CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Environmental Sciences

How tropical reptiles are affected by climate change

Bachelor Thesis

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Declaration:

I hereby declare that this bachelor thesis was written by me and me alone, merely using the cited sources. I agree with the loan of my work and its publication.

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Abstract:

Ecosystems around the world are affected by anthropogenic climate change. Causing extreme weather events, habitat loss and decline of many species. Tropical areas are extremely sensitive to these changes. Tropical rainforests are home to many different species and have the highest biodiversity of reptiles, making research, monitoring and future conservation plans for this area crucial for protecting rainforest flora and fauna. Therefore, this review was conducted in order to assess the present research on how climate change affects reptilians living in tropical areas and which are the main responses and adaptations of reptiles. After noticing many gaps and lack of information, we suggest more research is necessary to understand the threats of global warming to tropics and reptile species in order to have well-functioning conservation plans and to be able to protect these ecosystems and prevent extinction events.

Keywords: Climate change, tropical reptiles, rainforests

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1 Introduction

Climate change poses a great threat to wildlife all around Earth, destroying habitats, communities and entire ecosystems. Unstable environmental conditions such as storms, higher or lower temperatures, extreme rainfall and droughts are already evident and the occurrence of such events is predicted to increase in the near future (Brown, 2022; Vabrit, 2014). Decreased availability of freshwater and sea level rise are directly connected to global warming (Thackeray et al., 2019). There is noticeable habitat loss and unfavourable conditions in tropical areas, especially rainforests (Pough, 2022; Esquivel-Muelbert et al., 2018; Freedman et al., 2009).

Climate change in the tropics appears to move slower thus research in the area has started and moved slower than in northern regions where outcomes of climate change are swift and noticeable for everyone as ice is melting and sea level rising at a fast rate. In the last decade the importance of research on tropical regions has escalated, as the understanding of the importance of tropics for biodiversity has boosted (Corlett, 2012). The nation's greatest richness in species of any ecosystem is represented in tropical rainforests, which also have the greatest carbon dioxide reservoirs and the highest biomass yield of any biosphere on the globe (Esquivel-Muelbert et al., 2018).

Researchers cannot predict a species' long-term fitness and reproductive potential based solely on their knowledge of the reality of climate change. The capacity for adaptation, vulnerability to shift, and exposure all work together to give a fuller picture of the way animals will fare within the context of environmental volatility (Balzotti et al., 2016). Present changing climatic conditions are negatively affecting many different species of animals. Ectotherms being one of the most vulnerable due to their body temperature depending on the outer temperature, which with rising temperatures can cause overheating. Other factors contributing to sensitivity of reptiles to global warming include habitat destruction, environmental and ecosystem changes (Bonino et al., 2015; Berg et al., 2017). Tropical reptiles seem to be more liable to environmental changes as they are living at their limits daily. Making it difficult for them to survive in new environmental and climatic conditions. Studies show that reasons for vulnerability to climate change in tropical reptiles vary in different species and locations. Some variables being thermoregulation, small habitat range, temperature dependent sex-ratio and destruction of coastal areas (Pontes-da-Silva et al., 2018).

Changes in distribution have traditionally represented the most common adaptive strategy of animals to changing climate, which has led conservationists to concentrate on examining prospective changes in climatic and geographic limits for organisms regarding the prospect of current and future climatic variability. Yet, in order to understand the movements and distributions of animals fully it is important to look at other responses like phenology, genetic adaptation, phenotypic plasticity and microhabitat modifications (Reside et al., 2018). Reptiles adjust their physiological functions or their behavioural thermoregulations in response to climatic shifts. The term "acclimatisation" refers to physiological changes that take place in the context of the natural world. Gaining a deeper knowledge of individuals' susceptibility to environmental change requires an integrative analysis of organisms' behavioural and physiological adaptations (Mi et al., 2022).

As the majority of tropical ecosystems might experience circumstances that have never been encountered by any region in the past. Researchers have yet to understand the level of difference these new environmental conditions will have on the tropical species and what they are currently used to and how different tropical areas might differ from their current state. Therefore, future research is crucial for making correct decisions for conservation actions and ecosystem preservation. (Corlett, 2012). For instance, maintaining woodland connectivity across slopes, hills and mountains, could optimise the chance for lowland communities to move from hot and possibly lethal temperatures to colder acceptable conditions. Additionally, while planting new forests, it is necessary to have available woody debris, logs and other microhabitats for reptiles to hide from predators or unfavourable temperatures. (Shoo et al., 2014; Kanowski et al., 2005).

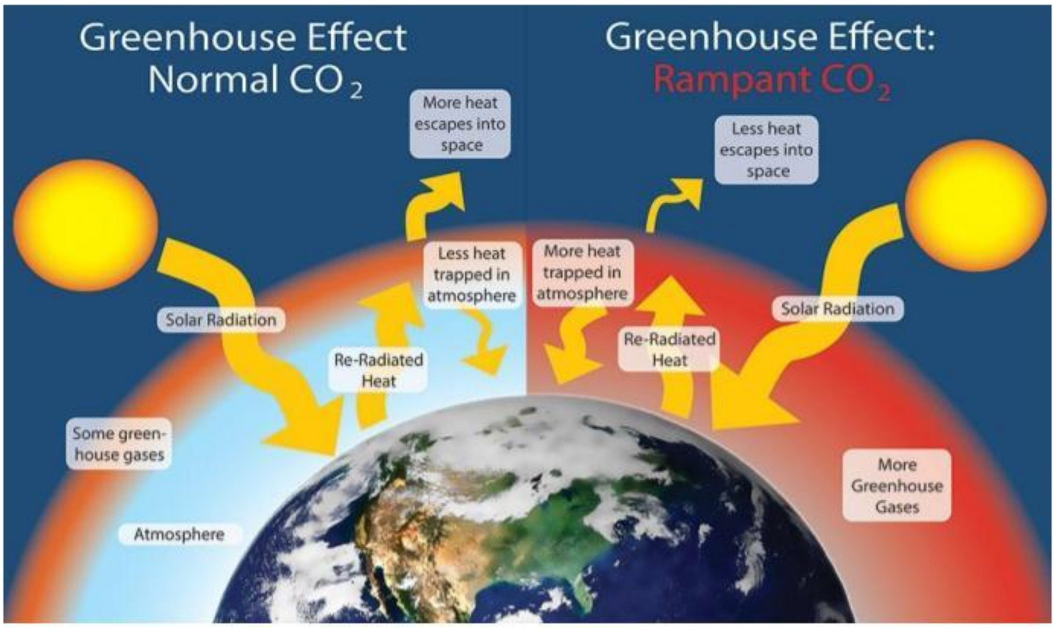
Goals

The aim of this thesis is to bring focus on climate change, tropical reptiles, tropical rainforests and how they are connected. We aim to answer questions on how tropical reptiles are affected by climate change, main targets being on understanding the changes that are evident and could occur in the future, which taxa could be the most threatened and what are the key features that are responsible for their threat, which climatic changes are the most dangerous and what is the importance of research about climate change's effect on reptiles. In order to show how largely tropical areas and reptile species living in different parts of tropics are influenced by new and unstable environmental conditions.

2 Literature review

2.1 Climate Change

Climate change is a change in weather patterns over a long period. It causes unexpected rainfall and temperature changes. In addition, it is connected with more frequent storms, hurricanes, droughts, floods and other extreme weather events (Brown, 2022). There are two types of climate change, one is natural and other anthropogenic, which means that it occurs due to human actions. Natural climate change has always been part of the Earth's cyclic climate system, where one cycle seems to occur around every 30 years. Modern day global warming seems to be greatly affected by anthropogenic sources, as it is a fast-paced change, led by industrial emissions, farms, planes, forestry and other human actions. Main gases that are increasing due to humans and are causing global warming and climate change are carbon dioxide, methane, nitrous oxide, hydrochlorofluorocarbons, hydrofluorocarbons and ozone. Together they are called greenhouse gases, even though these gases are part of the natural system and necessary for life on Earth, if the compositions change it can be destructive to the entire world. Anthropogenic climate change has many severe effects on organisms and their habitats (Vabrit, 2014; Change I.P.O.C, 2007). Figure 1 presents how rampant Carbon dioxide traps the solar energy into the atmosphere thus leading to rising temperatures on Earth, which can cause habitat alteration, droughts and overheating (Elder, NPS; see figure 1.)



Left: Normal biological processes generate regular levels of greenhouse gases, which trap part of the sun's energy and protect the earth from cooling.
Right: Earth's average temperature rises as a consequence of the enormous Carbon dioxide emissions that arise from burning fossil fuels because they trap extra heat.

Figure 1. Additional solar radiation is captured in the Earth`s atmosphere as consequence of higher levels of anthropogenic greenhouse gases like Carbon dioxide, leading to increased temperatures. Source: Will Elder, NPS

Climate change effect on different areas

Various locations are affected differently, for instance warmer air and sea temperatures in the north which cause low ice levels. There is an increase in severe heat waves in Europe and intense rainfall in Australia during storms, there are many finding which show drying in many parts of Asia and Africa. Unseasonable temperatures can be attributed to hot air being directed over western Europe from Africa or cold air being diverted from the North Pole and into North America by a polar vortex (Ornes, 2018; Thornton et al., 2014).

Temperatures in Africa have been getting warmer and will continue to do so. This is a major concern to Africa as higher temperatures cause problems with water resources and are harmful to local flora and fauna. As heat from Africa moves over Europe causing heat waves, the increasing temperatures in Africa are also a concern there. Continuously growing temperatures might lead to mortality of many colder region species (Hulme et al., 2001). Another problem caused by warming sea and surface temperatures and ice melting is for polar bears, who need ice in order to hunt and survive, which has become extremely difficult in the last years, causing many polar bears to die of hunger (Vabrit, 2014). Heat is the primary driver of snow fluctuations, although a variety of elements such as rainfall, flora, light-absorbing pollutants, and melting of ice have an impact. Variations in the amount of snow driven by mentioned drivers could increase localised surface heat leading to warming of lithosphere. This might result in decreased snow periods in the future. Such anticipated changes raise serious questions about the supply of water in several areas of high density as water availability in these regions is already limited. It also plays a role in availability of ground water due to already present fluctuations caused by floods and droughts (Thackeray et al., 2019; Taylor et al., 2013).

Increase in temperature has some impact on pollution levels as well, primarily due to harmful pollutants being involved in chemical reactions that are significantly influenced by temperature and natural emissions, which often rise with rising temperatures. As a result, some pollution levels that aren't particularly toxic right now might become damaging soon (Zlatev et al., 2016).

Oceans are currently warmer, with higher acidity, and productivity has increased due to changing climatic conditions. Oceanic acidification is exacerbated by human-caused greenhouse gases. Ever since the 19th century, both duration and severity of intervals of extremely high sea surface temperatures which damage marine plant and animal communities and increase the likelihood of severe climate events, have increased. Their occurrence will become more frequent as the release of harmful gases increases. In addition, due to escalating ice loss in the planet's northern latitudes, sea level is rising consistently (UN, n.d.; Smith et al., 2009; Fussel, 2009). Rising ocean temperatures and changes in water pH levels due to pollution have a harmful effect on sea organisms and whole ecosystems. Coral reefs could die out after an increase of only 1°C, as these habitats are already largely destroyed due to global warming and human actions (Vabrit, 2014).

Worldwide, ocean levels are rising rapidly at a higher rate than anticipated. Because of the amount of greenhouse gas emissions growing even more throughout the 21st century, sea level will keep rising. That can cause coastal erosion and the flooding of low-lying seaside areas, which will be especially detrimental to estuarine environments. The effects are most noticeable during storm surges and periods of high tide. It is more difficult for coastal animals and ecosystems to properly respond to rising seas and relocate inland where coastlines are heavily modified, for instance in densely populated places (Hobday and Lough, 2011; Fussel, 2009).

By the early 2000s, numerous effects of climate change on species had been extensively documented. Increasing interest in identifying species, habitats, and regions that are threatened the most by climate change (Foden et al., 2019). It is expected that climatic changes may lead to the disappearance of several terrestrial creatures, including birds, mammals, amphibians and reptiles. This could occur as a result of direct or indirect response to environmental factors, such as variations in rainfall pattern, humidity levels, and ecosystem features (Cosendey et al., 2022). In a changing environment, problems from wildfires, pests, and infections are anticipated to rise. In several forests all over the globe, the above entities and associated connections presently lead the disruption cycles. Throughout the future years, such forces may likely become even more significant worldwide. shifts in water supply, which are anticipated to fluctuate more dramatically nationally, will have a significant impact on how irregularities brought by additional factors, including dryness, storms and snowfall, alter in the future (Seidl et al., 2017).

Adaptations and behaviours to mitigate climate change

The shifts, degradation, and changes in the extent of areas offering suitable habitat are arguably the most significant ecological pressure on many species brought on by climate change (Foden et al., 2019). Forcing species to migrate in search of suitable habitats while isolating or possibly causing local extinction of others that were unable to adjust to the speed of the changes (Bradley and Diaz, 2021). With the help of plastic and evolutionary responses, animals are adapting to climate change by changing their shape, behaviour, phenology, and geographic range. Widespread changes in productivity, species interactions, sensitivity to biological invasions, and other emergent features are the consequence of responses by species and populations to direct effects of climate change on ecosystems, including extreme weather occurrences (Weiskopf et al., 2020; López-Alcaide and Rodrigo, 2011). Species, which are highly dependent on climate, particularly variations in ambient temperature primarily due to their biology and ecology are especially delicate to climate change. Tropical species, who are already living close to their physiological optimum levels, are no exception to this rule. Overheating due to higher air and water temperatures causes physiological stress, decreased performance, and increased disease susceptibility, all of which eventually cause population decreases and extinction. As a result, it is anticipated that many species may alter their existing distribution to follow future temperature change. For instance, there are more and more indications that certain species are migrating to the north and climbing in height in search of lower temperatures (Bezeng et al., 2018). As future regions with acceptable climates will change, becoming more constrained or too remote from the species' current global distribution it might be impossible for some species to change their habitat. Although it is evident that species with broad distributions are less likely to experience these issues than those with strictly constrained ranges. The rate of climate change, geographic scale, the presence of physical barriers, the ability of a species to disperse, physiological tolerance, and phylogeny are some of the complex interactions and factors that most likely contribute to the outcome of an ability of a species to survive. Animals have different alternatives, such as behavioural modifications like thermoregulation, to offset the impact or even occasionally take advantage of it. This is important to keep in mind when thinking about how climate change affects ectotherms (Bonino et al., 2015; Cosendey et al., 2022).

Future plans

There are plenty of approaches to combating global warming that will boost the economy by also enhancing our quality of life and saving the planet. In order to direct advancement, there are international frameworks and agreements in place, including the UN Framework Convention on Climate Change, Paris Agreement and the Sustainable Development Goals. Adjusting to environmental effects, reducing pollution, and funding necessary adaptations are the primary kinds of intervention. By transitioning from fossil fuels to green energy sources like wind or solar power, we can cut down on the gases that cause global warming (United Nations, n.d.). While creating future risk assessment maps and plans it is necessary to consider that climate change-related environmental stressors may hinder the species ability to adjust to future climate changes in its habitat. Climate change will have an impact on things like anthropogenic land use, future fire and drought regimes, storms and invasive species. The size and connectivity of ecosystems may suffer long-term deleterious effects as a result of such shifts. There is an increasing collection of climate change vulnerability assessment tools that are now accessible for scientists and developers to use. These tools typically use a query-based approach, in which professional judgement is used to understand how target species respond to inquiries about habitat quality and various elements of the phenology, physiology and biotic interactions (Balzotti et al., 2016, Foden et al., 2019). Each location, ecosystem and organism are impacted by global warming caused by humans. There is mounting proof that there are connections between anthropogenic climate change and severe storms and high temperatures, floods and on the contrary droughts. The magnitude of significance of climatic changes is unmatched in the past several hundreds to several decades. Particularly when it comes to ice caps, and the rise of the entire planet's seas, numerous alterations are permanent, but by taking action now it is possible to slow down the harmful effects of climate change for the future (United Nations, n.d.).

2.2 Tropical reptiles

There are four groups of reptiles, which are traditionally thought of as significant classes under the phylum Vertebrata: order Testudines-turtles, order Crocodilia-crocodiles and alligators, order Squamata which includes both snakes and lizards and the fourth order Tuatara which includes lizard-like reptiles from a historically distinct group (Stromsland and Zimmerman, 2017). The largest group is Squamates, over 11 000 known species of extant reptiles are lizards and snakes. Testudines are known to have 360 species and Crocodilians 26. Many of the species habit temperate areas but the greatest number of different species is found in the tropics (Pough, 2022).

Reptiles have unique skin consisting of scales or bony plates, for some species it can also be a combination of both. All of them periodically shed their skin's outer covering and they are all air-breathing species. Different classification methods for vertebrates have been proposed as a result of the development of molecular genetics and reinterpretations of evolutionary relationships. For instance, according to certain contemporary classifications, turtles belong to a unique group that has a different evolutionary history from all other reptiles, while crocodilians are more closely linked to birds than to other reptiles (Gibbons and Luhring, 2009).

The popular and scholarly understanding of reptiles have significantly changed as a result of new works and research on evolution and importance of reptiles in today's world and from a historical point of view. Today they are more appropriately viewed as animals with highly developed defensive, predatory, and migratory capabilities. For instance, killing their prey effectively while using venom with immaculate pace and power. Lizards may run through water, inject and spew toxins, or blend in with their surroundings to evade attackers. Skin tones can also alter to convey feelings and physical health and help hide from enemies. Employing magnetic properties to guide them, certain reptiles manage to migrate more than 12,000 kilometres (de Miranda, 2017). Some reptiles, particularly aquatic species like sea turtles and the pelagic sea snakes, move great distances and exhibit minimal genetic differentiation over vast geographic ranges. Nevertheless, it is increasingly frequent for native populations to differ in significant ways due to limited connection. Therefore, intraspecific heterogeneity in appearance, physiology, and behaviour is very common. Even though some reptiles can travel great distances it is more common that reptiles have short ranges due to their small bodies and minimal energy requirements. This results in relatively low estimates of gene transfer between populations, which can lead to the creation of solitary subpopulations even inside highly scattered taxa. (Shine, 2013).

Biodiversity

Biodiversity of terrestrial reptiles is strongly connected to the size and style of landscape metrics and forest patches. Attributes like less fragmentation and greater forest coverage contribute to having more reptile diversity (Russildi et al., 2016). The succession of reptile populations over geographical or temporal areas of forest with changing habitat quality involves both biological and environmental aspects. As an example, only in primordial forests do snakes appear to form distinctive, well-organised assemblages. When forests are recolonized after a disturbance, lizards may be more resilient than snakes and create assemblages that can be separated from significantly altered forest settings. This may suggest that snakes can be more in danger than lizards if habitats are destroyed and need rehabilitation, which may lead to loss in biodiversity (Luja et al., 2008). Research on predicting potential hazards to biodiversity from climate change has been quite active, and some studies indicate that climate change may pose the biggest threat to biodiversity globally in the next decades (Diele-Viegas and Rocha, 2018).

Thermoregulation and acclimatisation

The environment surrounding reptiles affects their metabolism and how active they are in their daily activities. Reptiles being ectotherms respond to environmental changes with physiological adaptations and/or behavioural thermoregulations. Physiological modifications that happen under natural conditions are called acclimatisation. Species from tropical areas are assumed to have limited physiological acclimatisation as the temperature does not have a wide range. Due to the more stable climatic circumstances compared to temperate regions, it has long been believed that the physiological adaptation of tropical ectotherms in shifting settings through acclimatisation is of limited consequence. Contrastingly reports about a variety of metabolic changes in tropical organisms dispute this idea (Berg et al., 2017). Animals with behavioural thermoregulation can alter their body temperature to enhance processes essential to fitness, such as digestion, development, reproduction, and locomotion. As environmental temperature variability is less at night than it is during the day, nocturnal species must be able to take advantage of rare microclimates in order to keep their fitness. Due to the comparatively warm night time temperatures, nocturnal lizards may have more options for thermoregulation in tropical settings. As an example, tropical nocturnal lizards can actively adjust their body temperature both during the day and at night if the environment is conducive. Understanding the thermal ecology of nocturnal ectotherms is crucial in a warming world because species may change their nocturnal habits to avoid critical day temperatures (Nordberg and Schwarzkopf, 2019). The majority of physiological functions advance quickly over what is known as the ideal temperature range, although they are slowed down at body temperatures above and below this range. Species who employ behavioural thermoregulation to keep their body temperatures within the ideal range do better than those who don't. The coadaptation of preferred body temperature should be favoured by natural selection if performance and fitness are directly correlated (Angilletta et al, 2002).

2.3 The effect of climate change on tropical reptiles

Extinction is a threat to one-fifth of the world's reptiles. One of the main problems being habitat loss that has a direct connection with global warming and climate change. Reptiles are vulnerable to climate change as they are sensitive and have low adaptability to the exposure of temperature and humidity fluctuations (Böhm et al., 2016) Lowland species will ultimately be at risk from climate change. Especially ectotherms like reptiles, seem to have restricted thermal optimums and a reduced ability to adapt to elevated temperatures. Several lowland species lose a lot of water through evaporation, that might make them more susceptible to desiccation pressure as climate warms (Laurance et al., 2011; López-Alcaide and Rodrigo, 2011).

Comparing to temperate reptile's tropical species seem to be more vulnerable to climatic changes. Their ability to acclimatise is not as developed. Temperate reptiles have different morphological ways to adjust to a larger variety of temperatures as temperatures have a larger scale yearly, with cold winters and warm summers. Tropical species live in a smaller temperature range and therefore do not usually need to alter between cold and hot temperatures (Sun et al., 2022). Also, when one moves closer to the equator, the reliability of thermoregulation behaviour declines. Such trends suggest a small window for altering the timing of activities in a warmer future and perhaps leading to the extinction of several communities in the centre and equatorial zones due to rising temperatures and growing environmental modification (Piantoni et al., 2019).

As an example, Cybotoids from lowland and highland ecosystems will probably experience various consequences from climate change. On one hand, it is likely that upland species will profit from global warming. As the environmental temperatures will resemble lizards' ideal temperatures more frequently and leading to shorter periods required for thermoregulation. On the other hand, many cool-adapted montane ectotherms could be forced to migrate upward as a result of temperature increase, which threatens to render present ranges physiologically unsuitable. Additionally, warmer temperatures can encourage organisms to ascend from lowland areas upwards, which might result in unfavourable invasions (Munoz et al., 2014). Based on study models and research, temperature seems to be one of the key elements of climate change affecting tropical lizards. Temperature changes that affect lizards' life cycle can be yearly annual changes in mean temperature, but even more important seem to be weather extremes like unfavourably high temperatures during the summer or severe colds during the winter which cause mortality in many tropical lizard species (Mi et al., 2022).

High variability in biotic factors like migration, death, and reproduction have a significant influence on the dynamics and demographics of many wildlife populations.

Additionally, studies show that abiotic elements like climate are believed to significantly influence it in tropical regions like Australia (Ujvari et al., 2015). Because of annual variations in the availability of food, several predators alter their trajectories. But the majority of the scholarly research on this subject has focused on endothermic species. even though some of the best instances of this behaviour are provided by ectotherms. Seasonal variations in feed preference and foraging environment and ability to move great distances to find new prey could be strong supporters for surviving during climate change (Natusch et al., 2020).

Migration

Climate change is forcing reptiles to change their geographical locations which result in competition for food and nesting areas between new species and current species. They may be directly impacted by habitat loss and habitat quality degradation brought on by selective tree cutting, or they may be indirectly impacted by a cascade of edge-related impacts involving the microhabitat's environmental factors. Distribution of some species is largely affected by canopy and altitude and a positive edge effect could decrease or become negative during different weather conditions for example the adverse rainfall season (Carvajal-Cogollo and Urbina-Cardona, 2015). Species may change one‘s distribution range to follow a climate niche, moving away from colder habitats when their favoured temperatures are warm and away from warmer regions when they prefer lower temperature. This means that a specific species may experience both positive and negative consequences from climate change depending on how readily available acceptable temperature settings are, which will affect how widely that species is distributed. This could be the difference between survival and extinction for those with a narrow range of distribution (Diele-Viegas and Rocha, 2018; Bradley and Diaz, 2021).

Adaptability to change

Evolution seems to favour maintaining high internal temperature in alpine settings over physiological adaptation to lower temperatures even though time invested in thermoregulating impacts other behaviours including feeding, protection from predators, and breeding. Looking at research it is possible that behavioural alterations are quicker than adjustments to physiological limits. Numerous physiological functions are temperature-sensitive; therefore, the development of physiological tolerances may require the coordinated change of numerous genes (Munoz et al., 2014).

One of the most important factors for surviving climate change seems to be adaptability in behaviour, it can either mitigate the harmful effects of rising temperatures or increase its positive effects. The outcome is determined by the physiological traits, accessibility of shadow, as well as the regional weather systems. Since many temperate ectotherms reside in conditions that have temperatures significantly lower than ideal, increasing their body temperature is their top objective. Therefore, these reptiles will gain from warmer conditions. However, species living in desert zones and tropics who thermoregulate in order to maintain body temperatures in warm climates are going to be in danger as these regions get warmer, particularly if there is little cover to protect them from heat (Huey and Tewksbury, 2009).

Physical and ecological dispersal barriers may at least partially confine populations that occur in various regions to those specific areas, which may aid in the establishment of geographic arrays of varied populations. Genetic variance may be geographically structured as a function of climatic factors. It has been suggested, in particular, that long-term climate stability encourages genetic variety. According to this theory, regions with less climatic changes have a higher probability of new clades evolving and persisting, with a lower chance of extinction or intorsion with other clades (Rodriguez-Robles et al., 2010). Research shows that species that are able to move to different elevations, can manage better during climate change. In particular, during times of rising temperatures, mountainous areas could allow elevation specialists to relocate upward or downward, preserving sustainable population numbers. In addition, islands usually favour lesser biodiversity, as there are less ecological specialists, and species with wider realised niches than do continents. These characteristics may all add to a decreased prevalence of elevational experts on islands which may contribute to islands being more threatened by climatic changes (Laurance et al., 2011). Protected zones are predominantly found in mountainous terrain at higher latitudes, which is helpful for animals that follow climatic conditions moving higher to the top of the hills and mountains. Highlands are expected to provide refuge for new populations, but upper-elevation specialists, which are primarily ectothermic animals, are anticipated to suffer, as they might not be able to compete for their habitat (Reside et al., 2018).

Temperature changes

Reptile body temperature is dependent on external temperatures. Therefore, as temperatures are increasing, and heat waves are more common due to global warming reptiles may have a risk of overheating (Diele-Viegas et al., 2020). As they have a limited ability to adjust their body temperatures physiologically through metabolic heating or evaporative cooling and must instead rely on behavioural thermoregulation. Recent research predicting the vulnerability of ectotherms to climate change suggests that tropical ectotherms are particularly vulnerable to temperature increases in the environment because they are already experiencing temperatures that are very close to critical thermal maxima and to optimal temperatures for performance (Pintor et al., 2016). The thermal characteristics of the environment have a significant impact on lizard activity patterns and habitat utilisation, with activity tending toward unimodality in temperate habitats and bimodality in warm or dry places due to changes in daily temperature regimes (Garcia, 2008). For instance, when on the bare ground in the middle of the day, the *Eremias* lizards studied in Asia were exposed to potentially fatal operating temperatures while being on open ground in the middle of the day. They have to use behavioural thermoregulation in order to stay safe, therefore lizards travel between sun and shade regions regularly to cut down on their activity in the sun sections. As global temperatures are rising the temperatures in the sun could become lethal even in those short periods *Eremias* spend in the sun. Accordingly thermal safety margins play an important role on how much desert lizards are affected by rising temperatures. In addition, different thermal behaviour and physiology in reptiles that have varied utilisation of microhabitats may enable individuals to survive together in constrained space (Li et al., 2017).

Reptiles behavioural thermoregulation is facilitated by microhabitat heterogeneity, and plant coverage at a location of habitation is probably especially critical in dry and desert environments areas with widely dispersed flora. Several desert lizard groups are observed to boost their movement in microhabitats which offer shade from high outer temperatures, while also serving as a heat barrier over colder periods. Additionally, the existence of plants near microhabitats like log piles in desert settings may enhance the number and diversity of reptile species present. This is likely because flora provides a variety of advantages, such as improved food supply, shelter from other animals, and opportunities for behavioural regulation of body temperature (Bradley et al., 2022). As the occurrence of weather extremes is predicted to rise, more focus has been placed on acute community response to climatic extremes, as opposed to chronic community response to average rainfall and temperatures, while determining distributional limitations. As an example, temperature in Florida limits the timing of the crocodile's breeding season, which is later compared to elsewhere in the species range. Based on research this could be the outcome of acute reactions, like crocodile deaths during freezing episodes, and chronic reactions, such as alterations within animals' capacity to reproduce (Mazzotti et al., 2016).

An animal's phenotypic features are influenced by its environment during development. As a result, an organism's phenotype includes both its genetics and the effects of stimuli experienced at a young age. The early developmental phases are frequently the most susceptible to environmental factors. Incubation conditions can have long-term impacts, particularly in external fertilisation, where the eggs develop outside the body of the host. Variations in thermal, hydric, and gas exchange conditions lead to variance in phenotypic features among hatchlings, including sex, size, form, and locomotion and learning abilities (Amiel and Shine, 2012). Difference in temperature has been found to have a direct effect on reptile eggs and hatchlings. Wrong incubation temperatures can strongly affect reptiles' fitness. As lizard hatchlings incubated in higher temperatures seem to have slower growth rates, smaller size and lower mortality rates (Braña and Ji, 2000).

Sea level and temperature rise, saltwater intrusion and storms

Global mean sea level rise is being caused by ocean thermal expansion and ice melt, which affects mostly species that depend on coastal habitats. These effects include salt intrusion into the water table, flooding of coastal areas, and increased coastal erosion (Broderick et al., 2003). Due to various ecological implications on shoreline ecosystems around the globe, all brackish water turtle populations are severely threatened in the entire or a portion of habitat areas. Such taxa suffer a growing proportion of land destruction caused by contamination, soil runoff, and other effects of rapid urbanisation, in addition to loss due to the fishing activities or as a result of being pursued as commercial (Rasmussen et al., 2011).

A prime example of a vertebrate with a pronounced sensitivity to environmental circumstances during incubation, development, and adult life phases is the sea turtle.

For low mortality and a balanced sex ratio turtles need to find new appropriate nesting places, for example coastal forest edges, where temperature is lower as temperature in old nesting places is rising to unhealthy levels (Patricio et al., 2018). In order to nest and lay eggs marine turtles travel great distances to find proper weather conditions and food supply. Therefore, changes in temperature in nesting places may lead to smaller mortality rates of marine turtles. Dramatic changes in weather patterns, habitat loss and vegetation decline have major effects on turtles' growth and body size which affects the amount of eggs laid (Broderick et al., 2003). Rising temperatures are a risk to marine turtles like Pacific loggerhead that are already an endangered species due to pelagic long-line fisheries. Warming sea temperatures cause less food supply and foraging areas for turtles. Marine turtles normally need at least a year to gain the needed body fat in order to lay eggs, but lower food availability leads to longer periods between nesting due to lack of nutrients and fat. If the annual sea temperatures keep rising turtles need to either adapt or find new foraging grounds in colder regions (Chaloupka et al, 2008).

Less is known about how other marine reptiles like estuarine crocodiles or sea snakes are affected by changing climate patterns. Nevertheless, it is known that estuarine crocodiles are firmly connected to temperature and therefore possibly also to changes in it, as temperature affects their sex-ratio, size, colouring and feeding habits. It is not well known what the limits are to changes in crocodile environments and how far on the scale the changes become harmful. This is similar when looking at sea snakes and how much they are affected by global warming. Research shows climatic factors, like sea and air temperatures and frequency of storms play the biggest role in marine reptile survival, but less is known about the threshold of sea snakes and crocodiles than turtles. Future research is needed, in order to understand the total effects environmental changes could have on daily activities, habitation and feeding patterns of these species (Hamann et al., 2007).

Tropical cyclones, which represent one of the most devastating natural disasters around the world, will potentially harm sea turtles by disrupting their environments needed for nesting and due to that increasing localised egg fatality, and perhaps tipping the population structure. As extreme weather conditions are a growing trend this can be devastating for turtles. For these reasons sea turtles are considered a conservation concern and therefore covered by a number of agreements, laws, and treaties. While some groups have begun to recover many turtle numbers seem to continue to drop due to changing environmental conditions. This is due to the fact that they are very vulnerable to climate change due to their life cycle history and physiological characteristics (Fuentes and Abbs, 2010). Tropical cyclones can have a significant impact on other coastal ecosystems, and it is predicted that climate change will affect the severity and spread of these storms. The American crocodile is one example of a species of reptile whose numbers are assumed to be impacted. Tropical cyclones are typically accompanied by torrential rainfall that have a negative impact on hatching success. This is especially noticeable on islands as storms tend to be more harmful and populations smaller, so the effect is more damaging. In order to maximise incoming sun's rays, which are a key heating source for egg incubation in hole-type nests, females choose open places for nesting. As a result of the greater openness of the nesting sites after hurricanes, nests were situated closer to vegetation and trees, to seek protection from heavy winds and flooding. Even though hurricanes seem to be a danger there is also a good outcome by regularly removing unwanted vegetation from certain locations and preserving the open, sandy habitats that American crocodiles prefer for nesting. Threat of hurricanes varies depending on the year but does not seem to have a large impact on the crocodile population survival in long term prospects (Charruau et al., 2010).

Animals with temperature-dependent sex determination (TSD) like crocodilians and some other reptile groups, are particularly susceptible to fast environmental change. In these species, whether an embryo develops into a male or female depends on the temperature it experiences during incubation. Because of this, the thermal regimes brought on by climate change have the potential to significantly affect population sex ratios. This might endanger population persistence and even result in local extinctions. All Crocodilian species that have been studied this far show a pattern of males born at intermediate temperatures, and females at low and high temperatures. As a result, depending on the intensity of temperature changes, climate change may favour males or females in population sex ratios (Bock et al., 2020).

Crocodilians may also be at risk from global warming because it could result in the saltwater inundation of their habitat, particularly freshwater swamps or floodplains, as a result of sea level rise. The majority of species need freshwater environments for breeding and nesting, and as these habitats often exist at low elevations near rivers or coasts, they are vulnerable to impending saltwater inundation. Although saltwater crocodiles have adapted to their salty habitat, as suggested by their common name, some of these species still need continual or frequent access to freshwater for reproducing (Fukuda et al., 2022). Another species threatened by saltwater inundation are Komodo Dragons, which are a unique island-endemic species based in Indonesia and the world's largest lizard. As their habitat range is very restricted, they are especially vulnerable to changes in their environment. The low-lying valleys where Komodo dragons are currently found in the greatest numbers are likely to be submerged by rising sea levels, resulting in a permanent loss of their preferred lowland habitat. Additionally, according to climate change projections, Indonesia will see high rates of temperature increase and rainfall reduction over the course of the next century. This will cause an extended dry season with an increase in the frequency of wildfires and a drop in soil moisture. The mesic forest cover is predicted to decrease, and the amount of drier vegetation communities will increase. By changing habitat and prey availability and having an adverse effect on both survival and reproduction, this vegetation modification is expected to have a severe effect on Komodo dragons. Additionally, the low-lying valleys where Komodo dragons are currently found in the greatest numbers are likely to be submerged by rising sea levels, resulting in a permanent loss of their preferred lowland habitat (Jones et al., 2020).

Arid areas

Species living in arid areas located in low altitude have developed in settings which encounter deadly ground temperatures every day during the summertime, in contrast to higher altitude tropical reptiles that seem to be susceptible to moderate rises in temperature. Ectotherms living in those conditions have a wide range of strategies for avoiding the hot air, such as altering their activity patterns and looking for cover under plants, in cracks and burrows or hiding under sand. These actions may help escape deadly heat and adjust to temperature rises by moving around during earlier times of the day or seasonally. The scant rainfall in deserts controls the supply of water and food resources, therefore changes in yearly precipitation, especially the lengthened and intensified drought periods, might have an immediate and detrimental effect on tortoise ranges (Barrows, 2011; McCoy et al., 2011). The desert tortoise has a range of characteristics that enable it to endure in a dry climate with infrequent rainfall. When it doesn't rain during the active season, animals tend to stay in their burrows, where they don't eat or eliminate wastes like urine or faeces; when it does, they tend to become active, drink rainwater, eliminate wastes like urine and faeces, store fresh water in their bladders, and resume feeding. Making the desert tortoise able to survive rising temperatures, global warming and droughts, but on the contrary frequent and heavy rainfall and extreme storms that can also come with climate change are a great danger to them (McCoy et al., 2011).

According to research, reptiles thermoregulatory strategies may exhibit behavioural plasticity on two timescales: instant and evolutionary. However, prolonged exposure to a constant set of thermal settings might lead to canalised thermoregulatory strategies. Immediate plasticity protects body temperatures from variations in ambient temperature. In a world of abrupt climatic swings, such developmental canalisation may cause issues because of inconsistencies between an animal's strategies and the present thermal constraints it must overcome (Aubret and Shine, 2010).

Researchers observed that sensitivity values differed considerably across Australian elapid snake species, including those with comparable locations that will be subjected to equal degrees of environmental change. They predicted that by the year 2050 many species are at risk of losing their suitable habitat in their current location. Some species like Master's snake (*Drysdalia mastersii*) and the Collared Whip snake (*Demansia torquata*) have characteristics that might make it impossible for them to find new suitable areas or survive in current regions with new unsuitable climatic conditions. Due to their special dietary needs or environmental conditions (Cabrelli et al., 2014).

According to a study on two species of tropical lizards in Northern Mexico, both species are in danger, albeit for different causes. A second species appears to be at a higher risk in the future as a result of changing climatic conditions, while the first is already at a higher risk due to habitat transformation, which may also be made worse by climate change (Ballesteros-Barrera et al., 2007). The variation in rainfall over the course of the year has a significant impact on lizard populations; during the dry period, while food is scarce, growth rates and activity decline. As organisms adjust to seasonal variations in environment features like water content, heat, solar output, availability of food, and predators, habitat utilisation may shift throughout dry and wet seasons (Siliceo-Cantero et al., 2016). With a rise in awareness in thermal niches and global warming over the past 20 years, Mexico and Australia are currently among the nations with the highest volumes of lizard ecology study. Given that these are tropical regions, where lizards will probably be most sensitive to climate change, especially taxa with small geographical ranges, this is not unexpected (Cosendey et al., 2022).

Critically endangered species

The International Union for Conservation of Nature (IUCN) has a combined list of reptile distributions and risk factors made by over 900 specialists all across the World. It identifies the main reasons and the level of vulnerability of species, where their habitats are, which conservation acts are taken etc. More than 10 000 known reptile species are listed in the IUCN red list, of whom 21% are threatened by extinction (Gland, 2022).

There are over 35 terrestrial and marine tropical reptile species that are listed critically endangered due to climatic factors and extreme weather events, figure 1 demonstrates 4 of these species. Three-Banded Centipede Snake (*Tantilla tritaeniata*) is a tropical snake species found only in the forests of Honduras, one of the reasons for the decreasing of this species are increasing extreme weather events due to global warming like storms and flooding. Cuban Crocodiles (*Crocodylus rhombifer*) are a resident of grasslands, forests and wetlands of Cuba, habitat shifting, and alteration caused by climate change is a reason for decline of this species. Giant Bronze Gecko (*Ailuronyx trachygaster*) is a lizard species living in the forests of Seychelles; they are threatened by the increasing number of droughts. Roti Snake-necked turtle (*Chelodina mccordi*) extant in artificial, aquatic and marine inland wetlands of Indonesia and Timor-Leste, this species has many factors for their populations decreasing, climate change being one of them due to habitat changes and alterations, extreme temperatures and droughts (IUCN, 2023; see figure 2).

Figure 2. Critically endangered terrestrial and marine tropical reptile species due to climatic factors and extreme weather events. a) Three-Banded Centipede Snake, photo: Roland Rumm b) Cuban Crocodile, photo: Getty images c) Giant Bronze Gecko, photo: L.Chonseng d) Roti Snake-necked turtle, photo: Pierre de Chabannes

The Three-Banded Centipede snake belongs to the group of Colubrid snakes and are food specialists that only eat centipedes. They are endemic to Guanaja Island of Honduras. In addition to needing a special diet their climatic conditions are narrow (IUCN, 2023). The Cuban crocodile is known to reproduce annually, the time of it is affected by rainfall, available water in water bodies and the atmospheric and water temperature. Their restricted range is one of the primary risks to the natural community. Factors like infrastructure projects, wildfires, water contamination from industrial run-off into their nesting environments, habitat transition brought on by shifting water systems, invasive foreign species of vegetation and animals make them already vulnerable so adding the increasing pace of changes due to climate change could be lethal (Targarona et al., 2010). A significant threat to Roti Snake-necked turtles under global warming is from burning and increasingly frequent prolonged droughts. Turtles spend the dry season in thick vegetation or remain in the water. The responses said that human-caused fires in the surrounding of the water bodies killed or exposed the reptiles to predation. Changes in climatic factors may have a significant impact on how harvest demand is affected. Massive turtle harvesting occasions, in which a large number of turtles are taken in one go, are only permitted during exceptionally dry periods while the water level recedes to its lowest point. A drier environment would result in more significant harvests and fewer relief seasons like deep water limits collection (Eisemberg et al., 2016). Giant Bronze Geckos, a species only found on two islands Praslin and Silhouette, are lizards from the genus *Ailuronyx* endemic to Seychelles Islands. Who live on the highest places of the canopy and feed on plants and insects. They have a small temperature range as the island temperatures are from 24°C to 32°C. In addition, their male and female ratio depends on the incubation temperature of the eggs. Therefore, changing climate patterns and rising temperatures can be dangerous for this species (Rocha et al., 2017). Research about these Critically endangered species is very scarce. Knowledge about their habits, requirements and daily activities is difficult to find and more future research is needed to understand them.

Climate change and its effects on reptile communities and the importance of understanding it is often undervalued. In order to bring attention to how big of a role in ecosystems reptiles play and how much global warming can decrease that value it is necessary to conduct more research and learn also about the threatened and vulnerable species, which have smaller communities not only well-known key species (McDiarmid et al., 2012).

2.4 Effects of climate change on reptiles living in tropical rainforests.

Tropical rainforests

Tropical rainforests presently cover about 12 million square kilometres, which is a third of the forests in the world. Tropical rainforests are mainly found in three areas: South-East Asia, Latin-America and Western Equatorial Africa. Characteristics of such forests are primarily heavy rainfall and constant warm temperatures. These forests are home to many reptiles (Park, 2002). Even though all vegetation changes some of the oldest major vegetation types present on Earth are found in Tropical rainforests. As above 100 million years ago when the first flowering plants first evolved the global climate patterns were warm and wet similar to modern tropical rainforests. Which therefore makes it possible for primitive plants to still grow in these areas (Smith, 2022). In addition to rainforests being one of the oldest ecosystems they are incredibly dense with flora and fauna. More than half of the world`s animal and plant species can be found in tropical rainforests. Biodiversity in those forests has a major impact on the whole planet, as rainforests help regulate and stabilise the climate. (Johnson, 2022)

Rainforests usually have a four-layer structure. Firstly, the top layer is called the emergent layer. This layer is made up of tall trees with a widely spread top in order to catch the sun rays for photosynthesis. Animals that live in these conditions need to be able to climb thin branches and glide or fly. Therefore, animals found in the emergent layer are usually light, for example birds, butterflies, bats and small rodents. Secondly, the canopy layer is composed of densely intervened leaves and branches forming a protective cover over the last two layers. By holding back strong winds, heavy rainfall and sunlight from reaching the lower layers a stable, dim and humid environment is created. Canopy is the layer with most animals, due to rich fruit and leaves which are good sources of food. Thirdly, a layer known as the understory. Plants and animals living in the understory need to be able to survive in even darker, moist conditions as minimal sunlight reaches this layer. Therefore, there is competition for sunlight and survival of flora. These darker low layers offer refuge and hiding places for animals. Canopies and understories are home to many key species and endangered rainforest animals like pythons, gorillas and forest elephants. Fourthly, the forest floor layer, dominated by shallow root systems of the high trees. Is the darkest of the four layers, making it very difficult for plants to grow there. In addition, leaves falling to the ground decay swiftly and do not create much fertile soil. Plants growing in the bottom of rainforest have adapted to getting the nutrients from this unfavourable soil with shallow roots. Due to organic matter falling from upper layers, the forest floor is perfect for decomposers, such as slugs, fungi, worms and termites. Other than decomposers also rodents and reptiles can be found on the forest floor hiding under roots, but even bigger predators such as leopards hunt for their prey in this dark layer (Johnson, 2022; Moeller, 2013).

Climate change in tropical rainforests

Compared to other ecosystems the fastest pace and largest scale extinctions and habitat alterations are taking place in today's tropical rainforests. Losses on this scale have not taken place since the major extinction event over 66 million years ago (Smith, 2022). The main reasons for rainforests disappearing are human actions and climate change. Areas of tropical rainforest are cleared for agricultural and industrial development such as harvesting wood, cattle ranches, roads, mining and hydroelectric dams. Over half of rainforest has already been destroyed since 1947 and due to human population and demand for supplies growing the threat to rainforest is getting bigger every year. (Johnson, 2022). Deforestation is amplified by raising temperatures and fires occurring more often and on a larger scale. These reduce the forests' ability to hold carbon and moisture which leads to poor air quality, drought and loss of biodiversity due to habitat degradation. Furthermore, it is abundantly obvious that current climatic trends have already had a considerable negative impact on species and ecosystems (Boulton et al., 2022). Tropical rainforest zones have already experienced rapid warming and, unexpectedly, a decrease in precipitation. Nevertheless, this decrease in rainfall is only occurring in the tropics of the Northern Hemisphere, there hasn't been much of a shift in the tropics of the Southern Hemisphere. The discrepancy may be related to the higher escalation in aerosol concentrations in the Northern part (Stork et al., 2007). Due to Climate Change, the world's Carbon levels have risen noticeably and continue to rise every year. The efficiency of forests should rise as atmospheric carbon dioxide levels rise due to boost in photosynthetic activity, but this is anticipated to come at the expense of the value and nutritive value of vegetation due to changes in protein and nitrogen phosphorus proportions, as well as decrease in leaf damage tolerance. The canopy animals and insects could be significantly impacted by such alterations (Stork et al., 2007).

Understanding the impact that climate change has on tropical rainforests is necessary as those are the most species rich ecosystems in the world. Tropical rainforests are thought to contain well over half of the world's biodiversity. Over half of the 25 "global biodiversity hotspots" are located in rainforests, where we can find at least 44% of the world's angiosperms and 35% of its vertebrates. Fewer is known about invertebrates, but it is suggested there might be many millions of them found in tropical rainforests.

Further Rainforests play a big role in regulating both carbon and water feedback globally (Corlett, 2011 and Stork et al., 2007).

It has been stressed by many scientists, that climate change has a strong effect on tropical rainforests (Corlett, 2011). As an example, large stretches of the Amazonian rainforest may be replaced by tropical savannahs, according to a research of possible future habitat distributions in South America. This is because of the region's rising temperatures and falling rainfall. Changes in vegetation structure could harm many tropical species even if future environmental circumstances remained the same (Berriozabal-Islas et al., 2018). Resulting in forest degradation, warmer temperatures, droughts and forest fires, causing biodiversity and habitat loss. In addition, changes in compositional dynamics of the whole rainforest community (Esquivel-Muelbert et al., 2018).

Due to climate change even, rainforests do not seem to be suitable for many snake species anymore, as temperatures are too high and rainfalls extremely unpredictable (Freedman et al., 2009). According to findings, some species will totally lose their core environment with an incredibly cautious warming of only 1°C, as well as the range of nearly every other genus will be significantly reduced. The idea that dispersal and environment are closely linked, a presumption that is largely accepted in ecology, underlies the projected reductions in region size with climate change. In terms of how true this premise is for different species, it will undoubtedly have significant variation due to the disruption of other ecological interactions (Williams et al., 2003).

Climate change will not have an equal impact on all reptile species. Some taxa are more sensitive than others, and geographical heterogeneity in the severity of the climatic shift plays a role as well. It has also been hypothesised that tropical species, particularly those found in lowland forests, will be more vulnerable among ectotherms. Due to behavioural buffering, these species could be more vulnerable to increases in mean temperatures and the frequency of heat waves since they are projected to have narrower thermal limitations (Llewelyn et al., 2018).

Effect of changes in weather patterns

As tropical forest reptiles are thermoconformers, due to that they may be particularly vulnerable to rising temperatures. However, higher desiccation rates brought on by these temperatures may make them more susceptible. It is therefore of considerable interest to find out whether the various tropical forest-dwelling reptile species are not just thermoconformers but also hydro conformers, or whether they have behavioural mechanisms that can counteract the combined effects of high temperature and low humidity on desiccation. Although some evidence suggests that greater desiccation levels alter temperature preference and other behaviours that affect water loss, such gaping, it is less clear if reptiles use behavioural hydro regulation to prevent desiccation. Additionally, certain reptiles only engage in activity during periods of significant precipitation or retire to humid burrows during dry periods, which emphasises the potential significance of hydro regulation (Pintor et al., 2016).

Research findings of four congeneric species living in the same area on Bay Islands of Honduras indicate that the susceptibilities to climate change vary significantly, none of the species on these islands seemed to be threatened by dying out due to changing environmental conditions. Thus, it stands to reason that several tropical forest lizards, which are spread on larger ranges, could have even better chances of avoiding extinction. Leading to an idea that tropical rainforest lizards seem to be one of the least affected reptiles, but many other researches have results contradicting this idea (Logan et al., 2013).

Rainforest lizards are expected to be some of the most sensitive tropical species, firstly, these reptiles are currently found in the coolest region of the tropical region and therefore are unable to migrate to colder locations. Consequently, overheating might quickly pass their thermal optimum and severely lower their functionality. Secondly, despite the fact that several types of lizards that live in forests and open areas coexist now, they reduce rivalry by dividing the area along a climatic niche axis. Rising temperatures might change these niches and make them also suitable for open area species, leading to clashes between species (Logan et al, 2015). Climate change poses a threat to lizards living on lower altitudes that reside in neotropical woodlands; in reality, many populations are possibly in danger. During the summertime these species, are at their physiologically optimal core temperature. The cumulative consequences of rising competition and attack from predators in open areas will further exacerbate issues for forest reptiles and might have a significant impact on the predator prey connections in rain forests. Furthermore, recent increased temperatures have possibly already impacted the productivity of certain taxa. Concerns about the reptile susceptibility have been highlighted in several investigations. In addition, it has been previously noticed that lowland rainforest lizard populations are declining in Costa Rica. These forecasts and patterns are alarming since these areas are hubs of biodiversity (Huey et al., 2009).

Precipitation regime is clearly important for *Xenosaurus* lizards, as shown by the factors that most significantly influence the climatic niche models, research results also show that a decline in precipitation conditions for this species in the region they inhabit is expected under all scenarios, creating more hostile environments for the lizards. The low values obtained from the indices of climatic similarity among the *Xenosaurus* species show that they could respond to local environmental changes. based on observations these lizard species will experience severe reductions in their acceptable climatic area due to climate change. The ability to migrate to new places, the structure of the vegetation, the rate of dispersal, the ability to withstand heat, and changes in the size of the biotic niche are some of the elements that affect the survival of the species (Berriozabal-Islas et al., 2018).

Depending on their reproductive strategy, individual snake species experience varying effects from temperature and humidity differently. When temperatures rise and precipitation falls, oviparous snakes' reproductive rates suffer because their nests no longer have the humidity, they need for egg development during the embryonic stage. Increase of forest temperature leads to the rise in body temperature which can encourage significant metabolic expenses that can cause the death of mothers and their offspring. Although variations in temperature and precipitation typically have a negative impact on both reproductive groups' physiological mechanisms, viviparity offers significant benefits because mothers can minimise the impacts of environmental constraints using precise behavioural regulation of body temperature. Accordingly, research demonstrates that snake species can experience significant range shifts as a result of anticipated changes and losses of climatically suitable habitats in the Atlantic Forest, with the majority of species experiencing span reductions near their distribution areas. The snakes which are most in danger seem to be amongst oviparous species. In these situations, the degree of physiological and phenotypic plasticity, evolutionary adaptability of each species to changing environments will determine the survival of animals in their native habitats. However, snakes' ability to adapt their behaviour to less-than-ideal temperature circumstances appears to be severely constrained. Additionally, because of the greater temperature uniformity among these habitats, reptiles in tropical forests have fewer alternatives for thermoregulation. Due to their limited heat tolerances, tropical rainforest reptiles are more susceptible to climate change and have a smaller thermal safety buffer. The requirement for nutrition and tolerance to famine in these snakes should grow as a result of the significant increase in their metabolic rates brought on by climate change. This could likely result in a decrease in the energy available for breeding (Lourenço-de-Moraes et al., 2019). Climate change comes with an increase in storms. Especially brutal are tropical cyclones, that affect different areas and species. Cyclone influence differs on location openness and topography of the area including downwind exposure and topographical shade. Very powerful cyclonic winds, nevertheless, can overwhelm the shielding advantages. Because of their lesser vegetation density and aerodynamically clean canopy, highland rainforests at higher altitude are typically more resilient to storms over low - lying jungles (Reside et al., 2014).

Habitat degradation and modifications to survive it

Many rainforests are being fragmented or even destroyed due to anthropogenic climate change. The vulnerability of reptiles to changes in environmental conditions and habitat degradation, the impact of the surrounding matrix, as well as the taxonomic variable ranges due to their distinct needs and life histories appear to be the key factors influencing the diversity and abundance observed in fragmented rainforests. When contrasted to reference locations, variations in species composition and diversity on the patch size gradient under study may indicate a propensity for nested extinction. It is characterised as succession of mortality, where small area species are the poorest subgroup and the most resilient are found in larger patches. Reptile populations in different tropical fragmented settings have shown the trend (Cabrera-Guzmán and Reynoso, 2012).

Considering climate warming, it is hypothesised that vast tracts of rainforest could serve as sanctuaries for preserving species diversity. According to some calculations, the danger of mortality in the majority of tropical forest regions is even greater. Nonetheless, occurrence of local extinctions does not mean that the species might not be able to persist. Large rainforest areas could make it possible for species to colonise other surrounding locations, but as large areas of rainforest are cut down yearly, reptiles might not have enough suitable areas to migrate in order to find refuge from global warming which might result in total extinction (Pontes-da-Silva et al., 2018).

Successful refugia are places with limited population movement, minimising harmful encounters with invading or novel competing taxa. The relevance of choosing shelter depending on limiting community turnover is contingent on the animals which have been protected as they are more vulnerable as historical data indicates that variable population assemblages are more widespread. It is projected that snake species now found in disturbed and savanna environments may infiltrate the rainforest zone. As canopy cover protects from the heat and holds moisture. These invasive species may have a negative influence on local populations (Freedman et al., 2009). For certain organisms to thrive in the context of global warming, refuge from these invading species is essential. It is demonstrated that native animals living in isolated places, including islands, are more protected from invasions as accessibility is limited and invasive species that do endanger these natives may typically be controlled and eradicated relatively easily (Reside et al., 2014).

It is necessary to have restoration projects, but new plantations and forests might not be habitable for reptile species. Consequently, in tropical areas, diversity of rainforest reptiles increases from ecological restoration plantings to old plantations to rainforest, having the most abundant richness. Changes in plant communities are generally consistent with the utilisation of reforested locations by rainforest reptiles. Research shows that despite such areas having a number of the physical features of a rainforest, no rainforest reptiles were identified in young monoculture or mixed-species timber plantations. As a result, the emergence of rainforest-like structural characteristics in reforested sites seems to trigger a barrier response in these species. Due to its impact on the temperature and lighting conditions in the forest understory, canopy cover may have a direct impact on the suitable conditions for reptiles living in rainforests. Studies on restored mining areas have also revealed that, in comparison to other wildlife, reptiles are notably slower to adapt to restoration. This reaction is thought to be caused by the stagnant rate of establishment of the necessary microhabitats. (Kanowski et al., 2005). Additionally, in a study on secondary forests based in Mexico results show how amphibian and reptile assemblages have changed along the chrono sequence locations under study. It was discovered that there was noticeable species turnover, especially in the reptile assemblages, demonstrating that habitat appropriateness varies along succession (Hernández-Ordóñez et al., 2015).

It is found that there is a significant correlation among amphibian and reptile balance and external conditions. The vegetation cover and density, soil organic cover, and heat are the crucial factors when it comes to their ensembles. Therefore, protecting rainforests and ensuring that these habitat conditions stay good for the species living in these forests should be a conservation concern taken into account when making new plans for the future (Urbina-Cardona et al., 2006). As an example, a good way of creating a better suitable environment and making young plantations habitable for reptiles are logs and woody debris. Which create microhabitats for reptiles to use for nesting, hiding from predators or unsuitable weather conditions. Research shows that plantations with woody debris have a greater comeback of reptile species than other restored forests (Shoo et al., 2014).

Mangrove forests

Mangrove forests are an important ecosystem for both marine and terrestrial species. The importance of mangroves for terrestrial species has been undervalued in the past. providing habitat for an incredible diversity of terrestrial animals, reptiles, and amphibians worldwide Mangroves offer many benefits for terrestrial organisms. In addition to marine reptiles there are many terrestrial species living in Mangrove forests including 118 different species of terrestrial reptiles. It is an excellent place for turtles like Loggerhead Turtle (*Caretta caretta*), Green Sea Turtle (*Chelonia mydas*), Mangrove Diamondback Terrapin (*Malaclemys terrapin rhizophorarum*), there are also many snakes found in Mangrove habitats, for example File Snake (*Acrochordus granulates*), Mangrove Pit-Viper (*Trimeresurus purpureomaculatus*), Mangrove Skin (*Emoia atrocostata*) and a few crocodiles such as Saltwater/Estuary Crocodile (*Crocodylus porosus*) (Rog, 2017 et al.; Rajpar and Zakaria, 2014). Terrestrial animals are recorded to not habit or use these ecosystems in just a small number of locations around the globe, mostly islands with small areas. Studies show a greater diversity of taxa in the tropical mangroves and a lesser diversity in temperate zones.

It is observed that certain organisms benefit from mangroves as feeding areas. In addition, these areas have been documented as being utilised by terrestrial species for mating, dispersal among main habitats, protection against natural irritants and anthropogenic disturbance (Rog, 2017).

Mangrove forests thrive in wet, anaerobic environments that are characterised by elevated salinity, tides, heavy winds, and warm temperatures at the land-ocean transition in tropical and subtropical locations. Mangrove ecosystems are extremely vulnerable to climate change as these ecosystems already live at their limit (Kathiresan and Bingham, 2001). Mangrove forests have a specific tolerance to water level, with high water events or sea level rise these limits are exceeded causing mortality in both animal and plant communities. Due to climate change it is predicted that there will be an increase in storms and cyclones especially in coastal areas, which is the location of Mangrove forests. By dethatching of leaves and plant loss, the rising severity and magnitude of extreme weather events have the ability to worsen the harm done to marshes. Storms can affect the height of the forest sediments by surface runoff, soil accumulation, peat breakdown, and soil deformation which cause tree die-off and sulphide soil poisoning. These factors can permanently affect the whole Mangrove forest ecology (Gilman et al., 2008). Figure 3. Represents the damage done to Florida's Everglades in September 2017 when hurricanes Irma and Maria destroyed large areas of Mangrove forests (NASA, 2017).

Figure 3. Before and After images of Florida's Everglades in September 2017 when hurricanes Irma and Maria destroyed large areas of Mangrove forests. Source: NASA Earth Observatory

Healing after massive hurricanes may take years or even decades, often forests are unable to go back to their original form. After big storms the composition of the forest differs from the before, the trees are damaged, nutrient cycles have changed and many animals have sought refuge elsewhere. This can result in loss of biodiversity in the forests. As reptiles are very sensitive to changes, this can cause mortality in many reptile species habiting Mangrove forests (Baldwin et al., 2001).

Not enough is known about the ecology of rainforest reptiles. The different behaviours, mating and other movements of both rainforest amphibians and reptiles seem to be rather similar but are not abundant to have evidence on how largely they are affected by anthropogenic and environmental stressors, climate change and other contributing factors (Janzen, 2011).

Importance for future

In many cases, it is hard to figure out the immediate and long-term effects of air and water pollution, illness and parasitism, and global warming. Challenges to make changes in the near future will get even bigger. Therefore, it is necessary to make an effort and comprehend these different impacts in order to lessen their effects on reptile communities in the wild and their surroundings, nesting sites and eating habits (Gibbons et al., 2000). Patterns of reptile movements and survival make them reliable ecological indicators of habitat quality and change, consequently, inventory data on species' abundance and even presence or absence, stand to support conservation and management efforts in severely fragmented rain forests (Luja et al., 2008).

3 Conclusions

Based on research and monitoring of reptiles which has been carried out in tropical areas it is possible to speculate that tropical reptiles are facing numerous destructive effects of climate change. Tropical rainforests which are biodiversity hotspots for both reptiles and other animals are disappearing due to global warming. Additionally, various other tropical areas are facing environmental changes including increasing temperatures, extreme rainfall, droughts and large scale of tropical storms. Leading to habitat destruction, invasions, community and ecosystem changes which can cause population declines or in some species extinctions. Reptiles are an important part of a well-functioning ecosystem. Thus, it is important to understand the scale of destruction by climate change on their populations, current research is contradicting, therefore it is difficult to bring out one taxon that is threatened the most, it differs a lot looking at separate species. In order to have more knowledge and make good conservation plans it is necessary to conduct more monitoring programs and include vulnerable and rare species, as currently research about these species is deficient. For future restoration programs to succeed it is necessary to understand the importance of microhabitats and composition of flora for the local reptile species, in order to make the environment suitable for species to relocate to. To avoid extinction events and protect reptiles from the harmful effects of climate change, future experimentation, monitoring and applied research is crucial.

4 Bibliography

Amiel, J. J., & Shine, R. (2012). Hotter nests produce smarter young lizards. Biology Letters, 8(3), 372-374.

Angilletta Jr, M. J., Hill, T., & Robson, M. A. (2002). Is physiological performance optimized by thermoregulatory behavior?: a case study of the eastern fence lizard, Sceloporus undulatus. Journal of Thermal Biology, 27(3), 199-204.

Aubret, F., & Shine, R. (2010). Thermal plasticity in young snakes: how will climate change affect the thermoregulatory tactics of ectotherms?. Journal of Experimental Biology, 213(2), 242-248.

Ballesteros-Barrera, C., MartÍnez-Meyer, E., & Gadsden, H. (2007). Effects of land-cover transformation and climate change on the distribution of two microendemic lizards, genus Uma, of northern Mexico. Journal of herpetology, 41(4), 733-740.

Baldwin, A., Egnotovich, M., Ford, M., & Platt, W. (2001). Regeneration in fringe mangrove forests damaged by Hurricane Andrew. Plant Ecology, 157, 151-164.

Balzotti, C. S., Kitchen, S. G., & McCarthy, C. (2016). Beyond the single species climate envelope: a multifaceted approach to mapping climate change vulnerability. Ecosphere, 7(9), e01444.

Barrows, C. W. (2011). Sensitivity to climate change for two reptiles at the Mojave–Sonoran Desert interface. Journal of Arid Environments, 75(7), 629-635.

Berg, W., Theisinger, O., & Dausmann, K. H. (2017). Acclimatization patterns in tropical reptiles: uncoupling temperature and energetics. The Science of Nature, 104, 1-9.

Berriozabal - Islas, C., Rodrigues, J. F. M., Ramírez - Bautista, A., Becerra - López, J. L., & Nieto - Montes de Oca, A. (2018). Effect of climate change in lizards of the genus *Xenosaurus* (Xenosauridae) based on projected changes in climatic suitability and climatic niche conservatism. Ecology and Evolution, 8(14), 6860-6871.

Bezeng, B. S., Tesfamichael, S. G., & Dayananda, B. (2018). Predicting the effect of climate change on a range-restricted lizard in southeastern Australia. Current zoology, 64(2), 165-171.

Bock, S. L., Lowers, R. H., Rainwater, T. R., Stolen, E., Drake, J. M., Wilkinson, P. M., ... & Parrott, B. B. (2020). Spatial and temporal variation in nest temperatures forecasts sex ratio skews in a crocodilian with environmental sex determination. Proceedings of the Royal Society B, 287(1926), 20200210.

Bonino, M. F., Moreno Azocar, D. L., Schulte, J. A., & Cruz, F. B. (2015). Climate change and lizards: changing species' geographic ranges in Patagonia. Regional Environmental Change, 15, 1121-1132.

Boulton, C. A., Lenton, T. M., & Boers, N. (2022). Pronounced loss of Amazon rainforest resilience since the early 2000s. Nature Climate Change, 12(3), 271-278.

Bradley, H. S., Craig, M. D., Cross, A. T., Tomlinson, S., Bamford, M. J., & Bateman, P. W. (2022). Revealing microhabitat requirements of an endangered specialist lizard with LiDAR. Scientific Reports, 12(1), 5193.

Bradley, R. S., & Diaz, H. F. (2021). Late Quaternary Abrupt Climate Change in the Tropics and Sub‐Tropics: The Continental Signal of Tropical Hydroclimatic Events (THEs). Reviews of Geophysics, 59(4), e2020RG000732.

Braña, F., & Ji, X. (2000). Influence of incubation temperature on morphology, locomotor performance, and early growth of hatchling wall lizards (Podarcis muralis). Journal of Experimental Zoology, 286(4), 422-433.

Broderick, A. C., Glen, F., Godley, B. J., & Hays, G. C. (2003). Variation in reproductive output of marine turtles. Journal of Experimental Marine Biology and Ecology, 288(1), 95-109.

Brown, T. (2022). Climate Change. National Geographic Society.

Böhm, M., Cook, D., Ma, H., Davidson, A. D., García, A., Tapley, B., ... & Carr, J. (2016). Hot and bothered: using trait-based approaches to assess climate change vulnerability in reptiles. Biological Conservation, 204, 32-41.

Cabrelli, A. L., Stow, A. J., & Hughes, L. (2014). A framework for assessing the vulnerability of species to climate change: a case study of the Australian elapid snakes. Biodiversity and Conservation, 23, 3019-3034.

Cabrera-Guzmán, E., & Reynoso, V. H. (2012). Amphibian and reptile communities of rainforest fragments: minimum patch size to support high richness and abundance. Biodiversity and Conservation, 21, 3243-3265.

Carvajal-Cogollo, J. E., & Urbina-Cardona, N. (2015). Ecological grouping and edge effects in tropical dry forest: reptile-microenvironment relationships. Biodiversity and Conservation, 24, 1109-1130.

Chaloupka, M., Kamezaki, N., & Limpus, C. (2008). Is climate change affecting the population dynamics of the endangered Pacific loggerhead sea turtle?. Journal of Experimental Marine Biology and Ecology, 356(1-2), 136-143.

Change, I. P. O. C. (2007). Climate change 2007: The physical science basis.

Charruau, P., Thorbjarnarson, J. B., & Hénaut, Y. (2010). Tropical cyclones and reproductive ecology of Crocodylus acutus Cuvier, 1807 (Reptilia: Crocodilia: Crocodylidae) on a Caribbean atoll in Mexico. Journal of Natural History, 44(11-12), 741-761.

Corlett, R. T. (2011). Impacts of warming on tropical lowland rainforests. Trends in ecology & evolution, 26(11), 606-613.

Cosendey, B. N., Rocha, C. F. D., & Menezes, V. A. (2022). Climate change, lizard populations, and species vulnerability/persistence: trends in ecological and predictive climate studies. Environment, Development and Sustainability, 1-22.

Diele-Viegas, L. M., & Rocha, C. F. D. (2018). Unraveling the influences of climate change in Lepidosauria (Reptilia). Journal of Thermal Biology, 78, 401-414.

Diele-Viegas, L. M., Figueroa, R. T., Vilela, B., & Rocha, C. F. D. (2020). Are reptiles toast? A worldwide evaluation of Lepidosauria vulnerability to climate change. Climatic Change, 159(4), 581-599.

Eisemberg, C. C., Costa, B. G., Guterres, E. C., Reynolds, S. J., & Christian, K. A. (2016). Notes on Chelodina mccordi timorensis Biology, Harvest, Current Threats, and Community Perceptions in the Lake Iralalaro Region, Timor-Leste. Chelonian Conservation and Biology, 15(1), 69-78.

Elder W. (2020). What is Climate Change? National Park Service.

Esquivel‐Muelbert, A., Baker, T. R., Dexter, K. G., Lewis, S. L., Brienen, R. J., Feldpausch, T. R., ... & Phillips, O. L. (2019). Compositional response of Amazon forests to climate change. Global Change Biology, 25(1), 39-56.

Foden, W. B., Young, B. E., Akçakaya, H. R., Garcia, R. A., Hoffmann, A. A., Stein, B. A., ... & Huntley, B. (2019). Climate change vulnerability assessment of species. Wiley interdisciplinary reviews: climate change, 10(1), e551.

Fuentes, M. M. P. B., & Abbs, D. (2010). Effects of projected changes in tropical cyclone frequency on sea turtles. Marine Ecology Progress Series, 412, 283-292.

Fussel, H. M. (2009). An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report. Climatic change, 97(3-4), 469.

Freedman, A. H., Buermann, W., Lebreton, M., Chirio, L., & Smith, T. B. (2009). Modeling the effects of anthropogenic habitat change on savanna snake invasions into African rainforest. Conservation Biology, 23(1), 81-92.

García, A. (2008). The use of habitat and time by lizards in a tropical deciduous forest in western Mexico. Studies on Neotropical Fauna and Environment, 43(2), 107-115.

Gibbons, J. W., Scott, D. E., Ryan, T. J., Buhlmann, K. A., Tuberville, T. D., Metts, B. S., ... & Winne, C. T. (2000). The Global Decline of Reptiles, Déjà Vu Amphibians: Reptile species are declining on a global scale. Six significant threats to reptile populations are habitat loss and degradation, introduced invasive species, environmental pollution, disease, unsustainable use, and global climate change. BioScience, 50(8), 653-666.

Gilman, E. L., Ellison, J., Duke, N. C., & Field, C. (2008). Threats to mangroves from climate change and adaptation options: a review. Aquatic botany, 89(2), 237-250.

Gland. (2022). World's reptiles comprehensively assessed – IUCN Red List. IUCN.

Hamann, M., Limpus, C. J., & Read, M. A. (2007). Vulnerability of marine reptiles in the Great Barrier Reef to climate change.

Hernández‐Ordóñez, O., Urbina‐Cardona, N., & Martínez‐Ramos, M. (2015). Recovery of amphibian and reptile assemblages during old‐field succession of tropical rain forests. Biotropica, 47(3), 377-388.

Hobday, A. J., & Lough, J. M. (2011). Projected climate change in Australian marine and freshwater environments. Marine and Freshwater Research, 62(9), 1000-1014.

Huey, R. B., Deutsch, C. A., Tewksbury, J. J., Vitt, L. J., Hertz, P. E., Álvarez Pérez, H. J., & Garland Jr, T. (2009). Why tropical forest lizards are vulnerable to climate warming. Proceedings of the Royal Society B: Biological Sciences, 276(1664), 1939-1948.

Huey, R. B., & Tewksbury, J. J. (2009). Can behavior douse the fire of climate warming?. Proceedings of the National Academy of Sciences, 106(10), 3647-3648.

Hulme, M., Doherty, R., Ngara, T., New, M., & Lister, D. (2001). African climate change: 1900-2100. Climate research, 17(2), 145-168.

IUCN. (2023). The IUCN Red List of threatened species.

Janzen, P., & Bopage, M. (2011). The herpetofauna of a small and unprotected patch of tropical rainforest in Morningside, Sri Lanka. Amphibian and Reptile Conservation, 5(2), 1-13.

Johnson, J. H. (2022). Rainforest. National Geographic Society.

Jones, A. R., Jessop, T. S., Ariefiandy, A., Brook, B. W., Brown, S. C., Ciofi, C., ... & Fordham, D. A. (2020). Identifying island safe havens to prevent the extinction of the World's largest lizard from global warming. Ecology and evolution, 10(19), 10492-10507.

Kanowski, J. J., Reis, T. M., Catterall, C. P., & Piper, S. D. (2006). Factors affecting the use of reforested sites by reptiles in cleared rainforest landscapes in tropical and subtropical Australia. Restoration Ecology, 14(1), 67-76.

Kathiresan, K., & Bingham, B. L. (2001). Biology of mangroves and mangrove ecosystems.

Laurance, W. F., Useche, D. C., Shoo, L. P., Herzog, S. K., Kessler, M., Escobar, F., ... & Thomas, C. D. (2011). Global warming, elevational ranges and the vulnerability of tropical biota. Biological Conservation, 144(1), 548-557.

Li, S. R., Wang, Y., Ma, L., Zeng, Z. G., Bi, J. H., & Du, W. G. (2017). Thermal ecology of three coexistent desert lizards: Implications for habitat divergence and thermal vulnerability. Journal of Comparative Physiology B, 187, 1009-1018.

Llewelyn, J., Macdonald, S. L., Moritz, C., Martins, F., Hatcher, A., & Phillips, B. L. (2018). Adjusting to climate: acclimation, adaptation and developmental plasticity in physiological traits of a tropical rainforest lizard. Integrative zoology, 13(4), 411-427.

Logan, M. L., Fernandez, S. G., & Calsbeek, R. (2015). Abiotic constraints on the activity of tropical lizards. Functional Ecology, 29(5), 694-700.

Logan, M. L., Huynh, R. K., Precious, R. A., & Calsbeek, R. G. (2013). The impact of climate change measured at relevant spatial scales: new hope for tropical lizards. Global Change Biology, 19(10), 3093-3102.

López-Alcaide, S., & Macip-Ríos, R. (2011). Effects of climate change in amphibians and reptiles. Biodiversity loss in a changing planet, 163-184.

Lourenço-de-Moraes, R., Lansac-Toha, F. M., Schwind, L. T. F., Arrieira, R. L., Rosa, R. R., Terribile, L. C., ... & Bailly, D. (2019). Climate change will decrease the range size of snake species under negligible protection in the Brazilian Atlantic Forest hotspot. Scientific Reports, 9(1), 1-14.

Luja, V. H., Herrando ‐ Pérez, S., González ‐ Solís, D., & Luiselli, L. (2008). Secondary rain forests are not havens for reptile species in tropical Mexico. Biotropica, 40(6), 747-757.

Mazzotti, F. J., Cherkiss, M. S., Parry, M., Beauchamp, J., Rochford, M., Smith, B., ... & Brandt, L. A. (2016). Large reptiles and cold temperatures: Do extreme cold spells set distributional limits for tropical reptiles in Florida?. Ecosphere, 7(8), e01439.

McCoy, E. D., Moore, R. D., Mushinsky, H. R., & Popa, S. C. (2011). Effects of rainfall and the potential influence of climate change on two congeneric tortoise species. Chelonian Conservation and Biology, 10(1), 34-41.

McDiarmid, R. W., Foster, M. S., Guyer, C., Chernoff, N., & Gibbons, J. W. (Eds.). (2012). Reptile biodiversity: standard methods for inventory and monitoring. Univ of California Press.

Mi, C., Ma, L., Wang, Y., Wu, D., Du, W., & Sun, B. (2022). Temperate and tropical lizards are vulnerable to climate warming due to increased water loss and heat stress. Proceedings of the Royal Society B, 289(1980), 20221074.

de Miranda, E. B. (2017). The plight of reptiles as ecological actors in the tropics. Frontiers in Ecology and Evolution, 5, 159.

Moeller, K. (2013). Anatomy of the Rainforest. ASU - Ask A Biologist.

Munoz, M. M., Stimola, M. A., Algar, A. C., Conover, A., Rodriguez, A. J., Landestoy, M. A., ... & Losos, J. B. (2014). Evolutionary stasis and lability in thermal physiology in a group of tropical lizards. Proceedings of the Royal Society B: Biological Sciences, 281(1778), 20132433.

NASA, National Aeronautics and Space Administration. (2017). Images of Change. Hurricane damage to Florida’s Everglades.

Natusch, D. J. D., Lyons, J. A., & Shine, R. (2021). Rainforest pythons flexibly adjust foraging ecology to exploit seasonal concentrations of prey. J. Zool, 313, 114-123.

Nordberg, E. J., & Schwarzkopf, L. (2019). Heat seekers: a tropical nocturnal lizard uses behavioral thermoregulation to exploit rare microclimates at night. Journal of thermal biology, 82, 107-114.

Ornes, S. (2018). How does climate change influence extreme weather? Impact attribution research seeks answers. Proceedings of the National Academy of Sciences, 115(33), 8232-8235.

Park, C. C. (2002). Tropical rainforests. Routledge.

Patrício, A. R., Varela, M. R., Barbosa, C., Broderick, A. C., Catry, P., Hawkes, L. A., ... & Godley, B. J. (2019). Climate change resilience of a globally important sea turtle nesting population. Global change biology, 25(2), 522-535.

Piantoni, C., Curcio, F. F., Ibargüengoytía, N. R., & Navas, C. A. (2019). Implications of climate change on the habitat shifts of tropical lizards. Austral Ecology, 44(7), 1174-1186.

Pintor, A. F., Schwarzkopf, L., & Krockenberger, A. K. (2016). Hydroregulation in a tropical dry-skinned ectotherm. Oecologia, 182, 925-931.

Pough, F. H. (2022). Reptiles, Biodiversity of.

Pontes-da-Silva, E., Magnusson, W. E., Sinervo, B., Caetano, G. H., Miles, D. B., Colli, G. R., ... & Werneck, F. P. (2018). Extinction risks forced by climatic change and intraspecific variation in the thermal physiology of a tropical lizard. Journal of Thermal Biology, 73, 50-60.

Rajpar, M. N., & Zakaria, M. (2014). Mangrove fauna of Asia. Mangrove ecosystems of Asia: Status, challenges and management strategies, 153-197.

Rog, S. M., Clarke, R. H., & Cook, C. N. (2017). More than marine: revealing the critical importance of mangrove ecosystems for terrestrial vertebrates. Diversity and Distributions, 23(2), 221-230.

Rasmussen, A. R., Murphy, J. C., Ompi, M., Gibbons, J. W., & Uetz, P. (2011). Marine reptiles. PLOS one, 6(11), e27373.

Reside, A. E., Butt, N., & Adams, V. M. (2018). Adapting systematic conservation planning for climate change. Biodiversity and Conservation, 27(1), 1-29.

Reside, A. E., Welbergen, J. A., Phillips, B. L., Wardell‐Johnson, G. W., Keppel, G., Ferrier, S., ... & VanDerWal, J. (2014). Characteristics of climate change refugia for A ustralian biodiversity. Austral Ecology, 39(8), 887-897.

Russildi, G., Arroyo-Rodríguez, V., Hernández-Ordóñez, O., Pineda, E., & Reynoso, V. H. (2016). Species-and community-level responses to habitat spatial changes in fragmented rainforests: assessing compensatory dynamics in amphibians and reptiles. Biodiversity and Conservation, 25, 375-392.

Rocha, S., Perera, A., Bunbury, N., Kaiser-Bunbury, C. N., & Harris, D. J. (2017). Speciation history and species-delimitation within the Seychelles bronze geckos, *Ailuronyx* spp.: molecular and morphological evidence. Biological Journal of the Linnean Society, 120(3), 518-538.

Rodrigues-Robles, J.A., Jezkova, T., & Leal, M. (2010). Climatic stability and genetic divergence in the tropical insular lizard Anolis krugi, the Puerto Rican ‘Lagartijo Jardinero de la Montaña’. Molecular Ecology, 19(9), 1860-1876.

Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., ... & Reyer, C. P. (2017). Forest disturbances under climate change. Nature climate change, 7(6), 395-402.

Siliceo-Cantero, H. H., García, A., & Gao, Y. (2016). Abundance and habitat use of the lizard Sceloporus utiformis (Squamata: Phrynosomatidae) during the seasonal transition in a tropical environment. Revista mexicana de biodiversidad, 87(4), 1301-1307.

Shine, R. (2013). Reptiles. Current Biology, 23(6), PR227-R231.

Shoo, L. P., Wilson, R., Williams, Y. M., & Catterall, C. P. (2014). Putting it back: Woody debris in young restoration plantings to stimulate return of reptiles. Ecological Management & Restoration, 15(1), 84-87.

Smith, J. M.B. (2022). tropical rainforest. Encyclopedia Britannica.

Smith, J. B., Schneider, S. H., Oppenheimer, M., Yohe, G. W., Hare, W., Mastrandrea, M. D., ... & van Ypersele, J. P. (2009). Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC)“reasons for concern”. Proceedings of the national Academy of Sciences, 106(11), 4133-4137.

Sun, B., Williams, C. M., Li, T., Speakman, J. R., Jin, Z., Lu, H., ... & Du, W. (2022). Higher metabolic plasticity in temperate compared to tropical lizards suggests increased resilience to climate change. Ecological Monographs, 92(2), e1512.

Stork, N. E., Balston, J., Farquhar, G. D., Franks, P. J., Holtum, J. A. M., & Liddell, M. J. (2007). Tropical rainforest canopies and climate change. Austral Ecology, 32(1), 105-112.

Stromsland, K., & Zimmerman, L. M. (2017). Reptile Immunology.

Targarona, R. R., Soberón, R. R., Tabet, M. A., & Thorbjarnarson, J. B. (2010). Cuban crocodile (Crocodylus rhombifer). Crocodiles: status, survey and conservation action plan. Third edition. Darwin: Crocodile Specialist Group, 114-118.

Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., Van Beek, R., Wada, Y., ... & Treidel, H. (2013). Ground water and climate change. Nature climate change, 3(4), 322-329.

Thackeray, C. W., Derksen, C., Fletcher, C. G., & Hall, A. (2019). Snow and climate: Feedbacks, drivers, and indices of change. Current Climate Change Reports, 5, 322-333.

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: a review. Global change biology, 20(11), 3313-3328.

Ujvari, B., Fisher, P., Rydell, J., Wahlgren, R., Wright, B., & Madsen, T. (2015). Population demography of frillneck lizards (C hlamydosaurus kingii, G ray 1825) in the wet - dry tropics of Australia. Austral Ecology, 40(1), 60-66.

United Nations. (n.d.) Climate Action.

J. Nicolás Urbina-Cardona, Mario Olivares-Pérez, Víctor Hugo Reynoso, Herpetofauna diversity and microenvironment correlates across a pasture–edge–interior ecotone in tropical rainforest fragments in the Los Tuxtlas Biosphere Reserve of Veracruz, Mexico, Biological Conservation, Volume 132, Issue 1, 2006, Pages 61-75. https://doi.org/10.1016/j.biocon.2006.03.014.

Vabrit T. (2014). Kliimamuutused ja kohanemisstrateegiad Eestis ja Euroopa Liidus. Original text in Estonian, translation done in English.

Weiskopf, S. R., Rubenstein, M. A., Crozier, L. G., Gaichas, S., Griffis, R., Halofsky, J. E., ... & Whyte, K. P. (2020). Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. Science of the Total Environment, 733, 137782.

Whitfield, G. J., Luhring, T. M., In, R., & Likens, G. E. (2009). Encyclopedia of Inland Waters, Academic Press, 497-505, 9780123706263.

Williams, S. E., Bolitho, E. E., & Fox, S. (2003). Climate change in Australian tropical rainforests: an impending environmental catastrophe. Proceedings of the Royal Society of London. Series B: Biological Sciences, 270(1527), 1887-1892.

Fukuda, Y., McDonald, P. J., & Crase, B. (2022). Lost to the Sea: Predicted Climate Change Threats to Saltwater Crocodile Nesting Habitat. Frontiers in Ecology and Evolution, 10, 171.

Zlatev, Z., Faragó, I., & Havasi, Á. (2016). Impact of Climatic Changes on Pollution Levels. In Mathematical Problems in Meteorological Modelling (pp. 129-161). Springer International Publishing.

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