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REPORT ON BHS CONSERVATION AND CAPTIVE BREEDING PROJECT WORK: SUMMARY 2021-2022

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FRONT COVER: **Newly Hatched Gharial. See article by P. Griffith *et al.* p. 5-9**

Introduction

This report provides an update on BHS activities concerned with current/recent applied scientific project work in the fields of conservation and captive breeding, covering the period 2021-2022. Due to the Covid pandemic there has been a significant gap or delay in progress of funded projects, caused by lockdowns, flight cancellations and difficulties in obtaining permissions and travel insurance for overseas fieldwork. Nevertheless, the situation is slowly returning to normal. In this issue we provide updates on established projects and provide details of research planned for the year ahead.

(i) Update on Gharial conservation in Nepal. Impressive progress has been made. This project has been carried out by an international team from the Institute of Zoology (UK) and the Gharial Conservation Breeding Centre, Chitwan National Park, Nepal. The BHS funds were initially used to construct incubators which have successfully hatch eggs. Further work is now ongoing to tag part-grown gharials for release and monitoring in the wild. **(ii) Update on the Northern Pool Frog Recovery** (UK). Following the extinction of the UK population, the reintroduction of this species from Sweden took place from 2005 to 2008. Scientists from the Amphibian and Reptile Conservation trust have established a tadpole head-starting programme funded by several donors, including a small grant from the BHS. This project is successfully increasing the number of froglets released to the wild year by year. **(iii) Captive breeding and conservation of the Golden Mantella frog**. This research, by Liverpool John Moores University, is essentially examining the fitness of captive bred frogs to be released into the wild. Field studies in Madagascar have examined whether wild females have a preference for male calls from wild or captive bred frogs. This work is ongoing and may have important implications for the reintroductions of captive bred animals. **(iv) Adders**: this relatively new project, by scientists at the University of Kent and the Wildwood Trust, was funded in 2022, and is concerned with the daily and seasonal activity, thermoregulation and microhabitat use by captive adders. This work is now fully underway and will allow detailed studies which are not possible on wild populations. It is hoped that results will help inform decision-making concerning any future captive breeding and reintroduction programme. **(v) The Loggerhead Turtle**: mitigating the impact of climate change in sea turtle reproduction (University of Bangor). Funding has been agreed for this new project which is planned to start in the summer of 2023.

To see reports/updates on some earlier funded project work, please refer to the following articles in the references and further reading section at the end of the report. Townson (2020) [Pool Frog re-introduction; Indian Python conservation; Golden Mantellas and re-introduction]. Townson (2018) [includes Agile Frog update; *Mantella cowani* conservation; Gharial breeding and conservation in Nepal]. Townson (2014) [includes Golden Mantella; Veterinary workshop in Kenya; Belalanda Chameleon; Cayman Iguana; Agile Frog]. Liddiard (2017) [Agile Frog in Jersey]; Burton (2010) [Captive breeding and conservation of the Cayman Island Iguana, *Cyclura lewisi]*. Buley and Villavicencio (2000) [Captive breeding and conservation of the Mallorcan Midwife Toad].

This programme of project work was established some 23 years ago (see Townson, 1999) and has been supported largely by independently raised funds. Although these grants are typically modest in value, they can nevertheless make a big difference in low-income countries, or make a significant impact when combined with larger grants from elsewhere. We have also seen that BHS grants can be important for young herpetologists involved in the initiation of conservation ideas/projects.

Enquiries regarding applications for ***BHS Project Grants*** *should be sent to:*

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Update on British Herpetological Society Support for ZSL Project with the Gharial Conservation Breeding Centre, Chitwan National Park, Nepal

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The BHS funds were firstly used to construct simple incubators from locally available parts for eggs in the Gharial Conservation Breeding Centre (GCBC) in Chitwan (Fig. 1). One of the major challenges in the headstarting programme in Chitwan National Park, Nepal, has been a lack of males produced from the programme. This has led to a lack of males in the wild: in 2017 following the death of an adult male in fishing gear, there was just one adult male remaining. Therefore, the Department of National Parks and Wildlife Conservation (with ZSL, NTNC and Himalayan Nature) translocated an adult male from a park in the west of the country. Luckily, since then one male has matured and at least two subadult males are close to maturation. However, the stochastic loss of all males in the Park remains a cause for concern, especially as the threat of death due to accidental bycatch in illegal gill net fisheries remains present. Since gharial have temperature dependent sex determination, the ability to control the sex of the eggs depends on the ability to control temperature of the eggs. The temperature and pattern of sex determination in gharial is not well understood, so the first step to managing sex ratio successfully is installing an incubator which allows both for the control and monitoring of the temperature, but that is also low-tech and made of low-cost parts, so it will function in the centre, and can be easily fixed by the team.

The GCBC in Chitwan National Park is within the National Park, with intermittent electricity and available space for incubation only inside an open-air building. Therefore we constructed a suitable incubator, which was essentially an insulted (thermicol) box with a pool of water inside, which contained an aquarium heater that turned on when a thermistor detected a fall below the desired temperature of egg incubation. The set-up was constructed and trialed under the guidance of the Herpetology Team at London Zoo, and following a successful pilot run, was installed in the GCBC in 2021 under the supervision of Assistant Conservation Officer Saroj Mani Poudel (Fig. 2). The incubator was used successfully in both 2021 and 2022, with monitoring and use carried out by the GCBC permanent staff. Seven hatchlings hatched successfully from ten eggs installed in the incubator in 2021 (Fig. 3), and thirteen hatchlings from twenty eggs in 2021, thought to represent a hatching success of 100% and 76% of eggs containing developing embryos at the start of installation in the incubator (eggs are collected at a mid-stage of incubation from the wild by the programme). The hatchlings were all judged to be healthy by the park staff, and added to the general rearing group for that year (Fig. 4). Individuals were permanently marked following GCBC marking protocol for identification at an age where sexing will be possible (>1m total length).

GPS-GSM Tags for Post-Release Monitoring

The BHS funds were secondly used to purchase GPS-GSM devices for post-release gharial monitoring. The major problem for the Chitwan gharial headstarting programme to date has been that the fate of released animals remains unknown. Without tagging to track individual animals, it is impossible to know the individual fate of most gharial. As part of a larger programme, in 2019 we tagged a cohort of 20 gharial with VHF transmitters, and were successfully able to determine the dispersal distance and fate of most gharial two years post-release. However, four gharial were lost in the first year, of which one was confirmed to have crossed the border to India, and a further two, possibly all three, were suspected to have also crossed the border into India, but were not detected by the Wildlife Trust of India who kindly tracked our gharial in India. The huge expanse of the highly braided Gandak river, and the exceptional distances released gharial occasionally travel (one individual was captured over 1000km downstream in the Hooghly River in 2020) mean that a form of satellite tagging was identified as a key next step for post-release monitoring. However, most forms of satellite tagging are prohibitively expensive for a small conservation project. We had successfully used custom-made GPS-GSM tags on wild-caught gharial in the Nepal programme, and therefore knew that – in theory – this technology worked. To be useful to the GCBC monitoring programme, however, the technology used would have to be cheap enough to use on multiple individuals annually, which excluded the use of most GPS-GSM tags available for wildlife tagging. Off the shelf GPS-GSM tags are available at low cost, which are used for tracking livestock, pets, vehicles and other personal items. Therefore we obtained 20 units (Lightbug Zero devices, see Lightbug.io), with the support of the BHS and other donors.

Firstly, we trialed the tags *in-situ* by placing them on basking beaches, placing them in the canoes of our partners working on the river's most remote stretches as fisherman, and carrying them along the river bank. The units worked very well in these trials, able to fix in even the most remote river sections, and re-upload when connecting to GSM later in the day. Following tests, we encased them in a waterproof shrink wrap and an epoxy coating to ensure they were totally waterproof. We embedded metal rings in the base of the epoxy to facilitate attachment to the gharial, and repeated our riverside tests to ensure the units were still functioning correctly.

We attached GPS-GSM units to five gharial due for release from the GCBC (Fig. 5), and released the gharial into their soft release enclosure as part of the annual headstarting programme. Unfortunately, the tags did not connect post-release, and the 2020 Covid-19 lockdown was called shortly after, precluding us from getting into the field to determine why. Although disappointing, we remain optimistic that the developments in low-cost GPS devices mean that a solution will be available in the near-future, and look forward to trialing new tags now that the lockdown restrictions are over.

We have provided some of the additional devices we purchased to colleagues working on terrestrial species as we suspect the issue was related to submergence or damage at pressure, and these tags could still provide a low-cost solution for non-aquatic species.

Fig. 1. Incubator constructed simply from locally available parts, installed at the Gharial Conservation Breeding Centre, Kasara, Chitwan.

Fig. 2. Twenty gharial eggs were installed in the incubator in 2022, from the annual wild egg collection programme.

Fig. 3. Seven hatchlings successfully emerged from the ten eggs installed in the incubator in 2021 with the remaining three eggs found to be interfile (n=2) or damaged prior to installation (n=1).

Fig. 4. Prem Sharma holds a newly hatched gharial during introduction of the incubator-hatched gharial to the enclosure-hatched gharial in 2021.

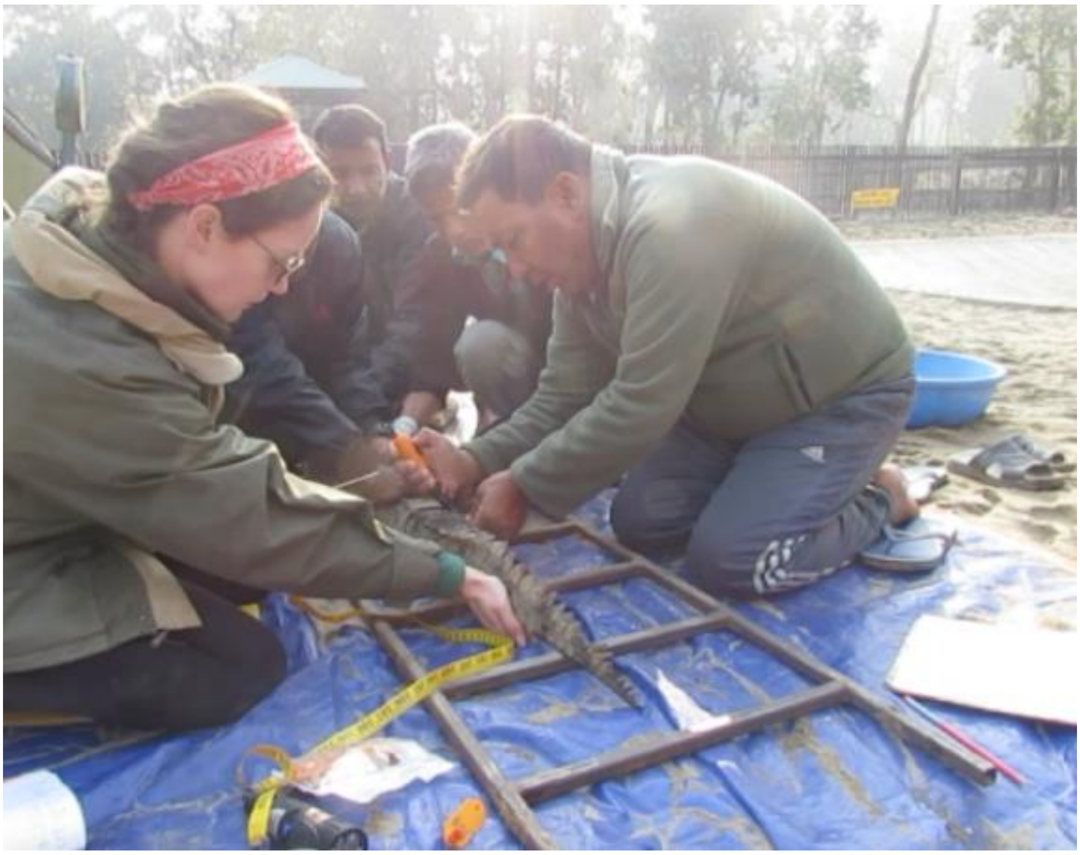

Fig. 5. Bed Bahadur Khadka, Phoebe Griffith, Prem Sharma, Aitaram Bote and Ram Majhi attach a transmitter to the tail of a gharial prior to the release of the gharial into Chitwan National Park. Gharial are tied to ladders for restraint.

Update on Northern Pool Frog Recovery

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The northern pool frog is England's rarest amphibian. After its decline to extinction in the 1990s it was reintroduced by taking frogs from Sweden and releasing them at a site in Norfolk, from 2005 to 2008. This international translocation has been a success in that it established a population (Foster et al., 2018) but this is not yet large enough to supply animals for further wild-to-wild translocations to additional sites. As an alternative approach head-starting has been adopted. Spawn has been taken from the newly-established population, hatched in captivity and the subsequent tadpoles reared until approaching metamorphosis, at which point they have been released back into the wild. Protecting the spawn and tadpole stages in captivity ensures that many more survive to become young frogs than would be the case in the wild. This provides stock for translocation with minimum impact on the donor population.

Translocation by head-starting was the method selected to reintroduce northern pool frogs to a second site, Thompson Common, a Norfolk Wildlife Trust reserve. This was the last known location of native English pool frogs before their disappearance in the 1990s. The head-starting protocols were refined over the four years in which tadpoles were released. In 2015 tadpoles were reared in a private home. In 2016 head-starting was moved to an outbuilding belonging to Forestry England, where tadpoles were reared by a volunteer. After a break head-starting was resumed in 2019 with more resources (Haysom et al., 2020). A new head-starting facility was set up using a re-purposed room, again provided by Forestry England. Eight rearing tanks measuring 60 x 60 x 45cm and other aquarium equipment were purchased with funds that included a grant from the British Herpetological Society Captive Breeding Committee. The job of rearing a cohort of tadpoles was carried out by ARC staff with support from the Zoological Society of London.

COVID-19 prevented head-starting in 2020 so the completion of the reintroduction to Thompson Common was carried out in 2021. Funding from the government's Green Recovery Challenge Fund enabled ARC to employ Ben King and Emily Jordan to undertake head-starting and other species recovery work. In late May approximately 860 eggs were taken from the first Norfolk site and transferred to the head-starting facility (Fig. 1). The resulting tadpoles were fed a varied diet primarily comprising fish flake food, blanched romaine lettuce and spinach. Tadpoles also grazed on algal and bacterial biofilms within the aquaria. Aquatic vegetation from the donor site was added to the aquaria, including water hornwort, water parsnip and water moss, after inspection to avoid introducing predatory invertebrates. The rearing tanks were heated to 20.5-23ºC and received supplementary UVB lighting for eight hours per day. Water quality was maintained by air-driven sponge filters and daily removal of uneaten food and detritus by siphon and replenishment with fresh water.

Fig. 1. Three of seven clumps of northern pool frog spawn taken from the wild in 2021, housed in half-litre food containers floating at the surface of one of the head-starting tanks.

Fig. 2. Head-starting tanks purchased with support of BHS funding, each containing three sponge filters, an aquarium heater and illuminated by overhead UVB lighting, set on custom-built stands. The heat lamps were installed to create basking hot spots, but were not used to avoid overly increasing tadpole development rate.

The tadpoles grew well and developed rapidly, growing to approximately 70mm by the time of release, from 14 to 22 July. Survival of eggs to hatching was 91%. Survival thereafter was 95%. In spite of the impressive growth and survival rates, limb malformations, generically referred to as Spindly Leg Syndrome, affected some larvae leaving 542 tadpoles (63% of the eggs originally taken) fit for release; 231 at the donor site, to compensate for the eggs originally harvested and 311 at Thompson Common, bringing the total released there since 2015 to 1051.

The results of annual surveys to monitor the new population indicate that this second translocation, using head-starting to restore northern pool frogs to the last known natural site in England, has been a success. Counts made during the breeding season in 2022 showed a marked increase from previous years and the frogs had colonised ponds some distance from the point of reintroduction.

The 2022 population surveys were then followed by drought and record high summer temperatures. Although northern pool frogs normally benefit from warm conditions, the weather extremes of summer 2022 resulted in most of their ponds drying out and hence relatively modest metamorph productivity. Additionally, the arid state of the terrestrial habitat presented a hostile environment for frogs of all life stages leaving the water. Ongoing monitoring will determine the impacts of the hot, dry summer. Although it is likely that the northern pool frogs at Thompson Common have been knocked back, the firm establishment of the population should ensure that they are sufficiently numerous to withstand fluctuations in environmental conditions.

Acknowledgements

ARC is grateful for a donation from the BHS Captive Breeding Committee, along with contributions from Amphibian Ark, Anglian Water Flourishing Environment Fund (a charitable fund managed by Cambridgeshire Community Foundation) and the Friends of Thetford Forest. ARC is also thankful to the generosity of suppliers, including Monkfield Nutrition, Matthew Rowthorn of Custom Aquaria, Hazel and Marc Darton of Wrigglies in Dunstable, and John Courtney-Smith of Arcadia, who all offered product discounts and free services.

ARC's northern pool frog recovery work is supported by numerous partners and funders, including Anglian Water, Forestry England, the Green Recovery Challenge Fund, Natural England, Norfolk Wildlife Trust and the Zoological Society of London.

ARC is also grateful to volunteers who have assisted with head-starting, Ed Barker, Michael Clubbs, Alan Spidy, Emily Coleman, Stephen McAvoy and especially the late Bill Landells for his particular contribution to bringing the northern pool frog back to Thompson Common.

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Do Female Golden Mantella Have a Preference for Captive or Wild Calls? Implications for the Reintroduction of Captive Amphibians

(This article is an abbreviated version of the original report).

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Introduction

The on-going global amphibian extinction crisis with 30% of all species being threatened with extinction has lead a worldwide *ex situ* conservation response (Gagliardo *et al.*, 2008). This represents hundreds of thousands of individuals being kept in biosecurity facilities worldwide. The rise in captive amphibian populations and their conservation importance, has emphasized the necessity of a systematic understanding of amphibian husbandry, particularly for species that are intended for reintroduction (Michaels *et al.*, 2014). Amphibians have been neglected in research on cognition, welfare, need for enriched environments, and other topics that have mainly been about mammals and birds (Burghardt, 2013). The few available studies have demonstrated that amphibians are more sensitive to the captive environment than previously thought (Passos *et al.*, 2017). The negative impact of the captive environmental noise on the calls of captive amphibians have already been demonstrated on a golden mantella frog study, as well as effect of captivity on their skin colouration. Calls and colouration are the main communication channels used by amphibians, the inability of captive bred individuals to communicate could negatively affect any conservation effort involved in a reintroduction programme. Species recognition is essential trait for survivorship of released animals, captive animals, if released, should be able to recognize and appropriately respond to wild conspecific. If animals are being bred for conservation purposes and a reintroduction is a future goal, these issues are of major concern. It is becoming apparent that the captive husbandry requirements of amphibians are more complex than first thought (Antwis & Browne, 2009). Thus, conservation breeding programmes could potentially produce maladapted amphibians that are unsuitable for release. It is imperative that more research is undertaken to ensure that the husbandry of animals bred in captivity for the purpose of reintroduction is optimised (Tapley *et al.*, 2015). The behavioural integrity of wildlife is one the most important aspects to conserve in a captive population (Teixeira *et al.*, 2007). During this project we aim to test if golden mantellas, both captive and wild, will show a preference for calls from wild or captive males, and if the skin colouration will affect this preference.

Methodology

Study subject: The golden mantella frog (*Mantella aurantiaca*) (Fig. 1) is a critically endangered species, found only in Madagascar with a distribution restricted to a fragment of forest that is under severe threat from mining, agriculture, timber extraction and over-collecting for the pet trade.
According to the Amphibian Ark, *ex situ* assistance is vital for the long-term survival of the golden mantella frog.

Study site: Mangabe area (Madagascar): Mangabe (Fig. 2) also known as the "blue forest" is a site of international biodiversity importance, divided into two administrative districts, Moramanga in the north and Anosibe An'ala to the south. Data sampling for this study was done in the Moramanga region. Most breeding ponds for the golden mantella frogs are found in this area according to recent studies concerning conservation priority sites.

Fig. 1. Golden mantella (*Mantella aurantiaca*) frog.

Fig. 2. Mangabe area in Madagascar, natural habitat of the golden mantella frog.

Playback experiment

Active frogs were collected by hand from the pond areas nearby and put in a plastic box until the experiment. Playback experiments were conducted from the 27th of January until the 4th of February 2020, during the species breeding season. During the first phase of the experiment, the phonotaxis accuracy of a wild golden mantella frogs to four different calls was tested: wild population of golden mantella frogs from Mangabe, wild animals from Andasibe, and two from captive populations: one from Chester Zoo and one from Mitsinjo presented in a two-choice playback-experiment using a randomized block design. Calls had already been edited for length and background noise using Audacity® recording and editing software. The acoustic stimuli were broadcasted antiphonally from two loudspeakers. The loudspeakers were placed at the ends of an experimental arena (Fig. 3) at an angle of 45°, ensuring that the calls will be broadcast towards the frog (located equidistant from the speakers) at a distance of 1 m.

Fig. 3. Experimental arena used for playback experiment at Mangabe, Madagascar.

Fig. 4. 3D printed golden mantella models painted with different colourations representing the three different populations, Mitisinjo, Chester Zoo and Mangabe.

A second phase playback consisted of a bimodal experiment that included 3D printed frog models with different colours to access the response toward animals with different skin colouration (Fig. 4). The models' colouration matched the measurements made with a spectrometer in a previous study with wild and captive golden mantellas. There were three different models for each population representing the variation found within each population, and avoid pseudo-replication. Frogs were placed 10 cm away from the front edge of the experimental arena at the beginning of every trial. Trials were not scored if animals did not enter the arena from the front edge of the board. The experiments were videotaped with a digital camera. If, after 3 minutes animals have not reached a speaker, the trial was terminated.

Partial Results

During the field trip 94 frogs were tested during the first phase of the experiment and 494 individuals were tested during the second phase. All animals were sexed and had their morphometric (snout-ventral length and mass) taken. Environmental data such as temperature, wind speed and humidity were also collected. The field trip was also used for collecting biological samples for corticosterone analysis to investigate stress levels in captive frogs and its consequences, and mouth swabs for genetics and telomere attrition analysis (Fig. 5). Telomere can be used to assess long term stress and its consequences, such as fast ageing.

Next steps

Over the next months, the frogs' behavioural responses to the playback experiments will be done by analysing the videos using BORIS software. For each playback, the following physical characteristics will be analysed to define the accuracy of phonotaxis: (1) number of jumps; (2) jump angles; (3) jump distances; (4) path straightness; (5) duration. The accuracy of the phonotactic approach will be quantified using jump angles and the straightness of the path; values are given as percentage of path length in relation to the straight-line distance. All statistical analyses will be done using R Studio. The same experiments will also be done at Chester Zoo, in order to compare the differences between the responses of wild and captive frogs.

Fig. 5. Golden mantella frog having its mouth swabbed.

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Daily and Seasonal Activity, Thermoregulation and Microhabitat Use in Captive Adders

(This article is an abbreviated version of the original proposal).

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Background

Although it is the most widespread species of snake in the UK, there is increasing concern over the status and conservation of the adder. Population analyses suggest widespread declines across the country (Gardner et al. 2019), and adders were recently classified as 'Vulnerable' in England in a UK Red List assessment (Foster et al., 2021). Despite the current Environment Secretary citing the adder as an example of a species that has been 'overlooked' and deserving stronger protection (https://www.gov.uk/government/speeches/george-eustice-speech-on-environmental-recovery-20-july-2020), there is concern that changes to planning legislation under consideration by parliament may remove the fragile and limited degree of protection the species currently receives. The adder is now thought to be extinct in several counties in England. One of these is Nottinghamshire, where a recent workshop identified captive breeding as a possible mechanism to generate snakes for reintroduction to restored sites within the county. Several zoos currently hold adders in outdoor, naturalistic enclosures (e.g. Wildwood, Chester Zoo, Jersey Zoo), and these provide an opportunity for behavioural research on the species that is not possible to carry out on wild populations. For example, although Hodges & Seabrook (2016a,b,c) have provided detailed information on thermobiology and refugia use in a natural population of adders, and radiotelemetry has been used to monitor movements (Nash & Griffiths, 2018), detailed, continuous observations of the daily activity profile of individual adders is only possible on captive snakes. Understanding the behaviour of such animals in relation to available microhabitats and the immediate thermal environment may be important to inform decision-making concerning any future captive breeding and reintroduction programme.

Here we propose to monitor the daily activity of adders using trail cameras in a naturalistic enclosure at Wildwood Trust, Kent. The resulting data should provide (1) the first detailed assessment of the activity patterns of different individuals; (2) a comparison of the behaviour of adult and juvenile snakes; and (3) relate the behaviour patterns to microhabitat structure and environmental conditions.

The adder facility at Wildwood Trust

The adder enclosure at Wildwood Trust is an oval-shaped enclosure measuring about 10 m x 5 m (Fig. 1). It is landscaped with grass tussocks and open basking places, and has a central hibernaculum where snakes are allowed to hibernate naturally. The adders bred in 2020 (approximately 6th - 15th August, according to ZIMS data), producing a total of at least 18 young which were allowed to stay in the enclosure. The current numbers comprise one adult male,

Fig. 1. Diagram of the outdoor adder enclosure, measuring 10m x 5m, at Wildwood Trust.

three adult females and up to 18 surviving juveniles. Adult adders are fed using forceps and eat warm, dead mice once every 3 days during the spring and summer months dependant on weather and temperature. If it is forecast to be warm (above 16°C) on consecutive days, they are fed to this schedule. Little and often is considered better as any post-feeding temperature drop can affect their metabolism, and therefore their digestive abilities. So 3 or 4 small mice each is usually the limit.

Juvenile adders are fed chopped up rat pinkies and small mice legs. This is placed near them, on basking spots and logs. The adults are kept away as they will compete heavily for food and have been shown to cannibalise on their young. They compete for food as they all bask together in harmony. At the end of summer, into early autumn, they are fed more frequently in preparation for hibernation. Feeding stops for both adult and juvenile when the temperature and activity drops for brumation (hibernation), late autumn into winter.

Unlike wild adders which usually flee when approached by humans, the captive adders are used to visitors and appear to bask and otherwise behave normally, even on busy days. Keepers have reported a shift in the areas of the enclosure used by the adders as the sun moves across the sky during the day, but the main basking points within the enclosure are known. Both adult and juvenile adders have been observed basking in these areas on sunny days.

Study design

Four trail cameras will be positioned along the base of the inside enclosure wall at approximately 2m intervals and centred on the known basking points. Pilot research has indicated that there is insufficient infrared heat differential between the adders and the immediate environment to automatically

trigger the cameras. Consequently, the cameras will be set to time-lapse so that an image is captured every 5 mins. Temperature dataloggers (ibuttons) will be positioned at basking points and at other key topographical features within the enclosure (e.g. open ground, grass tussock, log, rock etc) to create a thermal map of the enclosure at different times of day. Surface body temperatures of adders will be recorded at intervals throughout the day using an infrared thermometer that can be operated at a distance using a grab-stick.
The cameras and dataloggers will be placed in position in February 2022 prior to the adders emerging from hibernation. They will then operate continuously through the spring and summer months, with periodic downloading of data from the camera SD cards and temperature data from the dataloggers (e.g. an ibutton programmed to record once per hour can operate for six weeks before it is full). Weather data (i.e. temperature, rainfall, wind, light intensity and UV) will be collected at 1 hr intervals using the existing Davis weather station located at the DICE field site 4 miles away.

Personnel

For H&S reasons access to the adder enclosure will be restricted to experienced keeper staff who will monitor the equipment and download the data as needed. A volunteer who has experience of working with wild adders (Louise Masters) will periodically visit the park to collect data as needed, and – in conjunction with the keepers – take surface body temperatures. Staff from DICE (University of Kent) will provide advice and supervision on design, observations and data analysis.

Data analysis

The images will provide data on behaviour and enclosure use sampled at regular intervals. These will be used to construct daily activity profiles of different snakes in the enclosure and allow comparisons of adults and juveniles. The design will also allow seasonal activity profiles to be explored in depth, and the relationships between daily and seasonal activity and (1) the thermal conditions within the enclosure; and (2) prevailing weather conditions to be modelled statistically.

Dissemination of results

The results of the study will be presented at an appropriate BHS meeting, and written-up for publication for the *Herpetological Journal* (or an alternative zoo or herp journal). The results will aim to inform ongoing discussions concerning the captive breeding and reintroduction of adders in the UK, and in turn, wider conservation management.

Fig. 2. External view of the adder enclosure at Wildwood Trust.

Fig. 3. Internal view of open area with three adders basking.

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Research Project: Mitigating the Impacts of Climate Change in Sea Turtle Reproduction: Developing the Evidence Base for "Clutch-Splitting" as a Low-Cost Management Tool

(*This article is an abbreviated version of the original proposal. BHS has agreed help fund this project; planned start date summer 2023*).

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This research is part of a focused project to trial a novel management technique in mitigating the negative effects of climate change on reproduction in endangered sea turtle populations. Dr Leo Clarke, a postdoctoral marine scientist at the School of Ocean Sciences, Bangor University, is planning a collaborative project with colleagues from BIOS.CV, a local NGO in Cabo Verde, West Africa, that promotes the conservation of the archipelago's rich biodiversity.

Background

Understanding effective conservation management under climate change is critical. For sea turtles, like all reptiles, environmental temperature influences numerous life-history stages. Climate change and global temperature increases add to existing threats such as capture in fishing gear, plastic pollution, and poaching. Offspring sex and successful egg development is determined by incubation temperatures and for sea turtles, higher nest temperatures due to global climate change are causing heavily female-biased hatchling sex ratios and reduced hatching success and hatchling fitness. Elevated nest temperatures are further exacerbated by metabolic heat generated as the eggs develop. Sea turtles as a group are already of conservation concern and there is concern over their future in a rapidly changing climate. Given the unprecedented rate at which climate change is occurring, managers are considering what mitigation techniques are available. Researchers have investigated various techniques to reduce sea turtle nest temperatures (e.g., shading, watering, translocation to conservation hatcheries and laboratory incubation). These techniques are often resource and labour-intensive, however, and as sea turtles often nest in remote locations in developing countries, practical solutions should be simple and cheap.

The Project

A recent publication by the project team demonstrated how 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, effectively reduced overall nest temperatures in an experimental conservation hatchery setting. This reduced female-bias in hatchling sex ratios, with no adverse impact on hatchling fitness and showed evidence of increased hatch success. The proposed project now aims to practically implement the technique in the natural nesting environment of the endangered loggerhead turtle (*Caretta caretta*) for the first time, and collect additional data to inform its future implementation and enhance its effectiveness.

What Will This Work Achieve?

The work will contribute directly to the conservation of the local loggerhead population in Cabo Verde, as well as other populations globally. Cabo Verde supports the third-largest nesting population of the loggerhead turtle globally, supporting approximately 15% of all nesting females. Hatchling sex ratios in this population are heavily female skewed (~90% female), with a complete loss of male hatchling production predicted in the coming decades, and nests often approach lethal temperatures. The work supported by this grant will therefore support ongoing conservation efforts in Cabo Verde by balancing primary sex ratios and improving hatch success and overall reproductive output of the population. In addition, the evidence gathered through the work will better inform the implementation of the technique as an effective conservation intervention elsewhere, including an assessment of any potential adverse effects. Importantly, the project will investigate how reducing the group size of hatchlings that emerge from the nest through clutch-splitting affects predation rates, as group size on emergence can play a role in diluting predation risk. To improve our understanding of the thermal nesting environment more generally, the work will also assess variation in metabolic heating, thermal microhabitats and hatchling swimming performance across the beach as well as between split and whole nests. These are also key knowledge gaps for wider sea turtle conservation research.

Methods

The work will be carried out on Boa Vista island, part of the Cabo Verde archipelago in the eastern Atlantic Ocean off West Africa. The archipelago supports more than 95% of the loggerhead's nesting activity in the entire eastern Atlantic and the beaches on the southeast of Boa Vista are nationally designated as part of the Reserva Natural de Tartaruga, a protected area for sea turtles in Cape Verde.

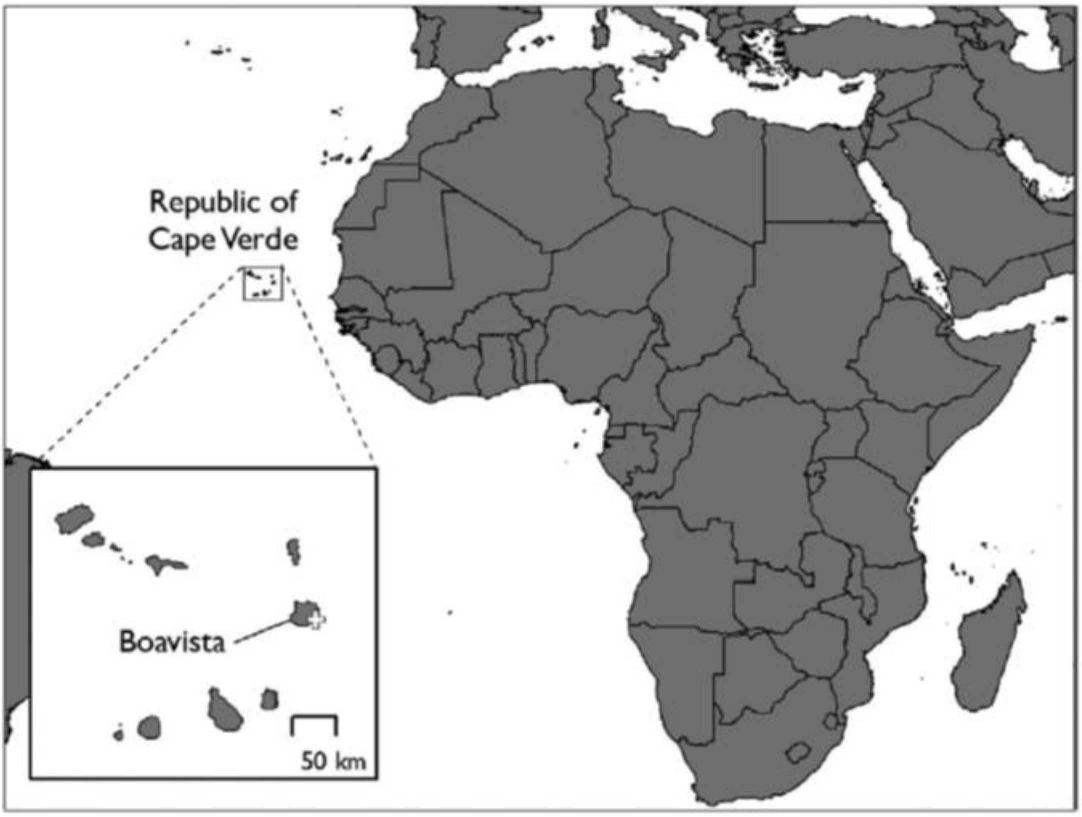

Fig. 1. Map showing the location of the Cape Verde islands 600 km off the West African coast and (inset) Boa Vista, the easternmost island of the Cape Verde islands. The approximate location of the study site is indicated as a white cross on inset.

"Clutch-splitting" will be implemented in nests across the full beach profile (from the lower to the upper beach) on the natural nesting beaches within the protected area. In "split" clutches, the number of eggs in each clutch will be halved, with half the eggs laid in the nest re-buried at the same depth adjacent to the original nest. An additional number of nests will be left to incubate whole as controls, again across each of the three beach sections. Nesting females will be encountered during nightly beach patrols and the coordinates of each nest included in the study will be recorded for future monitoring. Temperature data loggers will be deployed in nests to collect detailed temperature records throughout incubation, with a second logger buried 1 m from each nest at the same sand depth to monitor sand temperatures and allow metabolic heat to be calculated (taken as the difference between nest and sand temperatures).

Fig. 2. Loggerhead hatchling with temperature data logger.

Fig. 3. Image of the turtle hatchery.

Fig. 4. Hatchling turtles being released to the sea.

After the average incubation duration for Boa Vista, nests will be monitored nightly for hatching. Upon hatching, hatchling fitness will be investigated through swimming and running trials prior to release. During release, predation rates of hatchlings on their way to the sea will be recorded, following standard observation protocols that have been used for the Cabo Verdean population. Data loggers will be retrieved and temperature data will be downloaded. All nests will be excavated, and hatching success and predation assessed. Temperature data will be used to calculate metabolic heating, and incubation durations will be used to estimate hatchling sex ratios using published equations for loggerhead sea turtles. Data analysis will compare incubation temperatures, sex ratios and hatchling fitness between control and split nests and across the beach.

Outputs

The key outputs of the project will be a publicly available dataset and a peer-reviewed scientific publication on the project. Technical reports will be produced and circulated to all funders and relevant stakeholders, and it is envisaged that results will be presented at relevant scientific conferences. As a field assessment of a conservation intervention, the results of the work will also be communicated to the Conservation Evidence project for dissemination to practitioners. https://www.conservationevidence.com/

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