

Changes in the number and distribution of northern New Zealand dotterels (*Charadrius obscurus aquilonius*): results of four censuses undertaken between 1989 and 2011

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Abstract: This paper presents the results of four censuses of the northern New Zealand dotterel population undertaken between 1989 and 2011. During that period, the population increased by roughly 50%, from about 1,320 to about 2,130 birds. Most birds (85%) were in the northern part of the North Island (Northland, Auckland, and Coromandel Peninsula), but the taxon is expanding its range southwards on both the west and east coasts. On the east coast, a few pairs are now breeding close to Cook Strait. Population trends varied between regions, and almost all of the overall increase was a result of increases on the east coast. The highest rates of increase were on the Auckland east coast and on Coromandel Peninsula, probably because the intensity of management has been highest in those regions. In the Auckland urban area, birds now routinely breed inland, mainly on grass or bare earth; elsewhere, the taxon is almost entirely coastal. The proportion of birds on the west coast has fallen over the past 50 years, and about 85% of the taxon is now found on the east coast. If the overall increase in numbers has continued at the same rate since 2011, there would be about 2,600 birds in 2020. The size of the population and its rate of increase justify the recent down-listing of the subspecies to a threat ranking of At Risk (Recovering), but it remains Conservation Dependent. The recovery programme has been highly successful, and most management of the taxon is now undertaken by community groups, regional councils, and volunteers. Continuing threats include predation, flooding of nests, and disturbance during breeding; in future, continuing coastal development and increased recreational activity will probably degrade habitat further, particularly on the east coast, and climate change will have a range of impacts.

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INTRODUCTION

The New Zealand dotterel (*Charadrius obscurus*, NZD) is a large, endemic plover. There are two subspecies (Dowding 1994); these were raised to species level by del Hoyo *et al.* (2014), but this change has not yet been adopted in New Zealand. The southern New Zealand dotterel (*C. o. obscurus*) formerly bred inland throughout the South Island

(and probably in some parts of the lower North Island), but for about the past century breeding is thought to have been confined to Stewart Island (Dowding 1999).

The northern New Zealand dotterel (*C. o. aquilonius*, NNZD, Figure 1) breeds along the North Island coastline. Its range before the end of the 19th century is not clear, but in the 20th century and until about 1950 its breeding range was apparently confined to northern areas, from North Cape south to the Waikato coast in the west and

southern Coromandel Peninsula in the east (e.g. Falla 1940; Oliver 1955; Williams 1963), including some northern offshore islands. Fleming (1947) recorded a pair on territory at Tairua, Coromandel Peninsula, in September 1946, and noted "the last is apparently the southernmost record on the east coast of the North Island in late years". Records in Classified Summarised Notes (CSN) of *Notornis* from 1951–1960 and in Edgar (1969) show that the species expanded eastwards and colonised the Bay of Plenty coastline during the 1950s. By the 1960s, it was well-established as far east as Whale Island and Rurima Rocks, with a few birds reported around East Cape, and occasional sightings, mostly of single birds, in the southern North Island (Edgar 1969).

There are no early estimates of numbers, but Buller (1888) described the species as "nowhere very plentiful", and the population may never have been large. The first attempt at a population estimate was in the late 1960s (Edgar 1969), and recorded a total of 1,114 individuals; the author considered this an underestimate, and acknowledged the limitations of an estimate based on data gathered over a number of years. Reed (1981) recorded 1,024 individuals and noted that "Allowing for birds missed from counting and areas not surveyed, the population appears fairly static".

At unmanaged sites, annual adult survival is high, averaging 0.920 (JED, *unpubl. data*), but breeding success is typically low (Dowding 2006; Dowding & Davis 2007) and modelling shows that the NNZD population would decline by about 1% per year without any management (JED, *unpubl. data*). The main threats are predation (of all life stages, by mammalian and avian predators), flooding of nests by big tides and storm surges, and disturbance during breeding (Dowding & Davis 2007). Effective management of the taxon began at Opoutere, Coromandel Peninsula, in 1986; the management prescription currently in use addresses the main threats and has been refined over time (see Dowding 2006; Dowding & Davis 2007). It is now in place at many breeding sites.

The fact that the population was small and breeding success was low in many areas prompted a national census in 1989, undertaken as a joint exercise between the Ornithological Society of New Zealand (OSNZ) and the Department of Conservation (DOC) (OSNZ *news* 51: 7). A repeat was scheduled for October 1996 (Dowding 1993), followed by two further censuses at 7–8 years intervals.

This paper presents the results of four censuses of the NNZD population undertaken in 1989, 1996, 2004, and 2011. It also draws on other material to document the changes in numbers and distribution of the taxon over about the past 50 years. The

census period also coincided with the time when management of NNZD began and became increasingly widespread; the censuses therefore provided an opportunity to assess the effectiveness of management on a broad scale. In addition, the data collected on population size and rate of change have also allowed an informed determination of the threat ranking of the taxon.



Figure 1. Adult northern New Zealand dotterel (*C. o. aquilonius*) at Mimiha Stream, Bay of Plenty, October 2013 (Photograph: J.E. Dowding).

METHODS

Counts were conducted at sites known to have NNZD from past records, and in other suitable habitat, such as sandy beaches, sandspits, stream and river mouths, and shell banks and sandbars in estuaries (see Dowding & Moore 2006). The coastline was divided into regions (see Figure 2 and Appendix 1), normally with one OSNZ and one DOC coordinator in each region. Several months before each census, regional coordinators assigned counters to sites and distributed written instructions and recording sheets.

Censuses were conducted in October, when NNZD numbers are at an annual minimum (normally, no chicks will have fledged by then), and breeding adults are sedentary. This timing was chosen to optimise for minimal movement between sites, and so reduce the number of birds missed or double-counted. A core weekend was chosen for each census, based on suitable tide heights and times of day. Almost all counts were completed within a week of the core weekend. Counts were

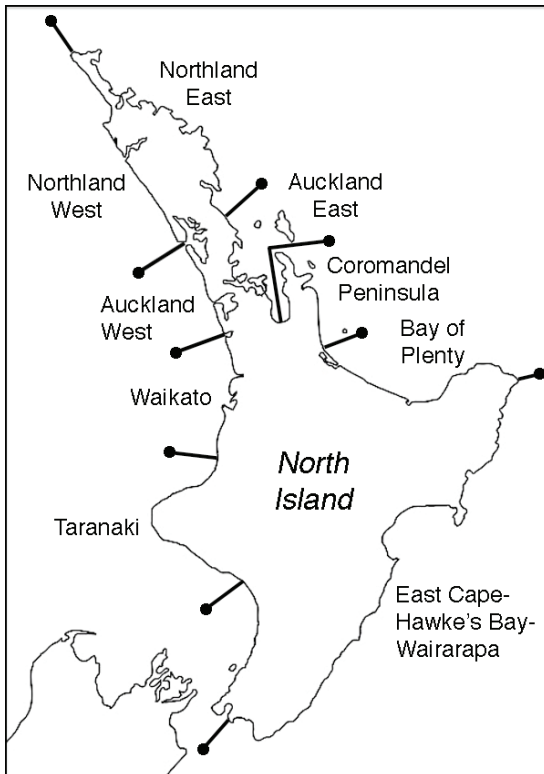


Figure 2. Map of the North Island showing the counting regions for northern New Zealand dotterels (*C. o. aquilonius*). Exact boundaries between regions are identified in Appendix 1.

carried out on foot, and nearly all were made within 2 hours of high water to ensure that off-duty and non-breeding birds foraging in nearby inter-tidal areas were not missed. Details of location, date, time, and observer contact details were noted on each record sheet, along with the number of NNZD counted. Unfledged chicks were sometimes recorded, but were not included in the counts.

Regional coordinators collated local recording sheets and checked them for missed sites or results that were unexpected. Copies of sheets were forwarded to the author, who collated the regional results, checked again for missing or anomalous results, and analysed the data. Counts were entered into MS Excel spreadsheets for storage and analysis. If a site was missed, or if counts from a site were much lower or higher than expected from previous data, a follow-up visit was undertaken as soon as practicable. When it was not possible to visit (or re-visit) a site, an estimate was used; this was either the count from the previous census or the most recent breeding season count available, whichever

was more recent. In a very few cases (probably less than five in any census), access through private property to potential habitat was refused.

These counts were attempts at a complete census (Dowding & Greene 2012), but given the resources available and the extent of coastline involved it is inevitable that a few birds will have been missed. In addition, there were occasional circumstances that may have affected some regional results. In 1989 in Northland, counters were limited, and some sites were therefore not checked within 2 hrs of high water, or within the allocated two-week survey period. Some sites were also checked in poor weather conditions. As a result, the 1989 Northland count is thought to be an underestimate. In October 2004, some long stretches of beach in Northland East were searched by quad bike and yielded much lower counts than expected; re-counts of those areas on foot in October 2005 gave higher counts, which were substituted in the final totals. In October 2011, the dates planned for the census coincided with the MV *Rena* oil spill in the Bay of Plenty; some census counters assisted with the spill response, and as a result sites in some regions were counted 2 or 4 weeks later than planned.

It should be noted that the number of sites surveyed increased with each census, mainly because as the population grew birds were discovered at new sites between censuses, and those sites were then added to the regional list of sites. The gross totals for each census are a minimum estimate of the population size at that date, but rates of change between them will not be comparable as it is not known whether sites not checked in earlier censuses had birds at that time. Rates of change between consecutive pairs of censuses are therefore presented as percentage changes in gross totals and in 'comparison' totals (i.e. totals from only the sites counted in both censuses of a consecutive pair). Because some sites not checked in the earlier census of each pair may have had birds then, the actual rates of change will lie somewhere between the gross changes and the comparison changes.

In addition to the data collected during the censuses, material from other sources was used; this included counts from Edgar (1969) and Reed (1981), records from CSN, records posted on eBird New Zealand, iNaturalist NZ, BirdingNZ.net, and personal communications to the author.

RESULTS

Changes in numbers, 1989–2011

Regional counts, east coast and west coast counts, and total counts from the four censuses are shown in Appendix 2. Figure 3 shows the changes in total numbers of birds counted between 1989 and 2011, and in numbers on the east and west coasts. The

east coast had a large majority of the total count in all censuses. It is also clear that the increase in total numbers is almost entirely due to increases on the east coast, with numbers on the west coast remaining roughly static. The percentage increases (gross and comparison) between consecutive censuses are shown in Table 1. Using rates of increase mid-way between gross and comparison censuses suggests that the population increased by 49.3% between 1989 and 2011.

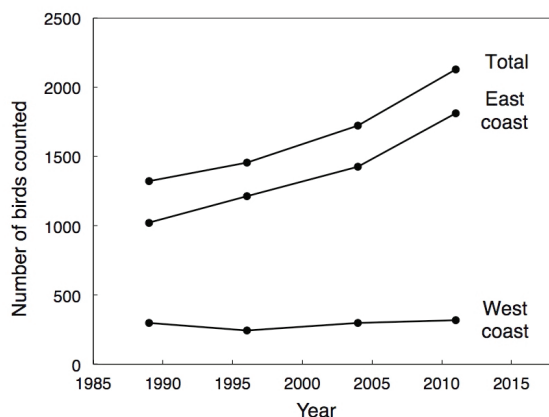


Figure 3. Numbers of northern New Zealand dotterels (*C. o. aquilonius*) counted in total and on the east and west coasts during the four censuses, 1989–2011.

Counts from the east coast regions are shown in Figure 4. Counts in Northland East have fluctuated; the 1989 count is thought to be an underestimate (see Methods) and the overall trend is not clear, with neither a consistent decline nor increase. There have been major increases in Auckland East and Coromandel Peninsula (based on gross counts, the latter population increased by 254% between 1989 and 2011), and the two regions between them accounted for 74% of the total (gross) increase between 2004 and 2011. The largest increase in a region as a proportion of the total population was also in Coromandel, which increased from 9.7% of the population in 1989 to 21.3% in 2011. In the Bay of Plenty, there was a slightly lower count in 1996 (for unknown reasons), but overall, the population in this region changed very little during the census period. The population south of East Cape was increasing but still relatively small in 2011, and has increased further in range and numbers since then (see below).

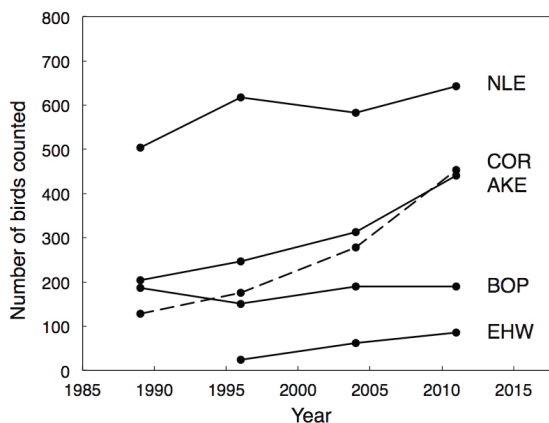


Figure 4. Numbers of northern New Zealand dotterels (*C. o. aquilonius*) counted in east coast regions, 1989–2011. NLE=Northland East, COR=Coromandel Peninsula (dashed line), AKE=Auckland East, BOP=Bay of Plenty, EHW=East Cape-Hawke's Bay-Wairarapa. The 1989 count in NLE is probably an underestimate (see Methods).

Counts from the west coast regions are shown in Figure 5. Counts in Northland West declined gradually between 1989 and 2011, and a comparison of the distribution atlases (Bull *et al.* 1985; Robertson *et al.* 2007) shows a widening gap in the local population between the Hokianga and Kaipara Harbours. The sudden increase in Auckland West between 1996 and 2004 was almost certainly due mainly to a larger area at South Kaipara Head being added to the search area from 2004 and more birds being found there. There was relatively little change in numbers at that site between 2004 and 2011. Numbers in Waikato declined between 1989 and 2004, but there was a slight increase in 2011 (Appendix 2) and numbers have increased further since then (see below). Numbers in Taranaki were low during the census period. Edgar (1969) noted two sightings, each of a single bird, in 1967 and 1968. Single birds seen at Pungaereere Stream, Rahotu, in late 1988 and in early 1989 were described as "the first records for these parts for years" (CSN *Notornis* 37: 211). Numbers were in single figures throughout the census period (Appendix 2), and only 2 breeding sites were recorded. Numbers and range have increased in the region since 2011 (see below).

The Northland, Auckland, and Coromandel Peninsula regions remain the strongholds for the taxon, with 85.5% of the birds counted in October 2011 between them.

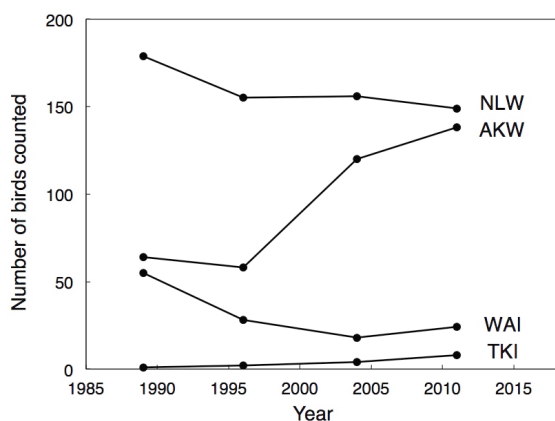


Figure 5. Numbers of northern New Zealand dotterels (*C. o. aquilonius*) counted in west coast regions, 1989–2011. NLW=Northland West, AKW=Auckland West, WAI=Waikato, TKI=Taranaki.

Changes in distribution, 1989–2011

The proportion of birds on the west and east coasts has changed steadily (Figure 6). Including counts from Edgar (1969) and Reed (1981), the percentage of the total population recorded on the west coast fell from 38% to 15% in the c. 43 years between the late 1960s and 2011, with a corresponding rise from 62% to 85% on the east coast.

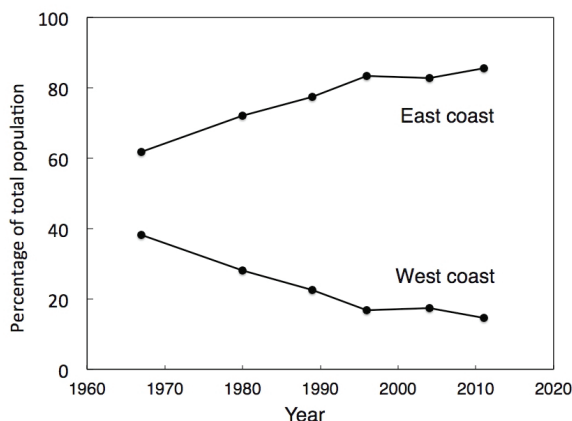


Figure 6. Change in the proportion of northern New Zealand dotterels (*C. o. aquilonius*) counted on the east and west coasts of the North Island between 1967 and 2011. Points for 1967 and 1980 were derived from Edgar (1969) and Reed (1981) respectively; other data were from this study.

The main change in distribution since 1989 has been the expansion of range southwards on the east coast. Small numbers of NNZD were recorded south of East Cape in the late 1980s (e.g. CSN 38: 293) and breeding was first recorded in the region in 1990 (Foreman 1991). The region was included in censuses from 1996 onwards. By 1996, birds were breeding at a minimum of eight sites between East Cape and Waikawa/Portland Island. By 2004, a few pairs were breeding in the area around Cape Kidnappers and by 2011, birds were recorded at Porangahau, with one pair at Riversdale Beach, Wairarapa.

In spite of this large and relatively rapid extension to the breeding range (from East Cape to Riversdale Beach between about 1990 and 2011), the birds in this area were still few and thinly spread, and accounted for only 4% of the total population in 2011. The number of birds and breeding sites in southern Hawke's Bay and Wairarapa has continued to increase since the 2011 census (see below).

Changes outside the core range since 2011

Waikato

The number of managed sites in Waikato has increased gradually in recent years, and the population is growing slowly. In 2011, 24 birds were counted in the region; by the 2017/18 season, at least 40 birds were present between Port Waikato and Marokopa (K. Opie & M. Lellman *pers. comm.*).

Taranaki

The population has also increased in Taranaki since the census period. In the October 2011 census, eight birds were counted and two breeding sites were known in the region. Since then, management has begun at several sites. During the 2017/18 season, there were estimated to be at least 25 birds, with a minimum of eight pairs breeding at six locations (E. Roberts, Taranaki Regional Council *pers. comm.*).

Manawatu-Wellington

There have been occasional records, mostly of single birds, between Whanganui and Wellington. Two birds (almost certainly a female-female pair) attempted to breed at Waikanae Estuary in 2017, and in 2018/19 a male-female pair fledged 2 chicks there (<http://www.birdingnz.net/forum/viewtopic.php?f=9&t=7228>).

Hawke's Bay-Wairarapa

While much coastline in this region was colonised between 1996 and 2011, big gaps in distribution were evident, e.g. in 2004 and 2011, there were apparently no breeding sites between Waikawa/Portland

Island and Ocean Beach, Cape Kidnappers, in spite of apparently suitable habitat being present. Since 2011, unpublished observations have recorded birds at an increasing number of sites in the region, particularly south of Cape Kidnappers. By the 2017/18 season, breeding had been confirmed at a minimum of 10 sites between Cape Kidnappers and Cook Strait. A pair was present at Riversdale Beach as early as spring 2009, but it is not clear whether they were breeding at that time (A. Rebergen, Royal Forest & Bird Protection Society, *pers. comm.*); breeding was confirmed there in 2012 (R. Smith, Greater Wellington Regional Council, *pers. comm.*). At the time of writing, the southernmost breeding site known was at the Pahaoa River mouth at 41.3969°S (N. McArthur, Wildlife Management International, *pers. comm.*), about 45 km north-east of Cape Palliser.

Change in habitat use in the Auckland region

In most parts of its range the NNZD is strictly coastal, and typically breeds on sandy beaches, sand spits, and shell banks (Dowding & Davis 2007). Inland breeding was recorded at a few locations in the late 1990s/early 2000s (e.g. the Waihi gold mine tailings dam 5–6 km inland, and at Kaitia airport about 10 km inland) but this was very unusual.

A notable change in habitat use occurred in the Auckland region during the census period, with a steady increase in pairs breeding away from beaches on grass or bare earth on golf courses, parks, motorway verges, race-track grounds, and construction sites. Distances inland ranged from 100 m to many kilometres, for example Albany Megacentre and Alexandra Park (both about 4 km from the coast), and Pukekohe race-track (about 17 km). If inland breeding is defined as birds that nest more than 100 m inland from the nearest beach or HW mark, about 11% of birds in the Auckland region (west and east coasts combined) were inland breeders in 2011. This marked change in habitat use was not detected in other regions over the census period.

DISCUSSION

These four censuses were attempts at total counts of the population. Given the very large area surveyed, and the limitations described above (see Methods) all the requirements of a total count could not be met rigorously. However, the NNZD is an easily-identified and highly visible bird that lives in open habitat, and counts were conducted over a limited period during the breeding season when movement is minimal. Importantly, a thorough knowledge of the distribution of the taxon has built up over recent decades, both from these censuses and from many other records gathered before and between them. A

very high proportion of the known or suitable habitat of the taxon was therefore surveyed, particularly in 2004 and 2011. In spite of the limitations identified, the two most recent counts are believed to be very close to complete and to provide a good estimate of the population size.

Changes in numbers

In spite of the difficulty of comparing results from the different censuses, the comparison counts (which are almost certain to be minimum estimates of change) strongly suggest that the NNZD population increased substantially in numbers between 1989 and 2011. There was however considerable regional variation (Figures 4 and 5), with little or no increase in numbers in some regions and slow declines in two west coast regions.

The long-term goal in the 2007 recovery plan was for a population of at least 2,200 NNZD by the year 2030 (Dowding & Davis 2007). If the rate of increase in the population has remained the same as that between 2004 and 2011 (and using a value midway between the gross and comparison increases for that period), the population in 2020 would number about 2,600 birds. This suggests that the 2030 recovery plan target has almost certainly been well exceeded already, largely because of the rapid increases in the Auckland East and Coromandel regions.

Those increases occurred in the areas that had by far the highest proportions of their populations managed during the census period. In Auckland East, this was partly because of extensive management of NNZD in Regional Parks by Auckland Council supported by volunteers, partly because of the activities of community groups with access to a large pool of volunteers in the region and, at a few sites, because NNZD benefited from management of New Zealand fairy terns (*Sternula nereis davisae*, NZFT) by DOC. On Coromandel Peninsula, sponsorship from 1995 to 2015 funded management of a very high proportion of the regional population, with volunteer 'minders' undertaking the management and DOC staff providing coordination, materials, and advice (Dowding 2006). That management was very effective at raising breeding success over a wide area (Dowding 2006).

Numbers fell gradually on the Northland west coast during the census period (Figure 5), and there appeared to be some loss of range, contrary to Goal 4.2.1 of the recovery plan (Dowding & Davis 2007). Management is required in this area to prevent further loss of range. As noted above, the sudden increase in numbers in Auckland West (Figure 5) was probably largely due to an increase in the search area at South Kaipara Head from 2004 onwards.

However, it was probably assisted by the onset of management for NZFT at that site in 1998 (Hansen 2006). Early in the census period, Waikato was the region of greatest concern; the local population was very small and declining (Appendix 2), and without management extirpation seemed possible (Dowding & Moore 2006). Management began in the region during the census period, and there was a small increase in the population between 2004 and 2011. That increase appears to have continued since 2011, but a census of the region in the near future would be useful to assess numbers and distribution.



Figure 7. Newly-hatched chick and eggs of northern New Zealand dotterel (*C. o. aquilonius*) at Pig Bay, Motutapu Island, November 2010 (Photograph: J.E. Dowding).

Threat ranking

In 2012, the NNZD was ranked Threatened (Nationally Vulnerable) (Robertson *et al.* 2013). The overall rate of increase in the population between 2004 and 2011 was at least 16.7% (Table 1). Given the size of the population, and a mean generation time of about nine years (JED, *unpubl. data*), the taxon no longer meets the Nationally Vulnerable threshold of a stable population ($\pm 10\%$) over three generations (Townsend *et al.* 2008). The current ranking of At Risk (Recovering) (Robertson *et al.* 2017) is therefore appropriate, but the taxon still has the Qualifier Conservation Dependent, i.e. “likely to move to a higher threat category if current management ceases” (Townsend *et al.* 2008). Under IUCN criteria, the NNZD is currently classified as Near Threatened (BirdLife International 2018).

Changes in distribution

Mid-20th century records are consistent in suggesting that until about 1950, the breeding range was limited to the northern North Island, and extended

Table 1. Percentage changes in the numbers of northern New Zealand dotterels (*C. o. aquilonius*) counted between consecutive censuses. Comparison totals are the totals from only the sites counted in both censuses of each consecutive pair (see Methods).

	1989–1996	1996–2004	2004–2011
Changes in gross totals (%)	+10.3	+18.2	+23.7
Changes in comparison totals (%)	+3.4	+14.1	+16.7

as far south as Coromandel Peninsula on the east coast (e.g. Oliver 1955). NNZD expanded into the Bay of Plenty in the 1950s (see Introduction), and colonised the area south of East Cape from about 1990 (Foreman 1991). During and after the census period, that southward range expansion continued into Hawke’s Bay and Wairarapa. As long as management continues, there is no reason to believe that the range expansion on both west and east coasts will not continue. The main gap in breeding distribution in the North Island now is the coastline between Whanganui and Wellington; this could be colonised by birds from either Taranaki or Wairarapa or both.

To date, almost all NZD seen on the South Island coast are known (through banding) or thought (because of plumage differences) to be *C. o. obscurus* from Stewart Island (Dowding & Murphy 1993; Dowding & Moore 2006). However, given the proximity of Pahaoa and Waikanae to Cook Strait, and the known dispersal ability of juvenile NNZD (Dowding & Moore 2006), it would not be surprising if birds from the North Island were found breeding in the northern South Island in the near future. A single bird seen and photographed at Ashley Estuary (about 25 km north of Christchurch) in August 2016 was, based on plumage, probably a NNZD (<http://www.birdingnz.net/forum/viewtopic.php?f=9&t=6024&p=29775>).

There has been a change in the proportions of the population on the west and east coasts over the past 40–50 years (Figure 7). That change was already under way from the 1960s, well before management of NNZD began. The reasons for the change are not clear, but it may be that west coast beaches provide less-favourable breeding habitat for NNZD. Black sand beaches can become very hot in summer, winds are typically stronger and on-shore, and in some areas the tides are bigger than on the east coast. These factors may result in breeding success of unmanaged populations being lower on average on the west coast than on the east coast.

A question that arises is whether the bias in

distribution of managed sites (which are nearly all on the east coast) has also contributed to the change in the relative proportions of the population on the two coasts. That suggestion is supported by the difference in growth rates of the west and east coast populations (Appendix 2); based on changes in the gross totals, the west coast population increased by 6.7% between 1989 and 2011, while the east coast population increased by 77.1% during the same period (the comparison totals show a similar difference). Dispersal of juveniles from the east coast to the west could also influence the proportions of the population on the two coasts, but such dispersal occurs infrequently; about 93% of chicks banded on the east coast bred on that coast (Dowding 2001).

NNZD appear to have been present in Hawke's Bay in the late 19th century. Robson (1883) recorded an 'Eastern Golden Plover' nesting on Waikawa/Portland Island, but this was almost certainly a New Zealand dotterel (Falla 1936). Hamilton (1885) also noted that the species occurred in the Petane district, between the Tutaekuri and Mohaka Rivers. Brathwaite (1955) commented that he knew of "no recent occurrences anywhere along this coast". This raises the possibility that NNZD were extirpated from Hawke's Bay in the late 19th or early 20th century, only to re-colonise about a century later.

Future censuses

The four censuses undertaken to date have provided valuable information on national and regional population sizes and trends, and on changes in distribution. Keeping to the 7–8 years census cycle (Dowding & Davis 2007, section 5.1.2) suggests the next North Island-wide census should have occurred in October 2018 or 2019. At some sites, particularly in the intensively managed regions of Auckland East and Coromandel (e.g. at Omaha Spit and Opoutere), the number of breeding pairs did not increase during the latter part of the 1989–2011 census period, in spite of continuing overall increases in the same regional populations. This suggests those sites may be at or near carrying capacity. However, new sites continue to be occupied, and there is nothing to suggest that the overall increase has slowed markedly since 2011. In particular, the rate of increase appears very unlikely to have fallen enough to change the taxon's threat classification at the next threat ranking round in 2020 or 2021. As long as current management continues, the taxon appears to be secure and is likely to continue increasing in numbers and range. Given the results of the four censuses presented here, and considering the very substantial resources needed to undertake a North Island-wide census, it is probably now appropriate to extend the interval between censuses.

A useful alternative in the short term would be to undertake a partial census, south of Port Waikato on the west coast and south of Gisborne on the east coast. This would provide information on the current population size and effectiveness of recent management in Waikato, and on the continuing expansion of range by NNZD into Taranaki and down the Hawke's Bay-Wairarapa coast since 2011.

Inland breeding

There are a number of possible reasons for the increase in inland breeding in the Auckland region. Most urban beaches in Auckland are severely degraded as habitat for NNZD by residential development causing narrowing of the beach and a loss of dunes, 'hardening' of parts of the coastline with structures such as stone walls and revetments, heavy recreational use of beaches by people and dogs, and by the presence of high densities of domestic animals (particularly cats and dogs) roaming from nearby houses. There has also been a rapid increase in the number of NNZD in the region (Figure 4), resulting in greater pressure on existing coastal sites. These factors, in combination with the availability of habitat away from the coast, have probably been responsible for the observed shift in habitat use. The taxon's ability to breed inland readily is perhaps not surprising, given that *C. o. obscurus* always breeds inland (Dowding 1999).

Birds breeding inland may face different or additional threats to coastal breeders, such as mowing of grassed areas used for nesting, an increased risk of crushing of nests by machinery and people on construction sites, and differences in predator guilds. Research on the relative survival and breeding success of inland and coastal birds would be useful. In addition, birds breeding on beaches normally show very high inter-annual site-fidelity (Dowding & Chamberlin 1991), whereas inland birds, particularly those that breed on bare earth or construction sites, may lose those sites when they become developed (or heavily vegetated), and their site-fidelity is often short-lived. A number of inland breeding sites were found in the Auckland region between 2005 and 2010, but they had been developed or were overgrown by the October 2011 census and birds were no longer present.

Impact of management

The 1989–2011 census period coincided closely with the time during which management of NNZD began and gradually became more widespread. This is a taxon that can be managed successfully by the community, using a management prescription that has been shown to increase productivity (Wills *et al.* 2003; Dowding 2006). Natal dispersal distances

of NNZD are relatively short, with 93% of birds breeding within 70 km of their natal site (Dowding & Moore 2006), so the benefits of management will be largely evident within the same region. The rapid increase in numbers documented here in the two regions with the highest proportion of pairs under management provides compelling evidence for the effectiveness of the management prescription at a regional scale, and over more than two decades. The number of sites being managed nationwide increased throughout the census period, and it appears that the overall rates of growth increased between censuses as well (Table 1 and Figure 3); this is also consistent with the suggestion that management has been effective at increasing the size of the population.

Islands free of mammalian predators have been important in the conservation of many threatened bird species in New Zealand. However, predator-free islands have probably played only a minor role in the recovery of the NNZD population. The 2011 census data suggest that only about 5% of the total population inhabits predator-free islands, in part because many of them have little or no typical breeding habitat, such as sandy beaches. In addition, productivity on these islands is still affected by other threats, including avian predators and loss of nests to flooding. It therefore seems likely that the widespread and effective management undertaken on the mainland during the period of the censuses will have largely swamped the contribution of the small NNZD populations breeding on islands free of mammals.

Early in the census period, much of the management of NNZD was undertaken by DOC. Increasingly, other agencies and groups have become involved, and almost all management is now undertaken by community groups, interested individuals, and regional councils supported by volunteers.

With many native bird taxa continuing to decline (Robertson *et al.* 2017), particularly on the mainland, the significant increase in the NNZD population over the census period is a notable conservation success story: the number of birds in the population increased by about 50%, there was a large overall increase in range, recovery plan goals were met early, and the taxon is no longer classified as Threatened. It is important to note however that the NNZD remains Conservation Dependent, and management needs to be maintained in core areas, increased in some areas on the west coast, and established at sites in newly-colonised regions. Unfortunately, the demise of the New Zealand Dotterel Recovery Group in 2006 and the expiry of the recovery plan in 2014 mean that specialist overview and up-to-date guidance for these and other tasks relating to the taxon are now lacking.

The future

In the longer term, sufficient habitat of suitable quality needs to be protected to sustain the growing population. About 81% of the global NNZD population in 2011 was on the east coast between Cape Reinga and East Cape. Much of this coastline is experiencing increasing development, and increasing levels of recreational use. Both have the potential to degrade dotterel habitat, and long-term protection of key breeding, flocking, roosting, and feeding sites will be required (Dowding 2006; Dowding & Davis 2007). In addition, climate change is bringing rising sea levels and a higher frequency of storm events (e.g. McGlone & Walker 2011), and these are likely to have direct and indirect negative impacts on coastal bird species (Lundquist *et al.* 2011), including the NNZD.

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Appendix 1. Northern New Zealand dotterel (*C. o. aquilonius*) count regions during censuses, 1989–2011.

Count region (abbreviation)	Regional limits
Taranaki (TKI)	Whanganui River mouth north to and incl. Awakino
Waikato (WAI)	Waikawau River north to and incl. Port Waikato
Auckland west coast (AKW)	Karioitahi to Kaipara Entrance, incl. Manukau Harbour and south Kaipara Harbour (north to and incl. Okahukura Peninsula)
Northland west coast (NLW)	Northern Kaipara Harbour and from Kaipara Entrance north to Cape Reinga
Northland east coast (NLE)	From Cape Reinga east and south to and incl. Mangawhai Wildlife Refuge, incl. Cavalli Islands and islands in the Bay of Islands
Auckland east coast (AKE)	Southern boundary of Mangawhai Wildlife Refuge to Waitakaruru, incl. Great Barrier Island and inner Hauraki Gulf islands
Coromandel Peninsula (COR)	Piako River, Firth of Thames to Orokawa Bay, incl. Great Mercury and Slipper Islands
Bay of Plenty (BOP)	North end of Waihi Beach to East Cape, incl. Whale Island and Rurima Rocks
East Cape-Hawke's Bay Wairarapa (EHW)	Waiapu River to Baring Head, incl. Waikawa/Portland Island

Appendix 2. Regional, west coast, east coast, and total counts of northern New Zealand dotterels (*C. o. aquilonius*) from the four censuses undertaken between 1989 and 2011, and regional and west coast-east coast percentages of the total count in 2011. NC=not counted.

Region	1989	1996	2004	2011	% of total in 2011
Northland West	179	155	156	149	7.0
Auckland West	64	58	120	138	6.5
Waikato	55	28	18	24	1.1
Taranaki	1	2	4	8	0.4
<i>West coast totals</i>	299	243	298	319	15.0
Northland East	504	617	583	643	30.2
Auckland East	204	247	313	440	20.6
Coromandel Peninsula	128	176	278	453	21.3
Bay of Plenty	187	151	189	190	8.9
East Cape-Hawke's Bay–Wairarapa	NC	24	62	86	4.0
<i>East coast totals</i>	1,023	1,215	1,425	1,812	85.0
North Island totals	1,322	1,458	1,723	2,131	100.0