (Mattioli et al., 2006).

In 2023, an IUCN SSC Position Statement both embraced and endorsed the actions of zoos and aquaria into the wider IUCN community (IUCN SSC, 2023). Despite zoos using Madagascar amphibians for viewing, breeding and marketing purposes, there have been no individuals returned to Madagascar from these organisations. However, there is the possibility of an alternative impact from these species being displayed within bright and attractive enclosures. On viewing these creative and attractive displays in zoological collections

A



B

Activity	Price unit ¹	Volume	Total
Valley rice (A)	UK £00.28 kg ⁻¹	1500 kg	UK £420.00
Hill rice (A)	UK £00.28 kg ⁻¹	500 kg	UK £140.00
Maize (A)	UK £00.02 cob ⁻¹	800	UK £16.00
Maize (A)	UK £00.35 kg ⁻¹	500 kg	UK £175.00
Manioc (A)	UK £00.20 kg ⁻¹	500 kg	UK £100.00
Bananas (F)	UK £00.25 tamgozany ⁻¹	800	UK £200.00
Coconuts (F)	UK £00.10 coconut ⁻¹	800	UK £80.00
Honey (F)	UK £00.50 litre ⁻¹	50 litre	UK £25.00
Honey (F)	UK £01.50 litre rum ⁻¹	100 litre	UK £150.00
Mangos (F)	UK £00.02 each	500	UK £10.00
Palisander (F)	UK £2.00 tree ⁻¹	20	UK £40
Other timber (F)	UK £0.50 tree ⁻¹	40	UK £20
Transport (F)	UK £0.38 shipment ⁻¹	6	UK £2.28

C

	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Wet season												
Dry season												
Farming ¹												
Fishing ¹												
Farming ²												
Fishing ²												
Timber ²												

1 denotes the villages Anjajavy & Ambohidrapasy.
2 denotes the village Ansangabe

Figure 3. Three factors of socioeconomic information collected. **A.** Researcher interviewing a village representative and a map of the localities of the survey. **B.** A list of resources collected in Ansangabe (F = forest sourced, A = agriculture sourced). Shaded data indicates negative impact on forests, unshaded indicates reduced impact. **C.** Seasonal activities for 3 village communities.

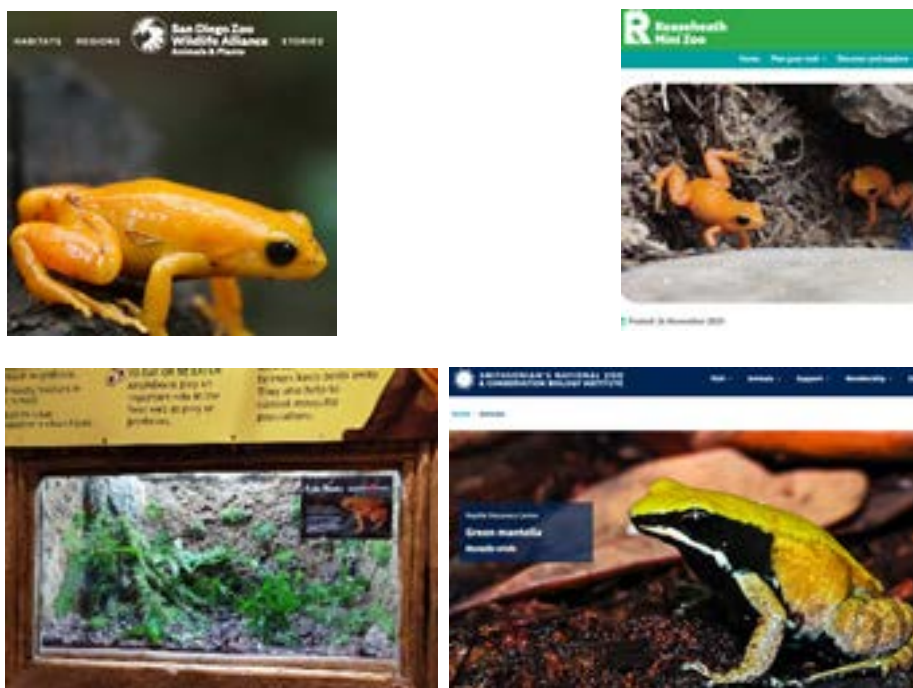


Figure 4. A selection of the marketing information and/or displays from zoological organisations using amphibians extracted from the web after a general search.

(Fig. 4) could excite members of the public to copy what they have seen and set up their own vivariums within their homes. Ultimately, this adds demand to the supply chain for these species, which is met from CB rather than originally sourced individuals. This potential scenario presents a conservation conundrum that requires much further research, regarding the impacts of alternative supply chains to the Malagasy sourced supply and on the wide conservation negative and positive impacts that result.

References

- Andreone, F., Carpenter, A.I., Crottini, A., D’Cruze, N., Dubos, N., Edmonds, D., Garcia, G., Luedtke, J., Megson, S., Rabemananjara, F.C.E., Randrianantoandro, J.C., Randriavelona, R., Robinson, J., Vallan, D. & Rosa, G.M. (2021). Amphibian conservation in Madagascar: Old and novel threats for a peculiar fauna. In: *Status and Threats of Afrotropical Amphibians*. 147–186 pp. Heatwole, H. & Rodel, M.O. (Eds.). Chimaira, Amphibian Biology, Volume 11, Part 7.
- Andreone, F., Carpenter, A.I., Cox, N., du Preez, L., Freeman, K., Furrer, S., Garcia, G., Glaw, F., Glos, J., Knox, D. et al. (2008). The challenge of conserving amphibian megadiversity in Madagascar. *PLoS Biol.* 6, e118.
- BBC (2024). Stolen lemurs and tortoises head home to Madagascar. <https://www.bbc.co.uk/newsround/articles/cy8n3yv67nxo>. Accessed in December 2024.
- Browne, R.K., Janzen, P., Bagaturov, M.F. & van Houte, D.K. (2018). Amphibian Keeper Conservation Breeding Programs. *Journal of Zoological Research* 2(1), 29–46.
- Carpenter, A.I. & Andreone, F. (2023a). Malagasy Amphibian Wildlife Trade Revisited: Improving Management Knowledge of the Trade. *Animals* 13, 2324.
- Carpenter, A.I. & Andreone, F. (2023b). Valorisation of Madagascar’s Wildlife Trade and Wildlife Tourism: What Are the Conservation Benefits? *Conservation* 3: 509–522.
- Carpenter, A.I., Andreone, F., Moore, R.D. & Griffiths, R.A. (2014). A review of the global trade in amphibians: The types of trade, levels and dynamics in CITES listed species. *Oryx* 48, 565–574.
- Carpenter, A.I., Dublin, H., Lau, M., Syed, G., McKay, J.E. & Moore, R.D. (2005). Overharvesting. In: *Amphibian Conservation Action Plan*. 26–31 pp. Gascon, C., Collins, J.P., Moore, R.D., Church, D.R., McKay, J.E. & Mendelson III, J.R. (Eds.). Proceedings: IUCN/SSC Amphibian Conservation Summit, IUCN/SSC Amphibian Specialist Group: Gland, Switzerland, 2007; Chapter 5.
- Carpenter, A.I., Rabemananjara, F.C.E., Behra, O., Raselimanana, A.P., Ratsoavina, F.M., Wollenberg-Valero, K.C. & D’Cruze, N. (2022).

- Valorisation of reptiles and amphibians from the wildlife trade and ecotourism, In: *The New Natural History of Madagascar*. 1452–1455 pp. Goodman, S.M. (Ed.). Princeton University Press: Princeton, NJ, USA.
- Carpenter, A.I. & Robson, O. (2008). Madagascar amphibians as a wildlife resource and their potential as a conservation tool: species and numbers exported, revenue generation and bio-economic models to explore conservation benefits, In: *Conservation Strategy for the Amphibians of Madagascar proceedings*. 357–376 pp. Andreone, F. (Ed.). Monografie del Museo Regionale di Scienze Natural di Torino.
- CIA (2024). Madagascar. <https://www.cia.gov/the-world-factbook/countries/madagascar/>. Accessed in December 2024.
- CITES Secretariat (2008). Review of significant trade in specimens of Appendix-II species. Twenty-third meeting of the Animals Committee Geneva (Switzerland), 19–24 April 2008. Convention on International Trade in Endangered Species of Wild Fauna and Flora. <http://www.cites.org>.
- CITES (2024). Notification to the Parties: Madagascar; Recommendation to suspend commercial trade of specimens of *Diospyros* spp. and *Dalbergia* spp. from Madagascar, May 2022. https://cites.org/sites/default/files/notifications/E-Notif-2022-031_0_0.pdf. Accessed in December 2024.
- Edmonds, D., Rakotoarisoa, J.C., Dolch, R., Pramuk, J., Gagliardo, R., Andreone, F., Rabibisoa, N., Rabemananjara, F., Rabesianaka, D. & Robsomanitrdrasana, E. (2012). Building capacity to implement conservation breeding programs for frogs in Madagascar: Results from year one of Mitsinjo’s amphibian husbandry research and captive breeding facility. *Amphibian and Reptile Conservation* 5(3), 57–69.
- Goodman, S.M. (2022). *The New Natural History of Madagascar*. Princeton University Press, Princeton, US.
- IUCN Redlist (2024). Amphibia; Madagascar. <https://www.iucnredlist.org/search?taxonomies=100050&searchType=species>. Accessed in December 2024.
- IUCN SSC (2023). IUCN Species Survival Commission acknowledges vital contributions of Botanic Gardens, Aquariums, and Zoos to wildlife conservation. <https://iucn.org/news/202310/iucn-species-survival-commission-acknowledges-vital-contributions-botanic-gardens>. Accessed in December 2024.
- Mattioli, F., Gili, C. & Andreone, F. (2006). Economics of captive breeding applied to the conservation of selected amphibian and reptile species from Madagascar. *Natura - Soc. it. Sci. nat. Museo civ. Stor. nat. Milano* 95(2), 67–80.
- Mongabay (2020). Madagascar minister calls protected areas a ‘failure,’ seeks people-centric approach. <https://news.mongabay.com/2020/08/madagascar-minister-calls-protected-areas-a-failure-seeks-people-centric-approach/>. Accessed in December 2024.
- Murphy, J.B. & Gratwicke, B. (2017). History of captive management and conservation amphibian programs mostly in zoos and aquariums. Part I Anurans. *Herpetological Review* 48(1), 241–260.
- Rabemananjara, F.C.E., Raminosoa, N.R., Ramilijaona, O.R., Andreone, F., Bora, P., Carpenter, A.I., Glaw, F., Razafindrabe, T., Vallan, D., Vieites, D.R. & Vences, M. (2007). Malagasy poison frogs in the pet trade: a survey of levels of exploitation of species in the genus *Mantella*. *Amphibian & Reptile Conservation* 5, 3–16.
- Rakotoarisoa, J.C., Rakotoarison, A., Rasoanantenaina, S., Robsomanitrdrasana, E., Edmonds, S.S.S., Soamiarimampionona, J., Tsimialomanana, E., Wolf, S. & Edmonds, D. (2024). Captive Breeding Reveals Insights Into the Ecology and Reproductive Biology of 11 Little-Known Malagasy Frog Species. *Zoo Biology* 2024; 1–12.
- UN (2022). World Population Prospects. <https://population.un.org/wpp/Graphs/DemographicProfiles/Line/450>. Accessed in December 2024.
- USAID (2021). New Program Targets Wildlife Trafficking and Corruption In Madagascar. <https://www.usaid.gov/madagascar/news/new-program-targets-wildlife-trafficking-and-corruption-madagascar>. Accessed in December 2024.

Breeding fire salamanders, with reference to both *Salamandra salamandra* and *Salamandra algira*

David Garthwaite

Email: dgrthwt@aol.co.uk

This study will be presented as a poster at the BHS/T&C Amersham meeting on 12th October 2025

Introduction

The fire salamander *Salamandra salamandra* ranges from Spain and Portugal in the south and west to Germany in the north, all the way through Europe to Romania and Bulgaria in the east. *Salamandra algira* occurs in both Algeria and Morocco. (See Raffaëlli, 2022, Seidel & Gerhardt, 2016; Sparreboom, 2014 for more information).

Substrates and enclosures used

Since 2000, a range of substrates and enclosures were trialed to determine which would be ideal to easily rear and maintain both adult and juvenile fire salamanders. These attempts were my own personal experience, and I am aware of others successfully maintaining fire salamanders using alternative substrates.

Substrates used, but largely dismissed, included damp paper towels, live moss, rehydrated dried sphagnum moss, leaf mould and coco fibre. (See Seidel & Gerhardt, 2016 for a full critique of the potential substrates for fire salamanders).

The final choice of substrate for adults was small pine bark chips (orchid grade) up to a depth of 5 cm in Wham Crystal (What More UK) plastic boxes (L 60 cm x W 40 cm x H 26 cm, 45 litres). A double row of holes was drilled on each side of the box close to the lid. This provided enough ventilation to prevent condensation in the boxes. Within each box were stacked cork bark curved/flat hides and an Exoterra (Rolf C. Hagen, Germany) large water dish. The large water dish, which was replaced daily, meant that adult fire salamanders were able to both immerse themselves and deposit larvae. The bark chips were spot cleaned as necessary and removed and replaced after three to four weeks. Enclosures of this size were suitable for single adults of larger subspecies such as *tingitana* and pairs or trios of adults for smaller subspecies including *bernardezi*.



Figure 1. Male *Salamandra algira splendens* in large Exoterra water bowl.

The isopod *Porcellio scaber* was added to newly set up enclosures as an attempt to control any mould growth. They also provided some additional food for the salamanders.

To prevent contamination of the outside environment, all soiled substrates were disposed of in the garden waste composting bin, as this material is composted at high temperatures by the Local Authority.

Water bowls were cleaned daily and soaked overnight in Milton sterilising solution (Procter & Gamble, UK), rinsed with water, and left outside for at least 24 hours before being used again. This meant that for every enclosure three

water bowls were needed; one in use, one in soak and one drying off outside. The plastic boxes were also washed off in the same solution, rinsed, and left to stand outside for at least 24 hours.

Temperatures and lighting

Since 2010 all animals have been maintained between 10–20 °C, although in the summer the temperature could reach 27–28 °C for short periods. Fluorescent lighting was maintained for 12 hours during the summer with the hours reduced to 8 hours in the winter. There was no specific lighting used for individual fire salamander terraria.

Rearing juveniles

For juveniles, Wham Crystal (What More UK) boxes, 11 litres (36.5 cm x 25 cm x 17 cm) or 17 litres (43 cm x 33 cm x 17.5 cm), were used, depending on the size of the juveniles, or the number being maintained. Boxes were set up with a 2–3 cm layer of small orchid bark chips, cork bark and either live moss or rehydrated dried sphagnum moss. The smaller boxes were used for either single large juveniles or groups of three or four newly metamorphosed juveniles.

Both *P. scaber* isopods and springtails were used in each box as these provided both food and a clean-up crew. In some cases, the isopods were sieved so that only smaller individuals were used.

Feeding

The basic diet for all salamanders has been small or medium sized banded crickets *Gryllodes sigillatus*, depending on the size of the adults or juveniles being fed. All crickets were dusted with calcium plus multivitamins. It was found that Repashy Calcium Plus with vitamin D3 adhered to the crickets longer than some other multivitamins. Tubs of red worms were used weekly as a supplement to the crickets, as were worms collected from the garden.

Rearing larvae

The 17 litre plastic boxes were used, with 3–4 cm of water, and dried dead oak leaves to provide cover for the larvae and increase the tannin level of the water (Seidel & Gerhardt, 2016). Tap water with the addition of a water conditioner (King British UK) was left to stand for at least one day before being used in the larvae boxes.

These boxes were suitable for eight small larvae, although as they grew the number of larvae was



Figure 2. *Salamandra s. gallaica* larvae in box with oak leaves.

reduced. As metamorphosis approached, the boxes were rested on 1 cm strips of wood so that they became tilted and allowed the young juveniles to climb out of the water more easily. Diet for the larvae included whiteworms, *daphnia*, bloodworms, tubifex worms and chopped earthworms. Tubifex worms eventually became the preferred choice as they were suitable for all sizes of larvae and could be kept for at least a week, if the water in which they were kept was changed daily. *Daphnia* was used mainly for smaller larvae.

Hibernation

Frost-free garages or household refrigerators are often suggested as the best place to hibernate fire salamanders. As these were not readily available it was decided to work with fire salamander species from the southern part of their range, principally Portugal and Morocco. These require cooling to 10 °C over the winter months. Because of the high summer temperatures, species and subspecies from these regions regularly breed during the autumn and winter months.



Figure 3. *Salamandra s. bernardezi* young Covadonga females.

***Salamandra s. bernardezi* Covadonga**

Salamandra s. bernardezi occur in northern Spain and a group of adult *bernardezi* originating from Covadonga were maintained for many years. Colouration and patterning of *bernardezi* across its range is extremely variable and Donaïre et al., (2016), document the range of phenotypes for this subspecies.

Between 1993 and 2010, adults were kept in outdoor enclosures and regularly produced fully metamorphosed young or larvae each year. From 2010 onwards, adults of *bernardezi* were maintained indoors during the winter and only moved to outdoor enclosures between May and November.

Fully metamorphosed juveniles and occasionally larvae were produced between March and May each year. A total of 12 juveniles were produced by a single female in 2020; in 2021 the same female produced 13 juveniles, and in 2022 she produced 10 juveniles. In 2023, 3 fully metamorphosed juveniles were produced.

On average, the fully metamorphosed juveniles ranged from 3.5–3.6 cm in total length, the larvae were smaller at just over 2 cm total length.

***Salamandra s. gallaica* Serra de Grandola**

In 2017 juveniles of *gallaica* from the Serra de Grandola in Portugal were obtained. The Serra de Grandola is close to the northerly distribution of *Salamandra s. crespoi* (Malkmus, 1983; 2004). By 2019, there were two pairs of adults, neither



Figure 4. Juvenile *Salamandra s. gallaica* Serra de Grandola.

of which were subjected to hibernation and were maintained between 10–15 °C during the winter months. One of the females produced 66 larvae between December 2019 and January 2020 at an average of 4 larvae per day. The maximum number of larvae deposited by this female in a single day was 9. The second female produced a total of 23 larvae over the same period at an average of 2 larvae per day.

The first larva metamorphosed after 39 days, with a total of 80 larvae metamorphosing (from both females) by March 2020. The length of time until metamorphosis for later deposited individuals was 52 days.

***Salamandra algira tingitana* Beni Arous (larviparous)**

There are two main forms of *algira tingitana* found in Morocco (Bogaerts, 2018). The more northerly form is live-bearing (juviparous) and occurs in the areas around Tagramt and Ceuta (Spain). The more southerly, larvae-bearing form (larviparous) occurs in the Beni Arous area.



Figure 5. *Salamandra algira tingitana* male Beni Arous (note pores on head which occur on the males of this species).

A trio of Beni Arous adults from juveniles metamorphosed in 2017 were maintained in two of the large 45 litre plastic boxes. One female was kept in each box, with the male being moved from one box to another every three to four weeks. In 2021, the largest female produced a total of 11 larvae between January and February 2021. A further 70 larvae were deposited between December 2021 and February 2022.

Data from 54 of the larvae showed an average time between deposition and metamorphosis of 51 days, and an average length at metamorphosis of 5.4 cm.

The second female produced 24 larvae in March of 2021 and a further 12 larvae between November 2021 and March 2022. Data from 6 of the larvae deposited in November and December showed an average metamorphosis time of 65 days and a metamorphosis size of 5.5 cm.

Both females also produced small numbers of unfertilised eggs and deformed larvae at the same time as producing viable larvae.

***Salamandra algira splendens* Chefchaouen**

Salamandra algira splendens occurs further south in Morocco than either of the two *tingitana* populations and can be found in the Rif and Atlas mountains. *Salamandra a. splendens* has been bred successfully in the past and Bogaerts (2018), details his experiences and those of others with this subspecies.

In 2019, juveniles of *splendens* were obtained and by 2021 there were two adult pairs of this subspecies. One of the females produced larvae, with 19 being produced in October 2021. There were 16 unfertilised eggs and 18 larvae that were either dead on deposition or were premature and had large yolk sacs still attached. The level of



Figure 6. Adult pair of *Salamandra algira splendens* Chefchaouen.

unfertilised eggs and dead larvae could have been due to the young age of the adult female.

Eleven larvae were reared through to metamorphosis. Some larvae died soon after being deposited and three others died close to metamorphosing, possibly drowning, even in shallow water. For this subspecies the larger larvae were reared individually as it was seen that some attacked each other as they grew.

Metamorphosis took place between January and February of 2022. The average size at metamorphosis was 6.7 cm ($n = 10$), with some larvae reaching 7.5 cm whilst they were still in the water. The average time taken to metamorphosis was 93 days ($n = 11$), with the shortest time being 85 days and the longest 109 days.

Acknowledgements

I am extremely grateful for the help and advice of many people over the years. These include, but are not exclusive to Dave Herbert, Tim Green, Dave Perry, Chris Mattison, Carl Miles, Simon Townson and Stuart Worth.

References

- Bogaerts, S. (2018). *Salamandra algira* Bedriaga, 1883 North African Fire Salamander. *Mertensiella*, 28, 160–171 pp. *Threatened Newts and Salamanders - Captive Care Management* Vol. 2.
- Donaire, D., Fonoll, R. & Rivera, X. (2016). Revisión fenotípica de las poblaciones asturianas de *Salamandra salamandra* (L). *Butlletí de la Societat Catalana d'Herpetologia* 23, 7–38.
- Malkmus, R. (1983). Beschreibung einer neuen Form des Feuersalamanders der Serra de Monchique (Portugal): *Salamandra salamandra* (*gallaica*) *crespoi*. n.subsp. - *Faunistische Abhandlungen Staatliches Museum für Tierkunde Dresden* 10(9), 169–174.
- Malkmus, R. (2004). *Amphibians and Reptiles of Portugal, Madeira and the Azores Archipelago, Distribution and Natural History Notes*. Gantner, A R, 522 pages.
- Raffaëlli, J. (2022). *Salamanders and Newts of the World*. Penclen Edition. 1,100 pages.
- Seidel, U. & Gerhardt, P. (2016). *The Genus Salamandra*. Edition Chimaira Volume 16, Frankfurt am Main, 543 pages.
- Sparreboom, M. (2014). *Salamanders of the Old World. The Salamanders of Europe, Asia and Northern Africa*. KNNV Publishing, Zeist, 431 pages.