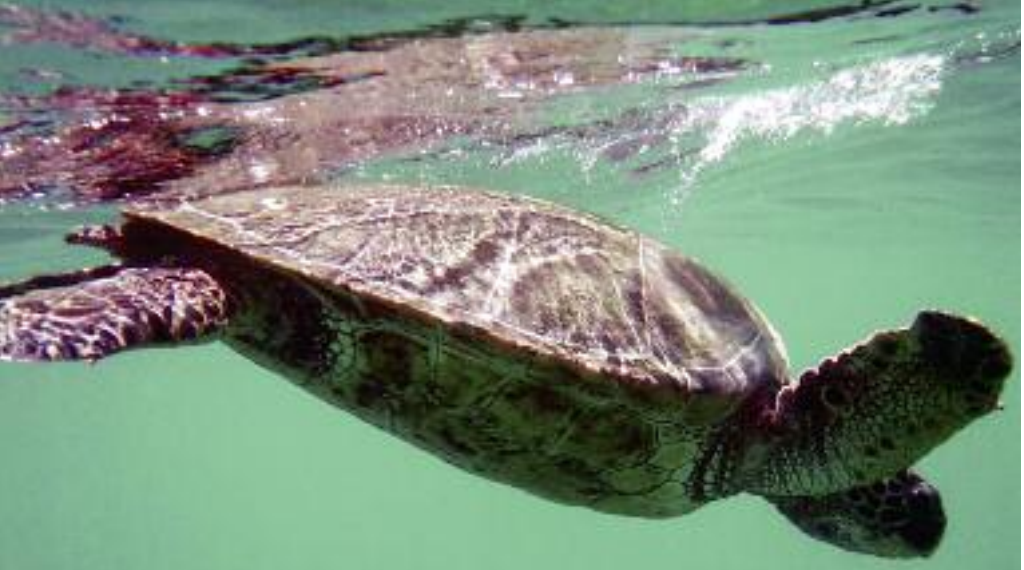

Bachelor sea turtles will have to keep their eyes open for new migration routes, foraging areas and rookeries.

SOME LIKE IT HOT

Global warming is changing the gender ratio of turtles born each year, with bachelors finding themselves in high demand. However, Mariana Fuentes says more serious consequences await turtle populations.

Climate change is emerging as a key issue in ecosystem and wildlife management throughout the world. According to the International Panel on Climate Change's (IPCC) Fourth Assessment Report, published earlier this year, warming of air temperature is projected to increase by 1.8–4°C over the next century, resulting in increasing sea levels and sea surface temperatures.

The animals expected to be most affected by climate change are those for which environmental temperatures strongly influence their:

- life history traits, such as species with temperature-dependent sex determination (e.g. sea turtles and crocodilians);
- behaviours, such as migration or foraging (e.g. sea birds); and
- seasonal reproduction (e.g. reptiles).

Considering this, sea turtles will be vulnerable to forecasted global climate change. Sea turtles are reptiles, and therefore rely on environmental temperatures to maintain their body temperature. This is critical for body functions such as digestion, reproduction and metabolism, as well as for behaviours such as migration, foraging and breeding.

As sea turtles lay eggs, temperature also plays a vital role in embryo development. Not only does successful incubation of sea turtle eggs require the temperature of the sand around the nest to be between 25°C and 34°C, but the sex of the offspring is determined by the incubation temperature.

More specifically, the incubation temperature of sea turtle eggs during the middle trimester of the incubation period determines the sex of the offspring. The temperature that produces 50% males and 50% females is generally around 29°C (this is slightly different between and even within species). Sea turtle eggs incubated above 29°C develop into females, while those below about 29°C develop into males. Sea turtle populations have a naturally biased sex ratio of four females for every male.

However, the increase in global and regional air temperature predicted by the IPCC in 2007 could lead to an increase in sand temperatures and a corresponding increase in the proportion of female turtles in the population. The early stages of this "bachelor paradise" can already be observed, with some turtle populations already presenting a higher female-skewed ratio than natural levels.

In 1999, which was a warm year, Dr David Booth and Dr. Katherine Astill of the University of Queensland found that 80% of the green turtle hatchlings in Heron Island were females. Similar results were found by researchers from the University of Wales and Glasgow, where 86–96% of green turtle hatchlings in Cyprus were females between 1993 and 1998. Furthermore, in Mon Repos, a major loggerhead rookery in Bundaberg, sand temperature collected in the late 1990s by the Queensland government indicated that hatchlings produced in the later half of the nesting season were entirely female.

While bachelor sea turtles may be looking forward to climate change, their prospective partners are not too thrilled about the predicted scenarios. As climate change warms the Earth, ice caps and glaciers melt and the sea level rises. Predictions from the IPCC are for an 18–59 cm rise by 2099. This will lead to increased inundation of turtle nests and loss of low-lying nesting habitats.

In 2005 researchers from the University of East Anglia and the Sea Turtle Club in Bonaire assessed the impacts of sea level rise on nesting beaches in the Caribbean. They used a GIS-based elevation model and estimated that one-third of the total current beach area available for sea turtle nesting could be lost due to a moderate rise in sea level (0.5 metres) .

Turtles that lose their nesting beaches are expected to seek out new nesting sites. Turtle-friendly sites have no artificial lights or human development, and therefore the suitability of alternative beaches is greatly reduced by today's ever-expanding coastal development.

Female turtles may not only lose important nesting grounds but also their reproductive rhythm. Sea turtles

The duration of the nesting season of some populations of turtles has decreased in more recent years.

Prolonged exposures to high temperatures can causes debilitation and death of eggs and hatchlings.

Optimal habitat available for sea turtle nests could be lost due to rises in sea levels.

have seasonal breeding cycles. However, changes in patterns of reproduction have been observed in various places throughout the world, including earlier nesting, reduced inter-nesting intervals, and a decline in time spent at nesting grounds. These changes appear to be strongly related to warming of the climate .

Earlier nesting and shorter nesting seasons are linked to warmer sea surface temperatures adjacent to rookeries. According to a 2006 study by Dr David Pike from Towson University, nests in Florida are not only being laid earlier and more evenly throughout the season but nesting seasons have decreased by 43 days in more recent years (1995–2003).

The consequences of earlier and shorter nesting seasons for sea turtle populations are still unknown. Nevertheless, it might include fewer clutches being laid and consequently lower reproductive output.

While future mums are not too sure what hit them and

Hatchlings incubated in warmer nests are smaller, and have a higher probability of predation as they cross the reef.

wonder if the changes in their reproductive patterns is an early sign of menopause, they also worry about the development of their eggs and hatchlings. Sadly, the scenario is not looking good. Successful embryo development only occurs when temperatures range between 25°C and 34°C. Therefore, higher temperatures are likely to decrease the success of hatchlings.

Unfortunately, nesting grounds are already heating up. In Mon Repos, the Queensland Government Turtle Project has found that nest temperatures since 1998 have reached 36°C for weeks at a time during hatchling season. Prolonged exposures to these temperatures make the nests resemble ovens, and eggs can overcook. This causes debilitation and death of eggs and hatchlings. Warmer nests may also cause the production of weak and, in some cases, deformed hatchlings.

Hatchlings incubated in warmer nests incubate for a shorter time, and therefore convert less yolk to hatchling tissue. This results in smaller hatchlings, which have lower swimming ability and therefore are more susceptible to predators. This puts even more pressure on these threatened species.

The prospect of losing critical habitat, changes in reproductive patterns and decreases in hatchling success could see turtle distributions shift to cooler climates. In 2006, Dr Clive McMahon and Dr Graeme Hays of Swansea University reported that the distribution of leatherback turtles in the north-east Atlantic has extended north by around 200 km per decade over the past 20 years due to an expansion of warmer waters. They also predicted further extensions as the warmer water expands into northern latitudes.

Expansion of migratory routes and redistribution of breeding sites in response to climatic changes is not a new phenomenon for sea turtles which have been on Earth for millions of years. Today's species have already endured periods of remarkable climate change and sea level rise.

However, with additional threats by human activities, distribution changes can have severe implications and cause further conservation challenges for endangered sea turtles. Turtles might start turning up where conservation measures are not in place, or management could be difficult because of coastal development.

In view of the potential impacts that climate change will have on sea turtles, it is not surprising that climate change was identified as a key hazard to sea turtles by the IUCN Marine Turtle Specialist Group in 2005, making the issue a high priority for further study.

Considering this, my PhD project focuses in assessing the risk that climate change may have to the terrestrial component of sea turtle reproduction. For this, the green turtle population in the northern Great Barrier Reef, one of the largest green turtle populations in the world, will be used as a case study.

Specifically, the project will forecast potential impacts of and responses to climate change by green turtles and provide suggestions for management options to reduce the susceptibility, and increase the resilience of green turtles to climate change. This will provide crucial information for the future management and conservation of sea turtle populations in relation to climate change.

Mariana Fuentes is a PhD student with James Cook University's School of Earth and Environmental Sciences.