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Relationship between Body Mass and Body Length of Resident Bird Species in Taiwan

Pei-Fen Lee [1], Tzung-Su Ding [2] and Hau-Jie Shiu [1]

[1] Department of Zoology, National Taiwan University,
Taipei, Taiwan, R.O.C.

[2] Department of Agronomy and Range Science, University of California
Davis, CA 95616, USA

ABSTRACT

We propose a simple linear regression equation to predict body mass from body length for the resident bird species in Taiwan. The data used in fitting the model were summarized from the literature. Body mass information was not obtained directly from Taiwan. We first examined the possible geographic variations in body mass using existing bird banding data collected by the Chinese Wild Bird Federation of Taiwan. The results indicate that variations between Taiwan and other geographic areas are generally small and acceptable. The overall linear regression for the body size relations based on 123 species is Log_{10}(Body mass in g) = -3.957 + 2.456 Log_{10}(Body length in mm), with a significant coefficient of determination (r^2 = 0.904). The equation was used to predict the mean and 75% prediction intervals for 30 bird species in Taiwan. The predictions for 14 species were compared with two independent data sets collected in Taiwan. Except for the Taiwan Magpie (*Urocissa caerulea*), the absolute relative errors vary from 2.4% to 50.1%, and all the known means are within the 75% prediction intervals. The collected data and prediction models are suitable for comparing large numbers of species and serving as the basis for predicting many ecological parameters at community, ecosystem, and landscape levels.

Key words: Body mass, Body length, Simple linear regression model, Taiwan

INTRODUCTION

Body size is a measure of the overall size of an organism (Clark, 1979; Piersma and Davidson, 1991), and is also one of the ultimate factors affecting physiological processes, life strategies, and behavioral and ecological functions (Peters, 1983). The information is fundamental for many aspects of avian studies. For example, measures of body size are frequently used in physiological and ecological studies as a baseline for descriptive statistics when comparing large numbers of species (Dunning, 1993). In certain community structure studies, calculating total biomass of consumers supported by local resources (e.g., Schluter and Repasky, 1991) is a common routine. Body mass also plays an important role in predicting the relationship of abundance and density (Griffiths, 1992; Blackburn and Gaston, 1997; Fa and Purvis, 1997), and species richness (Finlay *et al.*, 1996; Gregory, 1998). In ecosystem studies, body mass is essential for calculating energy transfer among trophic levels.

In avian biological studies, body size information is mostly recorded as mass (weight) or length. Body mass has been shown to be one of the more accurate and less variant measures in birds (Peters, 1983). Body mass is also more useful and desirable than body length for most physiological and ecological studies (Dunning, 1993). For this purpose, adult body mass is often regarded as the best single estimator of avian body size (Rising and Somers, 1989). Because of high metabolic rates, it is preferable to measure these data while birds are alive and in a natural condition. Compared to this requirement, body length can be easily and accurately measured in museum specimens. This explains why bird body length data are well documented, but body mass data are often difficult to locate, even for relatively common species. This situation is particularly true in Taiwan where ornithological studies are limited in numbers of researchers, manpower, and publications. To our knowledge, a comprehensive report on body masses of Taiwan's resident bird species is still lacking. Currently, body mass data are scattered in various forms, i.e., in reports and articles (e.g., Hachisuka and Udagawa, 1950; 1951), in organizations conducting banding operation (e.g., Shiu, 1996), and in museum collections. Gathering data from such diverse sources is a time-consuming and sometimes difficult task.

Recent work by Dunning (1993), who compiled body mass data of 6283 bird species primarily by searching published literature, solves part of the problem. Body mass data for over 100 resident species in Taiwan are available in Dunning (1993). However, avian studies conducted in Taiwan are seldom published in international journals, and therefore information specific to Taiwan was not collected by that report, which also means that most of the information in Dunning was derived from samples outside Taiwan. Since geographic variation in body mass is a well-known phenomenon, an immediate question of applying Dunning's data emerges: Can we use the data in Dunning (1993) to represent the species distributed in Taiwan?

Silva and Downing (1995) suggest using least-squared regressions to predict body mass from body length for many orders and family groups of mammal species in the world. These equations were derived from fitting a power function by linear regression of the logarithmically (base 10) transformed length and mass. Though they found many insignificant relationships for some family groups, they were able to obtain highly significant relationships with all coefficients of determination (r^2) greater than 0.837 for all the order groups. In general, the coefficients of determination for family groups are not necessarily greater than those in the order groups.

The purposes of this study are to evaluate the validity of applying Dunning's data in representing the resident bird species in Taiwan and to derive general equations to predict body mass data from available body length data. It is hoped that these body mass data can provide a basis for future community, ecosystem, and landscape studies in Taiwan.

MATERIALS AND METHODS

Data sources

The scope of this study is limited to the 156 resident species in Taiwan. We extracted body mass data from Dunning (1993), and body length data from Meyer de Schauensee (1984). Meyer de Schauensee (1984) did not explain where the body length measurements were taken from, but the citations of Hachisuka and Udagawa (1950; 1951) indicate that part of his data are directly from Taiwan. The data presented in Dunning (1993) are a worldwide collection. The data regarding body mass of resident species in Taiwan were mostly obtained from other geographic areas, and not directly taken from bird samples in Taiwan. A few of them were from captive individuals. We obtained avian body mass data for 126 species and body length data for 155 species. Except for the Greater Striated Swallow (*Hirundo striolata*), body length data for most of the resident species were compiled.

Data analysis

An independent data set of 34 species from the database of a bird banding study conducted by members of the Chinese Wild Bird Federation in Taiwan (Shiu, 1996) was used to evaluate geographic variations in Dunning's data. We evaluated this variation by calculating a relative error (*RE*, %) using the formula:

Where $BW_{Dunning}$ is the body mass value for a given species from Dunning (1993) and $BW_{Bird\text{-}Society}$ is the value reported by Shiu (1996). Absolute *RE* is the absolute value of *RE*.

We used least-square linear regression models to predict body mass from body length. Body lengths (mm) were estimated as mean measurable body length from bill to tail. When only range values were given, we used the arithmetic mean of minimum and maximum values to represent average body length. While body length data vary with sex, the average lengths of both sexes were used. Body mass data (gm) were also calculated by the same approach. The body mass data set used in this paper is listed in Appendix 1. The nomenclature of bird species follows Meyer de Schauensee (1984). Except for 30 species that have an abundant bird collection (Appendix 1), most of the body mass data used in this study have sample sizes smaller than 30. Due to their disproportionately long tail, the Pheasant-tailed Jacana (*Hydrophasianus chirurgus*) and the Black Paradise Flycatcher (*Terpsiphone atrocaudata*) were excluded after the first diagnosis of regression analysis.

Models were derived by fitting a linear regression of the $\log_{10}$ transformed body length (L) and body mass (W) (Log_{10} W = a + b Log_{10} L). We calculated an overall equation for all species and specific equations for every order and family group consisting of more than four species. The assumptions of the regression models were checked by using standard residual analysis in SYSTAT (SPSS, 1997).

The overall regression model (using all species) was used to predict the body masses of the 30 species which lack of body mass records in Dunning (1993). Means and 75% prediction intervals were calculated. The 75% prediction intervals are commonly used in forest inventory and wildlife population estimates. The performance of this prediction model was evaluated by calculating a similar *RE*. The item $BW_{Dunning}$ in the above equation was replaced by our predicted body mass value for a given species. Eleven species in Shiu (1996) were used for this comparison.

RESULTS

We evaluated the question of geographic variation by comparing two data sets: Dunning (1993) and Shiu (1996). Except for the Black-crowned Night Heron (*Nycticorax nycticorax*) that has a very large *RE* (86.8%), the absolute *RE*s for the other 33 species vary from 0% to 32.7% with a mean of 9.7% and median of 8.3% (Table 1). Overall, geographical variations are relatively small and acceptable. For the Black-crowned Night Heron, the maximum body mass (686 g, n = 36, from Shiu, 1996) measured in Taiwan is significantly smaller than that recorded in northeastern America and does not fall within the reported ranges (724-1014 g). Therefore, this may represent a true geographic variation, and this record was dropped in the following analyses.

The regression analyses (Table 2) indicate a positive relationship between body mass and body length for resident bird species in Taiwan. Except for the equations for the Families Columbidae (and Order Columbiformes), Paridae, and Sylviidae, all the other models have relatively high coefficients of determination, and the slopes and constants of the regression lines are significantly greater than zero. Some equations calculated from the family groups have a higher coefficient of determination than that of the overall model using all species. Because of its relatively larger sample size and broader prediction domain, we used the overall model to perform predictions.

This overall regression model has a significant coefficient of determination (r^2 = 0.904) and indicates a good fit of the data (Fig. 1A). Body mass and body length have a high correlation coefficient (r = 0.951, p < 0.0001). Residual analyses show that the regression function is linear, the error terms have a normal distribution, and the error variance is constant. The plot of residuals against predicted values (Fig. 1B) also shows that the model meets the assumptions of the linear regression.

Table 1. Body mass comparison for data reported by Dunning (1993) and those taken in Taiwan (Shiu, 1996).

Common name	Body mass (g)		Relative error (%)
	Dunning (1993)	Shiu (1996)	
Cattle Egret	338.0	264.2	27.9
Black-crowned Night Heron	883.0	472.8	**86.8**
Barred Buttonquail	58.0	59.5	-2.5
Greater Painted Snipe	121.0	149.4	-19.0
Kentish Plover	41.4	49.3	-16.0
Common Sandpiper	51.7	50.7	2.0
Little Tern	57.0	53.8	5.9
Common Kingfisher	27.0	30.9	-12.6
Barn Swallow	16.0	16.6	-3.6
Greater Striated Swallow	22.0	22.1	-0.5
Pacific Swallow	13.1	15.5	-15.5
Plain Martin	13.4	10.1	32.7
Black Drongo	49.8	55.6	-10.4
Blyth's Parrotbill	5.5	5.9	-6.8
Vinous-throated Parrotbill	10.9	9.1	19.8
Green-backed Tit	14.0	12.3	13.8
Gould's Nun Babbler	17.5	18.8	-6.9
Streak-throated Fulvetta	10.0	10.1	-1.0
Gray-cheeked Fulvetta	14.4	14.1	2.1
Streak-breasted Scimitar Babbler	32.0	37.6	-14.9
Rufous-capped Babbler	10.3	10.4	-1.0
Black Bulbul	42.9	52.8	-18.8
White-tailed Robin	27.0	24.5	10.2
White-browed Bush Robin	14.6	14.1	3.5
Zitting Cisticola	7.0	7.9	-11.4
Yellow-bellied Prinia	7.0	7.2	-2.8
Tawny-flanked Prinia	9.2	8.3	10.8
Snowy-browed Flycatcher	8.2	8.5	-3.5
White Wagtail	21.0	20.5	2.4
Japanese White Eye	10.0	9.0	11.1
Spotted Munia	13.6	12.8	6.2
White-rumped Munia	12.3	10.5	17.1
Gray-headed Bullfinch	20.0	21.8	-8.3
Eurasian Tree Sparrow	22.0	22.0	0.0

Table 2. Equations for converting avian body lengths (mm) to body masses (g) (both variables are $\log_{10}$ transformed) fitted for all, orders of, and families of resident bird species in Taiwan. Significance of *F*-test: NS $p > 0.05$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Order	Family	n	Intercept (a)	Slope (b)	r^2	*F*-test
All birds		123	-3.957	2.456	0.904	***
Ciconiiformes	Ardeidae	6	-4.642	2.673	0.939	*
Falconiformes	Accipitridae	5	-6.315	3.375	0.933	**
Galliformes	Phasianidae	6	-2.193	1.829	0.920	**
Gruiformes		8	-2.507	1.914	0.882	***
	Rallidae	6	-3.975	2.514	0.836	*
Charadriiformes		8	-1.166	1.280	0.766	**
Columbiformes	Columbidae	6			0.385	NS
Strigiformes		7	-2.816	2.064	0.943	***
	Strigidae	6	-3.165	2.215	0.932	**
Passeriformes		65	-3.324	2.136	0.870	***
	Corvidae	5	-3.770	2.343	0.774	*
	Paridae	4			0.885	NS
	Timaliidae	9	-3.258	2.117	0.923	***
	Turdidae	8	-3.388	2.186	0.880	**
	Sylviidae	6			0.007	NS
	Musciapidae	5	-4.792	2.757	0.779	*

Despite the high coefficient of determination, considerable variations exist (SSE = 4.708 and MSE = 0.039). Body masses for some species slightly deviate from the prediction line and the 95% prediction intervals (Fig. 1A). Part of this deviation is due to those species having body lengths ranging from 100 to 200 mm.

Using the overall regression model, we predict body masses for 30 resident bird species in Taiwan (Table 3). Twelve out of the 14 endemic species (86%) in Taiwan are included. The 75%

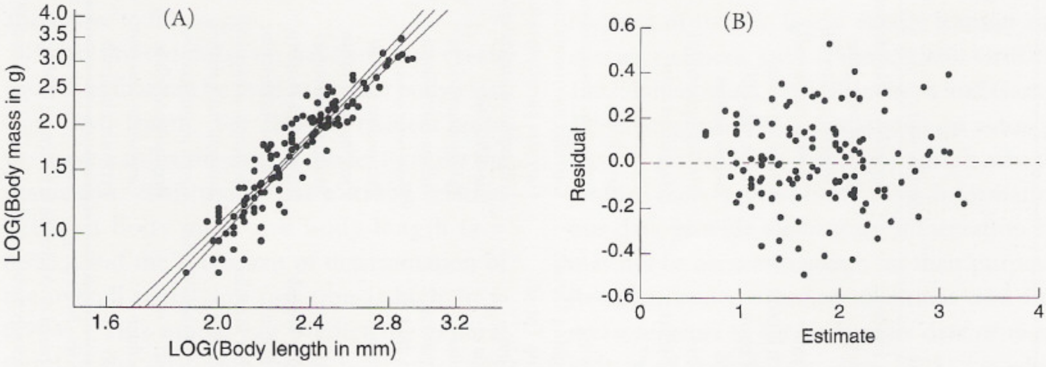

Figure 1. Relationship between body length and body mass (both were log10 transformed) for 123 breeding bird species in Taiwan; (A) scatter plot with the regression line and 95% confidence intervals, and (B) residuals against predicted values.

Table 3. Mean estimate and 75% prediction intervals of body mass for 30 resident bird species in Taiwan, including 11 endemic species.

			Data from this study			Data from banding studies			
Common name	Scientific name	Chinese name	Estimate mean (g)	Lower bound (g) of 75% prediction interval	Upper bound (g) of 75% prediction interval	Sample mean (g)	Range (g)	*n*	Relative error (%)
Malayan Night Heron	*Gorsachius melanolophus*	黑冠麻鷺	279.2	164.3	473.6				
Crested Goshawk	*Accipiter trivirgatus*	鳳頭蒼鷹	323.3	190.1	548.7				
Black Eagle	*Ictinaetus malayensis*	林鵰	1140.6	667.8	1952.8				
Ashy Wood Pigeon	*Columba pulchricollis*	灰林鴿	139.5	82.2	236.0				
Whistling Green Pigeon	*Treron formosae*	紅頭綠鳩	156.9	92.4	265.5				
White-bellied Pigeon	*Treron sieboldii*	綠鳩	169.2	99.6	286.3				
Tawny Fish Owl	*Ketupa flavipes*	黃魚鴞	760.4	446.0	1297.7				
Brown Wood Owl	*Strix leptogrammica*	褐林鴞	490.7	288.3	934.9				
Black-browed Barbet	*Megalaima oorti*	五色鳥	52.8	31.1	89.1	87.1	75.0-116.0	21	-39.4
Taiwan Magpie[+*]	*Urocissa caerulea*	台灣藍鵲	1009.7	591.5	1727.0	235.1		14	**329.5**
Yellow Tit[+]	*Parus holsti*	黃山雀	16.4	9.6	27.6				
Formosan Barwing[+]	*Actinodura morrisoniana*	紋翼畫眉	38.4	22.6	64.8	32.8	29.5-36.0	27	17.1
Formosan Laughing Thrush[+]	*Garrulax morrisonianus*	金翼白眉	85.8	50.5	144.9	77.0	65.0-90.5	43	11.4
Rufous Laughing Thrush	*Garrulax poecilorhynchus*	竹鳥	113.2	66.7	191.3	92.2		53	21.5
White-eared Sibia[+]	*Heterophasia auricularis*	白耳畫眉	70.0	41.2	118.1	48.0	39.5-57.0	89	45.7
Steere's Liocichla[+]	*Liocichla steeri*	藪鳥	38.4	22.6	64.8	31.8	24.5-40.0	215	20.8
Formosan Yuhina[+]	*Yuhina brunneiceps*	冠羽畫眉	17.3	10.2	29.2	12.3	10.5-17.0	83	40.9
White-bellied Yuhina[*]	*Yuhina zantholeuca*	綠畫眉	12.8	7.5	21.7	11.2		37	14.3
Brown-eared Bulbul	*Hypsipetes amaurotis*	棕耳鵯	113.2	66.7	191.3				
Light-vented Bulbul	*Pycnonotus sinensis*	白頭翁	43.8	25.8	74.0	29.2	23.0-34.0	146	50.1
Styan's Bulbul[+]	*Pycnonotus taivanus*	烏頭翁	46.7	27.5	78.8				
Collared Bulbul	*Spizixos semitorques*	白環鸚嘴鵯	52.8	31.1	89.1				
Taiwan Whistling Thrush[+]	*Myophonus insularis*	紫嘯鶇	113.2	66.7	191.3				
Collared Bush Robin[+]	*Erithacus johnstoniae*	栗背林鴝	14.2	8.3	24.0	14.6	12.0-17.0	50	-2.4
Rufous Flycatcher Warbler	*Abroscopus albogularis*	棕面鶯	7.0	4.1	11.9	5.8	4.5-7.0	9	21.5
Russet Bush Warbler	*Bradypterus seebahmi*	褐色叢樹鶯	20.8	12.2	35.0				
Yellowish-bellied Bush Warbler	*Cettia acanthizoides*	深山鶯	9.1	5.3	15.4	6.5	5.5-8.0	13	40.3
Taiwan Firecrest[+]	*Regulus goodfellowi*	火冠戴菊鳥	7.0	4.1	11.9				
Vinaceous Rosefinch	*Carpodacus vinaceus*	酒紅朱雀	16.4	9.6	27.6	22.7	20.0-29.5	30	-27.9
Brown Bullfinch	*Pyrrhula nipalensis*	褐鷽	31.0	18.2	52.4				

+ endemic species. According to Chang (1980) there are 16 endemic species in Taiwan, but the White-browed Shortwing (*Brachypteryx montana*) and the Island Thrush (*Turdus poliocephalus*) are dropped based on Meyer de Schauensee (1984).

[*] Body mass measurements provided by Dr. L. S. Chou, others are from Shiu (1996).

prediction intervals suggest the potential body mass ranges for the bird species. Using the data from banding studies, the prediction varied. The *RE* for the Taiwan Magpie (*Urocissa caerulea*) was exceptionally high (329%), while the absolute *RE*s for the other 11 species varied from 2.4% to 50.1%. Since the Taiwan Magpie has relatively longer tail than other species, the prediction was incorrect. Seven species have reasonable predictions with a close fit in the mean estimate (absolute $RE < 22\%$). Four species were overestimated, while two species were underestimated. However, all 13 estimated averages fall within our 75% prediction intervals.

DISCUSSION

The simple linear regression model based on the relationship between body length and body mass allows researchers to get a first clue on the possible body mass of some lesser known resident bird species in Taiwan. Ideally this relationship should be done and enhanced by adding more variables and by using multivariate analysis to perform the prediction (Dunning, 1993). However, data for such an approach are rarely available and require large sample sizes. This limitation is even worse in Taiwan where no comprehensive body size information is available in the literature, except for scattered reports in autoecological studies (e.g., Severinghaus, 1987). Given this restriction, a simple linear regression model is an alternative to fill the gap.

With limited data, we have tried to create equations that can be used to predict body mass from body length. For Taiwan's resident birds, we suggest using the overall model to make the prediction. This model has a strong relation between body mass and body length (r = 0.951), and the coefficient of determination of the overall regression function is high (r^2 = 0.904). This model can predict the general trend of the relation between body mass and body length for the resident bird species in Taiwan. However, it may not precisely predict the mean body mass value for a particular species. Due to variations caused by diverse shapes of bird species, the sum of square errors (SSE) of this regression model is also relatively large. This variability is higher for those species having body lengths ranging from 100 to 200 mm, therefore reducing the prediction accuracy and precision. Peters (1983) suggested that one of the most common charges against body size relationships is that they sacrifice precision to achieve generality, which is also true in our case.

Researchers should utilize our results with caution. The motivation of this paper is to integrate available data and make predictions by regression analysis to fill the vacancy of avian body mass information in Taiwan. Our predictions and the data extracted from Dunning (1993) are not intended to challenge the accuracy of measured data taken from Taiwan. We recommend using the data taken from Taiwan (e.g., Chou *et al.*, 1994; Shiu, 1996) in the first place if they are available, then the data taken from other geographic areas (e.g. Dunning, 1993). Our prediction here should only be employed when both kinds of information are unavailable. Moreover, the models integrated in this paper are aimed to help research at community, ecosystem, and landscape levels rather than at population or individual levels. These data are suitable for comparisons among large numbers of species and serve as the basis for predicting many ecological parameters in community or ecosystem studies (e.g., total biomass of trophic levels, energy transfer rate, species richness, etc.) (Peters, 1983; Griffiths, 1992; Finlay *et al.*, 1996; Blackburn and Gaston, 1997; Gregory, 1998). For studies on autoecology or population biology, which usually require more precise body mass information, our data provide elementary information but may not be accurate enough for their purposes. Researchers are urged to take their own field measurements to get body mass data or to use individual species (e.g., Lee, 1998) for which much data has been compiled to construct a linear regression.

Several approaches can be tried to improve the prediction accuracy. We discuss the following possibilities: adding more variables, performing prediction at lower taxonomic groups, and improving data quality. Birds are known to have various body shapes. Body length, recorded as the total length from bill to tail, is an overall, but rough and sometimes poor, measure of body shape. In our data, there is considerable variation in the proportion of tail length to total length. To improve the prediction accuracy, one can try to use the measure of body length minus tail length as the predictor of body mass. Also, performing multivariate statistics with many body measurements is another option.

Performing the prediction using more specific taxonomic groups, such as order, family, or even genus, is the other possible approach to improve precision. In general, members belonging to the same taxonomic group are more similar in morphology. However, this approach may be constrained by at least two problems. First, it requires a considerable sample size in an individual taxonomic group to build a good model. It may be possible to use data from around the world to derive these relationships. However, as Silva and Downing (1995) have shown in a mamml study, performing linear regression analysis using lower-level taxonomic groups does not guarantee a better fit of the data. Using the limited data of Taiwan, we also found similar results. We suspect similar results might occur in birds when using species compiled from all over the world. The second problem is associated with the domain limitation that each specific model can predict. Those species in specific taxonomic groups tend to have smaller body size ranges. An equation derived from such a data set can only predict those species that have body lengths falling within this domain. It is erroneous to extrapolate the data outside the domain.

Avian body mass varies according to time of day, season, and sex (Clark, 1979). Many species of birds vary in size across their geographic range (Dunning, 1993). Such variations may reduce the validity of using the data in model building. We evaluated the geographic variation issue by comparing Dunning's data with an independent data set from Taiwan. Except for one species, the results are reasonable. Despite this, our data set still needs some improvement. Three-fourths of the Taiwan resident bird data in Dunning (1993) have sample sizes of less than 30. The data from Meyer de Schauensee (1984) also need some updates. It is apparently that higher quality data are needed in the future to derive better and more accurate models.

With continuing efforts of long-term ecological research (e.g., Chou *et al.*, 1994), museum collection (C. W. Yen, pers. comm.) and bird banding studies (e.g., Shiu, 1996) in Taiwan, it is expected that more data on body mass and body size for bird species will be readily available in the near future. We expect to refine the models presented in this paper when these data become available.

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Appendix 1. Body mass data extracted from Dunning (1993) used in this study. Original data as ranges or as different sexes were arithmetically averaged.

Common name	Scientific name	Chinese name	*n*	Mean body mass (g)
Little Grebe	*Podiceps ruficollis*	小鷿	50	201.0
Brown Booby	*Sula leucogaster*	白腹鰹鳥	133	1093.0
Cattle Egret	*Bubulcus ibis*	黃頭鷺	9	338.0
Little Heron	*Butorides striatus*	綠簑鷺	34	212.0
Eastern Reef Egret	*Egretta sacra*	岩鷺	2	356.0
Chestnut Bittern	*Ixobrychus cinnamomeus*	栗小鷺	1	106.0
Yellow Bittern	*Ixobrychus sinensis*	黃小鷺	2	98.0
Black-crowned Night Heron	*Nycticorax nycticorax*	夜鷺	5	883.0
Mandarin Duck	*Aix galericulata*	鴛鴦	2	570.0
Besra Sparrowhawk	*Accipiter virgatus*	松雀鷹	13	122.0
Black Kite	*Milvus migrans*	老鷹	30	827.0
Crested Serpent Eagle	*Spilornis cheela*	大冠鷲	NA	1072.0
Mountain Hawk-Eagle	*Spizaetus nipalensis*	熊鷹	NA	3000.0
Osprey	*Pandion haliaetus*	魚鷹	24	1486.0
Formosan Hill Partridge	*Arborophila crudigularis*	深山竹雞	2	265.0
Chinese Bamboo Partridge	*Bambusicola thoracica*	竹雞	NA	270.0
Blue-breasted Quail	*Coturnix chinensis*	小鵪鶉	8	31.0
Swinhoe's Blue Pheasant	*Lophura swinhoii*	藍腹鷴	2	1100.0
Common Pheasant	*Phasianus colchicus*	環頸雉	7137	1396.0
Mikado Pheasant	*Syrmaticus mikado*	帝雉	4	1158.0
Barred Buttonquail	*Turnix suscitator*	棕三趾鶉	NA	58.0
Small Buttonquail	*Turnix sylvatica*	三趾鶉	NA	40.0
White-breasted Water-hen	*Amaurornis phoenicurus*	白腹秧雞	2	173.0
Common Moorhen	*Gallinula chloropus*	紅冠水雞	213	303.0
Ruddy-breasted Crake	*Porzana fusca*	緋秧雞	NA	60.0
Slaty-legged Crake	*Rallina eurizonoides*	灰腳秧雞	2	110.0
Water Rail	*Rallus aquaticus*	秧雞	50	120.0
Slaty-breasted Rail	*Rallus striatus*	灰胸秧雞	NA	110.0
Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	水雉	8	178.5
Greater Painted Snipe	*Rostratula benghalensis*	彩鷸	34	121.0
Kentish Plover	*Charadrius alexandrinus*	東方環頸衐	38	41.4
Common Sandpiper	*Tringa hypoleucos*	磯鷸	38	51.7
Brown Noddy	*Anous stolidus*	玄燕鷗	12	198.0
Little Tern	*Sterna albifrons*	小燕鷗	30	57.0
Roseate Tern	*Sterna dougallii*	紅燕鷗	299	110.0
Black-naped Tern	*Sterna sumatrana*	蒼燕鷗	NA	100.0
Green-winged Pigeon	*Chalcophaps indica*	翠翼鳩	14	124.0
Rock Pigeon	*Columba livia*	家鴿	78	355.0
Red Cuckoo Dove	*Macropygia phasianella*	長尾鳩	7	180.0
Spotted Dove	*Streptopelia chinensis*	斑頸鳩	343	159.0

Oriental Turtle Dove	*Streptopelia orientalis*	金背鳩	14	215.0
Red Turtle Dove	*Streptopelia tranquebarica*	紅鳩	1	104.0
Lesser Coucal	*Centropus bengalensis*	番鵑	5	120.0
Grass Owl	*Tyto capensis*	草鴞	8	419.0
Collared Owlet	*Glaucidium brodiei*	鵂鶹	3	58.0
Brown Hawk Owl	*Ninox scutulata*	褐鷹鴞	3	195.0
Collared Scops Owl	*Otus bakkamoena*	領角鴞	14	132.0
Common Scops Owl	*Otus scops*	角鴞	169	92.0
Mountain Scops Owl	*Otus spilocephalus*	黃嘴角鴞	16	67.5
Tawny Owl	*Strix aluco*	灰林鴞	18	475.0
Savanna Nightjar	*Caprimulgus affinis*	夜鷹	2	75.0
House Swift	*Apus affinis*	小雨燕	14	24.3
Fork-tail Swift	*Apus pacificus*	白腰雨燕	9	45.0
White-throated Needletail	*Hirundapus caudacutus*	針尾雨燕	16	120.0
Common Kingfisher	*Alcedo atthis*	翠鳥	15	27.0
Gray-capped Woodpecker	*Picoides canicapillus*	小啄木	3	23.3
White-backed Woodpecker	*Picoides leucotos*	大赤啄木	16	108.0
Gray-headed Woodpecker	*Picus canus*	綠啄木	28	137.0
Oriental Skylark	*Alauda gulgula*	小雲雀	17	26.3
House Martin	*Delichon urbica*	毛腳燕	252	14.5
Barn Swallow	*Hirundo rustica*	家燕	2331	16.0
Greater Striated Swallow	*Hirundo striolata*	赤腰燕	1	22.0
Pacific Swallow	*Hirundo tahitica*	洋燕	NA	13.1
Plain Martin	*Riparia paludicola*	棕沙燕	61	13.4
Large Cuckoo-shrike	*Coracina novaehollandiae*	花翅山椒	8	93.3
Gray-chinned Minivet	*Pericrocotus solaris*	紅山椒	4	14.0
Bronzed Drongo	*Dicrurus aeneus*	小卷尾	7	27.0
Black Drongo	*Dicrurus macrocercus*	大卷尾	3	49.8
Black-naped Oriole	*Oriolus chinensis*	黃鸝	5	82.0
Maroon Oriole	*Oriolus traillii*	朱鸝	10	74.0
Large-billed Crow	*Corvus macrorhynchos*	巨嘴鴉	28	518.0
Gray Treepie	*Dendrocitta formosae*	樹鵲	59	104.0
Eurasian Jay	*Garrulus glandarius*	松鴉	50	161.0
Eurasian Nutcracker	*Nucifraga caryocatactes*	星鴉	68	173.0
Eurasian Magpie	*Pica pica*	喜鵲	120	178.0
Blyth's Parrotbill	*Paradoxornis nipalensis*	黃羽鸚嘴	NA	5.5
Vinous-throated Parrotbill	*Paradoxornis webbianus*	粉紅鸚嘴	73	10.9
Black-throated Tit	*Aegithalos concinnus*	紅頭山雀	29	6.1
Coal Tit	*Parus ater*	煤山雀	50	9.1
Green-backed Tit	*Parus monticolus*	青背山雀	38	14.0
Varied Tit	*Parus varius*	赤腹山雀	11	17.0
Eurasian Nuthatch	*Sitta europaea*	茶腹	30	22.0
Gould's Fulvetta	*Alcippe brunnea*	頭烏線	NA	17.5
Streak-throated Fulvetta	*Alcippe cinereiceps*	灰頭花翼	2	10.0

Gray-cheeked Fulvetta	*Alcippe morrisonia*	繡眼畫眉	37	14.4
White-throated Laughing Thrush	*Garrulax albogularis*	白喉笑鶇	24	99.0
Formosan Barwing	*Garrulax canorus*	畫眉	NA	55.0
Pygmy Wren Babbler	*Pnoepyga pusilla*	鱗胸鷦鷯	8	12.0
Rusty-cheeked Scimitar Babbler	*Pomatorhinus erythrogenys*	大彎嘴	11	63.0
Streak-breasted Scimitar Babbler	*Pomatorhinus ruficollis*	小彎嘴	13	32.0
Rufous-capped Babbler	*Stachyris ruficeps*	山紅頭	19	10.3
Black Bulbul	*Hypsipetes madagascariensis*	紅嘴黑鵯	25	42.9
Brown Dipper	*Cinclus pallasii*	河烏	11	76.0
Northern Wren	*Troglodytes troglodytes*	鷦鷯	54	8.9
White-browed Shortwing	*Brachypteryx montana*	小翼鶇	4	21.6
Little Forktail	*Enicurus scouleri*	小剪尾	5	16.0
Blue Rock Thrush	*Monticola solitarius*	藍磯鶇	NA	50.5
White-tailed Robin	*Cinclidium leucurum*	白尾鴝	6	27.0
Plumbeous Redstart	*Rhyacornis fuliginosus*	鉛色水鶇	13	17.0
White-browed Bush Robin	*Erithacus indicus*	白眉林鴝	6	14.6
Scaly Thrush	*Zoothera dauma*	虎鶇	9	104.0
Island Thrush	*Turdus poliocephalus*	白頭鶇	38	61.7
Brown-flanked Bush Warbler	*Cettia fortipes*	小鶯	13	10.0
Bright-capped Cisticola	*Cisticola exilis*	白頭錦鴝	12	7.1
Zitting Cisticola	*Cisticola juncidis*	錦鴝	17	7.0
Striated Prinia	*Prinia criniger*	斑紋鷦鶯	3	15.1
Yellow-bellied Prinia	*Prinia flaviventris*	灰頭鷦鶯	1	7.0
Tawny-flanked Prinia	*Prinia subflava*	褐頭鷦鶯	11	9.2
Snowy-browed Flycatcher	*Ficedula hyperythra*	黃胸青鶲	19	8.2
Black-naped Blue Monarch	*Monarcha azurea*	黑枕藍鶲	21	11.1
Ferruginous Flycatcher	*Muscicapa ferruginea*	紅尾鶲	1	12.0
Vivid Flycatcher	*Niltava vivida*	黃腹琉璃	3	33.0
Japanese Paradise Flycatcher	*Terpsiphone atrocaudata*	綬帶鳥	2	18.7
Alpine Accentor	*Prunella collaris*	岩鷚	33	44.0
White Wagtail	*Motacilla alba*	白鶺鴒	93	21.0
Long-tailed Shrike	*Lanius schach*	棕背伯勞	26	38.4
Tufted Myna	*Acridotheres cristatellus*	八哥	3	113.0
Plain Flowerpecker	*Dicaeum concolor*	綠啄花鳥	15	6.2
Scarlet-breasted Flowerpecker	*Dicaeum ignipectus*	紅胸啄花鳥	21	6.0
Japanese White Eye	*Zosterops japonicus*	綠繡眼	NA	10.0
Black-headed Munia	*Lonchura malacca*	黑頭文鳥	28	12.6
Spotted Munia	*Lonchura punctulata*	斑文鳥	13	13.6
White-rumped Munia	*Lonchura striata*	白腰文鳥	11	12.3
Gray-headed Bullfinch	*Pyrrhula erythaca*	灰鷽	1	20.0
Eurasian Tree Sparrow	*Passer montanus*	麻雀	136	22.0
Russet Sparrow	*Passer rutilans*	山麻雀	NA	18.0

台灣地區留鳥之體長與體重關係

李培芬[1]、丁宗蘇[2]、許皓捷[1]

[1]國立台灣大學動物學系
[2]加州大學農藝及牧場學系

摘 要

本文探討台灣地區留鳥之體長（L）和體重（W）關係。由研究文獻中得到鳥類之體長和體重資訊，利用直線迴歸模式建立其預測方程式。由於絕大多數的鳥類體重資料，並非源自台灣，本研究先以相對誤差值，比較資料之地理變異，結果顯示此變異不大。所得之簡單直線迴歸迴歸式為$Log_{10} W = -3.957 + 2.456 \log_{10} L$，此式之決定係數為0.904。利用此方程式，預測台灣地區30種鳥類的體重，得各鳥種之預測平均值與75%上、下預測區間值。利用14種由鳥類繫放所得之體重資料，進行比較，顯示預測值與驗證值之間有些差異，除了台灣藍鵲之預測差距大外，其餘鳥種之相對誤差在2.4%與50.1%之間，但驗證值均落於75%預測區間內。本研究的預測模式與資料，較適合於鳥類群聚生態、生態系和景觀生態之研究範疇，可作為預測其他生態研究之參數值和比較各種鳥類之生態特色。

關鍵詞：體長、體重、直線迴歸、台灣