TABLE III

List of food items species recorded for Mallee fowl.

ITEM		SOURCE
Plant material		
Fungus		Chandler 1913, 1934; Bellchambers 1916
Trees	*Pittosporum* sp.	Frith 1962
	Eucarya acuminata	Cleland 1952
	Owenia acidula	Cleland 1952
Shrubs	*Cassia eremophila*	Frith 1962
	Acacia brachybotrya	Frith 1962
	A. hakeoides	Frith 1962
	A. buxifolia	Frith 1962
	A. rigens	Bellchambers 1916; Frith 1962
	A. stenophylla	Bellchambers 1916
	Eritostemon difformis	Frith 1962
	Beyeria opaca	Chandler 1913, 1934; Ross 1919; Frith 1962
	Dodonaea busariifolia	Table II
Herbs		Frith 1962
	Zygophyllum sp.	Table I and II
	Arthropodium strictum	Table I and II
Parasites	*Cassytha melantha*	Table I; Lea & Gray 1935
Animal material		
Insects	Blattodea	Table II; Frith 1962
	Coleoptra	Table II; Frith 1962
	Hemiptera	Table II
	Hymenoptera	Tables I and II; Ross 1919; Frith 1962
	Odonata	Table II
	Orthoptera	Table II
Arachida	Araneae	Table II

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THE EFFECT OF CYCLONE 'SIMON' ON TERNS NESTING ON ONE TREE ISLAND, GREAT BARRIER REEF, AUSTRALIA

Adverse weather can reduce the breeding success of seabirds. Marine terns are particularly susceptible to high winds where spray and rough sea surface can reduce fishing success (Boecker 1967; Langham 1968; Salt & Willard 1971; Dunn 1973, 1975; Taylor 1983). Hurricanes recorded in North America have resulted in the flooding of nest sites and entrapping of chicks in sand and vegetation (Owre 1967; Gochfield & Ford 1974; Nisbet 1972, 1978; Nisbet & Cohen 1975), and death through wetting of plumage and inability to maintain body temperature (White *et al.* 1976). Cyclones occur mainly from December to April along the Australian east coast with 1.7, 1.9 and 1.3 per year in January, February and March, respectively (Lourensz 1981). There is a report of tern mortality caused by a cyclone in the MacArthur Islands (MacGillivray 1914). This account refers to the effect of Cyclone 'Simon' on the breeding success of terns nesting on One Tree Island

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in the Capricorn-Bunker Group of the Great Barrier Reef, Australia.

STUDY AREA AND METHODS

The study area was One Tree Island (23°31′S, 152°05′E) in the Capricorn-Bunker Group, at the southern end of the Great Barrier Reef, 92 km NE of Gladstone. The island consists of coral rubble with clumps of stunted *Pisonia grandis, Pandanus* sp. and *Argusia argenta*, a ground covering by *Melanthera biflora, Ipomea macrantha*, and an area of *Sesuvium portulacastrum* surrounding a brackish pond. A more detailed description is given by Domm & Recher (1973), Hulsman (1979) and Heatwole *et al.* (1981). This account refers to a stay from 7 December 1979 to 27 February 1980, inclusive.

Six species of tern have been recorded nesting on One Tree Island (Serventy *et al.* 1971; Hulsman 1981), but only four nested during the above period. Most clutches of the Black-naped Tern *Sterna sumatrana* were lost during high tides combined with strong winds. This account refers to the ground-nesting Crested Tern *S. bergii* (1 000 pairs) and Bridled Tern *S. anaethetus* (300 pairs) and a small colony of tree-nesting White-capped Noodies *Anous tenuirostris* (= *minutus*) (30 pairs). Only the last group (subcolony) of Crested Terns to hatch was subjected to detailed study and may have contained younger, inexperienced birds. This may have effected their reproductive performance. Samples of the Bridled Tern and White-capped Noody breeding populations were also studied. Growth of chicks was measured using weight, wing length (from carpal joint to tip of longest primary) and culmen length (from skull to bill tip). An attempt was made to study chicks that had reached their asymptotic weight, so that further weights measured fluctuations around the asymptote. This allowed the effect of weather on the three species to be compared. All Crested Terns studied hatched between 11 and 15 January. Bridled Terns did not hatch so synchronously, but 19 of 24 hatched between 20 and 30 December and 7 of 11 White-capped Noddy chicks hatched between 25 December and 6 January. White-capped Noddy chicks were weighed every other day and Crested and Bridled Tern chicks were weighed every three days. The severe damage caused by the cyclone prevented me from weighing chicks on 27 February, when One Tree Island was evacuated.

WEATHER

On One Tree Island, there is little rain during the summer months. In December 1979 there was only 9.5 mm rain, and in January 1980 the rainfall was slight (<50 mm), except during 6-8 January, when tropical cyclone 'Paul' passed along the coastline about 50 km distant and a further 177 mm of rain was recorded. Winds and rain during this period destroyed 13 White-capped Noddy nests containing eggs. Between 10-13 February 165 mm of rain was recorded, associated with a storm on 10-12 February, with strong winds developing to gale-force by 14-15 February. From 23-26 February, tropical cyclone 'Simon' became stationary close to One Tree Island, resulting in gusts of wind of 140-150 km/hr and over 900 mm of rain was recorded by the Warden (Fig. 1). Average wind speeds in Figure 1 were derived from Heron Island Meteorological station, 20 km north, which experienced lower wind speeds

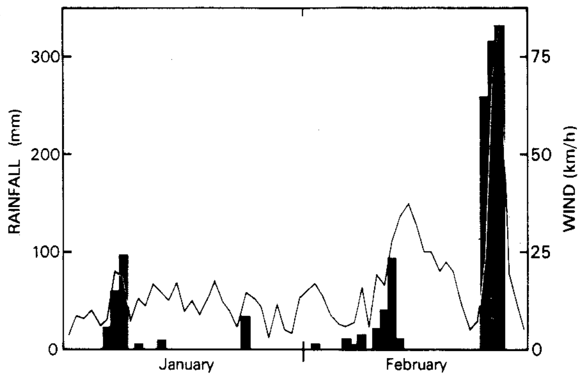

Figure 1. The daily rainfall (histogram) recorded at One Tree Island and the daily wind speed (graph) recorded at Heron Island in January and February 1980.

on 14-15 and 23-26 February than those on One Tree Island.

RESULTS

A summary of growth statistics of terns from One Tree Island is given in Table I. The asymptotic weights for 1979-80 season were reached in both Bridled Tern and White-capped Noddy chicks between 20-25 January, but the Crested Tern chicks did not reach their asymptotic weight until about 10 February. Once asymptotic weights were reached, there should be minimal changes in weight under normal conditions, while feather growth, especially of remiges and rectrices, continued.

The storm of February 10-12, coincided with a drop in weight in all three species. Although the chicks of the

TABLE I

A summary of Tern growth statistics (Langham 1983).

	Fledging Period (days)	Asymptotic Weight (g)	Adult Weight (g)	Growth Weight (K)[2]	$t_{10}-t_{90}$ (days)
Crested Tern	35-41	279 (318)[1]	320 (350)[1]	0.094 (0.107)[1]	38-40
Bridled Tern	58-60	128.5	130	0.114	38.5
White-capped Noddy	51-53	117	115	0.152	29

[1]1981-82 results when no cyclone occurred

[2]Logistic growth equation: $Wt = \frac{A}{1 + e^{-k(t - ti)}}$,

where Wt = weight at time t;

A = asymptote of growth curve; e = base of natural logarithm, 2.72; K = growth rate constant; ti = age at inflection point of growth curve (Ricklefs 1976)

[3]Represents time required to grow from 10% to 90% of the asymptote.

Bridled Tern lost weight during the storm, they did not appear to be affected by the subsequent gale and gained weight (Fig. 2). The White-capped Noddy chicks lost weight during the storm and gale-force winds, but quickly regained weight when the winds abated. In contrast, the Crested Tern chicks continued to lose weight until after the cyclone (Fig. 2).

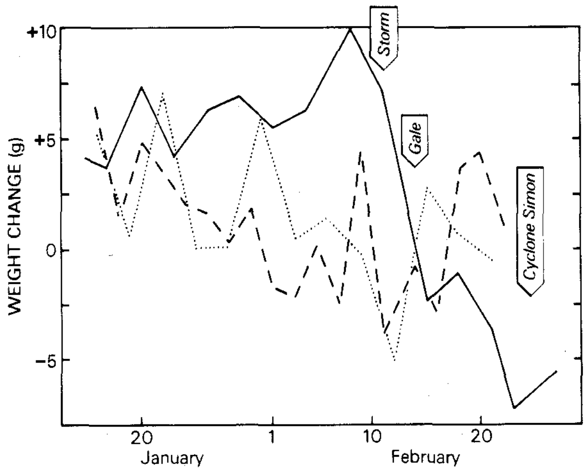

Figure 2. The mean weight change per day of tern chicks in late January and February 1980.
KEY: Bridled Tern = ...
White-capped Noddy = ---------
Crested Tern = ———

It was not possible to weigh chicks during cyclone 'Simon' but the effect on chick mortality was recorded after the weather cleared. During the cyclone, adult terns with fledged chicks disappeared from the island. Adults whose chicks had not fledged remained in the vicinity, although most chicks were too large to be brooded and the weather made it impossible to forage. Most of the adults crouched behind rocks and vegetation for shelter. The Crested and Bridled Tern chicks sought shelter in the vicinity of the nest site, whereas White-capped Noddy chicks attempted to remain near their nests in the branches of *Pisonia* trees.

Among the Bridled Terns, only one of the nine chicks still in the study area died during the cyclone. Apart from three chicks that died within 14 days of hatching, prior to 8 January, the remaining 12 chicks had fledged and were not seen subsequently. This gave an overall chick mortality of 16.7% (n = 24). Before the cyclone, five of the 11 White-capped Noddy chicks had died from being blown down from their nests during the gale-force winds between 12–16 February. These chicks starved as parents ignored chicks on the ground. Of the six chicks remaining on 17 February, four fledged and two died during the cyclone, giving an overall chick mortality of 64% (n = 11). Although the Noddy chicks gained in weight before the cyclone (Fig. 2), their position near their nest sites made them vulnerable to strong winds. The few adults that remained in the vicinity were also at risk from *Pisonia* trees that were blown down during the cyclone. Several adults were trapped under fallen trees and suffered injury as a result.

The mean weights and wing lengths of surviving and dying Crested Tern chicks are compared in Table II. Weights were significantly different from 18–23 February, and wing lengths significantly different from 4–23 February. The mean weights and wing lengths of the survivors (n max. = 5) and those dying (n = max. 14) are shown in Figure 3a & 3b. Dead chicks were retrieved from the colony area, but surviving chicks, recognized by their colourbands, could not be caught as they took to the sea.

TABLE II

Comparison of the weight and wing length of surviving and dying Crested Tern chicks.

	February date						
	4	8	11	15	18	21	23
Number surviving	4	5	4	5	5	5	5
Number dying	9	11	8	10	13	12	14
Weight							
Two way t-test	1.71	1.85	0.92	2.12	3.08	4.57	3.27
Level of significance	NS	NS	NS	NS	1%	0.1%	1%
Wing length							
Two way t-test	2.39	2.25	2.51	3.13	2.93	5.64	3.29
Level of significance	5%	5%	5%	1%	1%	0.1%	1%

The weights and wing lengths of surviving and dying Crested Tern chicks between 15–23 February were significantly different (analysis of variance, F = 12.52 and 9.64, P <0.01 respectively). The reason for these differences amongst chicks of the same age was not known, but age and experience of adults may have been responsible as in other terns (see Coulson & Horobin 1976; Mills & Shaw 1980).

DISCUSSION

The Bridled Tern chicks suffered little mortality during the cyclone. In contrast, the tree-nesting White-capped Noddies lost many eggs and chicks through nests and chicks either being blown down or trees being damaged. The cyclone caused heavy mortality in the late-hatching Crested Tern chicks. During the cyclone, the chicks of all three species lost weight because their parents were

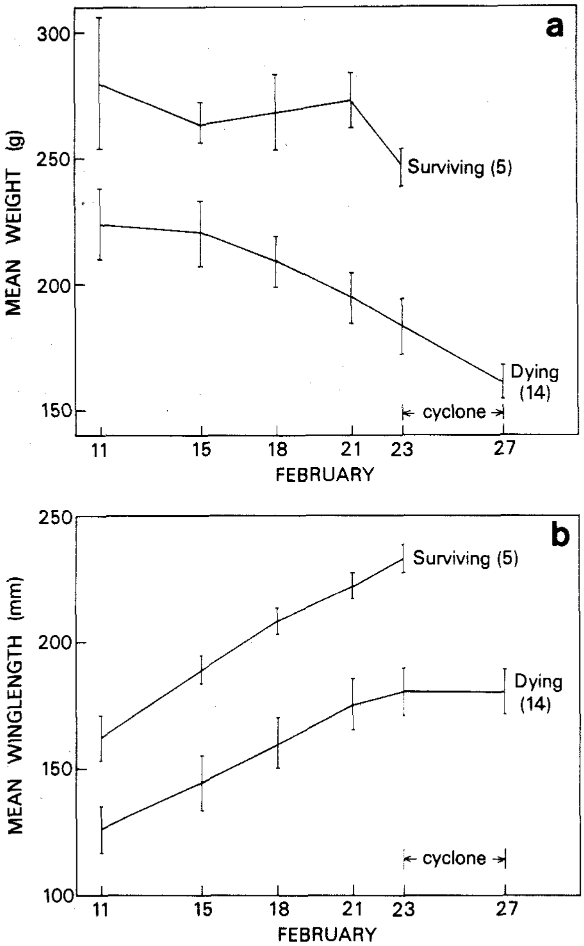

Figure 3. (a) Mean weights of Crested Tern chicks during 11-27 February (±1 *s.e.*)
(b) Mean wing lengths of Crested Tern chicks during 11-27 February (±1 *s.e.*)

unable to forage. Chicks also lost weight because they had to draw on their reserves to thermoregulate as rain and wind caused their feathers to lose their insulating properties.

Both the Bridled Tern and White-capped Noddy have a single egg clutch, as do most pairs of Crested Terns (mean clutch = 1.01, n = 1004) on One Tree Island, yet their chick growth patterns are quite different. The Crested Tern chick reaches it asymptotic weight and fledges between 35-41 days. Although the Bridled Tern and White-capped Noddy chicks reach their asymptotic weight at about 40 and 30 days, they do not fledge until 58-60 and 51-53 days, respectively (Table I). The Sooty Tern *Sterna fuscata* and the Brown Noddy *Anous stolidus* have similar chick growth patterns to the Bridled Tern and White-capped Noddy (Ashmole 1963; Feare 1976; Ricklefs & White-Schuler 1978; Ricklefs & White 1981).

Owre (1967) attributed most of the losses of Sooty Terns and Brown Noddies from hurricane 'Alma' to flooding or burying of nests. Common Terns *Sterna hirundo* suffered similar losses during hurricane 'Agnes' (Nisbet 1972, 1978; Nisbet & Cohen 1975; Gochfield & Ford 1974). White *et al.* (1976) described the effect of the same hurricane on Sooty Terns and Brown Noddies. Only the Sooty Tern chicks suffered a high mortality, mainly those less than ten days old. These young chicks, which would normally be brooded by their parents, died of exposure from wind and rain. All chicks suffered a weight loss and retardation of wing growth during the hurricane, similar to that described by Ashmole (1963) on Ascension Island during food shortages. Sooty Tern chicks in the Seychelles lost weight during periods of rain, but only those that had lost down through being pecked by adults were likely to die (Feare 1976). Brown Noddies were less affected by hurricane 'Agnes' probably as a result of their more protected nest sites and proximity of their feeding area (White *et al.* 1976).

Those species with a prolonged nestling stage appeared to suffer little mortality once they attained asymptotic weight, with the exception of those dying from nest destruction or flooding as reported for the White-capped Noddy and Sooty Tern, respectively. In contrast, and 74% of the Crested Tern chicks 36-40 days old close to fledging, died as a result of the storm and gales followed by a cyclone. Starvation, combined with exposure, appeared to be the main cause of weight loss and death in Crested Tern chicks.

The Crested Tern is an inshore-feeding species (Kikkawa 1976; Hulsman 1978; pers. obs.) whereas the other species considered above feed predominantly offshore, especially the Sooty Tern (Gould 1974). Ricklefs (1978) has postulated that the growth rate in semiprecocial species such as terns is related to the collection rate of adults. Offshore-feeding species tend to be slow growers because their food is patchy, being dependent on schools of predatory fish bringing the food of terns close to the surface (Ashmole 1963). The unpredictable nature of such schools could mean that chicks may have to withstand periods of starvation. The lower feeding frequency of offshore-feeding species compared to inshore-feeding species (Hulsman 1978; Hulsman & Langham in prep.) gives an indication of the time required for foraging. Also, the offshore-feeding species need to carry the many small food items in their crop, rather than as single items in their bill.

The first part of the growth curve was similar in all three species considered on One Tree Island as indicated by the growth constant (K) in Table I. The prolonged growth of the Bridled Tern and the White-capped Noddy resemble the Sooty Tern where daily energy requirements reach a maximum early, but then remain at that level until fledging, due to an increase in energy required for maintenance (Ricklefs 1978). Slow growth is an adaptation to the scarcity and patchiness of food in tropical waters, and also reduces chick mortality when adverse weather prevents foraging. Unfortunately, the choice of *Pisonia* as a nesting site of the White-capped Noddy in the Capricornia group puts the offspring at risk in strong winds.

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