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Analysis of biometric data to determine the sex of Woodpigeons *Columba palumbus*

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Sexual dimorphism is slight in Woodpigeons *Columba palumbus*. Although it is generally believed that males are somewhat larger than females, there is considerable overlap between the sexes. Recent studies have highlighted the use of discriminant function analysis in determining the sex of sexually monomorphic birds such as seabirds. This study examines whether discriminant analyses can be used to determine the sex of Woodpigeons. Analysis of 298 adult Woodpigeons showed significant differences in some morphological features of male and female birds. The measurement of the variables tail and tibio-tarsus demonstrated that 66% of the entire data set could be accurately sexed. When results were examined on a seasonal basis, spring results (using wing and tibio-tarsus) were most accurate, correctly sexing 90% of females and 86% of males. Winter samples, using weight and tail measurements, were the least accurate, correctly identifying 57% of females and 65% of males.

The Common Wood Pigeon *Columba palumbus* (Woodpigeon) is the largest member of the six breeding species of the order Columbiformes found in Europe. Woodpigeons constitute the largest biomass of any bird found in Ireland and Great Britain (Slater 1997), yet despite their abundance little is known about differences in morphology and external features between male and female birds. Witherby *et al* (1940) did give the measurements for a number of morphological features of the Woodpigeon, but the results were based on only 12 birds and therefore do not give a true reflection of the variation which can occur. Murton (1965) analysed summer and winter birds, but did not give results for spring and autumn. Neither publication gave details as to how best to determine the sex of Woodpigeons without internal examination.

Distinguishing the sex of an animal can greatly enhance the interpretation of behaviour and ecological data (Boersma & Davies 1987, Fletcher & Hamer 2003). However, sexing of birds which display little difference in plumage and size can present problems; this is further confounded if there is considerable overlap between male and female measurements.

It is apparent that sexual dimorphism is slight in Woodpigeons: most casual observers of the bird would be unable to tell the sexes apart by observation alone. Furthermore, empirical evidence is lacking in relation to the seasonal changes in morphological measurements of male and female Woodpigeons, and which external measurements are most useful in determining the sex of a bird.

The aim of this study was to investigate whether discriminant analysis of biometrics can be used to distinguish between the sexes, and if so, what season and what measurable variables give the most accurate results. Discriminant functions determine the most useful set of measurements, their relative contributions to the resulting discriminant score (calculated for each individual) and a critical value that separates males and females in the sample (Weidinger & van Franeker 1998). Discriminant analysis has been used extensively in determining the sex of seabirds, particularly gull and tern species (Hanners & Patton 1985, Evans *et al* 1993, Torlaschi *et al* 2000, Ackerman *et al* 2008). Very little evidence exists in relation to its use for Woodpigeons.

It is hoped that the use of single measurements or the combination of a number of measurements, incorporated into a discriminant function, may prove to be a simple and effective method to determine the sex of Woodpigeons in the wild.

MATERIAL AND METHODS

Data collection

A total of 298 adult Woodpigeons (154 males and 144 females) shot between 2000 and 2002 were examined during the course of the study. All specimens studied were shot by local shooters, as either quarry or agricultural pests, depending on the time of year. Generally, birds shot in autumn and winter were shot as quarry, whilst those shot in spring and summer were killed as agricultural pests.

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Birds were considered to be adults if they possessed the characteristic white neck markings found only on adult birds. All birds were shot in Ireland, in the northeast Leinster region, and were individually wrapped in plastic bags and transferred to freezers for storage, generally within 3–4 hours of being shot.

Birds were stored in freezers until dissection, whereupon they were allowed to thaw at room temperature. All birds were weighed and measured within 2–3 months of being shot. Sexing was undertaken by examination of gonads after dissection. All years were pooled together, following the example of Chardine & Morris (1989). When seasonal comparisons were undertaken, the monthly breakdown was as follows, spring (Feb–Apr), summer (May–Jun), autumn (Aug–Oct) and winter (Nov–Jan).

Biometric methods

Five morphological features of the Woodpigeon were examined, all of which can play a role in determining the sex of the bird. The five parameters selected were the same as those chosen by Murton (1965). All measurements were taken by DÓhU in keeping with the procedure recommended by Barrett *et al* (1989).

1. Gross weight – The gross weight of the bird consisted of the overall weight of the dead bird to the nearest gram.
2. Wing – Svensson's flattened wing method. This measures the length of the closed wing from the foremost extremity of the carpus to the tip of the longest primary remex using a 300mm wing rule (Visser 1976). All samples were dried with paper towels to remove surface water and measured to the nearest mm.
3. Tail – from the base of the tail to the tips of the feathers (flattened and dry, as above, accurate to 1 mm).
4. Culmen – The upper mandible was measured from the base of the feathers to the tip of the maxilla using callipers. Measurements were accurate to the nearest 0.1 mm.
5. Tibio-tarsus – the tibio-tarsus was measured from the patella to the lateral condyle using callipers. Measurements were accurate to 0.1 mm.

Statistical analysis

Sexual size dimorphism (SSD) was calculated by calculating the absolute value of the difference between mean values for males and females, and dividing this figure by the mean value for males. Prior to calculation of discriminant scores, Proc Stepdisc (in SAS software) was used to determine which variables were suitably significant to be included in the discriminant score. This stepwise procedure includes the variable contributing the most discriminatory power, or removes the variable contributing the least power, to the model. A significance level of 0.15 was set, at which no more variables could be added or removed. This procedure was undertaken for the data set as an entire sample, and also for each season individually.

Discriminant scores were calculated using Proc Discrim (SAS software). This resulted in a discriminant score for males (D_{male}) and females (D_{female}) being calculated. We classified Woodpigeon sex as being male if $D_{male} - D_{female}$ was > 0. Similarly we classified birds as female if $D_{male} - D_{female}$ was < 0.

A randomly shot Woodpigeon was considered equally likely to be male or female; therefore a prior probability of 50% was selected (priors equal).

RESULTS

The results for mean weight, wing, tail, tibio-tarsus and culmen, for male and female Woodpigeons, are presented in Table 1. As is evident from this table, different variables were significantly different between the sexes at various times of the year: *ie* males had significantly longer wings than females in autumn and winter, but there was no significant difference in spring and summer. As a result of variation in the significant values, separate discriminant scores were calculated for each season (Table 2).

Discriminant analysis (calculated from Table 2) showed that, of birds collected at random without information as to what season they were collected, 66% could be correctly classified to sex by the biometric parameters tail and tibio-tarsus. Sixty-four percent of males and 67% of females were correctly classified. However, as there were large variations in Woodpigeon morphology throughout the year, *eg* males were significantly heavier in winter than they were in spring, results were more accurate when they were analysed on a seasonal basis.

In spring-shot samples, 88% of birds were correctly identified to sex, using wing and tibio-tarsus measurements. Ninety percent of females and 86% of males were correctly identified. Spring gave the greatest accuracy of all seasons.

Seventy percent of birds collected in summer were correctly identified to sex, using weight and tail measurements. Seventy percent of females and 70% of males were correctly identified.

Of the birds collected in autumn, 73% were correctly identified to sex, using tail and tibio-tarsus measurements. Seventy-one percent of females and 75% of males were correctly identified.

Winter samples revealed that 61% of birds were correctly identified to sex, using weight and tail measurements. Fifty-seven percent of females and 65% of males were correctly identified.

As can be seen from the results, biometric analysis was most accurate in identifying sexes in the spring, summer

Table 1. Morphological measurements (mean ± standard deviation) and sexual size dimorphism (SSD) of Irish Woodpigeons

	Female	Male	*P*		SSD (%)
Total					
Mass (g)	523.16 ± 44.56	534.15 ± 54.81	0.060	ns	2.06
Wing (mm)	248.25 ± 6.50	250.93 ± 7.2	<0.001	***	1.07
Tail (mm)	160.81 ± 5.23	164.04 ± 6.64	<0.0001	***	1.97
Tibio-tarsus (mm)	34.2 ± 0.71	34.5 ± 0.78	<0.001	***	0.87
Culmen (mm)	21.6 ± 0.67	21.7 ± 0.69	0.206	ns	0.46
Spring					
Mass (g)	547.50 ± 32.88	563.32 ± 33.69	0.264	ns	2.81
Wing (mm)	247.00 ± 7.57	246.38 ± 7.39	0.843	ns	0.25
Tail (mm)	159.50 ± 5.32	158.62 ± 8.90	0.783	ns	0.55
Tibio-tarsus (mm)	34.0 ± 0.45	34.7 ± 0.58	0.004	**	2.02
Culmen (mm)	21.8 ± 0.40	21.9 ± 0.58	0.643	ns	0.46
Summer					
Mass (g)	514.37 ± 37.74	510.80 ± 36.81	0.659	ns	0.70
Wing (mm)	249.49 ± 6.30	251.89 ± 6.30	0.081	ns	0.95
Tail (mm)	161.58 ± 4.49	164.57 ± 4.89	0.004	**	1.82
Tibio-tarsus (mm)	34.2 ± 0.79	34.6 ± 0.62	0.012	*	1.16
Culmen (mm)	21.6 ± 0.73	21.9 ± 0.75	0.063	ns	1.37
Autumn					
Mass (g)	506.24 ± 43.55	509.48 ± 39.16	0.716	ns	0.64
Wing (mm)	248.78 ± 6.98	251.69 ± 6.44	0.047	*	1.16
Tail (mm)	160.40 ± 4.60	161.47 ± 5.69	0.352	ns	0.66
Tibio-tarsus (mm)	34.0 ± 0.64	34.3 ± 0.66	0.037	*	0.87
Culmen (mm)	21.2 ± 0.57	21.4 ± 0.64	0.136	ns	0.93
Winter					
Mass (g)	540.48 ± 47.17	568.24 ± 62.43	0.015	*	4.89
Wing (mm)	246.77 ± 5.94	250.71 ± 8.19	0.008	**	1.57
Tail (mm)	160.57 ± 6.31	164.31 ± 7.43	0.009	**	2.28
Tibio-tarsus (mm)	34.2 ± 0.71	34.5 ± 0.98	0.088	ns	0.87
Culmen (mm)	21.7 ± 0.66	21.7 ± 0.67	1	ns	0.00

and autumn. In each of these seasons over 70% of birds were correctly classified by the selected variables, reaching a peak in spring when 88% of birds were correctly sexed. Woodpigeons sampled in winter showed a larger variation in body measurements, and the accuracy of predicting the sex by biometrics alone was correspondingly reduced.

DISCUSSION

Determining the sex of a species is an important requirement for many ecological studies. Establishing the sex of a bird is difficult in species that display little sexual dimorphism. Whereas the sex of bird species such as gulls and terns, which lack sexual dimorphism, can often be identified by behavioural observations (Fletcher & Hamer 2003), this is more difficult with Woodpigeons. During the breeding season, when behavioural differences between the sexes should be at their most apparent, they are relatively slight in Woodpigeons. Both males and females display submissive and aggressive postures within the territory. Both sexes defend the territory (Murton 1965) and both sexes brood the eggs and the young (Colquhoun 1951, Ó hUallacháin 2004). Therefore, depending on behavioural observations alone is not sufficient to determine the sex of Woodpigeons. DNA-based techniques may be used to determine the sex of a species; however, these methods require blood samples to be taken and subsequent laboratory analysis, and as a result can be costly.

Discriminant function analysis has proven to be useful in identifying the sex of some tern and gull species (Hanners & Patton 1985, Evans *et al* 1993, Torlaschi *et al* 2000, Ackerman *et al* 2008). As has been stated previously, no comparable study has been undertaken with regards to other Columbiformes. The results from the present study

Table 2. Yearly and seasonal discriminant scores ($D_{male\text{-}female}$) for Woodpigeons.

Yearly	(0.08483).Tail + (0.46196).Tibio-tarsus - 29
Spring	(-0.22112).Wing + (4.6).Tibio-tarsus - 106
Summer	(-0.01375).Weight + (0.01474) Tail + (0.95586).Tibio-tarsus -49
Autumn	(0.15681).Tail + (0.52954).Tibio-tarsus - 44
Winter	(0.0078) Weight + (0.07139) Tail - 15.9228

Woodpigeons are male if D > 0 and female if D ≤ 0 ($P < 0.05$).

suggest that discriminant analysis could prove useful in determining the sex of Woodpigeons. The study highlights the fact that there is considerable overlap in the external measurements of male and female Woodpigeons. However, despite this overlap, the results indicate that in spring, summer and autumn, over 70% of birds collected were correctly sexed, reaching a peak in spring where the sex of 88% of birds was correctly identified.

A possible explanation for the greatest accuracy occurring in spring is related to the breeding season. Over 90% of the birds sampled in spring were not in breeding condition. Therefore they were not involved in sexual displays, egg laying nor collecting food for their young, all of which are activities which can influence the biometrics of the birds. In general there was very little variability in the activities of the birds at this time of the year, with most of the time being dedicated to feeding or roosting.

The majority of birds in summer and autumn were in breeding condition. Therefore they were involved in activities such as territorial and sexual displays, brooding of young or collecting food for young. All of these activities can impact on variables such as weight, wing and tail length. For example females must increase in body size and improve condition to be capable of laying viable eggs (Murton *et al* 1974). Therefore a female at the egg-laying stage may be heavier than a female involved in courtship displays. Similarly, birds brooding eggs and young will dedicate less time to feeding and may therefore be lighter than those involved in territorial displays.

Results for winter were the least accurate. This is due to the large variability in the biometrics of winter birds. For example the heaviest Woodpigeon in winter was 65% heavier than the lightest bird. A possible explanation for this is that most winter birds were shot as they were coming in to roost. Therefore the weight of the bird was greatly affected by the amount of food in the crop: some birds had very little, accounting for less than 1% of the overall weight, whereas other birds had a large amount of food in their crops accounting for almost 17% of the overall weight (Ó hUallacháin 2004).

The results from this paper indicate that the use of discriminant function analysis to determine the sex of Woodpigeons is not as accurate as when used in similar studies to determine the sex of gull and tern species (Chardine & Morris 1989, Fletcher & Hamer 2003, Weidinger & van Franeker 1998, Ackerman *et al* 2008). However, it is possible that if additional variables such as head-plus-bill length or bill-depth were measured in Woodpigeons, the accuracy of discriminant scores could be higher than those found in this study.

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REFERENCES

Ackerman, J.T., Takekawa, J.Y., Bluso, J.D., Yee, J.L. & Eagles–Smith, C.A. (2008) Gender identification of Caspian Terns using external morphology and discriminant function analysis. *The Wilson Journal of Ornithology* **120**, 378–383.

Barrett, R.T., Peterz, M., Furness, R.W. & Durinck, J. (1989) The variability of biometric measurements. *Ringing & Migration* **10**, 13–16.

Boersma, P.D. & Davies, E.M. (1987) Sexing monomorphic birds by vent measurements. *Auk* **104**, 779–783.

Chardine, J.W. & Morris, R.D. (1989) Sexual size dimorphism and assortative mating in the Brown Noddy. *Condor* **91**, 868–874.

Colquhoun, M.K. (1951) *The Woodpigeon in Britain*. HMSO, London.

Evans, D.R., Hoopes, E.M. & Griffin, C.R. (1993) Discriminating the sex of laughing gulls by linear measurements. *Journal of Field Ornithology* **64**, 472–476.

Fletcher, K.L. & Hamer, K.C. (2003) Sexing terns using biometrics: the advantage of within-pair comparisons. *Bird Study* **50**, 78–83.

Hanners, L.A. & Patton, S.R. (1985) Sexing Laughing Gulls using external measurements and discriminant analysis. *Journal of Field Ornithology* **56**, 158–164.

Murton, R.K. (1965) *The Woodpigeon*. Collins, London.

Murton, R.K., Westwood, N.J. & Isaacson, A.J. (1974) Factors affecting egg-weight, body-weight and moult of the Woodpigeon *Columba palumbus*. *Ibis* **116**, 52–73.

Ó hUallacháin, D. (2004) *The biology and ecology of the Woodpigeon* Columba palumbus *in Ireland*. PhD thesis, NUI, Galway.

Slater, P. (1997) *Differences in the breeding ecology of a parkland (suburban) and farmland (semi-rural) population of Woodpigeons* Columba palumbus. Thesis. Liverpool Hope University College.

Torlaschi, C., Gandini, E., Frere, E. & Peck, R.M. (2000) Predicting the sex of Kelp Gulls by external measurements. *Waterbirds* **23**, 518–520.

Visser, J. (1976) An evaluation of factors affecting wing length and its variability in the coot *Fulica atra*. *Ardea* **64**, 1–21.

Weidinger, K. & van Franeker, J.A. (1998) Applicability of external measurements to sexing of the Cape petrel *Daption capense* at within-pair, within-population and between-population scales. *Journal of Zoology* **245**, 473–482.

Witherby, H.F., Jourdain, F.C.R., Ticehurst, N.F. & Tucker, B.W. (1940) *The handbook of British birds.* Volume 4. H.F. & G.Witherby, London.

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