Effects of temperature on reptiles and the adaptations for survival

In comparison with endotherms, ectotherms can be found in a diverse range of habitats across the globe; however their dispersion is dependent on the access to sources of heat and their adaptation to their environment. The body temperature (Tb) of reptiles is affected by the surrounding environment from air/water temperatures /substratum they are in contact with. Thermoregulation occurs from behavioural responses to temperature (rather than passive thermoregulation found in amphibians) moving between different locations to find a more suitable climate. Many species have a wider range of tolerance to temperature than originally perceived, a few of which can survive sub zero (Tb). They are termed poikilothermic, using a range of unique adaptations to survive in these diverse environments.

2. 1 Introduction

Reptiles found in a range of diverse environments from the arctic to the equator. Their success and dispersion is dependent on access to external heat sources for their internal processes to operate sufficiently such as homeostasis (Spellerberg, 1973). There is diversity between species of reptile and their tolerance to different temperatures, in warmer climates temperature produces more generalist reptiles as temperature regulation is of lower importance. In comparison, reptiles in cooler climates face a difficult battle with temperatures and are more specialist in their ability to thermoregulate (Segura et al., 2007). The mechanisms used by species to survive in these environments are the main discussion points of this literature review. The adaptations to a variety of temperature and their ability to tolerate such habitats will be investigated.

3. 1 Thermoregulation in Reptiles

Reptiles are poikilothermic and rely on their environment as a source of heat to raise their body temperature (Tb). This is controlled via behavioural processes and these vary depending on the environment they are in. In species of reptiles that have the ability to alter skin colouration such as chameleons, geckos they can produce darker colours to increase the absorption of early morning sun. This behaviour allows them to reach optimal temperatures faster and also reduces the amount of time spent in the open which leaves them vulnerable to predation (Walton & Bennet, 1993). Optimal temperatures allow the reptile to function and metabolise however lower temperatures can slow processes down. Typically the metabolic rate is 10% of the equivalent size endotherm, this is an example of the low cost energy needed to sustain an ectotherm Schmidt-Nielsen (1964).

3. 2 Life at Sea as an Ectothermic; Methods of Thermoregulation

Marine reptiles have a close association with water; in some species they only leave the water to lay eggs. Those that are sea bound do not regularly show typical basking thermoregulatory behaviours. There are some species of marine turtle where there isn’t any proof of behavioural thermoregulation. Bostrom & Jones (2007) results showed that the Leatherback sea turtle (Dermochelys coriacea) can maintain body temperature (Tb) up to 18°C above that of the surrounding sea water. This adaptation allows the leather back turtle to have the widest global distribution of all reptiles. Therefore marine turtles are actually able to maintain body temperatures (Tb) without the need to bask because of the heat produced from the exertion of muscle contraction. Unlike most reptilian species they have insulation under the skin similar to mammals. This insulation of blubber allows the extremities to work in colder temperatures whilst the core temperature is maintained (Davenport et al., 2009). However research of the loggerhead turtle showed that although spending 90% of their time underwater they did spend time at the surface (Hochscheid et al., 2009); this surfacing behaviour could not be linked to thermoregulation behaviour. The turtles dived below a thermocline to access food, where waters could have a significant drop in temperature, therefore the theory is that these turtles are surfacing to increase their rate of heat absorption in the warmer waters. This would compare to the studies conducted by Tattersall et al., (2004) where snakes basked to increase temperature and therefore increase digestion efficiency.

The Yellow Bellied Sea Snake (Pelamis platurus) is an example of a sea snake which is adapted to swim through the water with its dorsally flattened tail used as a paddle to move through the water. It is found in tropical waters and thermoregulates whilst in water; it uses the diversity of water temperatures within a water column to actively alter its internal body temperature. During high temperatures it dives deep to reach cooler waters for periods of time. In comparison when in cooler waters is rises to warmer waters and has been known to bask on the surface, often exploiting its areas of blackened skin which encourages the absorption of heat from the sun (Graham et al., 1971).

3. 2 Surviving the Heat in Extreme Environments

Reptiles' low metabolic rate and various unique physiological attributes have enabled them to adapt to some of the harshest environments e. g. a high temperature habitat such as deserts. A variety of behaviours are exhibited by a range of reptiles attempting to maintain a sufficient (Tb). Although deserts are hot throughout the day and can possibly reach temperatures of 50°C+ they can at night have temperatures that drop to sub zero temperatures, around -5°C in the Sahara. Reptiles have a varied climate to contend with, including the need to maintain correct temperatures in extreme heat but also surviving the cold nights. Therefore sunrise is a prime time for reptiles to warm from the previous cold night. Many species have adaptations that utilise colour change to rapidly increase body temperature. Walton & Bennett (1993) studied the behavioural alteration of skin colour in species of reptile such as the chameleon to increase body temperature and reduce time spent in vunerable basking locations. This method of colour alteration not only increases the (Tb) at a faster rate but also reduces the amount of time in the open reducing the chances of predation.

Many reptiles make use of burrows to escape the daytime temperatures and make use of mammalian burrows to seek cooler temperatures. These burrows act as a microclimate and allow the ectotherms to maintain a temperature whilst the external temperatures remain intolerable. Schmidt-Nielsen (1964) studied the desert iguana (Dipsosaurus dorsalis) which is found in deserts distributed between south-western America and North Mexico. It is efficiently adapted to surviving harsh desert environments. It exhibits bipedal locomotion to sprint across hot sands, this behaviour allows the abdomen to be raised from the ground, removing its contact from the warm air emitted from the substratum. The bipedal locomotion is usually paired with a short period of digging to access the lower cooler sand when attempting to cross larger stretches of hot sands. Water is a scarce commodity in the arid desert environments; consequently the majority of water intake in reptiles is from their diet. Although living in the desert means that water is usually scarce, it is believed that a considerable amount of water intake is from their diet. One species ignores the importance of water and uses it as a product of thermoregulation. The Gila monster (Heloderma suspectum) expels water from its cloaca via evaporation to cool its internal body temperature Schmidt-Nielsen (1964). This method is similar to mammals such as humans which go through the process of sweating to reduce body temperature. As reptiles have no sweat glands this cloacal evaporation shows a direct correlation of use in temperature related intolerable conditions. DeNardo (2004) results showed that evaporative water loss was low at temperatures between 20. 5°C and35°C. The results collated showed a direct affect of (Tb) decrease however it was corresponding with the level of dehydration of the reptile which could, if over used, could pose a fatal threat.

Krochmal & Bakken (2003) discovered a link between viper facial pits and thermoregulation. It is perceived that the thermal sensitive pits on the upper lip of viper primary function are to locate potential prey items. However Krochmal & Bakken (2003) suggest that these facial pits may have been originally for thermoregulation purposes but over time have adapted for prey location as part of an evolutionary advancement. It is believed that initially they were used to locate an ideal site corresponding with the animals thermoregulatory needs. Ideal basking sites would produce larger cues to be detected from this thermal sensitive organ allowing them to select an environment with a preferred temperature in comparison to aiding the organism in prey acquisition.

3. 3 Nocturnal species; how to maintain a body temperature without daylight sun?

Aguilar & Cruz (2010) research revealed that the quality of the daytime refuge is an important factor of nocturnal activity performance. Depending on how warm the refuge is will directly affect their (Tb) and their performance during activity. Nocturnal reptiles are thigmothermic, they attain their heat from surrounding substratum rather than basking under the sun. Throughout the day the substratum temperature is maintained at a higher temperature from the sun even after dusk; during this time nocturnal reptiles become active absorbing heat from their environment. Nocturnal species are more tolerant to low temperatures in comparison with diurnal species (Aguilar & Cruz 2010). Templeton (1970) conducted a study on non-basking thigmotherms i. e. reptiles that had little or low access to sunlight, perhaps blocked out by thick foliage from a forest canopy. The results showed that they have more independence from sun light and can tolerate lower body temperatures.

3. 4 Surviving the Cold Environment as an Ectotherm

Fig. 1. The survival rates of red eared turtles at sub zero temperatures at different lengths of time. From Churchill & Storey., 1992.

Although more associated with hot climates, reptiles, in some species have acclimatised to living in colder environments. Species such as the European adder (Vipera berus), is distributed across temperate regions of Europe and

Asia. They show a tolerance to cold environments and can be found as north as the Arctic circle (Carlsson, 2004). Work conducted by Guisan & Hofer (2003) show that although reptiles can inhabit harsh environments, their success may be due to the ability to inhabit areas with beneficial sunlight capture, angle and substratum, therefore producing a suitable microclimate for them to survive. Besson et al. (2010) state that behaviour is a significant feature of thermoregulation but other physiological attributes aid in adapting to these environments. Small size allows the reptiles to gain larger benefits from short periods of sunlight allowing some reptiles to attend optimal temperatures quickly. To escape colder winter months they enter hibernation choosing beneficial hibernacula. The adder was categorised as virtually non freeze tolerant capable of surviving only a short exposure, not colder than approximately 4°C (Andersson & Johansson, 2001). Supercooling could play a role in winter survival but their precise choice of hibernation site is probably the most important.

Supercooling is a physical process exhibited by a few reptiles and amphibians. It is usually a motionless state where the specimen is able to survive sub zero freezing conditions often including parts of the body freezing. Costanzo et al. (1995) studied the process of supercooling and found that the internal constituents of the organism was associated by a cryoprotectant glucose. Similar research showed that this process also occurred in amphibians such as the wood frog, Rana sylvatica (Dieni & Storey, 2010). A chemical compound was discovered, Glucose-6-dehydrogrenase inside the liver, believed to be a property allowing the frog to be freeze tolerant (Dieni & Storey, 2010). Evidence of this ability has been regularly shown in turtles such as the painted turtle (Chrysemys picta); Storey et al. (1988) showed that the hatchings of C. picta could tolerate temperatures as low as – 4°C for a period of 24 hours. Although this shows tolerance to freezing, time is a critical factor to the survival (Fig 1.) Little is known about the physiological functions of supercooling, further research is needed to provide answers on the role of glucose as cryoprotectants. Further investigation into the properties of glucose as a cryprotectant could prove significant in methods of tissue preservation for hospital procedures and studies (Storey et al. 1988).

4. 0 Reproduction

Unlike other organisms, such as mammals, where sex determination is from the allelic combination from two gametes, reptiles' sex is determined by temperature. Which considering the diversity in environments can lead to complications. Egg laying reptiles are termed oviparous and temperature plays a fundamental role in sex determination. Witt et al, (2009) discovered a sex determining temperature at which anything above would produce females and cooler temperatures would produce males. Oviparous reptiles are usually laid within burrows or nests where temperatures can be maintained. In thermally demanding habitats, the location of the eggs can have a profound effect on the survival chance of the young. Suitable locations for oviposition can be limited therefore it can have a substantial impact on populations (Pike et al. 2006).

Viviparity is a means of embryonic development inside the body of the mother therefore giving birth to live young. As previously discussed, sex in reptiles is determined by temperature however the offspring are warmed by internal temperature. Shine (2006) showed an elevated rise in body temperature whilst gravid to maintain a sufficient temperature for embryonic development. Wapstra (2004) proposed that the female of this species of viviparous lizard (Niveoscincus ocellatus) can influence the sex of their offspring by altering its thermoregulatory behaviours. Viviparous reptiles are often found in the north and can withstand colder temperatures than oviparous reptiles due to the internal thermal regulation of the offspring. There are two species of oviparous snakes in Britain, Natrix natrix helvetica and Coronella austiaca however they manage to combat the cold British climate by ovipositing in a thermally distinctive man-made microhabitat (Lo¨wenborg, 2010). These microhabitats, such as compost heaps, produce enough heat to maintain a temperature sufficient to incubate the eggs.

Fig 2. From Tinkle & Gibbons, (1977)

Viviparity and oviparity in comparison do have their pros and cons (Fig2) however viviparity is often linked with evolution and adaptation to their survival in cold climates (Shine, 1999). However a minority of species have retained oviposition as a mode of reproduction. One example is the female Children’s python (Antaresia childreni) which exhibits parental care of the eggs by coiling around the clutch, altering the external conditions around the eggs like a microclimate (Stahlschmidt & DeNardo, 2010). Pearson et al. (2003) discovered that the carpet python was able to actively warm the eggs by shivering therefore for periods of time it is facultatively endothermic, maintaining heat via thermogenesis.

Conclusion

Reptiles are considered one of the most successful organisms on the planet due to their hardiness to survive and adapt to ever changing extreme environments. They harness diverse adaptations from using cryoprotectants to survive harsh winters to sacrificing vital water to decrease the body in intolerable temperatures. Their ability to survive is unchallenged and this literature review has supported this statement by comparing studies that demonstrated the diversity within this remarkable group of organisms.