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Weights and measurements of *Anas superciliosa* in New Zealand

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Abstract Weights and body measurements from 258 male and 203 female adult (>1 year) and juvenile (<1 year) grey duck (*Anas superciliosa*), were collected from freshly-shot specimens in May 1974 and 1975 at sites in North Island, New Zealand. Mean weights of adult (1069 g) and juvenile (1035 g) males were significantly greater than those of adult (967 g) and juvenile (926 g) females. Assessment of body mass relative to skeletal size using a mass-size index (weight/tarsus^2) did not detect any significant differences between any sex and age categories. Body measurements were of bill length and width, tarsus and middle-toe-and-claw lengths, and wing and tail lengths, and presented for each sex and age class. For every character measured, mean lengths for juvenile males were significantly longer than for juvenile females, and those for adult males significantly longer than for adult females. Within each sex, only mean wing and tail measurements from adults were significantly longer than those from juveniles. Significant differences in field weights and some body measurements between New Zealand and Australian *A. superciliosa* were identified.

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Keywords grey duck; *Anas superciliosa*; weights; measurements; New Zealand

INTRODUCTION

Anas superciliosa is the Australasian and south-western Pacific representative of the so-called mallard clade of dabbling ducks (Johnson & Sorenson 1999; Lavretsky *et al.* 2014). Its range extends (or once extended) from north-western Pacific islands within Micronesia, western Pacific islands of Polynesia and Melanesia, New Guinea and western Indonesia to Australia, New Zealand and nearby sub-Antarctic islands. Within that range, birds of the northern and western island population are recognised as being smaller than those elsewhere (Amadon 1943; Marchant & Higgins 1990), have a distinctive mtDNA haplotype (Rhymer *et al.* 2004), and are referred to as lesser grey duck (*A. s. pelewensis*) (Marchant & Higgins 1990). Historically, the Australasian populations were separated into 2 races, namely, Pacific black duck (*A. s. rogersi*) of Australia and New Guinea, and the nominate race, grey duck (*A. s. superciliosa*) of New Zealand and its nearby islands (Checklist Committee 1990). However, Rhymer *et al.* (2004) found shared mitochondrial haplotypes between the Australian and New Zealand populations, and taxonomic distinction at sub-specific level is no longer recognised (Checklist Committee 2010).

New Zealand's grey duck population has declined catastrophically in response to profound landscape change and wetland drainage during the late 19th and entire 20th century, and the introduction of an exotic ecological analogue, the mallard (*A. platyrhynchos*) (Williams & Basse 2006). The mallard's establishment was aided by the concerted, nationwide, captive breeding and release programmes of Acclimatisation Societies

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(Dyer & Williams 2010), especially during the mid-20th century. The larger mallard soon came to occupy all habitats in which grey duck were then plentiful, out-competing it for food and breeding space and hybridising with it (Williams & Basse 2006). Assessments of the grey duck's present-day distribution and numerical status of grey duck (Robertson *et al.* 2007, 2016) remain clouded by the uncertainty surrounding discrimination of grey duck from phenotypically variable grey duck x mallard hybrids, and mallard females.

Body measurements and weights reported in this paper arose from an attempt to define grey duck plumage and mensural characteristics at a time (1970s) when grey ducks were still widespread but rapidly declining, mallard numbers were burgeoning (Caithness 1982; Williams 1981), and confusion about the phenotype of hybrids between the two species was developing.

METHODS

Species identification

So as not to include in the dataset ducks of apparent grey duck x mallard hybrid ancestry, all specimens were examined to ensure 3 phenotypic criteria were satisfied: (i) there was no (white or mottled fawn) stripe on the secondary (greater) wing coverts, *i.e.,* above the wing's green and black-margined speculum; (ii) legs were khaki colour; and (iii) the cream face patches (between crown and superciliary stripe and between superciliary and malar stripes) were "clean" and without black mottling. These characteristics, highlighted in historic descriptions of grey duck (*e.g.*, Falla *et al.* 1966), best discriminated them from known hybrids which, at the time, were being bred at the Mount Bruce Native Bird Reserve by the New Zealand Wildlife Service.

Measurements

Weights and/or body measurements were obtained from 258 male and 203 female grey ducks retrieved as freshly-shot specimens during the first 2 weeks of May (mostly during 1974 and 1975) at locations in Manawatu (principally Pukepuke Lagoon, Himitangi), Waikato (principally Lakes Whangape and Waahi), Rotorua-Taupo, Northland (near Dargaville) and Taranaki (near Inglewood); Manawatu specimens comprised 62% of the total. Measurements were contributed by 3 people who followed the same methods, and whose measurements for each character were tested and confirmed not to be statistically different from each other's except for tarsus length; 1 contributor consistently returned longer tarsus measurements than the other 2 and those tarsal measurements were excluded from the data analysed and reported here.

Bill and tarsus measurements were made using Vernier calipers (to 0.1 mm), wing and tail were measured by ruler (to 1 mm), and weights (to nearest 10 g) obtained using a 0-1.5 kg Salter or Pesola spring balance. Sex and age of specimens were determined by cloacal characteristics (see Mosby 1963), juveniles being birds-of-the-year and adults one or more years old. Ages of 65 males were not recorded but data from these specimens are included in all-male analyses.

Measurements made were: bill length (length of the exposed culmen, from bill tip to commencement of feathers in the midline), bill width (width at bill base, directly below where the exposed culmen begins), [tarsometa]tarsus length (from the notch at the inter-tarsal joint to the point of articulation of the middle toe and conducted by bending the tarsal bone at 90^{o} to both tibia and toe), middle-toe-and-claw length (length of toe along upper surface from point of articulation with tarsus to tip of claw), tail length (length of longest midline tail feather from feather tip to feather root), and flattened wing length (length of folded wing from foremost extremity of carpal joint to tip of longest primary). When measuring wing length, the ruler was placed beneath the folded wing, the carpal flexure abutted to a stop-end on the ruler, and the wing flattened against the ruler. These measurements are those recommended by Gurr (1947) and now included in most bird-banding manuals (*e.g.*, Balmer *et al.* 2009).

For analysis, data were transcribed into an Excel spreadsheet, in which all statistical tests were conducted and from which frequency histograms were produced. A *z*-test was used to test for difference between sample means. A mass-size index, calculated as weight/tarsus^2 and sometimes considered an index of body condition (Labocha & Hayes 2012), was used to interpret sex and age class differences in weight relative to body size. The data, having all been collected in a single month (May), removed the seasonal variability in weight and body condition which breeding and moulting induce (Owen & Cook 1977).

RESULTS

Body measurements

Males

Measurements of juvenile and adult males, and of both ages combined, are summarised in Table 1, and frequency distributions of all measurements for all males depicted in Fig. 1.

Wing lengths of adults were significantly longer than those of juveniles, and their bills were significantly wider. For none of the other measured characters did these age classes differ (Table 1).

Table 1. Field-derived body measurements of male grey duck (*Anas superciliosa*) in New Zealand. The "All males" statistics include up to 65 birds not aged. All measurements in mm. Abbreviations: *sd* = standard deviation, *n* = sample size. Statistical comparisons of adults and juveniles record z-statistic value (*z* =) and probability value (*P* =). A *P*-value < 0.05 indicates a significant difference between adult and juvenile measurements.

		Bill width	Bill length	Tarsus	Toe & claw	Wing	Tail
Juvenile	Mean	21.2	52.2	44.3	60.0	258.3	85.6
	sd	0.8	2.1	1.7	2.2	6.8	4.7
	Maximum	23.1	58.1	48.8	65.7	279	95
	Minimum	18.3	47.4	40.6	53.5	241	69
	n	133	133	102	131	134	123
Adult	Mean	21.6	52.8	44.5	60.0	263.1	86.5
	sd	0.8	2.5	1.5	2.4	8.0	5.2
	Maximum	23.3	57.4	49.2	65.6	283	99
	Minimum	19.7	46.0	40.9	50.7	250	63
	n	57	58	40	59	58	57
Adult v.	*z*	3.1	1.6	0.69	0.27	3.89	1.24
Juvenile	*P*	0.002	0.10	0.49	0.79	<0.0001	0.15
All males	Mean	21.4	52.6	44.5	60.2	260.4	86.3
	sd	0.9	2.3	1.6	2.3	7.4	4.6
	Maximum	24.3	58.1	49.2	66.1	283	99
	Minimum	18.3	46.0	40.6	50.7	241	63
	n	242	256	142	241	257	244

Females

Measurements of juvenile and adult females, and of both ages combined, are summarised in Table 2, and frequency distributions of all measurements for all females depicted in Fig. 1.

Only wing lengths of adults were significantly longer than those of juveniles although tail lengths were almost so. There were no differences in the external skeletal measurements of the two age classes (Table 2).

Differences between males and females

For every character, measurements of juvenile males were significantly longer than those of juvenile females (all $P < 0.001$). Similarly, all measurements of adult males were significantly longer than of adult females (all $P < 0.001$), except those of the tail which were similar ($z = 0.2$, $P = 0.84$). However, when both ages were combined, and data from up to 65 un-aged males included in the all-male statistics, male characters were significantly longer than those of females for all measurements (all $P < 0.0001$).

The comparative percentage distributions of measurements of each character (Fig. 1) illustrate that the extent of overlap in measurements of the two sexes was 90-95%. The greatest differentiation was in wing length where 8.5% of male measurements exceeded the female maximum and 19.4% of female measurements were less than the male minimum.

Weight

Weights of juvenile, adult, and combined ages of females and males are summarised in Table 3, and the frequency distributions of all female and male weights depicted in Fig. 2A.

Adults were significantly heavier than juveniles (females $z = 2.46$, $P = 0.01$; males $z = 2.2$, $P = 0.03$). Males were significantly heavier than females in both age classes, and overall (juveniles $z = 9.8$, $P < 0.0001$; adults $z = 5.1$, $P = <0.0001$; combined ages $z = 13.3$, $P < 0.0001$).

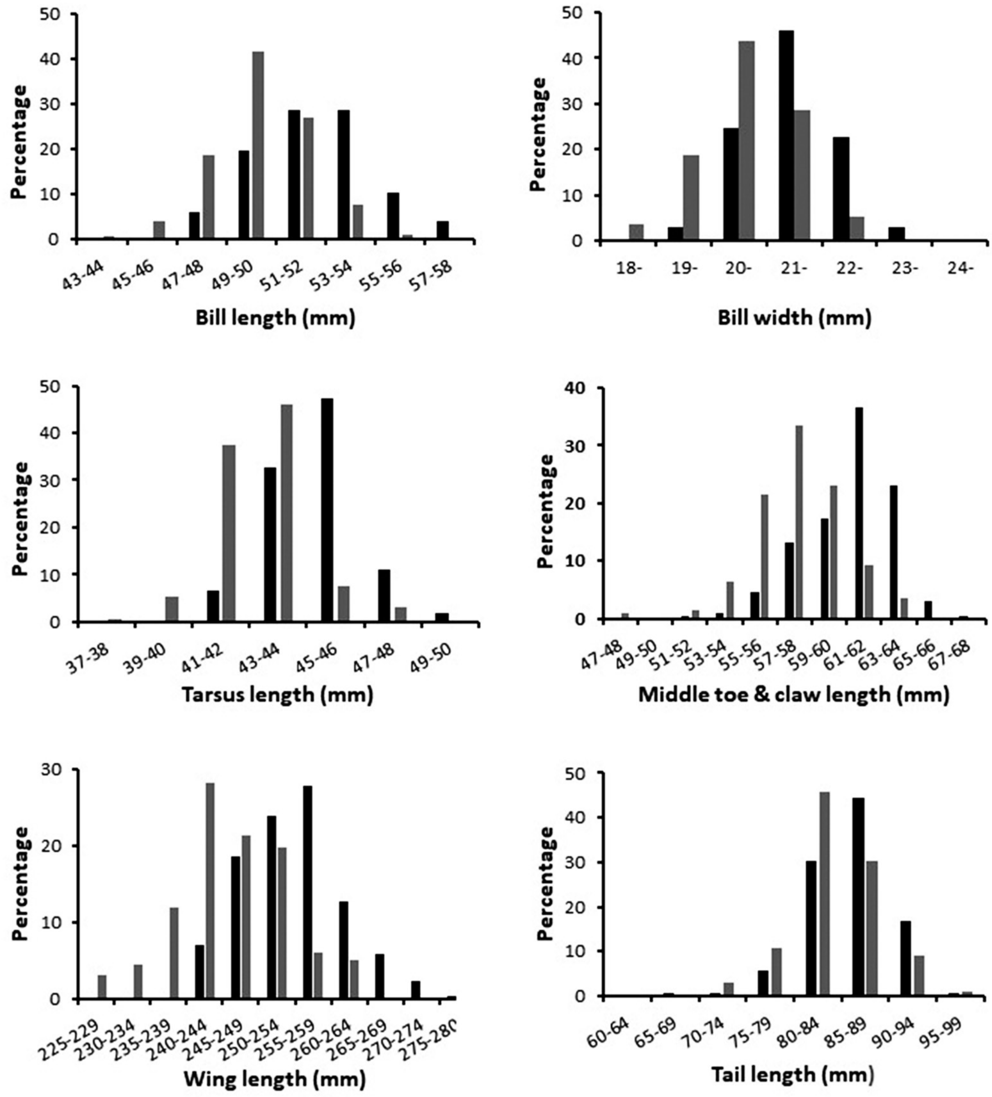

Fig. 1. Percentage distributions of field-derived body measurements of male and female grey duck (*Anas superciliosa*) in New Zealand (grey = female, black = male).

Overall, the mean male weight was 12.8% heavier than the mean female weight (Table 3). There was, however, extensive overlap in weight ranges; only 6.2% of females weighed less than the lightest male and while just 1.2% of females exceeded 1150 g, 13.2% of males did so. The weight range of 800–1150 g encompassed 86.4% of males and 92.7% of females (Fig. 2A).

Weight in relation to body size

Because weight reflects body size as well as physical condition (*e.g.,* quantity of muscle and fat) I calculated a mass-size index (= weight/ $tarsus^2$) to evaluate weight relative to skeletal size, and compared mean values and the percentage distributions of the indices between sex and age classes (Fig. 2B).

Table 2. Field-derived body measurements of female grey ducks (*Anas superciliosa*) in New Zealand. All measurements in mm. Abbreviations and statistics as for Table 1.

		Bill width	Bill length	Tarsus	Toe & claw	Wing	Tail
Juvenile	Mean	20.6	49.5	42.3	57.3	245.0	84.0
	sd	0.9	1.9	1.6	2.6	6.7	4.0
	Maximum	22.7	55.4	46.4	64.0	263	97
	Minimum	18.2	44.7	37.8	47.6	228	72
	n	141	150	112	139	150	147
Adult	Mean	20.5	49.2	42.5	57.4	251.4	96.1
	sd	0.9	2.1	1.8	2.7	7.8	5.0
	Maximum	22.4	54.9	47.0	63.3	265	94
	Minimum	18.7	43.2	38.5	50.4	230	73
	n	50	49	42	51	50	47
Adult v.	*z*	0.48	0.90	0.63	0.23	5.35	2.81
Juvenile	*P*	0.63	0.37	0.52	0.82	<0.0001	0.05
All females	Mean	20.6	49.4	42.3	57.3	247.0	84.5
	sd	0.9	2.0	1.6	2.6	7.5	4.3
	Maximum	22.7	55.4	47.0	64.0	265	97
	Minimum	18.2	43.2	37.8	47.6	228	72
	n	191	199	154	190	200	194

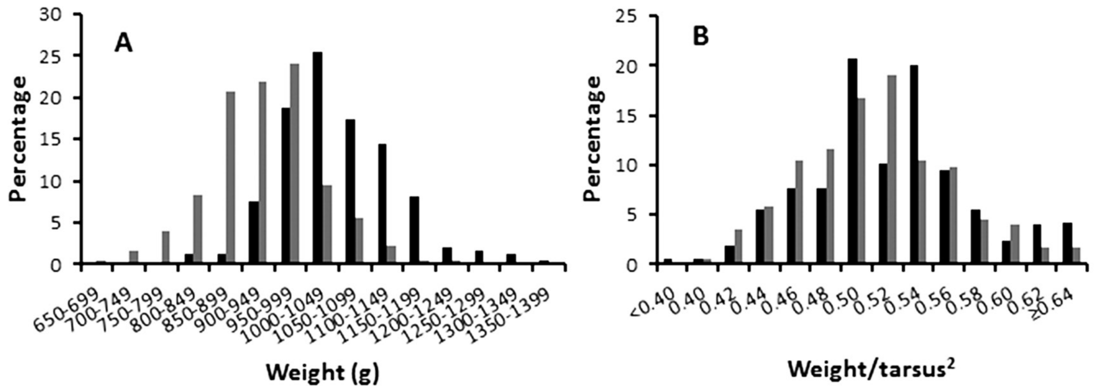

Fig. 2. Percentage distributions of field-derived weights (g) of male and female grey duck (*Anas superciliosa*) (combined ages) in New Zealand (A), and percentage distributions of a mass-size index (= weight/tarsus^2) of male and female grey duck (combined ages) in New Zealand (B). (grey = female black = male).

Table 3. Summarised field-derived weights (g) and calculated mass-size indices of aged male and female grey duck (*Anas superciliosa*) in New Zealand. "All male" statistics includes 65 birds not aged. Abbreviations as for Table 1.

		Male			Female		
		Juvenile	Adult	All	Juvenile	Adult	All
Weight	Mean	1034	1069	1054	926	961	934
	sd	93.3	91.0	92.2	81.3	90.0	84.2
	Maximum	1350	1392	1392	1191	1138	1191
	Minimum	804	920	804	710	700	700
	n	119	50	234	137	40	177
Mass-size index	Mean	0.528	0.541	0.534	0.520	0.532	0.523
	sd	0.055	0.053	0.053	0.048	0.055	0.049
	Maximum	0.678	0.665	0.694	0.683	0.645	0.683
	Minimum	0.342	0.456	0.342	0.408	0.428	0.408
	n	102	40	142	112	40	152

The mean mass-size indices of juveniles and adults within and between sexes did not differ significantly ($P = > 0.15$ for all). The mean mass-size index from juvenile and adult females combined (0.523 ± *sd* 0.050;) did not differ from that of juvenile and adult males combined (0.532 ± *sd* 0.055; $z = 1.59$, $P = 0.11$). Consequently, the distributions of indices of all females and all males (Fig. 2B) were similar, apart from minor differences in sample proportions in the depicted three central index values.

There was a very weak tendency for ducks with higher mass-size indices to have longer wings ($r = 0.12$, $P = 0.76$).). However, there was a significant relationship between wing length and weight for 3 sex/age categories (juvenile male $r = 0.076$, $P = 0.41$; adult male $r = 0.415$, $P = 0.003$; juvenile female $r = 0.339$, $P < 0.0001$; adult female $r = 0.579$, $P < 0.0001$).

Comparison with published body measurements and weights of grey duck

A previous compilation of field-derived body measurements and weights of grey ducks was obtained in May of 1947-49 from sites in lowland Manawatu (Balham 1952: Table 3). For both sexes, mean wing (female 248 mm, male 261 mm), tail (female 80.9 mm, male 83.4 mm), tarsus (female 43.9mm, male 46.3 mm) and bill (female 49.9 mm, male 51.9 mm) lengths were all similar with those reported in this study. However, tarsus and tail lengths of both sexes were significantly longer (tarsus: female $z = 6.70$, $P < 0.0001$; male $z = 6.32$, $P < 0.0001$; tail: female $z = 7.68$, $P < 0.001$; male $z = 4.84$, $P < 0.0001$). The mean weights of females and males reported by Balham (1952), converted to metric, were 981 g and 1090 g respectively, significantly heavier than those reported in this study (female $z = 4.23$, $P < 0.0001$; male $z = 3.10$, $P = 0.002$).

Comparison with published body measurements and weights of Pacific black duck

Body measurements and weights of Pacific black duck from inland New South Wales were reported by Frith (1967), and by Braithwaite & Miller (1975). However, the latter were a subset of Frith's measurements. Both results were included in the summation of measurements provided by Marchant & Higgins (1990). Fullagar (2005) amalgamated all measurements listed in Marchant & Higgins to produce a composite for the species descriptive neither of New Zealand nor Australian populations.

In the absence of variance estimates, Frith's summary indicates both sexes of Pacific black duck to have slightly longer wings and to be heavier than New Zealand birds.

Statistical comparisons of Braithwaite & Miller's measurements with those of Balham (1952) and from this study indicate male Pacific black ducks to be significantly heavier ($z = 2.50$, $P = 0.012$), have longer wings ($z = 2.58$, $P = 0.01$) but shorter bill lengths ($z = 2.96$, $P = 0.003$) than Balham's sample, and those from this study (weight $z = 6.3$, $P < 0.0001$; wing length $z = 3.6$, $P = 0.0003$; bill length $z = 6.51$, P

Table 4. Summarised field-derived body measurements and weights of Pacific black duck of indeterminate age in Australia (from Frith 1967/Braithwaite & Miller 1975). ± = standard deviation.

		Bill length mm	Wing mm	Weight g
Male	Mean	52/51±2	262/265±12	1114/1113±110
	Maximum	58/57	284/290	1400/1400
	Minimum	45/45	230/230	870/800
	n	157/100	139/100	131/100
Female	Mean	49/49±2	247/250±13	1025/1015±180
	Maximum	54/56	271/280	1280/1400
	Minimum	46/44	226/200	805/600
	n	107/100	109/100	207/100

< 0.0001). Female Pacific black ducks were heavier ($z = 4.25$, $P < 0.0001$) and had longer wings ($z = 2.14$, $P = 0.03$) than females measured in this study, but not so when compared with Balham's sample. Their bill lengths were statistically shorter ($z = 3.1$, $P = 0.002$) than Balham's sample but not so the females measured in this study.

DISCUSSION

Sex and age differences

Male grey ducks were larger than females across all characters measured, a sexual size dimorphism in common with almost all 43 *Anas* species (see Williams 2015: Fig. 6). However, mensural distinction between adults and juveniles of each sex was restricted to feather, not skeletal measurements. Males were heavier than females but this difference was a consequence of being skeletally larger, rather than having proportionately more flesh. That adults were not heavier for their (skeletal) size than juveniles indicate that, by the time of measurement, all young from the prior breeding season had completed their somatic growth and accumulated pre-winter body reserves. This contrasts with the later-breeding Australasian shoveler (*Anas rhynchotis*) where, at the same time of year, juveniles had lower weights relative to their skeletal sizes than adults (Williams 2014).

The smaller wing lengths of juvenile grey ducks may be a consequence of competing energy allocations for skeletal and feather development during pre-fledging growth. Shorter wing feathers may be less disadvantageous than small skeletal size at maturity while flight may be more energy demanding as a consequence, but if it is, this did not lead to juveniles being lighter than adults. Nevertheless, the significant relationships detected between wing lengths and body weights indicates that, at the individual level, there may be an important eco-physiological trade-off, unrelated to other measures of the duck's structural size. Wing length is expected to more closely relate to body condition and resources at the time of moult than to winter weight (Owen & Cook 1977).

Previously published measurements

Differences in means of some body measurements and of weights from grey ducks shot mostly in Manawatu and approximately 25 years apart (Balham 1952, this study), may simply be an example of sampling variation from within a widely distributed population. Equally, they may have arisen from slightly different measurement techniques being used (*e.g.,* for tarsus), inter-measurer variability, and the conversion, to metric scale, of weights originally recorded with less precision in ounces.

However, a broader latitudinal sampling may have detected regional or inter-island variation in size and weight in accordance to Bergmann's rule (Salewski & Watt 2017), as has been demonstrated in other New Zealand waterfowl *e.g.*, blue duck (*Hymenolaimus malacorhynchos*) (Marchant & Higgins 1990; Godfrey *et al.* 2003) and brown teal (*A. chlorotis*) (Marchant & Higgins 1990), and in the wide-ranging New Zealand falcon (*Falco novaeseelandiae*) (Trewick & Olley 2016). In contemporary New Zealand, grey duck is not a widely-dispersing species (Balham & Miers 1959; Williams 1981; M. McDougall *pers com*.) and limited historic dispersal is indicated by the geographic structuring of mtDNA haplotype occurrence (Rhymer *et al.* 2004).

Comparison with Pacific black duck

The detected differences in wing lengths and weights of *A. superciliosa* either side of the Tasman Sea contradicts the conclusions of Marchant & Higgins (1990) and Fullagar (2005), that New Zealand and Australian populations do not differ. That Rhymer *et al.* (2004) detected mtDNA haplotypes in common between New Zealand and Australian specimens does not necessarily negate the possibility of each geographic group demonstrating adaptive eco-physiological responses to local environmental conditions *e.g.*, with small differences in body dimensions and weights. Rhymer *et al.* (2004) also identified mtDNA haplotypes not shared, potentially indicative of prolonged separation between segments of the two populations. Whilst historic phylogeographic association has been demonstrated, the scale and frequency of contemporary gene flow has not, and dismissal of Australian *Anas superciliosa* being, predominantly, a geographically distinct population (subspecies *rogersi*) from those in New Zealand (subspecies *superciliosa*) may still deserve consideration. In any future mensural appraisal a more geographically widespread and numerically greater sampling than reported in this study would be required, and particularly important would be the discrimination of newly-fledged birds (juveniles) from those older (adults).

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