Aust. J. Wildl. Res., 1988, 15, 157–61

The Southern Oscillation Regulates the Annual Numbers of Green Turtles (*Chelonia mydas*) Breeding around Northern Australia

Colin J. Limpus[A] *and N. Nicholls*[B]

[A] Queensland National Parks and Wildlife Service, P.O. Box 5391, Townsville, Qld 4810, Australia.
[B] Bureau of Meteorology Research Centre, Melbourne, Vic. 3000, Australia.

Abstract

The green turtle (*Chelonia mydas*) is one of six turtle species which breeds around northern Australia and Indonesia. The number of green turtles observed nesting varies substantially from year to year. The interannual fluctuations in the number of nesting turtles are in phase at widely separated rookeries. They are also correlated with an index of the Southern Oscillation, a coherent pattern of atmospheric pressure, temperature and rainfall fluctuations which dominates the interannual variability of the climate of the tropical Pacific. Major fluctuations in the numbers of turtles breeding occur two years after major fluctuations in the Southern Oscillation. The relationship is strong enough to be useful in predicting, two years in advance, the numbers of green turtles breeding in Great Barrier Reef rookeries. This is the first study to report a biological impact of the Southern Oscillation that allows such a long-range prediction of the impact.

Introduction

The green turtle (*Chelonia mydas*) is a pantropical herbivorous sea turtle. It is one of six species of sea turtles breeding in tropical Australia. Typical of sea turtles, *Chelonia mydas* lives in widely dispersed feeding grounds, in this instance seagrass flats and algal rich reefs, but migrates to aggregate most of its breeding at a small number of traditional rookeries. Within the Great Barrier Reef region (GBR) there are two such major rookery areas, one centred on Raine Island in the north and the other in the Capricornia Section in the south. The green turtles nesting at these eastern Australian rookeries are drawn from feeding grounds not only within the GBR but from the region encompassed by Northern Australia, New Caledonia, Vanuatu, Papua New Guinea, Irian Jaya, to as far west as Ambon in Indonesia, i.e. the Coral Sea, Gulf of Carpentaria and the Arafura Sea (Limpus and Parmenter 1986). Green turtles nest almost entirely during the summer within the GBR; maximum nesting density occurs in December and January. During a breeding season, each female lays several clutches of eggs at about 2-weekly intervals (Bustard 1972; Limpus 1980; Limpus *et al.* 1984).

Materials and Methods

Data have been collected on the numbers of green turtles nesting on two islands at opposite ends of the GBR, Heron Island (23°26'S.,151°55'E.) and Raine Island (11°36'S.,144°01'E.), for the breeding seasons between October 1974 and April 1986. Because of different logistics of working on these islands, the size of the annual nesting population was assessed differently at each island. For Heron Island the annual total number of nesting female green turtles visiting the island was measured by a tagging census conducted over several months. For Raine Island, the average number of nesting females visiting the island per night at a standard time of the nesting season (early December) was measured. The natural

0310-7833/88/020157$03.00

logarithm of these data is graphed in Fig. 1 to illustrate that substantial variations occur in the numbers of turtles nesting, and that the variations on the two widely separated islands occur in phase. There is no evidence that these fluctuations in any way reflect fluctuations in the actual numbers of turtles in the feeding grounds.

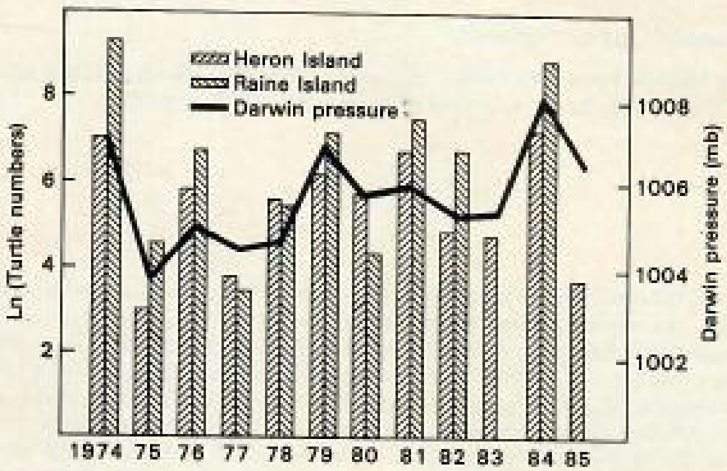

Fig. 1. Histograms of natural logarithms of the numbers of green turtles breeding at Raine Island and Heron Island between 1974–75 and 1985–86. Note that the numbers of nesting turtles were assessed in different ways at the two islands (see text). Darwin atmospheric pressure for Nov.–Jan. two years earlier is also shown. Data were unavailable for Raine Island for 1983–84 and for 1985–86.

Results

The numbers of turtles nesting at Heron Island and Raine Island have been correlated with an index of the Southern Oscillation (SO). The SO is a coherent pattern of pressure, temperature, and rainfall fluctuations which dominates the interannual climate fluctuations of the tropical Pacific and Indian Oceans (Rasmusson and Carpenter 1982). It is related to the El Niño phenomenon which has a marked effect on the marine biology of the east Pacific (Barber and Chavez 1983). The primary manifestation of the SO is an aperiodic seesaw in atmospheric pressure between the southeast Pacific and Indian Oceans. Darwin atmospheric pressure is one of several indices of the SO available and has been related to rainfall, sea surface temperature and tropical cyclone activity in and around northern Australia and Indonesia (McBride and Nicholls 1983; Nicholls 1984*a*, 1984*b*, 1985*a*). The atmospheric and oceanic fluctuations associated with the SO in this area suggested themselves as possible causes of the fluctuations in the numbers of green turtles breeding so these numbers were correlated with 3 month means of Darwin pressure from up to 3 years prior to the mid nesting season (1 January). Strong positive correlations were found with Darwin pressures 22–32 months prior to nesting. The strongest correlation was with the pressure averaged over the November–January period 2 years before the nesting season. The correlation coefficients between the pressure averaged over the November–January period two years before nesting and the turtle numbers were 0·78 (with Heron Island numbers) and 0·74 (with Raine Island numbers). Even with the small sample available (12 years at Heron Island, 10 at Raine Island) these are significant at the 2% level. Darwin pressures averaged over the period November–January two years prior to nesting are graphed in Fig. 1. The close relationship between Darwin pressure and the numbers of turtles nesting two years later, at both Heron and Raine Islands, is clear for the short period of data. The data are graphed as a scatter diagram in Fig. 2 which reveals the relationship more clearly.

The period 1974–75 to 1985–86 is the only one for which quantitative data on the numbers of turtles nesting at these islands are available. Qualitative descriptions of the numbers of turtles nesting at these islands are available from various sources for some earlier years. Those years with known poorer turtle numbers (e.g. 1928, 1949, 1964) were preceded by lower than normal Darwin pressures two years earlier. In addition, qualitative data suggest that males and females appear to be similarly affected. In poor seasons at Heron Island not only did the turtles not nest in abundance, but the females and the corresponding male component of the population did not arrive in abundance on the adjacent reefs for courtship (Limpus *et al.* 1984).

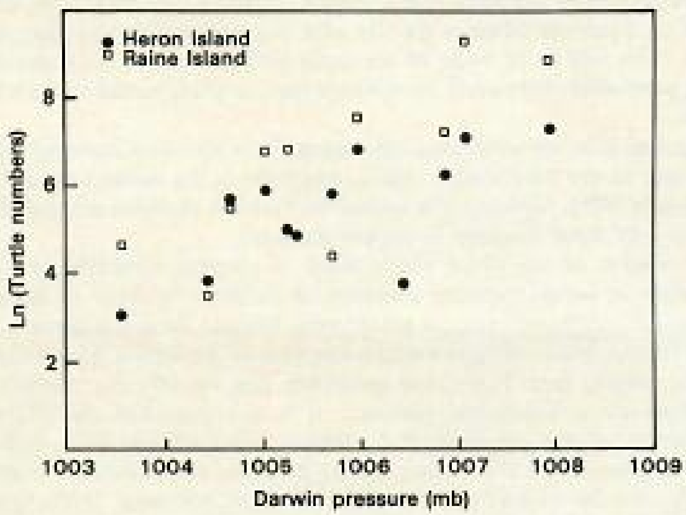

Fig. 2. Scatter diagram of data shown in Fig. 1.

Discussion

As noted earlier, the SO, of which Darwin pressure is an index, has marked effects on the atmosphere and ocean in the Australian region. It is not, therefore, totally surprising that the SO is related to fluctuations in the numbers of turtles breeding. Previous work has demonstrated strong biological impacts of the SO in this area, specifically crop yields (Nicholls 1985*b*, 1986). But why should there by a lag of 2 years? From any one feeding ground, only a portion of the mature females green turtles are breeding in any one year (Limpus and Reed 1985*a*, 1985*b*). In Australia, the same female green turtle has not been recorded breeding in successive years. Indeed the modal remigration interval recorded from Australian rookeries is 5 years (uncorrected for tag loss—Limpus *et al.* 1984). The events preceding a breeding season are as follows (Limpus, unpublished data). Most of the females have left their home feeding grounds a month or two before nesting commences in late October. Before that however, each female will have deposited several kilograms of yolk into the hundreds of follicles she has prepared for the breeding season. This vitellogenic process appears to take about 9 months, developing follicles being visually recognisable in ovaries in the late January before a breeding season. Before vitellogenesis begins the females will have already laid down additional fat deposits, but the duration of the fat deposition period is not known. Thus preparation for a breeding season commences more than 1 year before oviposition. The observed correlation between numbers of breeding turtles and the SO effects with a lag time of 2 years indicates that the SO may be determining the proportion of females able to acquire the fat reserves necessary for entering the vitellogenic phase of preparation. While the time sequence of preparation for a breeding season has not been documented with the males, the observation that fewer males migrate to courtship in the poorer nesting years suggests that they have a similar preparation time for breeding as the females.

There are also indications that the nesting density of green turtles in south western Java, based on egg harvest data 1981–84, fluctuates in parallel with that of the GBR green turtle rookeries (Limpus, unpublished data). This is to be expected given the wide region that the SO influences. This needs confirmation through measurement of the annual nesting density at one of these Indonesian rookeries and calculation of the correlation between numbers of green turtles breeding in any one year and the SO effects 2 years before. Once the same pattern can be confirmed for some widely spaced reference rookeries, it should be possible to predict up to 2 years in advance the size of a nesting population at any other rookery in the region. This will be of value in sea turtle management in the Australia–Indonesia region, being particularly relevant in areas where eggs, courting turtles or the nesting females are harvested.

Large fluctuations in annual nesting populations have also been reported from *C. mydas* rookeries outside of the Australasian region, especially in the western Atlantic basin (Carr *et al.* 1978; Schulz 1975). However, the annual fluctuations recorded at these other areas are not in parallel with those recorded in eastern Australia.

The other species of sea turtle which breed in tropical Australia do not appear to have fluctuations in annual breeding numbers synchronous to those of the green turtles. These other species are carnivorous or omnivorous whereas the green turtle is herbivorous. Given this difference in diet and given the involvement of fat deposition in early preparation for a breeding season, there is a strong possibility that the SO may regulate green turtle nesting numbers via a nutritional pathway. It is not suggested that Darwin pressure necessarily directly affects the nutritional pathway. Darwin pressure is used here simply as a convenient index of the SO. Rather, one of the other atmospheric or oceanic variables associated with the SO probably affects the nutritional pathway. If the atmospheric or oceanic variable affecting breeding could be isolated, this may allow the prediction of breeding fluctuations at rookeries located in other areas not markedly affected by the SO (e.g. western Atlantic Ocean).

Acknowledgments

This research was funded in part by a Marine Science and Technology Grant from the Australian Department of Science and a grant from the Raine Island Corporation and was conducted as part of the Queensland Turtle Research Project of the Queensland National Parks and Wildlife Service. This assistance is gratefully acknowledged.

References

Barber, R. T., and Chavez, F. P. (1983). Biological consequences of El Niño. *Science* **222**, 1203–10.

Bustard, R. (1972). 'Sea Turtles.' (Collins: London.)

Carr, A., Carr, M. H., and Meylan, A. B. (1978). The ecology and migration of sea turtles, 7. The west Caribbean green turtle colony. *Bull. Amer. Mus. Nat. Hist.* **162**, 1–46.

Limpus, C. J. (1980). The green turtle, *Chelonia mydas*, in eastern Australia. *James Cook Univ. N. Qld Res. Mono.* 1, 5–22.

Limpus, C. J., Fleay, A., and Guinea, M. (1984). Sea turtles of the Capricorn Section, Great Barrier Reef. In 'The Capricorn Section of the Great Barrier Reef: Past, Present and Future'. (Eds W. T. Ward and P. Saenger.) pp. 61–78. (R. Soc. Qd. and Aust. Coral Reef Soc.: Brisbane.)

Limpus, C. J., and Parmenter, C. J. (1986). Sea turtle resources of the Torres Strait region. In 'Torres Strait Fisheries Seminar, Port Moresby, 11–14 Feb. 1985'. (Eds A. K. Haines, G. C. Williams, and D. Coates.) pp. 95–107. (Aust. Govt Publ. Service: Canberra.)

Limpus, C. J., and Reed, P. C. (1985*a*). Green turtles stranded by Cyclone Kathy on the south-western coast of the Gulf of Carpentaria. *Aust. Wildl. Res.* **12**, 523–33.

Limpus, C. J., and Reed, P. C. (1985*b*). The green turtle, *Chelonia mydas*, in Queensland: population structure in a coral reef feeding ground. In 'Biology of Australasian Frogs and Reptiles'. (Eds G. Grigg, R. Shine and H. Ehmann.) pp. 47–52. (Surrey Beatty and Sons: Sydney.)

McBride, J. L., and Nicholls, N. (1983). Seasonal relationships between Australian rainfall and the Southern Oscillation. *Mon. Weather Rev.* **111**, 1998–2004.

Nicholls, N. (1984*a*). A system for predicting the onset of the north Australian wet-season. *J. Climatol.* **4**, 425–35.

Nicholls, N. (1984*b*). The Southern Oscillation and Indonesian sea surface temperature. *Mon. Weather Rev.* **112**, 424–32.

Nicholls, N. (1985*a*). Predictability of interannual variations of Australian seasonal tropical cyclone activity. *Mon. Weather Rev.* **113**, 1144–9.

Nicholls, N. (1985*b*). Impact of the Southern Oscillation on Australian crops. *J. Climatol.* **5**, 553–60.

Nicholls, N. (1986). Use of the Southern Oscillation to predict Australian sorgham yield. *Agric. For. Meteorol.* **38**, 9–15.

Rasmusson, E. M., and Carpenter, T. H. (1982). Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Niño. *Mon. Weather Rev.* **110**, 354–84.

Schulz, J. P. (1975). Sea turtles nesting in Surinam. *Zoologische Verhandelingen, uitgegeven door het Rijkmuseum van Natuurlijke Historie te Leiden* **143**, 1–144.

Manuscript received 17 September 1986; accepted 26 February 1987