The Effects of Rising Sand Temperatures on Sea Turtle Survival

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INTRODUCTION

Despite their resilience to past climatic shifts, sea turtles are exhibiting sensitivity to the unprecedented rates of change that are occurring today. Rising sand temperatures, as a result of global warming, are leading to issues with hatchling development and mortality. In addition, more marine turtles are being born female because of their temperature-dependent sex determination. The increased occurrences of female-biased sex ratios are posing a significant threat to major populations, since there are less males available to reproduce.

More Female Hatchlings

In marine turtles, the proportion of female hatchlings increases when the temperature of the sand that their eggs are incubated in increases (Figure 1).

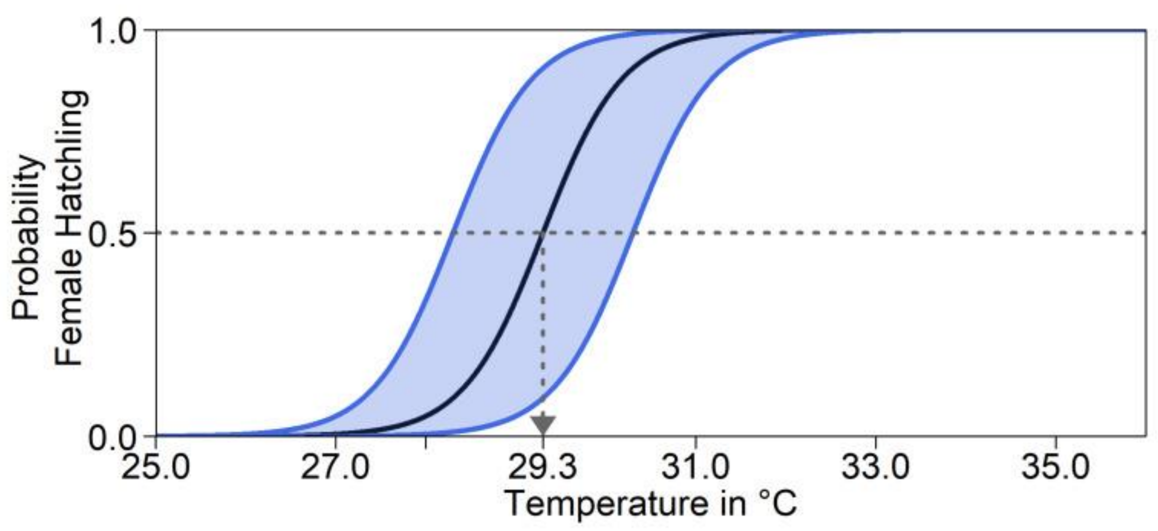

Figure 1. Probability of female hatchling depending on sand temperature.

With predictions of a minimum 1.8°C increase by 2100 (IPCC, 2014), more female-biased sex ratios are presenting themselves in major populations. Numerous studies done on some of the largest sea turtle populations in the world are demonstrating such a biased ratio, 2 examples of them being:

1. An investigation on the northern Great Barrier Reef rookeries found an extremely female-biased population of 99.1% juvenile, 99.8% subadult, and 86.8% adult-sized Green Sea turtles (represented by the orange in Figure 2), revealing that they have been producing primarily females for more than two decades and that complete feminization of this population is possible in the future (Allen et. al, 2018).

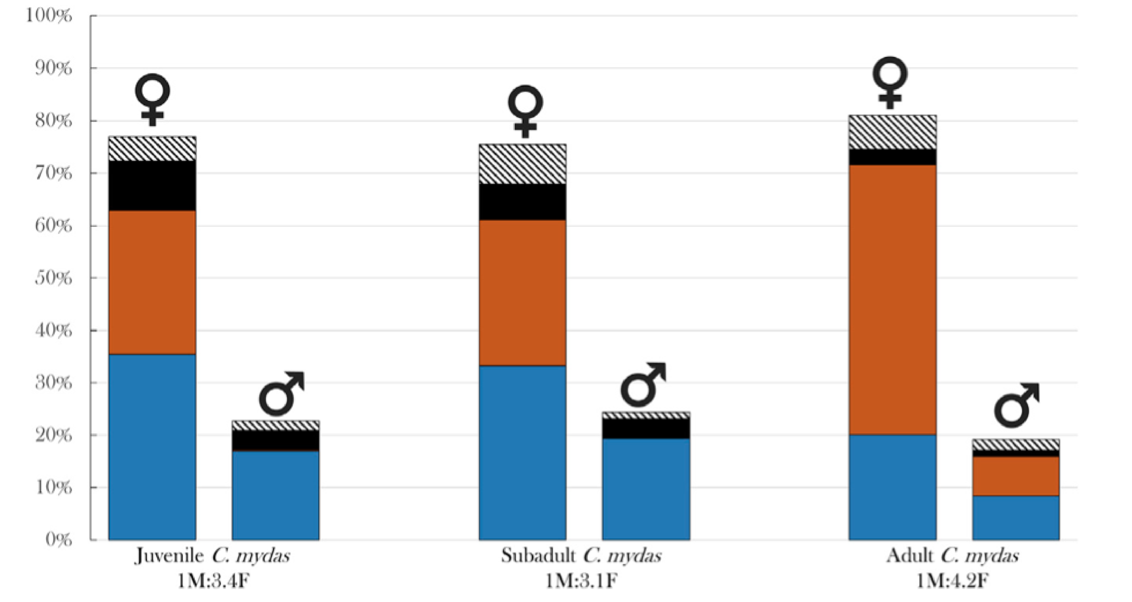

Figure 2. Percentage of female and male Green Sea turtles for each life stage at the major Great Barrier Reef rookeries in 2017.

2. Results from a 200-year time series of incubation temperatures and primary sex ratios for Green, Hawksbill and Leatherback Sea turtles suggested that all three species have had female-biased hatchling production since the beginning of the industrial revolution. Less than 15.5% of Green turtles, 36% of Hawksbills, and 23.7% of Leatherbacks produced males. (Berkel et. al, 2016).

Effects of Female-biased Sex Ratios

Male scarcity associated with female biased hatchling ratios should be a rising concern, as it reduces mating opportunities for females and therefore lessens the chance of fertilization. This can have a growing impact in as little as 20 years for some populations, as seen in the study completed on the northern Great Barrier Reef rookeries previously mentioned. In addition, evidence has shown that there are other threats associated with these sex-ratios, such as lower incidences of multiple paternity (a male mating with multiple females).

Lower incidence of multiple paternity

Populations experiencing extreme female-biased hatchling sex ratios tend to have a lower incidence of multiple paternity. A global analysis on such populations showed that when the female bias was >90%, the incidence of multiple paternity was 24.5% in the eastern Mediterranean, 36.4% on Redang Island (Malaysia) and 15.4% on the southern Great Barrier Reef compared to higher values of 61.1 – 91.7% at other sites (Hays et al, 2023) (Figure 3). These reductions in multiple paternity are important precursors to reductions in egg fertility, which may threaten overall population viability (Hays et al, 2023).

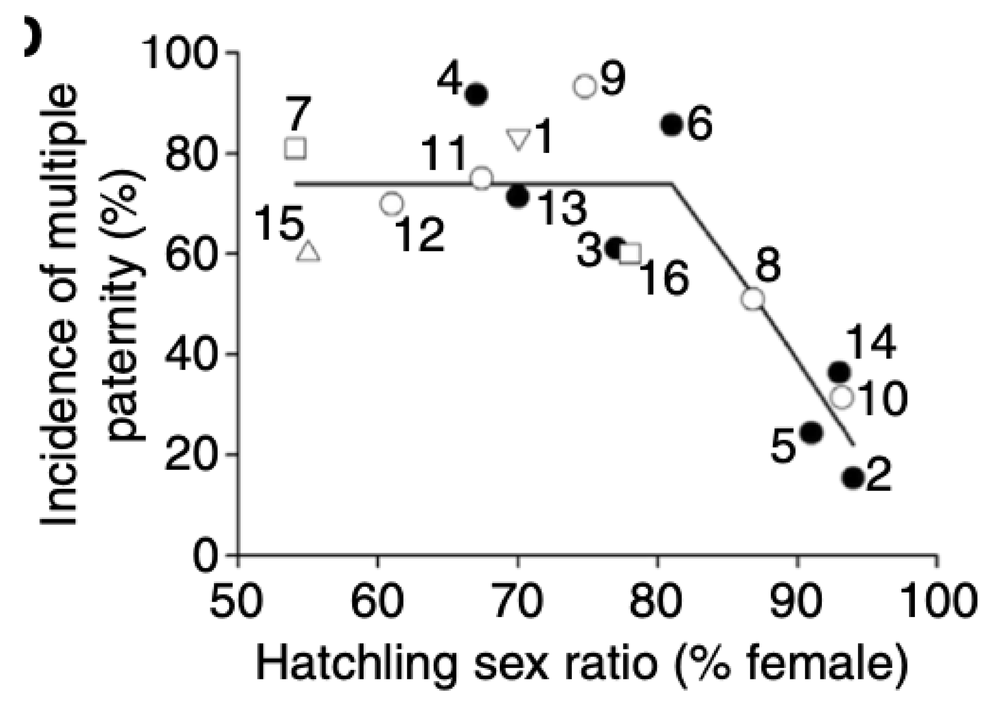

Figure 3. Incidence of multiple paternity (%) in relation to the hatchling sex ratio (%) for various sea turtle species at different global locations.

Reduced Hatchling Success & Fitness

For all species of marine turtles, there is a supposed thermal range of 25-33°C in which egg incubation is successful (Berumen, 2020). Prolonged exposure to temperatures above the 30 °C mark can result in smaller hatchlings, reduced locomotor performance, and hatchling mortality (Booth, 2017). A study done on Loggerhead sea turtles revealed just how difficult it is for hatchlings to survive when they have been incubated at higher temperatures (Figure 4).

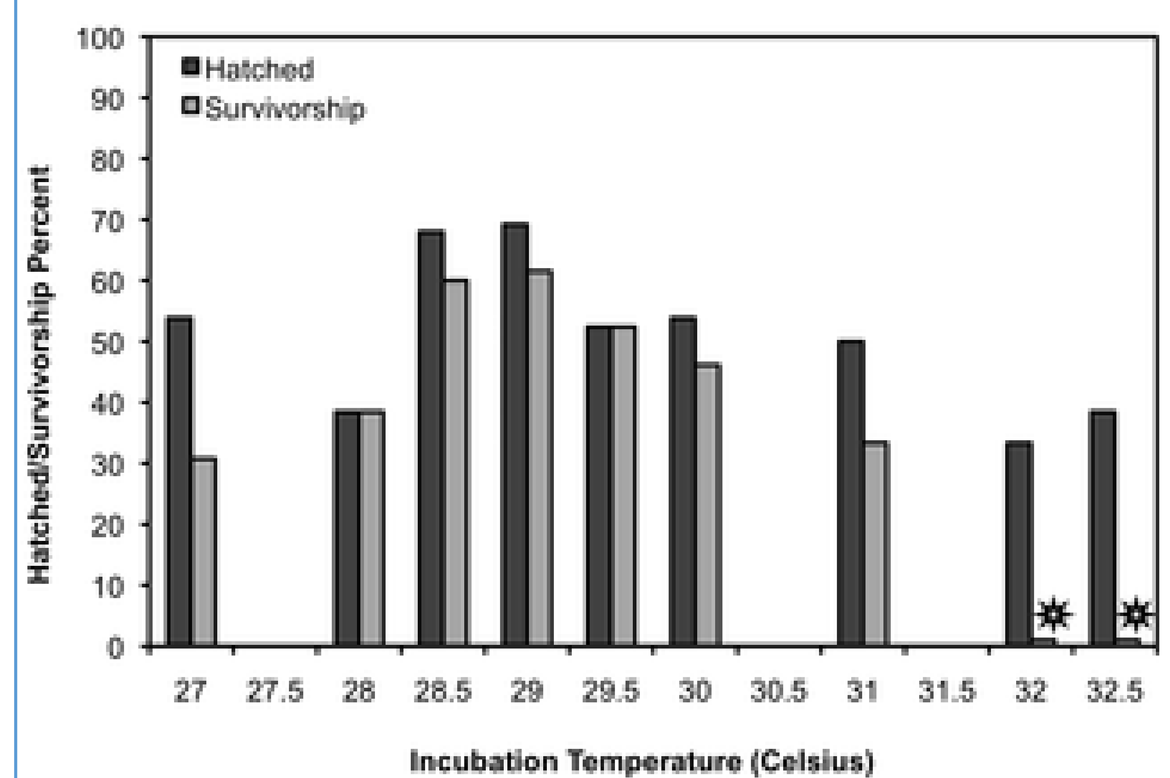

Figure 4. Overall percent of hatched eggs and percent of hatchlings that survived at various incubation temperatures for two major Loggerhead sea turtle clutches in 2011.

Shorter incubation periods

The higher the temperature of the sand, the less time the turtles have to fully develop tissue from yolk before hatching. Sea turtle hatchlings who are experiencing such short incubation periods tend to have relatively smaller body sizes that may hinder chances of survival (Hays et al, 2018). They have a harder time avoiding predation by gap-limited predators (predators that can only fit certain sized animals in their mouths). In addition, their crawling speed and swimming speed are both limited by their smaller body sizes (Booth, 2017).

Decreased locomotor performance

As for locomotor performance, hatchlings tend to show a decreased ability to self-right (flip over when turned upside down), crawl, and swim at high incubation temperatures (Matsuzawa et. al, 2002). All of which inhibit hatchling survival during their journey from nest to the open ocean. Figure 5 demonstrates their decreased locomotion, since hatchlings incubated at warm temperatures (red) had significant declines in time spent power-stroking as opposed to those incubated at cooler temperatures (blue) (Ando et al, 2018).

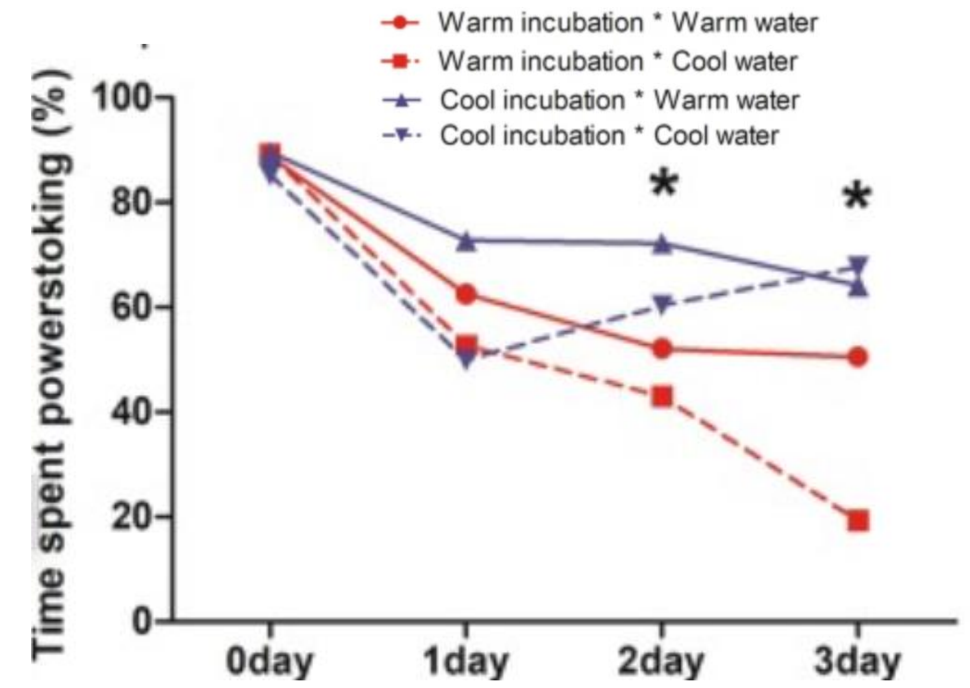

Figure 5. Comparison of time spent power-stroking for Loggerhead sea turtle hatchlings during their first 4 days of life at high incubation temperatures (red) and low incubation temperatures (blue).

Solutions

There are various conservation efforts in place that aim to inhibit the effects of rising sand temperatures. The most effective of these efforts being:

1. Increasing the shade and irrigation at nesting sites as well as relocating nest clutches to deeper depths allow for lower incubation temperatures and longer incubation periods.

2. Assisted hatching helps to increase the chances of avoiding predators for all hatchlings, especially those with decreased locomotor performance and smaller body sizes.

3. Increasing the protection of the beaches and nesting sites that have relatively cold incubation temperatures to provide females with a greater variety of egg-laying environments (Image 1) (Arlettaz et. Al, 2007).

Image 1. Sea turtle nest protection at a major Florida Green Sea Turtle rookery.

CONCLUSION

With the unprecedented rise in global temperatures comes a rise in sand temperatures around the world. Higher sand temperatures are resulting in reduced hatchling success and fitness, exposing the younglings to predatory threats. Increased sand temperatures are also causing more female-biased sex ratios that lower the chances of multiple paternity, egg fertility, and population viability. Conservation efforts prove to have some effectiveness in inhibiting the effects of rising sand temperatures, but little effectiveness in preserving overall populations. Future efforts should pay particular attention to the protection of beaches that already have relatively cold sand temperatures for females to have a greater variety of locations to lay their eggs.

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