The relative sizes and asymmetry of kidneys in passerine birds from Australia and North America

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INTRODUCTION

Avian kidneys normally consist of three divisions, each of which has many smaller lobes. However, there has been little work on variations in the size, shape and structure of kidneys in relation to birds' phylogeny, diet or environmental factors. Most attention has been devoted to possible adaptations of the kidneys of desert bird species to xeric conditions (e.g. Johnson & Skadhauge, 1975; Ambrose & Bradshaw, 1988) or to the kidney's involvement in saline tolerance in marine birds (Hughes, 1970). In this paper we examine the allometric relationships of the kidneys of nectar- and insect-feeding passerine birds from Australia and compare them with values for North American passerines in the literature.

Nectar is a major component of the diet of many honeyeaters (Meliphagidae), a dominant family of passerine birds in Australia. In earlier papers (Richardson & Wooller, 1986; Wooller & Richardson, 1988) we showed that honeyeaters had smaller gizzards and intestines than wholly insectivorous birds of comparable size. The more liquid diet of honeyeaters might also be reflected in kidneys larger or smaller in relation to their body weight than in sympatric, insect-feeding passerines.

Recent work clearly indicates that many Australian passerines are more closely related phylogenetically to each other than to birds elsewhere (Sibley & Ahlquist, 1985). Apparent similarities in body shape between insect-feeding passerines from Australia and those on other continents appear, therefore, to be due to convergence rather than to phylogenetic affinity. Thus, the nectar- and insect-feeding birds from Australia form part of a single endemic radiation, although they differ in their diets. In contrast, insectivorous birds from Australia and North America appear to have very similar diets but different origins, allowing the relative influences of phylogeny and diet to be gauged.

MATERIALS AND METHODS

Birds were collected from Western Australia, under licence, using mist-nets. They were weighed to ± 0.1 g upon capture, killed with an intraperitoneal injection of barbiturate, then fixed in neutral buffered formalin. Later, their kidneys were dissected out, pat-dried and weighed to ± 0.001 g. The overall length from the cranial pole to the caudal pole of each kidney and its maximal width were measured to ± 0.1 mm with vernier calipers. Left and right kidneys were measured separately.

Data on insectivorous passerines from North America were obtained from Johnson (1968). These specimens were also weighed to ± 0.1 g in the field and their pat-dried

kidneys weighed to ± 0.001 after fixation in formalin. All variables were transformed to natural logarithms and Pearson product-moment correlation coefficients and regression equations were determined, as detailed in Wooller & Richardson (1988). All regressions, ANOVA and other statistical treatments were performed using Statview 512+ on a microcomputer.

RESULTS

In each of the three groups considered, total kidney weight was significantly (all $r > +0.97$; $P < 0.001$) related to body weight (Figs. 1, 2), although some of these relationships differed significantly. Among Australian passerines (Fig. 1), the allometric relationship between kidney weight and body weight in 15 honeyeater species did not differ from that in 23 wholly insectivorous species in its slope ($F_{1,34} = 1.07$) but had a significantly lower intercept ($F_{1,35} = 23.6$, $P < 0.001$). Thus, honeyeaters had smaller kidneys, on average, than closely related birds of equivalent weight whose diet consisted mainly of insects.

Comparing the allometric relationship of kidney weight and body weight in 45 insectivorous passerine species from North America with that for the 23 species of passerine insectivores from Australia (Fig. 2), once again the slopes did not differ ($F_{1,64} = 2.00$) but the North American birds had a significantly higher intercept ($F_{1,65} = 22.37$, $P < 0.001$). Passerines from North America, therefore, had larger kidneys, on average, than passerines of the same weight from Australia, despite an apparently similar insect diet.

In the 35 Australian passerine species considered, the lengths of left and right kidneys differed in 94% of species and in 82% of these the left kidney was longer (Table 1). The differences in kidney lengths were significant in both honeyeaters ($F_{1,26} = 45.57$, $P < 0.001$) and insectivores ($F_{1,36} = 44.58$, $P < 0.001$). Kidney widths showed no consistent lateral asymmetry in either honeyeaters ($F_{1,26} = 2.71$) or insectivores ($F_{1,36} = 2.81$).
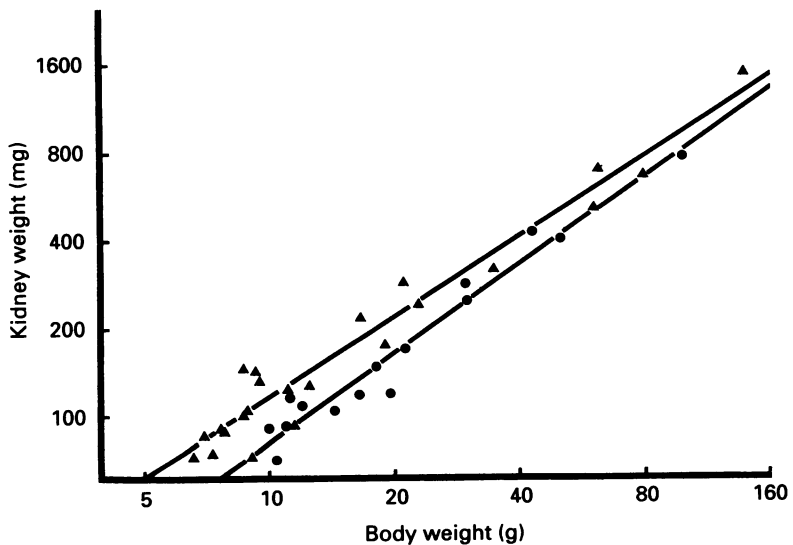

Fig. 1. The log-log relationships between total kidney weight (k, in mg) and body weight (m, in g) in 23 species of Australian passerine insectivores (▲), and 15 species of Australian passerine honeyeaters (●). The upper regression line represents the insectivores ($r_{21} = +0.98$, $P < 0.001$; $k = 13.8\ m^{0.93}$) and the lower line represents the honeyeaters ($r_{13} = +0.98$, $P < 0.001$; $k = 8.1\ m^{1.01}$).
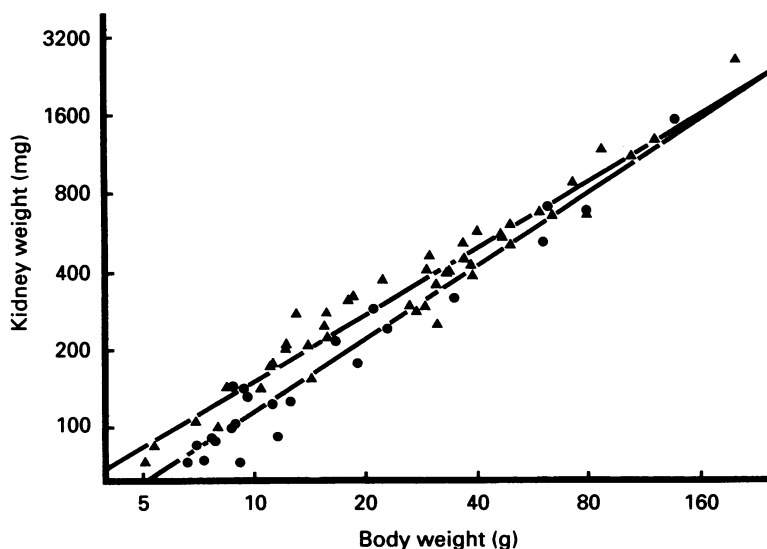
Fig. 2. The log-log relationships between total kidney weight (k, in mg) and body weight (m, in g) in 45 species of North American insectivorous passerines (▲) and 23 species of Australian passerine insectivores (●). The upper regression line represents the North American birds ($r_{43} = +0.97$, $P < 0.001$; $k = 21.7\ m^{0.85}$) and the lower line the Australian birds ($r_{21} = +0.98$, $P < 0.001$; $k = 13.8\ m^{0.93}$). North American data from Johnson (1968).

DISCUSSION

The strong relationships between body weight and kidney weight, similar in all groups examined, were close to those found earlier by Johnson (1968, 1979) and Hughes (1970) using passerine and non-passerine birds. Johnson (1979) found no evidence for insectivores having larger kidneys than herbivores. However, within the Australian endemic passerine radiation that we studied, honeyeaters had smaller kidneys, on average, than sympatric insectivores of the same body weight. The similar origins and environments of these two groups indicate that this difference was probably due to their different diets. Nectar is about 75% water, so that most honeyeaters have a very liquid diet with little need to conserve water. In contrast, insect-feeding birds might require larger kidneys to satisfy their water needs from a less liquid diet. Studies currently in progress are examining the internal structure of kidneys, especially the proportions of cortex and medulla, and the contributions of their sub-components, to help resolve this difference. However, any reduction in organ weight which does not reduce the functional efficiency of an animal is likely to be advantageous in a flying organism, such as a bird. The longer intestines of insectivores recorded in earlier studies (Wooller & Richardson, 1988) may also allow for more absorption of water along the length of the intestine.

The larger kidneys of North American passerines, compared to Australian passerines with a similar insect diet, are harder to explain. This difference was unlikely to be due to differences in processing, since both samples were similarly fixed *in situ*, dissected out, blotted and weighed. The two passerine groups are part of separate radiations, the Corvi and the Muscicapae (Sibley & Ahlquist, 1985), but it is difficult to envisage how this would account for a consistent difference in the overall size of their kidneys unless there are differences in structure. Most of the North American

Table 1. *The mean lengths and widths of left and right kidneys from Australian passerine birds (Sample sizes greater than one shown in parentheses)*

Species	Mean (±S.E.) length of kidney (mm)		Mean (±S.E.) width of kidney (mm)	
	Left	Right	Left	Right
Honeyeaters				
Anthochaera carunculata (5)	20·7 ± 0·4	20·5 ± 0·3	8·0 ± 0·3	7·9 ± 0·1
Acanthogenys rufogularis (12)	16·7 ± 0·4	16·2 ± 0·4	6·6 ± 0·3	6·6 ± 0·3
Manorina flavigula (10)	16·2 ± 0·4	16·3 ± 0·3	5·7 ± 0·1	5·7 ± 0·2
Lichenostomus unicolor (5)	14·4 ± 0·1	14·3 ± 0·1	6·0 ± 0·1	6·1 ± 0·1
Lichenostomus virescens (9)	14·2 ± 0·4	14·0 ± 0·5	5·3 ± 0·2	5·3 ± 0·1
Lichenostomus penicillatus (11)	11·7 ± 0·3	11·4 ± 0·3	4·6 ± 0·1	4·6 ± 0·1
Phylidonyris novaehollandiae (9)	11·1 ± 01	10·8 ± 0·1	5·0 ± 0·1	4·7 ± 0·1
Phylidonyris albifrons (5)	11·0 ± 0·1	10·8 ± 0·3	4·6 ± 0·1	4·5 ± 0·1
Melithreptus lunatus (3)	10·9 ± 0·4	10·9 ± 0·5	4·4 ± 0·3	4·2 ± 0·3
Lichenostomus flavescens (7)	10·4 ± 0·3	9·8 ± 0·3	4·3 ± 0·2	4·2 ± 0·2
Phylidonyris melanops	10·4	10·1	4·4	4·5
Ramsayornis fasciatus	10·1	9·3	4·8	4·3
Melithreptus albogularis	10·1	9·8	3·8	3·5
Lichmera indistincta (24)	9·4 ± 0·1	9·1 ± 0·1	4·1 ± 0·1	3·9 ± 0·1
Acanthorhynchus superciliosus (3)	8·8 ± 0·1	8·8 ± 0·1	4·0 ± 0·1	3·9 ± 0·1
Insectivores				
Corvus coronoides	33·2	35·3	12·1	12·4
Cracticus nigrogularis (4)	24·3 ± 0·7	24·0 ± 0·6	9·8 ± 0·2	9·8 ± 0·1
Oreoica gutturalis	19·2	19·5	7·5	7·6
Cracticus torquatus (4)	18·9 ± 0·3	18·3 ± 0·2	7·2 ± 0·3	7·3 ± 0·3
Colluricincla harmonica (2)	18·3 ± 0·2	17·6 ± 0·3	6·9 ± 0·5	7·1 ± 0·2
Merops ornatus	14·0	15·0	6·5	6·5
Pachycephala rufiventris (4)	13·7 ± 0·3	13·3 ± 0·2	5·6 ± 0·2	5·8 ± 0·1
Eopsaltria georgiana (3)	12·8 ± 0·4	12·6 ± 0·4	5·4 ± 0·3	5·6 ± 0·4
Sericornis frontalis (2)	12·2 ± 0·5	12·1 ± 0·4	4·5 ± 0·1	4·8 ± 0·1
Sericonis brunneus (2)	11·8 ± 0·1	11·6 ± 0·2	4·7 ± 0·1	4·7 ± 0·4
Malurus elegans (3)	11·5 ± 0·2	11·3 ± 0·2	4·7 ± 0·1	4·6 ± 0·1
Rhipidura leucophrys (3)	11·3 ± 0·1	11·2 ± 0·1	5·8 ± 0·2	5·8 ± 0·6
Zosterops lutea (2)	11·2 ± 0·4	10·9 ± 0·4	4·5 ± 0·1	4·3 ± 0·3
Zosterops lateralis (6)	11·1 ± 0·1	11·0 ± 0·1	4·1 ± 0·1	4·2 ± 0·1
Pardalotus striatus	10·7	11·2	4·2	4·0
Rhipidura rufiventris (2)	10·1 ± 0·2	9·7 ± 0·4	4·4 ± 0·1	4·2 ± 0·1
Acanthiza apicalis (2)	9·6 ± 0·1	9·5 ± 0·1	4·3 ± 0·1	4·4 ± 0·1
Malurus lamberti (4)	9·6 ± 0·1	9·2 ± 0·1	3·9 ± 0·1	3·9 ± 0·1
Petroica goodenovii (3)	9·2 ± 0·2	9·0 ± 0·1	4·3 ± 0·1	4·5 ± 0·2
Rhipidura fuliginosa	8·2	8·3	4·8	4·8

samples came from South-Western USA and the Australian samples came from South-Western Australia, areas with reasonably similar climates. Thus, differences in the aridity of their environments are unlikely to account for the differences between the two groups. However, the insects and other food items ingested may differ in the proportions of water and nutrients they contain. Hughes (1970) found that marine non-passerines, as well as having salt glands, also had significantly larger kidneys than non-passerines without salt glands. Different groups of non-marine passerine birds may also differ in the relative sizes of their kidneys due to the salinity and other properties of the water and food they ingest. Further work would be required to resolve these puzzling differences.

In most adult female birds, only the reproductive organs on the left side are functional (Gilbert, 1979). Similarly, in males, the left testis tends to be larger than the right in birds (Lake, 1981). The asymmetry in avian kidney size found in this study,

therefore, mirrors that seen in avian gonads. It is known that gonads and kidneys are closely related developmentally, but the exact reason for the observed kidney asymmetry has yet to be found.

SUMMARY

Despite their close taxonomic affinities, nectar-feeding passerine birds from Australia had smaller kidneys, on average, than sympatric passerines of equivalent weight that fed entirely upon insects. Insectivorous passerines from North America had larger kidneys, on average, than comparable insect-feeding passerines from the separate endemic radiation in Australia. Dietary and other environmental differences, rather than phylogenetic origins, may account for these differences. The left kidney of Australian passerines was significantly longer, on average, than the right. Kidney widths showed no lateral asymmetry.

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