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Impact of management on the breeding success of the northern New Zealand dotterel (*Charadrius obscurus aquilonius*) on Matakana Island, Bay of Plenty

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Abstract The breeding success of northern New Zealand dotterels (*Charadrius obscurus aquilonius*) on Matakana Island, Bay of Plenty, was determined over 8 seasons (1992/93-1999/2000) in managed and unmanaged areas. Management to enhance breeding success included shifting nests to reduce the risk of flooding during spring tides and storms, and reducing predator populations of brushtail possum (*Trichosurus vulpecula*), feral house cat (*Felis catus*), Norway rat (*Rattus norvegicus*), stoat (*Mustela erminea*), and southern black-backed gull (*Larus dominicanus*) at dotterel breeding areas. Measures taken to reduce the incidence of disturbance by people on breeding dotterels included erecting fences around nesting areas, and speaking to members of the public about the plight of the species. The number of breeding pairs on Matakana Island fluctuated between 19 and 31 during the 8 seasons. Overall, 35.1% of 276 nesting attempts resulted in broods hatching. The main causes of nest failure during incubation were flooding by high tides or storms, and predation. The proportion of nests in which 1 or more eggs hatched was fairly stable during the 1993/94 to 1997/98 seasons at 26.1-33.3%, but was 68.0 and 51.3% in the last 2 years. This marked improvement in nesting success was attributed to the increased duration of pest control: starting before dotterel breeding began and continuing until most broods had fledged. Nesting success during incubation in managed habitat (47.5%) was significantly greater than in unmanaged habitat (19.5%). Overall, 52.6% of chicks fledged. The number of chicks fledged per season (5 – 33), and fledglings produced per breeding pair (0.26 – 1.08) increased through the study. In conclusion, we make suggestions to further promote the conservation of the northern New Zealand dotterel.

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INTRODUCTION

The New Zealand dotterel (*Charadrius obscurus*) is an endemic, vulnerable shorebird (Hilton-Taylor 2000). It has a disjunct distribution, and the 2 populations are recognised as different subspecies (Dowding 1994). The northern New Zealand dotterel (*C. o. aquilonius*) breeds in coastal habitats of the northern North Island (Dowding 1994). This subspecies is listed in Category B (2nd priority) by the Department of Conservation (Tisdall 1994). The most recent census in 1996 indicated a population of *c.* 1500 birds (Dowding & Murphy 2001).

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Egg laying of the northern subspecies extends from late August to early January, with up to 3 replacement clutches being laid during this period (Marchant & Higgins 1993). Because incubation lasts 28-32 days, and chick rearing 36-46 days (Marchant & Higgins 1993), some breeding attempts are not completed until March.

The northern population is threatened by a variety of factors, particularly destruction and degradation of breeding habitat caused by agricultural and urban development, and dune stabilisation (Cumming 1991; Dowding 1993), disturbance and destruction of nests by people involved in recreational activities on beaches

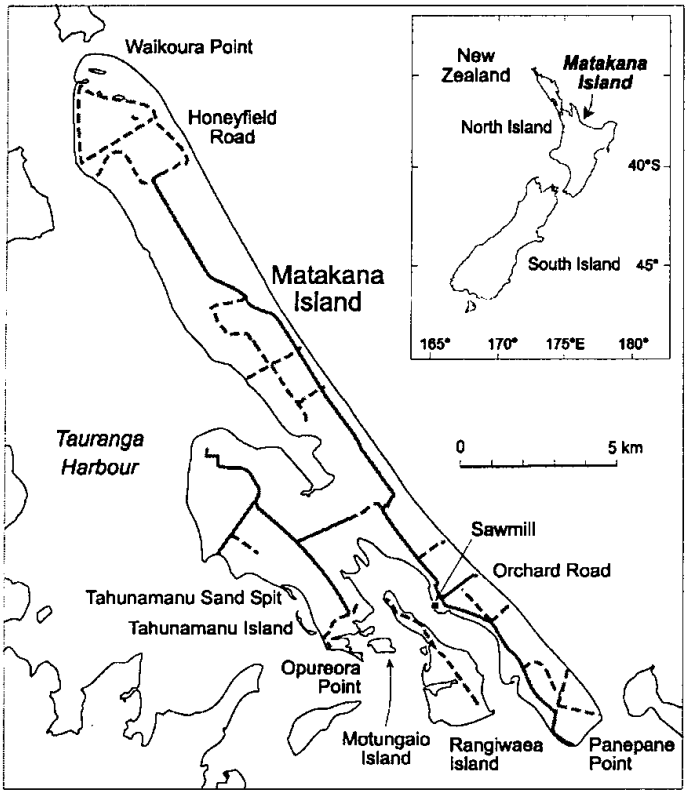

Fig. 1 Matakana Island in Tauranga Harbour, and New Zealand dotterel (*Charadrius obscurus*) nesting areas on the island.

(Chudleigh 1988; Dowding 1993; Lord *et al.* 1997; D.E. Wills pers. obs.), and predation (Chudleigh 1988; Dowding 1993; Dowding 1997; Dowding & Murphy 1996; Wills 1998). A variety of predators, both mammalian and avian, is known to take eggs, chicks or adult New Zealand dotterels. The predators include cats (*Felis catus*), dogs (*Canis familiaris*), stoats (*Mustela erminea*), rats (*Rattus* spp.), hedgehogs (*Erinaceus europaeus*), possums (*Trichosurus vulpecula*), black-backed gulls (*Larus dominicanus*), Australasian harriers (*Circus approximans*), and spur-winged plovers (*Vanellus miles*) (Chudleigh 1988; Dowding 1993, 1997; Dowding & Murphy 1996; Wills 1998).

Since 1986, considerable efforts have been made to increase the productivity of northern New Zealand dotterels by protecting breeding birds from disturbance and vandalism by people, and from predation, particularly by introduced mammalian predators (Dowding 1993). Such conservation actions have been carried out by a variety of organisations, particularly the Department of Conservation (and formerly the New Zealand Wildlife Service), and the Royal Forest & Bird Protection Society of New Zealand, at several sites in the North Island, mainly along the east coast. At most of these sites, wardens or volunteers roped off nesting areas, monitored breeding success, and provided information to the public about the dotterels and conservation measures being taken (Dowding 1993). In addition, predators were controlled at a few sites. Although more New Zealand dotterels fledged at managed than at unmanaged sites (Cumming 1991; Dowding 1997), there is little published information on the overall effectiveness or otherwise of such protection programmes (Dowding 1997). Here we report on the effectiveness of protection measures on New Zealand dotterels breeding on Matakana Island, Bay of Plenty, during 8 seasons (1992/93 to 1999/00).

STUDY AREA

Matakana Island (6100 ha) lies across the entrance of Tauranga Harbour (Fig. 1). It has a mild and sunny climate, with a moderate rainfall (*c.* 1300 mm year^{-1}) (Shepherd *et al.* 1997). The island is 24 km long and 1-5 km wide and so has an extensive coastline. Little of the island remains in native vegetation; most of it is covered in exotic plantations (mainly of *Pinus radiata*) or farmland. A detailed description of the natural vegetation of the island is given in Beadel (1989). Northern New Zealand dotterels typically nest on sandspits and beaches, particularly at the mouths of tidal estuaries, streams, and rivers (Dowding 1993). On Matakana Island, such habitat is found at the northern (Waikoura Point) and southern tips (Panepane Point) of the island, and at a few sites along the eastern shoreline. In addition, some pairs nest on sandspits and islets near Opureora, on the western side of the island (Fig. 1). Nesting areas consist mainly of open sandy beaches with flotsam (driftwood, seaweed) along the high tideline, and, occasionally, sparse, low-growing vegetation, such as spinifex (*Spinifex sericeus*), pingao (*Desmoschoenus spiralis*), and iceplant (*Disphyma australe*). In addition to the *c.* 300 residents, many people visit the beaches of Matakana Island, mainly in summer, for recreational activities, particularly fishing and surfing.

METHODS

Monitoring of dotterels

The monitoring period varied each season, generally starting earlier and continuing for longer as the study progressed (Table 1). Daily checks were made of most nesting and roosting areas to record numbers of territory holding pairs of dotterels. In some areas this was carried out from a 4-wheel motorcycle using 10 × 40 binoculars, or by walking to specific viewing areas, such as a hill-top or cliff, and using binoculars or a 20× telescope. At Panepane Point, the monitoring was done from a 15 m-high platform on a navigation beacon tower. Nest contents were usually checked once a week by walking past the nest at no closer than 2 m to determine the nesting success of each pair.

The outcomes at 2 nests during the 1992/93 season were monitored using battery-powered

Table 1 Duration of monitoring of New Zealand dotterel (*Charadrius obscurus*) breeding attempts and mammalian pest trapping and poisoning on Matakana Island during 8 breeding seasons.

Breeding season	Monitoring	Pest control
1992/93	29 Oct – 8 Jan	7 Dec – 8 Jan
1993/94	30 Sep – 23 Dec	4 Oct – 5 Nov
1994/95	29 Sept – 18 Jan	29 Sep – 16 Dec
1995/96	25 Sep – 26 Jan	26 Sep – 29 Dec
1996/97	9 Sep – 16 Jan	18 Sep – 23 Dec
1997/98	9 Sep – 30 Jan	9 Sep – 23 Dec
1998/99	7 Sep – 5 Mar	7 Aug – 17 Feb
1999/2000	11 Sep – 31 Mar	20 Aug – 14 Feb

time-lapse video equipment. The camera was set up about 20 m from the nest, with the recorder and battery up to 100 m away from the camera and well camouflaged. Infra-red lights allowed nocturnal activities to be recorded. Other than at these 2 nests, the identification of predators at failed dotterel nests was based on the interpretation of foot prints (Wills 1998).

When the terrain was suitable, both in managed and unmanaged areas (see below), nests close to the high tideline were shifted about 3 m, but up to 7 m in a few instances, up the beach to try and prevent them being washed away by high tides or storms. If the nest was not beside a piece of driftwood or seaweed that acted as a focal point for the pair, then a piece of driftwood was placed by the nest. A few hours later or the next day, the eggs and driftwood were moved to a new scrape a maximum of 2 m at a time.

Mammalian predator control

The period of mammalian pest control at the dotterel breeding areas varied each season, generally starting earlier and finishing later as the project progressed (Table 1). Victor® leg-hold traps were sited adjacent to dotterel breeding areas (in the *Pinus radiata* forest edge at Panepane Point, and in the *Leptospermum laevigatum* scrub edge at Orchard Road), set as described by Veitch *et al.* (1992), and were baited with either fresh fish, rabbit, possum, or black-backed gull meat. The traps were intended to capture cats, but possums and rats were also caught. Also, large tunnel traps, with drop-doors at each end, were baited with fresh rabbit meat to capture cats. Two Mk 4 Fenn® traps, baited with meat, a hen's egg or peanut butter, were set in tunnels to kill stoats, although rats were killed too. The only species of rat evident on Matakana Island during this study was the Norway rat (*Rattus norvegicus*). All traps were checked daily, and any animals that were caught were then killed.

Philproof® bait stations were set at the base of trees adjacent to Panepane Point and Orchard Road nesting areas to enable both possums and rats to reach baits. These stations were filled with Talon 20P® baits, containing the anticoagulant brodifacoum. In addition, rat bait tunnels (Veitch *et al.* 1992) were sited in sand dunes near 3 breeding areas. These were checked and refilled with bait, if required, at 3- to 4-weekly intervals.

To compared breeding success in managed versus unmanaged areas, "managed" areas were those where all pest mammal species were exposed to both traps and poisons (leg-hold traps for cats and possums, Fenn traps for rats and stoats, and poison bait stations or tunnels for rats and possums), and "unmanaged" areas had no predator control. Therefore, breeding attempts in areas that received limited predator control in a particular season (e.g., at the Sawmill site during the last 3 seasons, although there was trapping for cats and possums, there was no stoat or rat trapping) were not included in these analyses. Managed areas were Panepane Point in 1993/94–1999/2000, and Orchard Road in 1994/95–1999/2000. Leg-hold traps were used at Panepane Point in 1992/93, but trapping started late in the season (Table 1); it is therefore assumed it had no effect on dotterel breeding success, and so all areas are considered to have been unmanaged in 1992/93.

Avian predator control

Three methods were used to reduce the population of black-backed gulls roosting and nesting on Matakana Island. From 1994/95 to 1997/98, a concerted effort was made to reduce the number of gulls by poisoning them. A mixture of alphachloralose (8%) and margarine was spread on slices of bread, and the slices cut into 40 mm squares. These poison baits were placed at nests and roosting sites. Prefeeding with non-toxic baits was carried out when roosting gulls were targeted, but not when nesting gulls were to be poisoned. Dying gulls were killed and buried along with those found dead. Unknown numbers of gull eggs were pricked and chicks killed each season from 1994/95 onwards. Adult gulls were shot in 1999/2000.

Reducing public disturbance

People (e.g., beachcombers, walkers, fishers, water-skiers, surfers, picnickers, drivers of beach buggies and motorbikes) frequented the beaches of Matakana Island, especially during summer. Measures were taken to reduce the incidence and impact of public disturbance on breeding dotterels. DEW and JM spoke to people on beaches about the plight of the New Zealand dotterel, and handed out copies of a pamphlet that included information about its breeding biology, and the impact that predators and public were having on dotterels. In

addition, pamphlets and talks were given to children at schools or when classes came to a breeding area to learn about the dotterels. Occasional media releases, giving updates on results during a breeding season, were provided for local newspapers and radio stations to make people aware that they should not disturb the dotterels during beach visits.

Fences, consisting of ground-treated posts and 2 strands of wire, were erected during the 1996/97 and 1997/98 seasons around the dotterel breeding areas at Panepane Point and Orchard Road respectively, and maintained thereafter. Signs indicating the presence of breeding dotterels and requesting that the public not go inside the fenced-off areas were fixed to the fences.

RESULTS

Timing of monitoring and pest control

During 1992/93 to 1999/2000, the 1st clutches of New Zealand dotterels breeding on Matakana Island were laid in late August, and the latest in January. Chicks hatching from clutches laid in January would not have fledged until March (incubation *c.* 30 days, chick-rearing *c.* 40 days; Dowding *et al.* 1999). Thus, monitoring of breeding during the first 4 seasons began well after breeding had started, and some breeding attempts were still underway when monitoring finished in January (Table 1). It was only in the last 2 seasons that monitoring occurred throughout most of the dotterel breeding season.

Pest control lasted for just a month late in the 1992/93 season (Table 1). In the subsequent 4 seasons, dotterels had begun breeding before trapping and poisoning of pest mammals began, and pest control stopped before some breeding attempts had been completed. It was only in the 1998/99 and 1999/2000 seasons that pest control began before dotterel breeding, and continued until after most clutches had hatched (Table 1).

Predator control

Peak numbers of possums were trapped during the 3rd and 4th seasons of the study, with few being trapped (number and capture rate) after the 1996/97 season (Table 2). Most rats and cats were trapped during 1994/95 to 1996/97, and fewer than 10 season^{-1} (< 1 100 trap-nights^{-1}) of each species were caught subsequently (Table 2). In contrast, there was no decline in stoats trapped per season through the study, both in number and capture rate.

In 1982, about 500 nests of black-backed gulls were found along the eastern coast of Matakana Island from Honeyfield Road to Panepane Point (P.C.M. Latham pers. comm.). During the 1992/93 season there were *c.* 2320 nests (Wills 1993). In 1992/93, the location of gull colonies relative to those of dotterel nesting areas was: 20 gull nests at Panepane Point; *c.* 600 nests about 2 km north of Panepane Point; *c.* 1600 nests at the Bird Sanctuary Road colony 0.5-1 km from the Orchard Road dotterel area; and *c.* 100 nests by the Honeyfield Road dotterel nesting area (Wills 1993). By the 1994/95 season, numbers of gull nests had increased by 26% to *c.* 2920: 20 at Panepane Road; *c.* 700 near Panepane Point; *c.* 1900 at Bird Sanctuary Road; and *c.* 300 at Honeyfield Road (Wills 1998). However, by 1997/98, following the concerted poisoning effort in 1995/96 (Table 2), the total number of nests had declined by 47% to *c.* 1550: 20 at Panepane Road; *c.* 850 near Panepane Point; *c.* 600 at Bird Sanctuary Road; and *c.* 80 at Honeyfield Road (Wills 1998).

Number of dotterels

Some dotterel breeding areas were not known or were not surveyed early in this study, and so it is not known exactly how many New Zealand dotterels inhabited Matakana Island during the first 2 seasons (Table 3). However, we assume that no pairs bred at the Matakana sawmill site before 1997/98 because of bulldozer activity, 5 pairs bred at Tahunamanu Sand Spit and Island, and 1 pair nested at Opureora Point during the first 2 seasons, and none at Rangiwaea Island before 1996/97. If this was so, then the number of breeding pairs on Matakana changed little during the study, except in 1995/96 when no pairs bred at the northern end of the island (Waikoura Pt and Honeyfield Rd), and in 1999/2000 when 31 pairs were found compared to the previous highest tally of 27. While the total number of pairs at the northern end of Matakana declined substantially after the first 3 seasons, the number at the Orchard Road nest area remained fairly stable, and that at the southern end (Panepane Pt) increased (Table 3). Overall, the total number of breeding pairs fluctuated between 19 and 31 over the 8 seasons.

Incubation success

There was little variation in incubation success (proportion of nesting attempts that hatched 1 or more eggs) from 1993/94 to 1997/98 (Table 4). However, in 1998/99, incubation success doubled, and was moderate in 1999/2000. Overall, 35.1% of 276 nesting attempts during the 8 seasons resulted in 1 or more eggs hatching nest^{-1}. The 5 main causes of nest failure during incubation were flooding by high tides or storms (22.3%, n = 179 failed nests), predation by unidentified predators (14.0%), black-backed gulls (13.4%), and cats (11.7%), and disturbance or destruction by people (10.1%) (Table 5). Most cat predation occurred in the

Table 2 Number and capture rate (number captured 100 trap-nights^{-1}) of 7 species of predators of New Zealand dotterel (*Charadrius obscurus*) eggs and chicks killed on Matakana Island during each of 8 breeding seasons, 1992/93 to 1999/2000. Capture rate figures are given in brackets.

Species	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/2000
Brushtail possum	50 (20.0)	29 (5.9)	94 (9.5)	84 (9.3)	33 (2.7)	12 (0.9)	16 (0.6)	5[2] (0.1)
Norway rat	0	1 (0.1)	34 (2.2)	75 (6.4)	41 (2.4)	8 (0.4)	4 (0.1)	2 (<0.1)
Feral house cat	15 (6.0)	10 (2.0)	37 (3.7)	28 (3.1)	17 (1.4)	7 (0.5)	9 (0.3)	5 (0.1)
Stoat	5 (2.0)	1 (0.1)	2 (0.1)	0	3 (0.2)	1 (0.1)	5 (0.1)	5 (0.1)
Black-backed gull [1]	0	0	*c.* 400	*c.* 3200	63	72	0	324
Spur-winged plover	0	0	0	0	0	0	2	1
Australian magpie	0	0	0	0	0	0	0	1

[1] In addition to killing adults, unknown numbers for eggs were pricked and chicks killed each season during and since 1994/95.
[2] A further c. 17 were shot by the public at Orchard Road.

Table 3 Number of pairs of New Zealand dotterels (*Charadrius obscurus*) in each breeding area of Matakana Island, and in total, during 8 breeding seasons, 1992/93 to 1999/2000. ns, nesting area not surveyed; numbers in **bold** indicate seasons when predators in a particular breeding area were managed; numbers in parentheses are number of pairs assumed to have been present.

Breeding areas	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/2000
Waikoura Point	3	2	1	0	2	0	3	3
Honeyfield Road	8	8	7	0	1	3	0	0
Orchard Road	3	**4**	**5**	**5**	**5**	**3**	**3**	**5**
Matakana sawmill	ns (0)	ns (0)	ns (0)	ns (0)	ns (0)	2	2	4
Tahunamanu Sand Spit and Island	ns (5)	ns (5)	5	7	8	5	2	5
Opureora Point	ns (1)	ns (1)	1	1	2	2	2	2
Rangiwaea Island	ns (0)	ns (0)	ns (0)	ns (0)	0	0	1	0
Panepane Point	5	**6**	**8**	7	**9**	**9**	**13**	**12**
Total breeding pairs	19 (25)	20 (26)	27	19	27	24	26	31

Table 4 Incubation success (percentage of nesting attempts that resulted in 1 or more eggs hatching), number of chicks that fledged, and mean number of chicks fledged per breeding pair of New Zealand dotterels (*Charadrius obscurus*) on Matakana Island during 8 seasons, 1992/93 to 1999/2000.

	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00
No. of nests	22	26	32	44	46	42	25	39
Incubation success	18.2	30.8	28.1	29.5	26.1	33.3	68.0	51.3
No. of chicks fledged	5	6	10	14	20	24	28	33
Mean no. chicks fledged pair^{-1}	0.26	0.30	0.37	0.74	0.74	1.00	1.08	1.06

1996/97 season, and all 9 stoat predations were in the 1995/96 season (Table 5) during a 16-day period in October at the Orchard Road nesting area. Shell fragments from 8 eggs were found cached under an up-turned boat hull up to 400 m from the nesting area. Mammalian predators (cats, stoats, rats, and possums) caused at least 24% of failed nesting attempts during incubation (n = 179), avian predators at least 16.2%, and people (including their dogs and cattle) 12.3%.

The main avian predator of dotterel nests during incubation was the black-backed gull. In the 1st season, gulls preyed on 32% of dotterel nesting attempts; and this declined to 22% in 1994/95 and 13% in 1995/96 (Table 5). Of 2 dotterel clutches monitored using time-lapse video equipment in 1992/93, 1 was preyed upon by gulls, the dotterel being unable to drive off the 5 gulls involved. One instance of predation by a harrier (*Circus approximans*) was also seen. The harrier dived at an incubating dotterel; the dotterel escaped, leaving the harrier to eat the eggs. Spur-winged plovers (*Vanellus miles novaehollandiae*) were seen destroying 4 dotterel clutches, all in the 1997/98 season, by pecking 1 or 2 small holes in each egg.

Table 5 Causes of New Zealand dotterel (*Charadrius obscurus*) breeding failure during incubation on Matakana Island during 8 breeding seasons, 1992/93 to 1999/2000.

	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/2000
No. of nests	22	26	32	44	46	42	25	39
Causes of failure								
Flooding	3	7	6	7	10	2	2	3
House cat	2	0	0	0	15	1	1	2
Stoat	0	0	0	9	0	0	0	0
Norway rat	0	0	1	1	3	2	0	1
Brushtail possum	1	0	0	0	0	2	0	2
Australasian harrier	0	0	0	0	1	0	0	0
Black-backed gull	7	0	7	6	1	2	0	1
Spur-winged plover	0	0	0	0	0	4	0	0
Unidentified predator	4	2	1	3	2	2	3	8
Person/vehicle[1]	1	0	2	3	0	9	2	1
Dog	0	0	0	0	1	1	0	0
Cattle	0	0	1	1	0	0	0	0
Unknown causes	0	9	3	0	0	3	0	0
Abandoned	0	0	2[2]	1	1[3]	0	0	1
Successful nests	4	8	9	13	12	14	17	20

[1] Includes disturbance caused by people that resulted in the nest being abandoned, or eggs being destroyed.
[2] Includes 1 nest usurped by variable oystercatchers (*Haematopus unicolor*).
[3] Includes 1 nest usurped by another pair of New Zealand dotterels.

Not all data were available on the success of nests that were shifted to try and prevent them being flooded. Of 9 that were shifted in 4 seasons, the mean distance shifted was 2.9 m (range 1.5-7.0). Although just 1 was subsequently flooded, only 3 were successful, the other clutches being preyed upon by gulls (4) or destroyed by people.

Incubation success nest^{-1} of New Zealand dotterels varied considerably from season to season in managed (20-75%) and unmanaged areas (0-57%; Table 6). Overall, however, nests in managed areas were significantly more successful (47.5%, n = 139) than those in unmanaged areas (19.5%, n = 77; χ^2 = 15.4, with Yates' correction, df = 1, $P < 0.0001$). Even though any nest, whether in managed or unmanaged habitat, was shifted to reduce the chance of flooding during high tides and storms, dotterels in unmanaged habitat suffered significantly greater incubation failure as a result of flooding (20.8%) than those in managed habitat (2.9%) (χ^2 = 16.8, with Yates' correction, df = 1, $P < 0.0001$). Similarly, a significantly greater proportion of nests in unmanaged habitat failed as a result of predation (50.6%) than those in managed habitat (34.5%) (χ^2 = 4.70, with Yates' correction, df = 1, $P < 0.05$).

Chick-rearing success

Overall, 52.6% of chicks (n=266) fledged during the 8 seasons. The majority (89.7%) of the 126 chicks that failed to fledge disappeared. Of the remaining 13, 6 were killed by people, 3 were killed by black-backed gulls, 2 were found dead of unknown causes, 1 was killed by a dog, and 1 was euthanased because of a leg abscess. The proportion of chicks that fledged season^{-1} varied from 29 to 75%. In comparison, the mean number of fledglings produced breeding pair^{-1} season^{-1} increased from 0.26 for the 1st season to ≥1.0 for the last 3 seasons (Table 4). The total number of chicks fledged season^{-1} also steadily increased. Over the 8 seasons, chick-rearing success was not significantly greater in managed habitat (57.2%, n = 180) than unmanaged habitat (47.5%, n=61) (χ^2 = 1.36, with Yates' correction, df = 1, P = 0.244) (Table 7).

DISCUSSION

Dotterel population

Assuming our estimate of number of breeding pairs on Matakana Island is correct for the 1st 2 seasons, then numbers fluctuated little from 1992/93 to 1998/99 (24-27 pairs), except in 1995/96 (19). The reduction in numbers during 1995/96 occurred because there were no pairs at the Waikoura Point and Honeyfield Road breeding areas. During the previous summer, north-easterly storms and accompanying extremely rough seas completely eroded away these beaches. It was not until the following breeding season that sufficient beach had formed for pairs to again establish breeding territories in these areas. Even so, only 3 pairs nested at the northern end of the island during the last 4 seasons compared with 8-11 pairs before the beach erosion.

Whereas the number of breeding pairs on Matakana Island changed little during the study

Table 6 Comparison of incubation success (percentage of nesting attempts hatching 1 or more chicks) of New Zealand dotterels occupying managed (where trapping and poisoning of all pest mammal species occurred) and unmanaged sites on Matakana Island.

Season	Managed pairs						Unmanaged pairs					
			Reasons for failure						Reasons for failure			
	No. of nests	% successful	Unknown cause	Flooding	People /vehicle	Predation	No. of nests	% successful	Unknown cause	Flooding	People /vehicle	Predation
1992/93	-						22	18.2	-	13.6	4.6	63.6
1993/94	7	71.4	14.3	-	-	14.3	-	-	-	-	-	-
1994/95	14	50.0	21.4	-	14.3	14.3	12	0.0	8.3	33.3	-	58.3
1995/96	26	34.6	3.9	-	7.7	53.8	3	33.4	-	33.3	-	33.3
1996/97	29	20.7	-	3.4	3.4	72.4	5	20.0	-	80.0	-	-
1997/98	23	43.5	4.3	-	30.5	21.7	17	23.5	11.8	11.8	17.6	35.3
1998/99	16	68.6	-	6.3	12.5	12.6	7	57.1	-	14.3	-	28.6
1999/2000	24	75.0	-	8.3	4.2	12.5	11	9.1	-	9.1	-	81.8
TOTAL	139	47.5	4.3	2.9	10.8	34.5	77	19.5	3.9	20.8	5.2	50.6

(maximum from 19 to 31, a 39% increase), the number of fledglings produced season^{-1} increased gradually from 5 to 33, a 560% increase. The small increase in the number of breeders relative to that of fledglings produced suggests a number of possibilities: that the Matakana Island population of breeders was at carrying capacity, that there was a high mortality of breeders or fledglings or both, or that most fledglings dispersed and established at breeding sites other than at their natal site. There is evidence that fledgling New Zealand dotterels exhibit low natal site fidelity, with about 82% breeding away from their natal site (Dowding 2001). Whether such dispersal movements are the result of lack of unoccupied breeding habitat at the natal site or an innate impulse to breed elsewhere is unknown.

Predator population reduction and dotterel nesting success

The key objective of the northern New Zealand dotterel recovery plan in 1992-97 was to increase the number of northern New Zealand dotterels, and to increase the breeding range of the population (Dowding 1993). On Matakana Island, this was attempted by reducing predator numbers and disturbance by people so that nesting pairs could rear as many fledglings as possible. As a result of improvements to predator control and visitor education, by the 4th season of the project dotterel nesting success had improved markedly. During the 1st season (1992/93), when nest monitoring began about midway through the nesting season and pest control started in December, dotterel productivity was low, and at a level found at other unmanaged sites on mainland New Zealand (0.0-0.3 fledglings pair^{-1}) (Dowding 1997). The greatest productivity season^{-1} (*c.* 1 fledgling breeding pair^{-1}) was achieved during the last 3 seasons when nests were monitored and pests controlled during August/September-February. Thus, nests were protected for almost the entire nesting season (September-March). This level of productivity was similar to that achieved by New Zealand dotterels where intensive predator control was practiced; at Opoutere, Coromandel (0.6-1.0 fledglings pair^{-1}) (Dowding 1997), and at Opotiki, Bay of Plenty (0.7-1.3 fledglings pair^{-1}) (Glaser 2001). To achieve high productivity, the Matakana Island study indicates that predator control should commence before dotterel nesting starts, and continue until the last chicks have fledged. Likewise, Dowding (1997) advocated that cat control on Stewart Island be started before nesting of southern New Zealand dotterels (*Charadrius o. obscurus*) began to best protect adults from predation by feral cats.

Although the density of mammal predator populations on Matakana Island was not

Table 7 Comparison of chick-rearing success (proportion of chicks that fledged) of New Zealand dotterels (*Charadrius obscurus*) occupying managed and unmanaged sites on Matakana Island, 1992/93 to 1999/2000.

	Managed habitat			Unmanaged habitat		
Season	No. of nests	No. of chicks hatched	% of chicks fledged	No. of nests	No. of chicks hatched	% of chicks fledged
1992/93	-	-	-	4	11	45.4
1993/94	5	14	35.7	-	-	-
1994/95	7	19	42.1	2	6	33.3
1995/96	9	23	39.1	1	2	50.0
1996/97	6	16	62.5	6	18	55.5
1997/98	10	23	78.3	4	9	66.7
1998/99	11	33	66.7	4	12	33.3
1999/2000	18	52	59.6	1	3	33.3
Total	66	180	57.2	22	61	47.5

monitored independently from the trapping and poisoning programme, numbers and capture rates of possums, rats, and cats trapped declined little after the 1996/97 season, even though trapping and poisoning effort increased (DEW unpubl. data). This suggests that the predator populations had been much reduced as a result of the control programme during the previous seasons and did not recover between seasons, or that traps were being avoided. In contrast, the stoat population seems to have been little affected by the control programme.

It is no surprise that the control of mammal predator populations resulted in greater numbers of dotterel chicks fledging because possums (Brown *et al.* 1993; Brown *et al.* 1996), Norway rats (Moors 1990), cats (Pierce 1986; Rebergen *et al.* 1998; Sanders & Maloney 2002) and stoats (King 1990; Dowding & Murphy 1996; Sanders & Maloney 2002) are known to prey on birds' eggs and chicks, including those of waders. Cats and stoats are also known to take nesting adults and fledglings (Dowding & Murphy 1996). Cat predation was the main threat to the southern New Zealand dotterel population: following cat control through the dotterel's breeding habitat, this dotterel population gradually increased (Dowding & Murphy 2001).

Even though trapping and poisoning can reduce predator populations to very low levels (Saunders 2000), a single trap- or bait-shy animal that targets New Zealand dotterel nests can have a major impact on nesting success for a particular nesting season (Dowding & Murphy 1996). This probably explains why 15 clutches were taken by a cat or cats in 1996/97, yet only up to 2 clutches were taken by cats in other seasons. Similarly, 9 clutches were taken by a stoat or stoats in 1995/96, even though there was no obvious stoat predation during the rest of the study.

The black-backed gull is a known predator of dotterel chicks (Sibson 1967; Cumming 1991; Dowding *et al.* 1999). The black-backed gull population on Matakana Island increased during the 1980s and early 1990s, probably as a result of the huge food resource available at 5 refuse tips around Tauranga, just 4 km from Panepane Point. While the gulls destroyed many of the dotterel eggs lost during the first 4 seasons, few egg predations attributable to gulls occurred after the major gull poisoning campaign in 1995/96. However, a number of eggs and chicks that disappeared may have been preyed on by gulls. An individual gull that targets shorebird eggs and chicks could have quite an impact on the productivity of the Matakana dotterel population since its aerial hunting would enable it to search much of the island's beaches each day, both in managed and unmanaged areas.

Overall, dotterels breeding on Matakana Island in managed areas hatched significantly more clutches than those nesting in unmanaged areas. During incubation, losses to predators in the managed habitat in each of the last 2 years were just 12.5% of nests compared to 52% losses in unmanaged areas of Matakana, and up to 60% losses of New Zealand dotterel nesting attempts elsewhere (Dowding & Murphy 2001). It appears that the level of predator control in these years was adequate to protect nests at the egg stage. It would be useful to determine the causes of chick disappearances, and why chick survival was similar in managed and unmanaged areas. Similarly, Maloney & Murray (2000) indicated that determining the reasons for the disappearance of chick and fledgling black stilts (*Himantopus novaezelandiae*) was a priority to improve the conservation prospects of this species. Like Chudleigh (1988), we suspect that gulls are responsible for the demise of many chicks for the reasons given above, and being present in large numbers over the island with their nesting colonies next to or near the main dotterel nesting areas.

Flooding of nests

Nests were flooded during high-tides and storms regularly each season on Matakana Island despite management, accounting for 14.5% of dotterel nesting attempts during the 8 nesting seasons. By comparison, 29% of variable oystercatcher nesting attempts at managed sites in Northland failed because of flooding (A. Booth pers. comm. *in* Dowding & Murphy 2001), although none of the nests was shifted to try to prevent flooding. Flooding has been reported as one of the main causes of nest failure for several wader species that nest on beaches outside New Zealand, including hooded plover (*Charadrius rubricollis*) (Schulz & Bamford 1987), snowy plover (*Charadrius alexandrinus*) (Page & Stenzel 1981), and African black oystercatcher (*Haematopus moquini*) (Jeffery 1987). The data available on the impact of shifting nests inland from the high-tide area in an attempt to prevent them being flooded were too few and were compromised by predation. Because New Zealand dotterels did not abandon their shifted nests, further study of this topic is warranted to determine whether it improves nesting success. Ideally such a study needs to be done in an area where there is little or no predation, and where nests can be randomly allocated to treatment and control samples.

Impact of people on dotterel nesting

Disturbance by people probably has a serious effect on the nesting success of New Zealand dotterels. Results from 1 season suggested that sites with low levels of human disturbance had twice the breeding success (numbers of fledged chicks pair^{-1}) compared to high disturbance sites, but the difference was not significant (Cumming 1991). Nest failure caused by people resulted from both direct (trampled, crushed by vehicle, predation by dog) and possibly indirect causes (reduced incubation attentiveness while people remained near nests may have resulted in embryo death) (Cumming 1991). While much effort was made on Matakana Island during the dotterel breeding seasons to alert people on beaches to the presence of dotterel nests and chicks by fences and signs, distribution of pamphlets, and talking to people at or near nesting areas, there was no obvious reduction in the number of nests that failed due to disturbance by people. In most instances, people caused nest failure because they were unaware of where the well-camouflaged nests and eggs were, and so inadvertently drove over or trampled the eggs. However, there were 4 occasions in the 1997/98 season when a group of children wilfully trampled clutches. Since most people respect fenced-off dotterel nesting areas (Graeme 1989; this study), we consider it better to alert the public to nesting areas by putting up fences and signs, and having wardens present much of the time, as advocated by Bridson (2000), rather than doing nothing.

Conclusions

We conclude from our study that to further promote the conservation of the northern New Zealand dotterel, 2 things need to be done. The 1st is to analyse the data for dotterel breeding success from each site to determine whether management efforts need to be improved. By comparing breeding success between sites, particularly managed versus unmanaged, in relation to the methods of management used, particularly predator control, the most efficient and successful methods for promoting dotterel productivity at each site might be identified. To better monitor the impact that trapping and poisoning efforts are having on predator populations, it would be useful to monitor their populations by an independent method, such as using foot-print tracking tunnels for rodents and mustelids (Innes *et al.* 1995).

Secondly, a new census is warranted. It is now 6 years since the previous census of the northern New Zealand dotterel population. In the 1998/99 breeding season, and probably during each season since then, about 120 (20%) of the estimated 600 breeding pairs occupied managed areas (Dowding & Murphy 2001). Thus, given the vulnerable status of the subspecies, the time since the previous census, and the effort being made to boost productivity at some breeding sites, a re-census is warranted. If numbers of dotterels at managed sites have stabilized, this would suggest that such areas have reached carrying capacity, and a further population increase is dependent on fledglings establishing and surviving in unmanaged sites. If there is little benefit to the total population from the fledglings produced at managed sites, 2 actions should be considered: to establish more managed and therefore 'safe' sites for breeding dotterels, and/or to trial pulsed management at some sites, as has proven effective in sustaining a North Island kokako (*Callaeas cinerea wilsoni*) population (B. Basse *et al.* unpubl. data). Since northern New Zealand dotterels are long-lived (average adult life expectancy is c. 13 years (Dowding 1997), and some birds live for 30 years (Heather & Robertson 2000)), there is no need to carry out pest control every year to ensure population survival. Also, there is no value in producing lots of fledglings each year for a population that is at carrying capacity if most of them fail to recruit as breeding adults.

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