

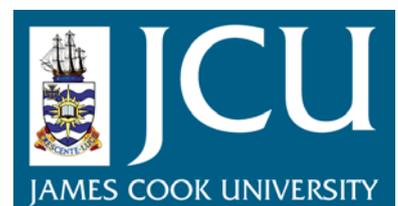
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Vulnerability of sea turtles to climate change: A case study with the northern Great Barrier Reef green turtle population

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*“The process of learning is often more important than what is
being learned”*

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Statement of contribution of others

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“The smallest act of kindness is worth more than the grandest intention”

Publications associated with this thesis

Peer-Reviewed Publications

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Fuentes MMPB (2007) Some like it hot. *Australasian Science*. Nov-Dec. p 34-36.

Fuentes MMPB, Dawson J, Smithers S, and Hamann M (2007) Surficial carbonate facies across key rookeries for the northern Great Barrier Reef green turtle population stock. Technical report for the Environment Protection Agency.

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Fuentes MMPB, Dawson J, Smithers S, and Hamann M (2008) Traits of surficial carbonate sediments at reef Islands: implications of climate change to island fauna. 11th International Coral Reef Symposium (2008) Florida, USA

Fuentes MMPB, and Dawson J (2007) Identifying surficial carbonate facies at key sea turtle rookeries to investigate the potential effects of climate change on turtle populations of the northern Great Barrier Reef. Greenhouse 2007: the latest science & technology (2007), Sydney, Australia

Other publications generated during my candidature

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Peer-Reviewed Publications

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Fuentes MMPB (2009) Hawksbill turtles at Masig Island. Technical report for Torres Strait Regional Authority and Kailag Enterprises.

Cinner JE, and **Fuentes MMPB** (2006) A Baseline Socioeconomic Assessment of Fishing Communities in Northern Madagascar. Report to the Wildlife Conservation Society Madagascar Marine Program.

Abstract

Sea turtles are vulnerable to aspects of climate change because they have life history, physiological attributes and behaviour that make them extremely sensitive to environmental changes. Arguably, the more detectable impacts of climate change to sea turtles will occur during their terrestrial reproductive phase (egg laying, egg incubation and hatchling success phase) since there are clear, and relatively straightforward, effects of increased temperature, sea level rise and cyclonic activity on sea turtle nesting sites and reproductive output.

Indeed, there has been a recent increase in research activity focusing on the potential impacts and implications of climate change to sea turtles' terrestrial reproductive phase. While first identified as an issue in the mid 1980s recent studies have begun to investigate and predict how specific climatic processes will affect sea turtle's nesting habitats and reproductive output. However, the studies conducted to date are limited temporally, because (1) they predict how a single climatic process will affect sea turtles, yet processes are likely to occur simultaneously and cause cumulative effects, and (2) they typically focus only on one nesting ground used by a particular turtle population and this approach does not provide a full understanding of how a population (management unit) will be affected. Consequently, there is a need for a structured approach to investigate how multiple climatic processes may affect the full range of nesting grounds used by a turtle population.

In my thesis I address the issue of cumulative impact by using a systematic and comprehensive methodology to assess how multiple climatic processes will affect the northern Great Barrier Reef (nGBR) green turtle population under a conservative and an extreme scenario of climate change for both 2030 and 2070. First, I identified how key processes: (1) change in sediment traits, (2) increased temperature, (3) sea level rise, and (4) cyclonic activity will affect the nesting grounds (n= 7) that represent the nesting habitat for 99% of the nGBR green turtle population. After I determined how each process will potentially affect the selected nesting grounds, I used expert opinion to gather information on the relative impact of each process on sea turtle nesting grounds. This information was then incorporated into a climate change vulnerability assessment framework.

To explore how changes in sediment will impact the nGBR green turtle population I conducted two steps. First, I described the sediment types and identified the reef-building organisms of each nesting ground. I then reviewed the literature on the vulnerability of each identified reef-building organism to climate change and how various sediment characteristics ecologically affect sea turtles. I found that the sediment from each of the studied nesting grounds is predominantly composed of well sorted, medium-grained to coarse-grained, sands and are dominated by Foraminifera, molluscs

or both. Dissimilarities in the contemporary sedimentology between the nesting grounds suggest that each will respond differently to environmental impacts such as increased temperature, sea level rise and ocean acidification. The implications of changes to island sedimentology on sea turtle ecology include changes in nesting and hatchling emergence success, and reduced optimal nesting habitat. Both of these factors can influence sea turtles' annual reproductive output and thus have significant conservation ramifications.

The second key process I examined was potential changes to incubation temperatures. For this, I first conducted a systematic process to select the best predictive model of sand temperature. Using Akaike Information Criterion I determined that a model incorporating both sea surface and air temperature as proxy indicators of sand temperature is the best model to predict future sand temperature for the study region. I then used sand temperature (at clutch depth), the developed models and air and sea surface temperature projected by the International Panel of Climate Change (IPCC) and the Australian Commonwealth Scientific and Research Organisation (CSIRO) to predict sand temperature for the selected nesting grounds. My models predicted a feminization of annual hatchling output into the nGBR green turtle population by 2030. Predictions are bleaker for 2070, when some of the nesting grounds (Bramble Cay and northern Dowar and Milman Island) used by this population are predicted to experience temperatures near or above the upper thermal incubating threshold (e.g. 33 °C) and likely cause a decrease of hatching success. Importantly, I identified that some nesting grounds (e.g. Raine Island, western Milman Island and Sandbank 7) will still produce male hatchlings, even under the most extreme scenario of climate change. This is crucial for future management as managers may choose to protect important male-producing regions to balance future population viability.

Further impacts to the nGBR green turtle population will potentially occur from sea level rise. To investigate how SLR will impact the different nesting grounds I first conducted beach profiles at each of the selected nesting ground and used the profile information to create a digital elevation model for each of them. Second, I used geographic information system (GIS) to map and quantify areas that will be inundated under various SLR scenarios. Using the predicted sea level rise values from the IPCC and CSIRO, my results indicated that up to 34% of available nesting area across all the selected nesting grounds may be inundated as a result of predicted levels of SLR. My data indicated that low sandbanks will be the most vulnerable to SLR and nesting grounds that are morphologically more stable, such as Dowar and Raine Islands, will be less vulnerable.

More positively, my study indicates that as climate change progresses it is likely that impacts from cyclones to the nGBR green turtle population will be very low. I used eleven of the latest regional climate models to investigate how cyclonic frequency will alter in a warming climate. Most models

predicted a tendency for a reduction in cyclonic frequency in the future. Thus a reduction in the impacts that the nGBR green turtle population will experience from cyclones is likely.

The second part of my thesis involved incorporating the predicted impacts from the climatic processes to each nesting ground into a vulnerability assessment framework for climate change. The framework used is based on the IPCC framework for climate change and is described as a function of sensitivity, exposure and adaptive capacity. The framework allowed me to: (1) assess how multiple climatic processes will affect the terrestrial reproductive phase of sea turtles; and (2) investigate how mitigating different climatic factors individually or simultaneously can influence the vulnerability of the nesting grounds. Thus I was also able to provide informed suggestions of management options to mitigate the potential impacts of climate change to the nGBR green turtle population.

The vulnerability assessment indicated that in the short term (by 2030), sea level rise will cause the most impact on the nesting grounds used by the nGBR green turtle population. However, in the longer term, by 2070 sand temperatures will reach levels above the upper transient range and the upper thermal threshold and cause relatively more impact on the nGBR green turtle population. Thus, in the long term, a reduction of impacts from sea level rise may not be sufficient, as nesting grounds will start to experience high vulnerability values from increased temperature. Therefore, a stronger focus on mitigating the threats from increased temperature will be necessary for long term management.

Some of the potential options to mitigate the impacts of increased temperature include changing the thermal gradient at beaches, nest relocation, and artificial incubation. The best management options will be site specific and dependent on a series of factors, including feasibility, risk (interaction and impact on other species and ecosystems), cost, constraints to implementation (both cultural and social), and probability of success in relation to selected sites. Thus, a “toolbox” with various strategies will be needed to address the impacts of increased temperature across the nesting sites used by the nGBR green turtle population.

The main strengths of the framework used here is that it can easily be adapted when information is obtained, and it can be transferable to different sea turtle populations and sea turtle life cycle phases provided the necessary data exist. This framework provides key information for managers to direct and focus management and conservation actions to protect turtle populations in the face of climate change. Indeed results from my thesis have been used by the Australian Government in their development of the outlook report for species and ecosystems of the Great Barrier Reef.

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