the Regent Honeyeater *Xanthomyza phrygia*. Emu 89, 140-154.
Garnett, S. 1992. Threatened and extinct birds of Australia. RAOU Report 82.
Keast, J.A. 1968. Seasonal movements in the Australian honeyeaters (Meliphagidae) and their ecological significance. Emu 67, 159-210.
Ley, A. 1990. Notes on the Regent Honeyeater *Xanthomyza phrygia*. Australian Bird Watcher 13, 171-173.
Ley, A.J. & Williams, M.B. 1992. The conservation status of the Regent Honeyeater near Armidale, NSW. Australian Bird Watcher 14, 277-281.
Loyn, R.H. 1987. Effects of patch area and habitat on bird abundances, species numbers and tree health in fragmented Victorian forests. Pp. 65-77 in Nature Conservation: the Role of Remnants of Native Vegetation. Eds D.A. Saunders, G.W. Arnold, A.A. Burbidge & A.J.M. Hopkins. Surrey Beatty, Sydney.
Loyn, R.H., Runnalls, R.G., Forward, G.Y. & Tyers, J. 1983. Territorial Bell Miners and other birds affecting populations of insect prey. Science 221, 1411-1413.
Lunney, D. & Leary, T. 1988. The impact on native mammals of land-use changes and exotic species in the Bega district, New South Wales, since settlement. Australian Journal of Ecology 13, 67-92.
Majer, J.D., Recher, H.F. & Ganeshanandam, S. 1993. Variation in foliar nutrients and its relation to arthropod communities on *Eucalyptus* trees in eastern and Western Australia. Australian Journal of Ecology 17, 383-393.
McFarland, D.C. 1986. The organization of a honeyeater community in an unpredictable environment. Australian Journal of Ecology 11, 107-120.
Paton, D.C. 1982. The diet of the New Holland Honeyeater, *Phylidonyris novaehollandiae*. Australian Journal of Ecology 7, 279-298.
Recher, H.F., Majer, J.D. & Ford, H.A. 1991. Temporal and spatial variation in the abundance of eucalypt canopy invertebrates: response of forest birds. Pp. 1568-1575 in Acta XX Congressus Internationalis Ornithologici, Christchurch 1990, 3. Ed. B.D. Bell *et al.* New Zealand Ornithological Trust Board, Wellington.
Saunders, D.A. 1989. Changes in the avifauna of a region, district and remnant as a result of fragmentation of native vegetation: the wheatbelt of Western Australia. A case study. Biological Conservation 50, 99-135.
Webster, R. & Menkhorst, P. 1992. The Regent Honeyeater (*Xanthomyza phrygia*): population status and ecology in Victoria and New South Wales. Arthur Rylah Institute for Environmental Research Technical Report Series No. 126.
Wykes, B. 1985. The Helmeted Honeyeater and related honeyeaters of Victorian woodlands. Pp. 205-217 in Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management. Eds J.A. Keast, H.F. Recher, H.A. Ford & D. Saunders. Surrey Beatty, Sydney.

On Cyclones, *Pisonia grandis* and the Mortality of Black Noddy *Anous minutus* on Heron Island

J. Ogden

School of Biological Sciences, Auckland University, Auckland, New Zealand

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The population of noddies on Heron Island (23°26'S, 151°51'E) has been increasing exponentially since early this century (Barnes & Hill 1989). The rate of increase has averaged *c.* 7% per annum, although it has not been even; considerable variation in numbers occurs from year to year (Hulsman 1984; Ogden unpubl. data). Periodic declines may follow cyclones, such as that in 1967 which killed many noddies and destroyed nesting trees (Kikkawa 1970). Cyclone 'David' in 1976 also did much damage on Heron Island (Flood & Jell 1977) and resulted in the deaths of noddy chicks from starvation because the adults were unable to collect food (Hulsman 1977).

On Heron Island, as elsewhere on the Great Barrier Reef, noddies nest mainly in *Pisonia grandis* trees (Dale *et al.* 1984; Hulsman *et al.* 1984; Barnes & Hill 1989) and utilise the shed leaves for nest building material. Both adults and chicks can become ensnared by the sticky fruits of *Pisonia* and they usually die when this happens. Chicks blown out of nests are usually ignored by adults (Congdon 1991) and become trapped in the fruit clusters on the forest floor. Cribb (1969) remarks that, 'considerable though this mortality is, it probably represents only a minute fraction of the total number of birds visiting an island'. Because Heron Island is an important tourist resort, and because numerous dying noddy chicks make a pathetic sight which excites the emotion and the scientific curiosity of visitors, there is reason to have some assessment of the importance of periodic large scale mortality to the population as a whole (*cf.* Hill & Rosier 1989).

In December 1978 and 1979, and in January 1992, I counted nests of Black Noddies in two 30 x 30 m plots of *Pisonia* forest on Heron Island. Single nest counts were made on the same day in each plot. The plots are described, and the methods used to estimate noddy numbers explained, in Ogden (1979) and Ogden (unpubl.). Plot 1 was in tall *Pisonia* forest with the main canopy at *c.* 14 m and a few taller trees. Plot 2 was in more open forest with a canopy at *c.* 10m. They are representative, comprising a 2% sample, of the *Pisonia* forest area. In two of the three years in which I counted noddy nests cyclones occurred in the area and the resulting chick mortality within the plots was counted. The dry season (August–October) of 1991, preceding my 1992 visit, coincided with an exceptionally prolific seeding by *Pisonia*, so that in January 1992 I was also able to make observations on this source of noddy mortality. The results were obtained fortuitously, and are presented as evidence of noddy mortality clearly attributable to one cause (chicks blown from nests by high winds) and circumstantially to another (entanglement of adults in *Pisonia* fruit clusters). In the Discussion I have extrapolated from the mortality counts, the estimated adult population sizes, and the estimated frequency of storm and seed production events of a similar magnitude, to suggest the average annual mortality rates from these causes.

Results

Cyclone 'Paul' affected Heron Island on 6, 7 and 8 January 1980 with winds of up to 25 km per hour and heavy rain. Several *Pisonia* trees were blown down in the research station area. Extensive mortality of noddy chicks occurred. In the resort and at the research station dead or dying chicks were so abundant that they were swept into piles and disposed of by the staff in buckets. Table 1 gives the mortality on 8 January 1980 in the two plots.

The total noddy population on the island at the time was probably *c.* 54 000 birds (Ogden in prep.). Extrapolating the figures in Table 1 suggests that, despite their conspicuousness, only between 600 and 1100 chicks perished. Even if mortality was higher in the less protected trees at the developed end of the island, it did not exceed a few per cent of the adult population. Another cyclone ('Simon') passed over Heron Island in February (24–26) of the same year, with winds of up to 82 km per hour. This caused widespread damage in the forest (C. Limpus pers. comm.) and presumably added considerably to the chick mortality during that year.

Table 1 Noddy chick mortality after Cyclone 'Paul', 8 January 1980.

	Dead chicks	Occupied nests	Mortality (% adults)
Plot 1	10	443	1.13
Plot 2	30	714	2.1

In 1992, Cyclone 'Betsie' caused gales on Heron Island from 11 to 13 January. Although a few high gusts occurred winds were not as strong as those associated with 'Paul' and rainfall was slight. No tree-falls were observed. Table 2 gives the chick mortality immediately after the storm (14 January 1992). Mortality averaged about 0.6% of the adult population (126 280; Ogden in prep.) suggesting that about *c.* 750 chicks were killed. This number agrees with observation in so far as it is less than that in 1980.

Table 2 also gives the number of dead adults on the ground in the plots. These birds were partly decomposed and all enmeshed in *Pisonia* fruit clusters. I assume they represent mortality from this cause as a result of the prolific fruit production a few months previously. Mortality was clearly concentrated beneath large fruiting trees and the higher value in plot 1 reflects the larger forest stature there. The average value (0.87%) implies that *c.* 1100 adult birds died from this cause in the latter part of 1991.

Discussion

The breeding season for Black Noddies is from October to March, with most chicks present during December, January and February (Kikkawa 1970). Some chicks fall from nests every year; these are usually abandoned by their parents, become enmeshed in *Pisonia* seeds and die. However, my observations indicate that this 'background' chick mortality is slight: chicks are abundant on the forest floor only after strong winds, arbitrarily defined as > 25 km per hour. This mortality due to

Table 2 Chick and adult mortality on 14 January 1992.

	Dead chicks	Dead adults	Occupied nests	Mortality as % of adult population Chicks	Adults
Plot 1	6	12	484	0.6	1.2
Plot 2	6	5	498	0.6	0.5

storms is highly periodic: cyclones or gale force winds occur on average every other year and last for only a few days. An analysis of the climatic records from Heron Island showed that winds of this strength occurred during December–February in 13 of the 21 years with records (1968–91; not all years have full records). Assuming that the 1980 and 1992 cyclones are reasonably representative, the average annual mortality rate due to strong winds in the breeding season is *c.* 0.7%. However, some dying chicks may have been removed by reef herons *Egretta sacra* that were frequently present on the ground under the nesting trees (*cf.* Braithwaite 1973). Consequently, chick mortality due to storms may be rounded up to *c.* 1% per annum. This excludes unmeasured but probably higher mortality associated with the most severe cyclones.

The 1991 mortality due to *Pisonia* fruits was certainly exceptional. The flowering and seeding of *Pisonia* was exceptionally prolific, and for the first time in at least 15 years *Pisonia* seedlings were seen in abundance (pers. comm.: A.J. Bruce; A.B. Cribb; I.D. Lawn; pers. obs.). On Heron Island I saw only one or two dead birds from this cause in a total of 12 weeks of observation in 1979 and 1980. Averaging the 1991 mortality over 15 years gives *c.* 0.06% per annum. Although this figure is probably an underestimate — some mortality occurs every year — it confirms Cribb's (1969) assessment that, in the longer term, this source of mortality is negligible.

Because my counts were made on single days following cyclones, rather than accumulated over the entire breeding season, they probably underestimate actual mortality rates. Adult mortality due to *Pisonia* fruit clusters may average *c.* 0.1% per annum. It is higher in years of prolific fruit production but these may be as rare as once per decade. Storms, although infrequent and of short duration, constitute a greater mortality risk. Mortality from this cause also varies greatly from year to year but appears to average about 1% per annum. However, the data base from which these estimates are derived is small and they should be regarded merely as giving the order of magnitude, requiring verification by further observation.

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References

Barnes, A. & Hill, G.J.E. 1989. Census and distribution of Black Noddy *Anous minutus* nests on Heron Island, November 1985. Emu 89, 129-134.

Braithwaite, R.W. 1973. Nesting habits of White Capped Noddies. Sunbird 4, 1-4.

Cribb, A.B. 1969. The *Pisonia*. Queensland Naturalist 19, 110-114.

Congdon, C.B. 1991. Parent-offspring recognition in the Black Noddy *Anous minutus*. Emu 91, 158-163.

Dale, P., Hulsman, K., Jahnke, B.R. & Dale, M. 1984. Vegetation and nesting preferences of Black Noddies at Masthead Island, Great Barrier Reef. 1. Patterns at the macro-scale. Australian Journal of Ecology 9, 335-341.

Flood, P.G. & Jell, J.S. 1977. The effect of cyclone 'David' (January 1976) on the sediment distribution patterns on Heron Reef, Great Barrier Reef, Australia. Pp. 119-125 in Proceedings of the Third International Coral Reef Symposium, University of Miami, Miami, Florida, May 1977.

Hill, G.J.E. & Rosier, J. 1989. Wedge-tailed Shearwaters, White-capped Noddies and tourist development on Heron Island, Great Barrier Reef Marine Park. Journal of Environmental Management 29, 107-114.

Hulsman, K. 1977. Breeding success and mortality of terns at One Tree Island, Great Barrier Reef. Emu 77, 49-60.

Hulsman, K. 1984. Survey of seabird colonies in the Capricornia Section of the Great Barrier Reef Marine Park. 3. Population parameters and some management strategies. Research Report to the Great Barrier Reef Marine Park Authority, Townsville.

Hulsman, K., Dale, P. & Jahnke, B.R. 1984. Vegetation and nesting preferences of Black Noddies at Masthead Island, Great Barrier Reef. 2. Patterns at the micro-scale. Australian Journal of Ecology 9, 343-352.

Kikkawa, J. 1970. Birds recorded at Heron Island. Sunbird 1, 34-48.

Ogden, J. 1979. Estimates of the population sizes of the Black Noddy and Wedge-tailed Shearwater at Heron Island in 1978. Sunbird 10, 33-40.