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The breeding biology of Hooded Plovers, *Thinornis rubricollis*, on Phillip Island, Victoria

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Abstract. The breeding biology of Hooded Plovers, *Thinornis rubricollis*, was examined between 1992 and 1996 on Phillip Island, Victoria, Australia. Particular attention was paid to their breeding success in relation to local population dynamics and the activities of humans and introduced predators. Three of twelve beaches used accounted for 52% of nesting attempts but only 10% of fledged young. The most common nest site was on flat beaches (52% of clutches); followed by nests on stony terraces (25%) or on the sides of primary dunes above flat beaches (23%).

Clutches were laid from August to March with a peak of laying in January. The average clutch recorded was 2.4 ± 0.1 eggs (range 1–3, median 3, n = 60). Hatching success was 25 of 149 eggs (16.8%) and 13 of 60 clutches (22%). Of the 83% eggs (in 78% of clutches) that failed to hatch, 29% eggs (25% of clutches) were in nests that had been disturbed by dogs, foxes (9% of eggs or 10% of clutches), or had been trampled by sheep (3% of eggs and clutches).

Annual breeding success was 0.0–11.1% of chicks fledged per egg laid, and, in the four years, only 6.7% of eggs resulted in fledged young. All 15 chicks that did not fledge were lost in the first three weeks after hatching.

The number of plovers recorded in counts on Phillip Island declined significantly between 1982 and 1998 and it is proposed that breeding success was too low to sustain the local population. Anthropogenic causes of nest failure were high and some management solutions and further research are recommended.

Introduction

The Hooded Plover, *Thinornis rubricollis*, of southern Australia has experienced some range contraction over the past century (Cameron and Weston 1999; Garnett and Crowley 2000) and the eastern Australian population, ~3000 birds, has been classified as 'vulnerable' by Garnett and Crowley (2000). Hooded Plovers prefer to nest on beaches in eastern Australia (Marchant and Higgins 1993) where vehicular traffic, human disturbance and introduced predators have been identified as significant threats (Buick and Paton 1989; Marchant and Higgins 1993; Dowling and Weston 1999; Weston 2000, 2001). Buick and Paton (1989) estimated that vehicular traffic on beaches in South Australia destroyed 81% of artificial nests and Dowling and Weston (1999) found that the major cause of mortality of eggs on the Mornington Peninsula in Victoria was trampling by people. Vehicular traffic is not permitted on Phillip Island beaches but other recreational activity is very high in summer, including exercising dogs, *Canis familaris*. Predation is a common cause of nest failure in plovers (Page *et al*. 1983; Lessells 1984; Patterson *et al*. 1991) and three potential predators of eggs, chicks and adults (dogs, foxes, *Vulpes vulpes*, and cats, *Felis catus*), have been introduced to Phillip Island (Dann 1992). On Phillip Island, Hooded Plovers nest in areas where human recreational activity is high, particularly in spring and summer, and near urban areas where dog and pedestrian activity is also very high. Accordingly, with high human visitation at breeding sites during breeding periods and with a suite of introduced mammalian predators, there is considerable scope for anthropogenic causes of breeding failure on the island. The aim of this study was to examine the breeding biology, particularly breeding success, of Hooded Plovers on Phillip Island in relation to the activities of humans and introduced predators.

Methods

The breeding ecology of plovers was examined from July 1992 to June 1996 on Phillip Island (38°28′S, 145°18′E) (Fig. 1) in southern Victoria following preliminary observations in 1991. The island's beaches were surveyed on foot by one or two observers each week from the beginning of July each year and the activities of pairs of adults were monitored closely until nest scrapes were found. Breeding plovers were found along ~16 km of coastline, consisting mainly of sandy beaches with some rock outcrops or stony terraces. Observations were made every few days until egg-laying began, when weekly visits were resumed. Young birds were caught by hand and colour-banded at about four weeks of age using colour bands (flags) glued together with Loctite 401. In addition, some adults were caught with loop-traps (Weston 2000) in the vicinity of nests and individually colour-marked with bands. All breeding birds were checked in subsequent years for bands.

The maximum length and breadth of eggs were measured with callipers to 0.1 mm and eggs were weighed to 0.5 g (Pesola 50-g spring balance). Clutch sizes were obtained from nests found within the first week of incubation and whose contents did not change over three consecutive days. Loss of eggs from a clutch was never observed and therefore circumstantial evidence was used to infer their fate. Egg loss

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or desertion caused by foxes, dogs, sheep and humans was inferred from footprints associated with the disappearance, destruction or desertion of eggs; whereas loss to storm tides was clearly identified by changes to the shoreline and nest site after storms. We defined fledging as having occurred once chicks were capable of a flight longer than 100 m. Runners attempted flight by jumping and fluttering for a few metres from ~30 days after hatching, increasing their activity until short semi-circular flights of 100–200 m were completed at 34–36 days.

An incomplete count of plovers on Phillip Island was made in 1980 (Lane 1982); there were three counts up to 1990 not including an incomplete count in 1986 (Weston 1993) and annual counts have been conducted each November 1990–98. Complete counts entailed the visiting of all areas on the island known to have been frequented by Hooded Plovers in the past over two consecutive days and included adults and juveniles.

Statistical testing was performed using Systat 10 (SPSS 2000). It has been assumed that all breeding events were independent but, without a fully marked population, it is likely that the data were influenced by pseudoreplication. However, with the small population available and the urgent need to examine their biology, this possibility could not be avoided. The Friedman test was applied to clutch sizes as the data were discrete and non-parametric.

Results

Age at first breeding

The age at first breeding was determined from observations of two birds colour-banded as chicks and assumed no previous, unseen, breeding attempts. The age of the first was 23.5 months ± 0.25 months based on the record of a bird sitting on eggs on 12 January 1993 that had hatched on 30 January 1995 ± 2 days. The second was 20.5 months ± 0.25 months from a bird that hatched on 15 February 1993 ± 2 days and was found sitting on a single egg on 31 October 1994.

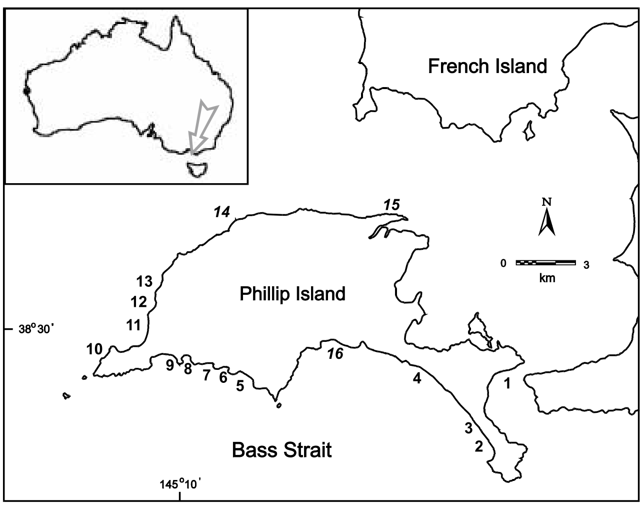

Fig. 1. The locations of Hooded Plover breeding sites on Phillip Island between 1992 and 1996. 1, Cleeland Bight; 2, Woolamai Surf Beach; 3. Anzacs Beach; 4, Forrest Caves; 5, Berrys Beach; 6, Hutchinsons Beach; 7, Thorny Beach; 8. Kitty Miller Bay; 9, Summerland Beach; 10, Cowrie Beach; 11, Flynns Beach; 12. Farm Beach; 13, Woolshed Bight. Three sites used in 1991–92 but not during this study are shown in italics: *14*, Saltwater Creek; *15*, Observation Point; *16*, Smiths Beach.

Table 1. The number of clutches laid and chicks fledged at the twelve breeding beaches used by Hooded Plovers on Phillip Island, Victoria, 1992–96

Breeding site	No. of clutches laid (% total)	No. of chicks fledged (% total)
Woolamai Surf Beach	5 (8.3)	3 (30)
Anzacs Beach	1 (1.7)	0
Cleeland Bight	2 (3.3)	0
Forrest Caves	12 (20.0)	0
Berrys Beach	7 (11.7)	0
Hutchinsons Beach	4 (6.7)	0
Thorny Beach	12 (20)	1 (10)
Kitty Miller Bay	3 (5.0)	0
Summerland Beach	4 (6.7)	2 (20)
Cowrie Beach	2 (3.3)	2 (20)
Flynns Beach	3 (5.0)	0
Farm Beach	5 (8.3)	2 (20)
Total	60	10

Nesting sites

Seventeen sites on 12 beaches along ~16 km of coastline were used for nesting during this study (Table 1; Fig. 1). Three beaches (Forrest Caves, Thorny and Berrys Beaches) (Fig. 1) accounted for 52% of the 60 nesting attempts recorded in the four years though they produced only 10% of the fledged young (Table 1). Some beaches had several frequently used breeding sites, sometimes used by different pairs simultaneously. In addition, three sites (Observation Point, the mouth of Saltwater Creek and Smiths Beach) (Fig. 1) were used by breeding plovers in 1991–92 but not in the four years of this study.

Nesting sites were classified into three types based on the geomorphology of the area around the site (Fig. 2). The commonest type, accounting for 52% of breeding attempts recorded, was above the high-tide line on flat beaches. Stony

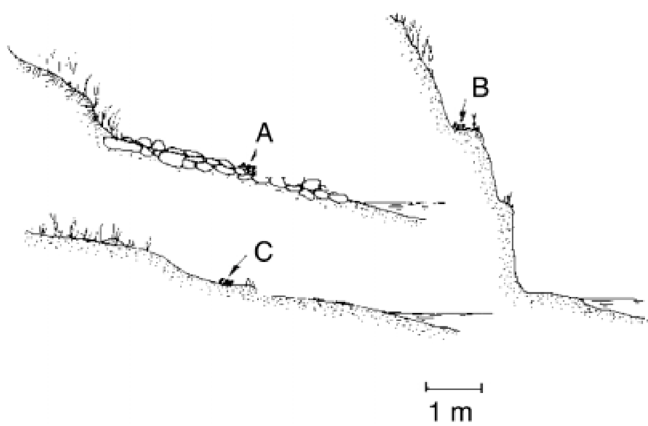

Fig. 2. Diagrammatic representation of the three types of nesting site used by Hooded Plovers on Phillip Island between 1992 and 1996: *A*, stony terraces; *B*, primary dune; *C*, flat beach. The arrow indicates location of nest site.

terraces, usually adjacent to beaches, were used in 25% of breeding attempts and the sides of eroding primary dunes above flat beaches were used for 23% of attempts. Nests were never found directly below high cliffs, but two nests were recorded within 2 m of the base of small cliffs up to 5 m in height. Nests on the sides of primary dunes were within 15–20 cm of a clump of grass or other vegetation except for two on bare rock; nests on flat sandy beaches were away from any vegetation or storm-washed seaweed that would obscure a seaward view from the sitting bird. Nests on stony terraces were placed on a relatively flat area of 10–20 cm surrounded by stones 4–10 cm in diameter, sometimes with a larger rock or two 20–30 cm in diameter within 0.5–1.0 m of the nest. The nest bowl often contained small quantities of sand, gravel, vegetation or broken shells.

Timing of breeding

Over the four years, clutches were laid from August to March with a peak of laying in January (Fig. 3). The mean laying dates (including first and replacement clutches) for individual years were all in the period between late November and early January (Table 2). Most clutches (68.3%) were laid from December to February (Fig. 3) and the mean laying date of all clutches combined for the four years was 22 December ± 6 days (Table 2).

Eggs

The average clutch over the four years was 2.4 ± 0.1 (range 1–3, n = 60) with 56.7%, 35% and 8.3% of clutches having three, two and one egg, respectively. Clutch size varied significantly in the four years (Friedman test = 60, d.f. = 3, $P < 0.01$) (Table 2). The dimensions (mean ± s.e.) of 34 eggs (of unknown laying order) were 36.8 ± 0.2 mm × 26.6 ± 0.1 mm (ranges 34.9–38.4 mm and 24.7–27.7 mm, respectively). Average weight (mean ± s.e.) of 37 eggs at various stages of incubation was 13.3 ± 0.3 g (range 10.5–16.5), although this is lower than the average weight of newly laid eggs because of weight loss during incubation. The mean number of clutches laid per pair in a breeding season was 1.4 (range 1.2–1.5) (Table 2).

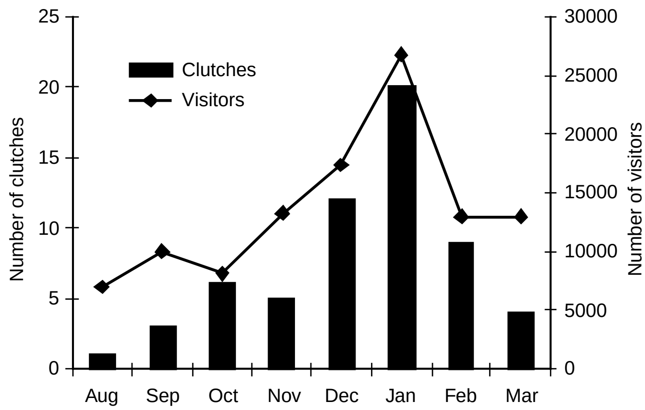

Fig. 3. The number of clutches laid each month by Hooded Plovers on Phillip Island from 1992 to 1996 (black bars) and the number of visitors recorded at the Phillip Island information centre each month from August 2000 to March 2001 (black line).

Hatching success

The hatching success for 149 eggs in 60 clutches was 16.8% eggs and 22% clutches (Tables 2, 3). Success in terms of eggs hatched varied between years from 6.9 to 25.7% (Table 2) but in some years there were too few data for statistical testing.

Of the 83% of eggs (in 78% of clutches) that failed to hatch, 29% of eggs (25% of clutches) were in nests that had been disturbed by dogs, foxes (9% of eggs or 10% of clutches), or had been trampled by sheep (3% of eggs and clutches) (Table 3). Storm tides washed away some eggs (8%) and human interference of various kinds accounted for another 10.7%. The causes of loss for 24.2% of eggs were not determined.

Table 2. Reproductive parameters of Hooded Plovers on Phillip Island, Victoria, 1992–96

Breeding parameter	1992–93	1993–94	1994–95	1995–96	Total
Breeding pairs	10	11	13	9	43
Mean laying date ± s.e. (months)	1 Jan. ± 0.36	27 Nov. ± 0.48	6 Jan. ± 0.36	6 Dec. ± 0.33	22 Dec. ± 0.20
Number of clutches	15	14	20	11	60
Number of eggs	43	35	45	26	149
Mean clutch size	2.86	2.5	2.25	2.36	2.43
Clutches per pair	1.5	1.3	1.5	1.2	1.4
Eggs hatched	3	9	10	3	25
% eggs hatching	6.9	25.7	22.2	11.5	16.8
Eggs hatched per clutch	0.20	0.64	0.50	0.27	0.42
Number of chicks fledged	3	2	5	0.0	10
Fledging success (%)	100	22	50	0.0	40
Chicks fledged per clutch	0.20	0.14	0.25	0.0	0.17
Breeding success					
Chicks fledged per eggs laid	0.07	0.06	0.11	0.00	0.07
Chicks fledged per breeding pair	0.30	0.18	0.39	0.00	0.23

Table 3. The fate of 149 eggs from 60 clutches of Hooded Plovers laid on Phillip Island, Victoria, from 1992 to 1996

Fate	% of eggs (n = 149)	% of clutches (n = 60)
Dogs	29	25
Unknown	24	22
Hatched	17	22
Human interference	11	10
Foxes	9	10
Storm tides	8	8
Sheep	3	3

Breeding success

Annual breeding success in terms of number of chicks fledged per egg laid varied from 0.0 to 11.1% and, in the four years combined, only 6.7% of eggs produced fledged young (Table 2). Fledging success (young fledged per egg hatched) was 0–100% among years and was 40% for all years combined. The causes of chick mortality were not determined but one chick, with a full stomach, was found freshly dead and appeared to have been trodden on by a human. Of the 15 chicks that did not fledge, all were lost in the first three weeks after hatching (Fig. 4). More than half (53.3%) disappeared in the first week after hatching, 26.7% in the second week and 20% in the third week. Three of the 10 fledged young produced during the four years came from Woolamai Surf Beach and the other seven came from Cowrie Beach (2), Summerland Beach (2), Farm Beach (2) and Thorny Beach (1).

Numbers on Phillip Island

The number of Hooded Plovers recorded in counts on Phillip Island between 1982 and 1998 declined significantly (ANOVA, $F_{1,10} = 10.4$, $P < 0.05$) from 26 to 11 birds (Fig. 5).

Discussion

Timing of breeding

Dowling and Weston (1999) examined the breeding of Hooded Plovers on the Mornington Peninsula in an area of Victoria 10–50 km north-east of the Phillip Island sites, and found that peak nesting occurred in December, slightly earlier than on Phillip Island (January) although the months in which clutches were found were the same (August–March). Elsewhere in south-eastern Australia, breeding has been reported from August to May (Marchant and Higgins 1993).

Phillip Island's human population increased from 5600 to >50000 in the January 2000 summer holidays, visitor numbers (~1 million to Phillip Island Nature Park) peaks in summer (January) and Easter school holidays (Anon. 2000) and numbers of visitors to the information centre on Phillip Island also peak in January (Fig. 3). These indices of human activity on Phillip Island indicate that the peak of Hooded Plover laying in January coincide with the highest level of recreational activity, which, given the propensity of both plovers and humans for sandy beaches, maximised the likelihood of human interference with plover breeding.

Hatching success

Egg predation is a major cause of breeding failure in many species of plovers (Page *et al*. 1983; Lessells 1984; Dann 1991; Patterson *et al*. 1991). Nest failure on Phillip Island was most commonly associated with dog and fox activity (around the nest) and these, together with other anthropogenic factors, accounted for the failure of 52% of all eggs. Dogs are well known elsewhere as predators of eggs and young of plovers (Nol and Brooks 1982; Pienkowski 1984*a*). Hatching success on Phillip Island (16.8% eggs) was low compared with that recorded in South Australia (31%: Buick and Paton 1989), and compared with that of Shore Plovers, *Thinornis novaeseelandiae* (79–89%: Davis 1994), and Double-banded Plovers, *Charadrius bicinctus* [44%: Bomford 1988; although see Phillips 1980 (10.4%)], in New Zealand.

Chick mortality and fledging success

In common with studies of Hooded Plovers elsewhere (Dowling and Weston 1999), Shore Plovers (Davis 1994) and Mountain, *Charadrius montanus*, and Piping Plovers, *C. melodus* (Graul 1975; Wolcott and Wolcott 1999), greatest losses of chicks occurred in the first few weeks after

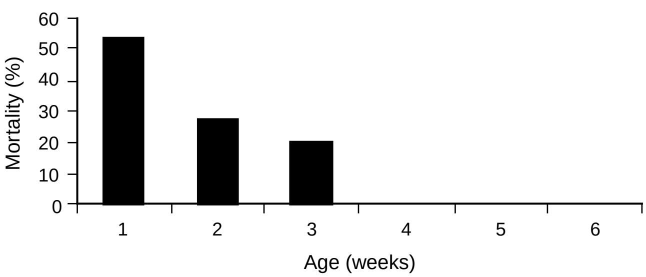

Fig. 4. The proportion of Hooded Plover chicks known to have died in each week after hatching on Phillip Island, Victoria, 1992–96 (n = 15). Note: no deaths were recorded in Weeks 4–6.

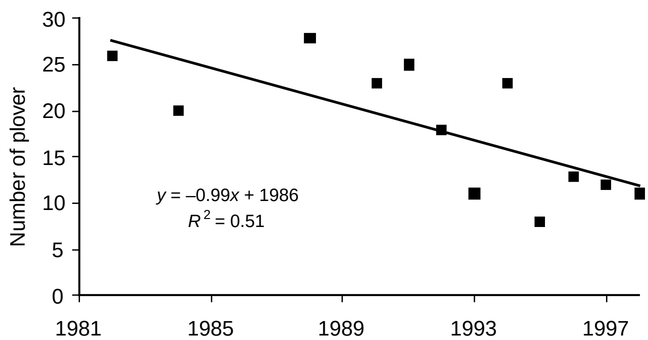

Fig. 5. The number of Hooded Plovers counted on Phillip Island in November at various intervals from 1982 to 1998.

hatching. Weston (2001) reported predation, crushing by vehicles and people and dehydration/heat stress as causes of chick mortality for Hooded Plovers. No causes of chick loss were definitely identified in this study, although one chick was suspected of being trampled by a human.

Fledging success in this study was highly variable but fledging success is highly variable for plovers in general (see review in Weston 2000). Fledging success of Hooded Plovers at Phillip Island was greater than, or within, the ranges recorded for plovers elsewhere. In all, 40% of chicks fledged in the four years of this study, which was double that reported by Weston (2000) for western Victoria (19.6%) and within the ranges reported for the congeneric Shore Plover in New Zealand (7–43%: Davis 1994) and the Piping Plover in North America (21–87%: Patterson *et al*. 1991; 0–100%: Maxson and Haws 2000).

Breeding productivity

Breeding productivity of Hooded Plovers at Phillip Island (0.23 chicks fledged per pair) was similar to that found for Hooded Plovers in western Victoria (0.18 chicks per pair: Weston 2000) and at the lower ends of the ranges recorded for Piping Plovers in North America (0.19–1.11 chicks per pair: Patterson *et al*. 1991) and for Shore Plovers in New Zealand (0.2–1.0 chicks per pair: Davis 1994).

It is difficult to evaluate the level of breeding productivity required to balance adult and juvenile mortality without knowing the adult and post-fledging mortality rates of this population. However, a simple model involving productivity, post-fledging survival and adult survival provides some insight into the relative contribution of each parameter to population size.

Over the four years of this study, the ~20 breeding individuals on Phillip Island fledged 2.5 chicks per year (10 fledged chicks in four years). Pienkowski (1984*b*) found in Ringed Plovers, *Charadrius hiaticula*, a survival from fledging to first breeding (at age two) of ~40%. Assuming a similar survival for Phillip Island Hooded Plovers, it would take 20 years of breeding to replace their number, i.e. the annual survival of adults would have to be very high (~95%) to maintain a stable population. If annual adult survival is less than 95%, population decline should be evident over a 20-year period. Weston (2000) found that the annual survival of breeding Hooded Plovers in western Victoria was 90.7% and, although higher than reported for Snowy Plovers, *Charadrius alexandrinus* (74.3%: Page *et al*. 1983; 75.2%: Warriner *et al*. 1986; 57.8–88%: Paton 1994), and Piping Plovers (66.4%: Root *et al*. 1992), it is low enough to result in a declining population on Phillip Island in the long term.

Alternatively, immigration to Phillip Island (see Weston 2000) could mask the effect of reduced reproductive rates on the local population size to some degree. However, the counts of Hooded Plovers on Phillip Island show an apparent decline in numbers in recent years, suggesting that the productivity of the plovers on the island, or the assumed survival of birds before they commence breeding, is indeed too low to maintain their number even if some immigration occurs.

Management implications and recommendations

It appears that poor hatching success is a major contributor to the decline in abundance of Hooded Plovers on Phillip Island. Several anthropogenic sources of nest failure, causing 48% of clutches to fail, should be addressed. Both sheep and cattle have unfenced access to several important breeding beaches on Phillip Island. Sheep flock on some beaches through the Hooded Plover breeding season, feeding on dune vegetation and, in particular, on the succulent sea rocket, *Cakile maritima*, which is an important refuge for chicks. Once sheep have grazed and trampled a site, Hooded Plovers abandon it for several weeks regardless of their breeding status (personal observation). Sheep trampling of eggs (3% of clutches) may be easily remedied by adequate fencing of stock from breeding beaches (notably Thorny, Hutchinsons and Berrys Beaches). Dogs come into Hooded Plover breeding areas either accompanied by humans or freely roaming from adjacent houses; they should be prohibited in all areas used by Hooded Plovers in the Phillip Island Nature Park at all times. Fox immigration onto Phillip Island is very infrequent (R. Kirkwood, personal communication) and, therefore, their eradication on Phillip Island should be pursued in the longer term. Predator-exclusion cages over nests have been successful in increasing hatching success of the Piping Plover (Melvin *et al*. 1992) and their efficacy for Hooded Plover management should be tested. Other sources of human interference may be alleviated if public awareness of the ecology and requirements of the birds was increased. In addition, the use of beaches for human recreation when plovers are breeding should be managed to reduce human impacts. It is essential that the breeding and abundance of the plovers on Phillip Island continue to be monitored to assess their productivity and conservation status and that the movements and survival rates of immatures and adults be assessed to understand the dynamics of the birds on Phillip Island.

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