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Sexing North Island robins (*Petroica australis longipes*) from morphometrics and plumage

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Abstract North Island robins are sexually dimorphic, males having darker plumage on their back and upper breast. However, males show delayed plumage maturation, and do not acquire the characteristic male plumage until after their first breeding season, 12-16 months after fledging. Therefore, sexing based on plumage alone will overestimate the proportion of females, and this may result in highly skewed sex ratios for translocations. Using measurements from robins of known sex on Tiritiri Matangi Island, I found tarsus length to be a useful indicator of sex. Of 82 robins measured, 80% of birds with tarsus length greater than 35.6 mm were male and 77% of other birds were female. If tarsus length is used in combination with plumage, it should allow sex ratios to be estimated reasonably accurately and without bias. However, additional data including wing chord measurements suggest that wing chord is superior to tarsus length for determining sex.

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INTRODUCTION

If birds are sexually monomorphic in plumage, it is often useful to be able to estimate sex from measurements. It is now possible to sex most bird species using DNA markers (Griffiths *et al.* 1998), and such techniques are necessary if 100% accuracy is required. Molecular sexing can be done from feathers, hence with negligible stress to birds. However, it currently requires a suitably equipped laboratory and skilled personnel, so involves a time delay and is expensive. While sexing using measurements is unlikely to be 100% accurate, it can be done immediately in the field at no cost. If birds can be sexed with reasonable accuracy from measurements, a preliminary indication of sex can be obtained at the time of capture. This is particularly useful when capturing birds from an unstudied population for translocation, so that the sex ratio of the founder group can be assessed.

In April 1992, I organised a translocation of North Island robins (*Petroica australis longipes*) from the Mamaku Plateau, near Rotorua, to Tiritiri Matangi Island, in the Hauraki Gulf (Armstrong 1995). The only information available for sexing robins was that males were known to have darker plumage than females on their back and upper breast (Flack 1985). Based on this criterion, I originally estimated that the founder group included 23 females (52%) and 21 males. However, the 33 birds that survived to the first breeding season on Tiritiri Matangi included 7 females (21%) and 26 males (sexes could be determined easily from behaviour once breeding started in September). All 7 females had been sexed correctly based on plumage. However, 9 of the 26 males had also been assessed as female, and still appeared female throughout the breeding season. The percentage of birds with "female plumage" had therefore not changed much over the 5 months since the translocation, indicating that the true percentage of females in the original founder group was much lower than originally thought.

Subsequent research on the Tiritiri Matangi robins (Armstrong *et al.* 2000) has shown that males do not moult into "male plumage" until after their 1st breeding season, 12-16 months after fledging. That is, males have *delayed plumage maturation* (Lyon & Montgomerie 1986), although they clearly become sexually mature in their 1st year, and can father offspring, as confirmed by Ardern *et al.* (1997) using minisatellite DNA. First year males are as successful as older birds at obtaining mates (Armstrong *et al.* 2000) and producing fledglings (Armstrong & Ewen, in press). It is therefore likely that the translocated males with "female plumage" were first-year birds, and that the others were older birds.

Delayed plumage maturation appears to occur in other North Island robin (R. Powlesland, pers. comm.;

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Table 1 North Island robins (*Petroica australis longipes*) on Tiritiri Matangi Island for which tarsus length was measured accurately and for which sex was determined from breeding behaviour.

Group	Males	Females	Total
Translocated from Mamaku Plateau, 1992	23	7	30
Translocated from Mamaku Plateau, 1993	3	7	10
Hatched on Tiritiri Matangi, 1992/93-1998/99	33	19	52

Table 2 Tarsus length with foot (TZ), head-bill length (HB) and weights of male and female North Island robins. Originals, translocated from Mamaku Plateau in 1992; Tiri adults, hatched on Tiritiri Matangi Island and measured ≥ 8 months after fledging; Tiri juveniles, hatched on Tiritiri Matangi Island and measured < 5 months after fledging.

		Tarsus (mm)			Head-bill (mm)			Weight (g)		
	Sex	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD
Originals	M	23	36.6	1.0	23	41.9	0.8	23	28.1	1.7
	F	7	35.1	1.0	7	41.7	0.5	7	26.6	1.4
Tiri adults	M	17	36.2	0.9	11	42.0	0.8	10	28.2	2.4
	F	8	35.0	0.8	4	41.6	0.3	2	31.5	0.7
Tiri juveniles	M	16	36.3	1.1	11	41.4	0.6	12	29.2	1.8
	F	11	34.5	1.0	6	40.5	0.5	8	27.1	1.6

B. Beaven, pers. comm.) and South Island robin (B. Lloyd, pers. comm.) populations that have been closely studied. Consequently, as sexing based on plumage will always overestimate the proportion of females in a sample of robins, a method of sexing robins from measurements would be useful. In this paper, I develop a sexing criterion based on the original birds translocated to Tiritiri Matangi, show the results of a second translocation designed to manipulate the sex ratio based on this criterion, then re-evaluate the criterion with data collected over subsequent years.

METHODS

During October-December 1992 I measured tarsus length, head-bill length, and weight of 30 robins (7 females, 23 males) on Tiritiri Matangi (Table 1). The birds were being caught primarily to take blood samples for DNA fingerprinting (Ardern *et al.* 1997), so I minimised the number of measurements to avoid excessive handling. I selected tarsus and head-bill measurements because these measurements have successfully distinguished sexes in other species (Jenkins & Veitch 1991; Pyke & Armstrong 1993). Tarsus and head-bill were measured to the nearest 0.1 mm with a plastic vernier caliper. I used the "tarsus length with foot" measurement (TZ), which involves bending the foot downwards, holding 1 end of the caliper against the notch on the upper end of the tarsometatarsus, and the other end of the caliper against the folded foot (Fig. 6.10 in Rogers 1989). I always measured the right leg while holding the bird in my left hand. Head-bill length (HB, also known as total head length or overall head) was the distance from the back of the head to the tip of the bill (Rogers 1989). Weight was measured to the nearest 0.5 g with a Pesola 100 g spring balance, with the bird in a cloth bag. I used discriminant analysis in SYSTAT to assess whether these measurements gave significant determination of sexes, and if so, to develop a sexing criterion.

In June 1993, I organised a 2nd translocation of robins from the Mamaku Plateau to Tiritiri Matangi, specifically targeting female robins, so as to adjust the sex ratio on Tiritiri Matangi. My strategy was to capture only birds that appeared female in plumage, then reject any bird estimated to be male based on the sexing criterion. Birds were measured initially by any of 9 people in the catching team. If accepted, they were re-measured later by an experienced handler (S. Anderson or S. Ardern).

From 1993 to 1999, I obtained tarsus measurements from additional robins on Tiritiri Matangi, all descended from the translocated birds. Most robins on Tiritiri Matangi were banded on the nest when 9-15 days old; I did not use the measurements taken at this age because the birds may not have reached full size. However, some birds were captured for banding after they had fledged, and some birds were captured for translocation to Wenderholm Regional Park in 1999. Sexes could be assigned to 52 of these birds (Table 1), either because they were adults at the time of capture or because they subsequently survived to adulthood. Head-bill length and weight were also measured for 32 of these birds (hence the smaller sample sizes for these measurements in Table 2). I measured 37 of the birds, and T. Lovegrove measured 15.

RESULTS

Tarsus length gave significant discrimination of sexes for the first 30 birds (F = 6.49, P = 0.017), whereas head-bill length (F = 0.03, P = 0.873) and weight (F = 0.36, P = 0.554) did not give significant discrimination when used in combination with tarsus. Using tarsus length alone, any bird with a tarsus less than or equal to 35.8 mm was predicted to be female, and any bird with a longer tarsus was predicted to be male. This criterion would have correctly sexed 78% of males (18/23), and 57% of females (4/7). The total percentage sexed correctly (73%, 22/30) was the same as that sexed correctly on plumage. However, because the errors are more evenly distributed between sexes, the estimated sex ratio (30% female, 9/30) was much closer to the true value (23% female, 7/30) than the extremely biased estimate based on plumage (50% female, 15/30). If sex had been assessed on both criteria (i.e. dark birds assumed to be males and light birds sexed from tarsus measurements), the percentage sexed correctly would have been 77% (23/30) and the sex ratio estimated to be 27% female (8/30).

In the 2nd translocation, robins were not captured if they had male plumage and were released if their initial tarsus length measurement was greater than 35.8 mm. Of 14 robins accepted for translocation, 2 had tarsi of 36.0 and 36.1 mm when re-measured, but the tarsus in the other birds was always < 35.6 mm. Ten of the 14 survived until September 1993 (Table 1), including the 2 birds with tarsi greater than 35.8 mm, both of which were male. Of the other 8 survivors, 7 (88%) were female. Therefore, the cut-off of 35.8 mm, in combination with plumage assessment was effective for obtaining a high proportion of females. This result contrasts with the 1st translocation where only 44% (9/16) of the survivors initially assessed to be female were actually females.

Using data for the 52 birds produced on Tiritiri Matangi, tarsus length was again the only variable that gave significant discrimination of sexes (F = 12.05, P = 0.002), with head-bill length (F = 1.37, P = 0.254) and weight (F = 2.16, P = 0.155) providing no additional discrimination. These data yielded a cut-off point of 35.4 mm (i.e. all birds with tarsus length greater than 35.4 mm were predicted to be male), in comparison to the cut-off point of 35.8 mm for the original translocated birds. The original 35.8 mm cut-off correctly sexed 89% of females (17/19), 73% of males (24/33), and 79% (41/52) in total. The lower cut-off of 35.4 mm would have correctly sexed 74% of females (14/19) and 85% (28/33) of males, and 81% (42/52) in total. The estimated sex ratio using the 35.8 mm cut-off was 50% female (26/52), whereas the 35.4 mm cut-off would have correctly estimated the sex ratio as 37% female (19/52).

The birds produced on Tiritiri Matangi were of known age when measured, hence I tested whether measurements varied with age as well as with sex. I divided birds into 2 categories, adults (measured at least 8 months after fledging) and juveniles (measured within 5 months after fledging, and usually within 2 months), and did 2-way ANOVA on measurements using age and sex as categories. These analyses were limited by small sample sizes (Table 2), but nevertheless suggested that head-bill length and weight both varied with age. Head-bill length was significantly larger in adults than juveniles (P = 0.001) and in males than females (P = 0.021), with no age-sex interaction (P = 0.321). Weight did not vary significantly with age (P = 0.062) or sex (P = 0.452), but there was a significant age-sex interaction (P = 0.004). In contrast, tarsus length was significantly larger in males than females (P < 0.001), with no effect of age (P = 0.459) and no age-sex interaction (P = 0.299).

Combining all 30 birds from the first translocation with the 52 birds produced on Tiritiri Matangi (Table 2), the mean tarsus length was 36.4 mm for males and 34.8 mm for females (birds from the 2nd translocation were excluded because they were selected based on tarsus length and were therefore a biased sample). There was considerable overlap between sexes, but the upper 3rd of birds were all male and the lower 3rd mostly female (Fig.1). The best cut-off point for this combined data set based on discriminant function analysis was 35.6 mm – 80% of birds with tarsus length greater than 35.6 mm were male and 77% of other birds were female.

DISCUSSION

The data suggest that North Island robins can be sexed with about 80% accuracy based on tarsus length alone. More importantly, use of tarsus should allow a reasonably unbiased estimate of sex ratio, rather than an estimate that substantially overestimates the proportion of females. There is still some uncertainty about the best cut-off point for assigning males and females, but our data from Tiritiri Matangi support a cut-off point of about 35.6 mm. The appropriate cut-off point may vary between populations, and would clearly be different for South Island robins (*P. a. australis*) and black robins (*P. traversi*) which differ from North Island robins in morphometrics (Fleming 1950). In the absence of known-sex birds, the optimal cut-off point can potentially be inferred from the overall size distribution using statistical methods (Rogers *et al.* 1986) or by simple visual inspection if there is clear bimodality (Pyke & Armstrong 1993).

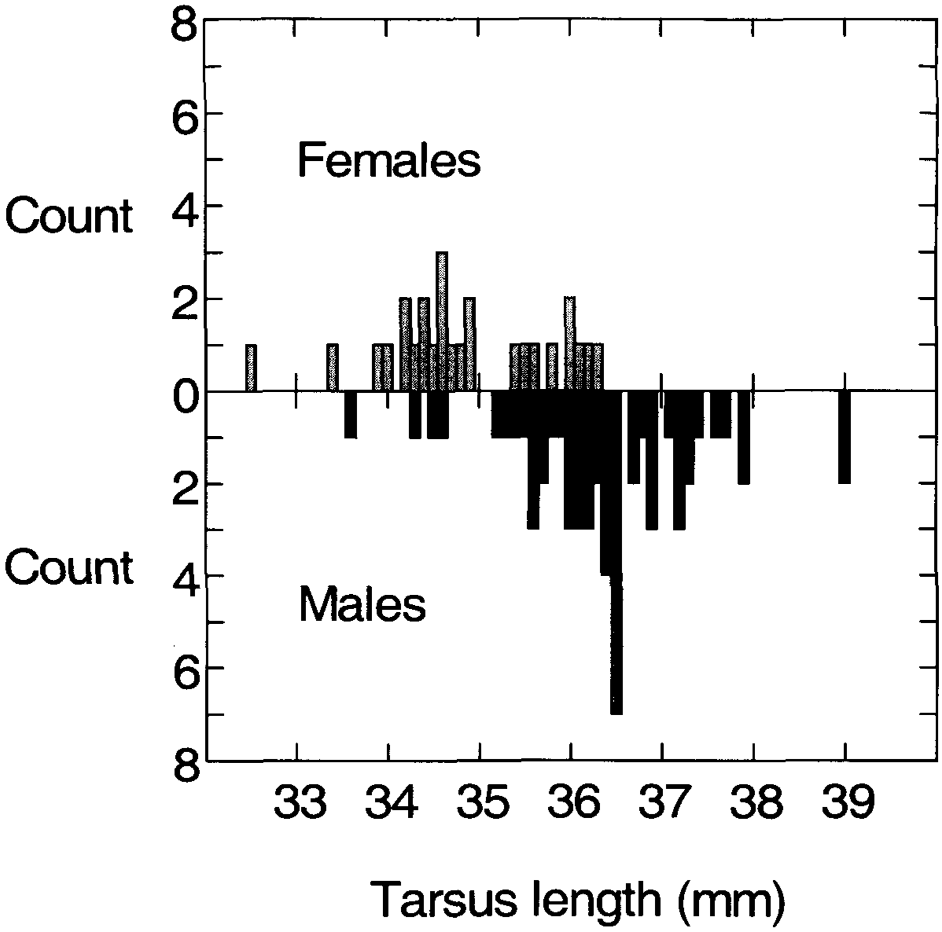

Fig. 1 Distribution of tarsus length with foot (TZ) measurements for male and female North Island robins (*Petroica australis longipes*) on Tiritiri Matangi Island, including the 30 birds from the 1st translocation and 52 birds of known sex hatched on Tiritiri Matangi, but excluding 10 birds from the 2nd translocation which were selected based on tarsus length.

The actual proportion of robins that can be sexed correctly may be higher than 80% if tarsus length is used in combination with plumage, depending on the age distribution of birds. If birds are measured as juveniles to get a preliminary indication of sex, as on Tiritiri Matangi, then there is no scope to use plumage information. However, if birds of various ages are being captured from a population for translocation, then plumage can be used to sex older males and tarsus length used to estimate sexes of the remaining birds.

The main reason that tarsus length gave the best indicator of sex is probably that tarsi reach full size at an early age, removing a key source of variation. My data collected from robins banded in the nest suggest that tarsi reach full size by about 14 days after hatching, and certainly before fledging at about 21 days (Powlesland 1997). In contrast, head-bill length was significantly larger in adults than juveniles and therefore appears to increase after fledging. Our data also suggest that weights may be affected by both age and sex, but these data were too sparse to draw any firm conclusion.

After doing this analysis, I learned that Doug Flack and Brian Lloyd used wing chord to sex South Island robins in the Chetwode Islands. Brian Lloyd (pers. comm.) suggested that at least 90% of birds were sexed correctly based on wing chord, but noted that the data were never analysed. Preliminary data collected on Tiritiri Matangi in the 2000/01 breeding season suggest that maximum wing chord (Rogers 1989) is effective for sexing North Island robins, most males (15/17) having wing chord >87 mm and most females (10/11) having a wing chord ≤ 87 mm. These data further suggest that wing chord is more informative than tarsus, and that the tarsus length provides no additional information if wing chord is used. Further data are needed to confirm this, and to establish an appropriate cut-off measurement for sexing based on wing chord. Wing chord is a more difficult measurement to take than tarsus length, and could be subject to higher inter-observer variability.

Our ability to sex robins on morphometrics and plumage would also be improved if we could reliably distinguish 1st-year birds from older females. Older birds could then be sexed on plumage alone, and measurements used only for 1st-year birds. When they leave their natal territories, juveniles can be recognised by their pointed rectrices and usually by yellow/orange on their feet and around their gape. However, these features disappear over time. Preliminary observations suggest that 1st-year birds have a pale leading edge on their alula that may distinguish them from older females, but this remains to be tested.

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