

Turtles in Turmoil: Implications of Climate Change for the Green Sea Turtle

by

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Part I – Introduction

Climate change is an issue that affects many aspects of the world around us. Global temperature is rising, and sea levels along with it. Weather patterns are shifting, and severe weather events are increasing. These physical changes to the environment affect plant and animal species in many ways, but some groups are harder hit than others. Reptiles are one such group. Because many groups of reptiles are ectothermic (meaning they must rely on the external environment to maintain their body temperatures), they are especially sensitive to changing climates. Some reptile species, including the green sea turtle (*Chelonia mydas*), also rely on environmental temperatures to complete some physiological and developmental processes.

In this case study, you will learn how the green sea turtle relies on the environment to complete a key reproductive process, and how future predictions for climate change might affect the continued existence of this species. To begin, read the following article from the US Forest Service:

- Olson, D.H., and D. Saenz. 2013. Reptiles and climate change [webpage]. USDA, Forest Service, Climate Change Resource Center. <<https://www.fs.usda.gov/ccrc/topics/reptiles-and-climate-change>>

After reading the article, answer the questions below.

Questions

1. Why are reptiles susceptible to changing temperatures?
2. Is it possible to describe the effects of climate change on reptiles as a whole? Why or why not?
3. How do changing climate trends affect lizard species in temperate climates?
4. Which groups of reptiles are more susceptible to temperature variation? Why?
5. What is temperature-dependent sex determination?
6. Sketch a graph that shows the trends in sex ratios across different temperatures in a species that exhibits temperature-dependent sex determination.
7. Where is the highest diversity of reptiles in the United States? Why are some species limited to this area?
8. According to the reading, how might climate change affect the distribution of some reptile species?
9. How can invasive plant species and human disturbance affect reptiles?
10. How can conservation managers help improve reptile habitat connectivity and avoid human disturbance?

Part II – Hypothesis Generation and Experimental Design

Green sea turtles spend most of their lives in the ocean. Males and females mate at sea. From November to January, female sea turtles come ashore and deposit their eggs into nests that they dig in the sand. They then cover the nests and return to sea. Male turtles may never return to land. Female green sea turtles always attempt to return to the beach where they were hatched to lay their eggs. The nests receive no further parental care. Hatchlings emerge unassisted from the nest approximately two months later and immediately return to the ocean. As is the case for many turtle species, green sea turtles exhibit temperature-dependent sex determination, which means the temperature at which eggs are incubated will determine the sex of the hatchlings, whereas the sex of offspring in many other vertebrate groups is determined chromosomally. In green sea turtle embryos, sex determination occurs during the middle third of egg development when the embryos are sensitive to ambient temperature. Outside of this period, embryos are not physiologically affected by temperature, unless it is extreme.

With rising temperatures due to global warming, an increase in sand temperature poses a threat to maintaining relatively even hatchling sex ratios at many of these ancestral nesting sites. Too few hatchlings of one sex may reduce the reproductive capability of that generation. Thankfully, several organizations around the world are involved in programs designed to aid in the conservation of this species. Some groups help to protect areas of beaches used for nesting, while others operate hatcheries that serve to help increase turtle hatchling survival. In the hatcheries, eggs are collected from wild nests and are either moved to human-dug nests in a protected area or are placed in artificial nest boxes. These artificial nests act as controlled, protected environments to ensure that as many eggs as possible survive. After hatching, young are then released into the sea. One region providing key natural nesting habitat for green sea turtles is found along the Queensland coast of Australia within the Great Barrier Reef (GBR). In fact, this region supports one of the largest green sea turtle populations in the world. In addition, the northern nesting beaches of the GBR are historically warmer than the southern nesting beaches of the GBR. Therefore, this location and population of green sea turtles provided a prime opportunity for Michael Jensen and colleagues to study the effects of temperature differences on sex determination in green sea turtles.

Imagine you are a scientist assisting Jensen's research team. You want to examine the effects of nest temperature on sex determination for the endangered green sea turtle. You begin by asking, *Does nest temperature affect the sex ratio of green sea turtle hatchlings?*

Questions

1. Develop a set of hypotheses that will allow you to test this question.
Null hypothesis:

Alternative hypothesis:

Prediction (direction of the effect):
2. Design a study to test your hypothesis.
 - (a) What variables will you measure?
 - (b) What factors will you control?
 - (c) What are your predicted results?
3. Sketch a figure to demonstrate your predicted results. Be sure to include temperature and sex ratios.

Part III – Data Interpretation

Jensen and colleagues wanted to determine how nest temperature affected sex determination in green sea turtle hatchlings for the green sea turtle. Using tagging data and genetic analysis, the researchers were able to track and identify which beach region (the warmer northern or cooler southern) adult sea turtles hatched from. The results of their study indicating the percentage of females observed at each life stage and the beach location from which they hatched are shown in Table 1.

Table 1. Percent female and male:female sex ratios for juvenile, sub-adult, and adult green sea turtles originating from the warmer northern Great Barrier Reef (Northern GBR), cooler southern Great Barrier Reef (southern GBR), other beaches, and orphans (nesting beach unknown) (adapted from Jensen *et al.*, 2018).

Nesting Origin	Juveniles		Sub-Adults		Adults	
	% Female	Sex Ratio (M:F)	% Female	Sex Ratio (M:F)	% Female	Sex Ratio (M:F)
Northern GBR	99	1 : 116	99	1 : 554	87	1 : 6.6
Southern GBR	68	1 : 2.1	65	1 : 1.8	69	1 : 2.3
Other	71	1 : 2.4	66	1 : 1.9	74	1 : 2.9
Orphan (nesting origin not identified)	77	1 : 3.4	86	1 : 6.2	75	1 : 3.1

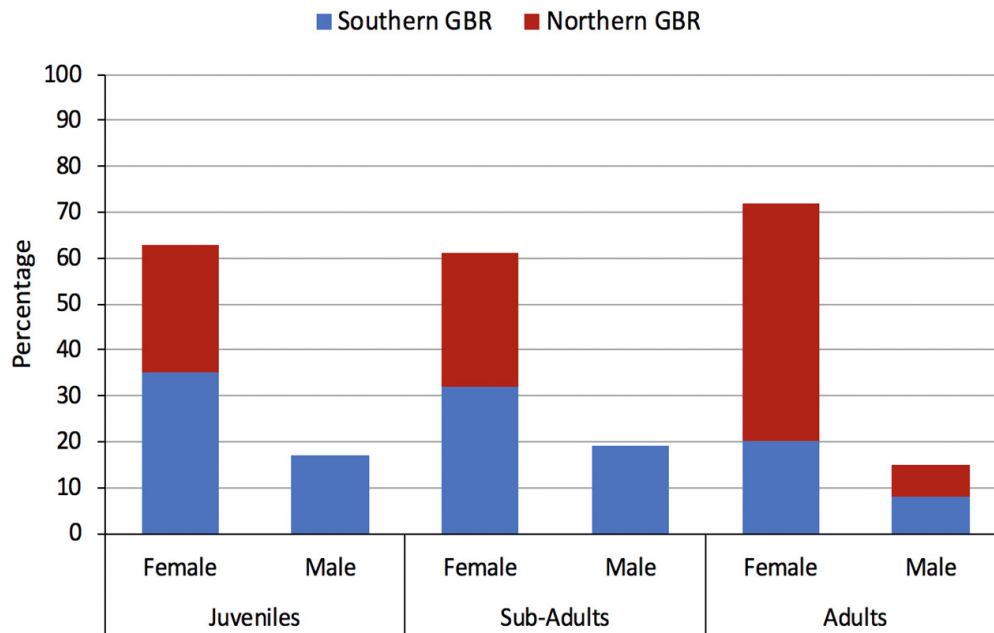


Figure 1. The relative proportions of male and female green sea turtles originating from the southern Great Barrier Reef (GBR) in blue and the northern Great Barrier Reef in red for juveniles, sub-adults, and adults (adapted from Jensen *et al.*, 2018).

Questions

1. Based on the data in Table 1, which nesting origin produced the largest male to female ratio and what are the implications of this for nesting temperature and sex determination in the green sea turtle?
2. Based on the data in Figure 1, which group of independent variables (location, turtle stage, and sex) exhibits the largest percentage? Approximately, what is the percentage?

Part IV – Future Outlook for the Green Sea Turtle

Jensen and colleagues discovered that nest temperature did in fact have an effect on the sex ratio of sea turtle hatchlings. Cooler nest conditions resulted in more male hatchlings, while warmer nests produced predominantly females. Further studies identified the pivotal temperature for sex determination in green sea turtles to be between 29° and 29.5°C, and that mean nest temperature must be within 25°–33°C for eggs to produce viable hatchlings (Hawkes *et al.*, 2009). Outside of this range, hatchlings may develop with abnormalities, or eggs may not hatch at all.

Prior to Jensen's study, another group of scientists measured how climate change affects the green sea turtle. Mariana Fuentes and colleagues observed several green sea turtle nesting sites along the Great Barrier Reef in Australia (Fuentes *et al.*, 2010). These researchers additionally recorded the temperatures of the sand within the nests and air temperatures from 2006 to 2009.

In order to determine how these nesting sites may be affected by climate change, Fuentes and colleagues constructed a computer model using historical air temperature measurements and current trends to predict how conditions may change in the coming decades. Table 2 below lists each nesting site, mean temperature measurements recorded at the time of the study, and two potential climate change scenarios.

Table 2. Current mean nest temperatures (°C) and future temperature predictions at green sea turtle nesting sites across the Great Barrier Reef (adapted from Fuentes *et al.*, 2010).

Site	2007/2008 Current	2030 Conservative	2030 Extreme	2070 Conservative	2070 Extreme
Bramble Cay	30.4	30.9	31.4	32.1	33.7
Dowar Island	29.85	30.35	30.725	30.875	32.025
Milman Island	28.68	29.3	29.76	30.32	31.92
Moulter Cay	29.4	30.2	30.7	31.2	32.7
Raine Island	29	29.6	29.9	30.2	30.8
Sandbank 8	29.5	29.8	29.7	30.1	31
Sandbank 7	28.5	29.05	29.35	29.7	30.5

Based on what you now know about the relationship between temperature and sex determination in green sea turtles, answer the questions below.

Questions

- Using 2007/2008 current temperature measurements, which nesting sites will produce predominantly male sea turtle hatchlings? Which sites will produce predominantly females?
- Using conservative predictions for the year 2030, which nesting sites will produce predominantly male hatchlings? Will the same sites continue to do so under the extreme forecast for 2030?
- In 2070, which nesting sites will produce predominantly male hatchlings?
- Based on 2070 extreme temperature predictions, are any nesting sites in danger of exceeding the highest possible temperatures for hatchling development?
- If nesting sites produce only female hatchlings, what problems might this cause for population sizes of the green sea turtle?

References

- Fuentes, M.M.P.B., M. Hamann, and C.J. Limpus. (2010). Past, current and future thermal profiles of green turtle nesting grounds: implications from climate change. *Journal of Experimental Marine Biology and Ecology* 383(1): 56–64. <<https://doi.org/10.1016/j.jembe.2009.11.003>>
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