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Population estimates and conservation of the New Zealand dotterel (*Charadrius obscurus*) on Great Barrier Island, New Zealand

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Abstract We present the first detailed data on the Great Barrier Island (GBI) subpopulation of the northern New Zealand dotterel (NNZD; *Charadrius obscurus aquilonius*). The breeding season population has averaged 48 birds (range: 41– 64) since 2000. At Awana on GBI, productivity has averaged >1.0 fledged chick per pair-year. The apparent survivorship of adult birds was less than that in the North Auckland subpopulation. After breeding, most GBI birds congregated at Whangapoua Estuary/Okiwi Spit in the north of the island, making this a site of international importance under the Ramsar Convention (1971). The post-breeding population of *c.*56 birds (range: 41 – 77) was augmented by local juveniles and input from elsewhere. Banding returns provided evidence of movement between GBI and the adjacent mainland subpopulation on the Coromandel Peninsula. There was no evidence that fewer predatory mammal species on GBI benefits the species at present. Conservation emphasis should focus on controlling mammalian predators and managing human impacts at breeding sites, especially early in the breeding season.

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Keywords Northern New Zealand dotterel; *Charadrius obscurus aquilonius*; conservation management; Great Barrier Island, Awana Beach, Whangapoua, movement patterns

INTRODUCTION

The New Zealand dotterel (NZD, *Charadrius obscurus*) is a threatened endemic plover comprising disjunct northern and southern subspecies (Dowding 1994). The northern New Zealand dotterel (NNZD, *C. o. aquilonius*) is almost entirely coastal and had a population estimated at *c*. 1700 individuals in 2004 (Dowding & Moore 2006). Colour banding of chicks and adults has shown that the subspecies contains at least 2 subpopulations (one in Northland and Auckland, the other in Coromandel and Bay of Plenty), with little or no dispersal between them (Dowding 2001).

The northern subspecies is ranked 'Threatened (Nationally Vulnerable)' by the Department of Conservation (DOC) (Miskelly *et al.* 2008). It is also classed as 'Conservation Dependent' meaning that it is "likely to move to a higher threat category if current management ceases" (Townsend *et al*. 2008). Management aims primarily to raise productivity by controlling predators and reducing disturbance during breeding; currently about 20% of the estimated 700 breeding pairs are managed annually. The NNZD appears quite plastic with regard to nesting site, breeds over a relatively wide

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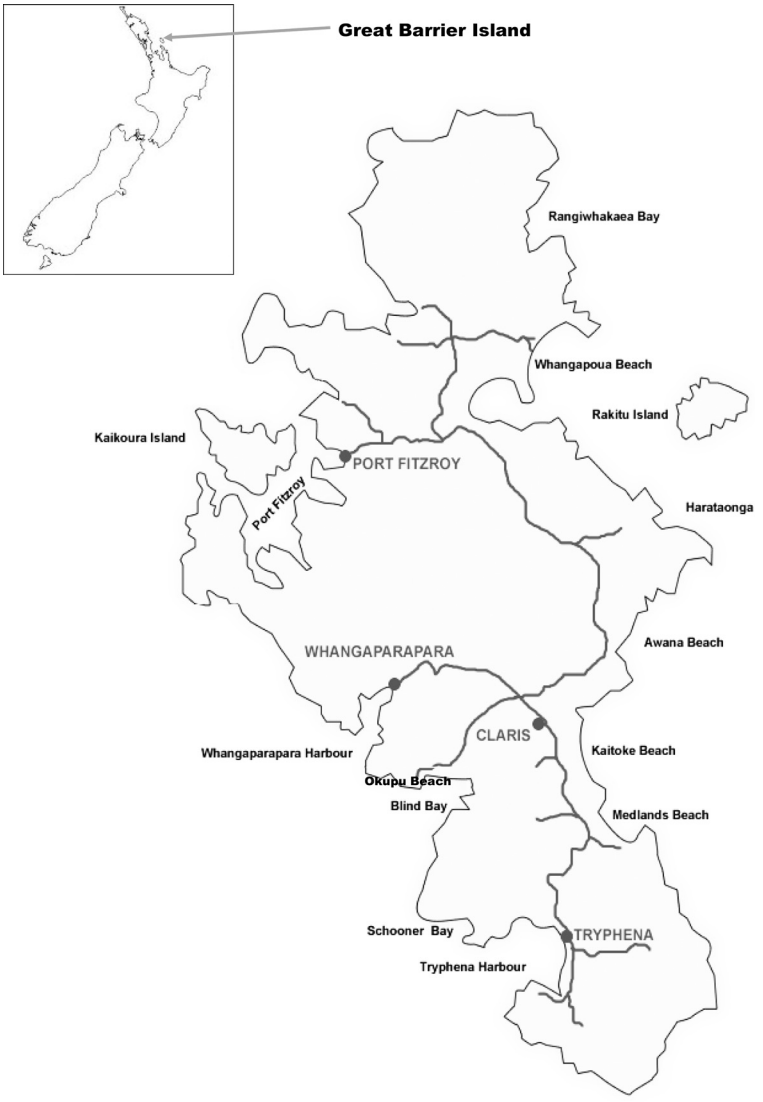

Fig 1. Map of Great Barrier Island showing locations mentioned in text.

seasonal window, and will readily re-lay if clutches are lost (Dowding 1993; Pye & Dowding 2002). Although a relatively small proportion of eggs may fledge, adults can live for up to 3 decades (Heather & Robertson 1996). Together, these observations suggest that the taxon is currently not in immediate danger of declining further, as long as the current level of conservation management continues.

In the short term, the major threats appear to be predation of eggs, chicks and adults by cats (*Felis catus*), stoats (*Mustela erminea*), hedgehogs (*Erinaceus europaeus*), dogs (*Canis familiaris*), southern black-backed gulls (*Larus dominicanus*) and Australasian harriers (*Circus approximans;* Dowding 1993; Dowding & Murphy 2001), flooding of nests (Dowding 1998), and disturbance during breeding (Lord *et al*. 1997, 2001). In the longer term, destruction and degradation of habitat by coastal development and increasing human recreational use of beaches threatens much of the NNZD population, particularly on the North I east coast (Dowding & Davis 2007).

The population of NNZD on Great Barrier I is of interest for 2 reasons. First, the large majority of the NNZD population is found on the mainland, because most offshore islands within its range are small or have little suitable habitat for the species (Dowding 1993). Great Barrier I (GBI; Fig. 1) is a notable exception, with a substantial group of birds breeding mainly on the sandy eastern beaches and over-wintering on the island at Whangapoua Harbour. From a conservation or evolutionary

Table 1. Characteristics of the main east coast nesting beaches on Great Barrier I and the number of breeding pairs of New Zealand dotterel.

Beach name	Approx. Lat. S	Length (km)	Dwellings[1]	Fresh-water streams[2]	Breeding pairs[3]
Medlands	36°16′	2	55 (150)	2	1-2
Kaitoke	36°15′	3	12 (50)[5]	3	3-5 (7)
Palmers	36°14′	1.5	2	2	1-2
Awana	36°13′	1	18 (150)	1	1-2
Harataonga	36°10′	0.5	1 (100)	1	0-1
Whangapoua[4]	35°08′	4	3 (150)	2	5-7 (11)
Rangiwhakaea	35°06′	0.6	0 (0)	2	0-1[6]

[1] Approximate number of nearby inhabited dwellings and holiday homes (2010). Maximum Dept of Conservation and other camp-site numbers in brackets.
[2] Permanent streams only, excluding some small streams.
[3] Estimated minima and maxima 1992/93–2010/11 (except Rangiwhakaea–see note [6]). Figures in brackets are numbers of pairs reported by other observers in 2003/04.
[4] This beach is unlike all others in that it is adjacent to an extensive estuary with mud-flats.
[5] Private camp-site at south end.
[6] Pair first recorded breeding in 2003/04.

perspective, the links (or lack of them) between this island population and dotterels on the North I mainland are of interest. Second, GBI has a limited predator suite, with brushtail possums (*Trichosurus vulpecula*), Norway rats (*Rattus norvegicus*), hedgehogs and mustelids (*Mustela* spp.) absent, although ship rats (*R. rattus*), kiore (*R. exulans*), cats, dogs and avian predators are present.

The NNZD was described as common on the east coast of GBI by Hutton (1869). After that, there appear to be no published reports of the species on the island until 1949 (Bell & Brathwaite 1964), and few since then (Bell 1976; Ogle 1980), until this study commenced in 1991 with monitoring at Awana and the first colour-banding of birds. This paper provides island-wide counts since 1999, estimates of NNZD productivity at Awana since 1991/92, and evidence of movements and survivorship based on observations of banded birds. Scattered information about the distribution and numbers of the island's NNZD population before 1991 is also collated.

METHODS

Distribution and population size

Information on the distribution and numbers of NNZD on GBI has been collated from the literature, unpublished Department of Conservation (DOC) records, and notes of individuals listed in the acknowledgements. Since Apr 2000, counts have been made at the post-breeding flock site (Whangapoua/Okiwi Spit; hereafter referred to as Whangapoua, and including the spit and the whole eastern beach and dunes to Tupuwai Point) and almost simultaneously on all other east-coast beaches. These counts were all made by JO, sometimes in conjunction with DOC employees (D. Barker, H. Jamieson, J. Flack, and A. Geary). Counts at Whangapoua were made at high water, when the birds were congregated near the end of the spit, rather than dispersed over the flats of the adjacent estuary. Birds were also sometimes present on the estuary or wet fields by the airport, or on the airstrip, but as they were not observed synchronously with the Whangapoua flock, it was assumed these birds had flown from Whangapoua (a few minutes flight) and had already been counted. At the other sites, beaches were traversed in both directions giving 'replicate' counts. Post-breeding counts were in late Mar or Apr from 2001 to 2012. In addition, 9 full counts were made at other times, 6 of these during the nesting period when birds were dispersed across breeding sites. In all cases where it was uncertain if some individuals had been counted twice due to movement, maxima and minima were recorded.

Samples of adult birds were colour-banded on GBI by JED in Nov 1991 and again in Nov 2004. Birds were caught on noose-mats while displaying near nests or hidden chicks. Each bird was given a numbered metal band and fitted with a unique combination of wrap-around plastic colour bands. The further minimum survival of these birds (date of banding to date of last sighting) was compared with that of adults banded in the same way during the same seasons on the mainland North Auckland east coast.

Management and monitoring at Awana

From 1992 to 2012, JO visited Awana beach every summer, usually arriving in mid-Dec and leaving between late Feb and Jun, although monitoring visits were also made in Oct or Nov in most years after 1999. First breeding attempts were probably

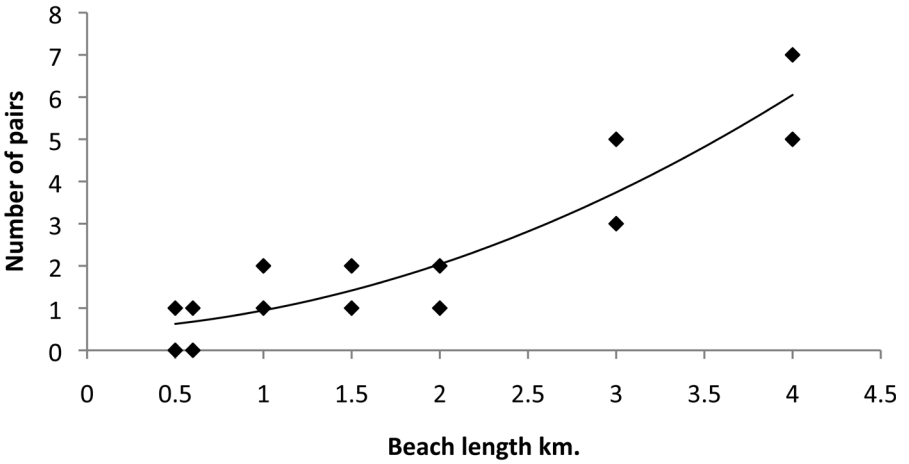

Fig 2. Beach length and number of nesting New Zealand dotterel pairs (maximum and minima).

often missed, but when they were successful, unfledged or young birds were recorded in Dec. Individual birds could be recognised from leg bands or subtle plumage differences and by their favoured locations on the beach; non-resident birds were readily identified by plumage and behaviour. Since 2008, weekly observations have been made throughout the year, excepting a few weeks in the winter (Jul – Sep).

In 1999, the Awana Beach-care Group and The Awana Catchment Trust were formed, partly to provide protection for the dotterels. Protective measures included: explanatory signage with a picture of NNZD near the beach entrance, discussions with local dog owners and with visitors on the beach, and consulations with staff of the Department of Conservation and the City Council. Known nests were 'guarded' as much as possible. Monthly cat and rat trapping was carried out close to the dotterels between 2003 and 2008. Since the 2001/02 breeding season a tape fence has been erected along the estuary to separate the nesting area from the track between campsite and beach.

RESULTS

Distribution and population size

Earlier records indicate that most or all breeding occurs on the sandy beaches of the island's east coast, a finding confirmed by our surveys. The breeding beaches form a series from the most developed beach (Medlands) in the south, to that least visited by holiday-makers (Rangiwhakaea) in the north (Table 1, Fig. 1). All the main breeding beaches except Palmers Beach have DOC campsites. The larger beaches, with more fresh-water estuaries or streams crossing them, have the larger NNZD populations (Fig. 2). The relatively large population on Whangapoua Beach presumably reflects the presence of the post-breeding flock there, and/or the extensive feeding grounds on the nearby mud flats of the Harbour.

Dotterels have also been observed by us and others on some of the smaller beaches between those listed in Table 1. On the west coast, attempted breeding (eggs) occurred at Okupu beach in 2009-10 and 2010-11, and birds were reliably reported at Tryphena, also on the west coast. In 2003-04, a pair bred in the north eastern portion of the island at Rangiwhakaea Bay ($36^{0}06'$ S, $175^{0}25'$ E; H. Jamieson, *pers. comm.*), the first breeding record for this site. We have not found any records of NNZD on any of the smaller islands around GBI, including Rakitu (Arid I.).

Counts of NNZD on GBI are given in Appendix 1 and summarised in Figs. 3 and 4. Counts for the whole island suggest an average breeding season population of 48 birds (range 41-64) and an average post-breeding population of 56 birds (range 41-77). Since 1992/93, the breeding population has consisted of 12 – 19 pairs (Rangiwhakaea 0-1, Whangapoua 6-8, Harataonga 0-1, Awana 1-2, Kaitoke/Palmers 4-7, Medlands 1-2, Okupu 0-1). However, in 2003-04 (and again in 2008-09) up to 7 pairs may have been present at Kaitoke (M. Galoboski, *pers. comm.*) and 11 pairs at Whangapoua (H. Jamieson, *pers. comm.*), and the total number of breeding pairs island-wide might have reached 25 pairs. Whangapoua is probably the most important breeding site, with half the island's spring population; currently the breeding season average there is 23 ± 3 (mean ± standard deviation) birds. For the whole island, the breeding population is estimated as 48 ± 8 birds.

The post-breeding flock number has fluctuated around an overall average of 56 birds since the mid-1990s (Fig. 3). Examining the data from Kaitoke and Whangapoua (the 2 main beaches) separately indicates a shift towards the former location since 2000 (Fig 4).

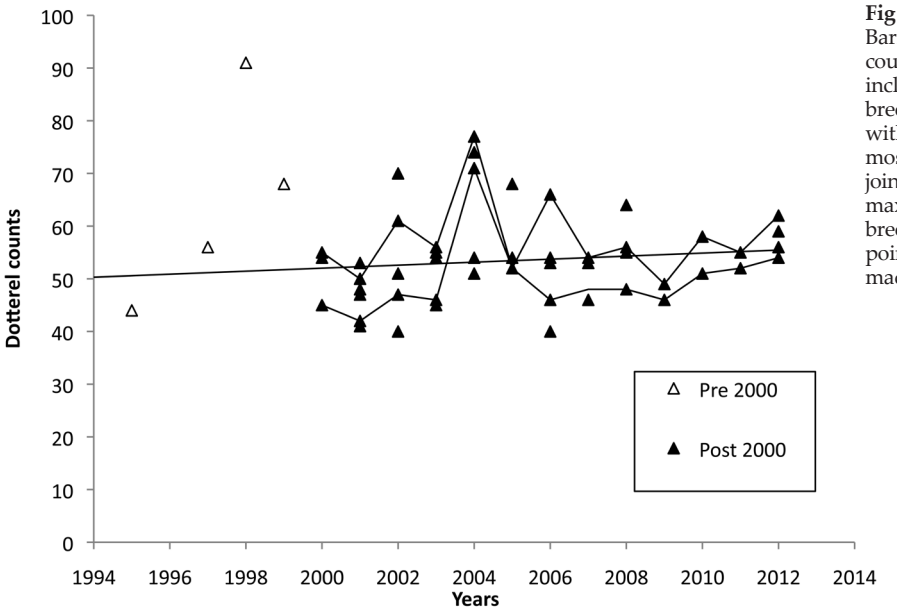

Fig 3. Summary of all Great Barrier New Zealand dotterel counts. Post 2000 counts include breeding, post-breeding and winter counts, with maxima and minima in most cases. The upper line joins post-breeding flock maxima, and the lower post-breeding minima. Other points represent counts made at other times.

Movement between sites on GBI

The number of NNZD seen at Whangapoua in Feb-Apr was double that during the breeding season; taken with the disappearance or decline of dotterels from the other beaches after breeding, this suggests post-breeding movement within GBI from other beaches to Whangapoua Estuary. Sightings of banded birds (Table 2) support this inference and also suggest that birds banded at Whangapoua remain at that location. Moreover, the 2 birds with the greatest longevity are from that site. However, some birds are present on Kaitoke Beach throughout the season, and so movement to the post-breeding flock at Whangapoua may not involve all birds every year. No GBI banded birds have as yet been recorded at Kaitoke. Individuals occasionally 'disappeared' from the closely monitored site at Awana for a few days, and flights between adjacent beaches have been observed.

Links to the mainland population

Although the banding data are few, they suggest that the GBI population is linked to that on Coromandel, and that this may be a factor in the relative stability of the population. Banding clearly demonstrated movement in both directions (Table 2), with a young Coromandel bird (M-Y) joining the post-breeding flock at Whangapoua at least twice (and ultimately pairing and breeding there), and a bird nesting at Awana (WO-M) on at least 3 occasions moving to the post-breeding flock at Colville on the Coromandel. In addition, a chick banded GY-MY at Opoutere, Coromandel in Oct 1992 was found breeding at Kaitoke, GBI (a straight-line distance of about 100 km) in Dec 1994. A non-breeding adult bird (apparently unpaired, but acting as a helper to the resident breeding pair) was banded M-YWG at Harataonga, GBI, on 15 Nov 1991; it was seen in a post-breeding flock at Colville Harbour, Coromandel in Apr 1993, and then at Medlands Beach, GBI in Sep 1995. It may have been seen again at Colville in Feb 1997. A breeding adult banded M-WRG at Awana, GBI on 15 Nov 1991 was still present and breeding at Awana in 1992/93. It was seen at Kawakawa Bay, South Auckland in Mar, Apr and May 1993, then returned to GBI and bred at Awana again in the 1993/94 season. No NNZD have been metal banded without colour bands on the island, so the sighting of only metal-banded birds (of unknown origin) at Palmer's Beach in 2004 and 2008 also suggests movement between GBI and the mainland. The wrap-around colour bands fitted to NNZD typically last at least 10 years when at the base of the tarsus (lower bands) and longer when higher on the tarsus (JED, *unpubl. data*). In addition, birds nearly always lose bands one at a time, and are seen with partial combinations; no such cases were recorded on GBI. It therefore seems very unlikely that the metal-banded birds seen were colour-banded individuals that had lost all their colour bands.

These records suggest that the GBI population is linked to the mainland mainly or entirely through the Coromandel Peninsula. This suggestion is supported by the fact that there is no evidence of movement of juveniles (the most mobile section of the population) from the North Auckland east coast to GBI. Between 1987 and 2003, at least 143 colour-banded chicks are known to have fledged from the North I east coast

Table 2. Summary of banded New Zealand dotterel survivorship and movements. Notes: W, Whangapoua estuary including Okiwi spit; Coro, sites on Coromandel (M, Matarangi spit, C, Colville, O, Opoutere); H, Harataonga; A, Awana; Med, Medlands: K, Kaitoke; S. Auck., South Auckland (Kawakawa Bay). [(1)] Excluding observations at Colville.

Bird	Date of banding	Last record	Survival (years)	No. of observations	Banding location	Other records
M/OWR	14 Nov 01	27 May 01	9.53	6	W	All at W
WR/OR	15 Nov 04	06 Apr 11	6.47	6	W	All at W
M/Y	14 Nov 06	08 May 11	4.48	4	Coro M	W
WO/M	14 Nov 04	20 Dec 08	4.10	58[(1)]	A	Coro C
M/YWG	15 Nov 91	05 Sep 95	3.81	3	H	Med
GY/MY	25 Oct 92	05 Sep 95	2.89	2	Coro O	K, Med
BW/WG	15 Nov 04	08 Apr 07	2.39	9	W	All at W
OR/M	14 Nov 04	31 Mar 07	2.35	27	A	W
GO/M	14 Nov 04	13 Sep 06	1.83	5	Med	W
M/WRG	15 Nov 91	09 Sep 93	1.82	8	A	W, S.Auck.
M/KR	14 Nov 04	17 Dec 05	1.09	3	Med	Med
OB/M	15 Nov 04	29 Jan 05	0.21	2	W	W
M/GWR	15 Nov 91	01 Jan 92	0.13	2	A	A
Average (s.d., 95% C.L.)			3.16 (2.61, 1.42)			

between Mangawhai and Auckland, the part of the mainland (excluding Coromandel Peninsula) that is closest to the Island. None of these birds has been reported from GBI (JED, *unpubl. data*).

Survivorship

Most mortality was at the egg and chick stages: during the breeding periods from 1991/2 to 2011/12 at Awana *at least* 85 eggs were laid but only 29 – 35 chicks fledged, and so probably < 30% of the eggs laid resulted in a fledgling. As neither the age nor the date of mortality of banded birds is known in most cases, 'survivorship' relates to the time between banding and the last sighting. On this basis, adult survival on GBI was 3.29 ± 2.49 (mean ± standard deviation) years (Table 2). The survivorship curve (Fig. 5) indicates that 50% of the population is likely to be under 3 years of age, and given a total GBI breeding population of *c.* 50 birds, few survive to 10 years. Comparison with birds banded at the same time on beaches north of Auckland (Fig. 6) suggests that adult survivorship of NNZD on GBI is considerably less than on the mainland. The 'minimal survival' data in Fig. 6 are not all the same as those in Table 2. The data in Fig. 6 are derived only from adults banded on the island (and North Auckland), while Table 2 includes immigrants and young birds, and not all were banded on GBI.

Breeding success at Awana

From 1991 to 2012, there was only 1 summer at Awana (1994/95) when no breeding attempt was recorded. At least 1 chick was raised in 14 years (70%), at least 2 in 9 years (40%) and 3 or more in only 4 years (20%). The overall annual productivity at Awana was estimated at 1.17 fledged chicks/pair, with a range between 0.97 and 1.40 (Appendix 2).

Although management since 1999 at Awana has not significantly increased productivity, the most productive years have been since management commenced. Furthermore, 2 pairs (possibly 1 from successful breeding in 2001) have established since 2002/03. In view of the lack of breeding success from 5 attempts in the 2003 and 2004 seasons, DOC reduced its nominal maximum camper numbers from 150 to 100 in 2005/06. Since then there has been attempted nesting every year. Failures (in 2006/07 and 2010/11) have been due to eggs being washed away by high tides, burial by wind-blown sand, or predation by an avian predator (probably southern black-backed gull).

Although, NNZD form monogamous pairs, the Awana breeding pair was apparently 'assisted' by a 'helper'. The male was distinguished by an intense orange breast and abdomen, and the female was WO-M. The helper had a paler orange breast than the breeding male, and was generally chased off by him, especially early in the season. However, it assisted in distracting potential predators. For example, it gave warning calls, and ran and flew about if anyone approached the nesting area or the chicks, and when a harrier flew over it took to the air with the other adult dotterels.

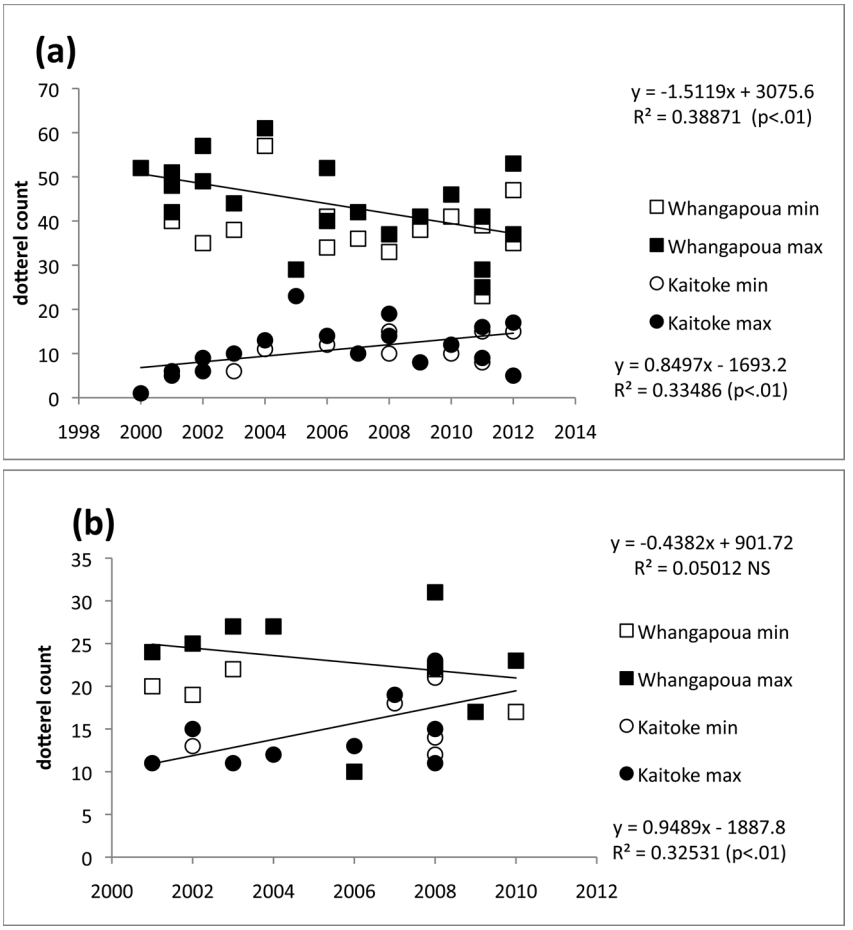

Fig 4. Maximum and minimum counts on Whangapoua and Kaitoke beaches, 2000- 2012. (a) Post-breeding flock counts; (b) breeding season counts. No data available from Kaitoke after 2010 due to access difficulties. Regressions through all data (max. and min.). Equations for each regression given at right. P value for correlation.

Other breeding records and management of NZD on GBI

In the Whangapoua/Okiwi basin, there has been control of feral cats and other predators, and dogs have been banned from the beach since 2000. This was primarily to protect brown teal (pateke, *Anas chlorotis*), but it was expected that NNZD would also benefit from these measures. However, no regular monitoring of breeding success has been carried out at this key site. At Medlands Beach, sporadic monitoring and some public education have been attempted by the Medlands Beach-care Group. In 2002/03, the first clutch, as at Awana, was destroyed by high tides. The next clutch was destroyed by a dog, but the final nesting produced 1 fledged chick in Mar. In 2003/04, a nest at the northern end had eggs predated in Oct, but the pair was reported with 2 chicks in Dec. A second pair had 2 chicks, although only 1 fledged bird was seen. At Kaitoke in 2003, the Kaitoke Ecological Project was initiated by R. Galaboski, involving beach patrols, dog control, cat-trapping and tape fences around dotterel nests. In 2003/04, 7 pairs may have been present at Kaitoke, and although 4 nests were reported destroyed by harriers (M. Galoboski, *pers. comm*.) at least 7 chicks fledged from that beach in 2003–04 and 3 in 2004-05. In 2005-06, 1 nest was used by 2 females and had 5 eggs. Four other nests also had eggs and 3 small chicks were seen, but fledging success was not recorded. The preliminary results from the Kaitoke Ecological Project indicate productivities of 1.0, 0.5 and > 0.5 fledglings in the 3 seasons commencing 2003/04. The productivity of the pair on Palmers Beach averaged *c.* 0.7 over the same years. Flooding, harriers, cats and dogs were all observed causes of mortality. On Palmer's Beach at least 1 chick fledged in each of 2004 and 2005, but in 2005/06, 3 chicks were killed by a dog (S. Gray. *pers. comm*.) and no fledging occurred. Nesting attempts have been made since then, but fledged chicks have not been seen. At Harataonga, a pair had a small chick on 15 Nov 1991, but whether it fledged is unknown. A pair nested successfully in 1994, and nesting was reported in 2003/4, but no

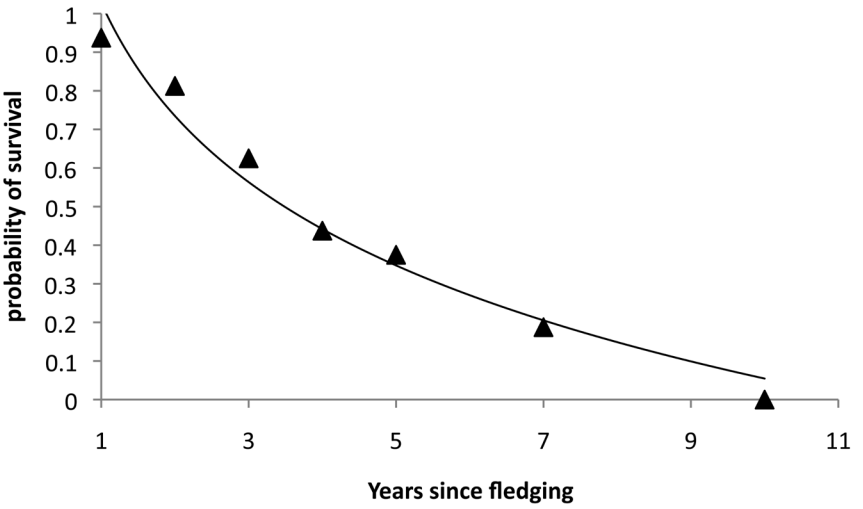

Fig 5. Estimated survivorship curve for banded New Zealand dotterels from banding date to date of last observation on Great Barrier I (includes birds banded on the island and immigrants banded elsewhere). Fitted negative exponential curve $y = -0.423.\ln(x) + 1.0278$ ($R^2 = 0.967$).

birds were seen there by JO on visits in early Dec and Jan. In 2005/06 a pair again nested at Harataonga, producing 3 chicks, 2 of which probably fledged. In 2010/11 a chick was fledged, and 2 in 2011/12. Although birds were sometimes reported from Okupu, no nesting is known to have occurred until 2009/10. This nest, and that in 2010/11, was enclosed by a tape fence, but nesting failed in both years. Disturbance by people and dogs was thought to be the cause (E. Pratt & S. Daly, *pers. comm*.).

DISCUSSION

Our study provides the first estimate of numbers, distribution and breeding success of northern NZ dotterels on Great Barrier I, and provides evidence of bird movements between beaches on the Island, and between Great Barrier and the Coromandel Peninsula.

Population size and distribution

The baseline (breeding season) population has remained roughly stable over the last decade at *c*. 48 birds. This constitutes about 3% of the entire NNZD population and about 12% of the Coromandel and Bay of Plenty subpopulation. The increase in total population in late summer/autumn is assumed to be due to a variable combination of local productivity and movement of juveniles to and from the mainland.

The high number of pairs nesting in 2003/04 (at least 18, and possibly up to 25 pairs nesting) could explain the very high post-breeding count (71-77) in late Mar 2004. However, the possibility that the high counts arise through incorrect identifications cannot be ruled out (Appendix 1, note[2]). The winter aggregation at Whangapoua typically comprises several small dispersed and moving mixed groups of NNZD and banded dotterels (*C. bicinctus*) in non-breeding plumage. Accurately counting the former alone can be difficult. Also, in 2004, at least 4 large sand dotterels (*C. leschenaultii*) in non-breeding plumage were present at Whangapoua on 31 Mar, only 9 days after the NNZD count on 22 Mar. If these birds – or more of them – were present at the time of the count they could easily have been misidentified and inflated the count. These possible sources of error do not apply to the breeding season counts, when the few remaining *C. bicinctus* are clearly distinguished by their summer plumage.

There are few estimates of the island's total NNZD population from before 1990, so determining any longer term trend in population size is impossible. Over the past 2 decades, the breeding-season population appears to have been roughly stable. The post-breeding population (Appendix 1b) has fluctuated considerably but averaged 56 birds. High numbers in some years may reflect higher local productivity, or immigration. Most immigration to GBI is likely to be from Coromandel Peninsula (see above) and management there has also increased. In recent years, there has been intensive management of NZD at Waikawau Bay and at other beaches on the east coast of the Coromandel Peninsula (Dowding 2006). These sites are well within the normal juvenile dispersal distance for the species (Dowding 2001).

Whangapoua Estuary is the most important site for the taxon on the island, holding about 1.4% of the entire NNZD population during the breeding season and about 2.7% in autumn. This makes it a site of international importance for the taxon in terms of the Ramsar Convention (1971). It was also ranked as "Outstanding" wetland habitat and as a "Site of Special Wildlife Interest" (SSWI) by the

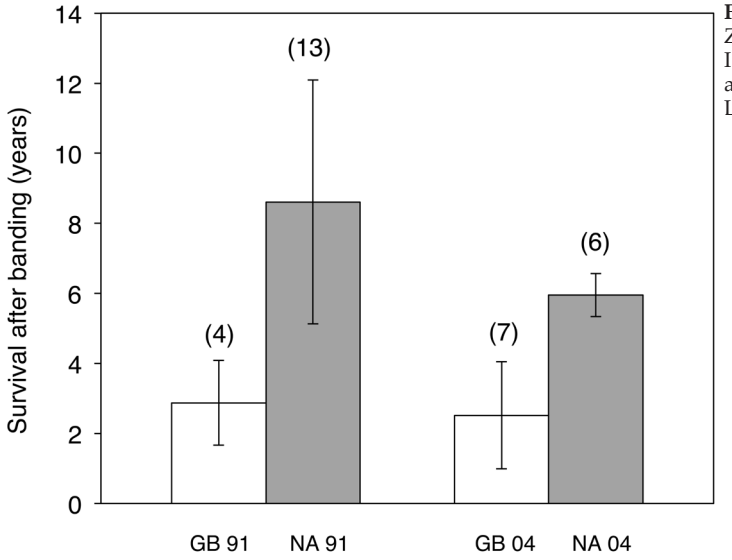

Fig 6. Comparison of survival of adult New Zealand dotterels banded on Great Barrier I (GB) and in North Auckland (NA) in 1991 and 2004. Error bars are 95% Confidence Limits (JED, *unpubl. data*.).

Fauna Survey Unit of the NZ Wildlife Service (Ogle 1980; Cromarty & Scott 1996). However, our results suggest that while the total NNZD population has remained stable, there has been a shift away from Whangapoua, coinciding with an increase on Kaitoke beach. The reasons for this are not known, but the spread of mangroves in the Whangapoua Harbour is slowly reducing the feeding area available to all waders and this could possibly be a factor.

Movement and survivorship

The annual movement patterns observed appear to be very similar to those of NNZD on the North Auckland east coast (Dowding & Chamberlin 1991). In late summer much of the population gathers in a post-breeding flock at Whangapoua, the only large tidal estuary on the island. This flock partially disperses to other east coast breeding beaches in winter and spring (Aug – Oct). However, some birds are found year-round at Kaitoke Beach.

Banding records are relatively few, but the available evidence suggests that NNZD on GBI are part of the Coromandel-Bay of Plenty subpopulation (Dowding 2001). These links to the mainland are not surprising – NNZD are strongly flighted and juveniles in particular have been recorded travelling long distances (Dowding & Murphy 1993; Dowding 2001). However, adult birds in the North Auckland population appear to survive longer than those on Great Barrier I. This finding was unexpected, given the absence of mustelids, which are known predators of adult NNZD on the mainland (Dowding & Murphy 1996).

Conservation

At Awana, the average productivity of >1.0 fledged chicks per pair is high. At unmanaged sites on the mainland productivity averages *c.* 0.25 (Dowding 1998), and levels of 0.5 – 1.0 are typical of managed locations. The absence of mustelids, Norway rats and hedgehogs on GBI may be a factor in the relatively high productivity recorded. As the Awana Beach is unlikely to ever support more than 2 pairs, maintaining a productivity of *c.* 1.0 is a reasonable conservation goal.

All the east coast GBI beaches, except Whangapoua, are being rapidly developed and visited by an increasing number of holiday-makers in summer. For example, at southern Awana the number of holiday homes has increased from 6 in 1991 to 18 in 2011. With the rapid growth of tourism over the same time period, 'people hours' on the beach during the breeding season was estimated to have increased at least 3-fold at Awana. Using the criteria of Lord *et al.* (2001), the beach and estuary at Awana would be classified as 'busy' during the period from *c.* Christmas to the end of Jan, and Medlands would be so classified for a longer period.

The key to success for the birds at Awana and Medlands seems to have been starting early (eggs in Sep or Oct). Late nests, or second attempts, are more likely to fail as the chicks coincide with the period of maximum dune, estuary and beach use by people and dogs (late Dec - early Jan). In this context the second successful brood at Awana in 2001/02 is notable. Regular beach patrols, tape fencing, and local publicity are probably crucial for the success of later nests, especially at popular beaches such as Medlands.

Feral cats are present on all the beaches. Although studies of gut contents in the Okiwi basin (D. Barker, *pers comm.* 2004) indicate that

mammals (especially rabbits, *Oryctolagus cuniculus*) are the main item of food, this does not mean that NNZD are not impacted. Prints close to a variable oystercatcher (*Haematopus unicolor*) nest at Awana in 2004 demonstrated that a cat had been driven off by the birds. A tendency for NNZD to nest in close proximity to oystercatchers, noted by JO at Awana and M. Galoboski (*pers comm*.) at Kaitoke, might confer some advantage to the former.

The NNZD is widely and thinly spread over most of its range. Management of more than a few important sites is therefore beyond the resources of DOC (Dowding & Davis 2007). Community initiatives, such as those at Awana and Medlands, are increasingly important in the recovery of the taxon and need to continue. Whangapoua has been identified in the NNZD Recovery Plan as the top priority site for management by DOC in Auckland Conservancy (Dowding & Davis 2007). Predator control is seen as the single most important action. However, the results discussed here indicate that the GBI dotterel population fluctuates about a relatively stable mean value, suggesting that it may be at, or close to, carrying capacity. If this is so, it might be determined by the number of suitable territories, or by some limiting aspect of food supply. With the exception of the Okiwi spit, territories seem to be centred on areas where fresh-water streams enter the sea, backed by dunes. There are only *c.* 12 such situations on GBI. The extensive silt flats at Whangapoua support a variety of other bird species, so it is possible that competition for food in winter is a limiting factor. The rapid spread of mangroves on the estuary (Ogden *et al*. 2006) may be a factor to consider in view of the apparent shift of the post-breeding population from Whangapoua to Kaitoke.

While the counts suggest that numbers of NNZD are stable on GBI beaches, we have insufficient data to determine whether the island's population is self-sustaining. The population's stability may be more apparent than real if it is being boosted by regular immigration from Coromandel Peninsula. Predator control (particularly targeting cats) seems necessary, given the apparently low survival of adult NNZD we recorded. Continued active surveillance by beach-care groups, DOC, and/or others, is also warranted. The practice of 'taping off' nesting areas and posting informative and dog-control notices seems essential. At Awana the campground is close to the dotterel nesting area, and is clearly a source of risk to the birds. Although closing this early in the season (Sep – mid-Dec) would probably give the early nesting birds a better chance of success, this may not be warranted at present. A policy of camper education by an informed camp warden would be a better solution.

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Appendix 1. Counts of New Zealand dotterels on Great Barrier I. Where number of breeding pairs was estimated this is given in square brackets. W, Whangapoua and Okiwi Spit; H, Harataonga; A, Awana: K, Kaitoke including Palmer's beach except where separate figures are given. M, Medlands. A - indicates no count. Notes: [1]Count not made at high water, probably an under-estimate. [2] Data questioned, see text. [3]. Semi-independent DOC total = 55. [4]. Semi-independent DOC total = 74. [5] Means and ranges from this study only. Sources: *1*, Davenport & Heather (1952). *2*, Bell & Braithwait (1964). *3*, D. Merton, *pers comm. 4*, Unpublished National Census. *5*, John E. Dowding, unpublished data. *6*, Unpublished records from Departtment of Conservation, GBI Area Office files (H. Jamieson, *pers. comm.*). *7*, T. Greene, *pers comm. 8*, Parrish & Lock (1996). *9*, Ogle, 1980. *10*, Unpublished OSNZ survey.

1a. Breeding season counts (Aug - Jan)

	W	H	A	K	P	M	Totals	Source
21 Nov 1950				> 12				*1*
Dec 1960	20-30	-	-	7 [3]		-		*2*
15-16 Oct 1965	[8+]			[6]				*3*
Oct 1989	17[1]	-	3	2		4	26[1]	*4*
13-15 Nov 1991	17 [8]	4 [2]	3 [1-2]	8 [3]		4 [1-2]	36 [15-17]	*5*
07-09 Sep 1993	34	2	4	12			52	*6*
19 Oct 1994	36	2						*7*
24 Nov 1994	[6]							*8*
Oct 1996	38	2	4	7		4	55	*4*
18-23 Oct 2001	20-24	-	3-5	11	3	4	41-47	this study
20-21 Jan 2002	19-25	-	4-7	13-15	2	2	40-51	this study
29-30 Nov 2003	22-27	0	4-5	11	4-5	4 - 6	45-54	this study
20 Oct 2004	27	0	4	12	5	3-6	51-54	this study
25-29 Dec 2006	10	2	4	13	4	7	40	this study
24 Jan 2007	-	-	-	18-19	-	-		this study
3-5 Jan 2008	22-31	0	2-5	21-23	1	2-4	48-64	this study
17 Jan 2008	-	-	3	12-15	-	-		this study

Appendix 1. Continued.

2 Aug 2008	-	-	4	11	4	-		this study
3 Sep 2008	-	-	-	14-22	-	-		this study
7 Dec 2009	17		7					this study
1-3 Oct 2010	17-23	2	4	-	2	-		this study
Mean (range)[5]	21(10-31)	1(0-2)	4(2-7)	14 (11-23)	3 (1-5)	4 (2-7)	48 (41-64)	this study

1b. Post-breeding (Feb - Apr).

	W	H	AA	K	P	M	Totals	Source
28 Mar & 12 Apr 1980	>30							*9*
17 Mar 1990	23[1]	2	3	3		-		*4*
28 Mar 1995	31	0	3	0		0		*6*
26 Feb 1995	26	2	3	8		0		*6*
22 Apr 1995	44	0	-	0		0	44	*6*
28 Feb 1997	51	0	0	5		0	56	*4*
12 Feb 1998	34	0	-	-		-		*6*
01 Apr 1998	58[2]	0	0	33[2]		0	91[2]	*6*
12 Apr 1998	53			5			58	*10*
Mar 1999	61	-	0	3		4	68	*6*
Mar 2000	52	-	0	1		1	54	*6*
26 Mar - 01 Apr 2000	40-50	-	0	5	0	0	45-55	this study
Mar 2001	48	-	0	5		0	53	*6*
09 Apr 2001	51	-	-	5		0	56	*10*
08-18 Apr 2001	42	-	0	6	2	0	42-50	this study
16 Mar 2002	57	-	2	9		2	70	*6*
05-07 Apr 2002	35-49	-	3	6	0	3	47-61	this study
21-22 Mar 2003	38-44	0	0	6-10	2	0	46-56[3]	this study
22 Mar 2004	57-61	0	0	11-13	2	1	71-77[4]	this study
11 Apr 2005	29	-	0	23		0	52	*6*
04-05 Mar 2006	41-52	-	0	12-14	0	0	53-66	this study
03 Apr 2006	34-40	-	0	12-14	-	-	46-54	this study
21 Mar 2007	36-42	-	0	10	2	0	48-54	this study
10 Mar 2008	33-37	-	0	14-10	5	0	48-56	this study
7 Apr 2008	-	-	0	15-19	-	-	-	this study
29 Mar 2009	38-41	-	0	8	0	0	46 - 49	this study
2 Apr 2010	41-46	-	0	10-12	0	-	51- 58	this study
20 Feb 2011	23-25	-	0	-	-	-		this study
24-25 Mar 2011	23-29	0	0	15-16	0	3	41-48	this study
6-7 Apr 2011	39-41	0	0	8-9	0	5	52- 55	this study
16-17 Feb 2012	35-37	2	0	15-17	0	3	54-59	this study
23 Mar 2012	47-53	-	0	5	0	4	56-62	this study
Mean (range)[5]	42 (23-61)	0 (0-2)	0 (0-3)	9 (5-17)	1 (0-2)	1 (0-5)	56 (41-77)	this study

1c. Winter (May - Jul)

	W	H	A	K	P	M	Totals	Source
Jun 1957	16-20 [8-10]							*2*
21 Jun 1992	15							*6*
26-27 May 2001	36	-	2	10-12	0	0	48-50	this study
13-16 Jun 2002	28-33	-	2-7	10	2-7	4	47-61	this study
15 May 2005	44-56	-	0	9-12	0	1	54-68	this study
19 May 2005	-	-	-	14	-	-	-	this study
8 Jun 2009	-	-	-	10	1	-	-	this study
9 May 2011	35-38							
Mean (range)[5]	38 (28-56)	-	3 (0-7)	11 (9-14)	3 (0-7)	2 (0-4)	55 (47-68)	this study

Appendix 2. Maximum number of adults recorded together, fledging success and productivity of New Zealand dotterels at Awana, Great Barrier I, 1991/92 – 2010/11. Notes: [(1)] Observations ceased at this date. [(2)] Probably 3, observations inadequate. [(3)] Female of successful pair was WO-M. [(4)] A pair with WO-M, another with OR-M. [(5)] M-WRG present Sep 1993.

Breeding season	Adults	Pairs attempting to breed	Chicks fledged	Eggs laid	Notes
1991/92	3	1	1	Sep-Oct	Chick just flying 15 Nov 1991 (JD)
1992/93	5	1	3	Oct	No observations before Dec 92 3 fledged juvs present 28/12/1992
1993/94	5	1[(5)]	1-3	Oct	Definitely 1 fledged, possible that other 2 were 'visitors'.
1994/95	2	0	0		Probably no breeding attempted.
1995/96	3	1	0-1	Oct-Nov	Chick still not flying - Jan 15[(1)]
1996/97	2	1	0	?Oct	No chicks seen.
1997/98	6	1-2	2	Sep-Oct	Unfledged chicks not seen
1998/99	6	1-2	1	Sep-Oct	Unfledged chicks not seen.
1999/00	5	1	1	Jan	Second breeding attempt.
2000/01	4	1	3	Oct	No second breeding attempt
2001/02	6	1	2 2	Nov Jan	Second brood laid as soon as first brood fledged.
2002/03	7	2	0 0	Nov Dec	Eggs destroyed by tide. 3 chicks failed to fledge
2003/04	7	2	0 0 0	Oct Dec Jan	Nest destroyed by vehicle Eggs disappeared 1 egg only, destroyed by tide.
2004/05	7	1-2	3	Nov	Apparently 2 pairs but only 1 certain nesting attempt.[(3)]
2005/06	7	1-2	2-3[(2)]	Sep	Apparently 2 pairs but only 1 certain nesting attempt.[(3)]

Appendix 2. Continued.

2006/07	6	2	0 0	Oct Dec	2 pairs [4] attempted nesting. Possibly 3 attempts in total. Eggs in Dec. nest destroyed by avian predator (probably black-backed gull) .
2007/08	5	1	2-3	Oct	Fledged late Dec. 2007[3].
2008/09	5	2	1 0	Sep Dec	WO/M disappeared in Oct 2008. Dec. nest destroyed by storm.
2009/10	7	2	0 2 1-2	Nov Nov Dec	2 eggs. Deserted. Buried by sand. 3 eggs, 2 hatched & fledged 3 eggs hatched
2010/11	5	1	0	Dec	3 eggs. Eggs disappeared in Dec.
2011/12	5	1-2	2	Nov	1 nest, 3 eggs, 1 unhatched.
Average estimates	5.1	1.3 25-30 pair-years	1.5 29-35 fledged	Oct Sep-Jan	Mean productivity = 1.17 Range = 0.97 - 1.40 (Range based on max. and min. pair years and max. and min. no. fledged.)