

Managing a breeding population of the Hooded Plover *Thinornis rubricollis* in a high-use recreational environment

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Summary

Mornington Peninsula National Park, Victoria, Australia, is heavily used by recreationists. It also holds a breeding population of the Hooded Plover *Thinornis rubricollis*, a rare endemic shorebird. We monitored the population of plovers over seven breeding seasons, 1991–1998. Mortality of nests (about 60%), and of chicks (over 70%) was high, but preliminary data suggests mortality was low in juveniles. The major cause of mortality of nests was trampling by people. The causes of mortality in chicks is unknown, but mortality was age dependent, and was highest in the youngest chicks. A combination of management techniques that have been phased into operation over the seven years of the study appear to be increasing the reproductive success of the population.

Introduction

The Hooded Plover *Thinornis rubricollis* is a rare shorebird endemic to southern Australia. The species is a solitary, territorial breeder. It has a total estimated population size of about 5,000 birds. In south-eastern Australia it is almost exclusively confined to high-energy surf beaches. The species breeds on these beaches and in nearby dunes (Marchant and Higgins 1993, Watkins 1993).

Concern over the Hooded Plover peaked when it appeared on a list of endangered vertebrates (Anon. 1991). However, the species has subsequently been removed from the endangered category (Garnett 1993). There are a number of potential threatening processes that have been identified, all of which are directly or indirectly related to humans. These include habitat alteration, predation (by introduced predators or natural predators at artificially high population levels), disturbance and nest crushing (Schulz and Bamford 1987, Marchant and Higgins 1993). Only one threat, nest crushing by off-road vehicles, has been quantitatively examined (Buick and Paton 1989). However, other potential threats are likely to impact on a much higher proportion of the population, as one State (Victoria) has banned the use of off-road vehicles on beaches, and all other states have restrictions in at least some regions. Non-vehicle based recreational use of beaches is ubiquitous, and people can occasionally be found even on the remotest of beaches.

The climate of southern Australia is Mediterranean (dry summers and wet winters), with the main holiday period occurring in summer. Thus, coastal areas near cities are heavily used by recreationists during the warmer months.

Throughout the eastern half of the range of Hooded Plovers, there is a significant spatial and temporal overlap between the presence of Hooded Plovers and human activity on beaches. In 1996, a breeding-season population survey of over 640 km of the Victorian coastline found that humans occurred in 82% of coastal regions where Hooded Plovers were also recorded (M. A. Weston unpubl. data). The heavy use of coastal areas by humans, and the strong dependence on the same areas by this threatened shorebird provide a challenge for managers. In this paper, we describe the Hooded Plover population at a major recreational destination, Mornington Peninsula National Park, central-southern Victoria. We describe the breeding habitat and season, examine the reproductive success and also assess the impact of active management in the park on plover breeding.

Methods

Study site

The Mornington Peninsula National Park (MPNP) is located 75 km south of the city of Melbourne, Victoria, Australia. The park is elongated and its width varies from 150 m to 2.0 km. The study area covers 28 km of ocean coastline (59.6% of ocean beach in the park) from Point Nepean in the west to Fingal Beach (west of Cape Schank) in the east (see Figure 1). Victoria has 1,100 km of ocean coastline (Duncan 1982) so the study area represents over 2.5% of the state's coastline. The study area includes 3.6 km of coast that is backed by sandstone cliff. This represents unsuitable habitat for Hooded Plovers, and none were recorded there during the study (B. Dowling unpubl. data). Coastal features of the park that represent suitable plover habitat include tidal rock platforms, sandy beaches whose form changes constantly, and dunes.

The study area is heavily utilized by humans. It has six major car parks with a combined capacity of 1,210 vehicles (see Figure 1). There are 29 other car parks, 18 access points with on-street parking, and numerous pedestrian entries from adjacent streets. In addition, there is an unknown number of private access points from properties adjoining the Park. About 14.5 km (60%) of the ocean beach in the study area is less than 0.5 km from urban residential development. In total, it has been estimated that in 1995–1996 2.5 million visitors used the park. This makes the park the most heavily visited national park in Victoria (Parks Victoria 1998).

Recreation and regulation

The vast majority of visitors to the park are recreationists, and the most heavily used sites are Portsea, Sorrento and Gunnamatta (Figure 1). Recreational activities include swimming, surfing, sunbathing, fishing, jogging and beach walking. During the warmer months two surf lifesaving clubs operate on the beaches. There are also a number of near-beach activities that occur in the dunes, these include dune-boarding and walking. Sightseeing also occurs but this tends to be at lookouts on the higher rocky bluffs, and therefore it is rarely at suitable Hooded Plover nesting sites. There are a multitude of less common activities, from kite-flying to cuttlefish collecting.

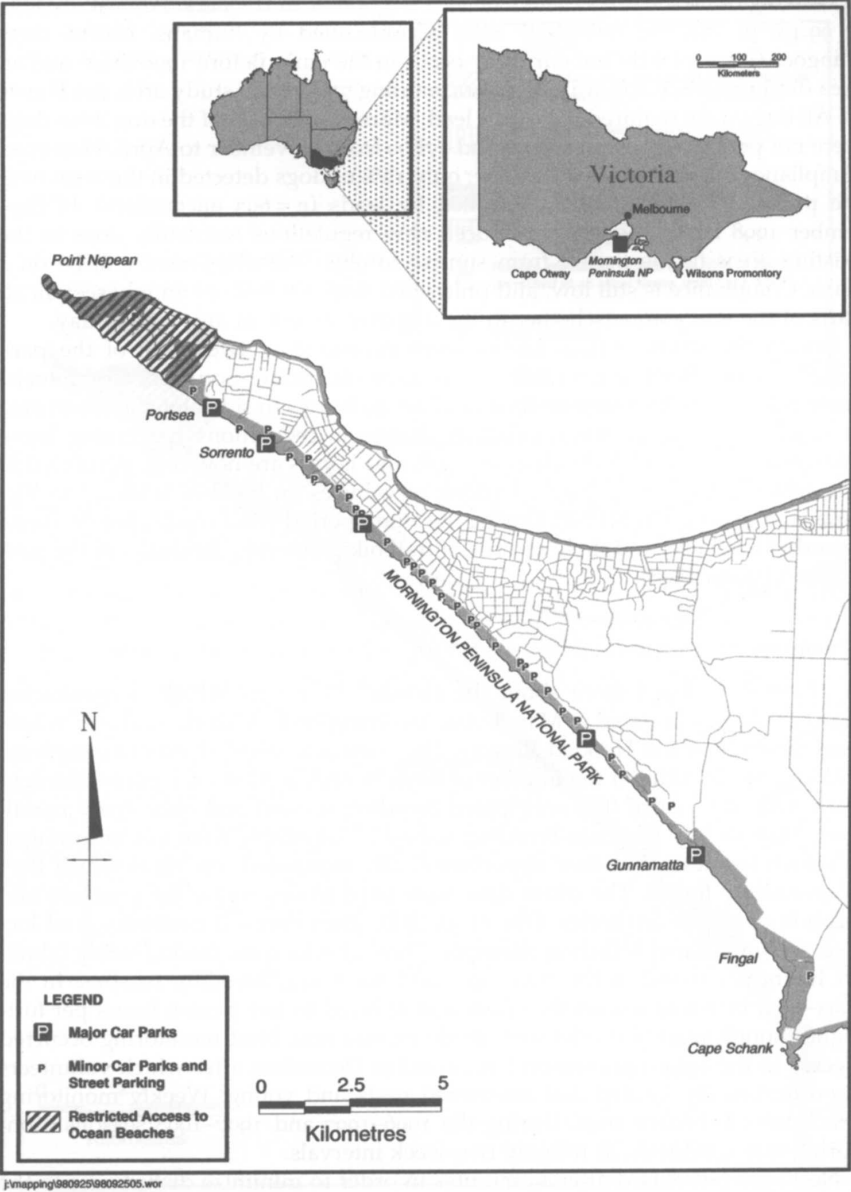


Figure 1. Mornington Peninsula National Park, Victoria, Australia. Access points for recreationists are indicated.

Walking domestic dogs *Canis familiaris* is popular in the park. Almost all dogs (c. 99.4% of the 700 recorded) were accompanied by humans. Native dogs (dingoes *C. f. dingo*) do not currently occur in the park. Before 1998 there was an area designated for dog-walkers (incorporating 75% of the study area, see Figure 2). All dogs were required to be on a lead. Moreover, in 42% of the dog-area, dogs were not permitted between 9h00 and 17h00 from November to April. However, compliance with these laws was low; only 12% of dogs detected in the area, over the period 1991–1998, were controlled by leads ($n = 693$ encounters). In September 1998 Parks Victoria introduced new regulations restricting dogs in the existing areas to the period from sunrise to 9h00. All dogs must still be on a leash. Compliance is still low, and unleashed dogs are still commonly seen in all parts of the study area (whether in the dog-area or not) at any time of day.

During the study period, horses were permitted in two areas of the park (Figure 2) and both recreational and commercial riding occurred. Commercial horse riding schools had permits that allow 20 horses to ride along a 600-m area of beach, up to eight times a day. A change in regulations concerning horse management occurred in September 1998, and horses are now only permitted in one area (Parks Victoria 1998). Driving of vehicles on beaches is illegal in Victoria, and was rare in MPNP. During the study period (1991–1998) there was one record of a vehicle, and three records of trail bikes entering the dunes in the park (Parks Victoria 1998).

Monitoring

In an effort to learn more about the Hooded Plover in MPNP, a monitoring programme was initiated in March 1991 involving Parks Victoria staff and volunteers (Friends of the Hooded Plover). The coast was divided into five sections, and volunteers counted the number of birds in each section once every fortnight from August to April (the anticipated breeding season) and once every month from May to July (the non-breeding season). Volunteers were not encouraged to search for nests, but they opportunistically monitored any nests which they inadvertently found. The count data were used to determine the presence and location of plover territories. One of us (B.D.) then checked territories, and located and monitored breeding attempts. These checks were made weekly (about six hours per week) in the 1991–1992 and 1992–1993 breeding seasons. In the 1993–1994 breeding season the effort was reduced to five person hours per fortnight, though weekly checks were made on one nest. Nest monitoring occurred weekly in the 1994–1995 season but ceased in December, after which volunteers opportunistically located and monitored nests and young. Weekly monitoring resumed in February 1996. During the 1996–1997 and 1997–1998 seasons monitoring was conducted at roughly two-week intervals.

Nest searches ceased after 15 minutes in order to minimize disturbance to the breeding birds. When a nest was located, weekly visits were made by B.D., or occasionally by a volunteer. Nests were observed from a distance and were never directly approached. Egg counts were made from a high point distant from the nest. Where egg counts were made, they only occurred once at each nest.

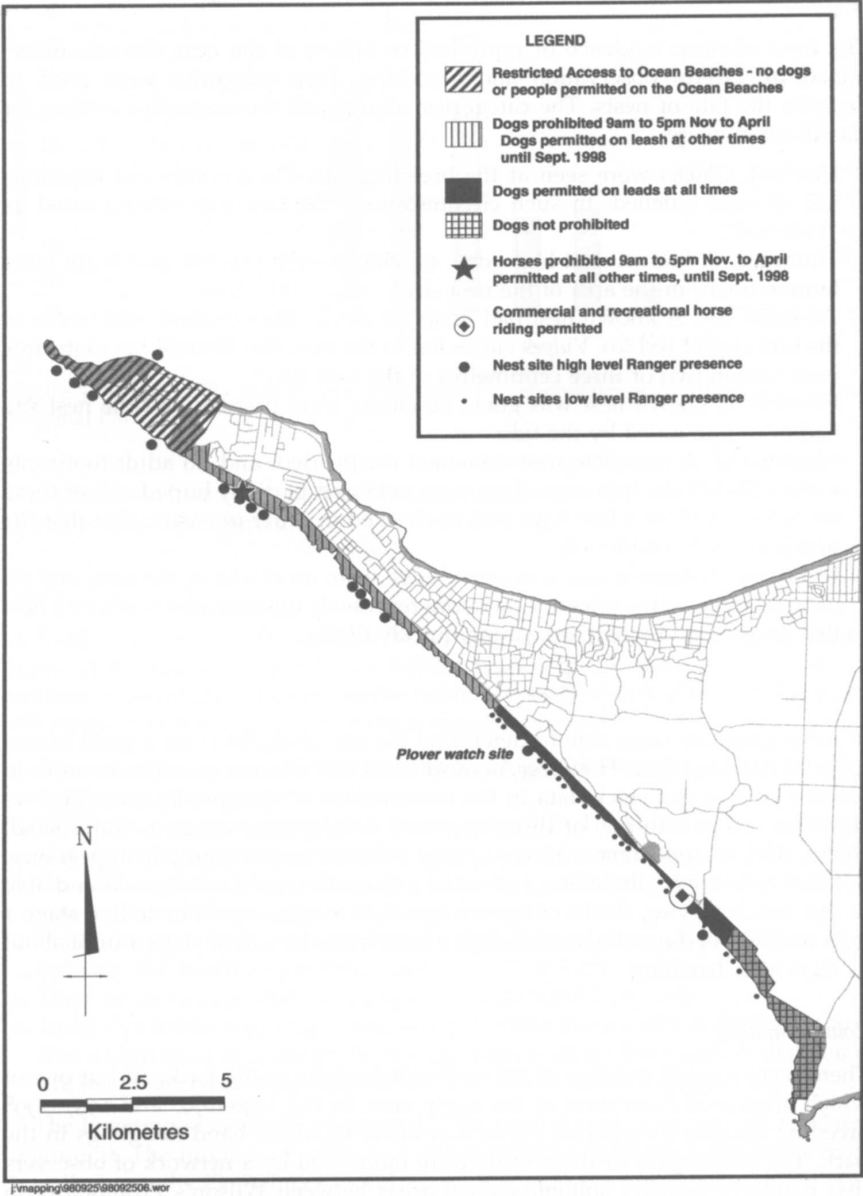


Figure 2. Management zones during the study period (recent changes to these zones have been introduced). The locations of nests located during the study period are also shown.

Nest fate

The most obvious evidence of reproductive failure at the nest site was determined by careful observation and searching. Five categories were used to describe the fate of nests. The categories, along with the respective criteria for classification, were:

1. Hatched. Chicks were seen at the breeding site. On a number of occasions not all eggs hatched. In such circumstances, the fate was still recorded as "Hatched"
2. Trampled. A known nest had gone, no chicks were present, and there were human tracks in the area of the nest site.
3. Taken by fox. A known nest had gone, no chicks were present, and tracks of the introduced red fox *Vulpes vulpes* led to the nest site. Several fox footprints were within two or three centimetres of the nest site.
4. Flooded. A known nest was gone, no chicks were present, and the nest site had been inundated by the tide.
5. Abandoned. A complete nest remained unattended, and no adult footprints were found in the nest area. Eggs were cold and partially buried. All of these nests were left for a few days and re-checked in order to ensure that that the nest had been abandoned.
6. Unknown. A known nest was gone, there were no chicks in the area, and no obvious tracks. This category therefore represents unsuccessful nests, or a nest that hatched and where the young quickly died.

Chick age

In some cases we were able to determine the age of chicks from a good knowledge of hatching date. However, in most cases this was not possible. In order to use the bulk of our chick data in the examination of age-specific mortality, we classified chicks into one of three stages of development: stage 1 (fluffy small chicks, dark in appearance, downy), stage 2 (larger runners, grey in appearance, not fluffy, no down, flightless) and stage 3 (juveniles, grey, adult-sized and able to fly). By classifying chicks of known ages into stages, we estimate that stage 1 lasts until 10–14 days of age, and stage 2 lasts from the end of stage 1 until about 35 days after hatching.

Colour-banding

There were a small number of colour-banded adults in the park, all but one of which originated from west of the study area. In the 1996–1997 and 1997–1998 breeding seasons a concerted effort was made to colour-band fledglings in the park. The movements of these birds were monitored by a network of observers that regularly searches suitable coastal areas between Wilson's Promontory in the east and Cape Otway in the west (see inset in Figure 1 for localities).

Results

Hooded Plovers were widespread along the ocean shore of the park. Breeding was recorded in every year. All breeding pairs were found along or adjacent to

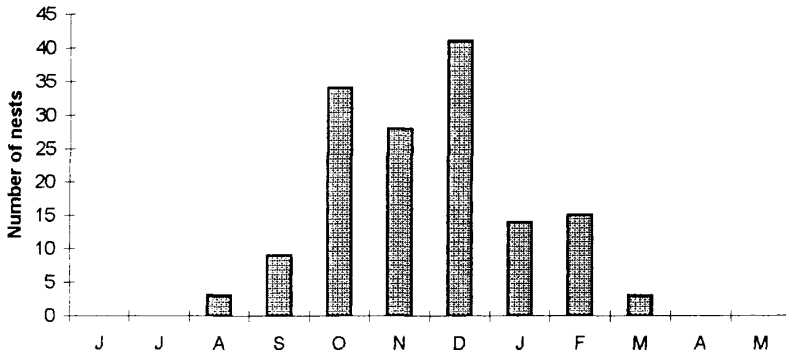


Figure 3. The monthly distribution of Hooded Plover clutches at Mornington Peninsula National Park.

the ocean beach, except one which was found on the sheltered northern aspect of the peninsula (Figure 2).

Nests

A total of 171 nests was located. Nests were classified into five main habitat types. A brief description of each habitat type is given below. Nests were not uniformly distributed between major habitat types ($\chi^2 = 11.3$, d.f. = 3, $P < 0.05$) so the proportion of nests in each habitat are also provided:

1. Beach nests were placed above the spring high tide line but below the storm tide level (25.0% of all nests, $n = 41$).
2. Cliff-top nests were placed above sandstone cliffs. The cliffs had 45° or steeper slopes (some were even undercut) and the nests were within 20 cm to 4 m of the cliff edge (20.5%, $n = 35$). One nest was located on a rocky outcrop that was surrounded by water at high tide.
3. Foredune nests were above the storm tide line and were placed on the slope between the beach and primary dune (16.0%, $n = 27$).
4. Dune nests were placed on the primary dune (32.8%, $n = 56$).
5. Unknown habitats were recorded when a brood was located as the first indication of breeding at a site (7.0%, $n = 12$). Observations have shown that chicks are led to the beach regardless of natal nest habitat (this study).

The breeding season was protracted, with nests found from August to March (Figure 3). The number of nests was not uniformly distributed across the main breeding months (September to February, $\chi^2 = 34.4$, d.f. = 5, $P < 0.01$). The peak number of nests occurred from October to December.

A total of 86 nests containing 212 eggs was checked to determine clutch size. The most common clutch size was three eggs (57.0% of the nests), followed by clutches containing two eggs (29.1%), and one egg (12.8%). One four-egg clutch was located in the park. The main clutch sizes (1–3 eggs) occurred in different frequencies ($\chi^2 = 26.1$, d.f. = 2, $P < 0.05$). Average clutch size did not vary between

Table 1. Fate of nests (number of clutches) in Mornington Peninsula National Park, 1991–1998

Season	Hatched	Trampled	Taken by fox	Flooded	Abandoned	Unknown	Total
1991/92	8	8	0	0	0	10	26
1992/93	16	17	2	0	0	3	38
1993/94	3	8	1	3	2	2	19
1994/95	2	1	0	0	0	11	14
1995/96	7	4	0	0	1	2	14
1996/97	21	8	0	0	0	3	32
1997/98	11	7	0	0	0	10	28
Total	68 (39.8%)	53 (30.1%)	3 (1.8%)	3 (1.8%)	3 (1.8%)	41 (24.0%)	171
Number of seasons in which each fate recorded	7	7	2	1	2	7	

seasons (One-way analysis of variance [ANOVA], $F_{5,79} = 1.156$, $P < 0.338$; the 1995–1996 season was omitted as only one clutch size was determined).

Nesting success

In total 60.2% of nests failed to produce chicks. The details of nest fate in each season are shown in Table 1. Abandoned eggs were collected after we were certain that they were not being attended. Seven eggs from three clutches were sent to Healesville Sanctuary (Zoological Board of Victoria) for post mortem. Three damaged eggs from one of these clutches contained advanced-term chicks; two eggs were ready to hatch (one was pipping) and the last was not as developed as the other two eggs. Two undamaged eggs from another clutch contained embryos about four or five days old. The third clutch was incomplete as one egg hatched, and two were abandoned. Internal examination of the eggs revealed no sign of embryo development.

Trampling was the most common cause of nest failure, and it occurred in every breeding season 1991–1998, and in all habitats (Table 2). The proportion of nests trampled differed between the habitat types ($\chi^2 = 10.4$, d.f. = 3, $P < 0.05$), with the highest proportion of nests trampled (51.2%) being on the beach where human activity is concentrated (pers. obs.). Nevertheless, trampling was common even in the dunes (21.4% of dune nests were trampled). Many beach users entered the

Table 2. Occurrence of nest-trampling (the main cause of nest failure in the park) and successful nests in each habitat type

Habitat	Total number of clutches	Number of nests trampled	Numbers of nests that hatched
Beach	41	21 (51.2%)	10 (24.4%)
Foredune	35	13 (37.1%)	16 (45.7%)
Cliff-top	27	7 (25.9%)	7 (25.9%)
Dune	56	12 (21.43%)	23 (41.1%)
Unknown	12	0 (Not available)	12 (Not available)
Total	171	53	68

dunes for privacy or shelter, and a few centred their activities in the dunes (such as joggers in training). Dune boarding (riding a board down the face of a dune) is becoming increasingly common. Additionally, many dune nest sites were located near unofficial access tracks. Nesting success varied across habitat types ($\chi^2 = 10.7$, d.f. = 3, $P < 0.05$), with the lowest success at beach nests, where trampling was most frequent.

Chicks

In the 1991–1992 and 1993–1994 seasons, weekly monitoring provided details on chick survivorship. In these seasons, we monitored 51 runners, and found that 33 (64.7%) were last seen (and reasonably assumed dead) at less than seven days of age, eight (44.4% of those still alive) were last seen between 7 and 14 days of age, three (30.0% of those still alive) were last seen between 14 and 28 days of age (Figure 4). Seven (70.0% of those alive after 28 days and 13.7% of the 51 chicks) survived to fledging. These data indicated that mortality of runners (proportion of chicks that disappeared) varied with age ($\chi^2 = 5.9$, d.f. = 2, $P < 0.05$, excluding fledglings which may have moved rather than died).

In order to use the bulk of our data in the examination of age-specific mortality, we used our stage of development data and examined stage-specific mortality (Figure 4). We recorded a total of 131 runners, from which we were able to determine the stage of disappearance for 128 runners (Figure 4). If flying young (stage 3) are excluded on the basis that they could have moved away rather than died, mortality (the proportion of chicks that disappeared) is significantly higher in younger runners compared with older runners ($\chi^2 = 21.9$, d.f. = 1, $P < 0.01$). Observations of the age at which stage 2 classification was assigned (based on the 51 known-age chicks checked weekly) suggested that the duration of stage 1 was considerably shorter than the duration of stage 2. This emphasises the high mortality in young chicks (less than c.10–14 days) compared with the remainder of the period to fledging (at least another 20 days). In total, of 128 runners that were satisfactorily monitored, only 27.3% fledged.

We had determined clutch size at only six nests that produced fledglings, and none of them successfully hatched all eggs and fledged all young. In these nests, the maximum number of fledglings from a nest was two. However, we were able to follow 24 successful broods (producing 35 fledglings) and determine how many fledged from each brood (we did not always know the clutch sizes). The number of fledglings per brood ranged from one to three, but these did not occur in equal frequencies ($\chi^2 = 10.8$, d.f. = 2, $P < 0.01$). Most commonly a single bird fledged (58.0% of successful broods). The production of two fledglings was less common (37.5%), and the production of three fledglings occurred only once (4.1%). The later record is probably a case where all eggs hatched and all chicks fledged.

Juveniles

Sixteen juveniles were colour-banded (eight in the 1996–1997 season and eight in the 1997–1998 season) after they were flying but while they were still closely associated with their territorial parents. Thus, in the two seasons, about 70% of

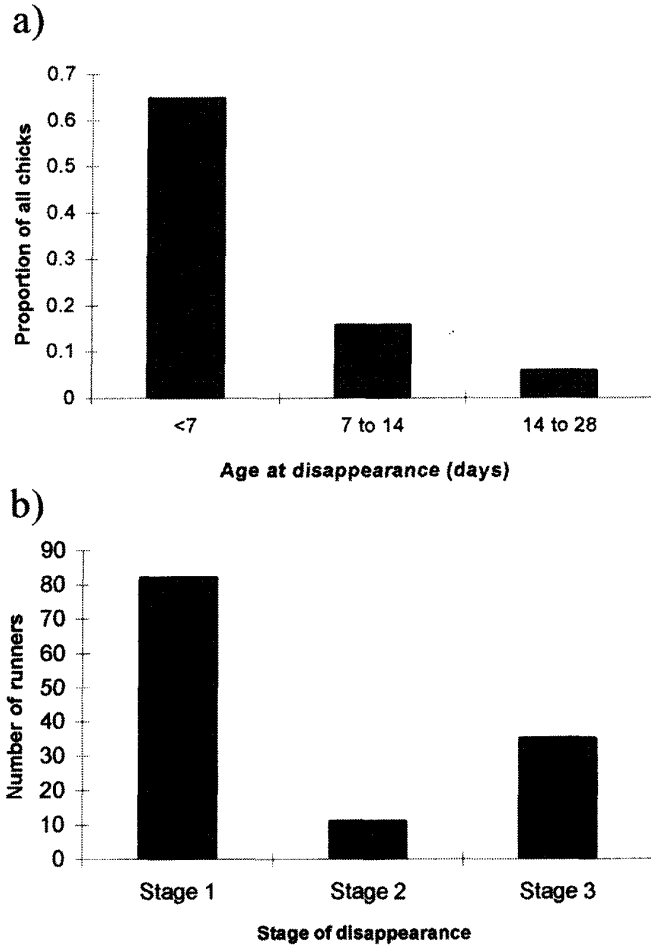


Figure 4. Age at which runners were last seen: (a) data from weekly checks ($n = 51$ runners pooled across seasons) and (b) stage at which runners were last seen ($n = 128$ runners pooled across seasons).

juveniles that hatched in the park were banded. All were still alive at July 1998. At this time, 14 were still in the park, and 75% had made at least one excursion from the park. Some have made substantial excursions along the coastline. We have located these juveniles as far west as Cape Otway and as far east as Wilson's Promontory (over 120 km to the south-west and the south-east respectively). Of the eight fledglings banded in the 1996–1997 season, all were in adult plumage in the 1998 non-breeding season. The limited banding data suggests there is a high survival rate once young birds are able to fly. The average age of first breeding needs to be determined before we can determine survival to recruitment into the breeding population. However, two juveniles banded in the park

Table 3. The reproductive success of Hooded Plovers under different management regimes (for an explanation of the management regimes, see Appendix 1)

Regulatory/ management condition	Number of clutches monitored	Number of successful clutches	Percentage of successful clutches	Number of fledglings	Mean number of fledglings per clutch
No dogs, 9h00 to 17h00	82	10	12.2	13	0.2
No dogs at any time	5	2	40.0	3	0.6
Plover Watch	13	4	30.8	4	0.3
Restricted access	22	8	36.4	15	0.7
Dogs at all times	49	0	0.0	0	0.0
Total	171	24	14.0	35	0.2

have been discovered breeding in their second year: one bred in the park, and the other bred at Sandy Point, over 115 km to the south-east.

Management

A variety of management techniques have been developed and implemented in the park. These management techniques are defined and described in Appendix 1. In addition to new techniques, a restricted access area exists in the far west of the park (see Figure 2). In this area no people or dogs are permitted on the ocean beach. The protection for this area has been strengthened by improved fencing and enforcement. Few recreationists have ventured onto the beach in this area since the improvements in the boundary fencing.

Effectiveness of management

Table 3 shows the reproductive success of Hooded Plovers under different regulatory and management regimes. These techniques were applied on a regional basis, so each managed or regulated area was a stretch of coastline. We consider that there is no intrinsic difference in quality of habitat between these sections that would translate into an underlying difference in reproductive success between areas. Unfortunately, we did not have enough data to test the effect of each regime on reproductive success. Rather, we combined the most intensive management regimes (No Dogs At Any Time, Plover Watch and Restricted Access) and compared them with the least managed condition (Dogs At All Times). We found that management significantly increased the proportion of clutches that hatched ($\chi^2 = 17.8$, d.f. = 1, $P < 0.01$). We examined whether dog management increased reproductive success by comparing hatching success (the proportion of nests that hatched) under active dog management (No Dogs 9h00 to 17h00, No Dogs At Any Time) with the Dogs At All Times category. Hatching success was significantly higher where there was some dog management ($\chi^2 = 7.4$, d.f. = 1, $P < 0.01$). It seems likely that some dogs eat or crush eggs, but it is also possible they indirectly compromise nest survival. Experience in England with Ringed Plover *Charadrius hiaticula* nests implicated dogs as an indirect source of clutch mortality, since their "inspection" of nests was watched by

Table 4. Implementation of different management techniques over the study period (\, actively pursued, * ongoing benefit)

Management technique	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98
Monitoring	\	\	\	\	\	\	\
Fencing			\	*	*	*	*
Permanent signs			\		*	*	*
Temporary beach closure						\	\
Plover Watch		\	\	\	\	\	\
Media coverage (papers)			\	\	\	\	\
Media coverage (TV)			\	\			
Education regarding dog regulations		\	\	\	\	\	\
Enforcement of dog regulations				\	\	\	\
Collection of roaming dog in adjoining streets			\	\	\	\	
Pamphlets and posters			\	\	\	*	*
Fox control in Restricted Access Area					\	\	*
Number of measures in effect	1	3	8	10	10	11	9

corvids and their trails followed by foxes (Pienkowski 1984). Both corvids and foxes are known nest predators of the Hooded Plover (this study, M.A.W. unpubl. data).

The data also allowed an examination of how survival of chicks to fledging varied between management categories. Again the low sample size, particularly for the high-management categories, dictated that categories be combined. The proportion of chicks that fledged was higher in the highly managed categories (No Dogs At Any Time, Plover Watch and Restricted Access) compared with the lower management category (Dogs At All Times and Dogs 9h00 to 17h00) ($\chi^2 = 26.0$, d.f. = 1, $P < 0.01$). The data allowed a comparison between the proportion of chicks that fledged in areas without dogs (Restricted Access and No Dogs At Any Time) to areas with dogs (Dogs And People At All Times). The proportion of chicks that fledged was significantly higher in the areas without dogs ($\chi^2 = 28.9$, d.f. = 1, $P < 0.01$). Not only does this suggest that such management regimes are a useful way of increasing chick survival, but it also suggests that chick mortality, the main causes of which are unknown, is related to the presence of dogs.

The combined effect of management on hatching success and survival of chicks to fledging meant that the mean number of fledglings produced per nest varied considerably between management categories. The average number of fledglings produced per nest varied from zero (Dogs And People At All Times) to 0.68 (Restricted Access).

During the course of the study, management was being improved and applied to a greater extent, in part because of our better understanding of key areas and problems. An implementation schedule of the management in the park is shown in Table 4. The number of management techniques in use or having a residual effect increased from one in 1991–1992 to nine in 1997–1998. The impact of these techniques can be quantitatively examined using the proportion of dogs that

were leashed as an indicator. In an effort to improve dog control, enforcement and public awareness activities were used more frequently as the study period progressed (see Table 4). There was a corresponding increase in the proportion of dogs that were leashed over the study period (Spearman $r = 0.857$, $P < 0.10$). The proportion of dogs leashed varied from 0.0% in 1991 to a maximum of 22.4% in 1998.

If the management we had implemented had been successful, we would expect an increase in reproductive success over the study period. The number of fledglings produced per season increased over the study period (Spearman $r = 0.811$, $P < 0.10$), as did the number of fledglings produced per nest (Spearman $r = 0.945$, $P < 0.02$). This provided further evidence that the management regime has increased reproductive success. This argument is strengthened from the results of a breeding study (1995–1998) on a nearby section of coastline on which Hooded Plovers were not managed, and which showed no increase in reproductive success (unpubl. data).

Discussion

Perhaps the most intensively managed plover in the world is the Piping Plover *Charadrius melodus* of North America. Numerous potential threatening processes have been examined for the species (e.g. Patterson *et al.* 1991, Melvin *et al.* 1994). Investigations have also been made into a variety of management techniques aimed at increasing reproductive success in the species. These techniques include gull deterrents (Maxon *et al.* 1996), fencing (Mayer and Ryan 1991), nest translocations (Prellwitz *et al.* 1995), the design and application of nest cages (Rimmer and Deblinger 1990, Melvin *et al.* 1994, Vaske *et al.* 1994), and captive breeding techniques (Powell *et al.* 1997). This body of research has allowed the nature and magnitude of threats to be identified, appropriate management techniques to be tested and their effectiveness examined. Such data are not currently available for the Hooded Plover.

Here we have described a population of breeding Hooded Plovers in a highly utilized coastal area. Overall, reproductive success was low. Beach nests had the lowest hatching success, and trampling rates were highest at these nests. Our data indicated that the management regimes that were being used increased both hatching success and the survival of young. This finding, along with the increase in reproductive success coincident with the increase in management effort and effectiveness, are highly suggestive that the suite of management techniques being applied is working. This is the first demonstration that management can help alleviate some of the threats to the Hooded Plover.

It is likely that further management effort will increase reproductive success higher than that achieved by the present study. In September 1998, new dog regulations were introduced in the park, restricting dog-walking hours to sunrise to 9h00 over most of the study area for the whole year. All dogs must be on a leash. The area available for horse riding has also been decreased. Our data suggest that these regulations should have a positive effect on reproductive success across the park. Nevertheless, further research into other management techniques (e.g. nest cages), and the refinement of existing techniques needs to continue. As a priority, these management techniques should address the main sources of

reproductive failure: nest loss, and mortality of young chicks. Additionally, investigation into the main threatening processes is required. This needs to occur across the range of the species, because threatening processes might be localized phenomena.

The main cause of nest failure detected in this study was trampling, which definitely would have been from recreationists. It is likely that recreational pressures on the Australian coast will increase in line with the increase in recreational activities predicted in other countries like the United States (Flather and Cordell 1995). This increase is likely to intensify the pressure on already heavily used beaches, and to cause recreational impact to expand and affect a greater proportion of Hooded Plover habitat, and therefore population. We suggest that the examination of threatening processes and suitable management techniques should be developed and refined in the near future. This would allow managers to incorporate appropriate design features (such as the location and type of access points) at the planning stage.

We would also suggest that the benefits of the management programme described by this study have not unidirectionally flowed to the plovers. Many park visitors were able to assist and participate in the effort to protect the Hooded Plover, even if only by cooperating with park staff and/or by obeying regulations. Many reported that their experiences with Hooded Plovers had enriched their visit. Additionally, a sense of local ownership and responsibility has been fostered which offers a less formal, community-level concern which is evident on the beaches at all times, and extends to beaches outside the National Park.

Acknowledgments

We would like to thank the Friends of the Hooded Plover (Mornington Peninsula): Tom Sault, Ian and Margaret Bell, Betty Mitchell, Malcolm Brown, Jan James, Jane Burke, Judy Davidson, Jean and Jock Smith, Val Ford and Lynette Eggleston. Without their support this work would not have been possible. We also thank Gary Mathieson (Highfield Staff), Wayne Hill, Kevin Yorke, Tony Varcoe, Glenn Hull (Parks Victoria), and Peter Menkhorst and Alan Crouch (Department of Natural Resources and Environment). Banding was carried out under appropriate Australian Bird and Bat Banding Scheme permits, Department of Natural Resources and Environment permits (RP97208, RP96113, RP95067, BB95005) and Parks Victoria permits (NP978/095, NP945/156, NP67/011). Funding agencies supporting the researchers were: Coast Care, Holsworth Wildlife Research Fund, Stuart Leslie Research Fund, Ingram Trust, Barwon Heads Committee of Management, and the Australian Bird Environment Foundation. M.A.W. held an Australian Postgraduate Research Award. Thanks also to Martin Schulz who made useful comments on a draft.

Appendix 1. Management techniques employed during the study period in Mornington Peninsula National Park.

Management technique	Description and discussion
Fencing	Ringlock fencing (e.g. 30 × 20 mm mesh size) was applied in three different ways: <ol style="list-style-type: none"> 1. Enclosure fencing, around an area of foredune. This was not considered successful because the plovers often didn't nest in the fenced area. 2. Fencing off the primary dune. Again the plovers didn't always nest behind the fence, at one site where they still nest in the fenced area a fox predated the nest or the beach is so disturbed the young chicks die. 3. Fencing of formal walking tracks and closing off unofficial tracks. This was successful in two ways: it prevented people dispersing into the dunes and each track brought people on to the beach in a single location, reducing disturbance over the whole area.
Permanent signs	These were installed at four sites in the general area of known nests. They read "Ground Nesting Birds. Please Keep Out"
Temporary beach closure	This occurred mostly in the Portsea area, and also at Gunnamatta Beach. Three temporary signs were placed at a site where a known nest or brood was present. Two signs were placed along the beach, and one was placed below the site. These signs read "Temporary Beach Closure due to Hooded Plover nesting in this area. Human disturbance on the beach or in the dunes will cause breeding failure". Additionally the signs requested that (1) people passing by do so along the beach, walking quickly, close to the water's edge, (2) that people do not sit in the area, and (3) that dogs and horses are strictly prohibited. People were thanked and information phone-numbers provided. These closures were backed up with ranger presence and compliance seemed good though not universal.
Plover Watch	Volunteers spent daylight hours at a breeding site with runners, asking people not to use the area, and to control their dogs. Additionally they educated beach-users. This was a labour-intensive programme (28 days of 12 hours per day for each Plover Watch) and so was targeted at sites with low visitor access. Unfortunately, at all Plover Watch sites, resources were insufficient to keep constant vigil.
Media coverage (newspapers)	Usually three or four local stories per year, in local and state newspapers. These stories generally provided information on appropriate behaviour for recreationists.
Media coverage (TV)	Two stories on national television. Again, these stories generally provided information on appropriate behaviour for recreationists
Education regarding dog regulations	Signage and ranger patrols were included in the park's management. Debate in local newspapers also increased awareness.
Enforcement of dog regulations	Fines (Aus. \$80.00) were issued by rangers while monitoring and on patrol. Patrols occurred for two days per week for four months over the breeding period.
Collection of roaming dog in adjoining streets	This was not conducted by Parks Victoria staff but by officers of the local council. This worked more as a warning for the neighbours. The narrow nature of the park means that roaming dogs could easily reach the breeding areas.
Pamphlets and posters	Information material specific to the species was produced and distributed free of charge. Volunteers handed them out during Plover watches and while doing surveys. Additionally, some posters were weather-proofed and mounted at the beach entrances.

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