# Abundance and distribution of water birds on the Rotorua lakes, 1985–2011

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## Abstract

Five-yearly censuses of the abundance and distribution of water birds on 18 of the Rotorua Lakes have been carried out since 1985, to reassess the status of the New Zealand dabchick (*Poliocephalus rufopectus*) population in the Rotorua Lakes area and to increase general knowledge about the values of these lakes for all water bird species. The 2011 survey represented the sixth census in the series and completed 26 years of data collection. During each census, all birds on the water and the surrounding shoreline were counted, with 18 species having been consistently counted since 1985. During the 2011 census, 23 985 adults of these 18 species were counted across the 18 lakes surveyed; numbers counted have fluctuated since the first survey in 1985. In 2011, New Zealand dabchick numbers showed a 15% increase from 2006 levels, continuing the overall increase that has been observed since 1991. Similarly, numbers of Canada geese (*Branta canadensis maxima*) and Australian coots (*Fulica atra australis*) also increased in 2011, while white-faced herons (*Egretta novaehollandiae novaehollandiae*), mallards / grey ducks (*Anas platyrhynchos* / *Anas superciliosa*), grey teal (*Anas gracilis*) and pied stilts (*Himantopus himantopus leucocephalus*) declined. Some of these variations are likely to be related to changes in conditions outside the Rotorua Lakes area—for example, grey teal numbers may be influenced by droughts in Australia. However, others may be due to changes in local conditions, such as land use, disturbance, predator numbers or prey availability. It is recommended that 5-yearly surveys of the Rotorua Lakes are continued, as well as further research into the factors influencing changes in the abundance of water bird species in this region.

Keywords: Rotorua Lakes, census, water birds, New Zealand dabchick, *Poliocephalus rufopectus*, shags, gulls, waterfowl.


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# 1. Introduction

In January of 2011, Department of Conservation (DOC) staff, members of the Ornithological Society of New Zealand (OSNZ) and volunteers counted all water birds on 18 of the Rotorua Lakes (Fig. 1). This census continued a series of c. 5-yearly surveys that started in 1985, with the primary aim of allowing a reassessment of the status of the New Zealand dabchick/weweia (*Poliocephalus rufopectus*; hereafter dabchick) population in the Rotorua Lakes area. The dabchick is an endemic species that has been classified as Nationally Vulnerable in the New Zealand Threat Classification System (R obertson et al. 2013), and which has its national stronghold in the Rotorua Lakes district where approximately one quarter to one third of the total population is concentrated. In addition, the surveys seek to monitor the populations of all other water bird species on the lakes, six of which are also classified as threatened or at risk (Table 1). This long-term monitoring provides a

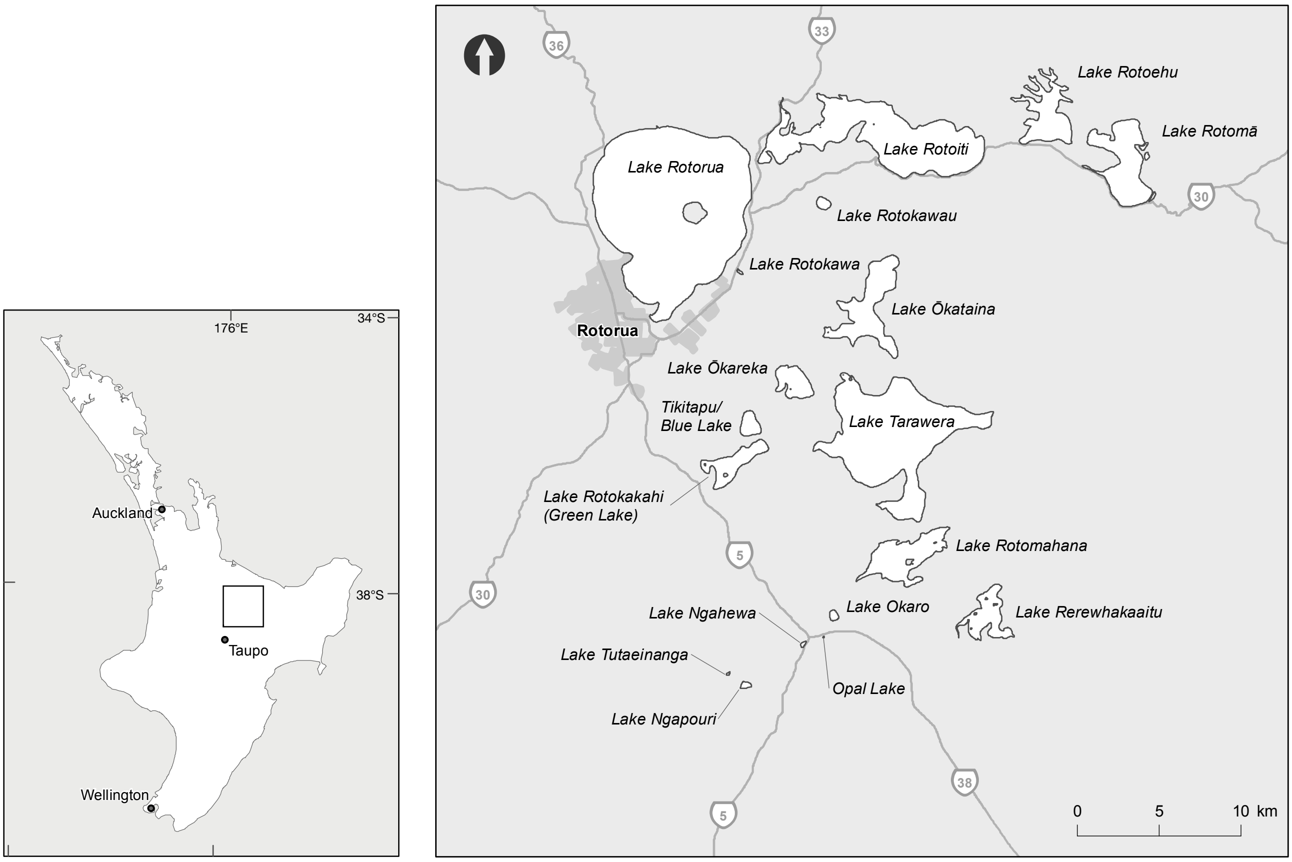


Figure 1. Location of the study area and the Rotorua Lakes that were surveyed. Full name for Lake Rotorua is Lake Rotorua/Te Rotorua nui ā Kahumatamomoe; Lake Rotoiti is Lake Rotoiti/Te Roto kite ā Ihenga i ariki ai Kahu and Lake Ōkataina is Lake Okataina/Te Moana i kataina ā Te Rangitakaroro.

Table 1. The seven species found on the Rotorua Lakes that are listed threatened or at risk in the New Zealand Threat Classification System (Robertson et al. 2013), and their conservation status.

| SPECIES | CONSERVATION STATUS |
|---|---|
| Black-billed gull (*Larus bulleri*) | Threatened: Nationally Endangered |
| Red-billed gull (*Larus novaehollandiae scopulinus*) | Threatened: Nationally Vulnerable |
| New Zealand dabchick (*Poliocephalus rufopectus*) | Threatened: Nationally Vulnerable |
| Pied Stilt (*Himantopus himantopus leucocephalus*) | At Risk: Declining |
| Black shag (*Phalacrocorax carbo novaehollandiae*) | At Risk: Naturally Uncommon |
| Little shag (*P. melanoleucos brevirostris*) | At Risk: Naturally Uncommon |
| Little black shag (*P. sulcirostris*) | At Risk: Naturally Uncommon |

valuable tool for assessing water bird population trends and species distribution patterns across the Rotorua Lakes. Therefore, while this report primarily focuses on results from the 2011 survey, it also includes comparisons with findings from the previous surveys, which have been reported elsewhere (Innes et al. 1999; Griffiths & Owen 2002; Evans 2006).

# 2. Methods

The census methods followed Innes et al. (1999). In brief, the entire surface and shoreline of 18 lakes in the Rotorua district were surveyed by boat or from the shore. Large lakes (Tarawera, Rotoiti/ Te Roto kite ā Ihenga i ariki ai Kahu (hereafter Rotoiti), Rotomā, Ōkataina/Te Moana i kataina ā Te Rangitakaroro (hereafter Ōkataina), Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi (Green Lake), Ōkareka and all parts of Lake Rotorua/Te Rotorua nui ā Kahumatamomoe (hereafter Rotorua) except the Sulphur Bay and Hamurana Stream areas) were surveyed from motor-boats travelling 50–100 m from the shore at speeds that allowed all species present to be identified and counted. Two or three boats were used simultaneously on some of the biggest lakes to allow counts of all individual lakes to be completed in 1 day, over a few hours. Smaller lakes were surveyed by kayak (Tikitapu/Blue Lake, Ngapouri, Ngahewa and Okaro) or on foot from the shore (Rotokawa, Rotokawau, Tutaeinanga, Opal and the Hamurana Stream and Sulphur Bay areas of Lake Rotorua). Lagoons adjacent to a lake (e.g. at Lake Rotomā) were surveyed in conjunction with the lake. As with previous surveys, individuals of species that were foraging on land (e.g. white-faced heron and paradise shelduck (*Tadorna variegata*)) or roosting in trees or on structures (e.g. shags (*Phalacrocorax* spp.)) adjacent to the lakes were included in the counts (Innes et al. 1999). To be included in the count, individuals had to be visible to the naked eye, although binoculars were always used to improve the accuracy of identifications and counts. The visible shoreline varied by lake according to surrounding vegetation.

In 2011, the majority of lakes (14 of the 18; 78%) were surveyed over 3 days (28–30 January 2011); the remainder were surveyed outside this time due to logistical reasons or weather, but all lakes but one were surveyed within 8 days (26 January – 2 February 2011) (see Appendix 1). This is similar to the time frames of previous surveys. Counts were generally conducted in fine, calm weather. However, the Lake Ōkareka survey was completed during 37 km/h southwesterly winds, with gusts of up to 56 km/h. This count was conducted by an experienced observer and the main areas of the lake that are inhabited by dabchicks were sheltered from the prevailing wind, which may have compensated in part for the less than ideal weather conditions; however, resulting numbers may be an underestimate, particularly for the more exposed areas of the lake.

The same species that were counted by Innes et al. (1999) and in subsequent surveys were again focussed on in 2011 to enable comparisons to be made; however, additional species were also counted, as there is interest in all species that are associated with the lakes and their margins. Conspicuous juveniles were counted separately from adults but were not included in the analyses. Observers not only counted dabchicks, but also recorded their locations on topographical maps to plot their distribution.

We investigated whether total number of species, total number of water birds, or abundance of individual species or functional groups were related to various physical, chemical and biological factors for which data were available and that were thought likely to influence these groups based on their natural history traits (Tables 2–4) using linear regression, and Kruskal-Wallis and Rank Sum tests. Regression trend lines and $r^2$ values are shown on graphs when $P < 0.05$.

Some limitations to the census methodology should be noted. Being highly mobile, birds may move amongst lakes. To try to minimise double-counting, surveys were completed within as short a timeframe as possible. However, it is likely that within the 3–8 days taken to complete all surveys, some movement of individuals will have occurred. In addition, despite procedures being

Table 2. Factors examined to explain changes in the numbers of water birds of the Rotorua Lakes. See Tables 3 & 4 for a description of the physical characteristics of 12 lakes and their catchments.

| GROUP OF WATER BIRDS | CENSUSES INCLUDED | LAKES INCLUDED | FACTORS EXAMINED |
|---|---|---|---|
| Total number of species | 1985–2011 | 12 lakes[a], each examined individually across all years | LakeSPI[b] overall index ranking |
| | 2011 | 12 lakes[a], examined collectively by year | Lake size (ha), lake surface area ($km^2$), lake shoreline length, TLI[c] value 2010, LakeSPI[b] overall index ranking for 2010–2011, lake altitude, average lake depth (m), maximum lake depth (m), catchment size, lake age, % pasture in lake catchment, % forest in lake catchment, % urban in lake catchment |
| Total number of water birds | 1985–2011 | 12 lakes[a], each examined individually across all years | LakeSPI[b] overall index ranking |
| | 2011 | 12 lakes[a], examined collectively by year | Lake size (ha), lake surface area ($km^2$), lake shoreline length, TLI[c] value 2010, LakeSPI[b] overall index ranking for 2010–2011 |
| | 2011 | 15 lakes[d], examined collectively by year | Individual factors contributing to LakeSPI overall ranking[e] |
| Total number of water birds; shags (combined total, and each of the three species separately) | 2011 | Rotorua, Tarawera, Rotoiti, Rotomā, Rotokakahi, Ōkareka | 2009 kōura (*Paranephrops planifrons*): catch per unit effort, mean catch weight (kg), mean size (orbit-carapace length; OCL), maximum size (OCL) |
| Total number of water birds; dabchicks; black shags | 2006 | Rotorua, Tarawera, Rotoiti, Rotomā, Rotokakahi, Ngapouri | 2006 kākahi (*Echyridella menziesi*) average density/$m^2$ |
| Divers (dabchicks, scaup, coots, all three species of shag), separately and combined | 1985–2011 | 12 lakes[a] | Average lake depth, maximum lake depth, mean LakeSPI[b] % native condition index, mean LakeSPI % non-native condition index, mean Secchi disk depth |
| Dabblers (shovelers, teal, mallards/grey ducks, swans), separately and combined | 1985–2011 | 12 lakes[a] | Average lake depth, maximum lake depth, mean LakeSPI[b] % native condition index, mean LakeSPI % non-native condition index |
| Grazers (shelducks, geese, swans), separately and combined; herons | 1985–2011 | 12 lakes[a] | % pasture in lake catchment |
| Herbivores (coots, mallards/ grey ducks, swans, shelducks), separately and combined | 1985–2011 | 12 lakes[a] | Mean Secchi disk depth[f] |
| Invertebrate eaters (dabchicks, stilts), separately and combined | 1985–2011 | 12 lakes[a] | Mean Secchi disk depth[f] |
| Fish eaters (all three species of shag, herons), separately and combined | 1985–2011 | 12 lakes[a] | Mean Secchi disk depth[f] |
| Shovelers | 1985–2011 | 12 lakes[a] | % urban in lake catchment |
| Swans | 1985–2011 | 12 lakes[a] | Egeria (*Egeria densa*) presence/absence, mean LakeSPI[b] % native condition index, mean LakeSPI % non-native condition index |
| Geese | 1985–2011 | 12 lakes[a] | Potamogeton (*Potamogeton* spp.) presence/ absence and number of species, mean LakeSPI[b] % native condition index, mean LakeSPI % non-native condition index |
| Shelducks | 1985–2011 | 12 lakes[a] | Mean LakeSPI[b] % native condition index, mean LakeSPI % non-native condition index |
| Shags (all three species), separately and combined | 2001–2011 | Rotoiti | Adult smelt (*Retropinna retropinna*) density (mean number per net) |
| Shags (all three species), separately and combined | 1996 | 11 lakes[g] | 1994–1995 larval smelt density (mean number per net) |
| Black shags, little black shags | 1996 | 11 lakes[g] | 1994 mean larval bully (*Gobiomorphus cotidianus*) catch per unit effort |

*Continued on next page*

*Table 2 continued*

| GROUP OF WATER BIRDS | CENSUSES INCLUDED | LAKES INCLUDED | FACTORS EXAMINED |
|---|---|---|---|
| Black shags, little black shags | 1996 | Rotorua, Rotoehu, Rerewhakaaitu, Tikitapu, Okaro | 1994 mean adult bully catch per unit effort |
| Black shags | 2001–2011 | Rotorua, Tarawera, Rotoiti, Ōkataina | Mean trout (*Oncorhynchus mykiss*) condition factor |
| Black shags | 2001–2006 | Rotorua, Tarawera, Rotoiti, Rotomā, Ōkataina, Rotoehu, Rerewhakaaitu, Ōkareka | Trout size at release (mm), number of stocked trout |
| Black shags | 2006–2011 | Rotorua, Tarawera, Rotoiti, Rotomā, Ōkataina, Rotoehu, Rerewhakaaitu, Ōkareka | Mean stocked trout growth rate at 300 mm, 400 mm and 500 mm |

[a] These 12 lakes were Rotorua, Tarawera, Rotoiti, Rotomā, Ōkataina, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi, Ōkareka, Tikitapu and Okaro.

[b] LakeSPI (Lake Submerged Plant Indicators) is a lake information and management tool used to assess and report on the ecological condition of New Zealand lakes (NIWA n.d.).

[c] TLI (Trophic Level Index) is used to indicate the health of lakes in New Zealand. It is calculated using four separate water quality measurements: total nitrogen, total phosphorus, water clarity and chlorophyll-a concentration (Bay of Plenty Regional Council n.d.).

[d] These 15 lakes included the 12 listed in footnote a, plus Lakes Ngapouri, Ngahewa and Tutaeinanga.

[e] The factors contributing to LakeSPI overall ranking were kākahi presence/absence, kōura presence/absence, number of native aquatic plants present (of those surveyed) and number of non-native aquatic plants present (of those surveyed); the ratio of native:non-native aquatic plants was also examined as an additional factor.

[f] Mean Secchi disk depth was used here as a substitute for macrophyte cover, as a correlation between the two has previously been found (Hansson et al. 2010), no information was available on the coverage of macrophytes for the Rotorua Lakes, and macrophyte coverage has been found to influence herbivores, invertebrate feeders and fish feeders elsewhere (Hansson et al. 2010).

[g] The 11 lakes were Rotorua, Tarawera, Rotoiti, Rotomā, Ōkataina, Rotoehu, Rerewhakaaitu, Ōkareka, Tikitapu, Rotokawau and Okaro.

Table 3. Physical parameters of 12 of the 18 surveyed Rotorua Lakes. Data obtained from Bay of Plenty Regional Council (n.d.).

| LAKE | LAKE SIZE (ha) | MAX. DEPTH (m) | MEAN DEPTH (m) | LONGEST AXIS (km) | SHORELINE LENGTH (m) | CATCHMENT AREA (ha) | ALTITUDE (m asl*) | APPROXIMATE AGE (YEARS) |
|---|---|---|---|---|---|---|---|---|
| Rotorua | 8060 | 44.8 | 11.0 | 12.1 | 45 845 | 50 060 | 280 | 140 000 |
| Tarawera | 4130 | 87.5 | 50.0 | 11.4 | 47 170 | 14 520 | 298 | 5000 |
| Rotoiti | 3400 | 93.5 | 31.5 | 15.0 | 59 260 | 12 160 | 279 | 8500 |
| Rotomā | 1110 | 83.0 | 36.9 | 5.2 | 24 875 | 2810 | 316 | 8500 |
| Ōkataina | 1080 | 78.5 | 39.0 | 6.2 | 29 120 | 6290 | 311 | 7000 |
| Rotomahana | 900 | 125.0 | 60.0 | 6.2 | 28 790 | 8370 | 339 | 125 |
| Rotoehu | 800 | 13.5 | 8.2 | 4.6 | 39 550 | 4710 | 295 | 8500 |
| Rerewhakaaitu | 530 | 15.8 | 7.0 | 3.8 | 24 140 | 5290 | 435 | 700 |
| Rotokakahi | 440 | 32.0 | 17.5 | 4.3 | 15 090 | 1860 | 394 | 13 300 |
| Ōkareka | 340 | 33.5 | 20.0 | 2.8 | 10 485 | 1980 | 355 | 19 000 |
| Tikitapu | 150 | 27.5 | 18.0 | 1.6 | 5065 | 570 | 415 | 13 300 |
| Okaro | 31 | 18.0 | 12.5 | 0.7 | 2150 | 367 | 423 | 800 |

* m asl = metres above sea level

Table 4. Catchment land cover composition (%) for 12 of the 18 surveyed Rotorua Lakes. Data obtained from Bay of Plenty Regional Council (n.d.).

| LAKE | PASTURE | INDIGENOUS FOREST/ SCRUB | EXOTIC FOREST | TOTAL FOREST/ SCRUB | URBAN | OTHER |
|---|---|---|---|---|---|---|
| Rotorua | 51.8 | 25.1 | 14.3 | 39.4 | 8.1 | – |
| Tarawera | 19.7 | 62.4 | 16.0 | 78.4 | – | 1.9 |
| Rotoiti | 15.9 | 36.4 | 46.2 | 82.6 | 1.5 | – |
| Rotomā | 23.4 | 46.0 | 26.7 | 72.7 | – | 3.9 |
| Ōkataina | 7.8 | 84.1 | 7.8 | 91.9 | – | – |
| Rotomahana | 43.2 | 39.7 | 16.3 | 56.0 | – | – |
| Rotoehu | 34.2 | 33.4 | 32.0 | 65.4 | 0.4 | – |
| Rerewhakaaitu | 75.3 | 7.2 | 15.2 | 22.4 | – | 2.3 |
| Rotokakahi | 26.3 | 16.6 | 57.1 | 73.7 | – | – |
| Ōkareka | 37.8 | 51.6 | 7.6 | 59.2 | 2.9 | – |
| Tikitapu | 7.0 | 74.3 | 17.9 | 92.2 | 0.8 | – |
| Okaro | 90.6 | 2.1 | 6.3 | 8.4 | – | – |

standardised as far as possible to minimise count variability arising from different counting conditions across surveys, there will be inherent observer differences and errors along with species detectability issues. Also, the single counts per census provide no measure of variation. Thus, the counts are a coarse index, and results should be viewed as indicative trends in abundance.

# 3. Results and discussion

In total, 23 985 adult water birds of the 18 focal species were counted during the 2011 survey (Appendix 1, 2). There was no readily discernible trend in the total number of water birds counted since the inception of the c. 5-yearly surveys (Fig. 2; Appendix 2; $F_{1,4}$ = 0.79, $P$ = 0.42, $r^2$ = 0.15). Furthermore, no breeding species that were present in previous counts were absent from the counts made in the 2011 survey, suggesting that the species richness of the water bird community has remained stable. Just 7 of the 18 consistently counted species (NZ scaup (*Aythya novaeseelandiae)*, black swan (*Cygnus atratus)*, paradise shelduck, red-billed gull (*Larus novaehollandiae scopulinus*), mallard / grey duck, little shag (*Phalacrocorax melanoleucos brevirostris*) and little black shag (*P. sulcirostris*)) each contributed ≥ 5% of the total annual count each survey and, combined, these species represented 80–87% of the total count each census (mean = 85%) (Appendix 2). New Zealand scaup and black swans together have comprised > 30% (range = 31–46%, mean = 37%) of the total number of water birds counted each census, and 3 species combined (4 in 2006) contributed ≥ 50% of the total count each year (Appendix 2). Obviously, counting errors for any of these abundant species will have had a far greater effect on the total water bird counts than errors made for the less common species.

In the following sections, we first investigate whether characteristics of the lakes are able to explain trends in water bird abundances, and then examine trends in the abundance and distribution of each species in turn.

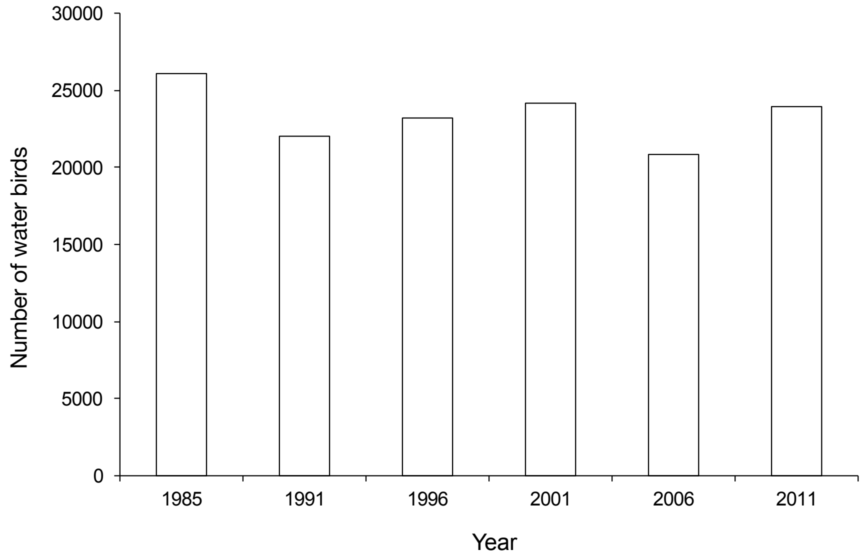


Figure 2. Total numbers of water birds of the 18 consistently counted species on 18 of the Rotorua Lakes from 1985 to 2011.

## 3.1 Characteristics of the lakes

### 3.1.1 Physical parameters

The total number of water birds counted per lake was related to lake size in 2011 ($F_{1,10}$ = 41.43, $P$ < 0.001, $r^2$ = 0.81) (Fig. 3) and in all other surveys (all $F_{1,10}$ ≥ 7.54, all $P$ ≤ 0.02, all $r^2$ ≥ 0.43). The number of species observed on a lake was weakly related to lake size in 2011 ($F_{1,10}$ = 8.40, $P$ = 0.02, $r^2$ = 0.46; Fig. 4) and in 2006 ($F_{1,10}$ = 5.15, $P$ = 0.05, $r^2$ = 0.34), but not in other survey years (all $F_{1,10}$ ≤ 2.79, all $P$ ≥ 0.12, all $r^2$ ≤ 0.22) (Fig. 5). In 2011, Lakes Rotomahana and Rotoehu appeared more species-rich than would be suggested by their size, possibly reflecting the diverse habitats associated with these two lakes. In contrast, Lakes Ōkataina and Tikitapu were more species-poor (Fig. 4). The low numbers and diversity of water birds on Lake Tikitapu may be due to its slightly unusual water chemistry, including low alkalinity and low concentrations of reactive silica (and, possibly, other major ions), which may inhibit the growth of diatoms and account for reduced plant abundance and vigour in this lake (Wilding 2000; NIWA n.d.). Lake Tikitapu also has only sparse emergent aquatic vegetation and no caves or peninsulas that may afford birds shelter, as well as experiencing heavy human recreational use throughout the year, which may influence bird use of this lake.

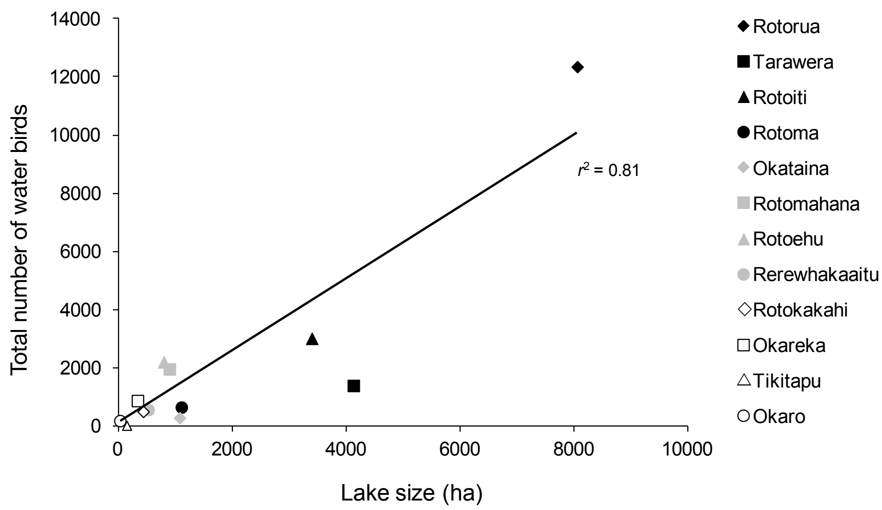


Figure 3. Relationship between the total number of water birds counted on 12 of the Rotorua Lakes in 2011 and lake size. Lake size data were obtained from www.boprc.govt.nz/environment/water/rotorua-lakes/.

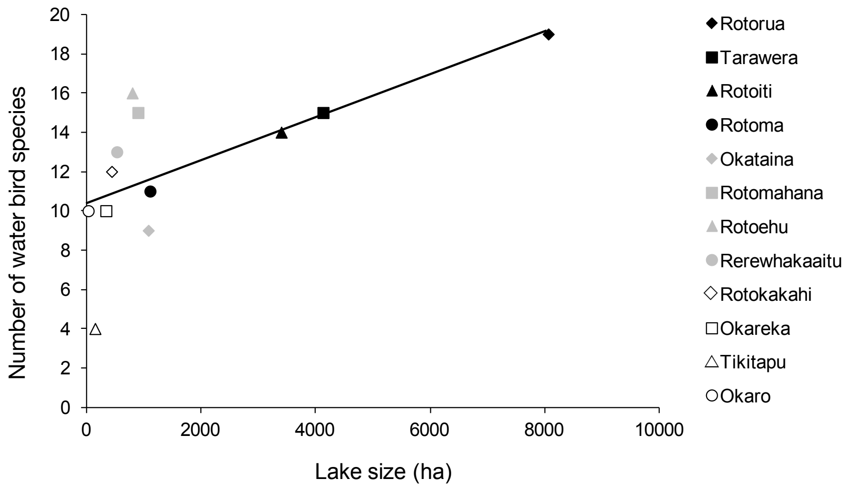


Figure 4. Relationship between the total number of water bird species counted on 12 of the Rotorua Lakes in 2011 and lake size. Lake size data were obtained from www.boprc.govt.nz/environment/water/rotorua-lakes/

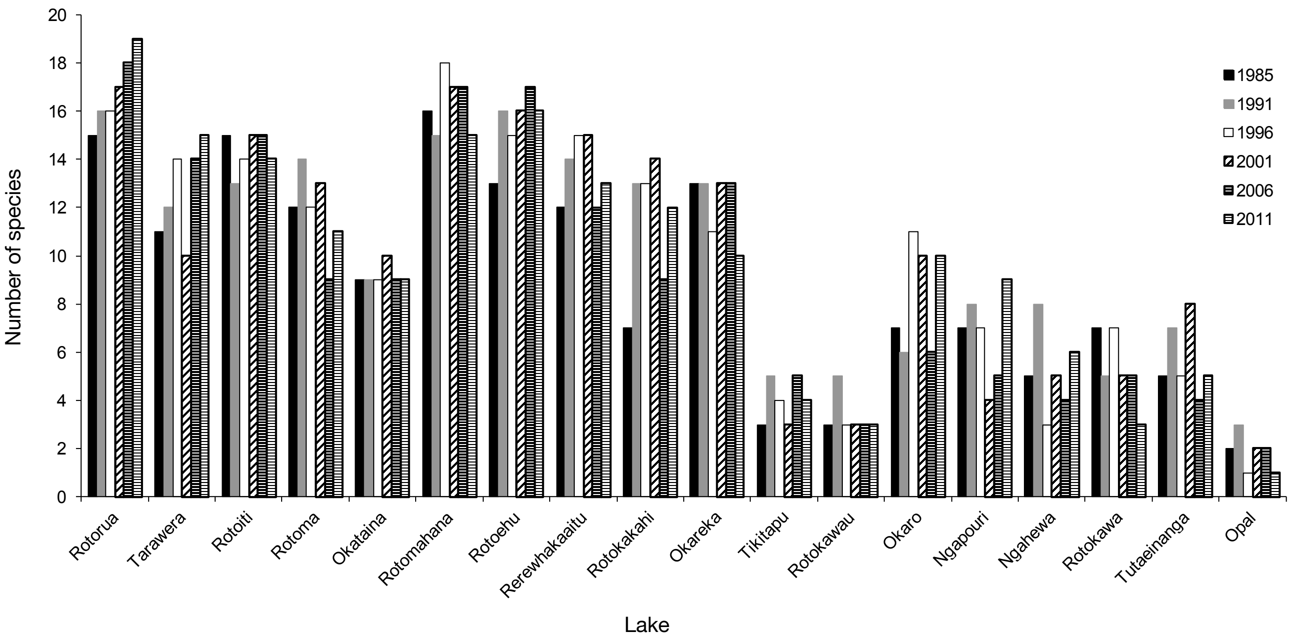


Figure 5. Number of water bird species counted on each of the Rotorua Lakes surveyed during 1985–2011. Lakes are arranged in order of decreasing size (left to right).

However, lake size only takes into account the water area of the lake, whereas water birds were also counted on the shorelines of all lakes. When the total number of water birds counted in 2011 was compared with the length of lake shoreline, there was no statistically significant relationship ($F_{1,10}$ = 3.74, $P$ = 0.08, $r^2$ = 0.27), but the number of species detected was weakly related to lake shoreline length ($F_{1,10}$ = 11.51, $P$ = 0.007, $r^2$ = 0.54). Lake Rotorua had more water birds and species relative to its shoreline length than any of the other lakes examined (Figs 6 & 7), and Lake Rotomahana also had more species than would be suggested by the length of its shoreline. In contrast, Lakes Tikitapu, Ōkataina and Rotoiti had fewer species than expected (Fig. 7).

Catchment and shoreline properties are also likely to contribute to both the total number of water birds and the number of species counted; for example, grazing species such as paradise shelducks (*Tadorna variegata*), black swans (*Cygnus atratus*) and Canada geese (*Branta canadensis maxima*) may be found in high numbers in surrounding pasture, whereas shags (*Phalacrocorax* spp.) are more likely to be found roosting in suitable trees overlooking the water. Several of the lakes have swampy, shallow margins that waterfowl and waders in particular find

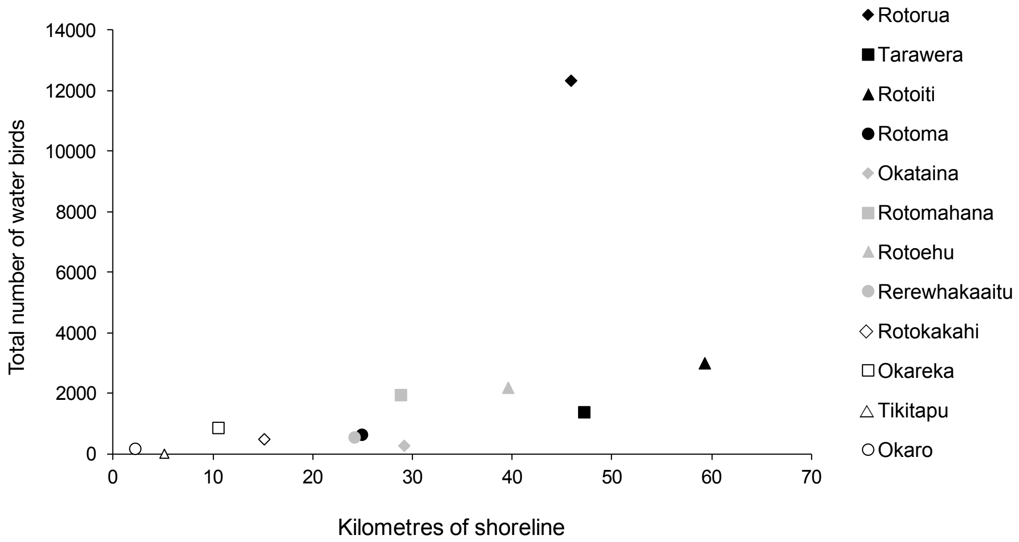


Figure 6. Relationship between the total number of water birds counted on 12 of the Rotorua Lakes in 2011 and lake shoreline length. Shoreline data were obtained from the Bay of Plenty Regional Council (C. Bichan, pers. comm.).

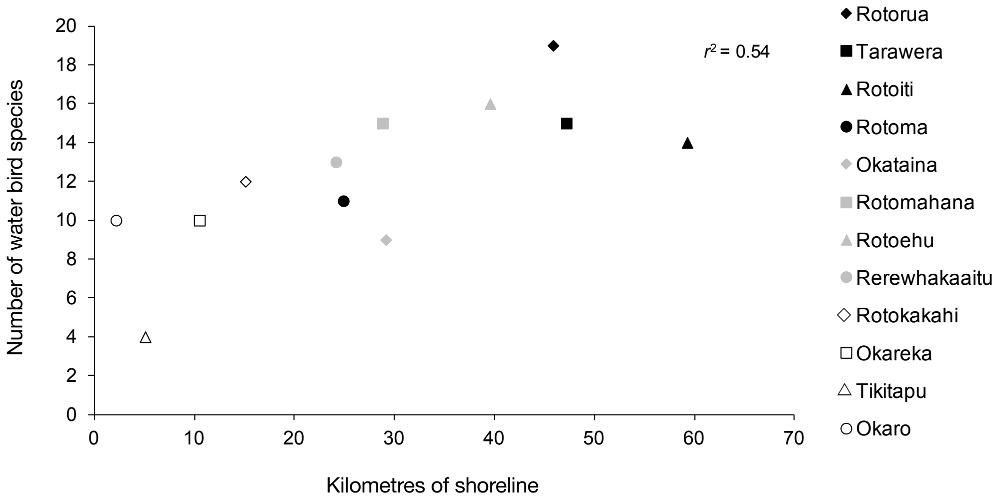


Figure 7. Relationship between the number of water bird species detected on 12 of the Rotorua Lakes in 2011 and lake shoreline length. Shoreline data were obtained from the Bay of Plenty Regional Council (C. Bichan, pers. comm.).

attractive for feeding. The total number of water birds counted in 2011 was positively related to lake catchment size ($F_{1,10}$ = 190.51, $P$ < 0.000, $r^2$ = 0.95), as was the number of species detected ($F_{1,10}$ = 8.34, $P$ = 0.02, $r^2$ = 0.45). None of the other physical factors measured (land cover, altitude, depth, age; Tables 2 & 3) could explain the observed patterns.

### 3.1.2 Chemical parameters

The Trophic Level Index (TLI) and Lake Submerged Plant Indicators (LakeSPI) index were used to examine the relationship between water quality and water bird abundance in 2011. Neither index significantly explained the total number of water birds counted (TLI: $F_{1,10}$ = 1.26, $P$ = 0.29, $r^2$ = 0.11; LakeSPI: $F_{1,10}$ = 1.98, $P$ = 0.19, $r^2$ = 0.17) or number of species detected (TLI: $F_{1,10}$ = 2.31, $P$ = 0.16, $r^2$ = 0.19; LakeSPI: $F_{1,10}$ = 2.03, $P$ = 0.18, $r^2$ = 0.17). Since there are historical LakeSPI data going back to the 1970s or 1980s, this index was also related to the total number of water birds and number of species counted across surveys by lake; however, again, there was no significant relationship for any of the lakes.

### 3.1.3 Biological parameters

For the 2011 survey, we examined the relationship between kōura (freshwater crayfish, *Paranephrops planifrons*) presence, kākahi (freshwater mussel, *Echyridella menziesi*) presence, number of native aquatic plant species and number of invasive aquatic weeds (all of which contribute to LakeSPI values) on the number of water birds counted by lake (Table 2). There were no significant relationships (all $F_{1,13} \leq 1.07$, all $P \geq 0.32$, all $r^2 \leq 0.08$). We also investigated the relationship between the number of water birds counted and kōura catch per unit effort, mean catch weight and size (mean and maximum orbit-carapace length), data for which were available for six lakes in 2009 (Table 2). Total number of water birds was positively related to kōura catch per unit effort ($F_{1,4} = 11.66$, $P = 0.03$, $r^2 = 0.74$), but this relationship was heavily influenced by Lake Rotorua's results (at least 4 times as many water birds counted as the other five lakes, and twice the kōura catch per unit effort of the next closest lake); indeed, when Lake Rotorua was removed from the analysis, there was no statistically significant relationship ($F_{1,3} = 0.31$, $P = 0.61$, $r^2 = 0.09$). Likewise, there was no relationship between the number of water birds counted in 2011 and kōura catch weight and size measurements in 2009 (all $F_{1,4} \leq 2.46$, all $P \geq 0.19$, all $r^2 \leq 0.38$).

### 3.1.4 Data limitations

There are several issues with the foregoing analyses, for example, differences in the timing of data collection (e.g. examining 2011 water bird counts in relation to 2009 kōura data). Also, the spatial variation in lakes can be large, such that point sampling methods such as those used to collect water quality data can misrepresent the general lake condition (Allan et al. 2007). There is also a long lag time between changes in land use and a corresponding change in water quality in the Rotorua Lakes: one study found that 8 out of 12 spring and groundwater well water samples had a mean residence time of >60 years (Parliamentary Commissioner for the Environment 2006). Therefore, the full effects of recent land use intensification may not be reflected in the water quality of the lakes for many years, and consequently water bird abundance changes will need to be monitored over the long term to detect any possible influences.

## 3.2 Species

### 3.2.1 New Zealand dabchick

Discounting fluctuations between surveys, there has been a 57% increase in total New Zealand dabchick (weweia, *Poliocephalus rufopectus*) numbers over the six surveys, from 364 in 1985 to 572 in 2011 (Fig. 8; $F_{1,4} = 26.10$, $P = 0.01$, $r^2 = 0.87$). Numbers of dabchicks have fluctuated on most lakes, but some fluctuations have been more pronounced than others; for example, numbers on Lake Ōkataina crashed from 28 in 1985 to 2 in 1991 and 1996, before increasing slowly back up to 19 in 2011; and similarly, numbers on Lake Rotomahana dropped from 21 in 1991 to 3 in 1996, bounced back up to 43 in 2001, more than halved to 15 in 2006 and doubled to 30 in 2011. Of note, however, is that there has been a general decline in numbers of dabchicks on Lakes Ōkareka (from 63 in 1985 to 29 in 2011) and Rotorua (from 20 in 1985 to 8 in 2011), and an increase in numbers on Lakes Tarawera (from 43 in 1985 to 106 in 2011) and Rotoiti (from 95 in 1985 to 269 in 2011).

The distribution of dabchicks across the lakes has also been variable throughout the period of the surveys, although dabchicks were present on 17 of the 18 lakes surveyed in both the 1985 and 2011 censuses. The only lake on which dabchicks were not present in these 2 years was Lake Rotokawa (Appendix 3), and dabchicks have never been recorded on this lake in any of the water bird surveys. Dabchicks have also been absent from Lake Okaro (1991, 1996, 2001, 2006), Lake Ngahewa (1996, 2006), Lake Tikitapu (1996), Lake Opal (1996) and Lake Rotokawau (2006) at times. Consequently, they were found on 16/18 lakes in 1991, 13/18 lakes in 1996, 16/18 lakes in 2001 and 14/18 lakes in 2006. In contrast, there was an increase in the distribution of dabchicks nationwide between 1985 and 2004 (Robertson et al. 2007), although this national result should

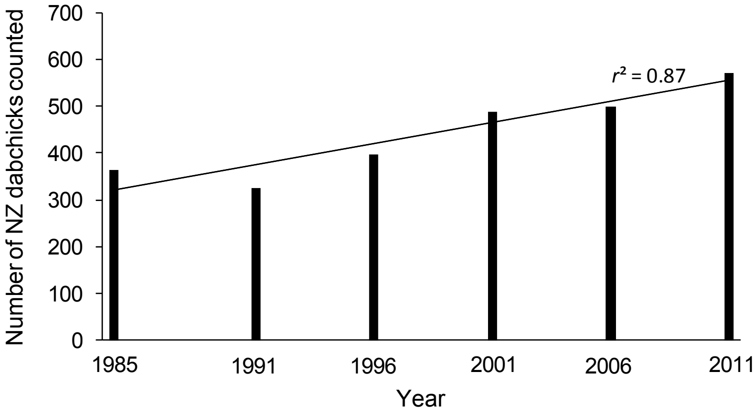


Figure 8. Total numbers of New Zealand dabchicks (weweia, *Poliocephalus rufopectus*) counted during the water bird surveys of the Rotorua Lakes, 1985 to 2011, showing the linear regression trend line.

be treated with caution as it may simply be the result of increased survey effort in 2004. It is of interest that there has been an increase in dabchick numbers throughout the c. 5-yearly surveys, even in years when dabchicks were found on fewer surveyed lakes (e.g. 1996: 396 dabchicks on 13/18 lakes; and 2006: 498 dabchicks on 14/18 lakes).

The observed changes in dabchick numbers were not related to lake water quality or any of the other possible explanatory factors examined (Table 2; all $F_{1,10} \leq 5.24$, all $P \geq 0.09$, all $r^2 \leq 0.39$). However, it is possible that other factors, such as human disturbance (including boating activity) and structures, may be affecting dabchick populations. Dabchicks are intolerant of disturbance by people on foot (Harris 2005; W. Shaw, Wildland Consultants, pers. comm.), and so the construction of a public walkway along the southern shore of Lake Ōkareka, which was started in 2001 and completed in 2003, may explain the decline in numbers from > 30 adult dabchicks in 1996 to only 3 adults in 2011 (Harris 2005). In contrast, human-made structures such as boat sheds and jetties appear to have a neutral or possibly even a positive effect on dabchick populations, presumably through providing nesting sites that are protected from waves and boat wash that would otherwise swamp nests (Bright et al. 2004).

Predation may also be having an impact on dabchick populations. In 2000, residents formed the Lake Tarawera Pest Control project to control rats (*Rattus* spp.), which were seen running freely during daylight hours along power lines and in shrubs in the settlement area alongside the western side of the lake, indicating that high numbers were present. Although most of these rats are likely to have been ship rats (*R. rattus*), the ongoing pest control project targets all rodents, and so will also be reducing numbers of Norway rats (*R. norvegicus*), which are thought to be a primary predator of dabchick nests (Buddle 1939). Since this project began, dabchick numbers on Lake Tarawera have increased from 52 in 1996 to 106 in 2011. Given that most dabchicks found on the lake inhabit (and nest alongside) the western shoreline adjacent to the Tarawera settlement, this increase in numbers may be a response to the reduction in predators.

### 3.2.2 Shags

Three species of shag have been regularly counted during the c. 5-yearly censuses of water birds on the Rotorua Lakes: little shag (kawau paka, *Phalacrocorax melanoleucos brevirostris*), little black shag (kawau tūī, *P. sulcirostris*) and black shag (kawau, *P. carbo novaehollandiae*). All three species are classified as At Risk: Naturally Uncommon in the New Zealand Threat Classification System (Robertson et al. 2013) and have experienced fluctuating counts over the duration of the surveys. Numbers detected of little shags and little black shags have increased and decreased in tandem, with neither species having fully recovered from a substantial decrease in count numbers in 1996. In contrast, black shags have shown a different pattern, and have had higher counts post-1996 (Fig. 9).

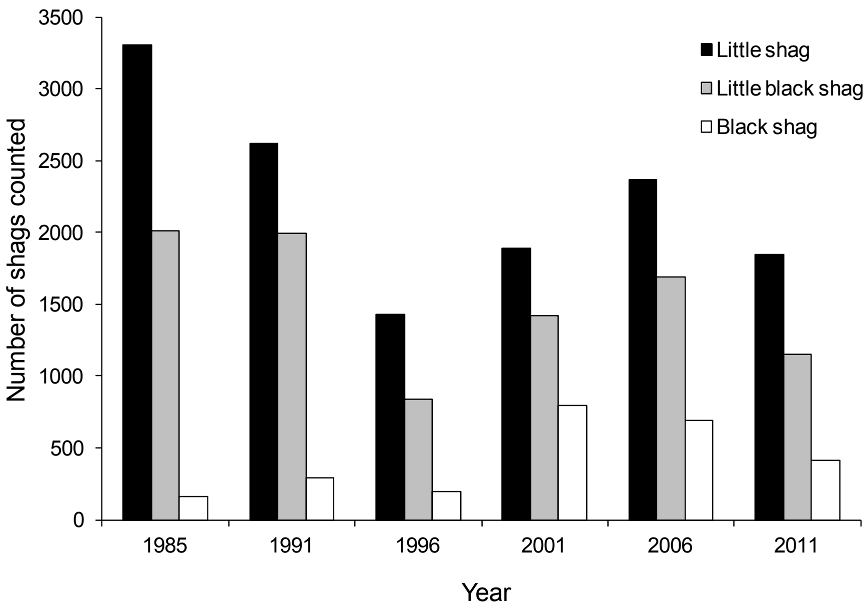


Figure 9. Total numbers of shags (little shag (kawau paka, *Phalacrocorax melanoleucos brevirostris*), little black shag (kawau tūī, *P. sulcirostris*) and black shag (kawau, *P. carbo novaehollandiae*)) counted during the water bird surveys of the Rotorua Lakes, 1985 to 2011.

The distributions of the three species have also varied among species and years, but in the opposite direction from fluctuations in numbers counted; i.e., as the number of individuals of a species counted decreased, the number of lakes on which the species was detected increased, and vice versa (Table 5; Fig. 9). Leaving aside fluctuations between censuses, the distribution of little shags has reduced from 16 lakes in 1985 to 14 lakes in 2011, while the distributions of little black shags and black shags have increased across the Rotorua Lakes over the same period (Table 5). This differs from the nationwide distribution of these species, which increased for little shags and little black shags, but remained stable for black shags between 1985 and 2004 (Robertson et al. 2007) (however, as previously noted, this latter result should be treated with caution due to a change in survey effort between 1985 and 2004).

Table 5. Number of lakes on which shags (little shag (kawau paka, *Phalacrocorax melanoleucos brevirostris*), little black shag(kawau tūī, *P. sulcirostris*) and black shag (kawau, *P. carbo novaehollandiae*)) were detected during the surveys of water birds on 18 Rotorua Lakes from 1985 to 2011.

| | 1985 | 1991 | 1996 | 2001 | 2005 | 2011 |
|---|---|---|---|---|---|---|
| Little shag | 16 | 17 | 17 | 14 | 11 | 14 |
| Little black shag | 6 | 9 | 12 | 13 | 8 | 13 |
| Black shag | 8 | 13 | 11 | 13 | 15 | 12 |

There were no relationships between shag counts and prey for which data were available (Table 2; kōura: all $F_{1,4} \leq 2.50$, all $P \geq 0.19$, all $r^2 \leq 0.38$; kākahi: $F_{1,4} = 0.74$, $P = 0.44$, $r^2 = 0.16$; smelt: all $F_{1,9} \leq 0.71$, all $P \geq 0.42$, all $r^2 \leq 0.07$; larval bully: both $F_{1,9} \leq 1.38$, both $P \geq 0.27$, both $r^2 \leq 0.13$; adult bully: both $F_{1,3} \leq 0.46$, both $P \geq 0.55$, both $r^2 \leq 0.13$; mean trout condition: $F_{1,9} = 0.13$, $P = 0.72$, $r^2 = 0.01$; trout size at release: $F_{1,7} = 1.31$, $P = 0.29$, $r^2 = 0.16$; numbers of stocked trout released: $F_{1,7} < 1.08$, $P = 0.33$, $r^2 = 0.13$; growth rates of stocked trout at 300 mm, 400 mm and 500 mm: all $F_{1,23} \leq 1.45$, all $P \geq 0.24$, all $r^2 \leq 0.06$). There were also no relationships between numbers of shags counted and lake physical, chemical, or biological factors thought likely to influence shag numbers (Table 2; all $F_{1,10} \leq 5.23$, all $P \geq 0.14$, all $r^2 \leq 0.20$). It is possible that the fluctuations in numbers counted of these three species are a result of count variability rather than actual population changes:

many shags were counted in breeding rookeries or roosts, where accurate counting is difficult. In addition, slight changes in peak breeding time may influence the conspicuousness of shags and the timing of post-breeding dispersal (all three species breed in the Rotorua Lakes district).

In the absence of knowledge about the population sizes of little shags and little black shags prior to 1985, it is not possible to determine whether the apparent decrease in total numbers of these species since 1985 should be cause for concern. However, if this trend continues, it may be advisable to investigate the causes of the lower numbers and possible management actions to reverse the decline.

### 3.2.3 White-faced heron

Discounting fluctuations between surveys, there has been a 57% decrease in total numbers of white-faced herons (*Egretta novaehollandiae novaehollandiae*) between the 1985 and 2011 surveys (Fig. 10; $F_{1,4}$ = 16.97, $P$ = 0.01, $r^2$ = 0.81). This may be a continuation of the general decline that has followed their rapid increase in numbers between the 1940s and 1970s (Heather & Robertson 2005). Heron numbers were not significantly related to the possible explanatory factors examined (Table 2; both $F_{1,10} \leq 0.77$, both $P \geq 0.40$, both $r^2 \leq 0.07$).

White-faced herons have consistently been present on the eight largest lakes (Appendix 3), with the exception of Rotomā in 2006. However, on the smaller lakes their presence has fluctuated from 0 to a few (≤ 5) individuals. White-faced herons were present on 14 of the 18 lakes surveyed in 1985; 12 in 1991, 1996 and 2001; 9 in 2006; and 10 in 2011 (Appendix 3).

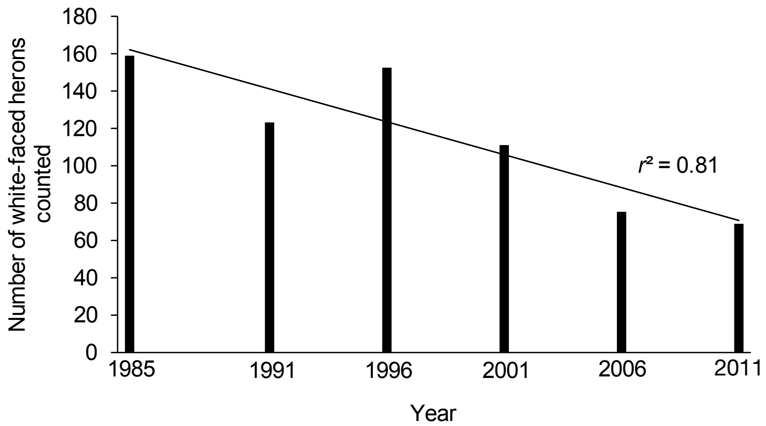


Figure 10. Total number of white-faced herons (*Egretta novaehollandiae novaehollandiae*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011, showing the linear regression trend line.

### 3.2.4 Waterfowl

#### *Canada goose*

From banding data, it appears that Canada geese (*Branta canadensis maxima*) were first introduced to the Rotorua lakes district in 1983, when nine birds were banded at Lake Rotorua (M. Nesaratnam, Department of Conservation, pers. comm.). Numbers of Canada geese counted have increased more than 20-fold since 1985, from 22 to over 500 birds (Fig. 11; $F_{1,4}$ = 16.97, $P$ = 0.01, $r^2$ = 0.81). At the same time, their distribution has also broadened, from being present on only two lakes in 1985 (Lakes Rotomā and Rerewhakaaitu), to three in 1991, five in 1996, seven in 2001 and 2006, and eight in 2011 (Appendix 3). Nationwide, the distribution of Canada geese also increased between 1985 and 2004 (Robertson et al. 2007), and the increases in Canada goose numbers and distribution on the Rotorua Lakes undoubtedly reflect the continuing colonisation and expansion of this species.

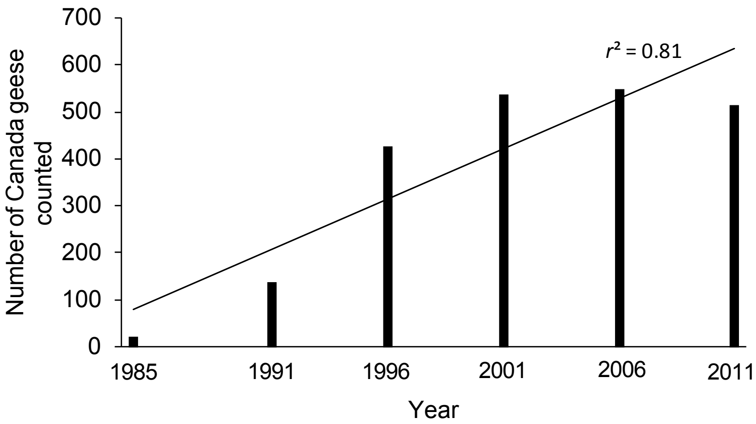


Figure 11. Total numbers of Canada geese (*Branta canadensis maxima*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011.

Since 1991, Eastern Region Fish and Game staff have conducted annual aerial surveys in mid-January of Canada geese on many of the same lakes that are censused by the c. 5-yearly water bird surveys (Rotorua, Tarawera, Rotoiti, Rotomā, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi and Ōkareka). Despite the different methodologies and slightly different timing of these surveys, both counts have shown similar trends in Canada goose numbers, with an initial steep increase in numbers followed by an apparent plateau over the last decade (Fig. 12).

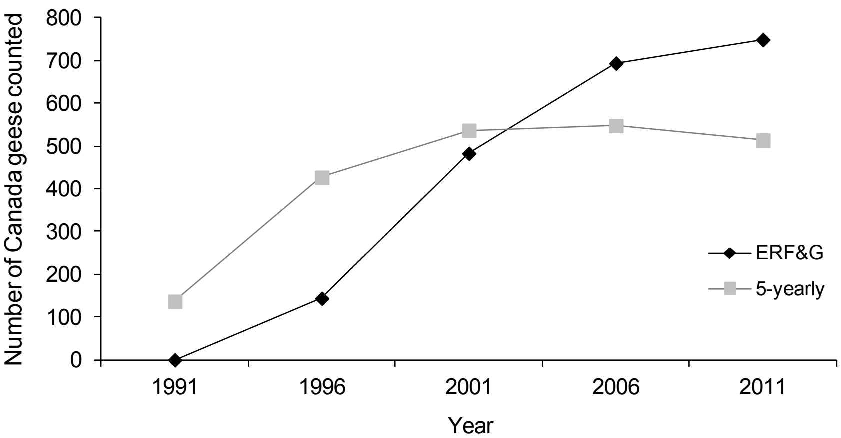


Figure 12. Counts of Canada geese (*Branta canadensis maxima*) obtained by Eastern Region Fish and Game (ERF&G) and the c. 5-yearly water bird surveys (5-yearly) of Lakes Rotorua, Tarawera, Rotoiti, Rotomā, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi and Ōkareka.

Potamogeton (*Potamogeton* spp.) is a favoured aquatic food of Canada geese (Heather & Robertson 2005), and data was available for 12 lakes regarding the number of potamogeton species present (no potamogeton present, native species of potamogeton only, non-native species only, or both native and non-native species present). We grouped lakes by their potamogeton species communities and tested whether Canada goose numbers were related to food availability by comparing the average number of geese counted over all censuses in relation to the number of potamogeton species present (Table 2). We found that mean Canada goose numbers were higher when lakes contained more species of potamogeton, suggesting that numbers increase with higher food availability (Fig. 13; Kruskal-Wallis test, $|H| = 14.86$, $P < 0.05$).

There were no significant relationships between the number of Canada geese counted and the other explanatory variables tested (Table 2; all $F_{1,10} \leq 0.16$, all $P \geq 0.70$, all $r^2 \leq 0.02$).

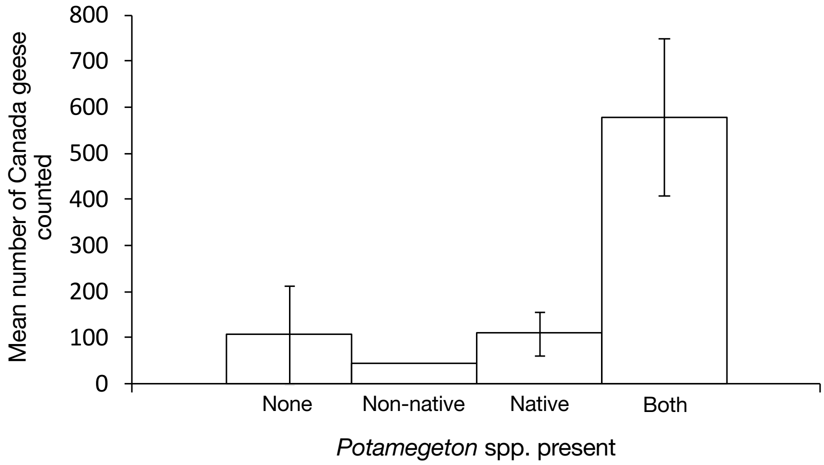


Figure 13. Relationship between the mean number of Canada geese (*Branta canadensis maxima*) counted on 12 lakes across all surveys and the presence of *Potamogeton* spp., a favoured aquatic plant food source of Canada geese. Bars show standard errors (there was only one lake [Lake Tarawera] with just non-native potamogeton present).

### *Black swan*

Total numbers of black swans (*Cygnus atratus*) counted have fluctuated over the duration of the censuses (Fig. 14). The number of swans counted was weakly related to whether *Egeria densa*, a favoured aquatic food source (Heather & Robertson 2005), was present in or absent from a lake (Fig. 15; Rank Sum test, T = 26, $P = 0.05$). There were no significant relationships with any other of the possible explanatory factors examined (Table 2; all $F_{1,10} \leq 3.49$, all $P \geq 0.09$, all $r^2 \leq 0.26$). There has also been no relationship between numbers and distribution. Black swans were present on 14 of the 18 lakes surveyed in 1985, 1991 and 1996, 13 lakes in 2001 and 2006, and 12 lakes in 2011. Across surveys, this species was absent from various combinations of 7 of the 8 smallest lakes (excepting Rotokawa), but was always present on the 10 largest lakes (Appendix 3). As with Canada geese, Eastern Region Fish and Game staff have completed annual aerial counts in mid-January since 1991 of black swans on ten of the same lakes surveyed during the c. 5-yearly censuses (Rotorua, Tarawera, Rotoiti, Rotomā, Ōkataina, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi and Ōkareka), and again these two surveys have found remarkably similar trends (Fig. 16).

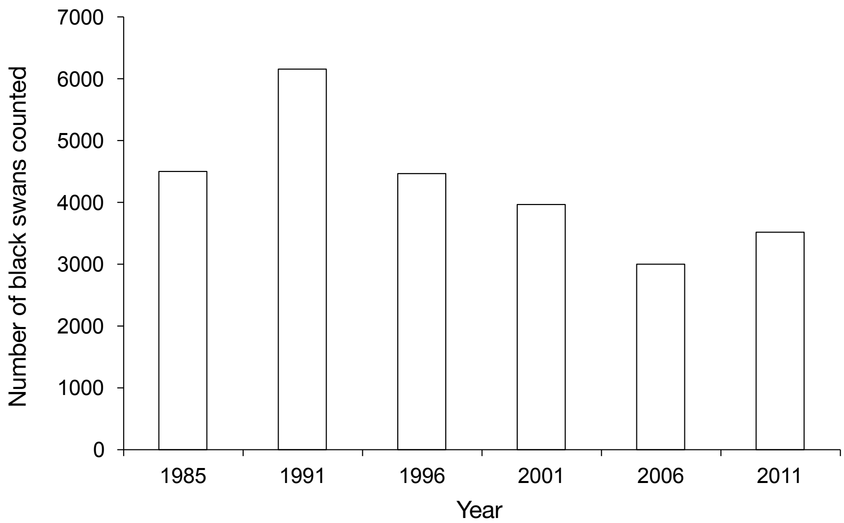


Figure 14. Total number of black swans (*Cygnus atratus*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011.

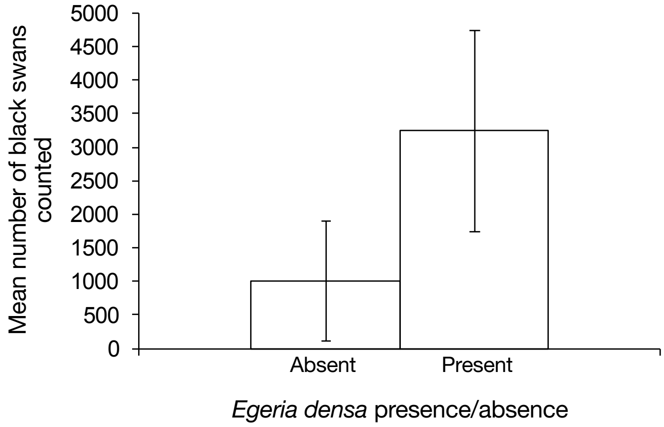


Figure 15. Relationship between the mean number of black swans (*Cygnus atratus*) counted on 12 lakes across all surveys and the presence of *Egeria densa*, a favoured food source of black swans. Bars show standard errors.

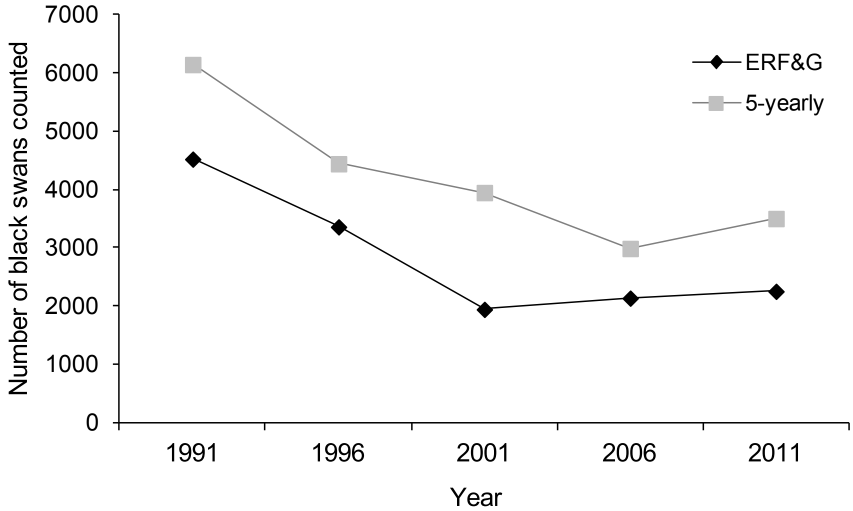


Figure 16. Counts of black swans (*Cygnus atratus*) obtained by Eastern Region Fish and Game (ERF&G) and the c. 5-yearly water bird survey (5-yearly) on Lakes Rotorua, Tarawera, Rotoiti, Rotomā, Ōkataina, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi and Ōkareka.

### *Mallard/grey duck*

The mallard (*Anas platyrhynchos*) and grey duck (pārera, *Anas superciliosa*) are treated as a single genetic complex here because they commonly hybridise. Despite some fluctuations between surveys, total numbers of mallards / grey ducks have declined 68% from 1985 to 2011 (Fig. 17; $F_{1,4}$ = 11.20, $P$ = 0.03, $r^2$ = 0.74). This decline was related to mean Secchi disk depth measurements ($F_{1,10}$ = 7.15, $P$ = 0.02, $r^2$ = 0.42), considered here as a proxy of potential food availability; as the water got clearer, number of mallards / grey ducks counted decreased (Fig. 18). This reduction in numbers was not reflected in their distribution across the surveyed lakes. Mallards / grey ducks were present on all 18 lakes in 1991 and 2006, but in various other surveys were absent from Lakes Rotokawau (1985, 1996 and 2011), Opal (1985, 2001 and 2011) and Tutaeinanga (1985). Thus, in 1985, they experienced their highest numbers (4121 birds) but were present on the fewest lakes (15/18). The decline in mallards / grey ducks indicated by the c. 5-yearly surveys may not be of concern. Eastern Region Fish and Game staff have monitored mallard / grey duck populations since 1997 using banding data, and their estimates of population size indicate an 11-year cyclical pattern (McDougall 2013). This has also been somewhat supported by c. 5-yearly counts, which show peaks in 1985 and 1996, and troughs in 1991 and 2011.

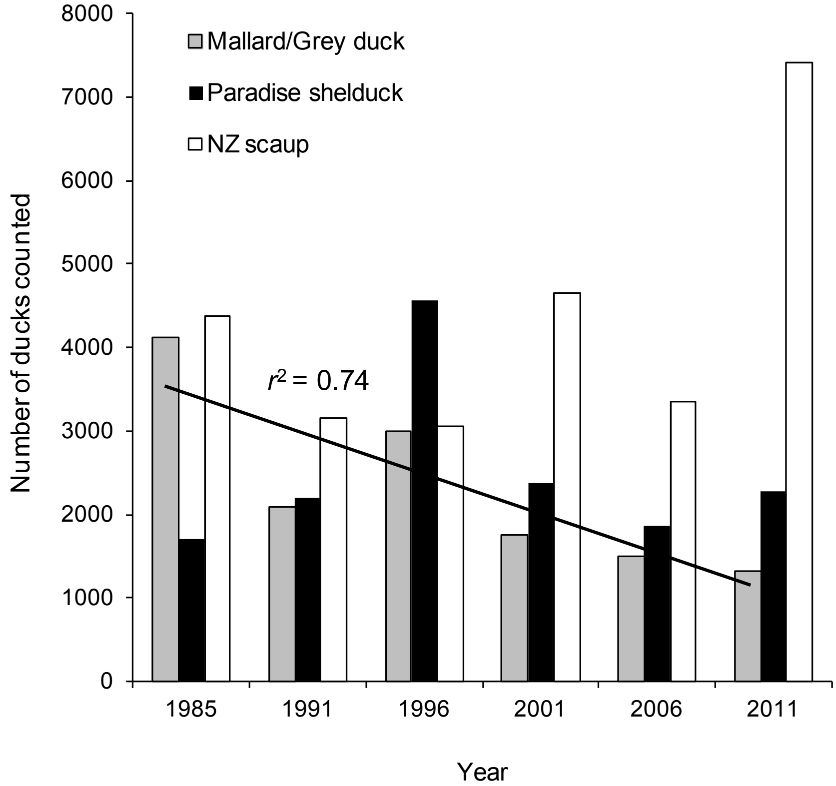


Figure 17. Numbers of mallards (*Anas platyrhynchos*) / grey ducks (pārera, *Anas superciliosa*), paradise shelducks (pūtangitangi, *Tadorna variegata*) and New Zealand scaup (pāpango, *Aythya novaeseelandiae*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011, showing the linear regression trend line for mallards / grey ducks. Mallards and grey ducks are treated together due to the high level of hybridisation between the two species.

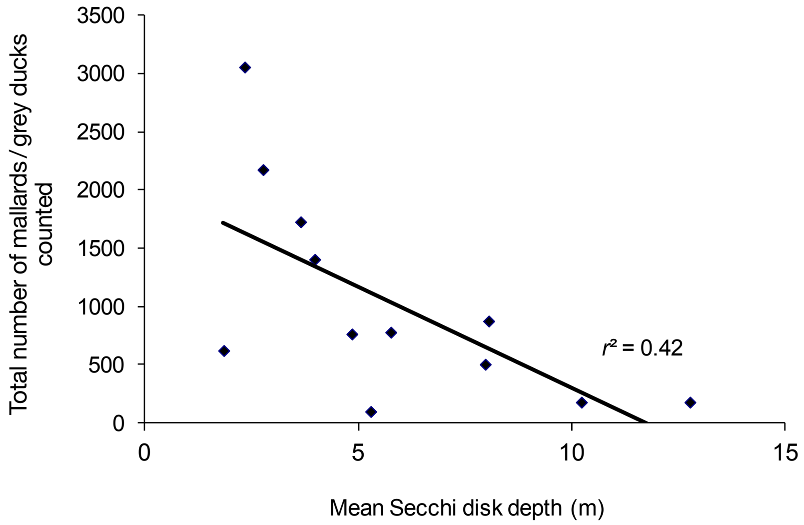


Figure 18. Relationship between numbers of mallards (*Anas platyrhynchos*) / grey ducks (pārera, *Anas superciliosa*) counted on 12 of the Rotorua Lakes across surveys and mean Secchi disk depth measurements in metres.

There was no peak in 2006, which would be expected for an 11-year cycle; however, this could in part be explained by some large avian botulism events that occurred on Lake Rotorua between 1996 and 2005 (M. McDougall, Eastern Region Fish and Game, pers. comm.). If the mallard / grey duck population is following an 11-year cycle, numbers should begin to show an increase that should be reflected by the time of the next census in 2016.

### *Paradise shelduck*

The numbers counted (Fig. 17) and distribution of paradise shelducks (pūtangitangi, *Tadorna variegata*) have fluctuated across the surveys. For the first three surveys (1985–1996), there was an increase in both numbers and distribution (with birds present on 12, 13 and 14 of the 18 lakes, respectively). However, during the last three surveys, counts were found to fluctuate despite birds being present on 10 lakes for all three surveys. Paradise shelduck counts were not related to any of the possible explanatory factors examined (Table 2; all $F_{1,10} \leq 1.22$, all $P \geq 0.30$, all $r^2 \leq 0.11$). Paradise shelducks have not been present on Lakes Tikitapu, Ngahewa or Opal in any of the surveys, probably due to these lakes being surrounded by plantation forests and thus having unsuitable shoreline grazing habitat. Furthermore, paradise shelducks have only been present on Lake Rotokawau once (1996) and on Lake Ōkataina twice (1985 and 2006), both of which are encircled by native forest. They have been consistently absent from Lakes Okaro and Ngapouri since the 2001 survey, and were absent from Lake Tutaeinanga for the first time in 2011. It is not known what changes may have occurred to these lakes in the last decade to make them apparently unsuitable for paradise shelducks, and shelducks may reoccur on these lakes in the future. In the Rotorua Lakes district, the distribution of paradise shelducks has contracted slightly from 12 lakes in 1985 to 10 lakes in 2011. In contrast, across New Zealand, their distribution increased between 1985 and 2004 (Robertson et al. 2007) (again, this nationwide result should be treated with caution due to a change in survey effort between 1985 and 2004).

Since 1991, Eastern Region Fish and Game staff have completed annual aerial counts of paradise shelducks in mid-January on Lakes Rotoiti, Rotomā, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi, Ōkareka, Ngapouri and Tutaeinanga. The trends in counts from this survey have corresponded with those of the c. 5-yearly survey, with the exception of 1996, when the c. 5-yearly survey detected almost 3000 birds at Lake Rotoehu, leading to a much higher total census result than that obtained by the Fish and Game survey (Fig. 19). The discrepancy in the 1996 counts is likely due to the differences in survey methodology, with light conditions on Lake Rotoehu making the aerial Fish and Game count difficult in this year (M. McDougall, Eastern Region Fish and Game, pers. comm.)

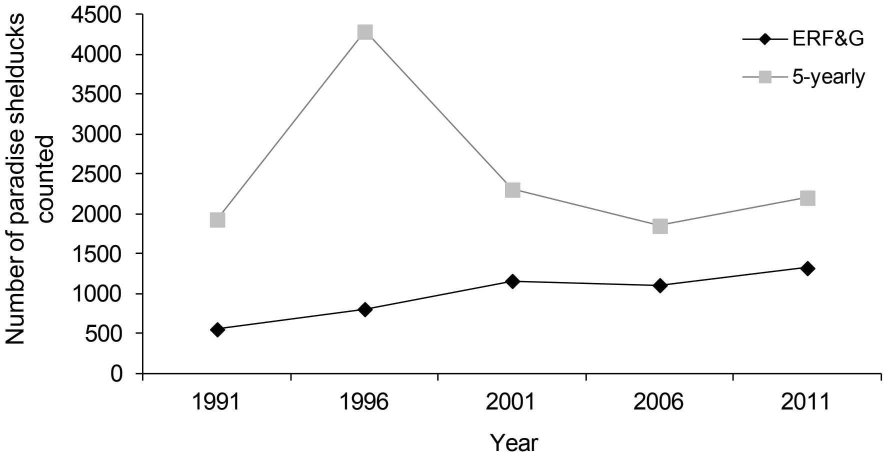


Figure 19. Counts of paradise shelducks (pūtangitangi, *Tadorna variegata*) obtained by Eastern Region Fish and Game (ERF&G) and the c. 5-yearly water bird survey (5-yearly) on Lakes Rotoiti, Rotomā, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi, Ōkareka, Ngapouri and Tutaeinanga. The discrepancy in 1996 resulted from almost 3000 paradise shelducks being detected on Lake Rotoehu by the c. 5-yearly water bird survey.

### *New Zealand scaup*

Numbers of New Zealand scaup (pāpango, *Aythya novaeseelandiae*) counted have fluctuated across surveys, with a large increase in numbers (c. 3000 additional birds) in the 2011 survey (Fig. 17). There was no significant relationship between scaup counts and any of the possible explanatory factors examined (Table 2; all $F_{1,10} \leq 1.99$, all $P \geq 0.19$, all $r^2 \leq 0.17$), and it is possible that the increase in numbers observed in 2011 resulted from favourable breeding seasons over the previous few years. These changes in numbers have not been reflected by changes in their distribution, which remained more or less constant in the Rotorua Lakes area between 1985 and 2011: scaup were present on 12 of the 18 lakes in 1985, 1996 and 2001, on 13 lakes in 2006 and 2011, and on 14 lakes in 1991. Since scaup are diving birds, they prefer large, deep lakes (Heather & Robertson 2005), which may explain why they have never been detected on Lake Tikitapu, have been detected in only one survey on Lakes Rotokawau, Ngahewa and Opal, and why their presence on other small lakes has been sporadic.

### *Grey teal*

There was an almost significant 95% decline in numbers of grey teal (tētē moroiti, *Anas gracilis*) between 1985 and 2011 (Fig. 20; $F_{1,4} = 6.64$, $P = 0.06$, $r^2 = 0.62$), primarily due to the population on Lake Rotomahana falling from 463 in 1985 to 64 in 1991, a crash from which it has not recovered. The decline in grey teal numbers is not likely to be of concern, as this species is highly mobile and disperses widely: it has been shown that grey teal numbers in New Zealand may change in response to droughts in Australia (Heather & Robertson 2005). Thus, it is unlikely that their decline is directly related to local conditions, and grey teal numbers were not significantly related to any of the possible explanatory factors examined (Table 2; all $F_{1,10} \leq 2.96$, all $P \geq 0.12$, all $r^2 \leq 0.23$; Fig. 20).

Grey teal have never been widely distributed on the Rotorua Lakes, being present on fewer than half of the lakes in any given survey (4/18 in 1985, 8/18 in 1991 and 2001, 6/18 in 1996 and 2011, and 3/18 in 2006). They appear to favour Lakes Rotorua and Rotomahana (present in all six surveys), Lake Rotoehu (present in five surveys, absent in 1991), and Lake Rerewhakaaitu (present in four surveys, absent in 2006 and 2011); however, a mixture of large and small lakes has been used by grey teal over the duration of the surveys.

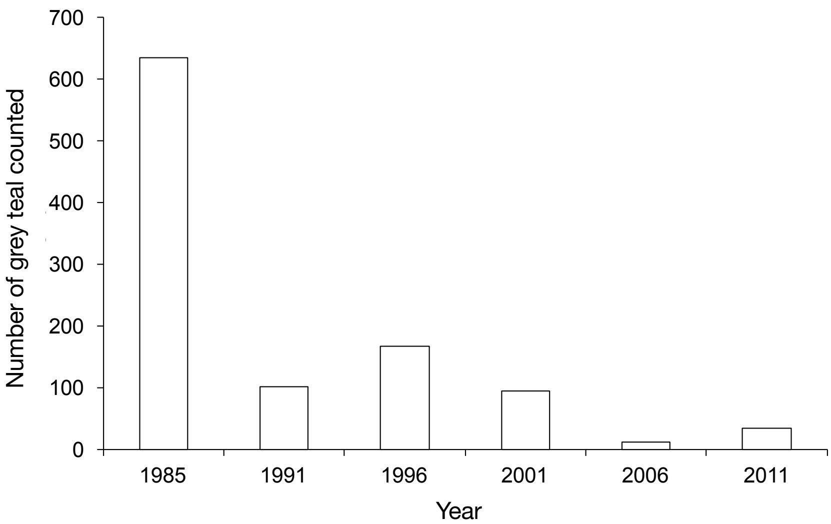


Figure 20. Number of grey teal (tētē moroiti, *Anas gracilis*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011.

### *Australasian shoveler*

Australasian shoveler (kuruwhengi, *Anas rhynchotis*) numbers have fluctuated greatly over the duration of the surveys, with the highest numbers detected in the first survey in 1985 (Fig. 21). Lake Rotorua had the highest number of shovelers in 1985 (83), but since then has yielded counts of fewer than 20 birds (next-highest count = 13 in 2011). Since the first survey, the highest number of shovelers has generally been on Lake Rotomahana, an isolated lake with few human or natural disturbances, and these counts have contributed up to approximately 75% of the total number in any given survey. Due to the preference of shovelers for low levels of disturbance, we examined

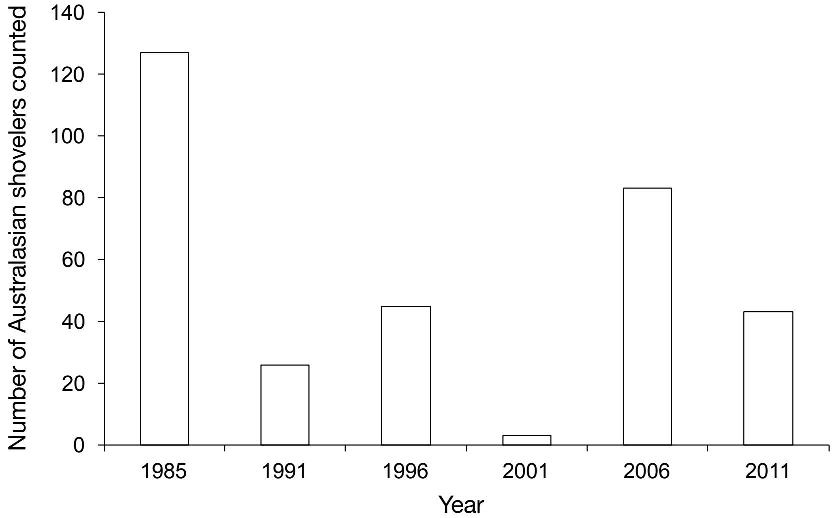


Figure 21. Numbers of Australasian shovelers (kuruwhengi, *Anas rhynchotis*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011.

the relationship between shoveler numbers and the percentage of urban settlement in lake catchments (Table 2), but found no relationship between the two ($F_{1,10}$ = 1.86, $P$ = 0.20, $r^2$ = 0.16). Shoveler abundance was also not significantly related to any of the other possible explanatory factors examined (Table 2; all $F_{1,10} \leq 2.11$, all $P \geq 0.18$, all $r^2 \leq 0.17$). Shovelers prefer shallow, fertile wetlands and lakes fringed with raupō, and, like a number of the other species monitored, are highly mobile within New Zealand (Williams 1981; Heather & Robertson 2005). Therefore, although the changes in numbers on Lakes Rotorua and Rotomahana may be related to habitat or water quality changes, they may also be unrelated to local conditions.

As for grey teal, Australasian shovelers have never been widely distributed on the Rotorua Lakes, having been present on only two (2001, 2011) or three (1996, 2006) lakes in most surveys, five lakes in one survey (1991), and six lakes in one survey (1985).

### 3.2.5 Australian coot

There has been a 130% increase in total numbers of Australian coots (*Fulica atra australis*) counted across the water bird surveys, from 328 in 1985 to 755 in 2011 (Fig. 22; $F_{1,4}$ = 28.67, $P$ = 0.01, $r^2$ = 0.88). Coot numbers were not significantly related to any of the possible explanatory factors examined (Table 2; all $F_{1,10} \leq 4.42$, all $P \geq 0.06$, all $r^2 \leq 0.31$). The distribution of coots has also broadened in this time, from 6/18 lakes in 1985 to 12/18 in 2011 (Appendix 3). Coots have not been recorded on Lakes Tikitapu, Rotokawau, Rotokawa or Opal. However, they have consistently been counted on most other lakes, with the exception of Lakes Rotorua, Okaro, Ngapouri and Tutaeinanga (present for only two surveys each), and thus appear to use both large and small lakes. As for Canada geese, the increase in Australian coot numbers and distribution undoubtedly reflects the continuing colonisation and expansion of this species.

### 3.2.6 Pied stilt

Despite some fluctuations between censuses, total numbers of pied stilts (poaka, *Himantopus himantopus leucocephalus*) counted decreased 79% between 1985 and 2011 (Fig. 23; $F_{1,4}$ = 14.51, $P$ = 0.02, $r^2$ = 0.78). The biggest declines occurred on Lakes Rerewhakaaitu (from a peak of c. 200 birds to 9 in 2011), Rotomahana (from over 100 birds to 12 in 2011) and Rotoehu (from c. 100 birds to 34 in 2011). Pied stilts are listed as At Risk: Declining in the New Zealand Threat Classification System (Robertson et al. 2013), and nationally, changes in land use are thought to be the main cause of population declines (Miskelly et al. 2008). In the Rotorua district, a change in agricultural land use from sheep to dairy farming has affected the water quality of the lakes, which, in turn, has resulted in the three above lakes being at risk of cyanobacterial blooms, particularly Rerewhakaaitu and Rotoehu (Bay of Plenty Regional Council n.d.). Recently, Lake Rotoehu has also experienced a hornwort (*Ceratophyllum demersum*) infestation (Bay of Plenty

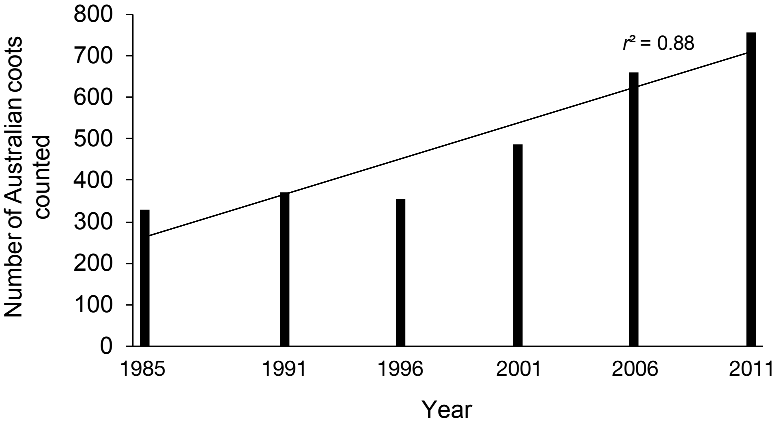


Figure 22. Numbers of Australian coots (*Fulica atra australis*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011, showing the linear regression trend line.

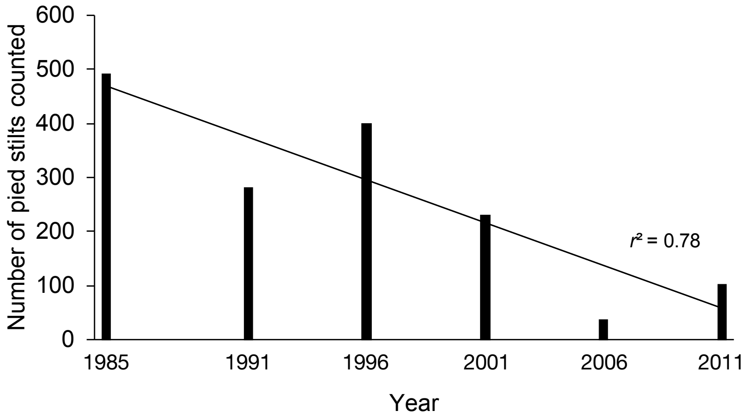


Figure 23. Numbers of pied stilts (poaka, *Himantopus himantopus leucocephalus*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011, showing the linear regression trend line.

Regional Council n.d.), and the expansion of grey willows (*Salix cinerea*) into the shoreline and littoral zone at South East Bay, Lake Rerewhakaaitu, will have prohibited access to the shallow feeding areas preferred by pied stilts. There was no relationship between the number of pied stilts counted and mean Secchi disk depth measurements (Table 2; $F_{1,10}$ = 1.13, $P$ = 0.31, $r^2$ = 0.10).

The distribution of pied stilts also contracted between 1985 and 2011, from being found on 11/18 lakes to 4/18 lakes, despite there being no change in their distribution nationally between 1985 and 2004 (Robertson et al. 2007). Changes in numbers and distribution of pied stilts do not correspond across years; for example, numbers of pied stilts were lower in 2001 than in 1996, despite birds being detected on 9/18 lakes in both years; and fewer pied stilts were counted in 2006 than in 2011, despite birds being detected on more lakes (5/18 lakes vs. 4/18 lakes, respectively). Across surveys, pied stilts have used both large and small lakes.

### 3.2.7 Gulls

#### *Red-billed gull*

The red-billed gull (tarāpunga, *Larus novaehollandiae scopulinus*) was the most numerous species of gull detected in each of the water bird surveys, numbering in the thousands (Fig. 24), despite being listed as Nationally Vulnerable in the New Zealand Threat Classification System (Miskelly et al. 2008). Numbers of red-billed gulls have often fluctuated widely, including by up to 112% between the 1991 and 1996 surveys. In contrast to their high numbers, the distribution of red-billed gulls has been relatively restricted, however, being detected on only three to five lakes: Rotorua and Rotoiti (all six surveys); Rotomahana (1985, 1996, 2001, 2011); Rotoehu (1991, 2006,

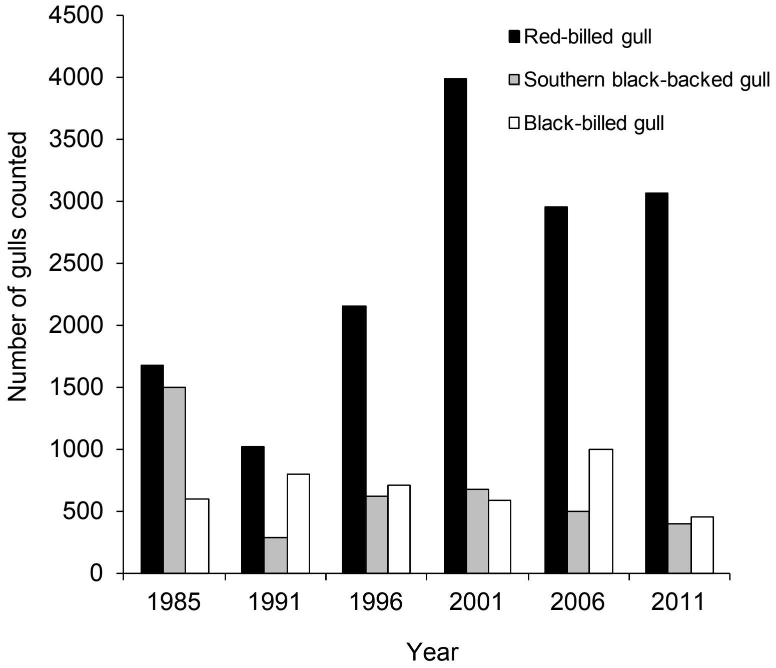


Figure 24. Numbers of red-billed gulls (tarāpunga, *Larus novaehollandiae scopulinus*), southern black-backed gulls (karoro, *Larus dominicanus dominicanus*) and black-billed gulls (tarāpuka, *Larus bulleri*) counted during the water bird surveys of the Rotorua Lakes, 1985–2011.

2011); Tarawera (2006, 2011); Rotokawa (one individual in 1985); and Okaro (two individuals in 2001). Thus, the distribution of red-billed gulls on the Rotorua Lakes has been quite stable since 1985. Numbers fluctuated independently of distribution for this species.

There are several breeding colonies of red-billed gulls at Sulphur Bay, Lake Rotorua, which have been monitored sporadically since the 1990s. Counts at these colonies have shown a trend of increasing numbers of red-billed gull adults, from c. 1500 in December 1998 to c. 2500 in 2000 and c. 2900 in December 2010. Of note, if we had solely relied upon counts at these breeding colonies, the large fluctuations in red-billed gull numbers around the Rotorua district would not have been detected, clearly demonstrating the value of large-scale, regular, long-term monitoring such as is carried out during the c. 5-yearly water bird surveys.

### *Southern black-backed gull*

Southern black-backed gulls (karoro, *Larus dominicanus dominicanus*) have generally been counted in the hundreds rather than the thousands, with the exception of 1985 (Fig. 24). Numbers of this species have shown similar changes to red-billed gulls, fluctuating among the surveys and increasing by up to 116% between the 1991 and 1996 surveys. The only time over which these two species showed different trends was between 2006 and 2011, when southern black-backed gulls decreased while red-billed gulls increased. However, total southern black-backed gull counts have declined while red-billed gull counts have not (Fig. 24). This downward trend in southern black-backed gull numbers may reflect the improvement in waste management practices at Rotorua's rubbish tip, resulting in less food being available for the gulls. A similar decline has also been found in other areas of New Zealand (Heather & Robertson 2005).

Southern black-backed gulls were distributed over 10–12 lakes in each survey, which contrasts with the restricted distribution of red-billed gulls. This species also had a stable distribution nationally between 1985 and 2004 (Robertson et al. 2007), despite changes in survey effort. Southern black-backed gulls were present on the eight largest lakes in all six surveys, and on the two next-largest lakes in five out of six surveys. They were only sporadically detected in low numbers on some of the smaller lakes. As for red-billed gulls, numbers fluctuated independently of distribution across lakes for this species.

### *Black-billed gulls*

As for the other two species of gull detected, total counts of the Nationally Endangered (Robertson et al. 2013) black-billed gull (tarāpuka, *Larus bulleri*) have shown substantial fluctuations over the duration of the censuses (Fig. 24), with the largest change being a 121% decrease from 2006 to 2011. However, black-billed gulls have shown the opposite trend to southern black-backed and red-billed gulls, increasing when the other two species decreased, and vice-versa. This may be because southern black-backed gulls and red-billed gulls are more associated with human-related food sources (direct feeding, rubbish tips, etc.), whereas black-billed gulls tend to forage for more natural foods on pastures and over waterways (Heather & Robertson 2005).

Sporadic monitoring of the small breeding colony at Sulphur Bay, Lake Rotorua (the only breeding colony in the Rotorua Lakes district) since the 1990s has indicated that numbers of black-billed gull adults have also fluctuated there, with a low of 250 birds recorded in 1999, a high of 540 counted in 2000, and intermediate numbers of c. 300–375 recorded in 1995, 1998 and 2010 (Sachtleben 2010).

The distribution of black-billed gulls was intermediate to that of red-billed and southern black-backed gulls, being counted on 4–8 lakes over the course of the surveys. This relatively stable distribution across the Rotorua Lakes contrasts with a nationwide decrease in distribution between 1985 and 2004 (Robertson et al. 2007), despite an increase in national survey effort over this time period. This species was present on Lakes Rotorua and Rotoiti in all six surveys, Tarawera and Rotomahana in five surveys, Rotokakahi in four surveys, Rotoehu and Okaro in three surveys, Rerewhakaaitu in two surveys, and Ōkataina and Tikitapu in one survey each. Once again, numbers fluctuated independently of distribution on lakes for this species.

# 4. Conclusions and recommendations

Over the 26 year period between 1985 and 2011, six c. 5-yearly water bird censuses were completed on 18 of the Rotorua Lakes. Eighteen species were consistently counted in all surveys, suggesting that the species composition of the Rotorua Lakes water bird community remained stable during this time. Just seven species combined contributed 80–87% of the total number of water birds counted each census. Most of the 18 focal species exhibited fluctuating counts between surveys, and there are no indications that any of the monitored species require urgent remedial conservation management at the current time.

The chemical and biological explanatory factors that we examined provided limited explanation of the changes in total water bird numbers among lakes. In contrast, the physical parameters of lake size, catchment size, and lake shoreline length explained variation in the total number of water birds counted and/or the number of species detected per lake in 2011. This is not surprising, assuming that habitat availability for water birds increases with lake size, while habitat types increase with lake shoreline length and catchment size.

Food availability appeared to explain variation in numbers across lakes of some individual species. Other possible explanations for species-specific changes in abundance are anecdotal and 'best guesses,' and include disturbance, predation, and changes in land use resulting in altered water quality and cyanobacterial blooms.

Because seven of the water bird species monitored by these censuses are listed as threatened or at risk, a better understanding of the factors influencing their abundances is desirable to inform management actions where required. We therefore recommend that:

1. These 5-yearly water bird censuses are continued. Future surveys should use identical methods to the previous surveys, to enable long term trends in total number of water birds and specific species to be measured and compared. The next census is due in late January 2016.

2. Based on the literature, a spatially explicit monitoring plan is developed for relevant biological, physical and chemical factors that are known to influence abundances of water birds of conservation interest. This will assist with the interpretation of trends of species of concern within and among lakes. Further multi-factorial modelling of data may also be more realistic to explain patterns in abundances. Remarkably little research has been undertaken on water bird species and communities in New Zealand. Additional factors that may influence both actual abundance and counts are disturbance and predation (including at breeding colonies, for colonially breeding species), disease, and growth or loss of riparian vegetation. However, it should be borne in mind that extrinsic factors may be responsible for local changes in abundance, which may be difficult or impossible to manage.
3. Research is undertaken on various aspects of dabchick behaviour and ecology, including movements, causes of nesting success and failure, and the impact of structures such as boat sheds and other 'artificial' nest sites on nesting success.
4. Movement studies are collated—or, if needed, conducted—for all Rotorua water bird species to determine the contribution of movement to variability in the c. 5-yearly counts. An intensive study at one lake examining daily counts for c. 2 weeks to determine whether there are daily fluctuations in species' numbers or movements at dawn or dusk may be helpful towards this end. Alternatively, a study using birds fitted with radio-transmitters to demonstrate whether individuals regularly use more than one lake to feed could contribute to providing this information.
5. The recommendations by Innes et al. (1999) are re-examined and completed where still relevant (note that most recommendations have not been acted upon to date).

# 5. Acknowledgements

For the 2011 survey and this report: many thanks to all the DOC and Eastern Region Fish and Game staff, OSNZ members, and volunteers who willingly gave their time to count the water birds on the Rotorua Lakes over the 26 years of censuses; boat owners who provided boats and fuel for the surveys; Te Arawa Lakes Trust, Rotokakahi Board of Control Trustees, Ngāti Rangiteaorere and Te Pumautanga o Te Arawa Trust, who granted permissions for censuses to take place; Joe Butterworth for all his invaluable help, and for kākahi and kōura data; Cam Bichan and Jenny Clarke at Bay of Plenty Regional Council for data on lake shoreline lengths and information on the water quality of the lakes; David Hamilton and Deniz Özkundakci at University of Waikato for data on the water quality of the lakes, including Secchi disk depths; Jennifer Blair at University of Waikato and Eastern Region Fish and Game for trout data; Dave Rowe at the National Institute for Water and Atmospheric Research (NIWA) for data on smelt and bully densities; Matt McDougall at Eastern Region Fish and Game for Canada goose, black swan and paradise shelduck aerial count data and information and discussions on mallard / grey duck populations; Mala Nesaratnam and Don Newman at the Department of Conservation Banding Office for Canada goose banding information; funding from the Ministry of Business, Innovation and Employment for write-up by John Innes under Contract CO9X0503; the reviewer and editors for helpful comments that improved the manuscript; and any others we may have accidentally overlooked. We also gratefully acknowledge all those who contributed to previous censuses and reports, as detailed in Innes et al. (1999), Griffiths & Owen (2002), and Evans (2006).

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# Appendix 1

## Water bird counts on the Rotorua Lakes, January 2011

Numbers are presented as adults + juveniles. Lakes are ordered left to right from largest to smallest.

| SPECIES | ROTO-RUA* | TARA-WERA | ROTO-ITI | ROTO-MA | OKA-TAINA | ROTO-MA-HANA | ROTO-EHU | RERE-WHAKA-AITU | ROTO-KAKA-HI | OKA-REKA | TIKI-TAPU | ROTO-KA-WAU | OKARO | NGA-POURI | NGA-HEWA | ROTO-KAWA | TUTAE-IN-ANGA | OPAL | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey date | 28Jan 2011 | 28Jan 2011 | 30Jan 2011 | 30Jan 2011 | 30Jan 2011 | 27Jan 2011 | 26Jan 2011 | 13Feb 2011 | 2Feb 2011 | 29Jan 2011 | 28Jan 2011 | 28Jan 2011 | 30Jan 2011 | 30Jan 2011 | 30Jan 2011 | 28Jan 2011 | 30Jan 2011 | 30Jan 2011 | |
| Dabchick | 8 | 106+10 | 269+13 | 25+1 | 19 | 30 | 37+1 | 6 | 12 | 29+3 | 11 | 1 | 4 | 7 | 4+2 | 0 | 2 | 2+1 | 572+31 |
| Black shag | 153 | 16 | 32 | 8 | 3 | 0 | 56 | 4 | 1 | 1 | 0 | 0 | 79 | 4 | 53 | 0 | 0 | 0 | 410 |
| L. black shag | 635 | 9 | 247 | 14 | 39 | 73 | 100 | 21+2 | 2 | 10 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1154+2 |
| Little shag | 972+6 | 167 | 243 | 47 | 38 | 102 | 147+5 | 55 | 44 | 17 | 1 | 1 | 12 | 1 | 0 | 0 | 0 | 0 | 1847+11 |
| White-f. heron | 10 | 18 | 2 | 1 | 6 | 10 | 17 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 69 |
| Black swan | 1268+18 | 235+7 | 683+7 | 7+3 | 30 | 579+25 | 323+4 | 151 | 46+12 | 180+8 | 0 | 0 | 0 | 10+ 5 | 0 | 11 | 0 | 0 | 3523+89 |
| Canada goose | 44+7 | 28+2 | 79 | 0 | 0 | 175 | 71 | 49 | 49 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 514+9 |
| Domestic goose | 31 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| Para. shelduck | 7 | 5 | 4 | 220 | 0 | 370 | 1238 | 20 | 201 | 149 | 0 | 0 | 0 | 0 | 0 | 56 | 0 | 0 | 2270 |
| Mallard/grey | 352+9 | 153+16 | 73 | 18+2 | 24 | 109+9 | 112 | 150+3 | 93+5 | 98 | 11+4 | 0 | 65 | 29 | 11 | 11 | 20 | 0 | 1329+48 |
| Grey teal | 4 | 0 | 0 | 0 | 0 | 10 | 6 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 3+5 | 0 | 1 | 0 | 34 |
| Shoveler | 13 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 |
| Scaup | 5121+218 | 472+26 | 737+7 | 249+5 | 126 | 350 | 5 | 70+16 | 35 | 233+11 | 0 | 0 | 4 | 8 | 0 | 0 | 3 | 0 | 7413+283 |
| Coot | 11 | 134+19 | 286+6 | 52+9 | 0 | 71 | 24+7 | 22 | 5 | 140+7 | 0 | 0 | 6 | 3 | 1 | 0 | 0 | 0 | 755+48 |
| Pied stilt | 48 | 0 | 0 | 0 | 0 | 12 | 34 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 103 |
| Bl.-backed gull | 328+38 | 27 | 12 | 10+2 | 1 | 2 | 5 | 3 | 4+3 | 0 | 0 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 397+43 |
| Red-billed gull | 2885+196 | 22 | 92 | 0 | 0 | 39 | 26 | 0 | 0+1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3064+197 |
| Bl.-billed gull | 186+3 | 1 | 253 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 452+3 |
| Gulls, ID uncertain | 272 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 272 |
| Caspian tern | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Others: | | | | | | | | | | | | | | | | | | | |
| S-w plover | 6 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 6 | 2 | 2 | 0 | 0 | 0 | 21 |
| Pukeko | 23 | 1 | 7 | 6 | 0 | 2 | 13 | 12 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 70 |
| Kingfisher | 0 | 4 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 1 | 0 | 4 | 3 | 0 | 0 | 0 | 0 | 17 |
| Khaki Campbell domestic duck | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| Domestic hybrid ducks | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| Sooty shearwater | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Mute swan (pet) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |

* Full lake names are: Rotorua/Te Rotorua nui ā Kahumatamomoe, Tarawera, Rotoiti/Te Roto kite ā Ihenga i ariki ai Kahu, Rotomā, Ōkataina/Te Moana i kataina ā Te Rangitakaroro, Rotomahana, Rotoehu, Rerewhakaaitu, Rotokakahi (Green Lake), Ōkareka, Tikitapu (Blue Lake), Rotokawau, Okaro, Ngapouri, Ngahewa, Rotokawa, Tutaeinanga, and Opal.

# Appendix 2

## Total number of adult water birds (plus the percentage of the total annual count that they comprise) of 18 consistently recorded species on the Rotorua Lakes during each c. 5-yearly survey, 1985–2011

NB. Data are for all lakes combined.

| SPECIES | YEAR (%) | | | | | |
|---|---|---|---|---|---|---|
| | 1985 | 1991 | 1996 | 2001 | 2006 | 2011 |
| Dabchick | 364 (1) | 326 (1) | 396 (2) | 489 (2) | 498 (2) | 572 (2) |
| Black shag | 159 (1) | 290 (1) | 193 (1) | 797 (3) | 690 (3) | 410 (2) |
| Little black shag | 2009 (8) | 1993 (9) | 839 (4) | 1422 (6) | 1694 (8) | 1154 (5) |
| Little shag | 3302 (13) | 2618 (12) | 1431 (6) | 1893 (8) | 2371 (11) | 1847 (8) |
| White-faced heron | 159 (1) | 123 (1) | 152 (1) | 111 (<1) | 75 (<1) | 69 (<1) |
| Black swan | 4496 (17) | 6151 (28) | 4462 (19) | 3961 (16) | 3001 (14) | 3523 (15) |
| Canada goose | 22 (<1) | 137 (1) | 427 (2) | 537 (2) | 548 (3) | 514 (2) |
| Domestic goose | 44 (<1) | 53 (<1) | 175 (1) | 92 (<1) | 18 (<1) | 32 (<1) |
| Paradise shelduck | 1705 (7) | 2199 (10) | 4573 (20) | 2369 (10) | 1862 (9) | 2270 (9) |
| Mallard/grey duck | 4121 (16) | 2081 (9) | 2991 (13) | 1761 (7) | 1490 (7) | 1329 (6) |
| Grey teal | 634 (2) | 102 (<1) | 168 (1) | 94 (<1) | 12 (<1) | 34 (<1) |
| Shoveler | 127 (<1) | 26 (<1) | 45 (<1) | 3 (<1) | 83 (<1) | 43 (<1) |
| Scaup | 4368 (17) | 3163 (14) | 3061 (13) | 4648 (19) | 3359 (16) | 7413 (31) |
| Coot | 328 (1) | 371 (2) | 356 (1) | 488 (2) | 659 (3) | 755 (3) |
| Pied stilt | 491 (2) | 283 (1) | 401 (2) | 232 (1) | 38 (<1) | 103 (<1) |
| Black-backed gull | 1501 (6) | 289 (1) | 624 (3) | 675 (3) | 496 (2) | 397 (2) |
| Red-billed gull | 1674 (6) | 1018 (5) | 2159 (9) | 3994 (17) | 2952 (14) | 3064 (13) |
| Black-billed gull | 601 (2) | 803 (4) | 714 (3) | 590 (2) | 997 (5) | 452 (2) |
| Caspian tern | 0 (0) | 15 (<1) | 13 (<1) | 7 (<1) | 1 (<1) | 4 (<1) |
| Total | 26 105 (100) | 22 041 (100) | 23 180 (100) | 24 163 (100) | 20 844 (100) | 23 985 (100) |

# Appendix 3

## Presence/absence of water bird species recorded on the Rotorua Lakes during the 2011 survey

Lakes are ordered top to bottom from largest to smallest. Cell shading indicates presence.

| LAKE | DABCHICK | BLACK SHAG | LITTLE BLACK SHAG | LITTLE SHAG | WHITE-FACED HERON | BLACK SWAN | CANADA GOOSE | PARADISE SHELDUCK | MALLARD/GREY DUCK | GREY TEAL | SHOVELER | SCAUP | COOT | PIED STILT | BLACK-BACKED GULL | RED-BILLED GULL | BLACK-BILLED GULL | CASPIAN TERN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rotorua | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Tarawera | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | | ■ | ■ | ■ | |
| Rotoiti | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | | ■ | ■ | ■ | |
| Rotomā | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | | | ■ | ■ | | ■ | | | |
| Ōkataina | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | | | ■ | | | ■ | | | |
| Rotomahana | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Rotoehu | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | | ■ |
| Rerewhakaaitu | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | ■ | ■ | ■ | | | |
| Rotokakahi | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | ■ | | ■ | | ■ | |
| Ōkareka | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | | ■ | ■ | | | | | |
| Tikitapu | ■ | | ■ | ■ | | | | | ■ | | | | | | | | | |
| Rotokawau | ■ | | | ■ | | | | | | | | | | | ■ | | | |
| Okaro | ■ | ■ | | ■ | ■ | | | | ■ | ■ | | ■ | ■ | | ■ | | ■ | |
| Ngapouri | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ | | | ■ | ■ | | | | | |
| Ngahewa | ■ | ■ | | | | | | | ■ | ■ | | | ■ | | ■ | | | |
| Rotokawa | | | | | | ■ | | ■ | ■ | | | | | | | | | |
| Tutaeinanga | ■ | | ■ | | | | | | ■ | ■ | | ■ | | | | | | |
| Opal Lake | ■ | | | | | | | | | | | | | | | | | |