Abundance and distribution of waterbirds of the Rotorua lakes, 1985-1996

John Innes
Landcare Research
Private Bag 3127
Hamilton
New Zealand

Kathryn Whaley
Landcare Research
C/- School of Marine and Environmental Sciences
Tamaki Campus
The University of Auckland
Private Bag 92019
Auckland
New Zealand

Keith Owen
Department of Conservation
PO Box 1146
Rotorua
New Zealand

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Summary

The abundance of nineteen waterbird species was counted during traverses of the entire shorelines of 17 Rotorua lakes in the summers of 1985, 1991 and 1996, by members of the Ornithological Society of New Zealand, assisted by the Department of Conservation and the Eastern Region Fish and Game Council. Also, the locations of all individuals of NZ dabchick were mapped. The overall waterbird community changed little over this decade, both in terms of total numbers of all species combined and species composition. However, 10 of the 19 counted species showed total abundance changes in either direction of ≥50% of the previous count on at least one of the count occasions. Few of these changes are defensibly explicable in retrospect, other than by weak correlations and educated guesses. Canada geese expanded their range from two to five lakes and increased their numbers 20-fold between 1985 and 1996. Little shags and little black shags declined greatly on Lake Rotorua from 1985 to 1991, and again by 1996, during the time of improving trophic state of Lake Rotorua. Red-billed and black-backed gulls declined after 1985, perhaps due to reduced food supply at the Rotorua rubbish dump. Widespread species such as grey/mallard, dabchick, black swan, paradise shelduck and scaup tend to be solitary nesters, shallow water or lake edge feeders, and tolerant of humans. Other species are not widespread for various reasons: Caspian tern are rare; Canada geese and coot are loyal to particular breeding sites; shoveler and grey teal are intolerant of humans; red-billed and black-billed gulls feed and roost in flocks and breed at only one site. Dabchicks were generally confined to shallow (<5 m) water on sheltered shorelines. We recommend that the counts should continue in their present format, with the objective of determining the status of waterbirds on all Rotorua lakes in the medium - long (10-20+ years) terms. We discuss whole-lake and site threats to waterbirds, and suggest priority research and management actions.

1. Introduction

Members of the Ornithological Society of New Zealand (OSNZ) assisted by the Department of Conservation (DOC), and the Eastern Region Fish and Game Council (ERFGC) counted all waterbirds on 17 Rotorua lakes during January to April in 1985, and January to February in 1991 and 1996. This report presents the data from this decade of OSNZ et al. counts, and makes first order interpretations from them. The results are discussed in relation to other counts of some game species conducted by ERFGC during 1991-1998 and of all waterbirds by Graeme Taylor (OSNZ) during 1981-1983.

This report fulfils five tasks posed by the Bay of Plenty Conservancy of DOC:

1. Determine the abundance trends of the waterbird populations on the Rotorua lakes over the 1985-1995 decade, and the reasons for any apparent variations.

2. Determine the distribution patterns of waterbird species using the lakes over this period.

3. Map the distribution patterns of NZ dabchick on the lakes.

4. Indicate likely risks to waterbird populations.

5. Provide recommendations on the research and management needs of these species, taking account of current threats and perturbations.

The physical attributes of the lakes and their catchments, and details of water quality, are summarised by Livingston *et al.* (1986) and Donald (1997).

2. Methods

2.1 OSNZ *ET AL.* COUNTS

The entire water areas and shorelines of (in order of size) Lakes Rotorua, Tarawera, Rotoiti, Rotoma, Okataina, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi, Okareka, Tikitapu, Rotokawau, Okaro, Ngapouri, Ngahewa, Rotokawa,Tutaeinanga and Opal were traversed by boat or viewed from the shore to count waterbirds in the summers of 1985, 1991 and 1996 (Appendix 1). Large lakes were surveyed from motor-boats travelling 50-100 m from shore at speeds slow enough to identify and count all species present. Five boats were used simultaneously on L. Rotorua, and two on Lakes Rotoiti and Tarawera. Some smaller lakes were surveyed by kayak or from the shore. Counts of individual lakes were always completed within one day, to minimise errors from birds moving between count zones and thus being counted twice. Lagoons adjacent to lakes (e.g., at L. Rotoma) were regarded as part of the lake, and counted accordingly. Hamurana Springs waterfowl were added to the L. Rotorua count total.

Species counted were dabchick, black shag, little black shag, little shag, white-faced heron, black swan, Canada goose, domestic goose, paradise shelduck, grey/mallard, grey teal, shoveler, scaup, coot, pied stilt, black-backed gull, red-billed gull, black-billed gull and Caspian tern (Appendix 2). Some of these species (e.g., dabchick, scaup, coot) are nearly entirely aquatic but may roost on or among emergent vegetation.The three shag species roost and nest in riparian trees but feed entirely in water. Some other species (e.g., white-faced heron, black swan, paradise shelduck, pied stilt, gulls) may forage on land as well as water; individuals of these species which were on pasture, trees, jetties or other structures adjacent to the lakeshores were included in the counts. Conspicuous juveniles of those non-colonial species breeding at the time of the surveys (dabchick, black swan, domestic goose, scaup, coot) were counted separately.

2.2 ERFGC COUNTS

Entire lake populations of black swan, paradise shelduck and Canada goose were counted by ERFGC staff annually in 1991-1998 on 11 major lakes (Appendix 3). Counts were made from an aeroplane; especially dense aggregations of birds (e.g., a paradise shelduck moulting site) were photographed and counted later from the photograph (M. McDougall, pers. comm.). Coincidentally and fortunately, counts were made in late January (ca. 28 January, the same time as the OSNZ counts); this originated as the approximate centre of the moult period for paradise shelduck.

2.3 GRAEME TAYLOR'S COUNTS

Graeme Taylor (OSNZ) counted dabchicks on many lakes, and all species on some lakes, during December 1981 to June 1983 (Appendix 4) with the same methods described in 2.1.

3. Results

3.1 ABUNDANCE TRENDS OF WATERBIRD POPULATIONS IN OSNZ COUNTS, 1985-1996, AND REASONS FOR CHANGES

The total number of counted birds was 26 331 in 1985, 21 973 in 1991 and 22 992 in 1996 (Appendix 1), and no breeding species noted in 1985 was absent from the later counts (Figs 1-3). This suggests that the waterbird community composition was stable over the count period. Total counts of seven of the species (dabchick, little shag, white-faced heron, black swan, domestic goose, scaup and coot) never varied by more than 50% from one count to the next. However, 10 of the 19 counted species (black shag, little black shag, Canada goose, paradise shelduck, grey/mallard, grey teal, shoveler, pied stilt, black-backed gull, red-billed gull) showed total abundance changes in either direction of $\geq 50\%$ of the previous count on at least one of the count occasions (Appendix 1; Figs 4a-g).

Counts of individual species on all lakes separately are shown in Figs 5a - r. Conspicuous juveniles are excluded from the counts of dabchick, black swan, domestic goose, scaup, and coot.

Counts of grey teal, shoveler, pied stilt, black-backed gull and red-billed gull all declined from 1985 to 1991, then increased again by 1996. Grey teal numbers declined on Lakes Rotorua, Rotoehu, Rotomahana and Rerewhakaaitu after 1985, and bounced back only on Rerewhakaaitu and, to a lesser extent, Rotoehu in 1996 (Figs 4g, 5j). Shoveler (Figs 4g, 5k) declined on Rotorua, Rotoehu, Rerewhakaaitu and Okareka, and increased in 1996 only on L. Rotomahana. Both of these species are highly mobile and disperse widely (Marchant & Higgins, 1990) so that large variations in their numbers at any site are to be

expected. Pied stilt (Figs 4d, 5n) declined on Rotorua, Rotoiti, Rotoma, Rotomahana, Rerewhakaaitu and Rotokawa, and increased subsequently on Rotorua, Rotoehu and Rerewhakaaitu. Black-backed gull (Figs 4e, 5o) declined on Lakes Rotorua and Rerewhakaaitu, and 1996 counts increased on Rotorua and Rotomahana. Red-billed gull (Figs 4e, 5p) also declined on Rotorua, and increased again there in 1996, and on L. Rotoiti. These changes for both species were perhaps due to new management at the Rotorua rubbish dump which reduced their access to food there after 1985.

Black shag increased greatly on L. Rotorua in 1991, and there were small changes on other lakes between counts, but the counts were generally low (159-290 total over the decade) and the percentage changes may overstate their importance (Figs 4c, 5b). Little shag declined greatly on L. Rotorua from 1985 to 1991 and had again by 1996 (Figs 4c, 5d). In fact, little shag declined from 1991 to 1996 on every major Rotorua lake except Okareka. Interestingly, little black shag numbers (Figs 4c, 5c) dropped greatly also on Lakes Rotorua and Rotoiti from 1991 to 1996, with some small increase in numbers on Rotoehu, Rotomahana and Rerewhakaaitu which may indicate new breeding colonies near those lakes. New colonies of breeding little and little black shags were noted on Patiti Island (L. Rotomahana) in January 1991; these were not present in 1985, and they were not noted again in 1996. No time-series of counts of small fish or koura or other shag food which may explain the changes on L. Rotorua is available from other authorities (D. Rowe, NIWA; A. Garrick, ERFGC, pers. comm.). However, Dr D. Rowe (NIWA, pers. comm.) does not think that bullies or smelt will have changed in numbers much in response to the improved condition of L. Rotorua since 1991, when direct sewage input ceased (Burns et al., 1997).

Perhaps the only change which is readily interpreted is the steady increase in numbers and range of Canada goose (Figs 4g, 5g), from just 22 geese on Lakes Rotoma and Rerewhakaaitu in 1985, to 427 on these plus Tarawera, Rotoehu and Rotomahana in 1996. This is undoubtedly documentation of the uncapped expansion of this species in this new area, as has occurred elsewhere in New Zealand.

Paradise shelduck (Figs 4f, 5h) have also increased greatly in total, nearly trebling from 1705 in 1985 to 4573 in 1996. The majority (78%) of this decade's increase was at L. Rotoehu, and the remainder occurred at Ngapouri, Rotokawa and Rotokakahi.

Ducks in the grey-mallard genetic complex declined overall after 1985 and increased again by 1996 (Fig. 4f), but many different patterns of change occurred at different lakes (Fig. 5i). Grey-mallard numbers fell after 1985 at the 6 lakes with highest numbers - Rotorua, Tarawera, Rotoiti, Rotoehu, Rotomahana, and Rotokawa - suggesting a real regional abundance shift, but a likely cause of this is unknown.

3.2 DISTRIBUTION PATTERNS OF WATERBIRDS ON ROTORUA LAKES

The presence/absence of all counted bird species on all Rotorua lakes in 1985, 1991 and 1996 is shown in Figs 1-3. Interestingly, only one species (grey-mallard in 1991) was ever seen on all lakes in any one year, mainly because few waterbirds of any species were present on some of the smallest lakes. Bigger lakes not surprisingly have more birds (Fig. 6), and bird density is usually greater on more enriched (eutrophic) lakes (Figs 7a-b). Consistent with this trend are the declines in bird numbers (mainly little shag, little black shag, and black swan) on Lakes Rotorua and Rotoiti after 1991, as the condition of these two linked lakes has improved (Burns et al., 1997). The high numbers of birds per hectare in L. Rotoehu in 1996 reflect large numbers of moulting paradise shelduck (Fig. 7b).

Species distributions are determined primarily by the distribution of the many biotic and physical factors that together constitute what is usually referred to as "habitat" for that species. Bird distributions and dispersion of social groups typically vary from month to month as these biotic and physical factors vary, or as seasonal cycles of breeding and feeding alter each species' requirements.

Life history information in the following accounts of species distributions was derived from Williams (1981), Marchant & Higgins (1990, 1993), Higgins & Davies (1996), and Heather & Robertson (1996). Other references are as given. Species are listed below in order of declining distribution:

1. Grey/mallard (mean distribution = 16.7/18 lakes, 1985-1996)

Genetic swarm of native grey and introduced mallard. Widespread because unspecialised in choice of habitat, tolerant of humans, eat plant and animal foods both in the water and on land, and because females disperse widely to breed solitarily. In these January counts, both males and females were in eclipse plumage after post-breeding moults, usually in quieter undisturbed backwaters. Counts are bound to be underestimates because many birds would be hidden in lakeside vegetation. On some lakes, they were concentrated in shallow bays, e.g., Halfmoon Bay and South East Bay of L. Rerewhakaaitu, and the southeastern bay of L. Rotomahana. Abundant on more eutrophic lakes with lakeside vegetation cover and some extensive shallows (e.g., Rotorua, Rotoiti, Rotoehu, Rotomahana, Rerewhakaaitu, Rotokawa, Okaro, Tutaeinanga) and rare on more oligotrophic, exposed, deeper lakes (e.g., Rotoma, Okataina, Tikitapu, Rotokawau).

Grey/mallards are strong fliers and disperse widely throughout New Zealand. One banded in Otago was shot 16 months later near Adelaide. It seems unlikely that the Rotorua lakes population is self-contained, so that changes in the total count there may not be attributable to factors operating on the lakes themselves. No local banding.

2. Little shag (mean distribution = 16.7/18 lakes, 1985-1996)

Native polymorphic cormorant. Feed mainly on koura, bullies, smelt, and (in L. Rotoehu) goldfish (Potts 1977) in water less than 3 m deep. Nest colonially

in live lakeside trees, often with little black shags. Breeding sites noted on or between these surveys were on the southwest corner of Patiti Island, L. Rotomahana (1991), the northern side of Kawaha Point, L. Rotorua (1985), Hemo Gorge below the highway near Waipa (1987), large mixed colonies on the southern and western sides of Mokoia Island, L. Rotorua (1991), and a large mixed colony on Matawhao Point, L. Rotoiti (1996). Colonies seem to move between surveys, perhaps when the nest trees are killed by droppings. Roost in small or large groups on lakeside living trees (e.g., lake margin under MtTarawera, pohutukawa trees adjacent L. Rotoiti) or on fallen or dead trees (e.g., Ngapouri, pines in Tikitapu) or on duck-hunters' hides (L. Rotoehu) or jetties (L. Rotoiti) or on small islets off Sulphur Point, L. Rotorua. Counts bound to be underestimates because of nesting and roosting adults in trees.

Disperse widely after breeding. No local banding but Australian banding of nestlings showed mean distances of recovery were 125 km after 2 months, 180 km after 3 months, and 300 km after 6 months.

3. Dabchick (mean distribution = 15.3/18 lakes, 1985-1996; see Section 3.3)

4. Black swan (mean distribution = 14/18 lakes, 1985-1996)

Introduced, conspicuous game species. Feed on lakeweed by upending to ca. 1m depth, and commonly graze on lakeside pasture (e.g., L. Okareka, and Mokoia Island, L. Rotorua). Only swan, shags and gulls are found often far (500 m +) from shore. Tolerant of humans on lakes where human activity is frequent. Like grey/mallard, abundant on shallow, meso- to eutrophic lakes (Rotorua, Rotoiti, Rotoehu, Rotomahana, Okareka) and rare on deeper, meso-oligotrophic lakes (Rotoma, Okataina). Some swan nesting or with broods during these counts.

Young swans tend to remain at or near their natal lake in their first year but are more likely to be recovered > 10 km away between 2 and 4 years, returning to natal lakes as adults. Banding shows that a few individuals move hundreds of km away. Research with coloured collars on swans showed that Rotorua swans regularly journeyed to L.Taupo and to Tauranga harbour, and occasionally to the Waikato. Williams (1981) describes a regional swan population with the Rotorua lakes as the major breeding area and Tauranga Harbour and L.Taupo as important feeding and moulting areas.

5. Paradise shelduck (mean distribution = 13/18 lakes, 1985-1996)

Endemic New Zealand game bird. Adults feed on vegetation both on water and on wetlands and pasture adjacent to lakes. In late January, most birds are still in large moulting flocks, and some are flightless. This is probably the only time of year when reasonably accurate counts are possible. Moult sites tend to be remote from disturbance and the same from year to year, e.g., the Te Wairoa Bay of L. Rotoehu, and the few shallow indented bays on L. Rotomahana. Most paradise shelduck in these surveys were at Lakes Rotoehu and Rotomahana, with smaller numbers at most other lakes. Virtually absent (<5 birds) in some surveys surprisingly from some large lakes (e.g., Tarawera, Rotoiti, Okataina, Okareka).

No banding data from Rotorua. Banding elsewhere indicates that paradise shelduck are largely sedentary, with birds from different moulting flocks rarely mixing (Williams 1981). Breeding adults are highly sedentary, leaving their home territory only briefly in January or February to fly up to 40 km to their moulting site. However, newly fledged male duckings may join groups of adults flying in directions other than back to their natal area, and many are shot more than 100 km away.

6. Scaup (mean distribution = 12.7/18 lakes, 1985-1996)

New Zealand protected endemic. Feed by diving to at least 2-3 m for aquatic invertebrates and plants, especially in the evening and at night. Lone females with broods seen on most lakes in January surveys. Other birds tend to be in resting flocks, often consisting mostly of males. Flocks are invariably in sheltered bays; they will move from day to day depending on the wind direction, but there are 'most frequented' sites on all lakes. In late January, most Scaup seem to be in resting flocks, often under willows. Counts will be underestimates because of reclusive nesting females and resting non-breeding birds of both sexes. Interestingly, Scaup are abundant on all larger Rotorua lakes (Rotorua to Okareka), but absent from most of the smaller lakes.

Movements unknown. No Rotorua banding. "Presumed to be mainly sedentary" (Heather & Robertson 1996).

7. White-faced heron (mean distribution = 12.7/18 lakes, 1985-1996)

Protected, self-introduced native. Feed on lake margins and in shallow wetlands on fish, frogs and tadpoles, aquatic and pasture insects, spiders, earthworms and mice. In summer they are generally solitary feeders. Some may be feeding young on nests at the time of these surveys. Widespread on all large Rotorua lakes, especially Rotoehu and Rerewhakaaitu.

Movements poorly understood. No Rotorua banding. "Move to coastal estuaries or margins of large inland lakes during summer after breeding" (Marchant & Higgins 1990).

8. Black shag (mean distribution = 10.7/18 lakes, 1985-1996)

Partially protected, native shag. Feed in water to 3 m deep on smelt, bullies, galaxiids, trout and koura. Usually roost together in small groups. More on L. Rotorua than all other lakes together, perhaps because there is a breeding colony in pohutukawa trees on the southern end of Mokoia Island (M. Day, 1991 survey; K. Owen, pers. comm.).

No information on movements. No Rotorua banding. In Australia, highly dispersive after breeding, with band recoveries hundreds of km away from breeding sites, depending on availability of water.

9. Black-backed gull (mean distribution = 10.7/18 lakes, 1985-1996)

Large, unprotected, native gull. Opportunistic feeder, taking refuse, carrion, fish, eggs, frogs, birds, worms and insects. There are breeding colonies at Rocky Point in Sulphur Bay (L. Rotorua), L. Rerewhakaaitu, and on the upper southwestern slopes of Mt Tarawera. Widespread in singles and small groups around all major lakes, especially those with breeding colonies.

No Rotorua banding. Elsewhere, mostly sedentary, although flocks may commute 30-40 km between roosting, breeding and feeding sites. In NZ, maximum distance moved by a bird banded as a juvenile was 450 km (Marchant & Higgins 1990). High fidelity to breeding areas.

10. Pied stilt (mean distribution = 9.3/18 lakes, 1985-1996)

Protected, common native stilt. Diet is mainly aquatic and terrestrial invertebrates, obtained from both shallow water and pasture. Thus, this species is common on lakes with extensive shallows, pumice beaches and pasture margins, especially Lakes Rotorua, Rotoehu and Rerewhakaaitu. In summer, stilts were widespread in scattered small groups around pumice beaches and other shallow margins, but were conspicuous.

No Rotorua banding. Probably sedentary, cf. southern North Island and South Island birds which move to coastal or northern areas after breeding. May be more dispersed in the breeding season.

11. Little black shag (mean distribution = 9/18 lakes, 1985-1996)

Protected native shag. Feed mostly on smelt, bullies and goldfish, sometimes in large cooperative flocks of communally feeding birds. In 1996, most little black shags were on Lakes Rotorua, Rotoehu, Rotoiti, Rotomahana and Rerewhakaaitu, near their nesting colonies. About 100 little black shags were noted to be nesting on Banded (Patiti) Island in L. Rotomahana on 25 January 1988 (Keith Owen, Classified Summarised Notes, *Notornis* 36, 1989: p. 200). Nearly 1000 nested on a silica islet in Sulphur Bay, L. Rotorua in 1982-83 (Innes &Taylor, 1984), but 2 years later the colony had moved, probably to Mokoia Island since "ca. 1000" were noted in a mixed (with little and little black shags) colony on the western side in 1991. The survey counts are bound to be underestimates because: many birds would have been nesting in late January; it can be difficult to count little black shags accurately in feeding flocks; and some little blacks would have been roosting in trees and thus would be hard to observe. Also, juvenile little and little black shags can be difficult to tell apart for inexperienced observers.

Hundreds of little black shag nestlings were banded in Sulphur Bay, L. Rotorua, by John Innes and Graeme Taylor during 1982-84. These young birds dispersed to coastal areas of the Bay of Plenty, Coromandel, Auckland and Northland in the autumn after breeding, but many returned to Sulphur Bay to breed. No banded birds were ever seen at Taupo, suggesting that little blacks there were bred in the large mixed colony on the western side of Motutaiko Island.

12. Black-billed gull (mean distribution = 7/18 lakes, 1985-1996)

Protected endemic gull. Feed in flocks on temporarily rich food supplies such as invertebrates on pasture, and on small fish and hatching chironomids in L. Rotorua. This species was common only on Lakes Rotorua, Tarawera, Rotoiti, Rotoehu and Rotomahana during 1985 to 1996, but the relative dispersion between lakes varied greatly between surveys, probably because of the changing locations of flocks on the particular days of survey. There is a long-standing breeding colony which moves to various sections of Sulphur Bay, L. Rotorua (Black 1955; unpubl. data), and in 1983-84 black-billed gulls bred at L. Rerewhakaaitu. Other colony sites may have gone unreported.

Many black-billed gulls were banded at Sulphur Bay and at L. Rerewhakaaitu by Graeme Taylor and John Innes during 1982-1984. Some of these banded gulls were seen all around Rotorua lakes, at Taupo, and (rarely) at the Bay of Plenty coast. Some gulls breeding at Rerewhakaaitu were previously banded as adults at Sulphur Bay. These data suggest that there is a central North Island black-billed gull population which breeds mainly at Sulphur Bay, L. Rotorua, and occasionally at other places in some years.

13. Australian coot (mean distribution = 7/18 lakes, 1985-1996)

Protected self-introduced native. Feed mainly on vegetation, but also on some invertebrates, all obtained by diving. Favour eutrophic, shallow, sheltered bays fringed with emergent reeds and other vegetation. Most abundant on Lakes Rotoiti, Tarawera, Okareka, Rotoehu, Rotoma and Rotomahana. The first recorded breeding of coots in the North Island was at L. Okareka in 1962. During 1987 to 1993, coot numbers on L. Okareka changed regularly each year from a low (ca. 50 birds) in November-February to a high (ca 250 birds) in May-August. At the time of these summer counts, breeding coots are on territories and non-breeding birds form small flocks in more open water. Counts will have missed some nesting birds and birds hidden in vegetation. Coots are absent from Lakes Rotorua, Okataina and Rerewhakaaitu, perhaps because of the absence of emergent vegetation and general absence of safe shelter. However, curiously coots (and dabchicks) are absent from some apparently ideal habitat, such as the northern bays of L. Rotoehu.

No Rotorua banding. Species is dispersive (regularly colonises new water).

14. Grey teal (mean distribution = 6.6/18 lakes, 1985-1996)

Protected native duck. Feed by dabbling in shallow water for seeds of aquatic plants, and aquatic invertebrates. Abundant on L. Rotomahana in 1985 but fewer counted anywhere since. Prefer eutrophic lakes with shallow margins and little human disturbance, especially Lakes Rotorua, Rotoehu, Rotomahana and Rerewhakaaitu. Some roosting birds would inevitably be missed in the counts.

No Rotorua banding. Elsewhere, many grey teal are highly mobile and disperse widely. "Erratic long-distance movements frequent and numbers on water bodies can change dramatically in a few days" (Marchant & Higgins 1990).

15. Shoveler (mean distribution = 4.7/18 lakes, 1985-1996)

Protected native duck, also a gamebird. Food of aquatic plants, zooplankton and invertebrates is sieved by dabbling in shallow water or mud. Like grey teal, prefer shallow, enriched lakes with little human disturbance. In 1985, most shoveler were on L. Rotorua; in 1996, nearly all were on Lakes Rotomahana and Rerewhakaaitu. Banding has revealed that the species is very mobile, and movements between islands are not uncommon.

No Rotorua banding. Elsewhere, "highly mobile with birds banded during summer moult recovered throughout country in autumn though individuals have returned to nest-sites from as far away as 800 km" (Marchant & Higgins 1990).

16. Red-billed gull (mean distribution = 3.3/18 lakes, 1985-1996)

Protected native gull, usually coastal. Feed on small fish, insects, earthworms, offal and scraps from humans. Breed in a traditional colony site at Sulphur Bay, L. Rotorua (since at least 1955; Black 1955), although the exact location selected varies from year to year primarily in response to water levels and disturbance. Over the last few years an additional breeding colony has established on small islets on the Rotorua lake front. Often roost with black-billed gulls on jetties or exposed sandy flats (e.g., mouth of Ngongotaha stream), where accurately separating 1 year olds of the two species can be difficult. Numbers of adults can also be difficult to estimate at breeding colonies, although nests are easily counted. In these summer counts, red-billed gulls were confined to near their breeding colony on L. Rotorua, being counted there and on Rotoiti, with just a few on L. Rotomahana.

Many red-billed gulls were banded at Sulphur Bay, L. Rotorua by Graeme Taylor and John Innes during 1982-1984. In the non-breeding season, a few of these were seen at the Bay of Plenty coast, but most remained around Rotorua.

17. Canada goose (mean distribution = 3.3/18 lakes, 1985-1996)

Protected introduced gamebird. Mainly graze on pasture adjacent to lakes, and also eat wetland and aquatic plants. In 1985, seen only on Lakes Rotoma and Rerewhakaaitu, but by 1996 Canada geese increased both their numbers and distribution, then occurring on Lakes Tarawera, Rotoma, Rotoehu, Rotomahana and Rerewhakaaitu.

No Rotorua banding. Elsewhere, essentially sedentary, although some long distance movement by 2-3 year old birds.

18. Caspian tern (mean distribution = 0.7/18 lakes, 1985-1996)

Protected uncommon native tern. Feed on small fish by diving. Breeding on a silica islet in Sulphur Bay, L. Rotorua, was recorded by Graeme Taylor in 1982, but spasmodically since (K. Owen, pers. obs.). In these surveys, counted only at the traditional roost site with gulls at Sulphur Bay, L. Rotorua.

Counts by Graeme Taylor in 1982-83 at Sulphur Bay showed 6-38 Caspians flocking there during January to May, before they dispersed to unknown breeding sites. Also recorded at Lakes Okareka and Rotomahana in 1982 as single birds by Taylor.

3.3 DISTRIBUTION AND NUMBERS OF NZ DABCHICKS ON ROTORUA LAKES

NZ dabchick is a protected endemic grebe which formerly occurred in the South Island but is now confined to the North Island. The most recent IUCN threatened bird listing (Collar *et al.*, 1994) lists the species as *Endangered*, defined as having a 20% chance of extinction in 20 years. This classification is applied in this case because no population exceeds 250 individuals. The threats they see are loss or alteration of habitat, disturbance, and introduced species. Dabchicks rank in the third priority (Category C) for action by the Department of Conservation (Tisdall 1994).

Dabchicks were on average on 15.3/18 lakes in the summer surveys, the third most widely distributed species we surveyed. They are most abundant on Lakes Rotoiti, Okareka, Tarawera and Rotorua, although the only lake from which they were absent in all three surveys was Rotokawa, the small, shallow, unclear, exposed lake adjacent to Rotorua airport. Dabchicks feed by diving for aquatic insects, molluscs, small fish and koura. They prefer shallow water (to 2 m deep) for feeding, with vegetation, rock crevices or human structures (boatsheds, jetties) for escape cover and nesting. Dabchicks stay near shore when the lake surface chop exceeds about 30 cm, when it is very windy.

The distribution of dabchicks on (in order of abundance) Lakes Rotoiti, Tarawera, Okareka, Rotorua, Rotoehu, Rerewhakaaitu, and Rotokakahi in late January - early February 1996 is shown in Figs 8a- d. The 369 adult dabchicks shown were 93% of the total adults counted. Dabchick are generally confined to shallow (< 5 m) water on shores sheltered against the prevailing southwesterly winds, or at the very tips of water arms. The distributions shown in these maps have not changed substantially on any lake during the decade of surveys, nor do the distribution patterns on the lakes *not* shown in the figures belie this generalisation. Lakes Rotoiti, Tarawera and Okareka between them have averaged 67% (range 55-80%) of the total lakes counts of adult dabchick in the three surveys in 1985, 1991 and 1996. Of these lakes, the highest dabchick density (in the world?) is on L. Rotoiti from Parikawau Point west to Te Weta Bay.

As noted above, the total number of dabchicks on the Rotorua lakes has varied only a little (364, 326, 396 in 1985, 1991, 1996) but there have been some large changes on individual lakes. The biggest increase occurred on L. Rotoiti (95, 112, 221) while large decreases occurred on Okataina (28, 2, 2), Rotomahana (20, 21, 3) and Okaro (9, 0, 0).

4. Discussion and recommendations

4.1 OTHER COUNTS

4.1.1 ERFGC counts

ERFGC counts agree that numbers of black swan more than halved on L. Rotorua between 1991 and 1996. Counts for this species by the ERFGC and OSNZ were generally similar, although ERFGC counted many fewer swans on Lakes Rotoiti and Rotoehu in 1996 (Appendix 3). ERFGC annual counts suggest that the decline of swan between 1991 and 1996 on Rotorua started in 1991 and continued until 1994; that numbers then rallied slightly, and subsequently (1997) halved again (Appendix 3).

4.1.2 Graeme Taylor's counts

Graeme Taylor's December 1981 - January 1982 counts at Okareka, Rotoma, Rerewhakaaitu, Rotoehu, Rotokakahi, Okataina, Rotomahana and Okaro confirm that the numbers of dabchicks on these lakes were very similar to those seen in the later OSNZ counts. Few of the counts of other species on any lake differ much from later count data. However, his count of 196 white-faced herons on L. Rotomahana in January 1982 is greater than the total count for this species on all lakes in all subsequent counts.

4.1.3 Sundry ex-New Zealand Wildlife Service counts

Black swan were counted on L. Rotomahana by Tony Roxburgh in January-February of 1971-1975 (DOC Rotorua, unpublished data). The mean swan count then (427) is very similar to the mean count from the OSNZ 1985, 1991 and 1996 surveys (466).

Wildlife Service staff also noted a black shag colony and 30 adult birds on Patiti Island in L. Rotomahana in 23 September 1955. The author noted that the main food of the young shags seemed to be trout. Handwritten under the typed report was the note: "I would suggest that we include the above rookery in our next shag shoot".

On 12 January 1955, T. Thomson and R. Cavanagh counted waterfowl on L. Rotomahana. They counted 1500 scaup, 300 black swan, 100 grey duck, 90 paradise shelduck, 54 grey teal, 31 shoveler, "14 pairs" of dabchick, 20 black shag, 42 little shag, and 90 black backed gull (breeding on Patiti Island). Another count in March 1960 found 414 scaup, 298 black swan, 154 grey duck, 4 mallard, 26 paradise shelduck, 87 grey teal, 92 shoveler, and 38 dabchick. Again, the key point must be that all of these species are still present on the lake in about the same numbers, 40 years later. Thomson and Cavanagah counted more scaup and dabchick and fewer paradise shelduck than most recent counts, but reasons for these differences are impossible to determine. Part of Rotomahana was declared a Wildlife Refuge in 1956, primarily to protect grey

teal there, and this was extended to the whole lake in 1967. Grey teal were thought to be in danger of extinction if shooting of them was allowed to continue. All L. Rotomahana counts from unpublished data, from File W/L: 34/14/5, Internal Affairs Dept, Wellington.

Hamurana Springs at the northern tip of L. Rotorua was declared a sanctuary in 1918, primarily for scaup. It was re-gazetted in 1931 and in 1958 became as a Wildlife Refuge. A Wildlife Service count in December 1956 found 260 scaup between the lake and the spring source, of which most were males.

4.2 COUNT OBJECTIVES, VALUE, ACCURACY

4.2.1 What have we learned compared with earlier work, especially that of Peterson, Rasch?

Existing reports or data on Rotorua waterbirds include Peterson (1981), Rasch (1989), and some valuable unpublished data which gather dust in Wildlife Service (Dept of Internal Affairs), DOC, ERFGC and OSNZ files and notebooks. The Banding Office also holds much valuable information about the movements of birds banded in Rotorua.

Peterson (1981) collated mainly NZ Wildlife Service data to prepare general descriptions of habitat use and environmental sensitivities of waterbirds on Rotorua lakes. She presented some reworked Wildlife Service bird abundance data which were based on monthly counts of waterbirds on all lakes. She referred to these being from "the first 11 months of a 3-year project" but she did not present the raw data and the data have subsequently been lost, perhaps permanently. It is not clear in the text how she derived the reworked data presented in her figure 1. Her general accounts of species and habitat descriptions, and species sensitivity and economic value ratings, are valuable and probably still accurate. This is an indictment of how little new information has been gathered on these species in the 17 years since her draft report was published.

Rasch (1989) produced an invaluable collation of forest, shrubland, freshwater wetland (including lakes) and coastal habitats, which describes and ranks their value for wildlife. Her report is based on 1982-84 field surveys by Wildlife Service staff. She also collated known distributions of endangered and threatened fauna, including waterbirds. However, the "Sites of Special Wildlife Interest" which she described are generally at a large scale (e.g.,"L. Rotorua"), although not always (e.g.,"Hemo Gorge Shag Colony"). These classifications may require updating.

The count data presented here are the first published of waterbird distribution, abundance, and trend on all Rotorua lakes. Interpretation of them at a detailed level is mostly impossible in retrospect because there was no organised co-collection of data on even first-order variables or factors (e.g., bird population dynamics including natality, mortality, immigration and emigration; habitat factors such as water condition, food type and abundance; human disturbance) which may explain observed changes in bird numbers. *However,*

the counts provide at least some backbone for fleshing further research on to, and they enable defensible conclusions regarding the general status of waterbirds on the lakes. It is clear, for example, that the waterbird community on all of the lakes has changed little since these counts began in 1985, and perhaps has changed little since our earliest available data were taken in the 1950s. This overview addresses large-scale and medium-term questions about likely trends of species (their status), and this is in the end more important for DOC to know than short-term individual or population responses to perturbations at particular local sites. *We recommend that the counts should continue in their present format, with the objective of determining the status of waterbirds on all Rotorua lakes in the medium (10-20 years) and then long (>20 years) terms.*

4.2.2 Count accuracy

Like counts of forest birds, the numbers of birds seen by an observer on a lake are unlikely to be the actual numbers present.

Factors which may *reduce* the count compared to the actual number include:

a) Roosting, moulting and nesting birds hidden in trees, emergent aquatic plants, caves, boatsheds, etc. Species likely to be nesting at the time of the OSNZ surveys (January-February) are NZ dabchick, black shag, little black shag, little shag, black swan, scaup, coot, pied stilt, black-backed gull, red-billed gull, black-billed gull, and Caspian tern.

   Numbers of birds nesting in colonies (shags, gulls) or moulting in flocks (shelduck) were usually counted and included in count data, although shag counts were probably inaccurate because not all nests can be seen. However, other cryptic and solitary nesting and roosting species were not counted.

b) Birds fleeing observers and not being counted. Shags are especially likely to flee in front of boats, especially on isolated lakes where they are presumably less habituated. Montgomery (1991) found that the mean boat-bird distance which caused little shags to flee trebled from 37 m at sites with high recreation use on L. Rotoiti to 110 m on L. Rotomahana. White-faced herons and pied stilts were also likely to depart when humans were present (Montgomery 1991). We found in the OSNZ surveys that most species (especially dabchick) would swim or fly from an approaching boat, and that care was always needed to look well ahead of the boat for such individuals.

c) Misidentifications. Most likely misidentifications are between juvenile red- and black-billed gulls, and between little and little black shags.

d) Actively moving birds. Flying gulls and communally feeding little black shags are both nearly impossible to count accurately.

e) Uncounted birds leaving a count zone and going to a part of the same lake which has already been surveyed. The TOTAL count for a species on all lakes will be reduced if any individuals fly from an unsurveyed

lake to a lake which has already been surveyed (i.e. they escape all counts).

Factors which may *increase* the count compared to the actual number include:

a) Birds fleeing observers and being counted twice,

b) Misidentifications,

c) Actively moving birds, all as above.

d) Counted birds leaving a count zone and going to a part of the same lake which has not yet been counted. The TOTAL count for a species on all lakes will be increased if any individuals fly from a surveyed lake to a lake which has not yet been surveyed (i.e. they are counted at least twice).

Research into the accuracy and errors of counts of any particular species would be useful, but for the overall count objective of monitoring the status of all species in the long term, we suggest that the present method is satisfactory. However, interpretation of the counts must acknowledge that they may have errors, although these errors should be the same from count to count. *It is crucial that the same count methods and timing (late January-February) are used in future counts.*

The count data should be statistically analysed for time trends after the next census. Each additional census will improve the ability of the analysis to detect any trends. The analysis will test whether there are significant trends through time (e.g. whether counts are increasing significantly), and whether these are consistent across all lakes.

4.2.3 NZ dabchicks

As for other species, the accuracy of the dabchick counts is unknown, although existing techniques yield similar results for different observers at the same lake (J. Innes, G.Taylor,W. Shaw, unpubl. data, and see Section 4.4.1).

The OSNZ *et al.* summer counts have clarified the importance of particular lakes and sites for this species; have suggested environmental factors which influence dabchick distribution; and have revealed that Rotorua lakes contain 20-25% of the total dabchick population (1500-2000 birds; Marchant & Higgins 1990). Following these counts, Gavin Reynolds (1997) undertook MSc research on dabchick habitat use on L. Rotoiti. Variables positively correlated with dabchick abundance were water clarity, and the number of caves and human structures along the shoreline. Exposure to the prevailing wind (southwest) was significantly negatively correlated with abundance.

4.3 THREATS TO WATERBIRDS ON ROTORUA LAKES

In theory, the following factors will affect the numbers of Rotorua waterbirds:

a) Breeding success (availability of suitable nesting sites and habitat; food supply and 'ecologically upstream' food web factors; rainfall; predation; disturbance; flooding of nests from storm events and boatwash) and mortality (predation, hunting, starvation, storm events, diseases such as avian botulism).

b) Immigration to and emigration from the Rotorua lakes area, and movement between lakes.

c) Evolutionary background, and behaviour of the bird species.

Few of these have been subjected to research and the list shows the large magnitude of the research task remaining. Mitchell & Wass (1995) suggest that the important ecological role of waterbirds in lake ecosystems has been largely overlooked by limnologists.

With so little documentation of these factors in relation to waterbirds at Rotorua lakes, only educated guesses can be made at what constitute threats.

We see two *classes* of threat:

a) Whole lake effects - primarily ecological (e.g., introduced macrophytes, algae, fish, birds; pollution and contamination, perhaps by volcanic eruption). These whole-lake effects are likely to result in food chain and other ecological disruptions which could drastically affect whole populations, especially if they occurred on all lakes. Threats to whole species other than by disease are extremely unlikely because no waterbird species is confined to the Rotorua lakes. The probability of a major disruption of water quality or ecosystem integrity on many lakes at once seems very small, but in fact most biological threats (new nuisance weed, alga, water plant pathogen, competitive or predatory bird) could reach all lakes via boats, anglers, or waterfowl.

   Vicky Froude (Aquatic plants management strategy draft, DOC unpubl. data, 1992) listed threats to aquatic plant management in each Rotorua lake, including the possible introduction of new species such as *Hydrilla,* funding shortages and uncertainties, lack of agreement over management roles and responsibilities, nutrient enrichment, threats to cover levels on lake margins, and various factors such as boat ramps and floatplane access which may hasten the introduction of new nuisance weeds to a lake. Industrial pollution such as acidification on Rotorua lakes on the scale approaching that in problem lakes overseas (e.g., Scheuhammer *et al.,* 1997) is extremely unlikely. It is unknown whether the naturally (geothermal) high mercury levels in some Rotorua lakes (Robinson *et al.,* 1995) are a threat to birds; this seems unlikely, given that the lakes have probably always had such high levels.

Water quality trends on the lakes in the last decade are summarised by Donald (1997). As noted in Section 3.1, the improvement in water quality in Lakes Rotorua and Rotoiti *was coincident with* declines in numbers of little and little black shags, and greys/mallards, and may have caused this change. However, bird numbers on L. Rotoehu - the only lake to have deteriorated in the last decade - have hardly changed at all in this time.

b) Site effects - disturbance to particular breeding, roosting, feeding and moulting sites. Probable site effects include human disturbance both on water and lake-edge; water extraction or outflow; roadway, hotel, industrial, residential and other construction; local effluent seepage; predation and disturbance by cats, dogs, Norway rats, mustelids and other predators at breeding colonies; and destruction of sites used for breeding, roosting, feeding or moulting by many species. Compared with whole lake effects, site effects will inevitably occur, but their impact will be much smaller, probably local and perhaps ephemeral, although not necessarily unimportant. Resource consents on the Rotorua lakes administered by Environment Bay of Plenty at 1 July 1997 include 63 discharges to water, 93 discharges to land, 44 uses of geothermal resource, and 51 `takes' of water (Donald 1997, appendix 1).

Serious threats will be at particular sites used by many individuals of a species at one time of year for a particular purpose, especially if that usage is historical. This includes breeding colonies, roost and moulting sites, winter flocking sites, and areas of especially high density of feeding or breeding birds. Probable undocumented examples of such impacts were the complete desertion of the long-standing little shag breeding colony on the banks of the Kaituna River above the Trout Pool due to commercial and recreational rafting, and the repeated relocation of breeding sites of red- and black-billed gulls around Sulphur Bay, L. Rotorua, in response to disturbance of various kinds.

Ingestion of lead from gun shot and fishing sinkers is a serious problem for some waterbircls in Australia, Britain, Canada, France, Spain, the Netherlands, Japan and the United States (Scheuhammer & Norris, 1996), but this is unlikely on Rotorua lakes except for a few sites where shooting is intensive and where waterfowl concentrate, e.g., Te Wairoa Bay of L. Rotoehu. Human disturbance is widespread on many lakes but apparently is not a serious threat to waterbirds, so long as there remain some areas free of disturbance, and so long as existing basic regulations such as the boat speed restriction to 5 knots within 200 m of shore are lionoured (Montgomery 1991), and the important lake margin vegetation cover is maintained as escape and breeding sites.

Unnatural fluctuations in water level would cause serious problems for waterbirds at any lake, due to flooding of nests and the drowning or drying out of littoral and lakeshore vegetation.

4.3.1 Dabchicks

Reynolds (1997) found that boat disturbance caused a short-term change in dabchick behaviour that lasted at least 15 minutes after the event. Interestingly, boats moving at 15 knots caused less disturbance than at 5 knots, but the risk of swamping nests was greater at 15 knots. Recorded nesting success is poor (17-19% of eggs fledge young; Marchant & Higgins 1990) due to water level fluctuation, wave action and disturbance of nests by other waterbirds. No other threats are known for dabchick. It would be valuable to know why dabchick disappeared completely from the South Island, but this is unknown (Heather 1988).

4.4 RESEARCH AND MANAGEMENT NEEDS OF ROTORUA WATERBIRDS

Priority research is that which best supports waterbird management, which is the joint responsibility of DOC, ERFGC, and to some extent Environment BoP and Rotorua District Council. Priorities are within the general areas of breeding, mortality, immigration, emigration, feeding and other behaviour of species that matter most (i.e., rare and endangered, indicator, economically important, and ecological community 'key species'). This research needs to determine what factors limit populations of waterbirds and what habitat components are necessary to maintain existing populations. At present there is insufficient knowledge about the roles of waterbirds in the lakes ecosystem(s) to declare which species are useful indicators of certain ecological conditions, and which have key species roles in food webs.

Some useful research on dabchick, little black shag, red-billed and black-billed gull was undertaken in the mid-1980s but it was never written up; it would be valuable to do so. Also, some valuable count data collected by the Wildlife Service have been mislaid, and perhaps are archived. These are irreplaceable data which may be worth hunting for.

4.4.1 Dabchicks

Little is known about the movements of adult or juvenile dabchicks that can assist intepretation of these counts, mainly because there are no known methods for safely catching and marking them. During October 1987 to June 1990, John Innes, Laurie Durand, Ray Jackson, Willie Shaw and Martin Day counted dabchicks each month on L. Okareka, part of L. Rotoiti, Sulphur Bay (L. Rotorua) and Te Wairoa Bay of L. Rotoehu. These unpublished data show that changes in the numbers of adult dabchicks on Lakes Okareka and Rotoiti (together about a third of all dabchicks on Rotorua lakes) did not decline when the large winter flocks built up after March each year at Sulphur Bay and Te Wairoa Bay, suggesting that winter flocks did not consist of adults moving from local breeding lakes.

However, the observed timing of breeding on Okareka and Rotoiti (juveniles seen October to June, peaking December to February) supports the second hypothesis that these large winter flocks consist of the young of the year

which aggregate after leaving their parents' territories. *This could be proved by marking adult and young dabchicks on Lakes Okareka and Rotoiti - this is priority research for this species.* Marking birds would also enable quantitative assessment of the impact of dabchick movement on count results. Monthly counts of adult dabchicks on Okareka (J. Innes, L. Durand, C. Shrubshall unpubl. data) and especially Rotoiti (W. Shaw,J. Innes, unpubl. data) both show occasional abrupt changes in numbers (e.g., halving) from one month to the next, although whether these are variations in abundance or conspicuousness is unknown.

5. Recommendations

5.1 MANAGEMENT

We recommend that DOC:

a) Maintain the 5-yearly OSNZ *et al.* counts (next count January 2001), with identical methods to previous surveys. Additional monthly or 3-monthly counts at some key sites or lakes, and analysis of existing banding data, would assist interpretation of the 5-yearly counts. The count data should be statistically analysed for time trends after the next census.

b) Prepare a register of important waterbird sites (e.g., feeding, breeding, moulting, roosting, flocking) *and the months they are used*, at a smaller scale than most of those listed currently as SSWI in Rasch (1989). This register could act as a planning and advocacy tool by declaring which sites are valuable (and when) for waterbirds. These would be likely to be strongly defended should resource consents be sought in relation to one of the sites.

c) Derive a waterbird species/habitat matrix register (see example in Appendix 5; Thomas 1979) to assist quick responses to site issues such as resource consent applications. Importantly, the register must show seasonal aspects of breeding, habitat use, conspicuousness and movement. Time of year is a crucial aspect of waterbird habitat use relevant to an AEE (Assessment of Environmental Effects) of any development proposal at the Rotorua lakes. A draft for New Zealand conditions could be assembled rapidly from existing knowledge and data.

d) Use actual impact occurrences (e.g., granted resource consents) as research opportunities, in a 'research-by-management' framework. These are most powerful when well designed, with replication, non-treatment sites, careful formal hypothesising, and routine measurement of key variables.

e) Foster university research on Rotorua waterbirds. This field is wide open for any basic and applied research.

f) Maintain close links with local OSNZ members, who undertake many useful surveys at their own expense.

g) Encourage the writing up of existing unpublished data on waterbirds in the Rotorua lakes region.

5.2 RESEARCH

We suggest that key research topics are:

a) Basic diet and life history information for all species, especially in a community setting. How are available aquatic food resources split between the various bird species using them, and do waterbirds compete with fish for food? What key habitat features determine the abundance and distribution of waterbird species?

b) Dispersal and seasonal movements of all species. These data would assist interpretation of the true significance of sites, and interpretation of episodic counts undertaken at only one time of year.

c) Co-ordinated time-series data on various aspects of the lakes' ecological communities, organised between DOC (non-game waterbirds and freshwater fish), ERFGC (game waterbirds and trout fishery), NIWA (zooplankton, fish, aquatic plants) and Environment BoP (water chemistry and quality). Can the currently routine collection of data by these different organisations be co-ordinated so that new understandings about the lake(s) *as an ecological community* would arise from the data?

d) Mark adult and young dabchick on Lakes Okareka and Rotoiti, to test the hypothesis that winter flocks at Sulphur Bay (L. Rotorua) and Te Wairoa Bay (L. Rotoehu) consist of the young of the year which aggregate after leaving their parents' territories. Methods for catching and marking dabchick need to be found first.

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Appendix 1 . Results of the OSNZ el al. counts of waterbirds on Rotorua lakes in 1985, 1991 and 1996.

1985	R'rua	T'wera	R'ti	O'taina	R'mahana	R'ma	R'ehu	Rer'wh'tu	R'kakahi	Okareka	Tikitapu	R'kawau	Okaro	Ngapouri	Ngahewa	R'kawa	T'inanga	Opal Lake	TOTAL
Dabchick	20	43+4	95+7	28+2	20+3	30+3	19	8+1	9	63+17	3+2	6	9+1	3	2	0	4+2	2+2	364+44
Black Shag	71	2	24	0	30	5	21	0	0	5	0	0	0	1	0	0	0	0	159
L. Black Shag	2000	1	1	0	2	0	0	0	0	3	0	0	2	0	0	0	0	0	2009
Little Shag	2181	167	443	50	76	87	154	42	54	23	4	2	3	9	3	0	4	0	3302
White F. Heron	14	13	22	11	16	8	17	46	2	3	0	0	3	2	0	1	1	0	159
Black Swan	1626+8	125+1	519+42	18	579+11	15	1317+142	15+8	22+10	254	0	0	0	2	1+5	2	1+4	0	4496+231
Canada Goose	0	0	0	0	0	17+3	0	5	0	0	0	0	0	0	0	0	0	0	22+3
Domestic Goose	present	0	0	0	44+14	0	0	0	0	0	0	0	0	0	0	present	0	0	3 lakes
Para. Shelduck	36	0	12	2	997	8	579	40	0	5	0	0	2	10	0	10	4	0	1705
Mallard/Gray	1241	175	498+1	36	421	66	850	77	167	50	4	0	133	143	4	254	0	0	4121
Grey Teal	70	0	0	0	463	0	35	64	0	0	0	0	0	0	0	0	0	0	634
Shoveler	83	0	2	0	6	0	14	14	0	8	0	0	0	0	0	0	0	0	127
Scaup	2304+14	429+9	703+113	113+4	815+5	72+18	21	41+42	12	123+10	0	0	0	0	0	3	0	2	4368+214
Coot	0	37+1	180+33	0	0	22+11	38	0	0	50+8	0	0	0	0	1	0	0	0	328+53
Pied Stilt	69	0	17	4	114	69	20	166	10	5	0	0	7	0	0	20	0	0	491
Bl. Backed Gull	1168	32	20+1	6	34	16	10	200	0	4	0	1	0	0	0	0	0	0	1501
Red Billed Gull	1648	0	90	0	25	0	0	0	0	0	0	0	0	0	0	1	0	0	1674
Bl. Billed Gull	390	100	90	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	601
SURVEY DATE	23/02/85	02/02/85	06/02/85	22/03/85	23/02/85	28/01/85	30/03/85	27/01/85	10/03/85	19/03/85	16/02/85	05/04/85	03/02/85	23/02/85	23/02/85	23/03/85	17/03/85	17/02/85	

1991	R'rua	T'wera	R'iti	O'taina	R'mahana	R'ma	R'ehu	Rer'wh'tu	R'kakahi	Okareka	Tikitapu	R'kawau	Okaro	Ngapouri	Ngahewa	R'kawa	T'inanga	Opal Lake	TOTAL
Dabchick	25+7	44+2	112+35	2	21	17+3	12+5	5	17	60+19	1	2	0	2	1	0	4	1+2	326+73
Black Shag	172	2	17	16	16	16	30	4	1	10	0	0	4	1	1	0	0	0	290
L. Black Shag	1641	17	140	0	40	33	115	0	2	4	0	0	0	1	0	0	0	0	1993
Little Shag	1098	121	673	50	86	61	336	87	66	13	3	2	13	4	3	0	1	1	2618
White F. Heron	2	11	31	13	17	4	33	8	1	1	0	1	0	1	0	0	0	0	123
Black Swan	3284+234	140+16	407+16	11+2	490+45	7+6	1550+255	98+11	29+6	130+1	29+6	1	0	0	0	2	2+5	0	6151+597
Canada Goose	0	0	0	0	0	65	9	63	0	0	0	0	0	0	0	0	0	0	137
Domestic Goose	15	0	0	0	38	0	0	0	0	0	0	0	0	0	0	0	0	0	2 lakes
Para. Shelduck	221	2	5	0	657	40	950	65	34	5	0	0	6	2	0	16	171	0	2199
Mallard/Gray	480+4	90+1	374+15	32	64	44	310+55	96	176	75	11+1	3	180+5	31	26	39	37	13	2081+97
Grey Teal	12	0	0	0	64	2	0	13	0	4	0	0	4	0	2	0	1	0	102
Shoveler	0	0	0	0	10	0	1	10	1	0	0	0	0	0	4	0	0	0	26
Scaup	1003+105	249+36	1163+423	161+6	264+3	63+4	29	31+7	64+1	125+29	0	0	0	4	2	2	3	0	3163+614
Coot	0	57+5	191+15	0	0	41+8	5+1	0	20	56+8	0	0	0	0	1	0	0	0	371+47
Pied Stilt	22+2	0	0	0	13	6	100+10	126+3	0	6	0	0	4	0	0	6	0	0	283
Bl. Backed Gull	88+3	38+1	18+1	5	49+3	10+4	14+2	26	15+1	25	1	0	0	0	0	0	0	0	289+15
Red Billed Gull	837+5	0	177	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1018+15
Bl. Billed Gull	23+2	19	478	2	133	0	129	13	6	0	0	0	0	0	0	0	0	0	803+2
Caspian Tern	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
SURVEY DATE	26/01/91	27/01/91	26/01/91	27/01/91	28/01/91	27/01/91	27/01/91	28/01/91	29/01/91	28/01/91	28/01/91	29/01/91	28/01/91	28/01/91	28/01/91	29/01/91	28/01/91	28/01/91	

1996	R'rua	T'wera	R'iti	O'taina	R'mahana	R'ma	R'ehu	Rer'wh'tu	R'kakahi	Okareka	Tikitapu	R'kawau	Okaro	Ngapouri	Ngahewa	R'kawa	T'inanga	Opal Lake	TOTAL
Dabchick	24+1	52+7	221+6	2+1	3	13+3	11	9	6	46	0	3	0	3	0	0	3	0	396+1
Black Shag	140	12	6	2	1	0	13	9	1	4	0	0	2	3	0	0	0	0	193
L. Black Shag	509	9	37	1	48	10	188	28	6	1	1	0	1	0	0	0	0	0	839
Little Shag	683	86	260	35	57	25	166	53+8	34	20	1	1	3	4	1	1	1	0	1431
White F. Heron	6	24	11	12	20	3	46	26	1	0	1	0	1	0	0	1	0	0	152
Black Swan	1483+30	193+20	1026+39	23	228+14	2+5	1182+15	73+4	29+7	204+18	0	0	0	2	5	9	3	0	4462+175
Canada Goose	0	2	0	0	22	120	124	159	0	0	0	0	0	0	0	0	0	0	427
Domestic Goose	0	45+2	0	0	130	0	0	0	0	0	0	0	0	0	0	0	0	0	2 lakes
Para. Shelduck	76	3	15	0	690	125	2822est	74+2	c150	4	0	1	31	344	0	179	59	0	4573+2
Mallard/Gray	306+4	231	214+17	33	822+9	15	526+7	164	61	113+2	30+3	0	62	87	15	136	169	6	2991+33
Grey Teal	9	0	0	0	21	0	31	97	8	0	0	0	2	0	0	0	0	0	168
Shoveler	1	0	0	0	35	0	0	9	0	0	0	0	0	0	0	0	0	0	45
Scaup	989+13	340+9	1073+95	110+8	210	83+10	28+3	138+33	17	167+19	0	0	0	1	0	30	0	0	3061+191
Coot	0	86	170+24	0	16	2	17+1	0	8	56+8	0	0	1	0	0	0	0	0	356+33
Pied Stilt	34+1	0	5	0	25	12	118	192+10	0	9	0	0	4	0	0	2	0	0	401+11
Bl. Backed Gull	284+21	23	9	12+2	216	11+5	3	55+3	6	3	0	0	2	0	0	0	0	0	624+31
Red Billed Gull	1836+4	0	318+4	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	2159+8
Bl. Billed Gull	72+18	41	61+2	0	82	0	454	2+2	1	0	0	0	1	0	0	0	0	0	714+22
Caspian Tern	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
SURVEY DATE	29/01/96	31/01/96	29/01/96	29/01/96	06/02/96	29/01/96	02/02/96	02/02/96	28/01/96	28/01/96	28/01/96	31/01/96	28/01/96	28/01/96	28/01/96	01/02/96	28/01/96	31/01/96	

Appendix 2. Common and scientific names of all birds counted (checklist order, OSNZ 1990).

Common name	Used in text	Scientific name
N Z dabchick	dabchick	*Poliocephalus rufopectus*
black shag	black shag	*Phalacrocorax carbo*
little black shag	little black shag	*P. sulcirostris*
little shag	little shag	*P. melanoleucos*
white-faced heron	white-faced heron	*Ardea novaehollandiae*
black swan	black swan	*Cygnus atratus*
Canada goose	Canada goose	*Branta canadensis*
domestic goose	domestic goose	*Anser anser*
paradise shelduck	paradise shelduck	*Tadorna variegata*
grey/mallard duck	grey/mallard	Hybrid swarm of *Anas superciliosa* and *A. platyrhynchos*
grey teal	grey teal	*Anas gracilis*
N Z shoveler	shoveler	*Anas rhynchotis*
N Z scaup	scaup	*Aythya novaeseelandiae*
Australian coot	coot	*Fulica atra*
pied stilt	pied stilt	*Himantopus himantopus*
Southern black-backed gull	black-backed gull	*Larus dominicanus*
red-billed gull	red-billed gull	*L. novaehollandiae*
black-billed gull	black-billed gull	*L. bulleri*
Caspian tern	Caspian tern	*Sterna caspia*

Appendix 3. Eastern Region Fish and Game Council counts of waterbirds on Rotorua lakes, 1991-98.

Black Swan

LOCATION	1991	1992	1993	1994	1995	1996	1997	1998
Rotorua	3302	2895	1720	1600	2200	1300	677	1169
Rotoiti	458	592	765	450	780	750	347	810
Rerewhakaaitu	108	77	120	300	130	135	70	15
Rotomahana	472	630	370	550	590	255	276	0
Tarawera	25	105	92	115	90	140	31	135
Blue & Green	8	26	20	36	10	45	59	27
Okareka	89	63	120	170	140	125	186	180
Okataina	7	16	5	14	20	4	2	0
Rotoma	6				6	0	5	0
Rotoehu		1486	684	600	320	650	260	803
Rotoma Lagoons	36	16	450					
TOTALS	**4511**	**5906**	**4346**	**3835**	**4286**	**3404**	**1913**	**3139**

Paradise Shelduck

LOCATION	1991	1992	1993	1994	1995	1996	1997	1998
Rotorua						0		0
Rerewhakaaitu	7	0	0	0		0		0
Rotomahana	462	315	206	560	100	380	102	0
Rotomahana Ponds						60	320	0
Tarawera	0	0	0	0	0	0	0	0
Blue & Green	0	0	0	0	0	80	30	206
Okareka	12	0	140	0		0	0	0
Okataina	0	0	0	0		0	0	0
Rotoma	72	146	605	0	100	100	100	0
Rotoma Lagoons	0							0
Rotoehu		980		1500	800	120	50	196
TOTALS	**553**	**1441**	**951**	**2060**	**1000**	**740**	**602**	**402**

Canada Goose

LOCATION	1991	1992	1993	1994	1995	1996	1997	1998
Rotoma		130	87	140	68	10	70	100
Rerewhakaaitu		70	100	162	117	134	30	60
TOTALS	**0**	**200**	**187**	**302**	**185**	**144**	**100**	**160**

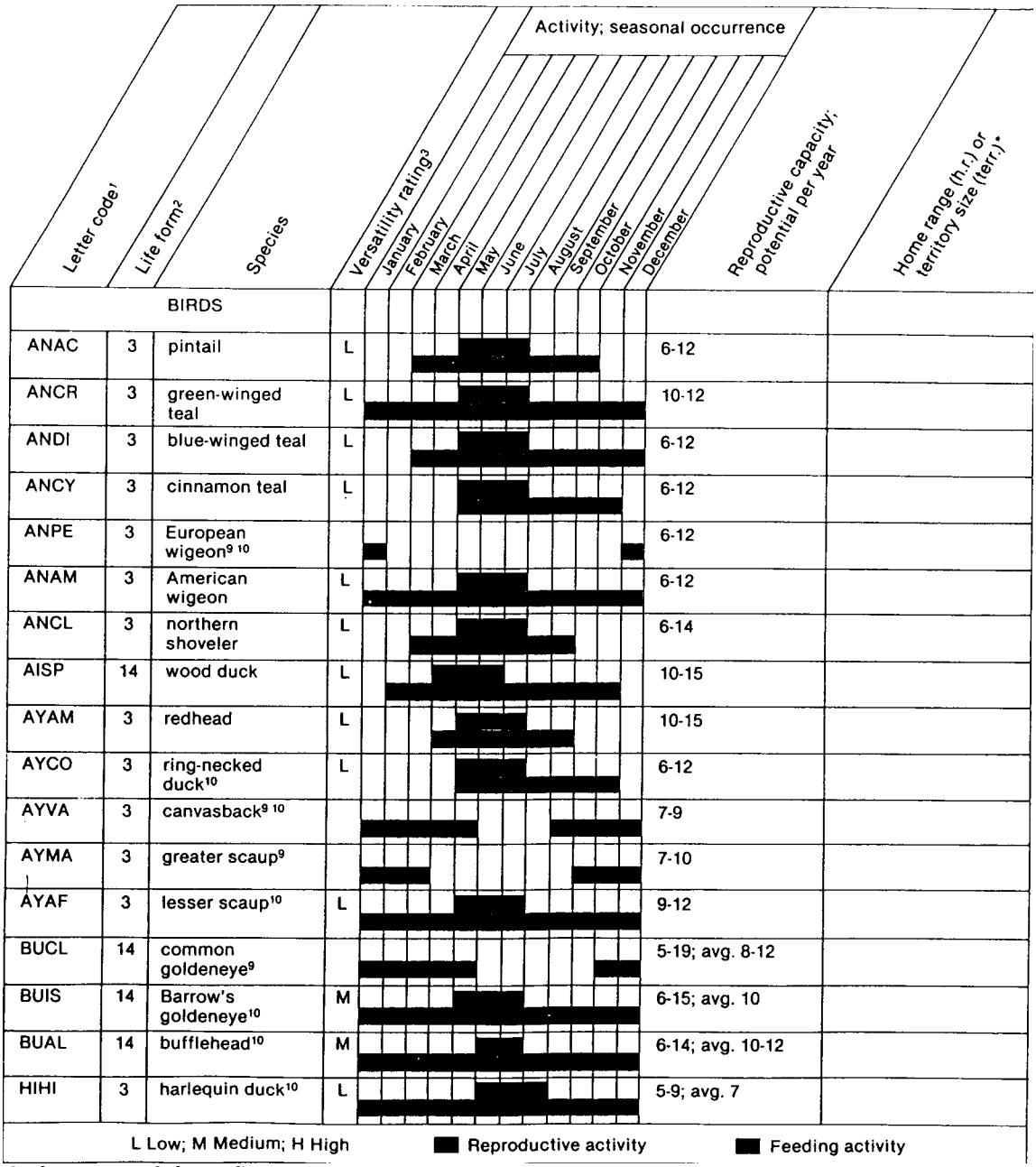
Appendix 4. Results of Graeme Taylor's counts of waterbirds on Rotorua lakes, 1981-1983.

LAKE	Okareka						Rotoma	Rerewhakaaitu
DATE	6.12.81	10.6.82	3.9.82	30.12.82	23.3.83	11.6.83	12.12.81	13.12.81
Dabchick	39	32	30	37	51	37	22	8
Black shag	0	2	1	7	13	1		
Little black shag	2	0	2	0	0	2		
Little shag	13	14	18	8	26	3		
W-F heron	5	1	2	3	6	3		
Black swan	212	192	121	232	258	231		99
Canada goose	0	0	0	0	0	0		
Domestic goose	0	0	0	0	0	0		
Paradise shelduck	1	65	16	16	13	32		
Mallard/grey	104	144	68	96	124	177		
grey teal	0	15	4	4	0	20		59+
Shoveler	2	4	4	0	0	8		
Scaup	130	284	150	140	186	149		112
Coot	52	117	80	86	58	87		
Pied stilt	26	6	14	29	11	8		341
BBG	2	8	c140	2	0	3		
RBG	0	0	0	0	0	0		
BBilG	0	0	0	0	0	0		
Caspian tern	0	0	1	0	0	0		

LAKE	Rotoehu	Rotokakahi		Okataina	Rotomahana			Okaro
DATE	24.12.81	2.1.82	21.5.82	3.1.82	10.1.82	14.6.82	19.6.82	21.5.82
Dabchick	4	9	15	18	16	22	29	7
Black shag					12	1	0	
Little black shag					0	10+	11	
Little shag					21	4	42	
W-F heron					196	c90	3	
Black swan				11	1078+	151+	91	
Canada goose					0	1	0	
Domestic goose								
Paradise shelduck					1047+	49	190	
Mallard/grey					432	63	c407	
grey teal					57	c100	33	
Shoveler					84	59	61	
Scaup				64	340	237	723	
Coot								
Pied stilt					115	30	43	
BBG					5	0	8	
RBG					0	Tot.112	3	
BBilG					0	Tot. 112	73	
Caspian tern					0	1	1	

LAKE	Opouri	Tikitapu	Rotokawa	Rotokawai
DATE	21.5.82	24.5.82	15.6.82	15.6.82
Dabchick	2	5		4
Black shag				
Little black shag				
Little shag				1
W-F heron				
Black swan			2	
Canada goose				
Domestic goose			6	
Paradise shelduck				
Mallard/grey			93	24
grey teal				
Shoveler				1
Scaup			11	
Coot				
Pied stilt			3	
BBG				
RBG				
BBilG				
Caspian tern				

Appendix 5. Example species/habitat matrices from Thomas (1979).



See footnotes at end of appendix.

Species	Minimum habitat required per individual, pair, colony, or population	Plant community groups (habitats)[4]															Special habitats (components)[6]									Unique habitats[6]		
																	Riparian zones											
		Dry meadow	Moist meadow	Other grasses	Sagebrush-bitterbrush	Other shrubs	Curlleaf mountainmahogany	Western juniper	Quaking aspen	Ponderosa pine	Mixed conifer	White fir (grand fir)[5]	Lodgepole pine	Subalpine fir	Alpine meadow	Rivers, creeks, streams	Lakes, reservoirs, ponds	Marshes, bogs, swamps	Standing; slow-running water	Fast-running water	Edges (ecotones)	Snags[7]	Logs[8]	Burrows	Cliffs, rimrock	Talus	Caves
BIRDS																												
pintail	0.2 ha (0.5 acre) emergent, riparian cover/pair	■	● ■	■												○ □	● ■	● ■	■								
green-winged teal	0.2 ha (0.5 acre) emergent, riparian cover/pair	■	● ■	■												○ □	● ■	● ■	■								
blue-winged teal	0.2 ha (0.5 acre) emergent, riparian cover/pair		● ■	■												○ □	● ■	● ■	■								
cinnamon teal	0.2 ha (0.5 acre) emergent, riparian cover/pair		● ■	■												○ □	● ■	● ■	■								
European wigeon[9 10]																■	■		■								
American wigeon	0.2 ha (0.5 acre) emergent, riparian cover/pair	■	● ■	■												● ■	● ■	● □	■								
northern shoveler	0.2 ha (0.5 acre) emergent, riparian cover/pair	■	● ■	■												○ □	● ■	● ■	■								
wood duck	≧0.8 ha (2 acres) of suitable marsh/pair					■			■	■	■					● ■	● ■	● ■	■	■	○	●	●				
redhead	0.2 ha (0.5 acre) emergent, riparian cover/pair		● ■													○ □	● ■	■	■								
ring-necked duck[10]	0.2 ha (0.5 acre) emergent, riparian cover/pair	■	● ■	■												● ■	● ■	□	■	■							
canvasback[9 10]																	■		■								
greater scaup[9]																■	■		■								
lesser scaup[10]		■	● ■	■												● ■	● ■	● ■	■								
common goldeneye[9]																■	■		■	■		●	○				
Barrow's goldeneye[10]		■	■	■	■	■	■	■	■	■	■					● ■	● ■	● ■	■			●	○				
bufflehead[10]		■	■	■	■	■	■	■	■	■	■	■	■	● ■	■	○ ■	● ■	○ ■	■			●					
harlequin duck[10]												●	●	●	●	○ ■			□	● ■			●				

Reproduction: ● Primary (≧40%); ○ Secondary (<40%) Feeding: ■ Primary (≧40%); □ Secondary (<40%)

Life form 3. Reproduces on the ground around water (or in emergent vegetation, or on floating vegetation[2]) and feeds on the ground, and in bushes, trees and water (45 species)

	SPECIES	Rivers	Streams	Sloughs	Lakes	Reservoirs ≥0.8 ha (≥2 acres)	Reservoirs <0.8 ha (<2 acres)	Intermittent ponds	Large ≥0.8 ha (≥2 acres)	Small <0.8 ha (<2 acres)	Rush, cattail	Sedge	Deciduous vegetation	Standing or slow-running water	Fast-running water	Grass-shrub	Shrub-forest	Grass-forest	Snags	Logs	Burrows	Cliffs, rimrock	Talus	Caves	Reproduction	Feeding
	REPTILES																									
CHPI	painted turtle	•		•		•	•								•										5	5
EUSK	western skink	•	•			•	•													•		F	•		6	7
DIPU	ringneck snake	•	•		•	•	•							•						•					7	7
THSI	common garter snake	•	•	•	•	•	•		•	•	•	•	•			F									11	12
	BIRDS																									
PONI	eared grebe	R		R	•	•			•		•	•		•	F										8	7
POPO	pied-billed grebe			R			R		R	R	R	R		•	F										7	2
PHAU	double-crested cormorant[1]	R				R								•	F										3	2
BOLE	American bittern[1]	F	F	F	•	F			•		•	•	•	F											5	10
BRCA	Canada goose[1]	•		•	•	•			•		•	•		F						R		R			9	8
ANPL	mallard	•	•	•	•	•	•	F	•	•	•	•		F	F					R					11	13
ANST	gadwall	•	•	•	•	•			•		•	•	•	F											9	10
ANAC	pintail			•	•	•			•		•	•		F											6	7
ANCR	green-winged teal			•	•	•	•	F	•	F	•	•	F	F											7	11
ANDI	blue-winged teal			•	•	•	•			•	•	•		F											7	8
ANCY	cinnamon teal			•	F	•	•	F	F	•	•	•		F											6	10
ANAM	American wigeon	•	F	•	•	•	•	F	•	•	•	•	•	F											10	13
ANCL	northern shoveler			•	•	•	F	F	•	F	•	•		F											6	10
AYAM	redhead			•	•	•			F		F	F		F											3	7
AYCO	ring-necked duck[1]	•	F	•	•	•	F	F	F	F	F	F	F	F	F										4	14
Letter code																									Reproduction	Feeding

Special habitats (components)

Marshes

Edges (ecotones)

Unique habitats

Number of habitats used by each species for:

[2]A number of species in this life form are specifically oriented to water in emergent vegetation or on floating vegetation, for reproduction and/or feeding purposes, but from a management standpoint (i.e., potential for managed impacts) they fit this category.

Letter code	Life form	Common name	Comments
BRNI	3	black brant	Uncommon; irregular migrant.
ANAL	3	white-fronted goose	Regular but uncommon migrant.
CHCA	3	snow goose	Irregular migrant.
CHRO	3	Ross' goose	Rare; irregular migrant.
ANPL	3	mallard	Regular nester along larger rivers, most lakes, and many ponds.
ANST	3	gadwall	Regular nester like the mallard but much more common during migration.
ANAC	3	pintail	Regular nester on small ponds and marshes.
ANCR	3	green-winged teal	Regular nester on small ponds and marshes.
ANDI	3	blue-winged teal	Irregular nester on small ponds; far more abundant during migration.
ANCY	3	cinnamon teal	Regular nester on small ponds and marshes.
ANPE	3	European wigeon	Rare; irregular migrant.
ANAM	3	American wigeon	Irregular nester but abundant migrant; occurs on most large bodies of still water.
ANCL	3	northern shoveler	Irregular nester on small ponds, but fairly common migrant.
AISP	14	wood duck	Uncommon, but regular occurrence in the few remaining suitable marshes. This species feeds within the aquatic features indicated rather than in the communities and successional stages associated with the aquatic zone. Feeding is displayed in the communities and successional stages only for purposes of relative interpretability with all other species—i.e., the species is not limited in feeding by the successional stage of the community surrounding the aquatic zone.
AYAM	3	redhead	Nesting largely peripheral to the Blue Mountains.
AYCO	3	ring-necked duck	Uncommon; irregular nester and migrant.
AYVA	3	canvasback	Irregular migrant.
AYMA	3	greater scaup	Irregular migrant.
AYAF	3	lesser scaup	Regular but not abundant migrant.
BUCL	14	common goldeneye	Regular but not abundant migrant.
BUIS	14	Barrow's goldeneye	Uncommon nester, but regular migrant. This species feeds within the aquatic features indicated rather than in the communities and successional stages associated with the aquatic zone. Feeding is displayed in the communities and successional stages only for purposes of relative interpretability with all other species—i.e., the species is not limited in feeding by the successional stage of the community surrounding the aquatic zone.

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