Natal and breeding dispersal of northern New Zealand dotterels

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Abstract

Dispersal patterns of juvenile northern New Zealand dotterels have been analysed, based on sight recoveries of birds colour-banded as chicks between 1986 and 1998. Birds bred 0-196 km from their natal site, with an average distance of 31 km and a median of 22 km. About 18% of birds returned to their natal site to breed and nearly all (93%) bred within 70 km of their natal site. Between fledging and breeding most juveniles moved much further than indicated by their natal dispersal distance.

Natal and first breeding sites are known for 120 birds; 77 of these were raised in the Northland-Auckland area and 43 in the Coromandel-Bay of Plenty area. There appears to be very little movement of juveniles between the two areas; over a period of 13 years only nine of 240 banded chicks that fledged were seen outside their natal area and no birds raised in one area were found breeding in the other. Analysis of breeding dispersal by adults shows that they move less than juveniles; none of 25 adults that moved from one breeding site to another crossed between the two areas. There is apparently very little effective dispersal (gene flow) between birds in the two areas and they currently appear to constitute isolated groups.

Information from some parts of the species range is sparse but it appears likely that birds in the Far North and the Auckland west coast are part of the Northland-Auckland group, and that birds on Great Barrier Island and in the Gisborne area are part of the Coromandel-Bay of Plenty group. The status of birds on the Waikato west coast is unknown.

Managed sites should be maintained in the two areas; the distribution and number of managed sites within each area should take account of natal dispersal distances. Important areas currently without managed sites that may require them to maintain the range of the species include the Far North and northern and southern sections of the west coast.

1. Background

The northern New Zealand dotterel *(Charadrius obscurus aquilonius)* is a large endemic plover found around the coastline of the northern and central North Island (Dowding 1994). The population numbered about 1500 in 1996 (Dowding & Murphy 2001) and was classified as endangered by Collar et al. (1994); the subspecies was ranked category B byTisdall (1994). Information on the species was summarised by Marchant & Higgins (1993).

The northern New Zealand dotterel (NZD) is thinly and widely spread along the coast of the North Island. Because little detailed information has been published on movement patterns of juveniles, it is not clear to what extent birds in different parts of the population are linked by dispersal. A study by McKenzie (1978) and Reed (1981) revealed that juveniles dispersed after fledg-

ing and some travelled considerable distances. Reed (1981) also stated that juvenile mortality was high. Many adults banded during the study were sedentary, some moved locally, and a few moved longer distances. However, partly because the colour bands used deteriorated quickly, and partly because coverage (especially outside the Auckland area) was limited, results of this study were limited (McKenzie 1978). In particular, little information was obtained on levels of natal-site fidelity and the extent to which dispersal resulted in gene flow between different areas. Dowding & Chamberlin (1991) found that most adults lived in groups on a defined stretch of coastline and moved within a restricted area, usually between their breeding, flocking and feeding sites. Juveniles moved more widely. It was also suggested that when an adult did move outside its usual area, it was normally because of mate loss. Dowding & Chamberlin (1991) concluded that gene flow in the species was brought about largely by natal dispersal of juveniles.

Management of the northern NZD to date has concentrated on raising productivity at key breeding sites by fencing off nesting areas, reducing disturbance and controlling predators (Dowding 1993). This approach has been largely successful, with productivity at managed sites typically ranging from 0.4 to 1.0 chicks fledged per pair (Dowding, unpublished); at unmanaged sites over three seasons productivity ranged from 0.07 to 0.34 and averaged 0.23 chicks fledged per pair (Dowding 1998). It now becomes important to determine how widely these juveniles disperse and where they are recruited in relation to their natal site. Such information will be useful in deciding the number and location of sites that should be managed in future.

This report provides unprogrammed scientific advice to the Department of Conservation on dispersal patterns of northern New Zealand dotterels (NZD) and outlines how this information might influence conservation management of the taxon. The request for this advice specified that the report should cover the following items:

1. Collate records of northern NZ dotterel banding and band recovery/resightings.

2. Analyse all the relevant data available to determine patterns of juvenile/sub-adult dispersal, and present results in map and other appropriate forms. Analysis should include relationships of dispersing birds to their source site - location, size (number of breeding pairs) and habitat character and management history - and give emphasis to birds settling/breeding relative to those that may be passing through.

3. Determine whether there are adult movements: (a) not conforming to the pattern described by Dowding & Chamberlin (1991), i.e. only localised movements within tight clusters, or (b) tending to modify the implications of dispersal patterns of juvenile/sub-adult birds identified under item 4; and if so document them.

4. Examine and present evidence bearing on the question of to what extent the (northern) NZ dotterel is functioning as a metapopulation, i.e. substantially separate sub-populations within which there are frequent movements and between which there are few or no movements.

5. Discuss the possible management implications of the dispersal/movement patterns and relationships identified, and make recommendations for appropriate management accordingly.

2. Definitions and methods

This report is based on a colour-banding study undertaken mainly on the east coast of the North Island since 1986 (Dowding & Chamberlin 1991). The study was a recommended research task (8.2.2) in the recovery plan for the species (Dowding 1993). Because NZD normally first breed at two years old (McKenzie 1978, Marchant & Higgins 1993), this report considers data from birds banded as chicks up to and including the 1997/98 season; the majority of birds banded later would not be breeding by the 1999/2000 season.

Colour-banded birds were located primarily by members of the Ornithological Society (OSNZ) and Department of Conservation (DOC) staff during OSNZ winter and summer wader counts, shorebird post-breeding flock counts and the two complete NZD surveys in October 1989 and October 1996, and by shorebird wardens and the author during management and research operations. Occasionally, members of the public reported banded birds from locations not usually covered by these observers; while such sightings were often recorded incorrectly or incompletely, in most cases they were checked by a more experienced observer before inclusion in the database.

During the period covered by this report, most activity (banding and resightings) occurred on the east coast of Northland and North Auckland (mainly south of the Bay of Islands), on west and east coasts around the greater Auckland area, on the Coromandel Peninsula, and in the western Bay of Plenty. These observations were supplemented by occasional dedicated searches for banded birds breeding in these and other areas, including the Far North, Great Barrier Island, and central and eastern Bay of Plenty. Important locations mentioned in the text are shown in Figure 1; additional locations are shown on the maps in Appendix 1.

Definitions of dispersal used are those of Greenwood & Harvey (1982). *Natal dispersal* refers to movement from the natal site to the site of first reproduction; subsequent movements of birds between breeding sites are termed *breeding dispersal. Effective dispersal* occurs when successful breeding follows either natal or breeding dispersal. In this report, natal dispersal distances are straight-line distances between natal and first breeding sites, measured to the nearest kilometre on NZMS 260 (1:50 000) or 262 series (1:250 000) topographical maps. Breeding dispersal distances are straight-line distances between one breeding site and the next, measured in the same way. Means are quoted + SE; however, as noted by Greenwood & Harvey (1982), distributions of dispersal are usually highly skewed towards the point of origin, and median values are therefore also quoted.

Pre-breeding movements are particularly difficult to document in a species such as this, where juveniles are highly mobile. However, where a bird banded

as a chick was recorded 10 times or more between fledging and first breeding (normally a period of about 20 months), I added the straight-line distances between sightings in chronological order to give a *minimum distance travelled.*

3. Results and discussion

3.1 COLLATE BANDING AND RECOVERY RECORDS

Between the 1986/87 and 1997/98 seasons, 257 northern NZD chicks (most 4 weeks or older) were fitted with individual colour combinations. Of these, 159 are known to have fledged. Between the 1994/95 and 1997/98 seasons, a further 131 chicks were cohort banded at managed sites (all chicks at one site were given the same combination in any one season); the number definitely fledged in the latter group is unknown but, assuming the same fledging: banding ratio as for individually banded birds, was probably at least 80. Many birds banded as chicks were later recruited into the breeding population and some subsequently yielded data on breeding dispersal. Further data on breeding dispersal were provided by some of the c. 300 birds banded as adults between 1986 and 1998.

In total, about 11 600 records of colour-banded birds (adults and juveniles) were collected between 1986 and 1999 and stored in annual sightings databases. From these, a further database was constructed, listing all birds banded as chicks with their natal site, first breeding site, other locations seen and natal dispersal distance.

3.2 DETERMINE PATTERNS OF JUVENILE DISPERSAL

Natal philopatry and natal dispersal distances

Breeding sites were found for 93 of the 159 individually-marked birds known to have fledged and for a further 27 of the 131 birds given cohort combinations. These 120 natal dispersal distances averaged 31.3 ± 3.06 km (range 0-196 km) and median distance was 22 km. The distribution of natal dispersal distances is shown in Figure 2.

It is clear from Figure 2 that the vast majority of birds (92.5%) bred within 70 km of their natal site. However, four (3.3%) of the 120 birds had natal dispersal distances of more than 100 km and two of them bred nearly 200 km from their natal site. Natal sites of the four birds undertaking long-distance dispersal were widely spread (Table 1).

Twenty-one (17.5%) of the 120 birds bred at their natal site. However, there is some evidence to suggest that natal-site fidelity differs considerably between sites. Few sites provide large samples, but the three natal sites with the largest numbers of birds having known breeding sites are shown in Table 2.

The reasons for these differences are not clear, but it seems likely that availability of suitable habitat to establish a breeding territory is an important factor. At Mangawhai, where natal-site fidelity was highest, there appears to be much suitable habitat available; at Opoutere and Wade River, territories on a sandspit and a small sand-bar respectively are crowded and very little space is available.

Managed v. unmanaged sites

Natal dispersal distances did not differ between managed sites (n = 84 birds) and unmanaged sites (n = 36 birds); mean for managed sites was 31.1 ± 3.68 km (median 22 km) and for unmanaged sites 31.9 ± 5.56 km (median 24 km) (Mann-Whitney, P = 0.56).

Site size (number of pairs)

In analysing the effect of site size on natal dispersal, sites were categorised as *small* (1-3 pairs), *medium* (4-10 pairs) or *large* (more than 10 pairs). Table 3 shows mean and median natal-dispersal distances of birds raised at small, medium and large sites.

Dispersal distances from small and medium sites did not differ significantly (Mann-Whitney, P = 0.220) but distances from large sites were significantly less than from small and medium sites (Mann-Whitney, P = 0.004 and P = 0.020 respectively). This result should probably be treated with caution. First, it should be noted that number of pairs does not necessarily reflect density of pairs at a site, and it seems likely that natal-site fidelity would be limited by high density rather than high absolute number of pairs. Second, few sites are represented in the `large' category; one of them (Mangawhai) had a high degree of natal-site fidelity (mean and median dispersal distances 11.1 km and 8 km respectively) and, with no fewer than 20 of the 36 records in this category, may have distorted the result. Excluding Mangawhai, dispersal distances from large sites were not significantly different from those from small or medium sites (Mann-Whitney, P = 0.305 and P = 0.962 respectively).

Direction of natal dispersal

Most chicks banded in this study were on the east coast of the North Island. Eighty-nine (74.2%) bred either north or south of their natal site on the same coast, 21 (17.5%) bred at their natal site, and 8 (6.7%) crossed to the west coast. Two birds (1.7%) banded at Opoutere bred inland on the Waihi Mine tailings dam, about 6 km from the nearest coast. Birds were no more likely to breed to the north (n = 47) or south (n = 42) of their natal site (X^2 [cont. corr.] = 0.05, df = 1, P = 0.820).

Sightings suggest that most northern NZD follow the coastline for much of the time, but they clearly also fly overland. A number of birds (both adult and juvenile) have been recorded moving between the North Auckland east coast and Kaipara Harbour. Others cross the Auckland isthmus regularly.

Are there two separated groups of birds?

As noted above, the majority of birds in this study were banded as chicks in the Northland-Auckland (NA) area (mostly on the east coast between Whangarei and Auckland) and in the Coromandel-Bay of Plenty (CB) area (nearly all at Opoutere and on Matakana Island). During a preliminary analysis earlier in the study, it was noted that no birds banded in one of these two areas had been found breeding in the other. This apparent division in the population is examined here in more detail and with larger samples.

Of the 120 chicks banded whose breeding sites are known, 77 were banded in the NA area and 43 in the CB area. No birds banded in one area have been found breeding in the other, suggesting that little or no effective dispersal occurs between the areas. It therefore becomes important to examine the apparent boundary zone and consider movements of birds banded there and nearby, particularly in relation to typical natal dispersal distances.

The boundary zone consists of the coastline of the Firth of Thames, from Raukura Pt in the north-west around to Deadmans Pt, south of Coromandel Harbour. The Firth is about 20 km across; measured along the shoreline, the boundary zone is about 100 km. This coastline contains little suitable nesting habitat for NZD, consisting largely of rocky coast or mangrove-fringed mudflats; there are none of the sandy beaches with dunes favoured in other parts of the species range. There are few birds nesting in the area, with 3-4 pairs spread along the shellbanks between Kaiaua and Miranda, 1-2 pairs on a shellbank near Thames airfield, and 1 pair each at Tapu and Waikawau on the east coast of the Firth.

There are thus few pairs in the boundary zone and there are no protected (managed) sites in the area. As a result, very few chicks fledge in the area of interest and the small number that have been colour-banded appear not to have survived. Even if juveniles produced in the Firth of Thames disperse to the north-west and to the east (i.e. into both NA and CB areas) as seems likely, they appear to be so few in number that they would result in very little gene flow between the areas.

The nearest site close to the apparent boundary having a reasonable sample size is Opoutere, about 40 km from the mid-line of the Firth of Thames. Of the 35 birds with known breeding sites banded as chicks at Opoutere and Ohui, 16 (46%) bred more than 40 km from their natal site but none of these was in the NA area.

Breeding sites of birds banded as chicks at Mangawhai, Wade River and Opoutere are shown in map form in Appendix 1. These sites had the largest number of natal dispersal records (Table 2); in addition, Wade River and Opoutere were on either side of the boundary zone and relatively close to it.

Pre-breeding movements

It is obvious from the sightings databases that many birds travelled a greater actual distance between natal and breeding sites than their straight-line natal dispersal distances indicate. Minimum distance travelled was therefore cal-

culated for the 35 juvenile birds that were recorded on 10 or more occasions after fledging and before breeding (Table 4).

There is a wide range of values (0-362 km); in addition, another juvenile in the CB area that has not yet been found breeding is known to have travelled a minimum of 510 km in its first 2 years. Although four of the birds in Table 4 were never recorded away from their natal sites, these data show that most juveniles have travelled a much greater distance than is indicated by their natal dispersal distance. Minimum distance travelled averaged 102 km (median 96 km), about six times further than the natal dispersal distance in this sample (average 18.1 km, median 16 km). It is highly likely that many movements were undetected and the minimum distance travelled is undoubtedly an underestimate. It might be expected that the observed distance travelled would simply be a function of the number of sightings, but there was no significant correlation between them ($r = 0.177$, Fisher's r to z $P = 0.31$).

There was also no correlation between natal dispersal distance and minimum distance travelled for this sample ($r = 0.175$, Fisher's r to z $P = 0.32$), suggesting that the birds wandering the greatest distance are not necessarily those that breed furthest from their natal site. This can be explained to some extent by the different pre-breeding movement patterns observed; some birds appear to move a long way in a single direction (with little or no doubling back), while others cover a large distance by moving regularly back and forth over a limited stretch of coastline before breeding at or near their natal site.

These data show that most juveniles can and do travel much further than natal dispersal distances indicate. Many appear quite capable of travelling from one area to the other, but few have been recorded doing so. During the 12 years of the study, only nine of at least 240 colour-banded juveniles with a natal site in one area have been seen in the other; details are shown in Table 5.

None of the nine birds was found breeding outside their natal area. Two of the nine were carrying cohort combinations; they were therefore not individually identifiable but no birds with those combinations were found breeding in those areas and they presumably either died or returned to their natal area. Three other birds were not seen again in either area and are assumed to have died. Of the four that were seen again, two had returned to their natal area and were breeding there, and two had returned to their natal area but had not yet been found breeding.

Together, the natal dispersal and pre-breeding movement data show that juvenile NZD bring about very little effective dispersal between the NA and CB areas.

1. Very few or no juveniles born in one area breed in the other; none was detected during this study, although natal and breeding sites were known for 120 birds. Even in the four cases where natal dispersal distance was greater than 100 km (Table 1), birds remained in their natal area.

2. Few juveniles undertook pre-breeding movements between one area and the other; in the 12 years of this study, 9 (3.8%) of about 240 banded chicks that fledged were seen outside their natal area. None of these is

known to have remained outside their natal area. Four individually-marked birds have been seen after being recorded outside their natal area and all had returned to their natal area.

Are there differences in dispersal parameters between the two areas?

Natal philopatry

There was no difference in degree of natal philopatry between the two areas. The proportion of birds breeding at their natal site (14/77 in the NA area, 7/43 in the CB area) was not significantly different (Fisher's Exact, P = 0.99).

Natal dispersal distances

Mean and median natal dispersal distances were compared between the NA area (n = 77) and the CB area (n = 43). Natal dispersal distance was significantly higher in the CB area (mean 43.9 ± 5.65 km, median 41 km) than in the NA area (mean 24.3 ± 3.34 km, median 16 km) (Mann-Whitney, P = 0.0005). There could be many reasons for this difference, but the most obvious is that it simply reflects the distribution of available breeding sites in relation to natal sites. No fewer than 35 of the 43 records from the CB area are of birds from Opoutere; there are no large breeding sites (and few small ones) close to Opoutere either to the north or south, and this may result in more birds breeding further afield. By contrast, 38 of the 77 birds in the NA area were banded between Whangarei and Tawharanui, a stretch of coastline with many medium-sized and large breeding sites.

Direction of natal dispersal

Directions of natal dispersal were also compared between the NA and CB areas (Table 6); the proportion of birds breeding in different directions from their natal sites did not differ significantly between the two areas ($\chi^2 = 2.07$, df = 3, P = 0.56).

3.3 ADULT MOVEMENTS

While juveniles appear to move very little between the two areas, significant mixing and gene flow could still occur if adults move across the boundary regularly. Dowding & Chamberlin (1991) noted that the majority of adults were sedentary; regular monitoring of more than 150 banded birds over the past ten years has confirmed that most adults move only between breeding, flocking and feeding sites within a restricted area (typically a 10-30 km stretch of coastline). Dowding & Chamberlin (1991) did detect a few longer-distance adult movements however, and suggested that these may have been a consequence of mate loss.

Including the three cases noted by Dowding & Chamberlin (1991), there are now 25 confirmed examples of breeding dispersal by colour-banded birds or pairs (Table 7). Mean breeding dispersal distance was 10.9 ± 2.35 km (median 7 km). In none of the 25 cases did a bird or pair move from one area to the other. However, there are few birds in the boundary area (and even fewer colour-banded), and breeding dispersal has not yet been recorded very close

to the boundary. It is therefore possible that breeding dispersal in the boundary zone could result in some gene flow between the two areas. Two factors suggest that such gene flow is very limited. First, there are very few birds in the area (see above). Second, the extent of mixing will be affected by breeding dispersal distance; from the data in Table 7, it is clear that mean and median breeding dispersal distances are small (and significantly less than natal dispersal distances; Mann-Whitney, P = 0.001); 19 (76%) of the 25 movements are within 10 km and 24 (96%) are within 30 km.

Data from banded birds within the Firth of Thames are limited. One bird banded as a chick at Opoutere bred at Tapu, north of Thames on the eastern side of the Firth. For at least three years this bird visited a post-breeding flock at Rangipo (on the western side of the Firth) each season, but always returned to Tapu to breed. In recent years, this bird has remained on the eastern side of the Firth, joining a post-breeding flock near Coromandel airfield. An adult banded at Miranda in 1997 (and breeding there) has been seen only there and at the nearby post-breeding flock site at Rangipo (about 5 km away). Two birds cohort-banded as chicks in 1996 (one at Opoutere, one at Matakana Island) bred at different times on a shellbank near Thames airfield in the south-eastern corner of the Firth; neither has been seen on the western side of the Firth.

To date, there appears to be only one case of a banded adult northern NZD moving a large distance: R-MB bred at Whatipu (Auckland west coast) with an unbanded bird from 1986-1989. It then disappeared and was seen in November 1990 at Ohau Estuary, about 400 km to the south and outside the normal breeding range of the species. It subsequently returned to Whatipu and still breeds there.

In summary, three lines of evidence suggest that breeding dispersal by adult birds is responsible for little or no gene flow between the two areas.

1. In none of the 25 known cases of breeding dispersal has a bird (or pair) moved from the NA area to the CB area or vice-versa.

2. Mean and median breeding dispersal distances are one-third those of natal dispersal distances, suggesting that adults are less likely than juveniles to cross the boundary zone.

3. Data from the few banded birds in the boundary zone has not yet shown any cases of breeding dispersal across the Firth.

It therefore seems likely that adult movements do not alter the implications of juvenile dispersal described in Section 3.2.

3.4 STRUCTURE OF THE NORTHERN NEW ZEALAND DOTTEREL POPULATION

The evidence presented in Sections 3.2 and 3.3 suggests that during the past decade neither natal nor breeding dispersal has resulted in significant effec-

tive dispersal (gene flow) between NZD on the Northland-Auckland east coast and the Coromandel-Bay of Plenty coast. The boundary zone between the two areas has little suitable breeding habitat and a small number of breeding pairs; there is so far no evidence that these birds effect significant gene flow across the boundary. Although some movement between the two areas may occur, banding data suggest that it is currently very limited and I conclude that the groups of birds in these two areas are currently isolated to a large extent.

Why is the population apparently divided in this way?

There is no reason to believe that there are significant genetic or ecological differences between birds in the NA and CB areas. Reasons for the lack of effective dispersal between them must be largely speculative, but one possibility is that the separation results from the existence of a stretch of coastline with little breeding habitat and few breeding pairs, which tends to isolate birds in the two areas. Such a habitat effect might be increased by behavioural traits. There may for example be some fidelity to the wider natal area (if not specifically to natal site); consistent with this is (a) the finding that many juveniles travel large distances but settle to breed a relatively short distance from their natal site, and (b) the observation that four juveniles seen outside their natal area returned to it. Whatever the reasons for the division, there appears to be little effective dispersal between the two areas.

Other parts of the population

Some parts of the northern NZD population have received little attention so far in this study, but sightings from a few birds provide some information.

Far North

Effective dispersal is known to occur on the east coast between the greater Auckland area and the Bay of Islands (BoI). Further work is required to determine whether birds north of the Bol are separated, but the species is distributed more-or-less continuously along this coast and it would be surprising if birds in the Far North were isolated from the NA group. Two juveniles, one from Waipu and the other from Mangawhai, were seen at Taupo Bay on different occasions, before both returned to Waipu to breed. The only known example of natal dispersal in this area is of a bird banded on Motukawanui (Cavalli Islands) and found breeding 55 km away at Karikari Bay; however, five years elapsed between banding and this sighting and it is possible that Karikari was not the bird's first breeding site.

Great Barrier Island

The NZD on Great Barrier Island (GBI) appear to be part of the Coromandel-Bay of Plenty group. One bird banded as a chick at Opoutere in 1992 bred at Kaitoke, GBI in 1994 and a one-year-old bird banded at Harataonga, GBI in November 1991 was seen at Colville, Coromandel in April 1993, and at Medlands, GBI in September 1995. This link to the Coromandel population is not surprising, given that the sea crossing from GBI to the peninsula is considerably shorter than that to the North Auckland mainland.

West coast

Birds breeding around the Kaipara Harbour and south to the Manukau Heads are clearly linked to the east coast population; five birds banded as chicks at three east coast sites have been found breeding in this area. Two east coast adults wandering after the loss of mates, as well as a number of east coast juveniles not yet known to be breeding, have been seen in Kaipara Harbour or at South Kaipara Head. Juveniles also move regularly across the Auckland isthmus between Waitemata and Manukau Harbours and natal dispersal between them has been recorded.

North of Kaipara Heads to Ahipara there is virtually no information; no birds have been banded, no banded birds have been reported, and surveys are very infrequent. Further north, the Aupouri Peninsula is relatively narrow, particularly at its southern end; based on overland movements north of Auckland and on the Coromandel Peninsula, it seems highly likely that there is movement of birds between west and east coasts in this area.

Little is known of movement patterns on the west coast south of the Manukau Harbour. Banded birds have been recorded moving between the southern Manukau Harbour and Port Waikato, both in this study and by Reed (1981), linking this area with the NA group. A bird banded as a chick at Opoutere was also seen at Port Waikato as a one-year-old, but was not seen again. Virtually nothing is known of movements south of the Waikato River; again, no birds have been banded there, no banded birds from other sites have been reported and surveys are infrequent. Whether this area is also linked to the NA group is not yet known.

Gisborne area

NZD have now been recorded breeding in this area for the past nine years and chicks have been banded since the 1994/95 season. As yet, there are no natal dispersal records of birds banded as chicks in the area, but this local population is clearly still linked to the CB area. At least three chicks banded near Gisborne have been seen at Ohiwa Harbour and at other sites in the eastern Bay of Plenty; more recently a breeding adult banded at Wherowhero was seen among the post-breeding flock at Ohiwa and later returned to Wherowhero. However, there are large stretches of unsuitable habitat with no NZD to the west and south of East Cape; as numbers build up in the Gisborne area, it will be interesting to see whether birds disperse less widely and the population becomes more isolated.

3.5 MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

As noted above, the apparent existence of two isolated groups of birds may be largely a function of the stretch of unsuitable habitat between them. What-

ever the reason for the division, the very low level of dispersal between the areas suggests that each is unable to provide the other with significant numbers of juveniles. It therefore seems obvious that managed sites are required in both areas to increase overall productivity in the two groups. This is the current position, with Waipu, Mangawhai, South Kaipara Head and a number of smaller sites managed in the NA area, and Opoutere, Matakana Island and some smaller sites managed in the CB area.

Within each area, information on natal dispersal distances from this study can now be used to refine the number and distribution of managed sites.

Selection of breeding sites for protection

Management of NZD consists largely of increasing productivity at key breeding sites. This results in local increases in the number of juveniles (although there is usually a lag of 1-3 years before productivity rises significantly). While other factors are clearly important (particularly the number of pairs at a site and the feasibility of predator control), future selection of sites should also take account of their distribution. This study has shown that most chicks produced at each site will breed within 50 km on either side of that site on the Northland-Auckland east coast and within 70 km of that site on the Coromandel-Bay of Plenty coast. Each managed site therefore has an rough `sphere of influence' of about 100-150 km of coastline (measured in a straight line). However, there is clearly some variation; chicks from Mangawhai, for example, have been found breeding on the east coast between Ruakaka to the north and Omaha to the south, a sphere of influence of only about 55 km in total. However, it needs to be remembered that some chicks do fledge from unmanaged sites and it is therefore probably unnecessary to have managed sites with spheres of influence that cover the entire coastline.

Another point that needs to be considered is whether spheres of influence may or may not effectively increase in size with time. Juveniles spreading out from currently managed sites will populate the surrounding coastline, but the extent to which these will provide second or subsequent `waves' of dispersal further along the coast is difficult to predict. However, most birds that breed away from their natal site will settle at unmanaged sites, so their productivity will be lower on average; in the absence of predator control and other management it seems likely that their survival as adults at those sites will also be lower. It cannot therefore be assumed that current spheres of influence will automatically grow in size.

On the east coast of Northland-Auckland, the large sites currently managed at Waipu and Mangawhai, in conjunction with a few smaller sites, appear to cover the area between about Whananaki and Auckland. Between them, Opoutere and Matakana Island cover the Coromandel Peninsula and the western and central Bay of Plenty. Little is known of dispersal patterns on the west coast, but if they are similar, the managed site at South Kaipara Head would have an area of influence from about Maunganui Bluff south to Auckland.

Based on the current distribution of managed sites, there are some obvious gaps.

1. The Far North east coast (from Cape Reinga to Bay of Islands) had a total of about 380 birds in the 1996 census (25% of the total population), but management is not established at any large breeding sites. The northernmost managed sites of any size are at Waipu and Mangawhai, and results to date suggest that these sites have little or no input to the Far North. Given the length of coastline and the high proportion of the total population in the area, effective management at a minimum of one large or two medium-sized sites appears to be a priority.

2. Northland west coast. As noted above, virtually nothing is know of movement patterns on the west coast from Kaipara Harbour to Cape Reinga. There has been little or no management or research in this area, but census results showed a decline of 13.4% (179 to 155 birds) between 1989 and 1996. The managed site at South Kaipara Head has the potential to boost numbers in the southern part of this zone (perhaps north to about Maunganui Bluff), but the area north from the bluff to Cape Reinga holds about 7% of the total population and has no managed sites.

3. Waikato west coast. Again, little is known of movement patterns, there has been little or no management or research, and birds are now few and widely spread. Census results showed a major decline of 49% (from 55 to 28 birds) in this area between 1989 and 1996. There are no managed sites and there is currently no evidence of links to other areas. If the Department wishes to preserve the current breeding range of the species, the establishment of one or more managed sites in this area is of the highest priority. Given the apparently rapid decline between 1989 and 1996, urgent action appears to be required. A first step would be to survey the area thoroughly to determine (a) whether the decline has continued since 1996 and (b) which sites would be the most suitable for management.

4. Eastern Bay of Plenty. Results of the 1996 census suggested a decline in this area since 1989, in contrast to most other parts of the east coast. The nearest large managed site is Matakana Island, which has an area of influence stretching approximately to Matata (although one bird from Matakana has bred at Waiaua Spit). In the Opotiki area about 11 pairs at three sites receive partial protection (for the distinction between full and partial protection see Dowding 1993, section 7.4.1.1). Full protection at a site such as Ohope-Ohiwa, and/or an upgrading of management around Opotiki would boost overall productivity in this area. However, because numbers of birds are not yet low and some management is currently occurring, this area should have lower priority than 1, 2 or 3 above.

5. Gisborne area. This area was not surveyed during the 1989 census, but there were probably no more than about 6-8 birds present at that time. The count of 24 in 1996 shows an increase in the area, which could probably be accelerated if one or two sites were managed; assisting colonisation in this area is task 8.1.3 in the recovery plan (Dowding 1993). Given that numbers are increasing without full protection, additional management in this area is also a lower priority than 1, 2, or 3 above.

Results from the 1996 census showed that there has been a marked decline in NZD numbers on the west coast and an increase on the east coast. There are many possible reasons for this change in distribution. One is that long-term weather patterns (such as the recent preponderance of El Nino conditions) have reduced breeding habitat or otherwise made breeding conditions less favourable on the west coast. In the short-medium term this hypothesis is very difficult to test and if the current decline on the west coast continues, extirpation may occur in some areas (particularly Waikato west coast) before the cause of the decline is established. A second possibility exists that the current distribution of managed sites is effectively changing the distribution of the population. Birds are declining on the west coast and increasing on the east coast; it is worth noting that virtually all managed sites are on the east coast, with only one large managed site (South Kaipara Head, which presumably has a limited sphere of influence) on the west coast. If this is the case, the present breeding range of the species may only be maintained by strategically located managed sites, some of them on the west coast. This hypothesis has the advantage that it can be tested more readily in the medium term by establishing managed sites on the west coast and subsequently monitoring population size in those areas.

Management of northern NZD to date has mainly been concentrated at larger breeding sites. This is partly for economic reasons (it is obviously more cost-effective to manage more pairs at fewer sites), and is partly unplanned; management at no fewer than three of the five large managed sites (Waipu, Mangawhai and South Kaipara Head) occurs primarily to protect New Zealand fairy terns but NZD benefit. In future, distribution of sites should also be considered; however, in some areas where management is required there may be no large sites at suitable locations. In these circumstances it may be necessary to manage two or more medium-sized sites instead of one large one. This approach will certainly be required if further management is undertaken on the west coast.

Recommendations

1. Managed NZD breeding sites should be maintained within each of the two isolated groups of birds identified to date (Northland-Auckland and Coromandel-Bay of Plenty areas) and in any other isolated groups identified subsequently.

   Justification: It is clear from the banding data that there is little or no gene flow between the two areas and each is therefore currently unable to provide useful numbers of juveniles (or adults) to the other. At the present time, management in one area does not benefit the other.

2. Within the NA and CB areas, natal dispersal distances (i.e. the area settled by juveniles from each managed site) should be taken into account in deciding the number and distribution of managed sites.

   Justification: Results of this study show that within both areas each managed site has a limited sphere of influence, typically about 25-70 km on each side of the site. The current distribution of managed sites was established before patterns of NZD dispersal were known, and there

are long stretches of coastline which are now known to receive little or no benefit from existing managed sites.

3. Managed sites should be established in the following three areas:
(a) the Far North east coast (Cape Reinga to Bay of Islands)
(b) the west coast of Northland (Maunganui Bluff to Cape Reinga)
(c) the Waikato west coast (south of Waikato River mouth)

Justification: None of the three areas currently has managed sites, there is no evidence to date that any of them receive significant immigration from managed sites, and two of the three have declining populations. It may be possible to halt or reverse these declines by effective management.

Priorities: Given the small population (possibly less than 30 birds) and rapid decline in the area, establishment of managed sites on Waikato west coast should have the highest priority and greatest urgency. Extirpation in this area would result in a significant contraction in the range of the species. The number of birds on Northland west coast is declining (but more slowly than on Waikato west coast) and there are no managed sites. This area should have second priority. At present there is no detectable decline on the Far North east coast, but the area holds a high proportion (25%) of the total population and there are no managed sites. In the short term, this area should have third priority for the establishment of managed sites but if future surveys indicate a decline, this priority should be reviewed.

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Table 1. Natal and breeding sites of birds dispersing more than 100 km.

Bird	Natal site	Breeding site	Distance (km)
YB-MR	Opoutere	Whangaparaoa, Cape Runaway	196
MW-RY	Urupukapuka I	Whakanewha, Waiheke I	195
GM-BO	LangsBeach	Otaha/Elliot'sBeach	115
BM-OG	Matakana I	Waiaua Spit	107

Table 2. Differences in degree of natal philopatry of northern New Zealand dotterels raised at three sites.

Natal site	Number found breeding at natal site (%)	Number found breeding elsewhere
Mangawhai	10 (50.0%)	10
Opoutere	6 (18.2%)	27
Wade River	1 (7.7%)	12

Table 3. Natal dispersal distances of New Zealand dotterels raised at small, medium and large sites.

Site size	Number of chicks raised	Natal-dispersal distance (km) Mean	Median
Small	19	46.5	26
Medium	65	32.4	29
Large	36	21.4	15

Table 4. Minimum distances travelled by 35 juvenile northern New Zealand dotterels.

Bird	Natal site	Natal dispersal distance (km)	Minimum distance travelled (km)	Number of sightings
Northland-Auckland				
YM-WR	Mimiwhangata	51	109	13
GM-B W	Ruakaka	13	96	13
GM-RW	Ruakaka	30	117	12
GR-RM	Waipu	0	0	17
GM-BG	Waipu	22	183	14
WY-GM	Waipu	14	132	20
YR-MR	Waipu	0	242	11
GM-BY	Waipu	62	121	11
GM-WY	Mangawhai	16	66	12
GM-OB	Mangawhai	0	0	11
RB-WM	Mangawhai	2	148	14
GM-OR	Mangawhai	0	0	13
OM-BW	Mangawhai	0	0	10
RG-RM	Mangawhai	16	356	11
MR-YB	Pakiri River	16	28	18
YB-YM	Pakiri River	35	142	16
MR-YR	Omaha	16	67	18
MR-WR	Omaha	0	0	28
GY-RM	Omaha	10	23	23
WO-GM	Omaha	22	22	26
YO-WM	Tawharanui	8	68	25
BW-MW	Tawharanui	23	160	10
MR-WG	Beehive Island	16	135	25
OR-RM	Wade River	12	131	16
RO-GM	Wade River	37	166	22
MR-WY	Wade River	58	123	22
Coromandel-Bay of Plenty				
WY-BM	Opoutere	41	61	21
WM-BW	Opoutere	26	96	11
WM-RO	Opoutere	0	8	19
GR-MW	Opoutere	0	18	18
WM-RR	Opoutere	46	74	13
GY-MW	Opoutere	0	29	27
WM-WR	Opoutere	8	112	13
WM-OY	Opoutere	0	362	24
YG-WM	Opoutere	32	175	12

Table 5. Juveniles New Zealand dotterels raised in one area and recorded in the other.

Bird	Natal site (area)	Recorded at (area)	Subsequent records
YM-RW	Whale I (CB)	Howick (NA) & Omaha (NA)	Not seen again
WM-OG	Opoutere (CB)	Mangawhai (NA) & Mimiwhangata (NA)	Returned to Opoutere (CB)
WM-OR	Opoutere (CB)	Port Waikato (NA)	Not seen again
RM-RB	Waiaua Spit (CB)	Waitemata Hbr (NA)	Ohiwa Spit (CB)
WB-RM	Tawharanui (NA)	Colville (CB)	Not seen again
WG-MR	Mangawhai (NA)	Colville (CB)	Unknown (cohort combination)
YG-WM	Opoutere (CB)	Mataitai (NA)	Bred at Waihi Mine (CB)
BM-RY	Matakana I (CB)	Mataitai (NA)	Unknown (cohort combination)
WM-OY	Opoutere (CB)	Mangawhai (NA) & Pakiri River (NA)	Bred at Opoutere (CB)

Table 6. Comparison of natal dispersal directions in the NA and CB areas.

Direction of natal dispersal	NA area (%)		CB area. (%)	
Bred north of natal site on east coast	33	(42.9)	14	(32.6)
Bred south of natal site on east coast	25	(32.5)	17	(39.5)
Crossed to west coast/moved inland and bred	5	(6.5)	5	(11.6)
Bred at natal site	14	(18.2)	7	(16.3)
Totals	77		43	

Table 7. Breeding dispersal of adult northern New Zealand dotterels.

Bird or pair	Breeding dispersal	Distance (km)
Northland Auckland		
M-YWY & M-WRW	Horseshoe Island to Omaha	1
B-MB	Pakiri River to Omaha	10
R-MB	Mairetahi to Whatipu	53
M-WRB	Tawharanui to Omaha	6
M-RWR	Omaha to Pakiri River	10
OR-RM	Waiwera to Te Muri	3
M-RWY	Omaha to Mangawhai	30
M-RGR	Omaha to Mangawhai	30
OM-WO	Wade River to Dacre Beach	1
M-ORY & M-WOR	Wade River to Gulf Harbour	7
M-WYG & M-YBR	Tawharanui to Beehive Island	10
GY-YM	Te Arai Stream to Pakiri River	13
YM-OW	Lagoon Bay to Motuora Island	5
OM-WO & RM-OB	Dacre Beach to Albany	9
M-YRW & M-OBY	Omaha to Horseshoe Island	1
M-BYW	Omaha to Te Arai Stream	22
M-WBY	Tawharanui to Omaha	7
M-WRO	Omaha to Tawharanui	6
WY-MB & RM-OW	Shoal Bay to Pollen Island	10
M-YWR	Poutawa Stream to Pakiri River	6
M-GWY	Poutawa Stream to Pakiri River	6
M-WBO & OG-YM	Omaha to Horseshoe Island	1
Coromandel-Bay of Plenty		
BM-BO	Grays Beach to Wharekaho	8
WM-OY	Opoutere to Ohui	4
BO-RM	Waihi Mine to Waikoura Point	14

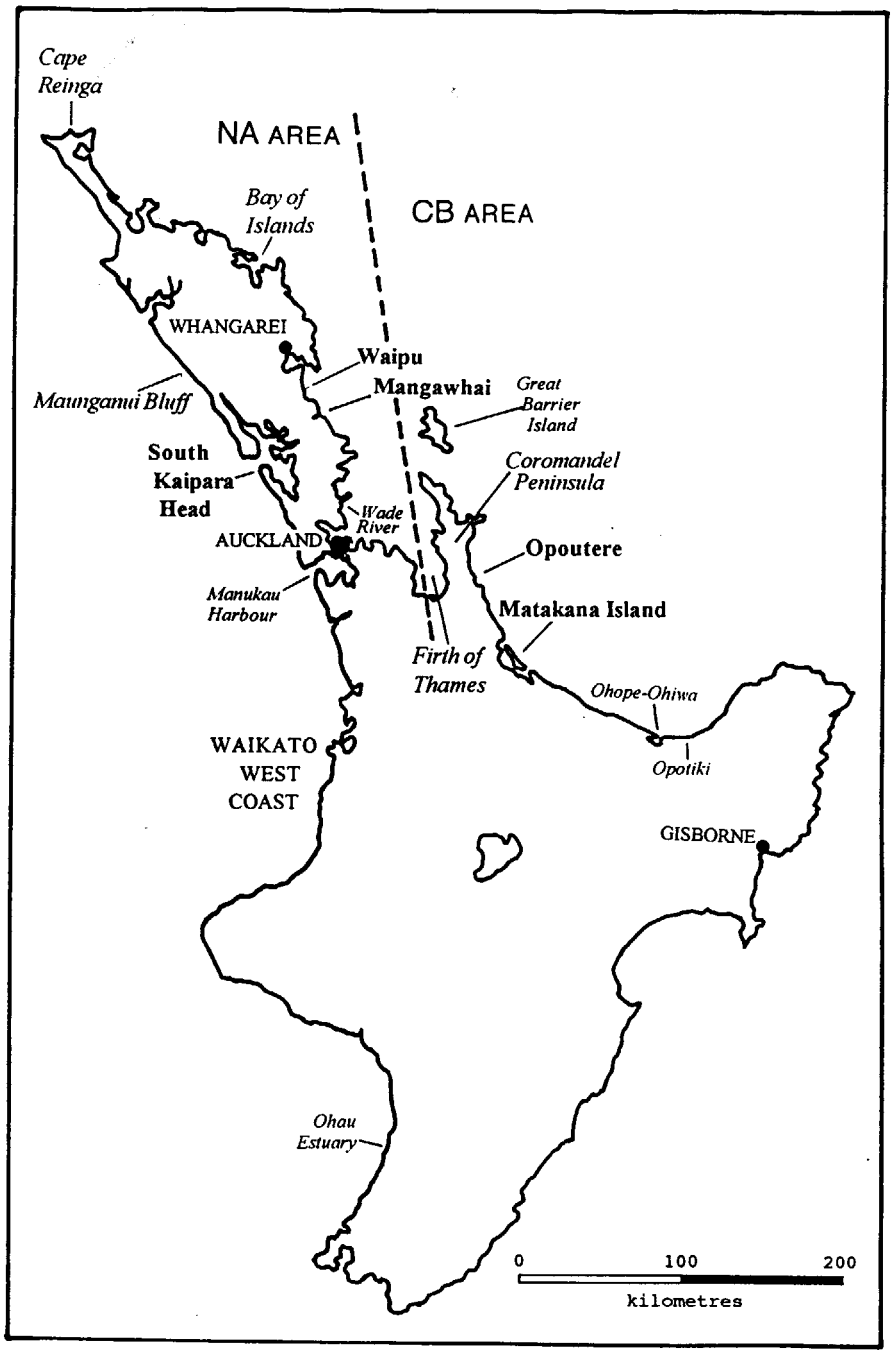


Figure 1. Map showing important locations and areas mentioned in the text. The five large managed sites are shown in bold type. The dashed line shows the apparent boundary between the Northland-Auckland (NA) and Coromandel-Bay of Plenty (CB) areas.

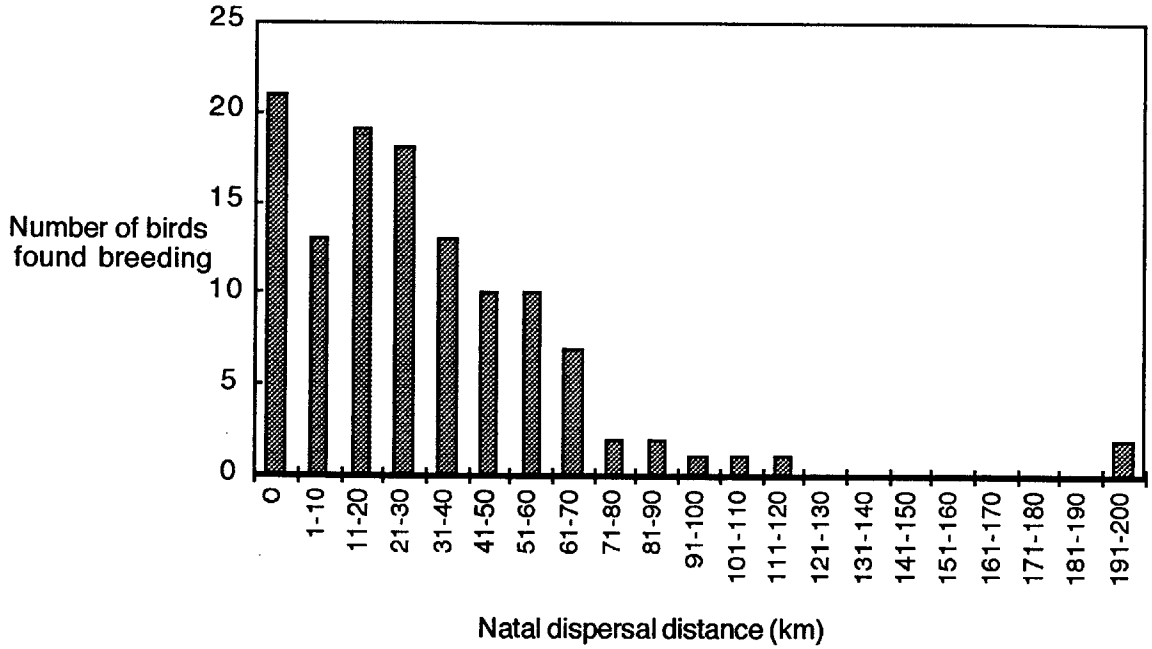
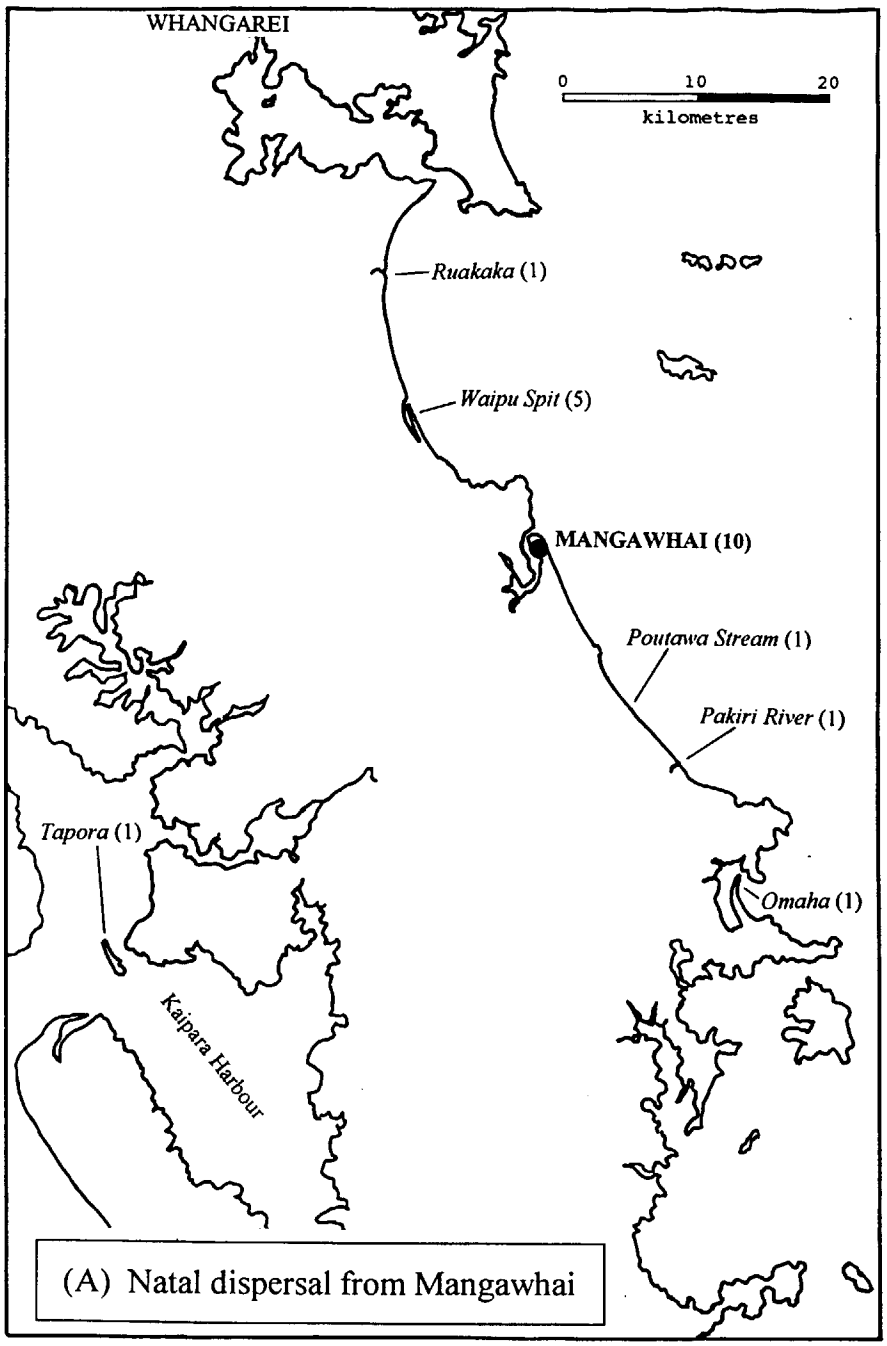
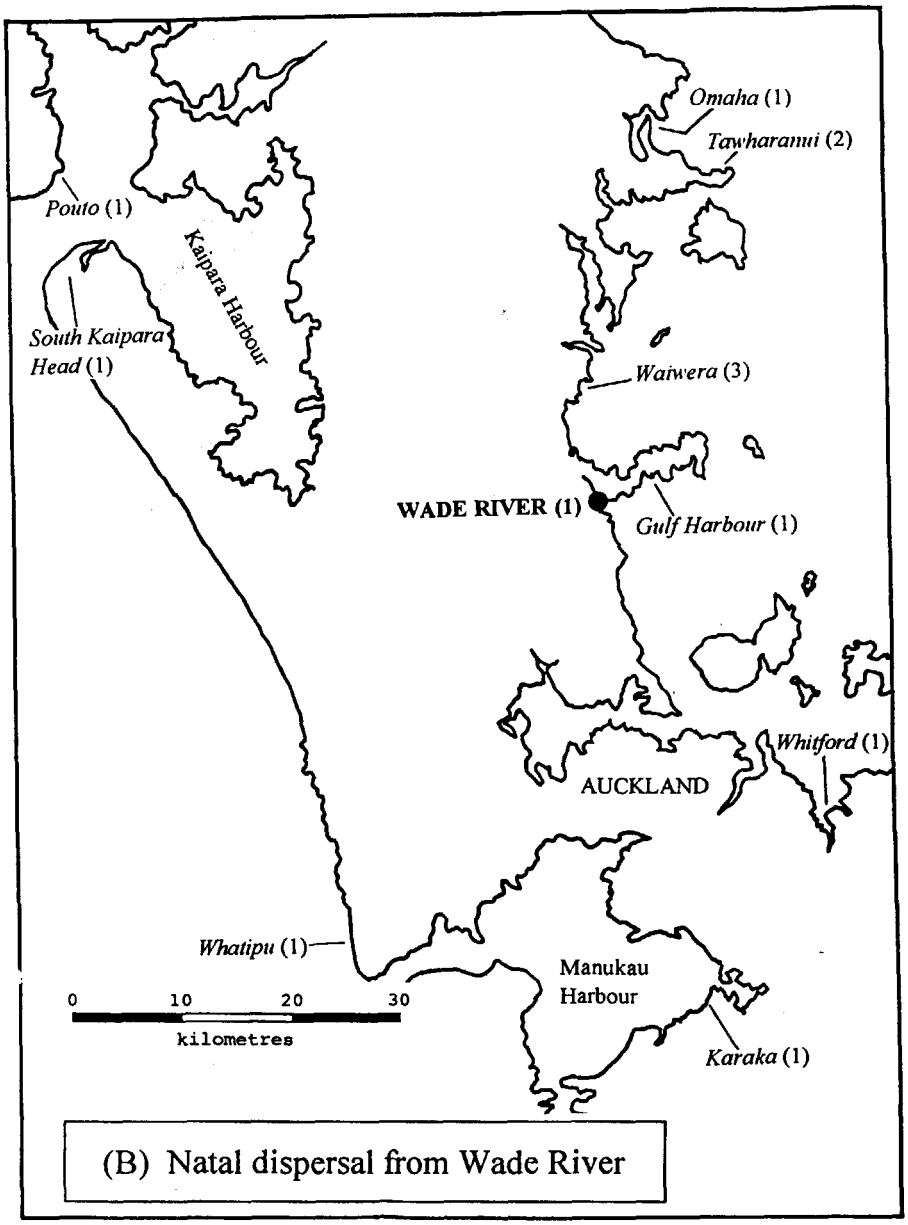
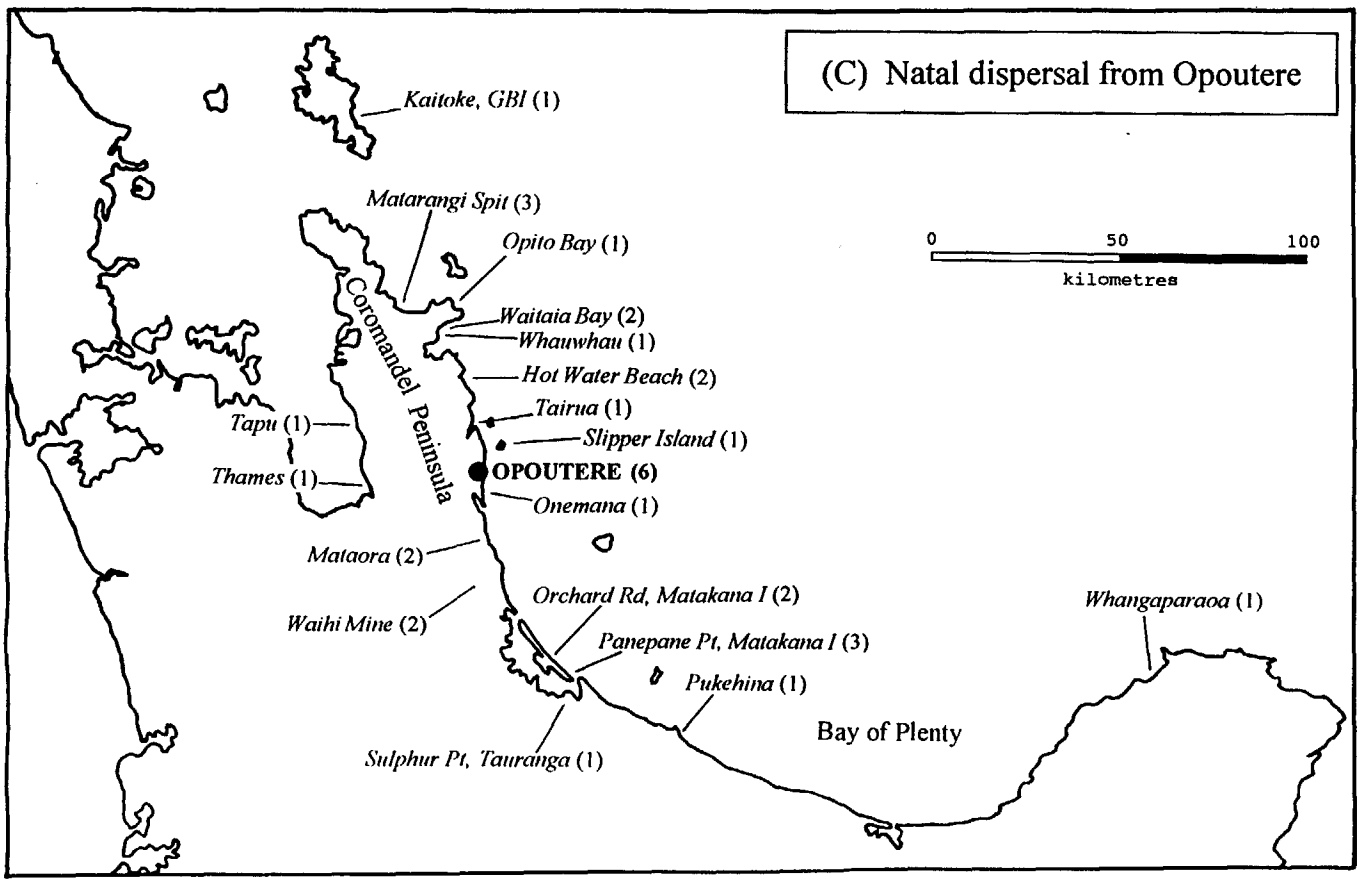


Figure 2. Distribution of natal dispersal distances of northern New Zealand dotterels.

Appendix 1. Maps showing natal dispersal of banded juvenile northern New Zealand dotterels from (A) Mangawhai, (B) Wade River and (C) Opoutere. The number of individuals found breeding at each site is shown in brackets.




Omaha (1)
Tawharanui (2)
Pouto (1)
Kaipara Harbour
South Kaipara Head (1)
Waiwera (3)
WADE RIVER (1)
Gulf Harbour (1)
Whitford (1)
AUCKLAND
Whatipu (1)
Manukau Harbour
0 10 20 30
kilometres
Karaka (1)
(B) Natal dispersal from Wade River


(C) Natal dispersal from Opoutere
Kaitoke, GBI (1)
Matarangi Spit (3)
Opito Bay (1)
0 50 100
kilometres
Waitaia Bay (2)
Whauwhau (1)
Coromandel Peninsula
Hot Water Beach (2)
Tairua (1)
Tapu (1)
Slipper Island (1)
Thames (1)
OPOUTERE (6)
Onemana (1)
Mataora (2)
Orchard Rd, Matakana I (2)
Whangaparaoa (1)
Waihi Mine (2)
Panepane Pt, Matakana I (3)
Pukehina (1)
Bay of Plenty
Sulphur Pt, Tauranga (1)