Correlations between human-made structures, boat-pass frequency and the number of New Zealand dabchicks (*Poliocephalus rufopectus*) on the Rotorua Lakes, New Zealand

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Abstract: Negative effects of human presence and activities on breeding success and survival of many water bird species are well documented. The New Zealand dabchick (*Poliocephalus rufopectus*) is a protected endemic New Zealand grebe, confined to the North Island mainland and classified as vulnerable. A third of the total New Zealand dabchick population live on the lakes of the central volcanic plateau, where there is potential conflict between humans and dabchicks. We used data from two independent surveys describing the distribution of New Zealand dabchicks to investigate the effect that human-made structures (i.e. jetties and houses) and human recreational activities (i.e. boating) have on the numbers of New Zealand dabchick pairs, chicks and nests in the bays of Lake Rotoiti, Tarawera and Okareka. Our results suggest that human-made structures and recreational activities are not significantly affecting the numbers and distribution of New Zealand dabchick pairs or nests at this time. Furthermore, the number of human-made structures was *positively* correlated with the number of chicks in the sampled bays. Humans and dabchicks may be distributed similarly around the lakes because factors such as wind exposure and shoreline topography made certain sites preferable for both species. Alternatively, human-made structures may provide protected nesting environments and/or cover for chicks from predators, refuges from harassment by other bird species, or other benefits. Pairs may therefore be able to raise chicks to the fledging stage more successfully. However, little is currently known about dabchick life history or population dynamics. We recommend that a method of capturing and marking be developed so that further monitoring of behavioural and population changes can be carried out. It is also necessary to conduct research on how boats and human activities at jetties affect incubating dabchicks and their young during the nesting phase.

Keywords: boating; human-made structures; New Zealand dabchicks; Rotorua lakes; water birds.

Introduction

The New Zealand dabchick, *Poliocephalus rufopectus*, is a protected endemic New Zealand grebe, confined to the North Island mainland and classified as vulnerable (defined as having continuous decline with severe population fragmentation and all populations < 1000) (Birdlife International, 2000). The total New Zealand dabchick (henceforth called dabchick) population is estimated at 1200–1500 birds (Marchant and Higgins, 1993), a third of which live on the lakes of the central volcanic plateau (Marchant and Higgins, 1993). Of these, Lakes Rotoiti, Tarawera and Okareka have the highest numbers (Innes *et al*., 1999). Very little is known about what limits dabchick populations and, although numbers in the North Island are considered to be stable (Marchant and Higgins, 1993), the reasons for their decline and probable extinction in the South Island are unclear (Heather, 1988).

On Lakes Rotoiti, Tarawera and Okareka, the highest densities of dabchicks are found in bays sheltered from the prevailing southwesterly winds (Innes *et al*., 1999). Houses and other human-made structures (e.g. jetties and boatsheds) also tend to be concentrated in these sheltered bays (Lusk and Lusk, 1981; Innes *et al*., 1999). Reynolds (1997) found that on Lake Rotoiti, dabchick density was positively correlated with the number of human-made structures. However, human activities (e.g. boating) are known to affect dabchick behaviour (Montgomery, 1991; Bright *et al*., 2003). Boats and their wave wash also damage nests (Batten, 1977; M. Day, *unpubl*.). Negative effects of human activities on breeding success and survival in many water bird species are well documented (e.g. Burger, 1981; Safina and Burger, 1983; Keller, 1991; Verhulst *et al.*, 2001). Human activities have been associated with nest abandonment and increased predation of eggs and young [reviewed in Hockin *et al.* (1992)]. Responding to human presence can also significantly increase daily energy expenditure (Regel and Pütz, 1997) and reduce the time available for feeding or other activities.

There have been few studies of the New Zealand dabchick and there is no reliable method of capturing and marking the birds. Thus, little is known about dabchick life history or population dynamics, or the consequences of human presence and recreational activities on dabchick reproduction and survival. Furthermore, because we do not know the reasons for dabchick extinction in the South Island, the overlap between human and dabchick habitat use on the Rotorua lakes may be cause for concern.

In this study, we used a long-term data set (1985–1993) and a more recent survey (2002) on dabchicks to investigate the effect that human-made structures and human activities may have on the numbers and distribution of dabchick pairs, chicks and nests in the bays of Lake Rotoiti, Tarawera and Okareka.

Materials and methods

Study sites

The dabchick counts were carried out on Lakes Rotoiti, Tarawera and Okareka in the Rotorua lakes district of the volcanic plateau of the North Island, New Zealand (38º05'S, 176º20'E: Fig. 1). Lakes Rotoiti and Okareka are mesotrophic lakes and Lake Tarawera is oligotrophic (Donald, 1997). The margins of Lakes Rotoiti and Tarawera are predominantly steep slopes and cliffs covered in native bush. Lake Okareka has a mixture of native bush, sandy shore and pasture land of varying gradients. All three lakes have a number of lakeside dwellings used seasonally or year round. The lakes are all used for a variety of recreational activities, particularly trout fishing, water skiing, sailing and canoeing (Donald *et al.*, 1991).

At Lake Rotoiti, most dabchicks are located on the northern shores of the western half of the lake. At Lake Tarawera, dabchicks are found on the western shores. At Lake Okareka, dabchicks are distributed right around the lake but are least common along the exposed eastern cliffs and farmland margins (Innes *et al.*, 1999; Lusk and Lusk, 1981).

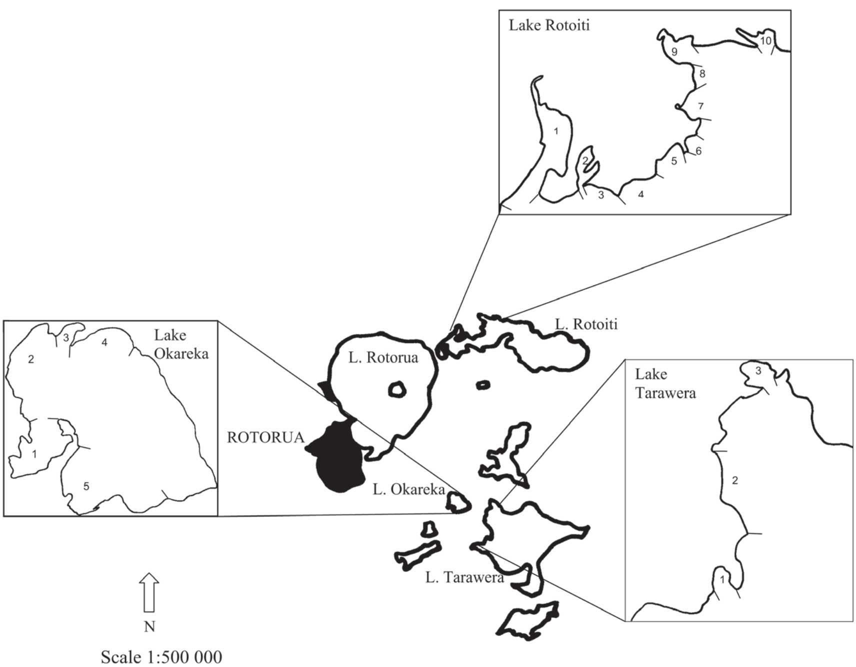

Figure 1. Map of Rotorua lakes and township. The bays (numbered) at Lake Rotoiti, Lake Tarawera and Lake Okareka where New Zealand dabchick pairs, chicks and nests were counted are shown as insets.

Ornithological Society of New Zealand data

Data for this analysis were obtained from a report (Innes *et al*., 1999) on information collected by the Ornithological Society of New Zealand (OSNZ). The report collated information on the abundance and distribution of water birds of the Rotorua lakes from 1985–1996. Specifically, we used the data collected (on a monthly basis) on the numbers and distribution of dabchick pairs and chicks on Lake Rotoiti (northwestern bays; Fig. 1) from 1987–1990 and Lake Okareka (western bays; Fig. 1) from 1987–1993.

From February–May 2002, we quantified boat traffic and the number of jetties and houses that were situated on the lake shoreline in each bay (bays were 320–2950 m long) surveyed at Lake Rotoiti and Lake Okareka by the OSNZ. Examination of aerial photographs of Lakes Rotoiti and Lake Okareka taken in 1992 show that the numbers and positions of jetties and houses in each bay were very similar to those counted in 2002. Thus, our data are likely to accurately depict the numbers of jetties and houses (and presumably boat-pass levels) present at the time of the OSNZ dabchick surveys. We included boatsheds in the jetty category; if both were at the same site, it was counted as a single jetty. The number of jetties and houses in each bay was highly correlated (Pearson's correlation $r = 0.826$, $P < 0.001$), so we incorporated the number of jetties and houses in a bay as a single variable. If there were ≥ 10 jetties or houses in a bay, the bay was classified as having a 'high number human-made structures' (five bays), if there were < 10 jetties or houses in a bay, the bay was classified as having a 'low number human-made structures' (10 bays). The decision for this classification was based on a natural split in the data set. For each bay surveyed by the OSNZ at Lakes Rotoiti and Okareka, we also determined the number of boats that passed within 200 m of the lake shoreline per hour. Each bay was visited two to seven times in either a kayak or small motorboat. We spent between one and four hours at each bay during these visits (the longer visits were made to bays sampled less often), and calculated boat passes/hr from the daily means. Bays were classified as 'high use recreational bays' (four bays) if there were > 2 boat passes/hr, and 'low use recreational bays' if there were ≤ 2 boat passes/hr (11 bays). The decision for this classification was also based on a natural split in the data set. We determined the classifications for high and low use recreational bays from observations of boat pass frequencies during autumn and winter, when there are fewer recreational activities on the Rotorua lakes (Reynolds, 1997).

The length of the lake shoreline in each surveyed bay was calculated using topographical maps (NZMS 260 sheets U15 and U16) and a planimeter (Type KP-27, Koizumi, Japan). Dabchicks are present in the highest densities in bays sheltered from the prevailing south-westerly winds (Reynolds, 1997; Innes *et al*., 1999), which may be a factor affecting distribution and numbers of pairs and chicks present in each bay. Therefore, we wanted to establish how well protected the bays surveyed on Lakes Rotoiti and Okareka were from the prevailing winds. We classified each bay as North, North East, East, South East, South, South West, West or North West, depending on the angle (0-360°) at which the majority of the shoreline was facing.

2002 data

From February–May 2002, we counted the numbers of dabchick chicks/juveniles associated with each adult territory (territories are usually 100–200 m across; Reynolds, 1997) and counted nests at Lake Rotoiti (northwestern bays; Fig. 1) and Lake Tarawera (western bays; Fig. 1). We made two to seven visits to each bay in either a kayak or small motorboat to accurately determine dabchick numbers. Between one and four hours was spent at each bay (again, longer visits were made to bays sampled less often). There was very little variation (< 5 % difference) between the number of dabchick pairs and chicks counted at subsequent visits to each bay. Dabchick nests were found by searching emergent vegetation and overhanging shoreline vegetation in a kayak. A total of 17 dabchick nests were found between February and May 2002 (the end of dabchick breeding season). Three of the nests had been recently used (i.e. were well maintained), and one of these nests contained an egg (egg disappeared soon after for reasons unknown). By the end of May 2002, only four of the 17 nests were still intact, the other 13 had been destroyed, presumably by wind and/or wave-wash. We calculated both the number of jetties and the number of houses within 20m, and within 200m of each pair. The locations of the nests and chicks were closely associated with the location of pairs (i.e. if a pair was ≤ 200m from a jetty, the nest and chicks were within 200m of the jetty).

We also determined the number of boat passes per hour as described above and the total number of jetties and houses in each bay. the length of lake shoreline and aspect of each bay was also determined as described above.

Statistical analysis

Ornithological Society of New Zealand data

After normality and homogeneity of variance testing (Shapiro-Wilks: $P < 0.05$), data were log $(1 + x)$ transformed. We calculated the mean number of juveniles and chicks in each bay for each year. There were no significant year-to-year differences in the total number of pairs present on Lake Okareka or Lake

Rotoiti from 1987–1993 ($F_{6,28}$ = 0.59, P = 0.74 and $F_{3,28}$ = 0.109, P = 0.95, respectively), so the data from different years were pooled. There was also no significant year-to-year difference in the number of chicks present on Lake Okareka ($F_{6,28}$ = 0.64, P = 0.70). There was a significant difference in the number of chicks on Lake Rotoiti between years ($F_{3,28}$ = 2.85, P = 0.05; the number of chicks in 1990 was disproportionately high). However, if the data for chicks were analysed for separate years, the results were the same as when data had been analysed with pooled data from each year. Thus, we present results from pooled data for all analyses on pairs and chicks.

The effect of boat passes/hr and number of jetties and houses in a bay on numbers of dabchick pairs and chicks was analysed using a General Linear Model multivariate analysis or ANCOVA (SPSS version 10 for Windows). The length of lake shoreline and aspect of each bay were entered as covariables in the model. Covariables are concomitant variables whose effect must be partialled out when estimating the effects of the explanatory variables. An ANCOVA helps to remove the effects of disturbing variables from an ANOVA and increases precision (Sokal and Rohlf, 1998).

2002 data

After normality and homogeneity of variance testing (Shapiro-Wilks: P < 0.05), data were log (1 + x) transformed and analysed using Canonical Correspondence Analysis (CCA) (CANOCO v. 4.0; ter Braak and Šmilauer, 1998). Canonical Correspondence Analysis is a form of canonical ordination, which uses ordination and multiple regression statistical techniques to relate the species composition of communities to their environment. Specifically, CCA is a multivariate direct gradient analysis technique used when species have unimodal responses to the environmental variables (assumption tested by general response model analysis). The amount of the species data explained by the environmental variables is given by the eigen values (between 0 and 1). In this study, dabchick data (number of pairs, chicks and nests) represent the species information, and boat passes per hour, total number of jetties and houses, and number of jetties and houses ≤ 20 m and ≤ 200 m from pairs, the environmental variables. The number of jetties and houses ≤ 20 m and ≤ 200 m were averaged across pairs in a bay. The length of lake shoreline and aspect of each bay were included as covariables (ter Braak and Šmilauer, 1998). Forward selection and Monte Carlo permutation tests (using 199 unrestricted permutations) were performed to identify the environmental variables that significantly explained variation in numbers of dabchick pairs, chicks and nests.

Results

Ornithological Society of New Zealand data

The frequency of boat passes/hr and the number of jetties and houses in a bay did not have a statistically significant effect on the number of dabchick pairs ($F_{1,12}$ = 1.00, P = 0.35 and $F_{1,12}$ = 0.32, P = 0.86, respectively). The frequency of boat passes did not correlate significantly with the number of dabchick chicks in a bay ($F_{1,12}$ = 0.072, P = 0.78; Fig. 2). However, the number of chicks was significantly higher in bays with high numbers of human-made structures ($F_{1,12}$ = 9.81, P = 0.01; Fig. 2).

2002 data

Forward selection and Monte Carlo permutation tests of the significance of environmental variables, show that the environmental variables (boat passes/hr, jetty and house data) did not make significant contributions to explaining variation in the numbers of dabchick pairs, chicks and nests in the studied bays (Table 1).

Discussion

Several studies have demonstrated negative effects of human presence on water-birds (e.g. Keller, 1989; Regel and Pütz, 1997; Verhulst *et al*., 2001; Bright *et al*., 2003). Our study stands in contrast with the majority of published literature. Canonical Correspondence Analysis of our 2002 data on the dabchick distribution in the bays of Lake Rotoiti and Tarawera suggest there were no negative effects of boat-pass frequency or number of human-made structures on the numbers of dabchick pairs, chicks or nests. Similarly, our analysis

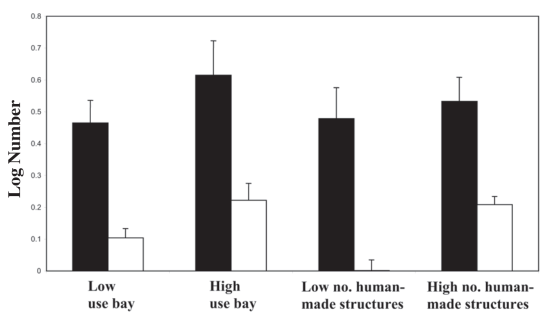

Figure 2. The mean number of pairs (closed bars) and chicks (open bars) associated with low (≤ 2 boat passes/hr) and high (> 2 boat passes/hr) use recreational bays and bays with low (< 10 jetties/houses) and high (≥ 10 jetties/houses) numbers of human-made structures. Error bars are S.E.

Table 1. Forward selection and Monte Carlo permutation tests on the significance of the explanatory effect of environmental variables on dabchick numbers and nests. Lambda-1 column lists the environmental variables in order of the variance they explain singly (i.e. when that particular variable is used as the only environmental variable). The variance is in addition to the variance explained by covariables. The Lambda-A column lists the environmental variables in order of their inclusion in the model, together with the additional variance each variable explains at the time it was included and, the significance of the variable at that time (*P*-value) together with its test statistic (*F*-value). Sum of all eigen values = 0.345.

Variable	Lambda-1	Lambda-A	*F*	*P*
Boat passes/hr	0.05	0.05	3.03	0.07
Houses	0.03	0.01	0.99	0.37
Houses ≤ 20 m	0.02	0.03	2.00	0.21
Jetties ≤ 200 m	0.02	0.01	0.20	0.78
Houses ≤ 200 m	0.01	0.01	0.24	0.79
Jetties	0.01	0.00	0.28	0.70
Jetties ≤ 20 m	0.01	0.01	0.54	0.55

of the OSNZ data collected on the numbers of dabchick in the bays of Lake Okareka and Rotoiti, suggest that there was no significant correlation between the boat-pass frequency, or the number of human-made structures, and the number of dabchick pairs. Furthermore, boat-pass frequency was not significantly correlated with the number of dabchick chicks. However, we did find a significant *positive* correlation between the number of human-made structures and the number of chicks (Fig. 2).

It is not surprising that we found a positive correlation between human-made structures and the number of dabchick chicks on Lakes Rotoiti, and Okareka. The highest densities of dabchicks (and humans) on Lakes Rotoiti, Tarawera and Okareka are found along the western shores, which are sheltered from the prevailing winds (Innes *et al*., 1999), suggesting that wind may be the major factor limiting dabchick populations. Dabchick nests are highly susceptible to swamping by rising water levels and wave wash (Marchant and Higgins, 1993) and a single storm can destroy many nests and wash away eggs (Lusk and Lusk, 1981; M. Day, *unpubl*.). Many human-made structures (i.e. jetties and boatsheds) provide nest sites for dabchick (M. Day, *pers comm*.), which might be protected from wind (and boat) wave-wash and storm events. Furthermore, the majority of boatsheds and jetties are used infrequently or rarely throughout the year, thus providing undisturbed nesting environments. Human-made structures may also provide appropriate and defendable boundaries for dabchick territories, and familiar areas for chicks to forage. Chicks could also use jetties and boatsheds to hide from predators such as Australasian harriers (*Circus approximans*) and to avoid harassment by other common bird species on the lakes (e.g. Eurasian coot, *Fulica atra*; black swan, *Cygnus atratus*) and humans. Pairs may be able to raise chicks to the fledging stage more successfully in areas with high numbers of human-made structures because of the added protection they provide.

Boats passing within close proximity to waterbirds are known to affect behaviour patterns and activity levels (Bright *et al*., 2003; Burger, 1998; Galicia and Baldassarre, 1997; Mikola *et al*., 1994). There is a change in activity patterns and a reduction in time spent diving (a behaviour associated with feeding) associated with motorised boat passes in the New Zealand dabchick (Bright *et al*., 2003); these effects are more pronounced when the frequency of boat passes is higher (Bright *et al*., 2003). However, the present study indicates that changes in behaviour associated with boat passes do not appear to be affecting the distribution of dabchicks. Dabchicks may become habituated to boats in high use-recreational areas (Bright *et al*., 2003) and/or be able to compensate for lost feeding time, especially in the summer months when daylight hours are greater.

At present levels, human-made structures and boating activities do not have a significant negative effect on the numbers and distribution of dabchicks on Lakes Rotoiti, Tarawera and Okareka. However, we know very little about dabchick life history or population dynamics so our findings need to be interpreted conservatively. There may be a threshold above which an increase in the numbers of human-made structures or recreational activity begins to have a detrimental effect on reproduction and survival of dabchick populations. We recommend that a method of capturing and marking be developed so that monitoring of behaviour and population changes can be carried out. It is also necessary to conduct further research on how boat-generated wave wash and human activities at jetties affect incubating dabchicks and their young during the nesting phase.

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Permit, Authority No. 4/516 and with approval from the University of Waikato Animal Ethics Committee, Protocol No. 532 and 533.

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