Roadside Behaviour of *Porphyrio porphyrio melanotus* (Aves: Rallidae)

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Abstract

The pukeko, or purple swamphen (*Porphyrio porphyrio melanotus*), commonly uses road margins throughout New Zealand, increasing the risk of road-induced mortality. We examined whether pukeko were exploiting the roadside as a resource. Potential resources on the roadside included food (e.g. new grass shoots and invertebrates), grit, and open areas for social behaviour. Using behavioral observations and the contents of gizzards and crops, we found evidence consistent with foraging (but not necessarily on invertebrates), and grit collection. There also appeared to be a strong social component. We examined the effect of roadside resource use on the ecology of pukeko.

Keywords: *Porphyrio porphyrio melanotus* - pukeko- roadside behaviour - foraging.

Introduction

Roadways have become a major component of human-modified landscapes with roads affecting perhaps as much as 19 % of the total area of the United States (Forman 2000). New Zealand has approximately 76 500 km of non-urban roads (Christchurch City Council 1998). If impacts extend out to >100 m from a road, (Forman 2000), the road-effect zone may influence up to 28% of New Zealand's land area (270 534 km^2). This is a crude calculation, but does emphasize the potential scale of road impacts. Roads have increased challenges facing resident species ranging from fragmenting populations with gene flow implications (Forman and Alexander 1998), affecting migration (Fahrig et al. 1995), modifying territories (Trombulak and Frissell 2000), allowing access by predators and competitors, to effects caused by mortality and/or sub-lethal effects such as altered sex and age ratios in local populations (Philcox et al. 1999). There has been a long, if sporadic, history of road-death related studies, which have suggested that roadside mortality and use is highly complex and taxon dependent. For example, factors influencing hedgehog (*Erinaceus europaeus*) road mortality are breeding activity, hibernation, abundance and habitat preferences (Brockie 1960; Davies 1957; Morris and Morris 1988), whereas factors influencing waterfowl (Anatidae) are population trends, terrain features, road type, traffic speed and the presence of water (Oetting and Cassel 1971; Sargeant 1981; Stout and Cornwell 1976). The addition of salt to roads may also attract species increasing mortality (Mineau and Brownlee; 2005). In recent times there has been increasing interest in studies of roadside and crossing behaviour of species, particularly with a view to modifying either the roads or the behaviors to lower mortality (e.g. (Clevenger and Waltho 2000; Forman and Deblinger 2000; Meunier et al. 2000; Reijnen et al. 1997; Spellerberg 2002; Trombulak and Frissell 2000).

One New Zealand species that seems particularly vulnerable to road mortality is the pukeko (*Porphyrio porphyrio melanotus* Temminck 1820) that is often seen on roadsides near wetlands or drainage ditches (Brown et al. 1986; Jamieson 1994). Estimates of pukeko road-mortality rates are very scarce (Booth 1984), mainly existing in unpublished reports and newspaper correspondence (e.g. Crossland 1996; Washington 1997). For example, Crossland (1996) estimated that more than 60 pukeko were killed annually on roads around Travis Wetland Reserve, Christchurch out of a resident population of 250 (summer) to 700 (winter).

Our research objectives were to examine pukeko roadside behaviour and test hypotheses as to why they utilised this zone that placed them at risk. There may be many reasons why a bird might utilise roadside habitat. We hypothesize that pukeko utilise the roadside to obtain resources. Resources relevant to pukeko are likely to be food (invertebrates hit by vehicles and shoots of grass from the mown verge), grit (for processing food in the gizzard), and/or social interactions (the roadside represents a relatively open environment where pukeko may interact with other individuals).

Study Area

Otukaikino Reserve (Wilson's Swamp) is a small (13 ha) freshwater wetland remnant situated north of Christchurch and just south of the Waimakariri River, South Island, New Zealand and is in the process of being restored. The wetland is completely surrounded by 3.8 km of roads with a motorway bounding one edge. There is a resident pukeko population of 20-30 with an unknown number of transient individuals (Washington 2000). Over the course of two years of study (1998-1999) there were 20 pukeko road deaths on the surrounding roads, which accounted for 29% of all vertebrate deaths on the road (12 species; Washington 2000). Pukeko often congregated along the motorway roadside and were easily observed from a hide.

Methods

Roads and life history

The motorway bordering the wetland was straight with approximately equal elevated and non-elevated sections. Information on sex, age and season of road deaths was collected during 1998 and 1999. Observers in cars driving along the motorway, between November 1998 and October 1999, recorded numbers of pukeko utilizing roadside habitat along the motorway verge. The northbound and southbound lanes of the Christchurch Northern Motorway were checked for pukeko road-kills daily, and the minor roads; Main North Road and underpass, were checked twice a week, making a total of 531 runs.

Roadside behavioural activity was recorded from an observation hide that was placed 13 m from the road, permitting viewing of roadside activity without disturbing or affecting normal behaviour. The hide was on the Christchurch Northern Motorway approximately 10 m north of the edge of the paddocks. This was the central position that allowed viewing of both ends of the motorway roadside. Individual pukeko behaviour was measured continuously from when it first moved within 10 m of the roadway. In addition to recording general conditions (e.g. time of day, weather) seven main categories of behaviours were scored: foraging (pecking), foraging (foot grasp), walking/running, social interaction, flying and fighting. Behaviours were identified using descriptions by Craig (1977).

Foraging

Pukeko are omnivorous, but primarily take grass shoots. Mowing of the roadside verge stimulates the growth of new grass shoots and this may provide a rich source of food for pukeko. Presence on the roadside was recorded in relation to mowing events.

The roadside may also act as a source of invertebrate food. One section of road, southern part of the motorway, was investigated for the presence and abundance of macro-invertebrates. In order to identify the invertebrate groups present and their relevant abundance, fifty samples, of 201 cm^2 were collected from the roadside using a Vortis suction sampler each month. Gizzard contents from 18 road-killed pukeko were sorted to identify invertebrate parts. Five intact crops were also obtained and sorted for and invertebrate parts. All collected invertebrates were identified to order level.

Grit

The gizzards and crops were also analyzed for their grit contents. Each gizzard's contents were dried and weighted. The composition of roadside pebbles in the grit size range was determined by collecting 12 random samples from where road-kills were found. Samples from gizzards and the roadside were wet-ground in ethanol and passed through a 100-mesh sieve. The material was then identified using x-ray diffraction with Cr Kμ radiation (50kV, 40mA) on a Philips vertical (PW 1050) goniometer fitted with 1° divergence receiving and scatter slips and a graphite monochronomotor. Samples were step-scanned for 10 seconds at 0.02° increments from 5° to 75°.

Social behaviour

Aggregation at the roadside was observed with pukeko coded either as individuals or groups. Group size was recorded and defined as two or more pukeko within 10 m of each other.

Statistical analysis

The effect of gender and season on the total number of pukeko road deaths were analysed using Yates χ^2 test. The relationship between the monthly number of road deaths and the average monthly number of pukeko observed near the motorway was analysed by 'least-squares' regression. The average length of time for pukeko observations was split into time periods and behavioural categories, and then analysed using ANOVA with post-hoc tests conducted using Fisher's Protected LSD test. The expected number of pukeko encounters following a 'rain event' was compared with the observed number using a χ^2 goodness of fit test. This test was also used to determine if group size was a random event. For this we compared the observed distribution of group size with expected values calculated from a Poisson distribution.

Results

Life history results

Eighteen of the 20 road deaths were on the non-elevated section of roadway. There number of road deaths was not significantly influenced by season (χ^2 = 0.4, *P* = 0.94) or with sex (χ^2 = 1.75, *P* = 0.18). All road deaths were adult birds.

More individual pukeko were observed at the roadside in spring (37 % of total observation time) than winter (23 %), summer (13 %) and autumn (15 %). There was no relationship between average monthly numbers of pukeko observed on the roadside and the monthly numbers of pukeko fatalities (r^2=0.008, *P* = 0.78; Figure 1).

The 'hide' data indicated that the time of day significantly influenced the length of time spent at the roadside ($F_{2,142}$=4.51, *P* = 0.01; Figure 2). Pairwise comparisons suggest that pukeko spent significantly shorter periods of time at roadside around midday than the mid-afternoon -dark period (*P* = 0.02). The midday period was almost significantly lower than the dawn- mid-morning period (*P* = 0.07).

Rain influenced pukeko proximity to the roadside with 83 % of observations occurring during rain or within 24 hours of a rain event. Assuming that rain is a random event (with a mean of 87 days with ≤ 1 mm of rain per year in Christchurch City Council 1997), there should be at most 164 days each year where it would either be raining or within 24 hours of a rain event. Accordingly, we would expect 45 % of our pukeko observations to have occurred either during rain or within 24 hours of a rain event. This expected value is significantly lower than the observed value of 83 % (χ^2 = 170.39, *P* < 0.001)

Once at the roadside, pukeko spent most of their time foraging (peck or grasp, Figure 3). Whilst ANOVA indicated significant differences ($F_{3,142}$=13.38, *P* < 0.001; analysis restricted

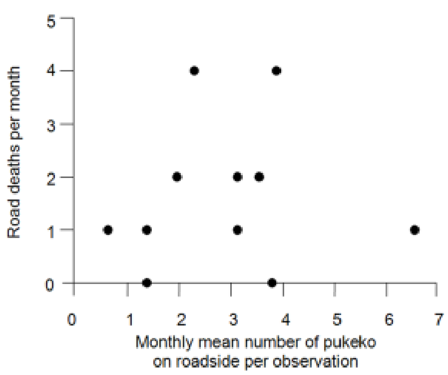

Figure 1. Relationship between numbers of pukeko on the roadside (n = 531) and road deaths (n = 20) during monthly observations.

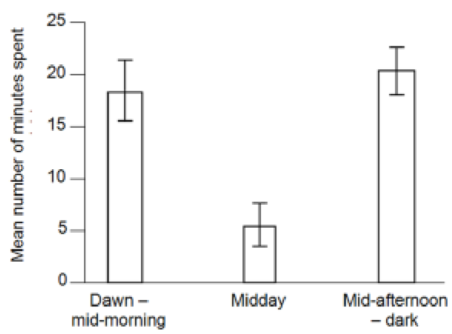

Figure 2. Time spent on the roadside over a day (± SEM). Mid-morning time period ended at 10 am and the mid-afternoon time period started at 2pm (with adjustments made during daylight saving).

Table 1. Abundance of invertebrate orders found in samples of roadside surrounding Otukaikino Reserve from April to July 1999 and September 1999 collected from the southern route of the Christchurch Northern Motorway.

Order	April	May	June	July	Sept
Araneae	408	199	149	203	684
Coleoptera	217	205	139	60	703
Diptera	40	56	3	18	86
Hemiptera	389	100	210	201	476
Hymenoptera	333	282	151	12	455
Lepidoptera	2	3	1	1	3
Lepidoptera larvae	45	48	31	16	78
Mantodea	3	2	0	0	5
Orthoptera	1	0	0	0	3

to the four most common behaviours), the average values varied greatly and peck was only significantly higher than walk ($P < 0.001$) and social interaction ($P < 0.001$).

Foraging

Mowing events were sporadic, but were no more frequent than once per month. Most pukeko (87 %) were observed on the roadside within two weeks of a mowing event and most were within one week (59 %).

Species from eight different invertebrate orders were collected from the roadside with spiders, beetles and true bugs (Araneae, Coleoptera & Hemiptera orders) being the most common (Table 1). All 18 gizzards contained invertebrate material (Table 2) that was predominantly spiders. The crops contained no invertebrate material.

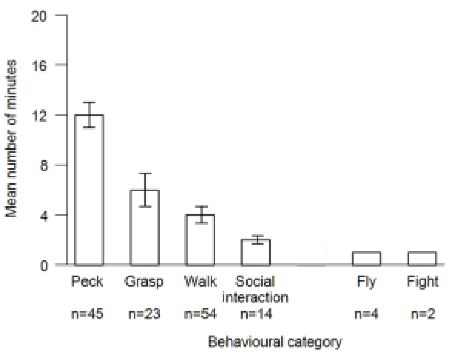

Figure 3. Average time (± SEM) for behaviours performed by pukeko while on roadside.

Grit

Pukeko gizzards contained a mean (± SEM) of 7.4 ± 0.7 g of grit material.

Table 2. Contents of gizzards from 18 road-killed pukeko around Otukaikino Reserve.

Item	Total gizzards
Grit	18
Vegetation (including seeds)	18
Animal material	18
Invertebrates	
Araneae	16
Lepidoptera	6
Coleoptera	4
Mantodea	2
Hymenoptera	1
Glass	18
Coal	18
Lead shot	16
Other metal	13
Shell	6
Bone fragment	4
Soft plastic	3
Hard plastic	1
Rubber	1
Wood	1

The vast bulk of grit material was clear or lightly coloured quartz (72.1 ± 6.0 %). Many other materials were also found in small amounts (Table 2). The roadside samples were predominantly greywacke with very little quartz present (6.3 ± 0.7 %).

Social behaviour

Pukeko were most frequently observed in pairs and trios. In most groups, distances between individuals were about 1 m. Compared to a Poisson distribution (λ=2.53), there were as many individuals and groups of five and six as expected. However, there were fewer groups of four and more trios and pairs than expected (Fig. 4). The pattern of observed group sizes was significantly different from that expected (χ^2 = 33.62, $P <$ 0.001).

All pukeko observed from the hide performed frequent tail-flicks. Many were also observed to vocalize, usually in response to calls from pukeko in an adjacent pasture paddock. Aggressive displays (clawing and sparring with feet) and chases were observed towards other species on the roadside. These chases occurred during the breeding season and may have been associated with courtship (Craig 1977).

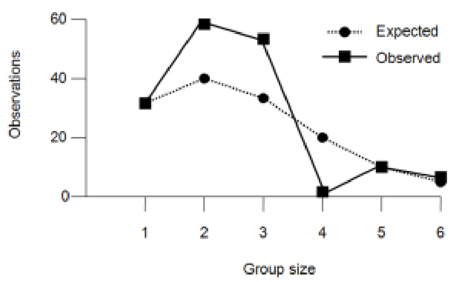

Figure 4. Expected (Poisson distribution) and observed distributions of group size of roadside pukeko.

Discussion

No attempts were made by any observed pukeko to cross the road despite the presence of apparently suitable habitat on the other side, which suggests that they were using the roadside itself as a resource. We identified several likely resources that might be exploited by pukeko: foraging habitat, grit and as sites for social interactions. We found some evidence of a role for all of these.

There was a temporal element to roadside activity both seasonally, with increased activity in spring, and daily, with decreased activity around the midday. Rainfall also had a positive effect on activity. Other studies have found that rainfall has an increase in pukeko activity, including reproduction. One such example has found that the inter-annual variation in Spanish purple swamphen abundance is related to rainfall (Sanchez-Lafuente et al. 2001).

There was some evidence that pukeko foraged for new shoots on the roadside as this was the most commonly observed behaviour. Spring is the season with greatest new shoot production, where rainfall stimulates new growth, and vegetative matter was found in the crops and gizzards of all road-killed birds. Vegetative matter is quickly expelled from the crop to the gizzard for processing some 12 (soft, e.g. berries) to 40 (hard, e.g. grains) minutes after consumption (Sturkie 1976; Young 1981) indicating that the birds killed on the road had recently consumed the plants (i.e., on the road side).

Pukeko may also utilise the roadside to forage for invertebrates. There was a diversity of invertebrate material found in the gizzards of road-killed pukeko, with the dominant material being parts of spiders (Araneae). However, no invertebrate material was found in any of the crops examined in this study. Although the exact passage rate of invertebrate material from the crop to the gizzard is unknown, given the hardnessof exoskeletons we might expect that it would be at least 30 minutes. If this is the case, the road-killed pukeko had not consumed invertebrates in the 30-minute period prior to being struck by a vehicle although they had been consuming vegetative material.

The samples from the gizzards also included some indigestible matter. This suggests that when the pukeko are foraging they may not distinguish the food matter that they are consuming. Therefore, some of the invertebrates that were found in the gizzards may not have been consumed intentionally.

Whilst the invertebrate foraging data is inclusive, there is strong support for pukeko gathering grit from the roadside. All 18 pukeko gizzards were found to contain primarily quartz of which there were no sources within the reserve. Also, quartz was present in quite low levels on the roadside with greywacke the dominant stone-type. The dominance of quartz in the gizzard indicates selectivity by pukeko that would require extended time on the roadside to collect. Grit was also found in all five crops, which indicated that it had been consumed in the immediate period before death (i.e., on the roadside). Grit, if freely available, needs to be replaced regularly. For example, 90% of silica granules consumed by red-winged blackbirds (*Agelaius musicus*) were expelled from the gizzard in the first 24 hrs after consumption (Fischer and Best 1995). Accordingly, grit consumption would provide ongoing motivation for pukeko to utilise the roadside.

Juvenile pukeko were not observed at the roadside, spending their time in the wetland, which indicated that this was an adult activity. Roadside behaviour certainly had a social component as indicated by the predominance of pairs and trios, the dominant unit of breeding groups in pukeko (Craig 1974). The roadside is habitat with high visibility and loose aggregations of pukeko (i.e. several groups of pukeko greater than 10 m apart) were common allowing an individual pukeko the opportunity to observe the condition and foraging ability of more individuals than they would be able in the reserve wetland. The predominance of tail flicking and vocalisations is consistent with this theory.

In conclusion, there appears to be several benefits of utilising the roadside for the population of pukeko located at Otukaikino Reserve. This multifactorial exploitation of roadside resources agrees with the complexity of factors interacting found in previous road mortality and roadside utilisation studies. While this behavioural complexity is not surprising for pukeko (Bunin and Jamieson 1996), it makes managing road death for pukeko difficult. It is impractical to exclude pukeko from the roadside as they are positively rewarded for using this habitat and its associated resources (i.e., grit, grass shoots and high visibility). However, it is also not obvious that roadsides are harmful to resident birds with no resident bird observed crossing the road during this entire study. With regards to managing other species interactions with roads, the message of this study is that the use of roads will be 'species specific' and complex making generic management more difficult.

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