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Post-moult dispersal of Australasian shoveler (*Anas rhynchotis*) within New Zealand

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Abstract Dispersal of adult Australasian shovelers *Anas rhynchotis* in New Zealand after being banded during their annual moult was determined from the locations at which they were shot by hunters. Birds banded at 2 southern South Island and 2 North Island sites between 1972 and 1986 dispersed the length and breadth of New Zealand. Some shoveler were recovered within 90 days of banding at opposite ends of the country from their banding sites. There was no obvious pattern to the recoveries. Birds were recovered from most of New Zealand's large lowland and coastal wetlands except from West Coast, South Island. Modal recovery distances for shoveler banded at Lake Whangape, northern North Island, and recovered in their year of banding or in later years were 201-400 km. For shoveler banded in southern South Island, modal recovery distances were 0-100 km in the year-of-banding and 101-200 km in later years. Birds banded while moulting or breeding at or near the southern-most banding site were later recaptured moulting at the northern-most. Shoveler disperse more widely than other New Zealand waterfowl species and can be viewed as comprising a single national population.

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INTRODUCTION

In most species of waterfowl (Family Anatidae), cessation of nesting and parental care is followed immediately by a period of moult during which all feathers are shed and replaced. Although the replacement of body feathers may extend over several months, and, in sexually and seasonally dichromatic species, may even occur twice before the onset of the next breeding season, wing feathers are shed simultaneously and replaced rapidly. Simultaneous shedding of wing feathers, thereby making individuals flightless, is rare in birds, occurring in only 11 families, all but one of

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which are aquatic or swampland inhabitants (Hohman *et al.* 1992). In waterfowl, spectacularly large flocks of moulting geese (Anserini), shelducks and sheldgeese (Tandornini), and ducks (Anatini, Aythyini) frequent traditional sites annually with attending individuals often travelling great distances from their breeding sites in what has become termed a moult migration (Salomonsen 1968). Evidence of individual fidelity to moulting sites is accumulating for many species (Williams 1979; Hohman *et al.* 1992).

Amongst waterfowl resident in New Zealand, conspicuous moulting flocks of paradise shelduck (*Tadorna variegata*), black swan (*Cygnus atratus*), Canada goose (*Branta canadensis*), and mallard (*Anas platyrhynchos*) have been recorded (Williams 1979, 1981a,b), and moulting is suspected within flocks of scaup (*Aythya novaeseelandiae*) which form in late summer (Marchant & Higgins 1990). Although Australasian shoveler (*Anas rhynchotis*) are now known to moult communally also (Williams 1981b), this was unknown until an aggregation of moulting birds was discovered by R.R. Sutton at Waituna Lagoon near Invercargill in 1971. Even today, flocks of moulting shoveler are seldom reported. Known moulting sites are characterised by their remoteness and lack of human disturbance, and by dense, emergent vegetation – such as *Carex secta*, flax (*Phormium tenax*), and wire rush (*Empodisma minor*) at Waituna Lagoon, raupo (*Typha orientalis*) and *C. secta* at Ram Island Lagoon in Otago, willow (*Salix fragilis*) at Lake Whangape in Waikato, and willow, raupo, and *C. secta* at Lindsay Lakes in Hawkes Bay – at the wetlandmargins into which birds escape when disturbed.

The nature and extent of dispersal of communally moulting waterfowl following completion of their wing moult appears largely determined by the availability of quality food throughout the winter period. Nearctic and Palaearctic waterfowl undertake the well-documented southern migrations to milder climate zones (Hochbaum 1955; Bellrose 1968; Salomonsen 1968) but even temperate zone species, especially those which do not maintain year-round pair bonds, show changes in habitat use between breeding and non-breeding periods that necessitate extensive local movement (Hohman *et al.* 1992: Appendix 5.3). Australian waterfowl have been described as showing "random dispersal" during the post-breeding period (Frith 1977), but movements for many species appear more deliberate and in response to rain-induced changes in habitat and food availability (Lavery 1970; Norman 1970, 1971a,b ; Marchant & Higgins 1990), just as they are in southern Africa (Siegfreid 1970).

Within New Zealand, movements of black swan, Canada goose, paradise shelduck, mallard, grey duck (*A. superciliosa*), and grey teal (*A. gracilis*) away from their communal moulting sites, or sites of seasonal abundance, have been determined from the return of bands on birds shot by hunters (Balham & Miers 1959; Mills 1976; Williams 1977, 1979, 1981a). Sampling is thus restricted to the gamebird hunting season (May-June) and limited to sites at which hunting is permitted. With the exception of grey teal (Mills 1976), these species all show limited dispersal during the initial 3-4 months between banding and hunting, indicating that their moulting sites provide habitat for prolonged residency during winter months. On the other hand, early analyses of shoveler band returns (Caithness 1975) suggested that shoveler undertook more extensive movements than had been recorded for other hunted waterfowl species in New Zealand.

In this paper, we use the return of bands from birds shot by hunters to appraise: (1) the extent of dispersal of adult shoveler following their annual moult at 4 localities in New Zealand; and (2) the general distribution of shoveler throughout New Zealand.

STUDY AREA AND METHODS

Moulting adult Australasian shoveler were banded during January or February or both at 4 sites during the period 1972 to 1986 (Fig. 1, Table 1). A total of 3473 (2402 ♂, 1071 ♀) shoveler was banded, and by 31 December 2000, 726 recoveries had been reported to the Bird Banding Office, presently maintained by the Department of Conservation. Nine birds were reported 10 or 11 years after banding, but none longer, and all the banded cohorts are now considered to be extinct. A further 75 birds were recaptured at banding sites up to 6 years after initial banding.

The flightless shoveler were captured by trained dogs (Fig. 2A) in the swampy margins of Waituna Lagoon in Southland, Ram Island Lagoon (part of the Lake Waihola wetland complex) in Otago, and in Hawkes Bay on 3 small wetlands known locally as Lindsay Lakes. Annual samples of 40-60 birds represented long and difficult hours of field effort. At Lake Whangape, canoes and boats were used to herd birds through the margin of willow trees along the Awarua Stream and thence up the stream to a pen constructed on the stream's bank. In 1 herding, in 1981, almost 700 shoveler were penned (Fig. 2B,C). All shoveler were sexed by cloacal examination (Larson & Taber 1980) and banded with a numbered stainless steel band bearing a return address.

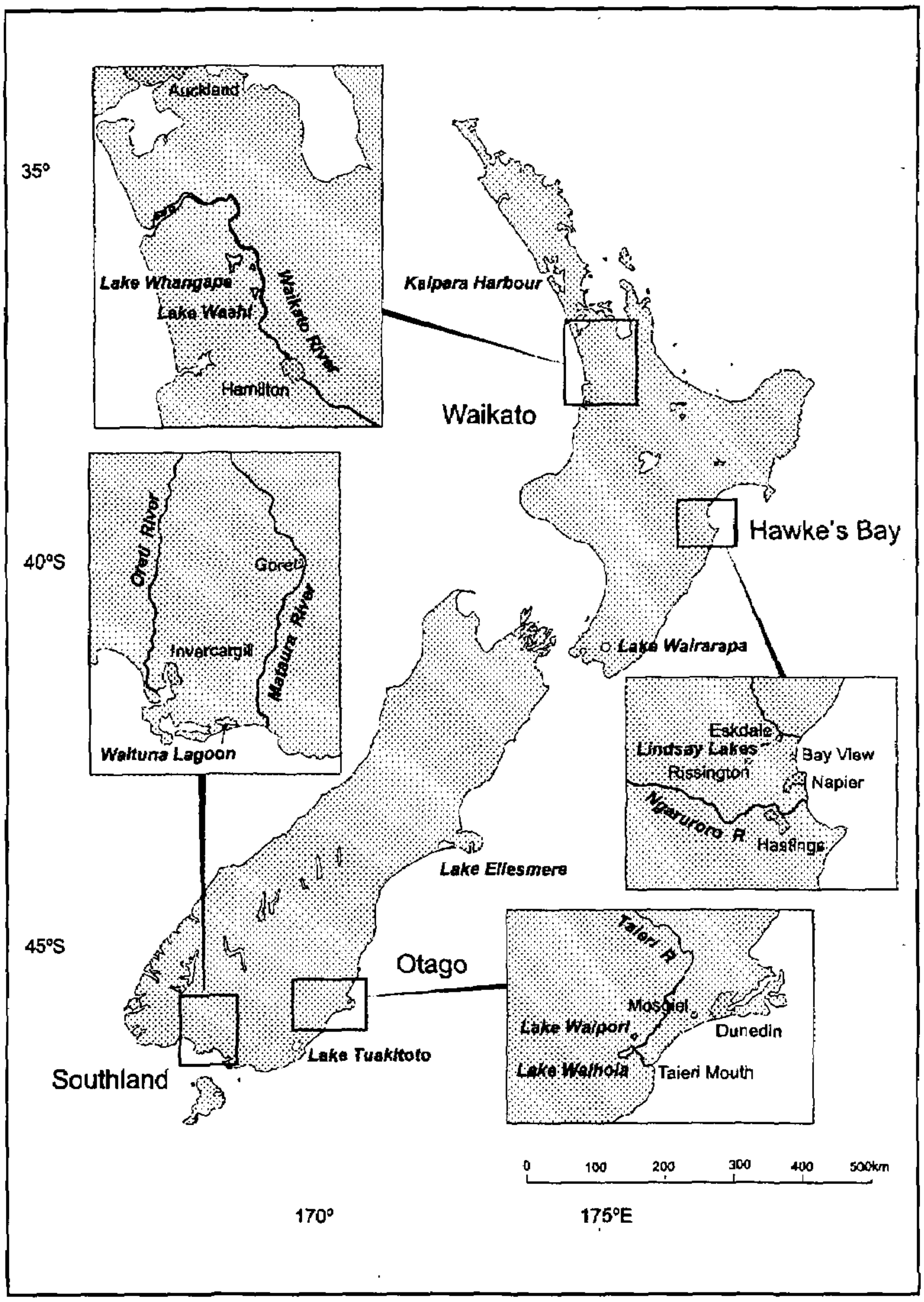

Fig. 1 Location of sites at which Australasian shoveler (*Anas rhynchotis*) were banded in New Zealand 1972-1986, and principal sites of recovery.

Shoveler were shot by hunters during the annual gamebird hunting season in May and June. Bands returned to the banding office were recorded in the banding scheme's files together with date of recovery (as reported by the hunter) and location of recovery. Location was recorded to the nearest 10' of latitude and longitude, thus describing an area of 217-296 km^2 (depending upon latitude). To assist initial interpretation of distribution, the recorded location of recovery of every bird was plotted onto maps of New Zealand, on which a 10' latitude × 10' longitude grid had been drawn. Distribution frequency tables (Tables 2-5) were constructed by drawing on these maps, consecutive arcs at 100 km intervals from the banding site and counting the number of recoveries in each grid square where >50% of the square's area lay within the interval between successive arcs.

Recovery data from each site were split into 2 sub-sets based upon the time of recovery after banding: year-of-banding (y-o-b) comprising birds shot in the gamebird hunting season 3-5 months following banding, and "later" (all other recoveries). The y-o-b recoveries provide a description of the extent of shoveler dispersal during the immediate post-moult period. For birds recovered in later years, unless they were recaptured at breeding or moulting sites in any year after initial banding, and then subsequently

Fig. 2 Capture techniques: **A**, "Meg" with 1 of the 300 moulting adult and fledgling Australasian shoveler (*Anas rhynchotis*) she captured at Waituna Lagoon and other wetlands in Southland (Photo: R.R. Sutton); **B,C**, Moulting adult shoveler penned and being banded at Lake Whangape, January, 1981 following a successful herding (Photos: I. McFadden).

shot, there are no complementary data to indicate the nature and extent of movements between banding and death.

RESULTS

Recoveries of shoveler banded at Waituna Lagoon, Southland

Of 65 recoveries reported by hunters, 23 were obtained in the gamebird hunting season immediately following banding (y-o-b) and the remainder in subsequent years extending to the 8th year. The locations of recoveries are illustrated in Fig. 3A. Relative to the number banded, significantly more males (28.9%) than females (13.9%) were recovered overall (χ^2 = 9.03, *df* =1, 0.01 > *P* > 0.001). Although a higher percentage of total recoveries was made in the y-o-b for females (47.1%) than for males (31.3%), this difference is not significant (χ^2 = 1.37, *df* = 1, 0.3 > *P* > 0.2).

Distribution of year-of-banding recoveries

The locations at which banded shoveler were shot 3-5 months after banding are illustrated in Fig. 3B. Of 23 y-o-b recoveries, 9 (39%) were at Waituna Lagoon, and all but 4 of the remainder were within 200 km of the banding site (Table 2). Three y-o-b recoveries, all males, were from North Island – 1 each from Lake Wairarapa, Lake Whangape and Sweetwater Lake near Kaitaia. The latter recovery was 92 days after banding and 1350 km from the banding site. The most distant y-o-b recovery of a female was *c.* 250 km from Waituna

Table 1 Name and location of Australasian shoveler (*Anas rhynchotis*) banding sites, years during which banding occurred, total numbers banded and (in parentheses) recovered by hunters. *, total (includes 29 captured attending ducklings); **, no banding in 1980 and 1983.

Banding site	Location	Years	No. of birds banded Males	Females
Waituna Lagoon	46° 34'S 168° 35'E	1972-79	166 (48)	122 * (17)
Ram Island Lagoon	45° 59'S 170° 06'E	1972-79	174 (31)	232 (35)
Hawkes Bay	39° 24'S 176° 46'E	1984-86	117 (20)	40 (8)
Lake Whangape	37° 28'S 175° 04'E	1978-85**	1945 (449)	677 (118)

Table 2 Numbers of banded Australasian shoveler (*Anas rhynchotis*) shot at different distances from their banding site (Waituna Lagoon, Southland) in their year-of-banding (y-o-b) and in all later years combined (Later).

		Distance from banding site (km)						
	Sex (*n*)	0-100	101-200	201-400	401-600	601-800	801-1000	>1000
y-o-b	Male (15)	9	3	0	0	0	1	2
	Female (8)	6	1	1	0	0	0	0
Later	Male (33)	14	6	1	4	0	2	6
	Female (9)	6	3	0	0	0	0	0

Table 3 Numbers of banded Australasian shoveler (*Anas rhynchotis*) shot at different distances from their banding site (Ram Island Lagoon, Otago) in their year-of-banding (y-o-b) and in all later years combined (Later).

		Distance from banding site (km)						
	Sex (*n*)	0-100	101-200	201-400	401-600	601-800	801-1000	>1000
y-o-b	Male (18)	10	5	0	0	0	2	2
	Female (25)	19	5	0	0	0	1	0
Later	Male (13)	2	5	5	0	0	0	1
	Female (10)	1	2	2	0	1	3	1

Table 4 Numbers of banded Australasian shoveler (*Anas rhynchotis*) shot at different distances from the banding site (Hawkes Bay) in their year-of-banding (y-o-b) and in all later years combined (Later).

		Distance from banding site (km)						
	Sex (*n*)	0-100	101-200	201-400	401-600	601-800	801-1000	>1000
y-o-b	Male (8)	1	1	3	0	0	1	2
	Female (3)	3	0	0	0	0	0	0
Later	Male (12)	4	2	2	0	0	1	3
	Female (5)	3	1	0	0	0	0	1

Table 5 Numbers of banded Australasian shoveler (*Anas rhynchotis*) shot at different distances from their banding site (Lake Whangape) in their year-of-banding (y-o-b) and in all later years combined (Later).

		Distance from banding site (km)						
	Sex (*n*)	0-100	101-200	201-400	401-600	601-800	801-1000	>1000
y-o-b	Male (125)	18	29	33	11	16	7	11
	Female (48)	11	8	11	5	6	1	6
Later	Male (324)	49	45	75	29	34	27	65
	Female (70)	15	10	12	7	6	11	9

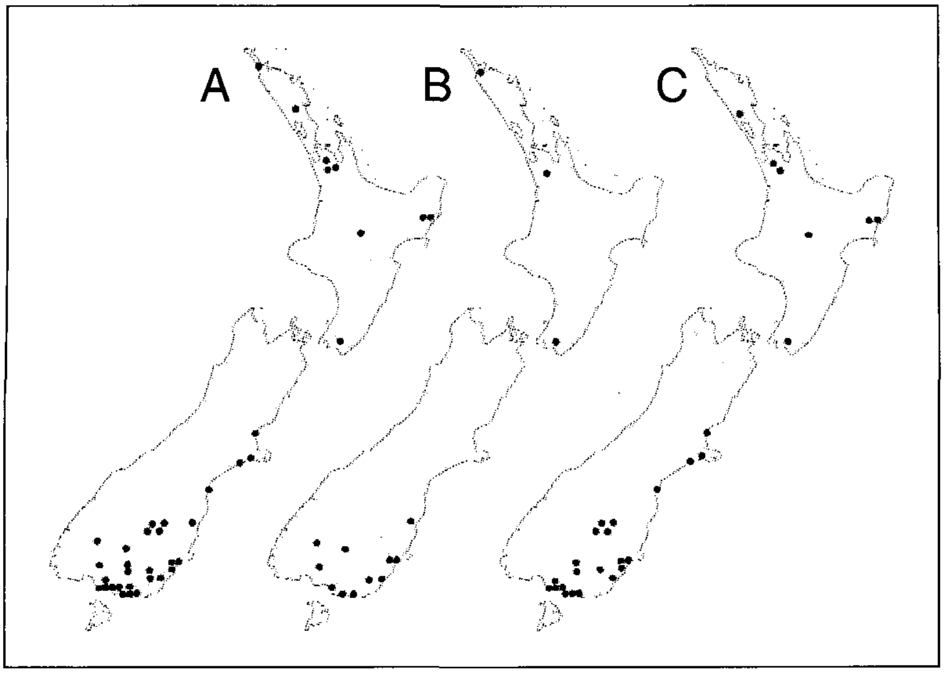

Fig. 3 Locations (10' × 10' latitude-longitude squares) in which adult Australasian shoveler (*Anas rhynchotis*), banded at Waituna Lagoon, Southland, 1972-79, were recovered: **A**, all recoveries; **B**, recoveries made in the year-of-banding; **C**, recoveries made 1 or more years after banding.

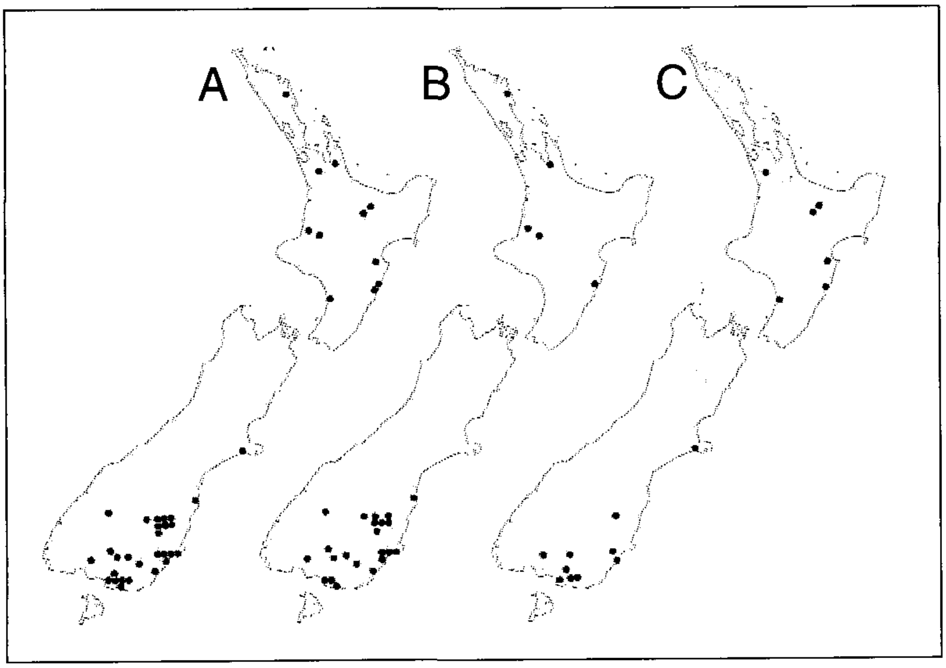

Fig. 4 Locations (10' × 10' latitude-longitude squares) in which adult Australasian shoveler (*Anas rhynchotis*), banded at Ram Island Lagoon, Otago, 1972-79, were recovered: **A**, all recoveries; **B**, recoveries made in the year-of-banding; **C**, recoveries made 1 or more years after banding.

Lagoon near Oamaru. The recovery distributions of males and females were not significantly different (Fisher exact test, $P = 0.63$).

Distribution of recoveries from 1 or more years after banding

Most of the 42 recoveries were obtained from wetlands on the Southland plains and at or near Lake Tuakitoto in coastal south Otago (Fig. 3C). All recoveries of females and 60% of the recoveries of males were within 200 km of the banding site, a pattern similar to that for y-o-b recoveries. All recoveries made north of latitude 44°S, about 350 km distant from the banding site, were of males. Eight recoveries were from North Island – 2 at Lake Wairarapa and 6 more than 1000 km distant from Waituna Lagoon (Table 2). These latter recoveries were from the Poverty Bay flats near Gisborne, Lake Taupo, lower Waikato River, and Kaipara Harbour. The recovery distributions of males and females did not differ significantly (Fisher exact test, $P = 0.51$). Combining data for both sexes, the y-o-b and later distributions were not significantly different (Fisher exact test, $P = 0.61$).

Recoveries of shoveler banded at Ram Island Lagoon, Otago

Of 66 recoveries reported, 43 were obtained in the gamebird hunting season immediately following banding (y-o-b) and the remainder in subsequent years extending to the 6th year. The locations of recoveries are illustrated in Fig. 4A. Similar proportions of males (17.8%) and females (15.1%) banded were recovered overall, and there was no significant difference in the proportions of males and females recovered in the year of banding ($\chi^2 = 1.29$, $df = 1$, $0.3 > P > 0.2$).

Distribution of year-of-banding recoveries

Most shoveler recovered within 3-5 months after banding were shot on wetlands close to their banding site (Table 3). Twelve (28%) of the y-o-b recoveries were from Ram Island Lagoon itself and another 21% on wetlands within 15 km distance. Two-thirds of the total y-o-b recoveries were within 100 km of the banding site and although a high proportion of the total female recoveries (76%) were made within this area, it was not significantly higher than for males (56%, $\chi^2 = 1.99$, $df = 1$, $0.2 > P > 0.1$) . Four males and 1 female were shot in North Island (Fig. 4B), the most distant recovery from Hikurangi in Northland occurring 90 days after banding. The recovery distributions of males and females were not significantly different (Fisher exact test, $P = 0.25$).

Distribution of recoveries from 1 or more years after banding

Later recoveries were, as with those made in the y-o-b, concentrated in the Otago-Southland region (Table 3, Fig. 4C) with most made in the lower Southland plains. From beyond this area 7 recoveries were from Lake Ellesmere and 6 from North Island. The recovery distributions of males and females were not significantly different (Fisher exact test, $P=0.29$) even though, and in contrast to y-o-b recoveries, all but 1 of the more distant recoveries were females.

Combining data for both sexes, the y-o-b and later recovery distributions were significantly different (Fisher exact test, $P = 0.001$) with the later recoveries being the more distant.

Recoveries of shoveler banded in Hawkes Bay

Of 28 recoveries reported, 11 were obtained in the y–o-b, 14 within the next 2 years and one each in the 5th, 10th, and 11th year. Similar proportions of the males and females banded were recovered.

Recoveries were widely dispersed (Fig. 5). In the y-o-b, 1 male was shot on the shores of Kaipara Harbour in Northland, 2 at Lake Wairarapa and 3 in the southern half of South Island, the most distant being at Waituna Lagoon. All 3 females were shot close to the banding site.

Fig. 5 Locations (10' × 10' latitude-longitude squares) in which adult Australasian shoveler (*Anas rhynchotis*), banded in Hawkes Bay, 1984-86, were recovered.

Recoveries in later years were either local or from south of Hawkes Bay and included 6 from South Island. Males dispersed to greater distances (Table 4) and only 1 female was recovered from South Island.

Recoveries of shoveler banded at Lake Whangape, Waikato

Of 567 recoveries reported, 173 were obtained in the gamebird hunting season immediately following banding (y-o-b) and the remainder in subsequent years extending to the 11th year. The locations of all recoveries are illustrated in Fig. 6A (females) and Fig. 7A (males). Relative to the numbers banded, a significantly higher proportion of males (23.1%) than females (17.4%) were recovered ($\chi^2 = 9.47$, $df = 1$, $0.01 > P > 0.001$), but significantly more of the female recoveries occurred in the y-o-b (females 40.7%, males 27.8%; $\chi^2 = 7.26$, $df = 1$, $0.01 > P > 0.001$).

Distribution of year-of-banding recoveries

Recoveries were widespread (Fig. 6B, 7B) with *c.* 30% of both male and female recoveries being in the South Island. Seventeen recoveries (6 ♂♂, 11 ♀♀) were from south of Dunedin and the most distant recovery was from Waituna Lagoon, 1155 km from Lake Whangape. The most northern

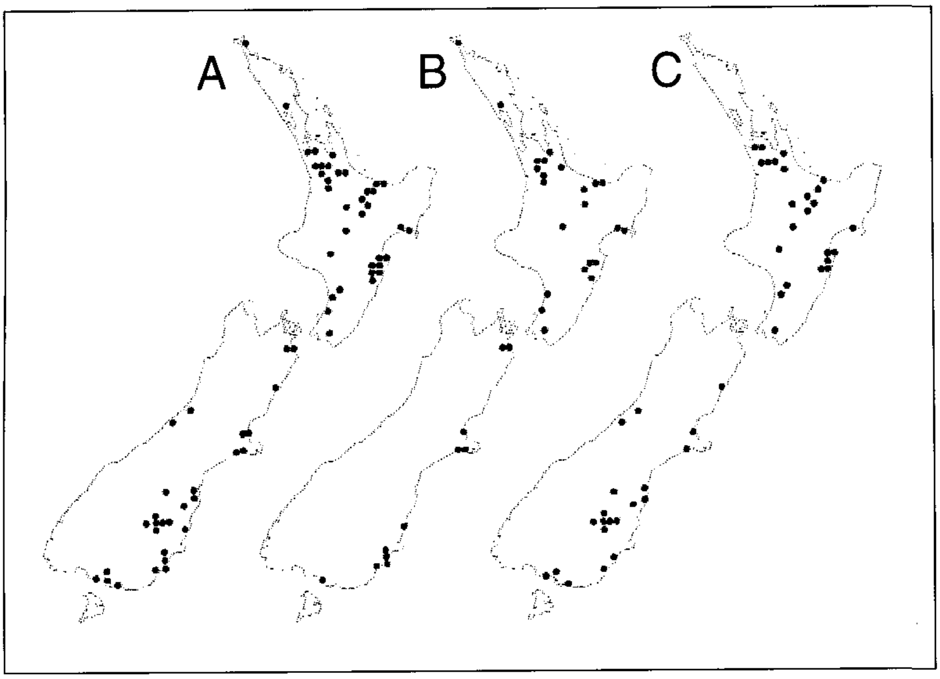

Fig. 6 Locations (10' × 10' latitude-longitude squares) in which adult female Australasian shoveler (*Anas rhynchotis*), banded at Lake Whangape, 1978-85, were recovered: **A**, all recoveries; **B**, recoveries made in the year-of-banding; **C**, recoveries made 1 or more years after banding.

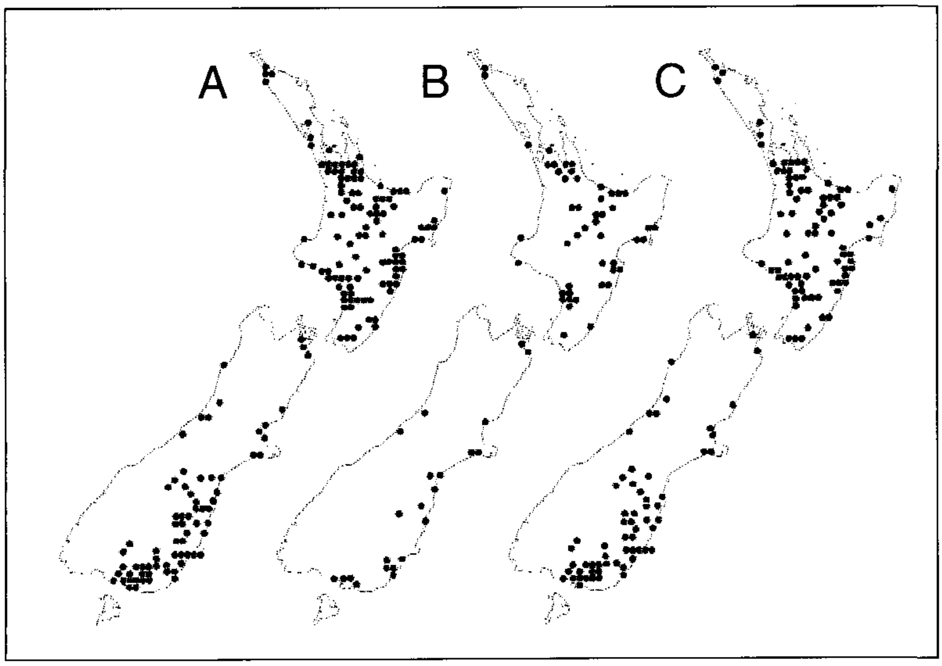

Fig. 7 Locations (10' × 10' latitude-longitude squares) in which adult male Australasian shoveler (*Anas rhynchotis*), banded at Lake Whangape, 1978-85, were recovered: **A**, all recoveries; **B**, recoveries made in the year-of-banding; **C**, recoveries made 1 or more years after banding.

recovery was from Lake Wahakari near Te Kao at the base of Parengarenga Harbour, 375 km from Lake Whangape.

There was no difference in the overall distribution of distances from Lake Whangape at which males and females were recovered (Table 5) (χ^2 = 3.93, df = 6, 0.7 > P > 0.5) and for both sexes. 40% of recoveries were made within 200 km of the banding site.

Distribution of recoveries: 1 or more years after banding
Recoveries ranged from the tip of North Island to the very south of South Island (Fig. 6C, 7C) and with almost 40% of both male and female recoveries occurring in South Island. Lakes Wairarapa and Ellesmere were recovery "hotspots", each being the locality of more than 30 recoveries. Although the recovery distribution frequencies of males and females (Table 5) were not significantly different (χ^2 = 7.7, df = 6, 0.3 > P > 0.2), proportionately fewer males were recovered close to the banding site and more beyond 1000 km from Lake Whangape.

When data for both sexes were combined, y-o-b and later recovery distributions were significantly different (χ^2 = 15.2, df = 6, P = 0.02) because of the higher percentage of later recoveries being made at distant locations.

Live recaptures

Repeat capture of moulting birds at the same sites in consecutive years resulted in 75 banded birds being recaptured. At Ram Island Lagoon, 3 females previously banded there were recaptured together with 2 females previously banded at Waituna Lagoon. Of 68 recaptures at Lake Whangape, all but 5 had been banded there previously, including 46 (38 male, 8 female) recaptures from the large 1981 cohort. The other 5 recaptures comprised 2 adults originally caught moulting at Waituna Lagoon 1 and 6 years previously, 1 from Ram Island Lagoon, and a male and female originally caught, 5 and 6 years previously, respectively, at breeding sites near Invercargill airport. At Waituna Lagoon, 2 females originally banded at the lagoon were recaptured there 1 and 2 years later.

Both Waituna Lagoon recaptures were later shot, 1 at *c.* 50 km from the lagoon and the other at Lake Taupo in the North Island. Ten of the Lake Whangape recaptures were shot later including 5 in the Otago-Southland region, 2 at Lake Wairarapa, and 1 on Lake Ellesmere.

DISCUSSION

Limitations and biases of hunter recoveries

In this study, the May-June efforts of hunters were used to provide a snapshot of the distribution of shoveler throughout New Zealand. The only other national survey of shoveler distribution was that undertaken between 1969 and 1976 as part of the Ornithological Society of New Zealand's bird mapping scheme (Bull *et al.* 1978).

In providing a "picture" of shoveler distribution, hunters introduce sampling biases. Firstly, not all lakes on which shoveler occur during May and June are hunted over. There are refuge areas and reserves, on which hunting is not permitted, throughout New Zealand. These include wetlands such as the Bromley ponds at Christchurch, Lake Papaitonga near Levin, and Westshore Lagoon at Napier on which shoveler are abundant in most months of the year. On the West Coast of the South Island, an area from which few shoveler were recovered during this study, many lakes are scenic reserves and not available to hunters.

Secondly, hunters have to have the ability to shoot shoveler. Caithness (1974) identified shoveler as being a challenging bird to shoot because of their fast and erratic flight. Variability in hunter skill is likely to affect the sampling process for shoveler, as it does for other game waterfowl (Williams 1977, 1981b).

Thirdly, recoveries from large lakes such as Lake Wairarapa and Lake Ellesmere are unlikely to reflect the abundance of shoveler present relative to smaller wetlands because hunters are unable to target birds in the middle of these lakes. Rafts of shoveler and other ducks in the middle of large lakes, or in sheltered coastal waters, are common during the hunting season and Caithness (1974) reported shoveler being among the 1st species to seek these refuges when harassed.

Finally, the distributional data are derived from bands returned by hunters, and not all hunters who retrieve bands may report them (Balham & Miers 1959). Hunters shooting ducks at or near banding sites, or at some "hotspot" where banded birds are regularly obtained tend to return proportionately fewer bands than people for whom a banded shoveler or other waterfowl is a novelty (Williams 1981b).

Despite these obvious limitations and biases, the data presented in this paper provide both a 1st indication of the extent to which shoveler disperse throughout New Zealand and a comparison of movements of birds from 4 localities sampled by the same means.

Differences between year-of-banding and later recovery distributions

Combining data for both sexes, y-o-b and later recovery distributions for Ram Island Lagoon and Lake Whangape birds were statistically significantly different. However, there were some differences for the sexes independently. The y-o-b and later recovery distributions were different for males banded at Lake Whangape ($\chi^2 = 13.33$, $df = 6$, $0.05 > P > 0.02$) and Ram Island Lagoon (Fisher exact test, $P = 0.01$). For females, the only significant difference was at Ram Island Lagoon (Fisher exact test, $P = 0.001$). For Lake Whangape males, proportionately more y-o-b recoveries were from close to the banding site and more "later" shoveler were recovered >1000 km away, whereas both sexes from Ram Island Lagoon were also recovered closer to their banding site in their y-o-b.

It is not clear on these data as to whether there is evidence for moulting site philopatry. If individual birds moulted at the same sites in consecutive years, and showed similar patterns of dispersal thereafter, then y-o-b and later recovery distributions would be similar. This was so for Waituna Lagoon birds but not for those banded at Ram Island Lagoon. However, at Lake Whangape, the difference existed for males only. The data were therefore contradictory, leaving the issue of moult site philopatry to rely on the more direct evidence of live recaptures.

Live recapture data provided evidence for some, but not total, moult site philopatry. Although some moulting shoveler banded at

Waituna Lagoon, Ram Island Lagoon and Lake Whangape were recaught at their initial banding site, birds from the 2 South Island sites were also recaptured at Lake Whangape. In addition, 2 birds (1♂, 1♀) originally caught as breeders in drains next to Invercargill airport, 30 km from Waituna Lagoon, were captured some years later moulting at Lake Whangape. Perhaps, had birds been banded at Lake Whangape over the same time period as at the South Island sites, Whangape birds would have been detected moulting in the far south.

Differences in recovery distributions between sites
The proximity of Waituna Lagoon and Ram Island Lagoon banding sites, the recovery of birds banded at the 2 sites from the same locations, and the reciprocal recapture of moulters suggested that birds banded there were likely to show similar patterns of dispersal. Their y-o-b recovery distributions were similar for both sexes but tended not to be so for later recoveries (Fisher exact tests: males $P = 0.01$; females, $P = 0.03$; sexes combined, $P = 0.001$) for which more Ram Island birds were recovered at greater distances from their banding site.

One explanation for this difference may be that Waituna Lagoon birds could disperse northwards over the Southland plains and into Otago wetlands, which contained abundant habitat that also attracted birds that moulted at Ram Island Lagoon (Fig. 4). Birds dispersing north from Ram Island Lagoon, however, reached the northern limits of these wetlands after about 100 km and thereafter had to travel further to reach the more sparsely distributed wetlands along the Canterbury coastline. Significantly, perhaps, Lake Ellesmere loomed larger as a recovery site for Ram Island Lagoon birds than for those from Waituna Lagoon.

On the other hand, the data may reflect a genuine difference in the dispersal tendencies of the 2 populations. Waituna birds of both sexes may simply have had a sufficiency of winter habitat available to them, so precluding the need for extensive northward dispersal.

Lake Whangape birds shared some of the characteristics of Waituna Lagoon birds in that most of their dispersal was in a single direction. Only 7.4% of recoveries were from north of the banding site, reflecting both the paucity of large freshwater wetlands in Northland and, possibly, the smaller number of gamebird hunters in the region compared to that within a 100 km radius south and east of the banding site. Nevertheless, the distribution patterns of birds banded at Waituna Lagoon and Lake Whangape were very different between males in y-o-b (Fisher exact test, $P = 0.001$) and for both sexes in later recoveries (males – $\chi^2 = 22.8$, $df = 6$, $P < 0.001$; females - $\chi^2 = 13.7$, $df = 6$, $0.05 > P > 0.02$). In all instances, Waituna Lagoon birds were recovered much closer to their banding site. In comparing Lake Whangape and Ram Island Lagoon birds, only the y-o-b recovery distributions differed significantly (Fisher exact tests: males, $P = 0.005$; females, $P = 0.001$), with proportionately more of the Ram Island birds being recovered close to the banding site. In other words, birds banded at Lake Whangape dispersed greater distances than those banded in the south.

Significant wetlands for shoveler
Some wetlands emerged as being particularly attractive to shoveler. This was demonstrated by the presence at and recovery from these wetlands of birds banded at 3, and in 1 instance, all 4 of the banding sites. North Island sites at which birds from 3 of the banding sites were recovered included wetlands along the shores of Kaipara Harbour, those adjacent Piako and Waihou Rivers on Hauraki Plains, Lakes Whangape and Waahi in the lower Waikato River catchment, around Lake Taupo in the upper Waikato River catchment, the sand dune lakes of coastal Manawatu, and Lake Wairarapa. In the South Island, Lake Ellesmere was a significant wetland along with 2 other Canterbury coastal lagoons (Washdyke near Timaru, Wainono near Waimate). Wetlands in the upper Taieri River basin, Lakes Waihola and Waipori (including Ram Island Lagoon), and coastal wetlands of southern Southland were all places at which both local and North Island birds were shot.

While Lake Tuakitoto near Balclutha had the distinction of being the only site at which birds from all 4 banding sites were recovered during this study, it is unlikely to have been the only wetland at which they co-occurred. Almost certainly Lakes Ellesmere and Wairarapa were also such places given that ducklings banded in Southland and Otago have been shot there (Sutton *et al.* 2002), and more extensive banding in Hawkes Bay would likely have revealed a wider pattern of dispersal than has been presently described.

The extensive distribution of recoveries of birds banded at Lake Whangape (Fig. 6, 7) indicated that during May and June in any year, shoveler were not aggregated at particular sites. Instead, they were widely distributed across, particularly, lowland and coastal wetlands of all sizes in both North and South Islands. The obvious "gap" in the distribution revealed by the return of bands by hunters was the West Coast of the South Island. Although this gap may have reflected fewer hunters and huntable wetlands, or hint at the Southern Alps being a dispersal barrier, it more likely reflected a genuine scarcity of shoveler on the generally oligotrophic or dystrophic wetlands of the region. Bull *et al.* (1978) depicted few records of shoveler from this area.

The combined distributions of all recoveries (Fig. 3A, 4A, 5, 6A, 7A) provided a more comprehensive distributional record for shoveler in New Zealand than was depicted by Bull *et al.* (1978). All of the regions in which shoveler were recorded during the national bird mapping project were also regions in which banded shoveler were reported shot. The 2 distributions reinforced the importance of lowland and coastal freshwater wetlands as shoveler habitat.

Timing of bandings and sex bias of captures

Shoveler were banded in Hawkes Bay each year in the last week of January and the 1st week of February. In all 3 years, almost 3 times more males than females were captured. At Lake Whangape, during similarly-timed banding in 1981, 1984, and 1985, 83% of 951 birds captured were males. However, in the 1st 2 years (1978, 1979) when banding was in the 2nd and 3rd weeks of February, 70% of 262 birds captured were females.

Banding at the 2 South Island sites revealed a similar pattern of sex bias in relation to time of capture. Captures at Waituna Lagoon were mostly attempted in the period from late December to the end of January: of the 259 birds banded there, 64% were males. However, at Ram Island Lagoon, of 122 captures during January and the 1st week of February 63% were males, whereas of 237 captures made between mid-February and mid-March only 31% were males. Male shovelers do not contribute to the parental care of ducklings (Marchant & Higgins 1990) whereas the parental duties for female shoveler generally cease in early February, when all young shoveler have fledged (RRS pers. obs.).

The data from this study indicate that although the periods of flightlessness during the annual moult of male and female shoveler overlapped, males completed their moult perhaps 2-4 weeks earlier than females. Furthermore, the timing of the annual moult appears to have been similar for shoveler at the geographic extremes of the country.

Dispersal relative to other New Zealand waterfowl

That so many wetlands were sites of recovery of birds that had moulted so far afield is evidence that shoveler disperse widely throughout New Zealand. The annual extent of dispersal, as shown by the y-o-b recoveries, indicates that some shoveler move the length of the country within weeks of regaining flight. Recaptures at Lake Whangape of birds that had previously moulted at southern South Island sites may be evidence that some individual shoveler reside in different parts of the country in different years, or that there are extensive post-breeding movements before the onset of moult.

Most of the common New Zealand waterfowl have restricted patterns of dispersal (Williams 1981b). Trans-island movements of banded mallards and grey ducks have not been a conspicuous feature of past analyses of band returns (Balham & Miers 1959; Williams 1981b) despite examples of trans-marine movements to Chatham Island and Australia and the colonisation by the mallard of the subantarctic Auckland, Campbell, and Macquarie Islands (Marchant & Higgins 1990). Although there is evidence that dispersal patterns of mallard have expanded as the pastoral landscape has extended and wetlands have become further reduced in number and extent, most of these ducks are still shot within 50 km of their banding sites (Williams 1981b).

Trans-island movements have yet to be recorded for paradise shelduck. This species shows even more restricted dispersal than grey ducks or mallards, especially in North Island hill country where over 70% of banded birds were recovered within 40 km of their banding sites. Paradise shelducks inhabiting the eastern foothills of the Southern Alps disperse more widely, often up to 100 km from their moulting site, in search of feeding and breeding habitat (Williams 1979, 1981c).

Mills (1976) reported that grey teal banded at both South and North Island sites had been recovered throughout New Zealand, thus demonstrating a pattern of dispersal similar to that recorded here for shoveler. However, immediate post-banding dispersal was not as extensive as the y-o-b recovery pattern for shoveler and Mills noted that some birds remained at, or near the banding sites for up to 2 years, particularly if the area was a breeding locality. Using counts of teal at specific lakes over 3 years, Mills (1976) identified seasonal peaks in teal abundance and from the pattern of sightings of conspicuously marked teal he concluded there was considerable daily movements of grey teal to and from particular wetlands. Overall, Mills concluded that grey teal was a mobile species with some members of the population moving frequently and over great distances, while others remained near the same site for long periods, in some instances for several years.

Compared with other common New Zealand waterfowl, Australasian shoveler demonstrate more extensive and widespread dispersal. However, the contrasting recovery distributions for Waituna Lagoon and Lake Whangape shoveler, in particular, could be interpreted as supporting a similar conclusion to that reached by Mills (1976) for grey teal.

Movements within Australia, and of other shoveler species
Within Australia, shoveler have a disjunct east-west distribution, being absent from Australia's arid centre and most common in the Murray-Darling districts of Victoria and New South Wales and in Tasmania (Marchant & Higgins 1990). Frith (1977) recorded the species as being "fairly sedentary and its movements are very much less extensive and more regular than those of the grey teal and, usually, only local in extent." However, Frith (1977) also noted that floods were invariably followed by a noticeable increase in the number of shovelers and commented that "every incoming flock of (grey) teal seems to include one or two shovelers". Banding results for shoveler in Australia have not been reported, but the species there is considered more sedentary than other ducks of the inland and shows no obvious seasonal pattern of abundance anywhere in its range (Marchant & Higgins 1990). Thus, the mobility of shoveler in temperate New Zealand, as reported in this study, is strikingly different from its perceived habits in Australia.

Other shoveler species also undertake extensive annual movements. The northern shoveler (*A. clypeata*), a vagrant to New Zealand in increasing numbers (Heather & Robertson 1997), breeds widely in the Palaearctic and western Nearctic (Cramp & Simmons 1977) and undertakes extensive annual migrations to southern wintering areas. These journeys may be of 2,000-4,000 km, for example from the eastern Baltic states to North Africa, from western Siberia to northern India (McClure 1974; Mednis & Hudec 1989), and from Alberta (Canada) to Mexico (Poston 1974). The Cape shoveler (*A. smithii*), which is restricted to southern Africa, principally South Africa and Botswana (Brown et al. 1982), is considered to be nomadic, showing no clear pattern of movements. Siegfreid (1965) speculated, however, that the duck's patterns of movements comprised "elements of true migration (regular north-south movement of at least a large part of the population), nomadism (irregular extensive random dispersal, including juvenile dispersal) and local restlessness (short distance, often regular movements)". He concluded that rainfall-induced variability in food availability was the proximate factor initiating movement and perhaps also determined the direction and distance traveled.

Management implications
Our study has provided evidence of nationwide movements by shoveler. It has also identified extensive overlap in the movement patterns of birds banded at sites over 1000 km apart, with, for example, a bird banded in Hawke's Bay having been shot at Waituna Lagoon and another on the edge of the Kaipara Harbour, both sites at which birds banded at Waituna Lagoon and Lake Whangape were recovered. Similarly, the results show that the same large coastal and lowland freshwater lakes throughout New Zealand are places visited by birds that had moulted at any of the banding sites used during the study. We also detected individual shoveler moulting at different and distant sites in different years. So extensive was the movement and interchange of individuals, that shoveler may be viewed as comprising a single, national population, a characteristic shared by few other of New Zealand's birds.

Their mobility raises the question as to whether Australasian shoveler in New Zealand are confined to New Zealand. Although no recoveries were made from beyond New Zealand, shoveler clearly have the ability to undertake trans-Tasman dispersal, either to or from Australia. Arrival in New Zealand of birds from Australia would, however, be difficult to detect, the alleged plumage differences between New Zealand and Australian birds notwithstanding (Sibson 1967; Madge & Burn 1988). An irruption of shoveler, similar to that of grey teal to New Zealand in 1957 (Marchant & Higgins 1990), would be indistinguishable from the sudden arrival of a flock of local birds unless it occurred, and was noticed, on many wetlands simultaneously, or unless some birds carried Australian bands and were recovered. Conversely, detecting movements to Australia would depend entirely on the recovery of banded individuals. Perhaps movement beyond New Zealand will first be detected at Chatham Island, where shoveler were resident and breeding until 1925 (Turbott 1990), but have not been seen subsequently (Freeman 1994). Vagrants occasionally reach Auckland Island (Turbott 1990), The Snares (Miskelly *et al.* 2001) and Stewart Island, where breeding has been recorded (Edgar 1972).

As a game species, Australasian shoveler are hunted under regulations that govern the time and duration of hunting and a hunter's daily kill. The variation of hunting regulations between regions and between years in response to local breeding success and abundance is one of the major tools of waterfowl managers. Ideally, hunting regulations should reflect the current demographic state of the population being hunted. For black swan and paradise shelduck, returns of bands by hunters have been used to delimit regional populations for management purposes (Williams 1981b) and there is, presently, considerable inter-regional variation in daily allowable kills. By the same process, hunting regulations for shoveler ought to be similar nationally unless further research determines that some of the key sites identified during this study are places of extraordinary concentrations of shoveler during the hunting season and where they are subjected to particularly high intensities of hunting.

Equally important in the management of the Australasian shoveler in New Zealand is the ecological status of the significant wetlands for shoveler. Presently, the ecology of shoveler in New Zealand is poorly known. There is only one, limited, evaluation of shoveler foods (Potts 1977), so there is little to guide understanding of why shoveler visit, and sometimes abruptly depart, particular wetlands in such large numbers. It is worth re-emphasising that recoveries by hunters provide a mere distributional "snapshot" of where birds are in May and June. The recoveries cannot identify the timing and extent of movements between wetlands, nor can they indicate why shoveler were at particular wetlands during the hunting season. A distribution without obvious pattern, as revealed by hunters' returns, almost certainly masks deliberate movement of shoveler throughout New Zealand in response to variations in food availability. Until year-round movements are investigated, the characteristics of specific lakes and wetlands that draw shoveler to them will remain poorly understood, the ecological value to shoveler of these lakes unappreciated, and the possible crucial dependence of shoveler on a national network of wetlands completely overlooked.

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