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Effects of Climate Change in Amphibians and Reptiles

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1. Introduction

During the past decade it has been documented that the average of earth temperature increased 6 °C in a period of 100 years. The higher amount of this phenomenon has been recorded between 1910 and 1945 and, from 1976 to present date (Jones, 1999; Kerr, 1995; Oechel et al., 1994; Thomason, 1995). From 1976 to present the temperature rising has been the faster recorded in the last 10,000 years (Jones et al., 2001; Taylor, 1999; Walther et al., 2002), and this caused the maximum daily temperature increase in the southern hemisphere (Easterling et al., 2000), as well as a significant temperature increase in the tropical forest areas (Barnett et al., 2005; Houghton et al., 2001; Santer et al., 2003; Stott, 2003). According to projections, the average temperature of earth may increase up to 5.8 °C (Intergovernmental Panel on Climate Change IPCC, 2007) at the end of current century, which actually represents and enormous threat for biodiversity (Mc Carty, 2001; Parmesan & Yohe, 2003).

Although the historical data describes a changing climate during the last 350 million years of amphibians and reptiles history (Duellman & Trueb, 1985), the abrupt rising of the temperature during the last century could have a great impact on ectotherm organisms, which depend of environmental temperature to achieve physiological operative body temperatures (Walter et al., 2002; Zachos et al., 2001). Thus, the accelerated grow of earth temperature could affect physiological, reproductive, ecological, behavioral, and distribution traits among amphibians and reptiles (Cleland et al., 2006; Dorcas et al., 2004; Pough, 2001; Gvozdik & Castilla, 2001). In this context, a review of the published studies is necessary to evaluate and summarize the evidence of climate change effects in amphibians and reptiles. This review should provide an overview that should be helpful for researches, students, and policy makers, in order to address how climate change affects amphibians and reptiles, and the possible responses of these organisms to climate change.

Due to the available published information are not equal for amphibians and reptiles, the present chapter are divided in two: amphibians and reptiles. In each chapter subdivision a physiological, reproductive, and distribution effects are issued as long as information was available. Additional information in amphibians such as synergic effects of environmental factors due climate change, and evolutionary adaptations are addressed. At the end of the chapter a conclusion section is added in order to summarize the most important trends addressed in this review.

2.1 Amphibians

Amphibians are very susceptible to environmental variation since they have permeable skin, eggs without shell (not amniotic eggs), and a complex life cycle that expose them to changes in both the aquatic and terrestrial environment (Blaustein, 1994; Blaustein & Wake, 1990, 1995; Vitt et al., 1990), also they are particularly sensitive to changes in temperature and humidity, as well as to exposure to large doses of UV radiation (Blaustein & Bancroft, 2007).

During the last twenty years a decline o of more 500 populations of frogs and salamanders has been documented (Stuart, 2004; Vial & Saylor, 1989). The reasons for this decline stills unclear because of the factor complexity and their interactions (Alford & Richards, 1999; Blaustein & Kiesecker, 2002; Kiesecker et al., 2001). However many cases of species decline share ecological traits, life histories or demographic traits such as: 1) high habitat specialization, 2) reduced population size, 3) long generation time, 4) fluctuating abundance, 5) low reproductive rate, and 6) complex life cycles. These characteristics suit species more vulnerable to threats (Reed & Shine, 2002; Williams & Hero, 1998). The traits alone may not cause the decline, but cause that organisms become more vulnerable after an initial perturbation like the rise of environmental temperature (Lips et al., 2003). Climate change may have adverse effects by itself on the survival, distribution, reproductive biology, ecology, physiological performance, and immune system of organisms when they are exposed to higher environmental temperatures or dryness (beyond their threshold of tolerance). Also, the effects of climate change could act in synergy with various biotic and abiotic agents like diseases and infections, intense UV radiation, habitat loss, exotic species (competitors and depredators), and chemical pollution (Young, 2001, as cited in Lips et al., 2003).

2.1.1 Physiological performance

There are basic physiological aspects of amphibians that are highly sensitive to temperature increase; first water balance due to their permeable skin and high evaporation rates (Shoemaker et al., 1992), second since amphibians are poiquiloterms[1], the thermoregulatory performance are related to the water balance, digestion, oxygen supply, vision, hearing, emergence from hibernation, development, metamorphosis, growth, and immune response.

Amphibians do not perform physiological process when they are near of their critical body temperatures, instead they are able for perform many functions in suboptimal temperatures and do not exhibit a unique thermal optimum. Therefore, temperature may strongly influence on species' geographic distribution, so on the amphibian's distribution limits are determined by the extreme temperatures, in consequence the species that with broad tolerance to thermal regimens should be able to expand their ranges and then colonize new habitats. Finally, the two processes that are more sensitive to changes in temperature in amphibians are reproduction and development (Berven et al, 1979; Rome et al., 1992). The hormonal regulation of reproduction are affected by temperature, then an increase in temperature could affected the reproductive cycles of amphibians due to changes in the concentration of the hypothalamic hormone (GnRH) which acts directly on the gonads (Herman, 1992; Jorgensen, 1992).

Considering the information presented above, there are four aspects of climate change that could strongly affect the physiological performance in amphibians: 1) temperature increase,

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[1] For which the temperature determines the appropriate functioning of many processes that have different thermal sensitivities.

2) the increase of the dry season length, 3) decrease of soil moisture (due changes of precipitation and temperature rise), and 4) increase in rainfall variation. This would affect organisms at population and community levels. As an example Carey & Bryant (1995) found that the individual growth rate, reproductive effort, and life span could change, with a parallel change in the activity patterns, microhabitat use, and thermoregulation.

2.1.2 Reproductive biology and phenology

The increase of temperature and thermal variation are the basic signal for emergence and reproduction in anurans, particularly in species from temperate zone (Duellman & Trueb, 1986; Jorgensen, 1992). Climate change linked with other factors such as photoperiod (Pancharatna & Patil, 1997) may affect the breeding patterns of amphibians. Amphibians in Canada are affected by the precipitation decrease and increased temperatures during summer (Herman & Scott, 1992; Ovaska, 1997). In The United Kingdom there has been evidence of early oviposition in *Bufo calamita*, *Rana sculenta* and *Rana temporaria* between 1978 and 1994, which is correlated with the increase of spring temperatures during the last 20 years (Beebee, 1995; Forchhammer et al., 1998). Also, an earlier beginning in the oviposition period (2 to 13 days between 1846 and 1986) in *Rana temporaria* in Finland has been recorded and correlated to changes in air and water temperature (Terhivou, 1988). Historical and recent climate data from Ithaca, New York suggest that the temperature rising during the 20th century has changed the matting patterns of *Pseudacris crucifer*, *Lithobates sylvaticus*, *Lithobates catesbeianus*, and *Hyla versicolor*, by promoting the vocalization behavior for 10 to 13 days earlier than the expected from historical data (Gibs & Breisch, 2000).

In addition, it has been proposed that the change in precipitation patterns (Duellman & Trueb, 1985) can affect the reproductive phenology of amphibian species that breed in ponds. If ponds are filled latter in the season, then the short water permanence should lead to an increase in competition and a higher predation rate. Meanwhile organisms are concentrated in the remaining ponds and they are more vulnerable diseases outbreaks. Changes on amphibian's phenology could present complex effects over populations, changing the population structure, and then a rapid decline of sensitive populations (Donelly & Crump, 1998).

2.1.3 Distribution

It has been suggested that climate change is the cause of species migration to higher altitudes and latitudes, and then the subsequent shrinkage or loss of amphibian populations and distribution (Pounds et al., 1997). Exploring the relationship between current amphibian distribution and the possible effects of global warming on species distribution in order to build distribution models based on different algorithms such as GARP or MAXENT (Stockwell & Peters, 1999), neural networks, and generalized lineal models (Thuiller, 2003), It would possible to model for the basic conditions for the species to survive. General models of amphibians in Europe suggest that a large portion of species could expand its distribution along Europe if they are able to disperse unlimited, but if species are not capable to disperse, the distribution range of most of the species could be drastically reduced. This scenario could be the most likely because the current levels of habitat fragmentation and degradation, especially in the aquatic habitats. According to the projections of Araujo et al. (2006) the majority of the amphibian species from Europe could lost most of their distribution areas for 2050. This supports the hypothesis that climate change will cause the future decline of amphibian's populations. As an example, the pletodontid salamanders of the central highlands of Mexico *Pseudoricea leprosa* and *P. cefalica* could face important levels of habitat loss for the increased rise of temperature. Models predict that *P. leprosa* could possible loss the 75% of its distribution range for the year 2050 (Parra-Olea et al., 2005). These salamanders have limited dispersal behavior; so on they must face the loss in its distributional range in situ (Easterling et al., 2000; Mc Carty, 2001).

2.1.4 Synergy with biotic and abiotic factors (diseases, infections and physiological performance)

It is clear that the amphibians survival is linked to abiotic factors such water availability, the increase in temperature (Pouns et al., 1999; Pounds, 2001), and the increase in cloud cover (Pounds, 2006) could alter weather patterns and hydrology of the places when amphibians inhabit. The association of this factors with the exposure to higher doses of UV-B radiation due the thinning of the ozone layer (Kiesecker et al., 1995), and the interaction with biotic (diseases and infections), and physiological performance (immune system and tolerances thresholds) could be the main precursors of the events that cause widespread mortality in amphibians and the decline of their populations.

The emergence of disease and infections outbreaks due climate change is related with the decline of several amphibian species (Pounds, 2006). The link between climate change and the coming out of epidemics in amphibians and their subsequence decline has been attributed to the changes in environmental conditions that enhance outbreaks (Pounds & Crump, 1994; Pouns & Puschendorf, 2004). As temperature increases amphibians can exceed their physiological tolerance limits, therefore pathogens could reach their suitable thresholds, and outbreaks should be suited with faster dispersion at high temperatures (Epstein, 2001; Harvel et al., 2002; Rodo et al., 2002). A significant association between rises of local temperature (until thermal optimum levels) with occurrence of chytridiomycosis outbreaks in temperate zones has been described (Bosch et al., 2007). In the Peruvian Andes, the ponds originated by the water of the melting glacial retreat are colonized by three species of frogs *Pleurodema marmorata*, *Bufo spinulosus*, and *Telmatobius marmoratus*, and subsecuenty by the pathogen *Batrachochytridium dendrobatidis* (*Bd*), which possibly causes dead in the adults and declines in metamorphic juveniles and tadpoles. The *Bd* outbreak could be related with the rise of temperature in the ponds, with a subsequent achieve of the tolerable levels by *Bd* (Seimon et al., 2007). Therefore, the amphibian decline are consequence of a complex multifactorial processes that are related with host and parasites, since there is a synergic effects in life histories of hosts and parasites, because both are influenced by the same factors: humidity and temperature (Lips et al., 2008).

2.1.5 Thinning of the ozone layer and UV-B radiation

It has been suggested that climate change can work in synergy with the ozone layer reduction to increase the exposure of organisms to UV-B radiation (Blustein et al., 1994a, 1998; Schindler et al., 1996; Yan et al., 1996). Worrest & Kimeldorf (1976) found that high levels of UV-B radiation (290-315nm) cause developmental abnormalities and mortality in *Bufo boreas* tadpoles before metamorphosis. Therefore amphibians that breed in mountain aquatic habitats such as temporary ponds or lakes can be quite susceptible to increased levels of UV-B radiation. Because amphibian embryos develop in shallow lakes and mountain ponds are often exposed to direct sunlight, and therefore, considering the reduction of the ozone layer and higher doses of UV-B radiation (Stebbins, 1995). A deeper water column can reduce UV-B radiation, but in sites/localities with decreased rainfall per year, and the subsequent shallowness of ponds or streams an increase in the embryos exposure to UV-B radiation is expected. In the Pacific Northwest an outbreak of *Saprolegnia ferax* was described as the cause of extensive mortality of *Bufo boreas* embryos in shallow waters, also the exposition to higher levels of UV-B radiation causes that amphibian embryo more sensitive to infection by pathogens (Blaustein et al., 1994b; Kiesecker et al., 1995; Kiesecker et al., 2001; Laurance et al., 1996; Pounds et al., 1994; Pounds, 2001).

In spite of this, it has be found significant variation among species in the activity levels of photolyaze, an enzyme that repairs DNA for damage caused by UV-B radiation (Hays et al., 1996). The hypothesis of UV-B radiation sensitivity predicts: 1) Significant differences between species of amphibians in relation to the photolyaze repair activity in eggs, and differential success between clutches exposed to solar radiation, 2) a correlation of these differences to the extent of exposure of eggs to sunlight, and 3) high-repair activity in species that are not in decline compared with those declining. Blaustein et al. (1994b) reviewed 10 species of amphibians in Oregon. The enzyme activity was higher in species that are not declining and low in declining species. Field experiments showed that in *Hylla regilla* embryos, a species that is not in decline had high activity of photolyaze with higher clutch success, differing from two species in decline (*Rana cascadae* and *Bufo boreas*) with low levels of photolyaze activity (Blaustein et al., 1994b).

2.1.6 Other climatic variables and their influence on amphibian's declines

It has been suggested that the cause of exposures of amphibian embryos to UV-B is not the thinning of the ozone layer, but the unusual weather patterns such as high temperatures, which is linked with the assumption that the increasing frequency and intensity of El Niño Southwester Oscillation (ENSO) phenomenon as a result of climate change, inducing a high embryo mortality in the Pacific Northwest amphibians (Kiesecker & Blaustein 1997, 1999). In extremely dry and warm years a large proportion of the oviposition sites of *B. boreas* recorded very low levels of water depth, causing that aquatic habitats provide few protection against UV-B. In shallow water (20 cm.) filaments of *S. ferax* attack up to 80% of the embryos on average compared to 12% at 50 cm of water depth. Otherwise, the exposure of organisms to extreme temperatures may be an alternative explanation for the increased mortality of amphibian embryos in shallow waters (Pounds, 2001). The alteration of precipitation patterns may be related to the occurrence of ENSO, in this way, the increased frequency and magnitude of this phenomenon can increase the incidence and severity of *S. ferax* outbreaks (Kiesecker & Blaustein, 2001).

In addition to the evidence mentioned above there are some other hypothesis that predicts the highlands clime alteration by the rise of temperature in the sea surface due the evaporation increase sea surface in the tropics, this trend accelerates the atmospheric warming of the nearby highlands (Graham, 1995). One of these scenarios is "weather-related outbreaks" (Pounds & Crump, 1994), which predicts that the host parasite relationships are affected by climate, so amphibian mass extinctions in forests areas that apparently have no significant disruption could be evidence of how deep and unpredictable climate change result of warming sea surface alter the ecological interactions and generates potentially devastating effects. The case of the Harlequin Frog (*Atelopus varius*) could be considered under this situation. As climate increased since 1983 in the localities when this frog was distributed, the increased of vulnerability to this frogs to lethal parasites also increased, with the subsequent loss of several populations of this frog (Crump & Pouns, 1985, 1989). Finally it has been suggested that as the habitat dries up and frogs gather near the available waterfalls, the probability of being attacked and infected by parasites increase, resulting in high mortality (Pounds et al., 1999).

2.1.7 Increased cloud cover

The Chytridio fungus pathogen is distributed from the deserts, rain forests in the lowlands to the cold mountains enviroments (Ron, 2005). It is consider as a non-lethal saprophyte parasite (Daszak et al., 2003, Retallick et al., 2004), which grows in the amphibian skin (Berguer et al., 2004; Piotrwski et al., 2004). However this fungus has become more common recently, with an increase of lethal records in places with low climate temperatures (Daszak et al., 2005; La Marca et al., 2005). This pathogen has been associated with amphibian mortality in upland regions even during winter (Alexander & Eischeid, 2001; Berguer et al., 2004). The global warming has been considered as a key factor in the spread of the *Bd*, and then the decline of amphibian populations, because of the sequence of events that propitiate the parasite development (altering the local temperature though the effect of changing ambient humidity and light) causing favorable conditions for the fungus growth and propagation.

Linked with the increase of the fungal infection, it is important to understand how environmental changes affect the immune system of amphibians. Environmental temperatures have a large effect on amphibians' immune system, and this is an important factor that makes them more susceptible to the emergence of pathogens (Carey et. al., 1999; Maniero & Carey, 1997; Rojas et al., 2005). The effects of temperature on the amphibian susceptibility to the outbreaks caused by the *Bd* fungus, which causes high mortality at low temperatures is a basic research issue that should be addressed to understand interactions between amphibian decline and climate change (Berguer et al. 2004; Woodhams et al., 2003). Immunity in ectotherms organisms depends on temperature, which can be decisive for the dynamics of disease in amphibians, especially in temperate regions. Seasonal changes in temperature can cause short-term decrease in optimal levels of immunity, causing a drop in the production of immune system cells during these periods until the organisms achieve to adapt as predicted by the hypothesis of the delay and the hypothesis of seasonal acclimatization (Raffel et al., 2006).

As an example, the Red-Spotted Newt (*Notophthalmus viridescens viridescens*) shows considerable variation at their basal levels in different immune parameters (lymphocytes, neutrophils and eosinophils) when they are affected by significant thermal variation. These findings suggest that temperature variability causes an increase in the susceptibility of amphibians to infection, and this has important implications for the emergence of diseases. The effects of delay and acclimatization may also cause infections after the unusual climate change, or could turn the evolution of parasites life-history strategies to take advantage of periods where host are more susceptible. Finally the increased variability of weather conditions predicted by the climate change scenarios could lead to longer or more frequent periods of immune suppression in amphibians which may increase their decline (Hegerl et al., 2004; Schar et al., 2004).

2.1.8 Consequences of climate change on the ecology of amphibians

It has been suggested that the climate change and its interaction with several factors could easily cause the disappearance of rare, endemic, and isolated species compared with common and broad distributed species with numerous sub-populations which are less threatened (Davies et al., 2000). Endemic species use to have unique environmental specializations, and the possibility of losing them could be higher (Grimm, 1993). It is predicted that populations of amphibians at the edges of their distributional ranges may be particularly vulnerable to changes in local and global climate (Pounds and Crump, 1994; Wyman, 1990). Therefore anurans assemblages may be dominated by species with wide ranges of ecological and physiological tolerance. Also, if weather patterns changes, some regions may be affected by the decreasing in the abundance of terrestrial invertebrates (basic diet of amphibians; Blaustein & Kiesecker, 2002; Bradford, 2002; Kiesecker & Blaustein 1997a). Populations also could be affected by changes in births, mortality, emigration, and immigration rates. This can alter the operational sex ratio, age-population structure, and genetic variability. If the population size declines, the young frogs can grow more slowly than adults and reduce the energy allocated to reproduction (Stearns, 1992).

I has been speculated that terrestrial frogs of the dry zones of the world could be forced to use the fewer wet areas available, consequently this large aggregations would propitiate higher contact between individuals and thus more vulnerability to parasites and predators, as has been demonstrated for *Atelopous varius* in Costa Rica (Pounds & Crump, 1987). Species with continuous reproductive cycle may experience a reduction of the breeding season, restricting the oviposition to wet periods only. In environments with unpredictable rainfall patterns, the frogs may experience hard times locating the adequate ponds for their larvae, and therefore populations of these species could decline more rapidly (Alford & Richards, 1999; Berven & Grudzien 1990; Gulve, 1994; Sjogren, 1991).

2.1.9 Climate change and possible evolutionary adaptations of amphibians

To understand the relationships between the biotic and abiotic factors causing the amphibians decline must be considered five evolutionary principles: 1) the development is limited by historical constraints, 2) not all evolution is adaptive, 3) the adaptations are often linked through trade-offs, 4) the development could only alter existing variations, and 5) the evolution takes a lot of time! Therefore, in an evolutionary context although amphibians have been exposed to sunlight and UV-B radiation through its evolutionary history, by now they are facing an unprecedented situation that put them at risk (Cockell, 2001). For example behavior, morphology, and lifestyles that have enabled them to persist for millions of years, today could be highly risky because exposure to sunlight involves receive high doses of UV-B radiation that cause mutations and cell death, decrease growth rates, disable the immune system (Trevini, 1993). Thus in the context described above, the exposure to UV-B radiation can be especially harmful to those species in which natural selection shaped behavioral strategies necessarily exposed to relatively high doses of solar radiation (e.i. species they have to put their eggs in water). In addition, many other selection pressures (biotic and abiotic) are intense and relatively new (i.e. chemical pollution, disease, etc.). Although these might cause a relatively rapid change in some populations, while other threats such as the emergence of infectious diseases combined with environmental changes can be so intense that amphibians cannot adapt to them (Kiesecker & Blaustein, 1997b). Since not all evolution is adaptive, as showed the evidence that in several species of amphibians still lay their eggs in shallow water and communal masses, exposing them to potentially harmful agents such as UV-B, exposure to temperatures that exceed their tolerance limits and conditions (Romer, 1968). Such behavior probably has persisted over millions of years, but under current conditions these behaviors may cause the damage by a large number of elements such as those mentioned above. Amphibians exhibit maladaptive characteristics because the evolution takes time. Obviously, amphibians, and other organisms have defenses against the harmful factors. Exposure to sunlight over evolutionary time has undoubtedly resulted in mechanisms that help animals to withstand UV-B radiation (Cockel, 2001; Hoffer, 2000).

2.2 Reptiles

As we mention before the global modification of ecosystems has been induced the global warming and is identified as a significant and immediate threat that could radically affect the ability of species to survive. It is of great interest the ability of species to adjust to changes in the thermal environment, habitat structure and other fundamental niche axis. For terrestrial ectotherms, an increase in average temperature may affect their spatial distribution, physiological performance, reproductive biology and behavior (Dunham, 1993; Grant & Porter, 1992). As reptiles depend of external heat sources to regulate their body temperature climate is a key factor influencing the distribution and abundance of species (Pough, 2001; Zug, 1993).

In contrast to the work conducted with amphibians, which has been extensive research on biological and ecological consequences of climate change, reptiles provide a scenario with broad potential. Although there are studies that suggest interesting perspectives on the issue, and then are exposed works concerning on the effects of ecological, physiological, reproductive, behavioral and evolutionary change in reptiles.

2.2.1 Physiological performance in reptiles and climate change

There are proposals that combine the spatial and temporal variation with the physiological (speed and strength) and morphological traits (shape of limbs) ecologically relevant. For example, in the *Urosaurus ornatus* lizard has been measured the speed and endurance of various populations, as well as the shape and size of their limbs through the altitudinal range where lizards are distributed. This lizard exhibit significant variation in the shape of his limbs corresponding to available perch types for each population, speed, and endurance. Thus the possible change in habitat structure and thermal regimes could result in an alteration of development patterns of lizards and cause changes in body shape and size of adults and in the way they use their habitat, behavior strategies, and physiological performance. Under this scenario only some population would be at risk, even though their evolutionary responses are consider slower compared with the speed of environmental change (Miles, 1994). On the other hand, long-term experimental studies with young *Notechis scutatus* snakes in enclosures with cold (19-22°C), intermediate (19-26°C), and hot (19-37°C) thermal gradients, suggested that these snakes compensated restricted thermal opportunities, although behavioral plasticity depending on thermal environment experienced to birth, therefore these conditions influenced subsequent thermoregulatory strategies (Aubret & Shine, 2010).

2.2.2 Life histories and distribution

In relation with the impact of climate change on the life-history of reptiles, there have been some changes in traits of species with limited dispersal ability such as *Lacerta vivipara*, which lives in the isolated mountain peaks of the southern Pyrenees (Chamaillé-Jammes et al., 2006). According to the author’s records individual body size increases dramatically in four populations studied for 18 years. Body size increase in all age classes appears to be associated with an increase in temperature experienced by the offspring in their first month of life (August). The maximum daily temperature in this region during August raised 2.2 °C and lizard snout-vent length increased over 28%. As a result, body size of adult females increased dramatically, with the following increase of the litter size and the reproductive effort. One of the populations surveyed by a capture-recapture study suggested that adult survivorship was correlated with May temperature. All the fitness components investigated responded positively to increase in temperature, so it can be concluded *Lacerta vivipara* has obtained benefits of climate change. Instead, it is possible that climate change drastically alters the marshes, the main habitat for the *Lacerta vivipara*, due to temperature increase could cause more evaporation and reduces its moisture (IPCC, 2001), and the species may not be able to cope with changes in their habitat. (Chamaillé-Jammes et al., 2006). Araujo et al. (2006) also suggest that a continuous increase in temperature could cause a long-term contraction in suitable habitat for lizards and therefore increase the risk of local extinction.

2.2.3 Thermoregulatory behavior and global warming

Global warming and the potential reduction in areas with suitable characteristics for the distribution of the lizard *Heteronotia binoei* was calculated the climate component of their fundamental niche through physiological measurements (thermal requirements for egg development, thermal preferences, and thermal tolerances). The environmental data analyzed was high-resolution climate data from Australia (air temperature, cloud cover, wind speed, humidity, radiation, etc.), and biophysical models projecting over the Australian subcontinent to predict the effects of global warming. Estimates predict relatively little effect on the maintenance of metabolic costs, mainly due to the buffering effect of thermoregulatory behavior of lizards. The lizards could be able to regulate their body temperature (and their metabolic rates) moving between thermally suitable places at the surface (shuttling), as has been shown for the nocturnal ectotherms, and other diurnal lizards like *Psammodroums algirus* in the Mediterranean region of Spain (Diaz & Cabezas-Díaz, 2004; Kearney & Predavec, 2000). On the other hand, lizards also should evade high thermal environments hiding in shelters in the hottest hours of day (Kearney, 2002), and changing their daily and stationary activity periods (Bawuens et al., 1996), and their habitat selection (Stevenson, 1995).

2.2.4 Effects of climate change on reproductive biology of reptiles

Climate change is a threat to reptile populations due that in some lineages the temperature experienced by embryos during incubation determines the offspring sex ratio. Increases or decreases of temperature could turn to bias in the proportion of the clutch toward one sex. Nests exposed to an increase heat produced dramatic differences in sex ratios compared to those placed in shaded sites (Doody et al, 2004; Janzen & Morjan, 2001; St. Juliana et al., 2004). For this reason reptiles can useful as indicators of biological impact due global warming (Janzen & Paukstis, 1991; Mrosovky & Provancha, 1992). For example, related studies has been conducted in North America with the loggerhead turtle (*Caretta caretta*); results suggest that organisms could alter their nesting behavior as adaptive mechanism to the warming of historical nesting sites, that range from southeastern Florida to southeastern

Virginia, where the sand temperature is lower and produces a higher proportion of males compared with those in Florida (Heppell et al., 2003). According to the IPCC (2001), Florida could experience a significant increase in temperature, so there is a high possibility of bias in the sex ratios, and a complete feminization of the setting of these the vast majority of the United Estates populations (Shoop & Kenney, 1992). The results indicates that an increase of 2° C is sufficient to cause feminization of clutches, and an increase of 3° C should drive to lethal incubation temperatures. As an alternative to temperature increase, turtles could potentially alter their nesting specific environment, looking for areas covered by vegetation, with greater proximity to the sea or groundwater. If turtles alter their oviposition season just a few days may be adapted to 1° C warming and if they did around a week, they could avoid the most extreme scenario (3° C); and this strategy could be the most viable adaptive mechanism for marine turtles in response to climate change (Hawkes et al., 2007).

In addition, evidence from genetic and behavioral analysis of the Painted Turtle populations *Chrysemis picta* in southeastern United States indicates that this turtle may disappear if do not develops traits that determine whether a balanced sex ratio, which directly affects their population dynamics (Girondot et al., 2004). Studies like those of Girondot et al., (2004) shows that species with temperature sex determination could be very sensitive to even modest variations (≤ 1 °C) in their local thermal environment. A slight increase in temperature could produce a high bias towards production of females (39° C). Such bias towards females results in a highly unequal sex ratio among adults and therefore if there are no males, females may lay eggs unfertilized eggs, and annual cohorts of offspring could lost and then the probability that the population becomes extinct.

The analysis of seasonal temperature variation and nesting behavior in *Chrysemis picta* suggest that pre-oviposition could mitigate climate change impacts on local populations located in less boreal latitudes and allow the production of males (Hays et al., 2001). Such nesting behavior modification may reduce the impact of local climatic variation, but may be insufficient for the populations living further north, since the young individuals may be low ability to survive the warm summer temperatures. It is believed that the metapopulation structure of these turtles among in the Mississippi River basin could help to mitigate the bias in sex ratio of the population caused by climate change if there is enough variation in both the thermal structure of suitable nesting areas, and migration rate between populations (Janzen, 1994).

In contrast, among the rhyncocephalians, lizards, and snakes with temperature sex determination, the threatened by global warming is higher in the tuatara (*Sphenodon punctatus*); a long generation time (which indicating limited potential to respond to rapid climate change), and extreme low temperature variation toward sex determination, with less than 1 °C drive the difference for the production of males or females (Nelson et al., 2004). Climate projections predict a significant increase among 1.4-5.8 °C in a very short period of time over the next 100 years (IPCC, 2001). Under this scenario reptiles may have four options to endure global warming: 1) modify its geographical range, 2) develop a genetic sex determination, 3) change their nesting behavior or 4) simply disappear (Janzen & Paukstis, 1991; Morjan, 2003). The tuatara may successfully manipulate the sex ratio of offspring by selecting the nesting site accord to vegetation, but apparently deeper nests in warm years to avoid bias toward males, which supports the proposition that the most viable strategy to deal with the effects of climate change is search sites with vegetal cover to nest. In the case of an abrupt increase in temperature that places the animals in the limit of their physiological tolerance, the peripheral populations of the tuatara would become extinct (Nelson et al., 2004). Finally some studies provide evidence that supports the proposal that the populations of reptiles compensate for differences in climate primarily through behavioral strategies (Doody et al., 2006; Gvozdika, 2002; Hertz & Huey, 1981). For example, in the Australian water dragon *Physignathus lesueurii* the maternal nesting behavior can respond for adjust the sex ratio and maintain viable populations across environmental extreme conditions, this compensate for climate differences by discriminating between potential nesting sites. This trait may be the most important to helping the species with thermal sex determination to compensate global warming (Janzen, 1992, 1994b).

3. General conclusions

Global climate change has influenced many aspects of the biology and ecology of amphibians and reptiles, which in some cases was caused the decline of their populations or serious threats. However evidence suggest that the phenomenon itself does not directly affect the organisms, but acts in combination with biotic and abiotic factors increasing its effects, as we illustrated in the case of diseases and infections the drying aquatic habitats draying up, the invasion of competing species, and the diminishing of the immune system due thermal stress regarding to the reproductive biology of organisms suggests that climate change affects several aspects among the most visible traits: phenology, survivorship and fecundity. However, it remains unclear if global warming will alter population dynamics of all populations or some one would be balanced due areas with suitable conditions for distribution and survival of organisms, mainly in the case of amphibians, whose survival depends largely on the presence of moisture and healthy aquatic habitats. However, there are non or very few data and projections turtles and crocodiles, comparing with lizards, which has been suggested that around of 50% of the Mexican *Sceloporus* lizards would disappear for 2080, since if maximum environmental temperature continues rising constantly due a overcome of physiological threshold of tolerance and the reduction of their daily activity times, which would cause an energetic shortfall as a consequence of low food intake (Sinervo et al., 2010).

Some potential adaptive responses already has bee suggested in different traits (behavior, physiology and morphology) among species affected by climate change. To test the likelihood of change in this traits due climate change requires the use of tools such as statistical analysis that incorporate phylogenetic hypotheses for the organisms under study, also an accurate estimate of the trait change rate both amphibians and reptiles is needed to understand the speed of the extraordinary rising of global environmental temperatures and their effects in biodiversity.

It is certain that climate global change will affect amphibians and reptiles around the world due synergic effects with other abiotic and biotic conditions. Our efforts should be concentrate in save as many populations and species we can, but first them all to understand the synergic effects and implement strategies to buffer them in regions when populations and species would be in the highest risk. It is quite possible that we cannot do anything against global warming and climate change, but we still can decide based on scientific evidence what, when and how to do about it.

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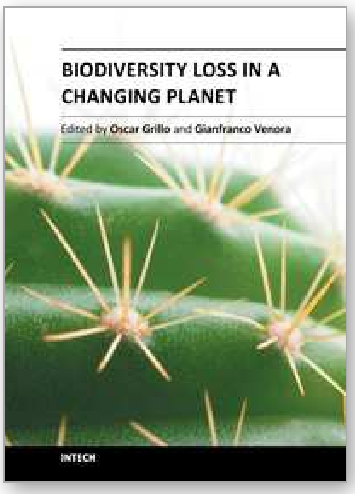

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Every ecosystem is a complex organization of carefully mixed life forms; a dynamic and particularly sensible system. Consequently, their progressive decline may accelerate climate change and vice versa, influencing flora and fauna composition and distribution, resulting in the loss of biodiversity. Climate changes effects are the principal topics of this volume. Written by internationally renowned contributors, Biodiversity loss in a changing planet offers attractive study cases focused on biodiversity evaluations and provisions in several different ecosystems, analysing the current life condition of many life forms, and covering very different biogeographic zones of the planet.

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