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Front Cover: Cuban treefrog *Osteopilus septentrionalis.* See article on page 8.
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Alien herpetofauna pathways, invasions, current management practices and control method ethics: A review of some significant problems in the USA

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ABSTRACT - Regardless of nomenclature, non-indigenous, exotic, alien herpetofauna can cause dramatic changes in the ecosystems in to which they are introduced. Through human globalisation, species easily cross international boundaries (via the pet trade, hidden in cargo and as biological pest control) and make their home in new regions and waterways. Exotic amphibians and reptiles are no exception and have been introduced into the United States. Some have become invasive species, which have had a substantial negative impact on the regions economy, their new environment and resident species. Currently, the main management tools used for handling invasive herpetofauna issues in the U.S. have been prevention, education, control and eradication measures. However, there seems to be gaps in the literature regarding the use of ethics in the control and eradication methods with regard to invasive reptiles and amphibians, which should be given consideration in future management efforts. This review is not comprehensive, but rather a brief summary of the most widely recognised U.S. alien amphibian and reptile pathways into the U.S., the transition of alien herpetofauna to invasive species, current invasive management efforts, a discussion of the ethics of invasive species management and how best to move forward with research and conservation efforts. This review focuses on the U.S. states of Florida and Hawaii, and the U.S. territories of Guam and Puerto Rico, which is mainly due to much of the available research focusing on these regions due to the high instance of invasive herpetofauna. However, California, Georgia, Louisiana, New York, Ohio and Texas are also mentioned. The alien species most commonly referenced in this review are the brown tree snake (*Boiga irregularis*), bullfrog (*Lithobates catesbeianus*), Burmese python (*Python bivitattus*), Cuban brown anole (*Anolis sagrei*), Cuban treefrog (*Osteopilus septentrionalis*), European wall lizard (*Podarcis muralis*), green iguana (*Iguana iguana*), Italian wall lizard (*Podarcis sicula campestris*), Mediterranean house gecko (*Hemidactylus turcicus*), Nile monitor (*Varanus niloticus*), northern curlytail lizard (*Leiocephalus carinatus armouri*) and red-eared slider (*Trachemys scripta elegans*).

INTRODUCTION

Of the more than 500,000 estimated alien species that have been introduced into new ecosystems worldwide, there are more than 50,000 introduced species in the United States (Pimentel, 2005). Alien species provide an estimated value of US $800 billion per year and also can cause US $120 billion in damages and control measures, not to mention the ecological costs, on which are hard to put a price (Pimentel, 2005). Through various channels, alien amphibians and reptiles make their way into the United States. Some of those that enter the U.S. establish themselves in the native ecosystems and some of those that are established become invasive species. There are 56 non-native species of amphibians and reptiles known to occur in Florida and 33 non-native species of amphibians and reptiles known to occur in Hawaii - the two states most affected by invasive herpetofauna species (Krysko, 2011; Pitt, 2005; and Engemen, 2011). However, it is important to note that exotic reptiles and amphibians can be found in numerous other states and have established populations in some of those states.

Although the number of introduced species of herpetofauna is relatively low when compared with the overall number of introduced species, their impacts on their new ecosystems and economic costs on the states left with managing them are substantial. Only human-caused habitat destruction is more harmful than introduced species in respect to negative effects on native species and ecosystems (Enge et al., 2004).

This review does not cover every species of exotic amphibian and reptile in the U.S., but highlights several widely recognised species, their introduction pathways into the U.S., the means through which some have become invasive, current management practices and a discussion on the ecological ethics of managing invasives and the best way to move forward with regard to future management. It should be noted in this review that "alien species," "exotic species", "non-native species" and "non-indigenous species" are all synonyms and interchangeable.

Alien Herpetofauna Pathways into the U.S.

Human movements around the globe have easily allowed for the transfer of reptiles and amphibians from their native locales to new lands, farther and faster than ever before.

Figure 1. The brown tree snake (*B. irregularis*) is native to Australia, Indonesia and Papua New Guinea and regarded as one of the world's most destructive invasive species. It easily escaped notice in the commercial and military cargo, moving to and from the U.S. territory of Guam shortly after World War II. *B. irregularis* subsequently decimated 18 of Guam's native species, including birds, bats and lizards (Pimentel et al., 1999; Lowe, et al., 2000; Pitt, 2005; Rodda & Savidge, 2007). Photo Credit: Tom Charlton.

Figure 2. The American bullfrog *(L. catesbeianus*) has a natural range over a vast portion of eastern North America, from the Mississippi River and Great Lakes all the way east to the Atlantic Ocean, but is still considered alien and often invasive when present in non-native American habitat (Adams & Pearl, 2007). The IUCN lists the American bullfrog on its list of "100 of the World's Worst Invasive Alien Species" (Lowe, et al., 2000). Photo Credit: Michael Gadomski.

Global transportation networks have grown and thus goods and people are finding their way to even the most remote terrestrial and marine locations, therefore increasing homogeneity of species around the world and reducing biodiversity (Pitt, 2005). Exotic amphibians and reptiles are no exception and have been introduced into the United States both accidentally and intentionally.

Accidental and intentional introductions

Non-indigenous reptiles and amphibians have entered the United States accidentally as "contaminants" of trade via airports, seaports, roads, railways, canals, and even pipelines (Hulme, 2009). Invasive brown tree snakes (*Boiga irregularis*, Fig. 1), coquí frogs, geckos, and blind snakes travel around the globe as stowaways in air and sea cargo before finding their new home in the States (Pitt, 2005). While *B. irregularis* hide in the cargo of ships, coquí frogs, geckos, and blind snakes (*Ramphotyphlops braminus*) hide amongst agricultural produce (Pitt, 2005). Native to Australia, Indonesia and Papua New Guinea, the shy and nocturnal *B. irregularis*, known as one of the world's most destructive invasive species, easily escaped notice in the commercial and military cargo, which was coming to and from the U.S. territory of Guam shortly after World War II (Pimentel et al., 1999; Lowe, et al., 2000; Pitt, 2005; Rodda and Savidge, 2007).

Guam may have one of the world's most invasive reptiles, but Florida has the largest number of established non-native amphibian and reptile species in the United States (Enge et al., 2004). The United States accounts for more than 80% of the world's total trade in reptiles, many of which enter through Florida (Simmons and Burridge, 2002). Florida is especially susceptible to the establishment of alien herpetofauna and has more exotic reptiles and amphibians species than any other state, due to its major ports, US $300 million captive wildlife industry, subtropical climate, reduced native species, habitat destruction and hurricanes - the latter facilitate the release of captive animals (Enge et al., 2004; Pitt, 2005; Hardin, 2007; Engeman et al., 2011; Krysko, 2011). The main port of entry for exotic herpetofauna entering the U.S., either accidentally or intentionally, is Miami, Florida (Hardin, 2007; Pitt, 2005). In 2005 and 2006, 3,982 Florida captive wildlife facilities were permitted to have non-native species (Hardin, 2007). During the years 1989 through 2000, U.S. Fish and Wildlife Service Law Enforcement Management Information System (LEMIS) records indicate that approximately 6,067 shipments containing live nonerycine boas, pythons and relatives entered the United States, representing 404,177 individuals, 17 genera, and 40 species (Reed, 2005).

With so many exotic species entering the U.S. it is not surprising that some find their way into the wild. Due to this, along with other influencing factors, pythons and chameleons, have been introduced both accidentally and intentionally into Florida (Hardin, 2007; Pitt, 2005). They have been imported for the pet trade and either escaped or were released by owners who no longer wanted them (Pitt, 2005). Intentional releases are also responsible for introducing alien species including bullfrogs, *Lithobates catesbeianus* (= *Rana catesbeiana*, Fig. 2), and various species of turtle released as a food source, cane toads (*Rhinella* (= *Bufo*) *marina*) and poison dart frogs (*Phillobates* sp.) for biological control to combat pest species and veiled chameleons (*Chamaeleo calyptratus*) for aesthetic reasons (Pitt, 2005; Hulme, 2009).

Native introductions

Unlike the other species discussed in this review, the red-eared slider turtle (*Trachemys scripta elegans*) and the bullfrog (*L. catesbeianus*) although native to the U.S., are considered invasive in non-native parts of their range.

Figure 3. Burmese pythons (*P. bivitattus*) are usually difficult to locate, because of their camouflage and the marshy, difficult-to-navigate habitat of the Everglades where they have become established (Engeman et al., 2011). Photo Credit: Susan Jewell, U.S. Fish & Wildlife Service/Wikimedia Commons.

Figure 4. European wall lizard (*P. muralis*), a native to southern and central Europe and northwestern Asia Minor, has established a population of several thousand in urban areas within Cincinnati, Ohio. The population stems from just two introduced lizards from Italy in 1951 and its dispersal has since followed the railroad tracks (Hedeen & Hedeen, 1999). Photo Credit: Lucarelli/Wikimedia Commons.

T. scripta elegans, indigenous to the U.S. is the most widely invasive reptile species in the world due to introductions from the pet trade and food markets (Thomson et al., 2010). The native range of *L. catesbeianus* covers a vast portion of eastern North America, from the Mississippi River and Great Lakes east to the Atlantic Ocean, but is still considered alien and often invasive when present in non-native American habitat (Adams & Pearl, 2007).

Pet trade introductions

Unintended alien species introductions from other countries due to the pet trade include the Burmese python (*Python bivittatus*, formerly *Python molurus bivittatus*; Fig. 3), Nile monitor (*Varanus niloticus*) and green iguana (*Iguana iguana*). Since the 1970s, escaped and released pet *P. bivittatus* have been present in southern Florida and subsequently making their way into newspaper headlines (Engeman et al., 2011). Additionally, such natural and destructive events as Hurricane Andrew may have unintentionally released more individuals into the wild (Engeman et al., 2011).

Although, not an ideal pet, given its large size and its skittish disposition the monitor lizard *V. niloticus* is the second-most commonly sold African monitor species in the U.S. and can retail for as little as US $10 (Enge et al., 2004). Due to escapes, intentional release by owners who find them to be too much to handle or illegal release by reptile dealers trying to establish a local breeding population from which they plan to capture and sell them, *V. niloticus* has established populations in Florida (Enge et al., 2004).

Native to Central and South America and the Caribbean, *I. iguana* is also a popular pet of reptile enthusiasts. When owners are no longer interested in keeping them, they are released into the wild and, like many invasive species, populations have grown rapidly in the U.S. (Falcón et al., 2013). Although it is legal to own *I. iguana* in Florida and Puerto Rico (but illegal to import them into Puerto Rico), it is illegal to release them into the wild (Falcón et al., 2013). Hawaii, where *I. iguana* have also become established and pose a risk to endangered hibiscus and Kokia, is a different story and possessing *I. iguana* can cost up to US $200,000 in fines and 30 years in prison (Falcón et al., 2013).

Another well-documented pet trade introduction is the European wall lizard (*Podarcis muralis*, Fig. 4), a native to southern and central Europe and northwestern Asia Minor. Unlike the previously mentioned species, this species does not require a tropical habitat to thrive and has established a population of several thousand in urban areas within Cincinnati, Ohio (Hedeen and Hedeen, 1999). The population apparently stems from just two introduced lizards from Italy in 1951(Hedeen and Hedeen, 1999). The lizard's population dispersal followed the railroad tracks, due to its preference for splintered wooden ties in railroads in the human-modified habitats of its native range (Hedeen and Hedeen, 1999).

The Italian wall lizard (*Podarcis sicula campestris*, Fig. 5) was accidentally introduced to Long Island, New York due to a car accident around 1967, which released several individuals intended for a pet store (Mendyk, 2007). The city's municipal yard with its paved areas was perfect habitat for *P. s. campestris* to colonize and since then, the species has dispersed and established several populations (Mendyk, 2007). Long Island's railroads, power-lines and drainage ditches provide connected, unobstructed prime habitat for the lizards to disperse freely, including into New York City (Mendyk, 2007). Without any native lizards present in the area, *P. s. campestris* does not face direct competition for food or habitat and will likely continue to spread throughout Long Island and New York City (Mendyk, 2007). Currently, there is no evidence implicating *P. s. campestris* with environmental damage,

Figure 5. Italian wall lizard (*P. sicula*) was accidentally introduced to Long Island, New York due to a car accident around 1967, which released several individuals intended for a pet store. Long Island's railroads, power-lines and drainage ditches provide connected, unobstructed prime habitat for the lizards enabling colonization into other areas, including into New York City (Mendyk, 2007). Photo Credit: Richard Bartz/Wikimedia Commons.

Figure 6. Northern curly-tail lizard (*L. carinatus armouri*) in Morikami Gardens, Delray Beach, Florida, USA. An endemic to the islands of Little Bahama Bank, the current established population stemmed from just 20 released pairs on Palm Beach in the 1940s (Meshaka et al., 2005). Photo Credit: Ianaré Sévi/ Wikimedia Commons.

but much remains to be learned about their ecology in the U.S. (Mendyk, 2007).

Regardless of where alien herpetofauna end up in the U.S., the invasion pathways have opened up previously unavailable corridors through which thousands of alien reptilian and amphibian species enter the U.S. daily. In addition to exotic herpetofauna, the channels allow introduction of parasites and pathogens that may accompany exotic herpetofauna. It is important to understand the access points and pathways available to non-indigenous herpetofauna, since some have been known to become invasive through predation, competition and disease. Once the pathways by which alien herpetofauna enter the U.S. are fully understood, the better equipped U.S. wildlife managers and conservationists will be to prevent future introductions.

When Alien Herpetofauna Become Invasive

There is a fine line between being an introduced alien species and an invasive species. Just by being present in an ecosystem, alien species naturally will have some sort of effect on native species, whether it is beneficial or harmful, predatory or competitive, but not all will become invasive and most have negligible environmental impacts (Hardin, 2007). The non-indigenous species whose presence is truly damaging to the ecosystem's function, native inhabitants or economy will receive the designation of 'invasive species.' Although Florida and Hawaii have the greatest numbers of invasive herpetofauna in the U.S. with 30 species found in Florida and 12 found in Hawaii, there are at least 53 invasive species of reptiles and amphibians in total in the U.S. (Pimentel et al., 1999; Bergman et al., 2000). During the fiscal years 1990 to 1997, assistance was requested to alleviate damage caused by various exotic reptiles in Arizona, Guam, Louisiana, Maryland, Maine, Minnesota, Missouri, Oklahoma, Puerto Rico, Texas, Utah, and Wisconsin. This included, for example, the mangrove monitor (*Varanus indicus*) in Guam and *B. irregularis* in Hawaii and Guam (Bergman et al., 2000). The International Union for the Conservation of Nature (IUCN) lists *B. irregularis*, *L. catesbeianus, O. septentrionalis* and *T. scripta elegans*, which are all invasive in the U.S., on its list of "100 of the World's Worst Invasive Alien Species" (Lowe et al., 2000). Additionally about 42% of the species on the Threatened or Endangered species lists are at risk primarily because of non-indigenous species, which demonstrates the negative implications of invasive species (Pimentel et al., 1999).

Snakes

Invasive species, the same as any species, have specific ecological requirements for survival and propagation. However, successful invasive species tend to be generalists, which can reproduce effectively and abundantly, mature quickly, eat almost anything, tolerate a variety of habitats, be transported easily (either intentionally for the pet or wildlife trade or accidentally as elusive and unseen cargo), and enter a climatically similar ecosystem, which has low species diversity and is stressed by human or natural disturbance (Pitt, 2005; Salinas, 2006). The successful invasion of Guam by *B. irregularis* is due to the fact that it meets most of these criteria and does not have any natural predators on the island (Lowe, et al., 2000). Given the small size and neutral colour of *B. irregularis* and an ability to remain concealed in cargo, boats and aircraft, it poses a threat of invasion to other islands, if serious management efforts are unable to contain it (Lowe, et al., 2000). The areas most at risk are tropical hubs for traffic and trade (Lowe, et al., 2000). In areas where *B. irregularis* has proliferated, it has eliminated all breeding populations of seabirds, 10 of 13 native bird species, 6 of 12 native lizard species, and 2 of 3 bat species (Pimentel et al., 1999;

Figure 7. Brown Anole (*A. sagrei*) a native of Cuba and the Bahamas, is now found in Florida, Georgia, Texas and Hawaii. *A. sagrei* may be responsible for the displacement of native green anoles (*A. carolinensis*) (Gerber, 1991; Echternacht, 1999; Campbell, 2000). Photo Credit: Alberta P./Wikimedia Commons.

Figure 8. Mediterranean house gecko (*H. turcicus*) also found in western India, Somalia, Canary Islands and now throughout the southeastern United States. However, *H. turcicus* is being replaced by introduced competitively superior geckoes - the tropical house gecko (*H. mabouia*) and Indo-Pacific gecko (*H. garnotii*) - in Texas and Florida (Meshaka et al., 2006). Photo Credit: ZooFari/Wikimedia Commons.

Bergman et al, 2000; Lowe, et al., 2000; Wiles et al., 2003; Reed, 2005; Rodda and Savidge, 2007).

Additionally, *B. irregularis* has been responsible for power outages, livestock losses and hospitalized people with its bite (Bergmann et al., 2000). In 1987, a single snake-related power outage cost the power company more than $250,000 and according to a 1996 estimate, snake-related power outages is conservatively $1 million per year (Pimentel et al., 1999). *B. irregularis* accounts for US $12 million in damages and control costs annually (Pimentel, 2005). For all its currently documented negative effects, *B. irregularis* harmful presence may be even greater (Wiles et al., 2003). For example, seed dispersal and pollination carried out by the former residents are now severely reduced (Wiles et al., 2003). It is difficult to know with any certainty what the future holds for these plant species, which can take years to potentially go extinct, but preventing further damage through successful control of *B. irregularis* and protecting native species remain crucial (Wiles et al., 2003; Richardson and Ricciardi, 2013).

There are 315 vouchered records (verified with specimens or photographs) of Burmese pythons (*P. bivittatus*) in Florida, which are native to southern China, Vietnam, Cambodia, Thailand, Laos, Myanmar, Bangladesh, and eastern India (Krysko et al., 2011). *P. bivittatus* have increased dramatically since 2000 and have spread throughout much of southern Florida, including all of Everglades National Park (Krysko et al., 2011; Dorcas, et al., 2012). This large snake consumes mammals and birds, including endangered species, and recent research indicates that severe declines in mammal populations coincide with the expansion of *P. bivittatus* in the Everglades (Dorcas, et al., 2012). Nocturnal road surveys of mammals before 2000 displayed a 99.3% decrease in the frequency of raccoon observations and decreases of 98.9% and 87.5% for opossum and bobcat observations, respectively with no rabbits detected from 2003 to 2011 (Dorcas, et al., 2012). Given that raccoons and bobcats are considered commonly occurring mammals in the National Park, the results do not bode well for species of conservation concern (Dorcas, et al., 2012). However, according to K.G. Smith, there is "presently no evidence for an overall homogenizing effect of non-indigenous amphibians and reptiles in Florida," but this "should not be confused with an absence of the effects of non-indigenous species in Florida" and the chance for future changes (Smith, 2006).

Lizards

Of the established alien reptiles found in Florida, most are lizards (31 species, mostly iguanids and geckos). This compares to a single chelonian, the red-eared slider (*T. scripta elegans*), one crocodilian, the spectacled caiman (*Caiman crocodilus*), and three snakes (Hardin, 2007). Although *I. iguana* is well established and considered a problem species, there is no evidence indicating they are responsible for severe ecological damage and hence are only of minor concern (Hardin, 2007). On the other hand, the Nile monitor (*Varanus niloticus*), Africa's largest lizard and a voracious predator, is cause for great concern (Hardin, 2007).

The presence of *V. niloticus* in southwest Florida potentially threatens a species of special concern, the burrowing owl (*Athene cunicularia*) (Hardin, 2007) and expansion further south could potentially threaten nest sites of already vulnerable species such as the Brown Pelican (*Pelecanus occidentalis*), sea turtles, diamondback terrapins (*Malaclemys terrapin*), and the endangered American crocodile (*Crocodylus acutus*), since it is well known to feed on crocodile eggs in Africa (Enge et al., 2004; Hardin, 2007). However, other species, for example, alligators, may be less impacted, because of their stable and large populations (Enge et al., 2004). A prolific and generalist predator, *V. niloticus* preys on arthropods, crabs, crayfishes, mussels, gastropods, fishes, anurans, lizards, turtles, snakes, young crocodiles, eggs, birds, small mammals, carrion, and even human food scraps, and hence has the potential to drastically and negatively affect local wildlife through competition for resources (food and habitat) and through increased predation pressures on native species (Enge et al., 2004).

In contrast to the assessment of Hardin (2007), Falcón et al 2013 have indicated that *I. iguana* are invasive in Florida and are considered a nuisance, considering their appetite for garden plants of the native and non-native variety (Falcón et al., 2013). *I. iguana* is present in Hawaii and other Pacific islands and will likely continue to spread, if effective control methods are not implemented (Falcón et al., 2013). They are feeding generalists and capable of severely reducing native plant populations and facilitate seed dispersal of invasive plants (Falcón et al., 2013). Although pet *I. iguana* may carry Salmonella, wild invasive individuals are unlikely to harm humans, but the same cannot be said for the local reptiles, which may contract diseases and parasites (Falcón et al., 2013). In terms of economic costs, other than consuming commercially important plants, *I. iguana* burrows create erosion damage to roads in both Florida and Puerto Rico with estimated repairs costing US $2,480/ha (Falcón et al., 2013).

The curlytail lizard (*Leiocephalus carinatus armouri*, Fig. 6), an endemic to the islands of Little Bahama Bank, has been established in Florida's southeastern coast since the 1940s, when 20 pairs were released on Palm Beach (Meshaka et al., 2005). It is now also established on sites in Florida's southwestern coast (Meshaka et al., 2005). *L. c. armouri* prefers sunny, rocky conditions that are abundant in developed areas along Florida's coastline (Meshaka et al., 2005). Where *L. c. armouri* populations are close to those of brown anoles (*Anolis sagrei*, Fig. 7), the latter have declined (Meshaka et al., 2005). Since *Anolis sagrei* is also non-native in the U.S., predation by *L. c. armouri* has acted as an unintended biological control. However, native lizards are also at risk of displacement where *L. c. armouri* is established. Those at risk include the green anole (*A. carolinensis*), six-lined racerunner (*Cnemidophorus sexlineat sexlineatus*), southeastern five-lined skink (*Eumeces inexpectatus*) and the Florida scrub lizard (*Sceloporus woodi*) (Meshaka et al., 2005).

The introduced brown anole (*A. sagrei*), a native of Cuba and the Bahamas, also may be responsible for the displacement of native green anoles (*A. carolinensis*) (Gerber, 1991; Echternacht, 1999; Campbell, 2000). The species was first observed in the Florida Keys in 1887, but did not arrive in mainland Florida until the 1940s (Garman, 1887; Oliver, 1950; Bell 1953). *A. sagrei* are now established and expanding in Florida, preferring urbanised areas, including along highways, campgrounds and hotels (Campbell 1996). The populations have spread via cars and potted plants to Georgia, Louisiana and Texas (Campbell 1996). Adult *A. sagrei* prey on smaller *A. carolinensis*, as well as displacing them from their native habitat (Gerber, 1991; Echternacht, 1999; Campbell, 2000). *A. sagrei* was first noticed in urban areas in Hawaii in the 1980's (Goldberg et al., 2002). Given the successful invasion of the southeastern U.S., it is possible that *A. sagrei* may negatively impact Hawaii's native, low-elevation insect fauna (Goldberg et al., 2002).

Unlike *A. sagrei*, where populations are on the rise, the invasive Mediterranean house gecko, *Hemidactylus turcicus* (Fig. 8) populations are apparently declining in Florida. Native to the Mediterranean area and the Canary Islands, *H. turcicus* has, until recently, enjoyed colonization success in Florida, Louisiana and elsewhere in the southeastern United States (Conant and Collins, 1991; Meshaka et al., 2006). *H. turcicus* prefers urban areas, which can potentially be predator-free (Meshaka et al., 2006). However, recently, *H. turcicus* has been replaced by introduced competitively superior geckoes - the tropical house gecko (*H. mabouia*) and Indo-Pacific gecko (*H. garnotii*) - in Texas and Florida (Meshaka et al., 2006; Non-natives - Mediterranean Gecko, n.d.). The newly established geckos have the advantage of continuous reproduction against the more limiting seasonal reproductive cycle of *H. turcicus* (Non-natives - Mediterranean Gecko, n.d.).

Figure 9. The Cuban treefrog (*O. septentrionalis*) was introduced into Florida in 1951 and has since been introduced to Hawaii, Georgia and Puerto Rico (Salinas, 2006; Glorioso et al., 2012). In Florida, *O. septentrionalis* preys on invertebrates (beetles, spiders, orthopterans, ants, roaches, and caterpillars), small vertebrates and less often, native frogs (Glorioso et al., 2012). Photo Credit: Thomas Brown/Wikimedia Commons.

Frogs

The Cuban treefrog, *Osteopilus septentrionalis* (Fig. 9), is a native of Cuba, the Bahamas and the Cayman Islands and since 1951 has been an established invasive species in Florida (Glorioso et al., 2012). In Florida, *O. septentrionalis* preys on invertebrates (beetles, spiders, orthopterans, ants, roaches, and caterpillars), small vertebrates and less often, native frogs (Glorioso et al., 2012). Yet, where *O. septentrionalis* is present, native treefrog populations have been reduced. This is likely due to competition for food and potential *O. septentrionalis* predation on native treefrogs during different stages of the lifecycle rather than predation on adults (Glorioso et al., 2012). Female *O. septentrionalis* are not highly selective with their mates and are able to reproduce rapidly and spread easily as an invasive (Salinas, 2006). Because of this and other factors, *O. septentrionalis* has successfully invaded Hawaii, Georgia and Puerto Rico (Salinas, 2006).

In a very different region of the United States, a similar threat to native northern leopard frogs, *Lithobates pipiens,* is transpiring. The once widespread *L. pipiens* (formerly *Rana pipiens*) has declined significantly in the U.S. due to habitat destruction, climatic changes, chytrid fungus, and invasive species, for instance *L. catesbeianus* (Johnson et al., 2011). Although *L. catesbeianus* are not solely responsible for the reduction of *L. pipiens* - both species co-exist in the native northeastern U.S. range of *L. catesbeianus*, competition with and predation on *L. pipiens* occurs in the western U.S. (Johnson et al., 2011). *L. catesbeianus* requires wetlands for successful reproduction and thus *L. pipiens* fare better where wetlands are not a permanent ecological fixture (Johnson et al., 2011). Where *L. catesbeianus* are rare or absent, such as in the wetlands in northwestern Colorado, *L. pipiens* are believed to be present (Johnson et al., 2011).

Research has indicated that native red-legged frogs (*Rana aurora*), when placed in clumped-resource ponds with *L. catesbeianus* were smaller, took longer to reach metamorphosis, had lower tadpole survivorship, and lower numbers of adult frogs than those who were not placed with *L. catesbeianus* (Kiesecker et al., 2001). However, *R. aurora* that were in scattered-resource ponds with *L. catesbeianus* were less impacted by their presence (Kiesecker et al., 2001). Knowing that *R. aurora* could survive alongside *L. catesbeianus* in the latter conditions will help wildlife managers better focus their management efforts on those areas where co-habitation is not possible.

Red-eared slider turtle

The red-eared slider (*T. s. elegans*), a popular pet species, which is native to the Mississippi River drainages, and has been introduced to many parts of the U.S. and through competition threatens several native turtle species (Thomson et al., 2010; Krysko et al., 2011). One of the locations where red-eared sliders are present is the Sacramento River, the largest river drainage in California, which also supports significant populations of the native western pond turtle (*Emys marmorata*), a species of special concern in California (Thomson et al., 2010). The western pond turtle has declined significantly in many parts of its range, mainly due to habitat loss, but its population remains stable in the Sacramento River, which is why it is so important to conserve these strongholds (Thomson et al., 2010). Although *T. s. elegans* may be able to spread throughout the Sacramento River, its current concentration is near urban areas and is rare near large populations of *E. marmorata* (Thomson et al., 2010). Currently, *T. s. elegans* does not compete with *E. marmorata* for food, but that is not to say that they will not in the future (Thomson et al., 2010). The bigger concern is the potential for *T. s. elegans* to transfer disease, which could spread throughout the Sacramento drainage and render *E. marmorata* and other species at risk (Thomson et al., 2010).

Herpetofauna parasites

In addition to potentially carrying pathogens that spread disease, the exotic pet trade has opened channels for transfer of parasites, including ticks, hemogregarines and ascarid nematodes, to native U.S. reptiles (Reed, 2005). In Florida, exotic ticks, which were transported on imported tortoises, snakes, and monitor lizards, have been identified at 29 of 32 reptile premises in 18 counties (Burridge et al., 2000). Of the 4 Amblyomma tick species identified, *A. marmoreum* and *A. sparsum* are vectors of heartwater, a lethal disease of domestic and wild ruminants such as cattle, sheep, goats, and deer (Burridge et al., 2000). Once exotic ticks are introduced, research suggests that they can easily spread around Florida, with *A. marmoreum* feeding on a host reptile for up to 111 days (Burridge et al., 2000). In that time, ticks are unknowingly transferred between importers, breeders, wildlife parks and zoos, pet stores, private owners and perhaps the wild (Burridge et al., 2000). Yet, it is not clear if they are spreading to native species (Burridge et al., 2000). The pet trade may also be responsible for facilitating the spread of the deadly chytrid fungi beyond borders and accelerating the decline of amphibians globally (Reed, 2005).

Current Management Practices of Invasive Herpetofauna

Prevention through education and prohibition

It may be self evident, but prevention is the best control tool for managing invasive herpetofauna (Davis, 2012). In order to prevent future introductions of invasive species, money is best spent on educating the public and cargo inspectors (Pimentel et al., 2005). The Florida Fish and Wildlife Conservation Commission's, similar to other states in the U.S., operates a policy of education of pet owners and prevention of releases rather than prohibition, which would impact the pet industry (Hardin, 2007). Of course, prevention does not resolve the issue of already established populations of invasive species, which is why a combined effort is necessary for realistic and successful eradication or, at least, control of invasive reptiles and amphibians.

In the 1970s, regulations for captive and non-native wildlife were established in U.S., which included "risk-based bio-security for problematic species" and "prohibition of a limited number of species that posed unacceptable risks to the ecosystem, economy, or human health and safety" (Hardin, 2007). Of course, economic interests are always at play with regard to government regulations and hence, species that clearly pose risks, are still allowed to be imported. That being said, more recent measures have been enacted to help mitigate problems associated with imported reptiles. In 2008, owners of certain large reptile species were required to implant passive integrated transponders to identify individual animals, should they escape and a "pet surrender network" is currently being developed (Hardin, 2007).

Baiting, trapping and shooting

Once established, control efforts for locating and eradicating alien herpetofauna are much more complex and expensive than prevention measures. The Burmese python is a prime example. Surprisingly, given their size, *P. bivittatus* are hard to locate, due to effective camouflage and the marshy, difficult-to-navigate habitat of the Everglades where they are found (Engeman et al., 2011). One solution is bait placement laced with Acetaminophen, the main ingredient in Tylenol® a toxin to *P. bivittatus* (Engeman et al., 2011). This method is used in Guam to control *B. irregularis* (Engeman et al., 2011). Additionally, researchers are testing the effectiveness and potential use of trap-drift fence and multi-capture traps (Engeman et al., 2011). In 2013, a public "Burmese Python Challenge" took place in Florida. "Nearly 1,600 people from 38 states - most of them inexperienced hunters" and not particularly well-trained in identifying Burmese pythons from native snakes, were set loose into the wilds of the Everglades (Dell'Amore and Andries, 2013). Scientists claimed the hunt was a success, resulting in the killing of 68 pythons, but there is concern about whether using the public in this way, especially employing inexperienced hunters, is the wisest or most humane course of action for python eradication (Dell'Amore and Andries, 2013). Due to the "sociological impact," there are now greater restrictions on possessing this and other large reptile species (Hardin, 2007). Ecologists are attempting to understand the impacts of *P. bivittatus* and it is currently unclear how far-reaching their presence will be on native species. For example, an isolated population of Boa constrictor, confined to a "habitat island" in Miami has existed since the 1970s with no expansion or other impacts (Hardin, 2007).

Florida also uses trapping and shooting of *I. iguana* for controlling the spread of this well-established species including allowing members of the public to humanely kill *I. iguana* (Falcón et al., 2013). Similar to other invasive species, complete eradication is unlikely, if even possible, which is why prevention of new releases is crucial (Engeman et al., 2011). However, intense control methods should be attempted in localized contexts such as on islands, where the effects of invasive species can be far more detrimental (Engeman et al., 2011). Eradication strategies for *I. iguana* could involve locating males during the mating season, luring nesting females with artificial nests, destroying nests and eggs, educating pet owners about negative effects of release, and granting amnesty for turning *I. iguana* in where they are illegal to keep (Falcón et al., 2013). Additionally, using dogs to find nests may prove useful, since there has been some success with this method in locating both *B. irregularis* and *I. iguana* in their native range (Falcón et al., 2013).

When it comes to management practices not all species are treated with such urgency as *P. bivittatus* or *I. iguana* in terms of public concern or finances assigned for their control. Although bullfrogs (*L. catesbeianus*) are listed by the IUCN to be among the 100 worst invaders in the world, which accounts for their negative impact on the conservation of native species, bullfrogs do not receive the attention and resources necessary for proper control methods (Lowe et al., 2000; Adams & Pearl, 2007). This is most likely due to their lack of economic impact and the difficulty faced by management agencies in controlling them (Adams & Pearl, 2007). The abundance of *L. catesbeianus* is positively related to winter and summer precipitation and wetland habitat, which is required for breeding (Ficetola et al., 2007). Therefore, preventative control methods should focus on high-risk areas with the most suitable habitat in terms of precipitation and permanent wetlands (Ficetola et al., 2007). Although *L. catesbeianus* can coexist with native amphibians, albeit with minor negative effects, it still may be advisable to eradicate *L. catesbeianus* when present in isolated ponds that are home to endangered indigenous species in order to prevent further stress on an already vulnerable population (Adams & Pearl, 2007).

Combined prevention and elimination efforts with habitat restoration

Unlike *L. catesbeianus* control of the elusive and highly invasive *B. irregularis* is a high priority for wildlife managers. If a *B. irregularis* can fit its head through a hole in a cargo ship leaving Guam, it puts any Pacific island port that Guam trades with at risk (Rodda and Savidge, 2007). Those islands whose species have not co-evolved with snakes, will be even more at risk of negative impacts from introduction of *B. irregularis* (Rodda and Savidge, 2007). In order to prevent their spread to other islands, including Hawaii, wildlife managers have had success with control measures, such as visual searches, dog searches, and snake traps in Guam airports and seaports (Rodda and Savidge, 2007). Although complete eradication has not been possible on the island, acetaminophen, a toxin to *B. irregularis,* can be used in aerial broadcast and bait stations, along with snake traps and snake barriers, to control the population (Rodda and Savidge, 2007). In terms of protecting native wildlife, fortunately, Cocos Island, 25 small islets, buoys, and rocks off Guam provide areas that are free of *B. irregularis* and hence of *B. irregularis* predation (Wiles et al., 2003). Continued planting of important roosting and nesting trees and shrubs and continuing nest box programs will not eradicate the snake problem, but will at least help local birds continue to reproduce (Wiles et al., 2003).

Biological Control

Since many invasive species, for instance *B. irregularis,* are present in new ecosystems without natural enemies - predators, parasites, pathogens and competitors - they are often able to reproduce and spread more easily in these new environments (Messing and Wright, 2006). Biological control, the introduction of an invasive species' natural enemy into their new range, has been used to try to control pest invasives, but sometimes with severely negative effects, such as introducing more invasive species (Messing and Wright, 2006). Although this is a management tool for controlling current invasives, given the history and high risks associated with biological control methods, this should be viewed as a last resort.

Risk maps

Risk-averse management tools include risk maps, which can assist conservationists in locating potential invasive species hotspots and hopefully aid in prevention of potentially negative exotic species establishment (Hulme, 2009). Risk maps should account for climatic and habitat suitability, entry points, expansion limitations, and ability to reproduce in the new ecosystem (Hulme, 2009). Once exotic species managers know where to look for future or current populations, they are then able to incorporate inspection and prevention measures such as fumigation of commodities, exclusion zones and dispersal barriers (Hulme, 2009). According to Rodda et al., *Python molurusa*, a similar species to Burmese pythons, may be able to expand their population into southern and southwestern states, considering their native range extends into similar temperate climate zones (Rodda et al., 2009). However, they go on to say, that since their limiting ecological factor has not been identified in their native distribution, "it is not yet possible to determine the equivalent North American boundaries" (Rodda et al., 2009). Although *P. bivittatus* have been reported in several locations in the U.S., the only known breeding populations are in Everglades National Park and Big Cypress National Preserve (Pyron et al., 2008). According to ecological niche models, the Everglades National Park is primary habitat, given its similarity to native ecosystem of *P. bivittatus* (Pyron et al., 2008). Since the tropical marshland is limited to southern Florida, *P. bivittatus* is unlikely to leave, even if climatically, other regions in the U.S. are suitable (Pyron et al., 2008). Models based on climate change actually show a reduction both in available suitable habitat for *P. bivittatus* in the U.S. and natural range (Pyron et al., 2008). Although *P. bivittatus* can survive in cooler climates than found in southern Florida, research shows that individuals from the established Florida population had thermoregulatory issues and were incapable of surviving winters in temperate states such as South Carolina (Dorcas et al., 2011). It is important to note that individuals of *P. bivittatus* originating from more temperate areas may be better suited to withstanding winters in areas such as South Carolina, unlike those from tropical origins (Dorcas et al., 2011). If possible, genetic variation and species' origins should be taken into consideration for management and prevention of Burmese python potential expansion in the U.S.

Importance of successful management

Successful management of invasive species is critical in safeguarding ecosystems, their native species and local economies. According to Richardson and Ricciardi's paper, decades of research implicate invasive species as contributing to native species extinctions and local ecosystem disruptions (Richardson and Ricciardi, 2013). However, it is important not to generalize, since while some invasive species have been directly linked to extinctions, such as the effects of *B. irregularis* on endemic species extinctions in Guam, not all invasive species are linked to extinction events (Gurevitch and Padilla, 2004). However, when extinctions do occur, they may not show the full story of an ecosystem's ability to function, which is why it is important for conservationists to assess the effects of invasive species on indigenous species populations to better manage the issues (Richardson and Ricciardi, 2013).

It is also important to note the distinction between invasive predatory species vs. invasive competitor species, since predators often have a greater negative effect than a competitor (Gurevitch and Padilla, 2004). Additionally, although alien species may alter their new ecosystem, it may be more important to try to incorporate them into management plans, rather than waste resources trying to eradicate them, which is often a futile task (Davis, 2011). The function of a species within a community, whether it is beneficial or harmful, should be the focus of conservationists and land managers, not whether they are native or alien (Davis, 2011). However, it is important to remember the "evolutionary context in species interactions," thus, "the more 'alien' …the greater the likelihood it will be ecologically disruptive" (Richardson and Ricciardi, 2013).

Control Method Ethics

Alien reptiles and amphibians have been entering the U.S. over the past century at unprecedented rates and their import, whether intentional or not, is very unlikely to cease in the foreseeable future. Although the majority of exotic herpetofauna entering the States do not escape or establish wild populations, some of those that have, have had serious negative impacts on native species, meriting further research and substantial funding for their management. Although prevention is the most ideal and cost-effective strategy for dealing with invasive herpetofauna, eradication or strict control over current established populations is vital. In addition to finding, testing and utilizing viable management methods, consideration must also be given to the ethics of these methods- especially eradication. Not only are some of the invasive reptiles and amphibians found here in the States vulnerable in their native ranges and merit conservation consideration, but they are also sentient beings that should be treated humanely with regard to termination control methods.

It is also important to ask, "Are invasive species the drivers or passengers of change in degraded ecosystems?" the question A.S. MacDougall and R. Turkington asked in their 2005 paper. Most ecosystems; in which invasive species thrive; are degraded in some way, which may indicate that invasive species are not leading the negative changes, but contributing to or taking advantage of an already anthropogenically created negative situation (MacDougall and Turkington, 2005). Understanding this can help wildlife managers make better decisions with regard to control and ecosystem restoration.

Conservationists, wildlife managers and the public also should remember that exotic species are neither good nor bad in their own right, and defining them as such can be misleading (Slobodkin, 2001; Davis, 2012). A pristine, stable and diverse ecosystem and its native inhabitants are often considered "good" while a degraded and diversity-poor ecosystem is viewed as "bad" (Slobodkin, 2001). Invasive species often fall into the "bad" category, even though, and ironically so, they are often more successful at surviving than "good" species (Slobodkin, 2001). Despite their often harmful effects, invasive herpetofauna deserve humane treatment with regard to their management. Thus, it is important to identify species that are harmful, since once harm is claimed, society expects that harm to be mitigated or expelled (Davis, 2012). Additionally, species diversity is intrinsically valuable and should be preserved, but to do so, should not require demonizing other species. Doing so may lead to inhumane management and mismanagement of invasives.

Today, the European wall lizard may number in the hundreds of thousands in Ohio, but according to W. Gibbons' paper, the non-native lizards "are beloved creatures" (Gibbons, 2014). Large reptiles such as *P. bivittatus* do not have such a loving following amongst the public, which is likely why the "Burmese Python Challenge" hunt in 2013 had such a strong public turnout. Public attitudes clearly may play a role in management of invasive species. However, wildlife managers should be careful not to focus only on sensational species or public nuisance species, which can potentially lead to ignoring more ecologically damaging invasives.

Further research is required to explore all possibilities of management methods, which allow invasive species to coexist with native species. These practices may focus more on promoting the constancy of native species rather than fighting against invasive species, which may be implausible to eradicate completely, given resources available and the extent of their range. Additionally, research, combined with ethics must inform action in order to successfully and humanely manage the exotic reptiles and amphibians in the U.S. Although managing alien species is complicated by each individual species ecological adaptations, hopefully, understanding the pathways and successful and ethical management of one species can lead to more successful prevention and management of other similar alien species.

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Towards evidence-based husbandry for caecilian amphibians: Substrate preference in *Geotrypetes seraphini* (Amphibia: Gymnophiona: Dermophiidae)

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ABSTRACT - Maintaining caecilians in captivity provides opportunities to study life-history, behaviour and reproductive biology and to investigate and to develop treatment protocols for amphibian chytridiomycosis. Few species of caecilians are maintained in captivity and little has been published on their husbandry. We present data on substrate preference in a group of eight Central African *Geotrypetes seraphini* (Duméril, 1859). Two substrates were trialled; coir and Megazorb (a waste product from the paper making industry). *G. seraphini* showed a strong preference for the Megazorb. We anticipate this finding will improve the captive management of this and perhaps also other species of fossorial caecilians, and stimulate evidence-based husbandry practices.

INTRODUCTION

The paucity of information on caecilian ecology and general neglect of their conservation needs should be of concern in light of global amphibian declines (Alford & Richards 1999; Stuart et al., 2004; Gower & Wilkinson, 2005). Conservation breeding programmes are becoming more important for the long-term survival of many amphibian species (Gascon, 2007; Griffiths & Pavajeau, 2008). The requirements of captive amphibians are complex (Antwis et al., 2014; Antwis & Browne, 2009; Ogilvy et al., 2012; Verschooren et al., 2011) and further research is needed to ensure that this lack of knowledge does not undermine future conservation breeding initiatives. Maintaining caecilians in captivity provides opportunities to investigate behaviour and reproductive biology (Kouete et al., 2012; Wilkinson et al., 2013), to develop treatment protocols for amphibian chytridiomycosis (Wake, 1994; O' Reilly, 1996) and to establish husbandry requirements.

Whenever possible, husbandry should be informed by field data (Tapley & Acosta, 2010; Michaels & Preziosi, 2013) but these are often unavailable, especially for understudied taxa such as caecilians. Folklore husbandry, i.e. methods or supposed best practices established without evaluation and often justified for unknown reasons (Arbuckle, 2009), is obviously less desirable than integrating existing ecological and biological information into evidence-based husbandry plans that attempt to mimic good conditions in nature (Arbuckle, 2013). It should be noted that the natural conditions in which animals are encountered in the wild may not always be optimal.

Few species of caecilians are maintained in captivity (Gower & Wilkinson, 2005) and little has been published on the captive husbandry of terrestrial caecilians (Wake, 1994; O' Reilly, 1996). A basic parameter in terrestrial caecilian husbandry is substrate, but data on tolerances and preferences in the wild or in captivity are mostly lacking. Terrestrial caecilians are reported from a wide range of soil pH (Gundappa et al., 1981; Wake, 1994; Kupfer et al., 2005). In the laboratory, burrowing capabilities of four species of terrestrial caecilians were limited by soil compaction, and they showed preferences for burrowing in the least compacted soil available and for utilising existing, rather than constructing new burrows (Ducey et al., 1993). More data are required on the habitats that are preferred or tolerated by caecilians and it is likely that substrate preference will differ between caecilian species.

Geotrypetes seraphini is a widely distributed caecilian, found from Guinea to Angola (Scholz et al., 2010). It is likely to be surface active on occasion given that it has been collected in pitfall traps (Wollenberg & Measey, 2009) and appears to be fairly regularly collected from the wild for the pet trade (Gower & Wilkinson, 2005). It is maintained by several zoological collections including Zoological Society of London, London Zoo. In December 2013, two *G. seraphini* at ZSL London Zoo were observed with inflammation around the vent and a marked swelling in the last 2 cm of the body that palpation indicated was due to a solid mass in both individuals. Specimens were anesthetised in an aqueous solution of tricaine methanesulfonate (MS-222) for further examination. In both cases, compacted coir substrate formed a solid mass at the end of the gastrointestinal tract, one specimen died during the procedure and the second died the day after. Post mortem examination did not determine whether or not there was an issue in the function of the hindgut or cloaca resulting in the mass of substrate, or whether the substrate was the primary cause of the compaction. There were no other remarkable pathological findings. Coir had been used as a substrate for this species for several years at ZSL London Zoo without problem, but it was decided to investigate an alternative substrate. Here we present experimental evidence for a clear substrate preference in captive *G. seraphini*.

METHODS

Historic and current husbandry

Geotrypetes seraphini have been in the herpetology living collection at ZSL London Zoo for five years and have bred on two occasions. Initially, animals were maintained in groups in various sized plastic boxes containing moist coir at ambient room temperatures (18-28˚C) in an off-show area and fed *ad libitum* on annelid worms (*Lumbricus terrestris* and *Dendrobanea* species) three times per week supplemented irregularly with 3rd instar live and dead crickets (*Gryllus bimaculatus* and *G. assimilis*) and bloodworm (*Chironomus* species) in shallow water-filled dishes.

In March 2013 a dedicated caecilian breeding facility was initiated at ZSL London Zoo as part of a collaborative project with The Natural History Museum's Herpetology Research Group aimed at developing methods for caecilian husbandry and revealing life-history and behaviour. The facility currently comprises two climatically-controlled rooms and houses seven species of caecilian.

Substrate type

Megazorb (Northern Crop Driers (UK) Ltd.) was selected as a potential substrate for *G. seraphini* after communications with other keepers of fossorial caecilians who used a similar product, Carefresh® (product of U.S.A./Absorption Corp in WA, www.absroptioncorp.com) because of its availability, ease of maintenance and because it is sterile and meets laboratory standards (Danté Fenolio & Dennis Parmley, pers. comm). Although Carefresh® was available in the UK, the manufacturers were unable to confirm that the product was unbleached and therefore potentially harmful to caecilians. Megazorb is a waste product of the paper industry that contains unbleached wood-derived cellulosic fibre and inorganic pigment (kaolin and calcium carbonate).

Choice chamber experiment

On the 2nd January 2014, eight *G. seraphini* (wild-caught from Cameroon) were weighed and moved into eight individual choice chambers (Fig. 1) constructed using 360 mm x 200 mm x 200 mm faunariums (Exoterra, Rolf C. Hagen (UK) Ltd., Castleford, UK). A solid 150 mm acrylic sheet secured with aquatic grade silicone, incompletely divided each enclosure equally such that caecilians could only move between substrates by moving over the surface. Humid coir or moist Megazorb (washed in tap water) were added on different sides of the choice chamber to a depth of 150 mm after squeezing out excess moisture (Fig. 1). Neither substrate was sterilised but all handling of substrate and caecilians was while wearing powder free nitrile gloves.

Ambient temperature ranged between 20-27˚C (night minimum/day maximum) following discussions with Marcel Tala Kouete, a researcher who has worked in the field with *G seraphini*. Photoperiod was 10L:14D for the duration of the study.

At the start of the trial all individuals were weighed and four individuals were placed in the coir and four in the Megazorb. An identical ninth choice chamber included only a humidity and temperature data logger (Lascar (UK) EL-USB-2-LCD) in each of the substrate types, recording every five minutes for the duration of the study. Choice chambers were rotated every three days by 180˚ to control for potential positional effects (e.g. due to different lighting). Caecilians were fed three times a week with two live *Dendrobanea* worms or two pre-killed *G. assimilis* placed in each side of the choice chamber at each feeding event. If the substrate started to dry out visibly, aged tap water was added and the top 2 cm of the soil was turned by hand. The pH of each of the substrates was recorded using a K181 pH Soil Testing Kit (Bosmere © UK).

The position of each caecilian was recorded once every day between 09:00 and 16:00 hrs by gently lifting the choice chamber. Location could be established mostly without disturbing animals because parts could usually be seen through the clear base and/or sides of the chamber. Otherwise the position of each caecilian had to be established by sifting through the substrate in the choice chamber by hand. A control was not deemed appropriate in this study because health issues had been observed in animals that had been provided coir as a substrate. Because Megazorb had not previously been used as a substrate for caecilians it was not considered appropriate to house them on this substrate alone. The experiment ended after 39 days, on the ninth of February 2014, the *G. seraphini* were weighed and two separate groups transferred to enclosures with a Megazorb substrate.

Figure 1. Choice chambers used to assess substrate preference in *G. seraphini,* with Megazorb to the front of each chamber and coir to the rear.

RESULTS

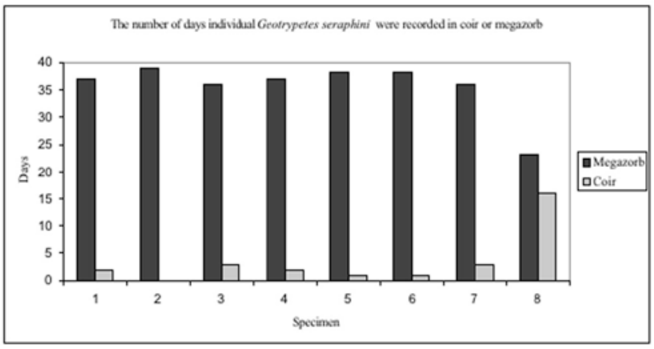

Figure 2. The number of daily records for each caecilian in each substrate type.

Specimen	Mass (g) 02.01.14	Mass (g) 09.02.14
1	10.3	11.7
2	8.5	8.1
3	14.2	14.2
4	16.2	19.2
5	16.5	20.2
6	21.6	23.9
7	10.6	10.4
8	9.6	10.2

Table 1. Body masses of each caecilian at the beginning and the end of the choice chamber trials.

Substrate	Mean temperature (C)	Mean humidity (%rh)	pH
Coir	22.7 (+/- 1.5)	98.8 (+/- 2.8)	7.5
Megazorb	22.8 (+/- 1.4)	100.3(+/-3.8)	7.5

Table 2. Temperature, humidity and pH of each of the substrate types.

All individuals were recorded much more frequently (91% of the 312 daily observations) in the Megazorb (Fig. 2). Burrows were seen in both types of substrate in all individual choice chambers, even for individual 2, which was never observed in the coir during the daily inspections. Caecilians were generally secretive and never observed feeding. Five out of eight individuals became heavier, the mass of one individual did not change and two individuals lost weight over the 39 day period (Table 1). Temperature, humidity and pH were very similar in both substrates (Table 2).

DISCUSSION

We made no observations at night when *G. seraphini* is expected to be most active, but our results indicate a clear preference for Megazorb over coir as a diurnal resting site in our captive *G. seraphini* (Fig 2). Temperature, humidity and pH were similar in both portions of the chamber and do not explain the preference between the two substrates (Table 2) although substrate humidity could not be completely standardised in this study because the different substrates appeared to dry out at different rates (the surface layer of coir seemed to dry out more rapidly than Megazorb). Rotating the choice chambers had no impact on the temperature or the humidity recorded by the data loggers. Burrows appeared to be more clearly defined in the Megazorb and were perhaps more stable in this substrate due to the larger particle size than the coir, and substrate preference might be explained by caecilians selecting substrates in which they did not have to frequently construct new burrows, which is energetically costly (Ducey et al., 1993). Coir is somewhat powdery and *G. seraphini* in this substrate often had small coir particles attached to their skin (BT, pers. obs.).

We compared only two substrates for one species. Other substrates should be evaluated and substrate preference might vary with the species in question. Neither of the tested substrates are natural for *G. seraphini* which, in Cameroon have been collected by digging in (mostly wet) soil, sometimes under logs and occasionally under leaf litter (MW & DJG, pers. obs). Further research evaluating substrate preference choice incorporating leaf litter and other refugia would be beneficial. Some caecilians may be epigeic at least some of the time (Gower et al., 2004) and refugia may be as important as substrate type for these taxa. This study demonstrates that improved (and evidence-based) husbandry for caecilians can be progressed through simple experiments. It is hoped that this study will encourage similar research for other caecilian species.

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Habitat use and activity with new records of the agile snouted tree frog (*Scinax agilis*) on the north coast of Bahia, Brazil.

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ABSTRACT - The agile snouted tree frog *Scinax agilis* (Anura, Hylidae) is one of the *restinga* frog species, with reported distribution in the Espírito Santo, Alagoas, Sergipe and Bahia states, especially in sand dune habitats, known locally as restinga. On the north coast of Bahia, north-eastern Brazil, it is known, according to literature, only from the cities Camaçari and Mata de Sao Joao. In this study we fill the geographic distribution gap in the region including presence in six new localities and cities. We also report findings on diurnal and nocturnal activity patterns and the use of microhabitats at the different vegetation type habitats. We found *S. agilis* in dry forest, scrub and beach vegetation and also at the temporary or permanently flooded river plains. Most records (52.2 %) were on river plains during daytime surveys mainly from 1200 to 1800 hours. Bromeliads were the most frequently used microhabitat (45.4%) followed by aquatic plants. The agile snouted tree frog association with flooded river plains and associated plant communities reinforces the urgent need for conservation measures to preserve the *restinga* remnants in the region.

INTRODUCTION

The agile snouted tree frogs are typically small sand dune habitat frogs. Snouted tree frogs of the Genus *Scinax* is formed of 111 species, distributed through Mexico, South America and the Caribbean (Duellman & Wiens, 1992; Frost, 2013). In Brazil 90 *Scinax* species are known, and they occur at all the country's eco-regions (Segalla et al., 2012). The agile snouted tree frog (*Scinax agilis* Cruz & Peixoto, 1983) is included in the *Scinax catharinae* (Faivovich et al., 2005) group and its type locality is Ibiriba (19° 14' S; 39° 55' W) at the city of Linhares, on the south-eastern state of Espírito Santo. Its distribution was recently expanded to the states of Bahia (Peixoto, 2003), Alagoas (Toledo, 2005) and Sergipe (Passos et al., 2012), but remains with major distributional gaps.

The agile snouted tree frog (Fig. 1) is typically found on the coastal sand dune ecosystem, locally known as "restinga". It is found either at open areas as well as inside forests and dense scrub, and usually on bromeliads (Cruz & Peixoto, 1983; Toledo, 2005; Juncá, 2006). The species is listed as Least Concern at the IUCN Red List assessment, mainly as a result of its distribution extension. This assumes there is a large population, however its main ecosystem and associated habitats are under severe threats, via deforestation (Peixoto & Pimenta, 2004), which may cause some concern. At this study we present new distribution localities and cities at one of the most representative *restinga* system along the species distribution, and also look at the habitat use and activity of a few subpopulations on the north coast of the state of Bahia, Brazil.

Figure 1: Adult agile snouted tree frog (*Scinax agilis*) from Busca Vida, city of Camaçari. Adults averaged SVL = 130 mm

MATERIALS AND METHODS

The study took place from June 2010 until August 2013. We sampled the intended sites every two months on a regular basis. Six localities on the north coast of Bahia were sampled: Busca Vida (-12.863831, -38.262675) a locality in the city of Camaçari; Imbassaí (-12.483250, -37.958667) in the city of Mata de São João; Massarandupió (-12.315722, -37.832139), in the city of Entre Rios; Baixio (-12.105083, -37.697639), in the city Esplanada; Barra de Itariri (-11.950278, -37.611917), in the city Conde; and Costa Azul (-11.664167, -37.483611) in the city Jandaíra (Fig. 2); the entire coast line encompasses an extension of about 220 km.

At each of these sample units, four vegetation type habitats were thoroughly surveyed: beach vegetation; flooded river plain; scrub vegetation; and sand dune dry forest. The four habitat types were surveyed simultaneously, when surveyors applied a visual search survey at a 500 m belt transect. The survey seasons covered all daylight periods and seasons all along the three years. A day cycle started at 6 am for the first survey and ended at the last, or sixth survey of the same year at 6 pm (six cycles per year). During the third and last year, night surveys were also applied following the same procedures, from 7 pm to 9 pm. The overall survey effort covered 1,728 hours. We sampled specimens for taxonomic confirmation and reference, under the national environmental licensing program authorization MMA-ICMBIO / SISBIO nº 23355-2. Sampled specimens were deposited at the Herpetological Reference Collection at the Centre for Ecology and Conservation of Animals (CHECOA) at the Universidade Católica do Salvador. We also collected distributional data from literature for comparison purposes.

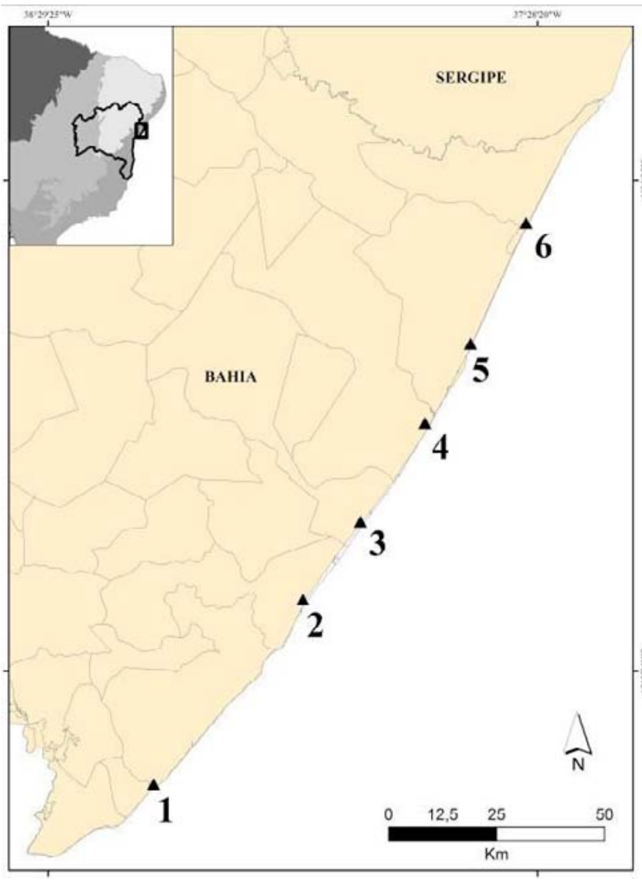

Figure 2: *S. agilis* geographic distribution new records on the north coast of Bahia. 1) Busca Vida; 2) Imbassaí; 3) Massarandupió; 4) Baixio; 5) Barra de Itariri; 6) Costa Azul.

RESULTS

We recorded 1,163 adult *S. agilis* at the six localities (Fig. 2). The animals were found inhabiting the four different habitat types at the restinga ecosystem: temporary and permanently flooded river plains (n=608), dry forest (n=446), scrub vegetation (n=69) and beach vegetation (n=40).

The agile snouted tree frog also used differently the available microhabitats. We detected the frogs on bromeliads (n=529), on macrophyte vegetation (n=300), scrub vegetation (n=128), leaf litter (n=86), suspended branches (n=68), moving in temporary ponds (n=32) and on bare sand soil (n=20). We also recorded cases of communal microhabitat use. We found animals sharing the same bromeliads. Over 15 individuals used the same plant at the locality of Costa Azul and over 17 at the locality of Busca Vida.

Animals were mostly found active during daytime. Over 62 % of the sightings and records were made between 12:00 and 6 pm, and 32% from 6 am to noon. During night surveys only 5.4 % records were observed at the same sites. Although the beach habitat type showed very low frog frequency, most of the sightings occurred at the night surveys, with 72.5 %. The scrub vegetation on the other side had 52.1 % of the records from 2 pm to 6 pm, most then, during the day (Fig. 3).

All six localities represent new records for the species on the north coast of Bahia: Busca Vida, Imbassaí, Massarandupió, Baixio, Barra de Itariri and Costa Azul. Together they include another six municipalities into the species distribution, all of them on the coast, and filling a 212 kilometers distributional gap, from Praia do Forte, Mata de São João, Bahia (Juncá, 2006) to Areia Branca, Sergipe (Passos et al., 2012) (Table 1).

DISCUSSION

The activity patterns of *S. agilis* showed that the species is rather more active during the day. However it is more commonly found at sites where humidity and shade is higher. It was particularly found at the temporary or permanent flooded river plains. The soil humidity and type seems to be the major factors shaping the frogs' communities' structures (Bastazini et al., 2007), which was also observed at the studied localities. Barreto et al. (2012) found a similar result for the marsh frog (*Pseudopaludicola* sp. (*aff. falcipes*)) at the same localities, and they also

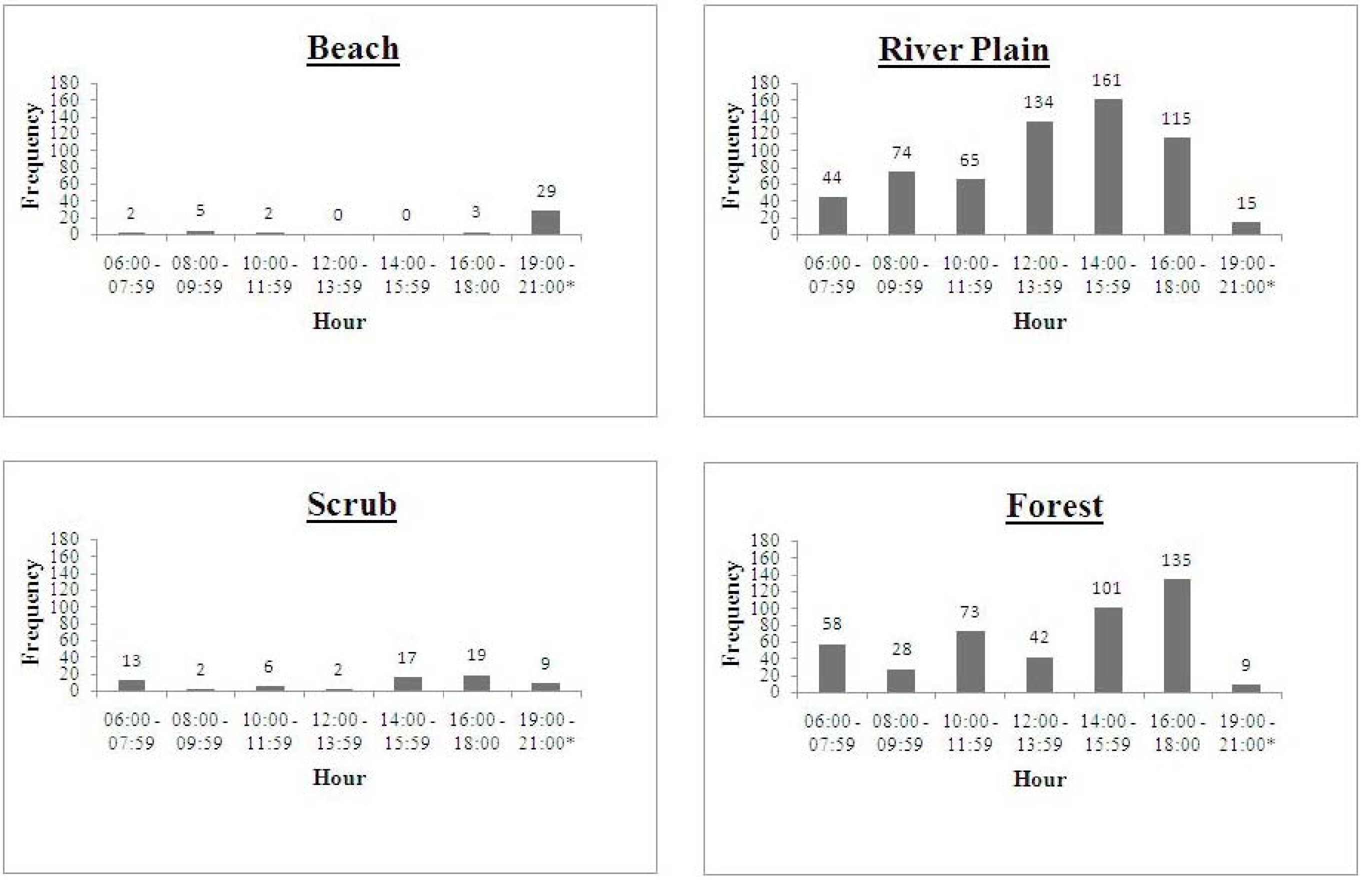

Figure 3: Number of recorded individuals at each time slot during the visual search surveys on the four different vegetation type habitats: beach, river plain, scrub, dry forest.

pointed out the flooded plains as a kind of nursery, where frogs tend to use during the breeding season, suggesting they are fundamental to retain those subpopulations. All of the aforementioned aspects reinforce the importance of maintaining the river plains and other water bodies aiming the *restinga* conservation.

We found that *S. agilisis* a daytime forager, however it will have low levels of night activity in disturbed locations. When we compared the previous year's daytime and night activities we found that the amount of hours were notably higher during the day (n=140) in comparison to night foraging (n=62). It was possible to detect the agile snouted tree frog inhabiting seven different microhabitat types at the sampled *restinga* formations. According to Eterovick et al. (2010), the variety of habitat use by adult frogs may represent their response to several local selective pressures. These would be caused by other species, the environmental structure or even disturbance. Nevertheless the most important and far higher frequented microhabitat for the species were the bromeliads (45.5 %). These plants were mainly represented by the genus *Hohenbergia* spp. They are locally known as tank bromeliad as a result of their architecture promoting the maintenance of large amounts of water, even during dryer periods. These plants were very abundant at the study localities (Cogliatti-Carvalho et al., 2008). Along with scrub, herbaceous and macrophyte vegetation, and also suspended branches above water bodies these vegetation types formed 88.1 % of the entire microhabitats records. This possibly suggests a strong association of the agile snouted tree frog to plant community composition, and not just their abundance. However, bromeliads and macrophytes (especially the elongated ones) are commonly used for shaping gardens at hotels, resorts, golf courts and residential areas at the studied localities. All of these may shed light on understanding the reasons for the maintenance of some of the subpopulation, given the plants are frequently present in gardens, even in urbanized landscapes.

The alarming habitat loss in the region, especially when it comes to *restinga* habitats is a main and worrying threat to any amphibian population (Tinôco et al., 2008). When suppression comes into place, bromeliads, macrophytes and scrub are the main lost vegetation, even on law permanent protected zones and this may seriously affect the agile snouted tree frog on the north coast of Bahia. The new geographic distribution data for *S. agilis* confirms the species are endemic to *restinga* habitats. These new records add important information to its contiguous distribution on the coastal regions of the Brazilian states of Espírito Santo, Bahia, Sergipe e Alagoas. The presumed species endemism and severe habitat threats call attention to the need for conservation action to preserve these populations as well as other restinga restricted species.

LOCALITY	COORDINATES	VOUCHER	SOURCE
Lagoa Sete Pontas, Itapemirim – ES	-21.011111, -40.833889	MBML 4887	Specieslink
Restinga de Setiba, Guarapari – ES	-20.629339, -40.426642		Pombal et al., 2010
Ponta da Fruta, Vila Velha – ES	-20.519156, -40.373542	EI 7124-38	Peixoto & Gomes, 2007
Restinga de Camburí, Vitória – ES	-20.319444, -40.337778	MBML 4903	Specieslink
Reserva Florestal Vale do Rio Doce, Linhares – ES	-19.433889, -39.893311	EI 7155-56	Peixoto & Gomes, 2007
Ibiriba, Linhares – ES *	-19.233333, -39.916667		Cruz & Peixoto, 1983
São Mateus – ES	-18.716111, -39.858889	CFBH 1567	Specieslink
Parque Nacional de Itaúnas, Conceição da Barra – ES	-18.593333, -39.732222	CFBH 1938	Specieslink
Mucuri – BA	-18.081472, -39.926444		Peixoto et al., 2003
Trancoso – BA	-16.615278, -39.092331		Rocha et al., 2003; 2008
Belmonte – BA	-15.991944, -38.971667		Pombal et al., 2010
Arembepe, Camaçari – BA	-12.697500, -38.324167		Nunes et al., 2007
Busca Vida, Camaçari – BA ▲	-12.863831, -38.262675	CHECOA 2606	This work
Praia do Forte, Reserva Sapiranga, Mata de São João, – BA	-12.585278, -38.028333		Juncá, 2006
Praia do Forte, Fazenda Camurugipe, Mata de São João – BA	-12.575000, -38.056389		Juncá, 2006
Imbassaí, Reserva Imbassaí, Mata de São João – BA ▲	-12.483250, -37.958667	CHECOA 2820	This work
Massarandupió, Entre Rios – BA ▲	-12.315722, -37.832139	CHECOA 2510	This work
Baixio, Esplanada – BA ▲	-12.105083, -37.697639	CHECOA 3214	This work
Barra de Itariri, Fazenda Milagres, Conde – BA ▲	-11.950278, -37.611917	CHECOA 2548	This work
Costa Azul, Jandaíra – BA ▲	-11.664167, -37.483611	CHECOA 2937	This work
Areia Branca – SE	-10.977917, -37.048472	ZUEC 17842-44	Passos et al., 2011
Passo do Camarajibe – AL	-9.303889, -35.439444		Toledo, 2005

Table 1: Locality with geographic distribution records for the *S. agilis* in Brazil. * type locality of *S. agilis*. ▲ New records of *S. agilis* for the north coast of Bahia, Brazil.

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Notes on daily activity patterns in *Teius teyou* (Squamata: Teiidae) in the dry Chaco

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ABSTRACT - Previous studies have indicated that *Teius teyou* is more active during the hottest hours of the day. Here we show that in the Paraguayan Chaco *T. teyou* avoids high temperatures in the summer. We observed that *T. teyou* is more active in the morning with temperatures around 30ºC, and less active between 13:00 and 15:00 h when temperatures were in the range 36 to 39ºC.

INTRODUCTION

The whip-tailed lizards *Teius* are a genus of green lizards from South America, characterised by the presence of only four toes (Cei, 1993; Carreira et al., 2005). *Teius teyou* is mainly distributed in the xerophytic environments of Chaco formations in Argentina, Bolivia, and Paraguay (Cei, 1993; Cabrera, 2012) where it actively searches for prey (insects and other arthropods) and fruits (Varela & Bucher, 2002) during daytime (Álvarez et al., 1992; Cappellari et al., 2007). Members of the genus are fast runners with Cei (1993) indicating *T. teyou* can run bipedally and is active in the hottest hours of the day. *T. teyou* is heliothermic employing sun basking to achieve preferred body temperatures. Nevertheless, heliotherms must avoid excessively high body temperatures and in this short note we provide information of basking patterns of *T. teyou* along a roadside edge including during the hottest hours of the day.

METHOD

The observations were made during the summer between 16th and 20th December, 2013 at the Estancia Agropecuaria "Solito" (24.290833°S, 58.837222°W, datum= WGS84), Presidente Hayes Department, Paraguay. Observations were daily between 08:00 and 20:00hrs, at intervals of 1.5 to 2 hours. A total of seven observations were made per day giving a total of n = 35. The monitoring was made along a transect of 1200 m length, where the number of specimens of *T. teyou* (no discrimination was made between males and females or age class) at both sides was recorded (Fig. 1).

The study area was a dirt road that transversed a typical xerophytic Chaco environment, with clay soils, thorny forests (abundance of cactus and bromeliads), and almost no herbaceous understory (see ground view in Fig. 1). Annual precipitations varies from 800 to 1,000 mm and mean annual temperature between 24° and 25° C. Climatic data were (daily and by hour) taken from World Weather Online (www. worldweatheronline.com) based on General Bruguez Meteorological Station (50.9 km from the study area).

Figure 1. Study area showing the 1200 m transect (red line) on a road, along which specimens of *T. teyou* were monitored. Darker green areas belong to dry forest, and light green surfaces represent grasslands. Left upper corner: detail of the ground view showing the vegetation.

RESULTS AND DISCUSSION

We observed the first individuals of *T. teyou* around 08:00. Most lizards (24) were observed between 10:00 and 10:30 (Fig. 2). With increasing temperatures, the activity of *T. teyou* was reduced. The numbers of observed lizards started to rise again in later afternoon but generally activity was lower than in mid-morning (Fig. 2). After sunset a few individuals remained active in the remaining light.

Andrade et al. (2004) found that diurnal activity in the Teiid lizard *Salvator merianae* begins once environmental temperature approach those experienced by lizards in their burrows, which remains warmer than overnight external temperature. More studies are required to establish if this also applies to *T. teyou*. As it can be seen in Fig. 2, activity of *T. teyou* decreased during the hottest hours of the day

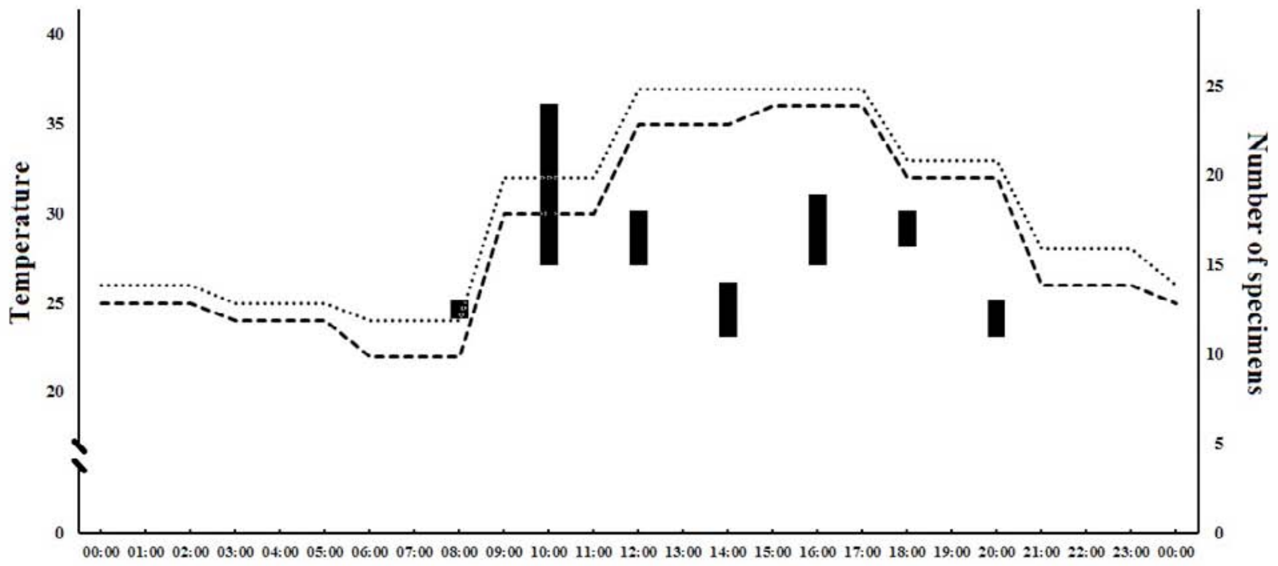

Figure 2. Graph showing activity pattern of *T. teyou* throughout the day (black bars) related to minimum (dashed line) and maximum (dotted line) temperature in ºC.

and once favourable body temperatures were attained they avoided excessive heat by resting in burrows or among vegetation; activity was reduced when the air temperatures were in the range 36-39ºC. This spatiotemporal pattern was also observed in the genus Ameiva (Rivera-Vélez & Lewis, 1994; Blair, 2009) and in some other South American lizards including *Liolaemus occipitalis* (Bujes & Verrastro, 2008). However, in contrast the highest activity in *Ameiva ameiva* in Caatinga was between 1200 and 1500hrs (Sales et al., 2011). In conclusion, *T. teyou* apparently demonstrated activity patterns that were temperature dependent.

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*Rana temporaria (*European common frog*)*, British altitudinal range extension.

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The most widespread British amphibian *Rana temporaria*, is found in every mainland county in Britain (NBN, 2014). Beebee & Griffiths (2000) describe it as "breeding in mountain bogs and tarns up to 1,000 metres above sea level," though it can be found up to 3,000 m above sea level in the Pyrenees (Arnold, 2002).

On 22nd July 2014 numbers of *R. temporaria* tadpoles and one adult were found in the shallows of Lochan Buidhe (British national grid NH983010) at an altitude of 1,120 m above sea level. The site is near the summit of Ben Macdui, Britain's second tallest mountain and the highest peak of the Cairngorms.

Figure 1. Lochan Buidhe, and its surrounding habitat, from the north.

The lochan itself (fig. 1) is shallow (less than 1 m deep throughout) with very gently sloping sides and is oligotrophic. Aquatic vegetation is made up mainly of algae and bryophytes (principally the liverwort *Nardia compressa* with a little *Sphagnum papillosum/ palustre*) and with some emergent sedge *Carex rariflora*. There were no aquatic macrophytes, presumably due to the effects of freezing and ice scouring in such a shallow high-altitude water body (Light, 1975), and the margins are *Anthelia julacea-Sphagnum denticulatum* spring (NVC class M31, EUNIS class D2.2C). The surrounding vegetation is *Nardus stricta-Carex bigelowii* grass-heath (NVC class U7, EUNIS class E4.32) and *Juncus trifidus-Racomitrium lanuginosum* rush-heath (NVC class U9, EUNIS class E4.21) with rocks. These habitats are associated with harsh climates with strong winds and poor soils (Averis et al., 2004). Indeed snow was still lying c. 200 m from the site. It is probably similar to those areas occupied by *R. temporaria* in the Arctic Circle, where these habitats are more widely found (Ratcliffe & Thompson, 1988).

A review of the NBN (2014) found records of *R. temporaria* from elsewhere on the Cairngorm Massif and also from the lower part of Ben Nevis, Britain's highest mountain, but all were below 1,100 m with only 2 records above 1,000 m. There are 32 peaks in Britain higher than Lochan Buidhe (Scottish Mountaineering Club, 2014), however a review of maps and aerial photographs did not show any water bodies at greater altitudes, with the exception of some small pools (altitude 1,190 m) close to the summits of Ben Macdui and Cairngorm. When surveyed (visual search and dip net) no amphibians were found in these pools, although given the dispersal ability of *R. temporaria* and its tendency to frequent ponds one year and desert them in another, it remains possible that they are sometimes used as breeding sites.

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Varanus flavescens (yellow monitor): Thermoregulation

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Varanus flavescens is one of three monitor lizard species in Bangladesh (Islam, 2009). Their distribution includes floodplains of the Indus, Ganges, and Brahmaputra rivers in Pakistan, Northern India, Nepal, and Bangladesh (Auffenberg et al., 1989; Visser, 2004; Islam 2009). Although the species is widely distributed in Bangladesh, it is considered to be endangered (IUCN, 2000; Khan, 2008). Very few behavioural records are available, because the highly secretive nature of these lizards makes them difficult to locate (Visser, 2004). Like many diurnal lizard species, yellow monitors regulate their body temperature by shifting between sunny and shady areas, hence basking is an important behaviour. In this note, we report a most unusual type of thermoregulatory behaviour exhibited by *V. flavescens*.

On 30 December 2012 at 09:28 am, an adult *V. flavescens* was observed in Mithapukur Upazilla (sub district) of Rangpur district, Bangladesh (25.651188˚N, 89.174946˚E, WGS 84 elev. 35 m) beside a permanent water body. It was lying on a pile of straw ash at the edge of the water (fig. 1), about one meter above the water level. The ash was moderately hot but with no fire because it had been lit by fishermen about half an hour previously. The lizard tried to place itself under the ash and seemed to absorb heat from it. The weather was very foggy, the air temperature was about 10˚C and the sun had not been seen for the last three days. We observed the lizard closely but it remained inactive and did not appear to be afraid of us. After half an hour we found the lizard at the same place. We also found a burrow about 8 m away from it.

Figure.1 *V. flavescens* absorbing heat from a pile of ash.

Yellow monitor lizards are least active between November and February (Visser, 2004). They are known to dig burrows on cold nights during this period (Auffenberg et al. 1989). Because of the cold and lack of sunshine, the lizard might have been compelled to absorb heat from the alternative source of the embers. This kind of thermoregulatory behaviour has not been recorded previously

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Elapomorphus quinquelineatus (five-lined burrowing snake): Feeding on squamate eggs.

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Certain snakes are known to feed upon squamate eggs, and specialised species of snakes can have morphological and behavioural traits associated with this food habit (Scanlon & Shine, 1988; Queiroz & Rodrigues-Robles, 2006). For example, the Taiwan snake (*Oligodon formosus*) uses enlarged blade-like rear maxillary teeth to make repeated slashes in the leathery egg shell, allowing the snake to insert its head and swallow the yolk (Coleman et al., 1993). The American Scarlet snake (*Cemophora coccinea*), another egg-eater specialist, possesses enlarged posterior maxillary teeth that pierce large eggs. A combination of vigorous chewing and depressing of the snake's body expel most of the egg's contents (Palmer et al., 1970). These two snakes, and the African colubrid of the genus *Prosymna*, another squamate egg-eater, also swallow the whole egg (Broadledy, 1979). Among Neotropical dipsadid snakes, at least *Drepanoides anomalus* (Pseudoboini) and some species of *Lystrophis* (Xenodontini) may be squamate egg-eater specialists. However, some none egg-eater specialist dipsadids occasionally use this food item (see Greene & Jaksic, 1992; Gaiarsa et al., 2013). Here we report an additional possible case of egg eating among neotropical dipsadid. This is the first time egg eating has been reported for an Elapomorphini snake, which accepted snake eggs in captivity.

An adult female *Elapomorphus quinquelineatus* (SVL = 580 mm, tail = 60 mm, diameter at the middle body = 10.6 mm, head width = 10.3 mm, mass = 32 g) was collected on 10 July 2013 in the municipality of São Paulo (23°32' S, 46°37' W) and housed in a 54 x 37 x 15 cm terrarium with a corrugated paperboard substrate. The snake always accepted young snakes as food, but refused mice (*Mus musculus*) and small lizards (*Hemidactylus mabouia*). On 4 November 2013 at 8:35 hrs, this snake laid two eggs with normal appearance (aspect and coloration). Approximately 20 minutes after the eggs were laid, the snake ingested one of the eggs. The other egg was not removed from the terrarium, and after approximately 12 hours the snake ingested it. The swallowing time ranged from four to almost seven minutes. After this, eggs of the three dipsadid snakes (n = 4, Table 1) were placed in the terrarium on different days at a minimum interval of three days. Two *Sibynomorphus mikanii* eggs with a diameter of <10 mm (and therefore smaller than the snake's diameter) were ingested, but we did not observe the snake swallowing them. A large *Liophis miliaris* egg (diameter ≈ 15 mm) was entirely ingested, and the snake took over 30 min to swallow it (Fig. 1, Table 1). In the last experiment with a larger *Oxyrhopus guibei* egg (diameter ≈ 8 mm), the snake tried grasping the egg numerous times but stopped after 4 hours. The snake died a few months later and its remains were deposited in the herpetological collection of the Instituto Butantan (IBSP 85164).

E. quinquelineatus belongs to the Elapomorphini that also includes two other genera (*Apostolepis* and *Phalotris*) and almost 40 species of rear fanged snakes that are widely distributed in South America (Ferrarezzi, 1993; SBH, 2014). These burrowing snakes seem to be very specialised predators, feeding upon elongated squamata (Savitzky, 1979). Factual data on the food habits of *Elapomorphini* are scarce in the literature, but dissection of preserved specimens has always revealed amphisbaenids and fossorial snakes in their guts (e.g. Zamprogno & Sazima, 1993; Bernarde & Macedo-Bernarde, 2006; Braz et al., 2013). Recent reports described amphisbaenians as prey of *E. quinquelineatus* (Hartmann, 2009; Caramaschi & Niemeyer, 2012; Duarte, 2012) confirming that this snake has a diet similar to other Elapomorphini. However, eggs are an unrecorded and unexpected food item for such snakes. The data in the present study was obtained from snakes in captivity, where they can eat food items that are not eaten in nature (pers. obs.). However, an egg is an inert item that is unlikely to be accepted by a snake if it is not recognised as food. Moreover, the snake refused to eat the mice and lizards. Thus, it is plausible that *E. quinquelineatus* could ingest a snake egg if it found one in nature. Among neotropical snakes, the Pseudoboini group may comprise the highest number of species that prey upon squamate eggs, including the highly specialised *Drepanoides anomalus* (Martins & Oliveira, 1998; Gaiarsa et al., 2013). Queiroz & Rodriguez-Robles (2006) verified that egg eating is especially likely to arise in snake species that already feed on animals that lay eggs. We expect that squamate egg eating is most common among Pseudoboini snakes because this group feeds predominantly on squamates (Gaiarsa et al., 2013). However, Elapomorphini snakes also fall within this prediction because they feed on fossorial squamates and they exploit a microhabitat where other squamates usually lay their eggs.

Figure 1. *E. quinquelineatus* (captive female) swallowing a large egg of the xenodontid snake *L. miliaris.*

Date	Species	Egg length / egg diameter (mm)	Egg mass (g)	Ingestion time
04/11/2013	*E. quinquelineatus*	-	-	6m 40s
04/11/2013	*E. quinquelineatus*	-	-	4m 14s
08/11/2013	*S. mikanii*	27.5 / 9	3.0	Not timed
11/11/2013	*S. mikanii*	28 / 8.6	3.3	Not timed
14/11/2013	*L. miliaris*	26 / 15.7	5.6	32m 26s
25/11/2013	*O. guibei*	31.2 / 18	6.2	Not ingested

Table 1. Eggs of various snake species offered to a captive *E. quinquelineatus*, their dimensions and time taken for complete ingestion.

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Drymoluber brazili (Brazil's woodland racer): Defensive behaviour

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When considering anti-predatory mechanisms, snakes are among many vertebrates that have defensive strategies (Greene, 1988). Most snakes, when presented with the opportunity, prefer to flee or remain immobile (cryptic coloration) when confronted by a predator. However, when necessary, some snakes defend themselves by biting, cloacal discharge, constriction or, very rarely, using tail breakage (Greene, 1988; Zug, 1993; Martins & Oliveira 1998). *Drymoluber brazili* (Gomes, 1918) (Colubridae) is primarily a diurnal terrestrial snake, which occurs mainly in open areas in the Cerrado (Costa et al., 2013). We observed the defensive behavior of *D. brazili* during a field trip in an isolated cerrado area in Araripe National Forest (FLONA Araripe-Apodi) (see Ribeiro et al., 2012), Barbalha municipality, Northeast Brazil (7°21'55" S; 39°26'26" W, 912 m a.s.l.), on March 17, 2012, 15:30hrs. The specimen of *D. brazili* was observed foraging at the edge of shrubs and perceiving the approach of collectors, performed the following sequence of defensive behaviors: attempting to escape remaining immobile in the bushes; after being rediscovered, fled again, and after it was restrained with a snake handling stick began a vigorous sequence of rotations around its own body, followed by repeated bites with a rapidly vibrating tail. Once the snake was restrained by the tail, the collector held its writhing body; that was followed by tail breakage, enabling the snake to escape again. No blood was evident on the injured tail. Gomes (1918) reported a *D. brazili* responded with a body attack position whilst at the same time rapidly vibrating its tail. In this report, the vibration of the tail occurred only after restraint, presumably such behavior can complement tail breakage flow, since strong vibration of the tail on the ground, can facilitate or even induce breakage. Costa et al. (2013) noted that the snakes of the genus *Drymoluber* presented evidence of pseudoautotomy (intervertebral breakage, no capacity for spontaneous separation and no regeneration), which can be confirmed in the present study. Other genera of Neotropical snakes are also recorded as having Pseudo-autotomy, for example *Coniophanes*, *Dendrophidion*, *Mastigodryas*, *Thamnophis* (see Dourado et al., 2013).

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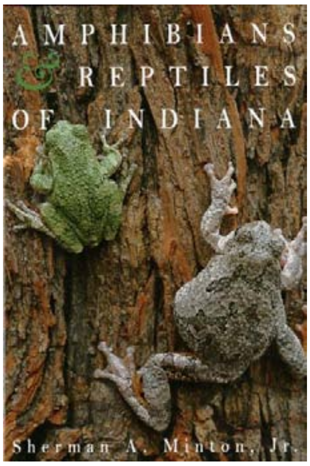
Amphibians & Reptiles of Indiana

Sherman A. Minton, Jr. (2001)

Indiana University Press, IN, 404pp, 2nd Revised edition. ISBN: 1883362105



My first thought when the book arrived was of the sheer thickness of it. Being asked to do a review on a book that concerns the reptiles and amphibians of just one state within the United States brings one to think of a thinner volume. However, this book holds information on 38 amphibian and 58 reptile species, making it an impressive book indeed. The information on the sheath and the foreword provides a lovely insight into the late Sherman A. Minton, Jr's life and his dedication in the study of herpetology. This lifelong commitment shines through on every page, with his personally gathered information and extensive catalogue of pictures included within the book.

Amphibians & Reptiles of Indiana provides a concise but varied introduction that highlights the extent of the author's research, which has gone into creating this superb book. The author has compiled a vast amount of information with tantalizing snippets on Indiana's topography and climate, endangered/special concern species, herpetological research history and much more. By far the most useful section within the introduction is the detailed explanation of the 'dots and stars' map system (found with the majority of species accounts). This mapping system coupled with the detailed Map 2 (Counties of Indiana, p12), Map 3 (Drainage Systems of Indiana p14) and the information on species distribution, gives the reader a rough guide on the locality and identification to at least the group level. For accurate identification the author highly accentuates the need to use species keys and to seek professional advice, rather than relying solely on species pictures. He explains further that misleading identification by the use of pictures is due to the variation of colour or patternation found in many species.

The bulk of the book is separated into two main sections, 'Amphibians' and 'Reptiles' of Indiana. These are subsequently divided even further; 'Salamanders', 'Toads and Frogs' for the amphibians and 'Turtles', 'Lizards', and 'Snakes' for the reptiles. The beginnings of the amphibian and reptile sections are superbly done, with a singular detailed key for the amphibians and similar keys for each of the three subdivided sections on turtles, lizards and snakes. I have always been rather daunted by species keys, due to their lengthy and complicated nature; however, the keys in this book are simplified and are only detailing the step by step anatomical features for the species present within Indiana. The larval key in the amphibian section is a pleasant addition, which would test the reader's skills even further. Even with the handy glossary (pages 368 to 373); the reader would need to have decent anatomical knowledge of herpetofauna to make full use of the keys. Furthermore, the author emphasises that even with the help of this guide, many species can only be identified to the group level in the field.

The book is systematic in its layout and all of the sections go into great detail on each species from salamanders to toads and turtles to snakes; all species are subdivided under their family designation. The author provides information on:

Identification: a brief but distinctive account on morphological information to identify each species. If similarities occur with other species, the author provides the reader with the characteristics to differentiate between them. For example the Ravine Salamander (*Plethodon richmondi*) is noted to be difficult to distinguish from the unstriped morph of the Redback Salamander (*Plethodon cinereus*); however, they differ in body length and width. Further details on the variations that can occur within the state itself are discussed.

Description: this provides a more in-depth account on each species general appearance and expands on the specific identification (above). The primary information focuses on measurements of males and females of each species including, tail length, head length/width, limb length, carapace/plastron length and scale numbers. This is a generalised list and does not account for all of what is found, due to the sheer amount of information given per species throughout the book. The author shares his personal accounts on mean body length of adult male and female from caught specimens. This area truly portrays the amount of knowledge gained by Sherman A. Minton, Jr over his many years of research.

Range: short but to the point, the author pinpoints the locations on a map of Indiana incorporating the 'dots and stars' map system and a map of their range within the eastern United States.

Habitat and Habits: this is by far the most interesting area for each species, Sherman A. Minton, Jr provides the reader with detailed information on the specific habitat preferences of each species, for instance the crayfish frog *Rana areolata circulosa* that make their home within the large chimney-building crayfish burrows of open, grassy, damp areas. Interesting facts on feeding habits, such as the switch in juvenile and adult Western fox snake *Elaphe vulpine vulpine*, where the young feed on snakes, lizards, and invertebrates and the adults largely on small mammals. Also covered are species breeding habits (including mating/egg laying/maturity times and the authors personal accounts on specific dates), period of activity throughout the year, species specific habits when being captured or pursued and much more.

The species descriptions are finished with really nice but small sections on, species excluded or doubtfully recorded from Indiana, species possibly occurring in Indiana and exotic, introduced and extralimital species. Throughout this book the late Sherman A. Minton, Jr continually gives his personal accounts, making Amphibians & Reptiles of Indiana more interesting and diverse. Some herpetological books just give general accounts for species, but due to the author's great efforts, his personal accounts add a great connection to his work and accuracy to the descriptions. It is, however, a rather specialist book, aimed at the enthusiast who is interested in the herpetofauna of Indiana or the eastern United States.

All in all I cannot give this book the justice it deserves but I found it to be a very good enlightening read, with lots of detail and a useful field guide. I do, however, think that it would be more suited as two separate books. The amphibian and reptile sections are substantial enough on their own and with a durable outer finish to combat most weather conditions, would improve their usefulness in the field.

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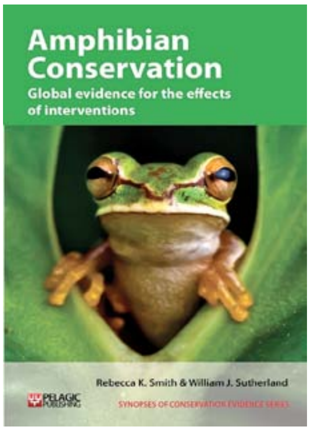
Amphibian Conservation: Global Evidence for the Effects of Conservation

Rebecca Smith and William Sutherland (2014)

Pelagic Publishing, 276 pp, ISBN: 1907807853



This book attempts to summarize all of the published evidence relating to conservation interventions aimed at amphibians and specifically, where interventions have been quantitatively monitored. This ranges from very small specific interventions such as the introduction of artificial hibernacula to wide ranging interventions such as the Million Ponds Project in the UK. No attempt is made to make recommendations, merely to lay out the evidence in an easy to read and easy to find format in a way that can help decision makers at a local, national or international scale make more informed judgements as to the most effective measures to implement. The first half of the book is arranged into chapters that each relate to a specific threat such as climate change, transport networks, agriculture and pollution whilst the second half examines the impact of habitat management, species management (captive breeding and translocations) and education and awareness raising.

One of the big plus points of this book is that it is very easy to establish if there is evidence available about a particular subject and where to find the source material. In this respect it serves its purpose well. However, it is intriguing to examine whether the book can actually be applied by land managers or those giving advice to land managers to fine tune the management of sites for their amphibian populations. The Kent Reptile and Amphibian Group regularly gives advice to a wide range of organisations and individuals about managing ponds and terrestrial habitat for amphibians and most of the advice is based around generally accepted best practice guidance. At least 90% of advice is covered by just a few basic principles. In other words, creating ponds is good, and almost always more cost effective than managing existing ponds, discouraging birds and fish is useful, maintaining structurally complex terrestrial habitat will help and not moving the widespread amphibians around except under exceptional circumstances is the best option. So, could this book confirm that this is sound advice based on well established, published literature or just the ramblings of well meaning amateurs that is at best ineffective or in a worst case scenario, counterproductive?

Things started well, pond creation gets a resounding thumbs up though the success of specific species depends upon the kind of ponds created and some studies have expressed doubt that the creation of ponds specifically for translocated species leads to self-sustaining populations. In contrast, evidence suggests that pond restoration can have mixed effects on existing amphibian populations. Fish control similarly has good evidence to back up its effectiveness although the use of piscicides can also kill off amphibian populations. The evidence to support other interventions is less conclusive as the example of excluding waterfowl shows. The book simply states that 'We captured no evidence for the effects of preventing heavy usage or excluding wildfowl from aquatic habitat on amphibian populations.' Herein lays the challenge of writing a book such as this. The complexities of amphibian habitat management and the impact of interventions on a range of species mean that there simply isn't enough published information to fully inform a land manager. Other examples, particularly broad ranging interventions such as introducing a grazing regime or the management of terrestrial habitat have evidence of both success and failure. This simply illustrates that for most interventions it is the fine-tuning of management techniques and regimes that yield success rather than simply the type of intervention itself. In short, this book provides a useful starting point for justifying specific interventions (or not intervening) and can help direct the reader to further information.

One of the conclusions it is impossible not to draw from reading this text is that there are still significant areas of amphibian conservation that are not covered by scientific literature. This is exemplified by the lack of evidence for either protecting brownfield sites or habitat connectivity having a positive impact on amphibian populations. It is a challenge to summarize so much information into one relatively small book and even more of a challenge to make sense of what all the data means. This book is a useful tool and perhaps an ideal first step for identifying or rejecting potential interventions for amphibian conservation but does not provide all of the answers to making the most of the limited resources available for amphibian conservation. That would just be too simple wouldn't it?

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Contributions to the History of Herpetology Volume 1

Revised and Expanded Edition
Kraig Adler, Editor 172pp, Ithaca, New York: SSAR (2014), ISBN: 978-0-916984-89-2

The First World Congress of Herpetology at the University of Kent in 1989 was associated with a number of "firsts". One of them was the publication of volume 1 of this work, destined eventually to have two further volumes added. Together they are a compendium of short (mostly 3-400 word) biographies of almost all of the world's major herpetologists up to the 1960s. There had been nothing like these books before, and there has been nothing like them since - they are unique. The selection of which volume an individual should appear in appears to have been made on the basis of providing a balanced coverage. This one starts with Conrad Gessner (the early authors included were not herpetologists - the word hadn't been coined then - but zoologists whose works contained a significant element of descriptions of reptiles and amphibians: Gessner is famous for Historia Animalium in five volumes published between 1551 and 1587). It finishes, just over 150 accounts later, with Avelino Barrio.

Of most interest to British readers, probably, will be the accounts of the lives and work of George Boulenger and Malcolm Smith, who between them, in very different ways, dominated the English herpetological scene between 1882 and 1958. Other well-known British herpetologists, Angus Bellairs and Garth Underwood, for example, appear in other volumes.

Sometimes, when I look at a book on - say - Old Testament textual analysis or the archaeology of Dartmoor, I am overwhelmed by the thought that anyone can have so much detailed knowledge about such a small segment of endeavour. I had the same feeling looking at this volume. I rather doubt that anyone would ever sit down to read it from cover to cover. But as a work of historical reference, it's invaluable. I think it's likely to remain the definitive work of its kind for many years to come.

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