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BREEDING SUCCESS AND PREDATION AT NESTS OF BANDED DOTTEREL (*CHARADRIUS BICINCTUS*) ON BRAIDED RIVERBEDS IN THE CENTRAL SOUTH ISLAND, NEW ZEALAND

Summary: Egg and chick loss at banded dotterel (*Charadrius bicinctus*) nests was studied over the 1992/93 season on the Tekapo, Ohau and Ahuriri Rivers in the Central South Island. Egg loss at nests was higher on the Ohau and Tekapo Rivers than on the Ahuriri River, especially early in the season. Only 11 % and 12 % of nests fledged one or more chicks on the Tekapo and Ohau Rivers respectively, compared to 42 % of nests on the Ahuriri River. Nests on islands within the braided riverbeds were more successful than nests on the mainland. Proximity of nests to potential predator cover did not influence hatching success although close proximity of nests to rabbit burrows increased the risk of predation. A lack of knowledge of the predator species involved in this study hampers assessment of the impact of various factors on the breeding success of banded dotterels. Further research to identify predators is necessary to target conservation management and better protect banded dotterel and endangered riverbed birds.

Keywords: banded dotterel, *Charadrius bicinctus*, breeding success, braided rivers, predation.

Introduction

Predation is an important cause of nest failure worldwide (Nice, 1957; Ricklefs, 1969; Martin, 1993) and when predation rates exceed recruitment rates populations may be at risk of extinction. The banded dotterel (*Charadrius bicinctus* Jardine and Selby) is a relatively common, small, endemic plover that breeds in a variety of open habitat types throughout New Zealand, including braided river beds in the central South Island (Pierce, 1983). The endemic black stilt (*Himantopus novaezelandiae* Gould), wrybill (*Anarhynchus frontalis* Quoy and Gaimard) and black-fronted tern (*Sterna albostriata* Gray) also breed on braided river beds. All three species have low and/or declining abundance and are threatened by introduced predators and changes in vegetation (Bell, 1986; Pierce, 1986; Reed, Murray and Butler, 1993; Project River Recovery, *unpubl. data*). The higher abundance of dotterels facilitates study of their breeding success and predation. A better understanding of the importance of predation at banded dotterel nests could assist with the recovery of black stilt, wrybill and black-fronted tern populations.

The eggs, young and adult birds breeding on braided rivers are probably preyed on by introduced mammals such as ferrets (*Mustela furo* L.), stoats (*M. erminea* L.), cats (*Felis catus* L.), hedgehogs (*Erinaceus europaeus* Barret-Hamilton) and Norway rats (*Rattus norvegicus* Berkenhout), and by native predators such as Australasian harriers (*Circus approximans* Peale) and black-backed gulls (*Larus dominicanus* Lichtenstein) (Pierce, 1987). However, the relative importance of these predators is not known.

Previous studies in the Mackenzie Basin, especially work by Pierce (1986, 1987) in the Cass and upper Tekapo Rivers, showed that nest site location and timing of breeding influenced the breeding success of braided river birds. Pierce (1987) also suggested that sudden declines in rabbit (*Oryctolagus cuniculus* L.) abundance following 1080 (sodium monofluoroacetate) poisoning may be a precursor to high rates of predation at riverbed bird nests.

The unstable river channels and high levels of disturbance present in braided rivers is a key factor regulating vegetation and the use of the areas by breeding birds. The original vegetation on braided rivers is highly specialised and consists primarily of ground cover plants, such as common scabweed (*Raoulia hookeri*) and an absence of tall vegetation (Parkinson and Cox, 1990). Reduced frequency of flooding because of the construction of hydro-electric power impoundments has led to the accumulation of silt, thereby creating habitat for trees, herbs and grasses. The new exotic vegetation is unsuitable for breeding waders, provides cover for predators and creates habitat for the predators' main prey, rabbits and hares (*Lepus europaeus* de Winton) (Pierce, 1987).

This study examines predation rates at banded dotterel nests on the Ahuriri, Tekapo and Ohau Rivers, at different times of the 1992/93 breeding season and investigates whether predation rates are related to physical nest site parameters (proximity of nest to cover, possible den sites, and water). This study also reviews predation rates recorded at banded dotterel nests in previous studies to test the hypothesis that rabbit poisoning triggers higher predation rates at nests.

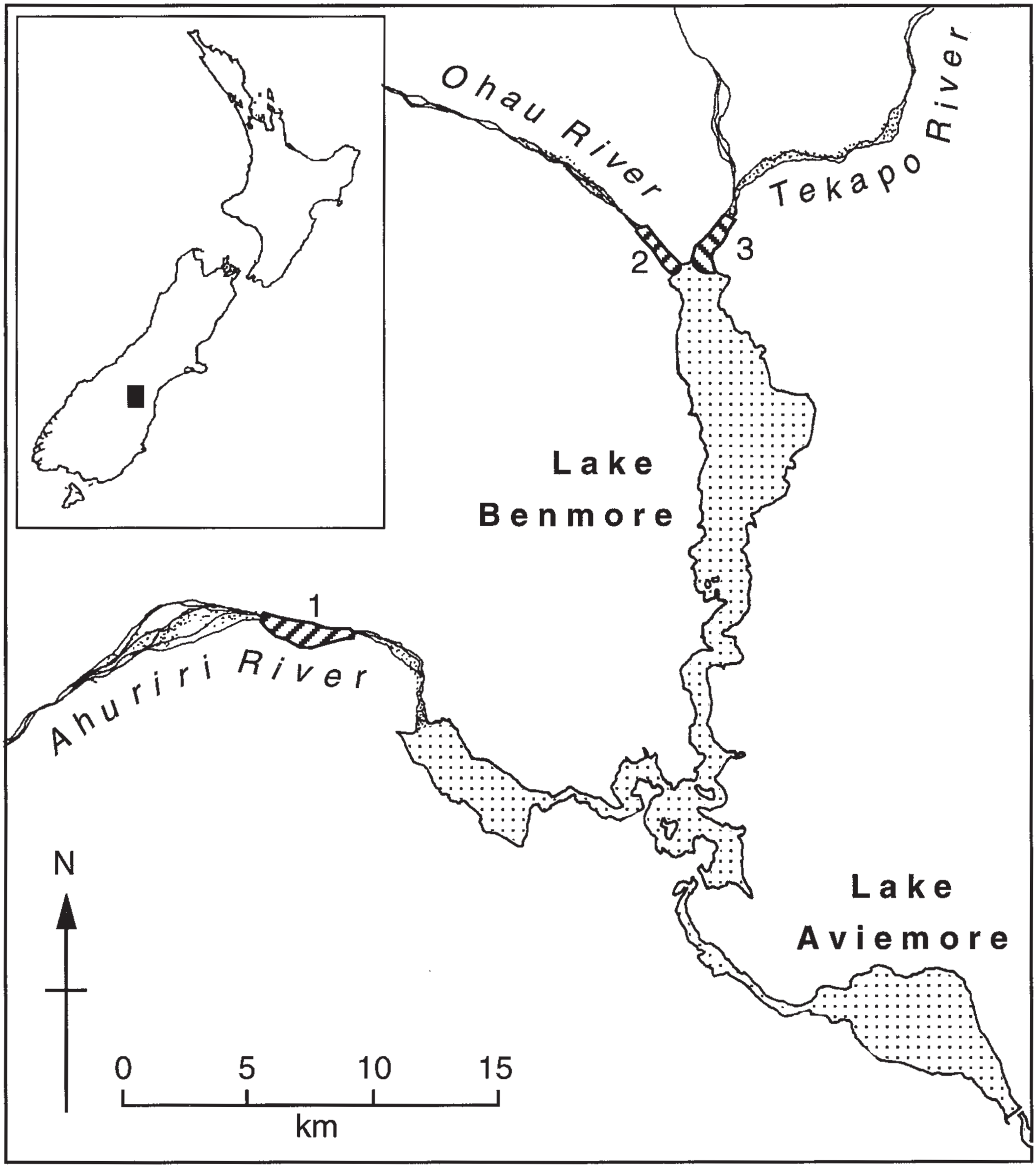

Figure 1: *Map of Ahuriri (1), Ohau (2) and Tekapo (3) River study sites.*

Study sites

We studied banded dotterel breeding success at three sites in the central South Island, New Zealand (Fig 1). The Ohau River study site was in the lower river delta area over a 2200 m length of the river which was free of willows (*Salix fragilis* L.) and lupins (*Lupinus polyphyllus* Russell cultivar, Sims). The Tekapo River site was also in the lower river delta and 2400 m long but had areas with willows present and absent, and areas where willows had been removed in autumn 1992. The Ahuriri River study site had some areas with gorse (*Ulex europaeus* L.), lupins and willows and was 1650 m in length. Rabbits were poisoned (aerial drop of carrots laced with 1080) at the Ohau River study site in March/April 1992, the Tekapo River delta in April 1991 (B. Glentworth, *pers. comm.*) and the Ahuriri River study area in May 1991 (R. Bungard, *pers. comm.*).

Methods

Breeding banded dotterels were monitored in the three study sites from 9 September 1992 until 10 February 1993. Nests were found between 9 September and 30 December 1992 by observing the adult birds returning to the nest. Each nest was then marked with a 20-30 cm high stone cairn, placed 3-5 m from the nest. The nest locality was mapped on an aerial photo (scale 1:6000), over-laid with a 50 x 50 m grid. All nests were monitored every 2-4 days.

The cause of egg failure was recorded as predation, flooding or desertion. Egg disappearance was assumed to be predation. Failure at the chick stage was recorded, although the cause (eg. predation, starvation, trampling) could not be determined because all evidence of chicks disappeared.

Breeding birds were caught using a netting drop trap which the bird activated as it returned to its nest (for details of trap design see Mills and Ryder, 1979). Usually at least one of each pair of banded dotterels was individually colour banded for identification. After hatching, the survival and fledging of the young was monitored by locating families of banded dotterels with chicks or by observing parent behaviour. Loss of chicks resulted in adult behaviour changing from very obvious shows of loud calling, flying and running to much quieter, less alarmed behaviour.

In this study, breeding success is divided into "hatching success" (percentage of nests that hatched at least one egg) and "fledging success" (percentage of nests that fledged at least one chick). Survival during the period between hatching and fledging is here called "chick success". "Nest predation" is defined as nests preyed on at the egg stage.

The period of nesting was divided into "early", "mid" and "late" season, based on breeding patterns of banded dotterels in the three study areas. Early season nests hatched or failed before or on 20 October 1992; mid season nests between 21 October 1992 and 30 November 1992 and late season from 1 December 1992.

Some nests failed before they were found. Therefore a daily nest survival rate was calculated using the Mayfield method to ensure that the importance of predation was not underestimated (Mayfield, 1975). Hatching and fledging success are presented as a percentage of the number of nests found during the study. Only hatching success rates could be used to compare with other studies as other studies did not include records of fledging success.

Physical nest site parameters were described by recording:

1. Whether the nest was on an island or the mainland. Islands were surrounded by a stable water flow of >1 m^3 sec^{-1}, measured using a Gurley meter (January 1993).
2. Distance to nearest potential predator cover. Cover could be vegetation, debris, logs and wood piles. A cover of 30 cm in height was considered to be large enough to hide a potential predator. Nearest cover was measured for two heights: >30 cm (low) and >100 cm (high).
3. Distance to possible den site. Predator den sites included rabbit burrows, logs, debris, dense vegetation, large willow trees and wood piles (present on the river bed after willow removal).
4. Distance to nearest river channel or any water. The river channel was the nearest flowing water; any water could be a river channel or a back water (standing water).

Chi-square tests were used to compare predation rates and hatching success between areas and between periods, according to the categories shown in Table 1. Partitions were chosen to divide the number of observations into about three equal groups (prior to calculation of loss rates).

Table 1: *Distance categories (m) for physical characteristics of the nest sites.*

Physical character	Near	Middle distance	Far
Cover (>30 cm)	5-10	11-30	>30
Cover (>100 cm)	5-30	31-70	>70
Possible den site	0-20	21-50	>50
Any water	0-20	21-40	>40
River channel	0-40	41-100	>100

Table 2: *Number of banded dotterel nests found during the 1992/93 season in the Ahuriri, Ohau and Tekapo study sites and the outcome of each nesting attempt. "Lost eggs" = % nests that lost eggs due to predation, "chicks lost" = number of hatched nests that lost all chicks. Egg survival rates were calculated using the Mayfield method, [95% binomial confidence interval] from Mainland, Herrera and Sutcliffe (1956).*

Study site	No. of nests	Number (%) of nests: Hatched ≥1 egg	Lost eggs	Deserted	Fledged ≥1 chick	Chicks lost	Minimum no. of chicks fledged	Egg survival, %
Ahuriri	50	37 (74) [66-90]	12 (24) [13-38]	1 (2) [0-11]	21 (42) [28-57]	16 (43) [29-62]	26	67
Ohau	50	16 (32) [20-47]	33 (66) [51-79]	1 (2) [0-11]	6 (12) [5-24]	10 (63) [27-73]	7	17
Tekapo	53	21 (40) [27-54]	31 (58) [43-72]	1 (2) [0-11]	6 (11) [5-24]	15 (71) [57-82]	7	21
All areas	153	74 (48) [40-56]	76 (50) [42-58]	3 (2) [0-6]	33 (22) [16-29]	41 (55) [47-63]	40	33

Past studies of banded dotterel breeding success were reviewed and the relationship between predation rates and 1080 poisoning was examined using a Kruskal-Wallis test.

Results

Overall breeding success

During the study, 153 nests were found in the three study sites during incubation (Table 2). A small number of pairs of banded dotterel were found with chicks in all three sites for which no nest had been found. These birds were not included in the study.

No nests were flooded in any of the study areas during the study period and only three nests were deserted, one in each area. Accordingly, egg predation rates were approximately the reverse of hatching success rates. The deserted nests were excluded from the analysis except where stated in the text.

Hatching success differed significantly between the three areas (χ^2=20.55, d.f.=2, p=0.0001). Hatching success was higher on the Ahuriri River than the Ohau and Tekapo Rivers, because of lower egg predation rates on the Ahuriri River. Nest survival, using the Mayfield method, was higher on the Ahuriri River than on the Ohau and Tekapo Rivers. The Ahuriri River had a greater fledging success than the Ohau and Tekapo Rivers (χ^2=18.46, d.f.=2, p=0.0001). At least 57 % of the nests that hatched chicks on the Ahuriri River , survived to fledge one or more young, compared with 37 % of nests on the Ohau River and 29 % on the Tekapo River. However, the difference in chick survival (the period from hatching to fledging) between the three areas was not significant (χ^2=4.72, d.f.=2, p=0.094). The cause of death of the chicks was unknown.

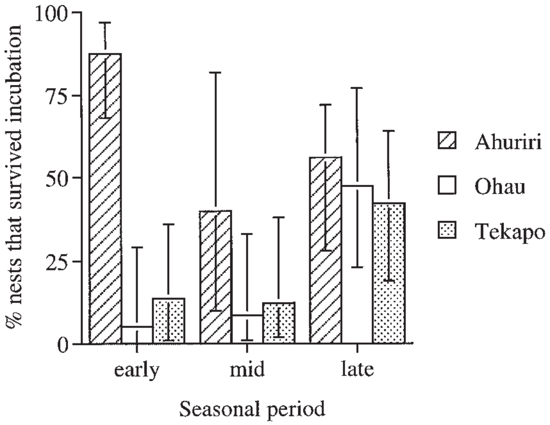

Figure 2: *Banded dotterel nest survival rates in 1992/93 on the Ahuriri, Ohau and Tekapo Rivers in early (<21 October 1992), mid and late (>30 November 1992) season, using the Mayfield method. Error bars are 95% binomial confidence intervals from Mainland* et al. *(1956)*

Seasonal differences

The seasonal distribution of egg losses differed markedly between areas. Hatching success was significantly higher on the Ahuriri River than on the Ohau and Tekapo Rivers in early season (χ^2=29.43, d.f.=2, p=0.0001), but was similar in mid and late season (Fig 2). Fledging success was higher on the

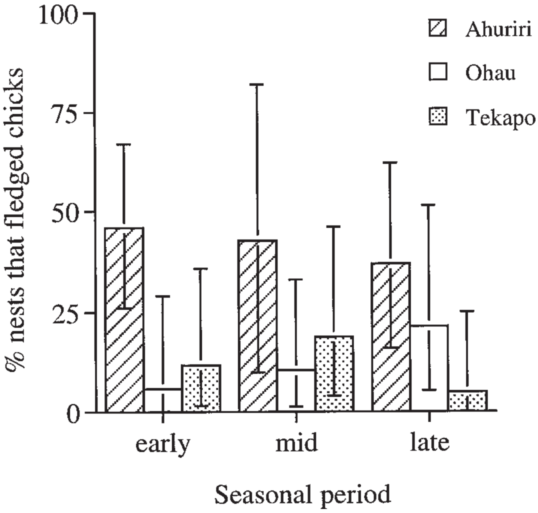

Figure 3: *Percentage of banded dotterel nests that fledged young in early (<21 October 1992), mid and late (>30 November 1992) season on the Ahuriri, Ohau and Tekapo Rivers. Error bars are 95% binomial confidence intervals from Mainland* et al. *(1956)*

Ahuriri River than on the Ohau and Tekapo Rivers in early season (χ^2=10.68, d.f.=2, *p*=0.005) and late season (χ^2=6.01, d.f.=2, *p*=0.0495) but not mid season (Fig 3).

Hatching success among early, mid and late season periods within the individual study sites was different on the Ohau (χ^2=6.78, d.f.=2, *p*=0.034) and Tekapo Rivers (χ^2=6.65, d.f.=2, *p*=0.036) where hatching success increased over time. There was a marginally significant result for the Ahuriri River (χ^2=5.95, d.f.=2, *p*=0.051) where hatching success decreased over time. However, fledging success did not differ among seasonal periods within the study areas.

Table 3: *Number of banded dotterel nests that survived on island and mainland nest sites on the Ohau and Tekapo Rivers (combined). "Hatching success" is the number of nests that successfully hatched ≥1 eggs, "Chick success" is the number of successfully hatched nests that fledged ≥1 chicks, [95% binomial confidence interval] from Mainland* et al. *(1956).*

Location	Number of nests	Hatching success	Chick success
Island	48	26 (54%) [39-68%]	12 (46%) [27-67%]
Mainland	55	11 (20%) [10-33%]	0 (0%) [0%]

Island and mainland nests

Banded dotterel nests on islands in the Ohau and Tekapo Rivers were more successful than mainland nests (Ohau χ^2=4.01, d.f.=1, *p*=0.045; Tekapo χ^2=13.66, d.f.=1, *p*=0.0002) (Table 3). The data for the Ahuriri River could not be analysed statistically because only three island nests were found (all successful). All fledglings on the Ohau and Tekapo Rivers combined originated from island nests (Table 3). Only 12 pairs fledged one or more chicks.

For Ohau and Tekapo Rivers combined, the percentage of nests that hatched increased from early to late season on both islands and the mainland, but for islands this difference was not significant (χ^2=4.15, d.f.=2, *p*=0.126). On the mainland, hatching success was very low in early (5 %) and mid (6 %) season, while late season had a higher hatching success (50 %). This seasonal difference was highly significant (χ^2=14.05, d.f.=2, *p*=0.0009; Fig 4).

Distance to cover

The mean distance of nests to low cover (>30 cm) was 20 m (n=150, SE=1.52 m, range 5-120 m), and to high cover (>100 cm) was 46 m (n=150, SE=3.02 m, range 5-200 m). No significant differences in nest predation rates were found between the distance categories defined in Table 1 for either level of cover.

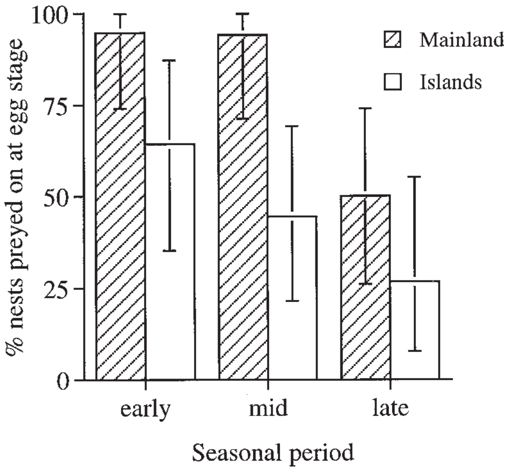

Figure 4: *Egg predation at banded dotterel nests on the mainland (n=54) and islands (n=47) in the Ohau and Tekapo Rivers combined in early (<21 October 1992), mid and late (>30 November 1992) season. Error bars are 95% binomial confidence intervals from Mainland* et al. *(1956)*

Distance to possible den site

The mean distance between nests and possible den sites was 43 m (n=150, SE=3.30 m, range 5-275 m). Nests more than 50 m from a possible den site had a significantly lower predation rate than nests within 50 m of a possible den site (χ^2=7.74, d.f.=2, p=0.021). When the data were analysed for each river separately, only the Ohau and Tekapo River nests showed lower predation rates when nests were further than 50 m from possible den sites. The expected values for Ahuriri River were too low and could not be analysed separately.

Table 4: *Breeding success and predation rates at banded dotterel nests on South Island Rivers. "Years since poisoning = years since study area was poisoned with 1080 against rabbits; "Hatching success" = % nests that hatched ≥1 eggs; "Nest predation" = % of nests preyed on at the egg stage; "Other cause" = % nests lost at egg stage due to desertion, trampling and/or flooding; "Fledging success" = % nests that fledged ≥1 chicks. [95% binomial confidence interval] from Mainland* et al. *(1956).*

Source	Area	Year	Years since poisoning	No. of nests	Hatching success	Nest predation	Other cause	Fledging success
Bomford (1988)	Cass River	1977	2+	37	43 [27-60]	54 [37-70]	3 [0-13]	
Hughey (1985)	Rakaia River	1982	1	27	70 [50-86]	0 [0]	30 [14-50]	
		1983	2+	42	38 [24-54]	10 [3-24]	43 [28-59]	
	Ashley River	1983	2+	58	50 [37-63]	24 [14-38]	26 [16-39]	
Pierce (1987)	Cass River	1983	2+	47	70 [55-83]	23 [12-38]	7 [1-18]	
		1984	0	71	56 [44-68]	38 [27-50]	6 [2-14]	
		1985	1	54	87 [73-93]	11 [5-24]	2 [0-11]	
		1986	2	58	72 [59-83]	24 [12-38]	4 [0-12]	
	Upper* Tekapo	1984/ 1986	0	21	??	55 [43-85]	??	
		1984/ 1986	2+	33	??	24 [18-52]	??	
		1985	1	7	??	38 [4-71]	??	
		1985	2+	25	??	30 [28-69]	??	
This study	Ohau River	1992	0	50	32 [20-47]	66 [51-79]	2 [0-11]	12 [5-24]
	Ahuriri River	1992	1	50	74 [66-90]	24 [13-38]	2 [0-11]	42 [28-57]
PRR	Ahuriri River River	1993	2	38	74 [56-86]	??	??	26-37 [14-54]
(unpubl. data)		1994	2+	47	77 [53-84]	19 [9-33]	4 [1-15]	47 [32-62]
		1995	0	77	36 [26-48]	47 [35-59]	17 [10-28]	25 [15-35]

* poisoned and non-poisoned zones in 1984 and 1986 (years when poisoning occurred) were combined to increase sample size for analysis

Distance to water

The mean distance of banded dotterel nests to any water was 38 m (n=150, *s.e.*=2.54 m, range 0-170 m). The mean distance of nests to a river channel was 77 m (n=150, *s.e.*=5.01 m, range 0-280 m). The distance between nests and a water body did not influence nest predation rates or hatching success (χ^2=2.759, d.f.=2, *p*=0.252).

Breeding success and 1080 rabbit poisoning

A review of past studies of banded dotterel breeding success and nest predation rates showed variation in these rates over time and space (Table 4). Analysis of nest predation rates with respect to years since the area was 1080 poisoned indicated that predation was higher in years following 1080 operations (H=7.157, d.f.=2, *p*=0.0279).

Discussion

This study only spanned one breeding season of banded dotterels and therefore cannot take into account any variation occurring from year to year. In addition, individual chick survival was difficult to assess during this study due to the large size of the study areas, the cryptic behaviour of the chicks and movements of some broods away from the original nest site. With little knowledge of predation rates of chicks and adults, accurately determining the effect of predation on banded dotterels as a population is hampered. Lack of knowledge of the predators involved in the observed predation rates also causes difficulty in assessing the factors affecting nesting success. However, our results do have important implications for management of the braided river habitat.

Spatial predictors

Proximity of banded dotterel nests to a water body or to cover did not have a significant effect on nest predation rates, contrary to the results of Pierce (1987). In addition, findings by Pascoe (1995) suggest predation risk would be higher where there was cover because of the greater concentration of rabbit faecal pellets and predators there. This discrepancy may be a result of variation in the abundance and distribution of cover within the study sites, leading to differences in the distribution of predation events. Further research is necessary to determine whether our result can be repeated, although following seasons on the Ahuriri River appear to show the same result with successful breeding in areas with patchy vegetation (Project River Recovery, *unpubl. data*).

Close proximity to possible den sites had an effect on nest success, although the criteria for possible den sites differed from that for cover only by the presence of rabbit burrows. This suggests rabbit burrows may play a significant role in harbouring predators. Rabbit burrows were common den sites in coastal Otago for ferrets (Alterio, 1994). Alternatively, because cats and ferrets prey predominantly on young rabbits and hares (Gibb, Ward and Ward, 1978; Pierce, 1987), predators may visit areas with rabbit burrows more frequently, increasing the risk of predation for those banded dotterel nests close to rabbit burrows.

Islands provided significantly more successful nesting sites than the mainland. However, it is likely that the flow of water as well as width, depth, presence of boulders and water velocity are all potential factors affecting predator movements to islands. In addition, islands without rabbits may be unattractive to ferrets and cats (Pierce, 1987). Counts of rabbit pellets in the Tekapo River study area showed twice as many pellets on the mainland compared to islands; and significantly more cats, ferrets, and hedgehogs were trapped on the mainland than on islands (Pascoe, 1995). Islands where cats and ferrets were trapped were usually larger and/or contained dense vegetation compared to islands where no cats or ferrets were caught (Pascoe, 1995). Our study did not relate banded dotterel breeding success to island size or island vegetation. Further studies are necessary to determine whether predator abundance is lower on small bare islands and whether breeding success of river birds nesting on such islands is increased. It is important to understand the mechanisms by which islands are more successful nest sites because if barren islands are important this may imply that the best protection is afforded by concentrated vegetation removal on islands as opposed to on the mainland. However, the Ahuriri River site had only three banded dotterel nests on islands, indicating that in years of low predator abundance mainland areas can be successful breeding areas.

Overall breeding success

Banded dotterel nests on the Ohau and Tekapo Rivers had lower hatching success than nests on the Ahuriri River because of lower egg predation rates at the latter study site. Fledging rates and chick survival were also lower on the Ohau and Tekapo Rivers and, although the cause of death of chicks was not known, it is likely that a high proportion of chick deaths were also attributable to predators. However, it is possible that the survival of chicks was slightly underestimated because of the difficulties involved in monitoring chicks.

High predation rates of eggs and low fledging rates of chicks of banded dotterels recorded in this study suggests predation strongly affects breeding success. The rate of predation on banded dotterels in this study is comparable to predation rates for rarer river bed birds (such as black stilts and black-fronted terns) that nest in the same river beds as banded dotterels. Pierce (1986) suggested predation was responsible for 64% of black stilt breeding failures, indicating that predator management could be vital in managing endangered populations.

The importance of predation

Predation was the main cause of failure of banded dotterel nests in this study. Analyses of egg survival using the Mayfield method indicate that the difference between the sites is indeed significant and not the result of methodological differences.

Pierce (1987) recorded high predation rates at banded dotterel nests in portions of the upper Tekapo River in 1984 and 1986 following rabbit poisoning. An analysis of the poisoned zones against the non-poisoned zones indicates higher banded dotterel nesting success in the non-poisoned zones (χ^2=11.626, d.f.=1, p=0.0007; from Pierce (1987)). The poisoned zones were adjacent to the non-poisoned zones therefore the areas were not fully independent. Nevertheless, the strong result obtained suggests there were differences in predation rates that were related to poisoning.

Increased predation rates may occur as a result of prey switching by predators from rabbits to native birds after 1080 poisoning operations targeting rabbits (Pierce, 1987; Newsome, *et al.* 1996). The elevated predation rates recorded at the Ohau site may have been linked to recent 1080 poisoning whereas lower predation rates were recorded at the unpoisoned Ahuriri site. The explanation for high predation rates at the unpoisoned Tekapo site is unknown. Our study was not designed to test the hypothesis of high predation rates following rabbit poisoning operations but an analysis of historical data suggests that diet-switching of predators to riverbed bird species may occur after 1080 poisoning of rabbits. However, interpretation of this analysis is difficult due to possible differences in methodology, predator guilds and poisoning regimes among sites. Well-controlled and replicated experiments are required before the relationship between 1080 poisoning and prey-switching is fully understood.

Temporal changes in abundance of rabbits and their predators after a poisoning event may have contributed to the different seasonal patterns for the predation rates observed. If so, the prior poisoning at Ohau may have reduced the availability of predator food sources early in the spring, resulting in the elevated nest predation rates earlier in the season.

Predator species

The relationship of nest predation rates to 1080 rabbit poisoning and to physical parameters of nest sites are difficult to establish when predator(s) identity is not clear. Video monitoring of banded dotterel nests on the Ahuriri and Ohau Rivers recorded hedgehogs, ferrets, cats and stoats as predators at the nest but little sign was left because the adult birds cleaned out the nest within hours of the predation event (Mark Sanders, *pers. comm.*). The resulting sign was consistent with that which Pierce (1986) attributed to mustelids. In addition, other video evidence of nest predation events suggests past methods of classifying predator sign are often inaccurate (Brown *et al.*, *in press*). Therefore it is virtually impossible to determine which predators were responsible for the high predation rates found in this study based on nest sign alone. In addition, chicks are active and move away from the nest site prior to fledging, and they may be killed by other predator species than those preying on eggs.

Determining the key predators would help assess the mechanisms leading to high predation rates, the effects of poisoning and would also help explain the seasonal differences in predation rates by linking the breeding and dispersal rates of the predators to the observed nest predation rates.

Insufficient knowledge of the predator species involved in this study hampers assessment of the impact of various factors on the breeding success of banded dotterels. Continued research using video monitoring of nests combined with careful recording of sign left after recorded predation events is necessary to determine the predators involved and will aid in ascertaining the impact that 1080 poisoning, rabbit abundance and physical parameters of nest sites have on breeding success. This information will give a better basis on which to make management decisions to protect banded dotterel and other endangered endemic waders.

Acknowledgements

This work was funded by Project River Recovery, Department of Conservation. Thanks to Department of Conservation staff, Twizel, for support and use of office facilities; and to Ron Nilsson and Lynn Adams for help in the field. Kerry Brown, Ed Minot, Mark Sanders and an anonymous reviewer provided useful comments on earlier drafts.

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