Age Determination of Pheasants (*Phasianus Colchicus*) using Discriminant Analysis

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Most gallinaceous birds can be identified as juveniles or adults using the outermost primaries (P9 and P10) which are retained until after the first breeding season and are often identifiable by colour and wear. The pheasant *Phasianus colchicus*, however, moults all ten primary feathers during its post-juvenile moult so alternative techniques are required. To date the method most widely used on live birds is measurement of the shaft diameter of the proximal primary feather, P1, which is replaced first before the bird is fully-grown. Using a known-age sample of 752 free-living pheasants, this study presents a discriminant function analysis using proximal primary feather measurements and other morphological characteristics to achieve a greater level of accuracy of ageing. Ageing accuracy was high, especially for males, at over 95%. The model was less accurate for females, with 83% and 94% respectively for the two year groups. When our model was applied to an independent data set of unknown-age birds 85% were classified. Less than 3% could not be aged accurately and the remainder were unclassified due to missing measurements. Our model offers a reliable method of ageing pheasants, both live and dead, however researchers are cautioned to potential year, origin (stock) and site effects.

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Introduction

The ability to age pheasants is valuable in population dynamics studies because age affects many biological parameters, including survival probability, breeding status and reproductive success (Brittas et al. 1992, Woodburn 1999). It can also be useful to know the age structure of pheasant populations in field experiments so that the effect of age can be taken into account. In general ageing techniques classify birds into 2 groups rather than into specific year classes (Wishart 1969, Sayler 1995, Newton 1998). Pheasants are generally classed as juvenile if they are <1 year old (birds entering their first spring), and adults thereafter.

For many gamebirds plumage characteristics provide the most reliable means of separating juveniles from adults. In most species primary flight feathers are moulted sequentially, starting with the proximal (innermost) feather, and progressing distally in a fairly regular time pattern. Typically primaries P9 and P10 are retained until after the first breeding season, providing a means of ageing. In juveniles they may be more worn, duller in colour or shaped differently compared to adults (Dimmick and Pelton 1994).

Pheasants differ in that they moult all 10 primaries during their post-juvenile moult rather than retaining P9 and P10 (Petrides 1942), which makes ageing by feathers alone more difficult. Game biologists have tried several techniques for ageing pheasants, with varying degrees of accuracy. Some of these are:

- Bone histology involves examining the layered appearance of very thin sections of bone from pheasant legs. It is a successful technique for ageing males, but because of resorption of

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bone to supply calcium for egg shells it is unreliable for females (Stone and Morris 1981). Another disadvantage is that it can only be applied to dead birds.

- A jaw test is sometimes used by hunters in the field (Linduska 1943). The force required to break the lower jaw is less in juveniles because of the incomplete calcification of their bones. This method is not accurate enough on its own (Nelson 1948), and cannot be used on live birds.

- Eye lens weight has been used with reasonable success in some bird species (Payne 1961, Campbell and Tomlinson 1962), but has not been found to be useful for pheasants since it can only separate adults and juveniles reliably in autumn (Dahlgren et al. 1965) and can be used only on dead birds.

- The Bursa of Fabricius is a small sac-like cavity opening into the cloaca of birds. In juvenile pheasants the bursa is evident and usually between 15-40 mm deep, but is very shallow or completely closed in adults (Linduska 1943, Kirkpatrick 1944). The depth of the bursal cavity provides a good indicator of age during autumn and early winter, but after January it begins to regress in juveniles making this method less reliable. Although this test is easier to perform on dead birds it can be used on live birds as well, but it may be quite stressful.

- Ageing by measuring spur length is applicable only to males. It is fairly reliable until December, because after December worn-down spurs of older males and the growing spurs of young males can overlap in length making age determination based on spur length alone unreliable (Linduska 1943, Stokes 1957, Gates 1966).

- Primary shaft diameter involves measuring the diameter of the shaft of the proximal (innermost) primary; the first primary shed during the post-juvenile moult. Because it is replaced before the bird is fully grown and retained until moulting the following year (Westerskov 1957), the proximal primary of a fully-grown juvenile is likely to be smaller than that of an adult (Wishart 1969). Using this method, Greenberg et al. (1972) found that the separation between the two age classes was 98% reliable in males and 92% reliable in females, while Robertson (1985) found 100% and 83% respectively. The method can be applied to both live and dead birds and used throughout the year, but requires calibration for each pheasant population examined.

In this study we applied discriminant function analysis to age a sample of pheasants. This technique has been widely used in biological studies of many species to differentiate between groups. In insect systematics it has been used for groups of closely-related species that are morphologically very similar (Barker 1998) and where environmental variation within species may mask between-species differences (Blackman 1992). It has also been valuable in sexing birds, which are sexually monomorphic in plumage (Kavanagh 1988, Green and Theobald 1989, Clark et al. 1991).

The objective of this investigation was to determine whether discriminant function analysis using a combination of morphological parameters together with proximal primary feather measurements from known-age tagged pheasants could be used to age untagged birds from the same population more accurately than just using feather data alone.

Study Area

The study was carried out on an area of predominantly arable farmland in Dorset, southern England (Grid Reference SU 0119). It covers an area of 400 hectares, with 10% of the area being broadleaved woodland and 3% permanent grassland. Hand-reared pheasants (reared intensively in pens) were released on the study area each year to supplement the population for shooting during the winter. All birds were tagged with individually numbered patagial wing-tags at the time of release in late summer. A proportion of the spring breeding population successfully reproduced in the wild each year, as determined by annual brood counts after harvest, so the resident pheasant population was a mixture of hand-reared birds and parent-reared offspring of previously hand-reared birds.

Methods

Data were collected from pheasants during February and March between 1988 and 1995, when a proportion of the birds were caught in walk-in funnel catchers (Woodburn 1999). Several body measurements were recorded from each bird including body weight, tarsus length, head length and spur length in males. A proximal primary feather (innermost) was removed and if the bird had not been previously released (and therefore tagged) then it was also tagged with an individually numbered patagial wing-tag.

The proximal primary feathers collected in spring were placed in a drying oven at 50° C for 24 hours before being measured (within 8 hours of drying). This helped to reduce variation in the measurements due to relative humidity (Greenberg et al. 1972). The shaft diameter was measured at the level of the cuticle tissue scar near the base of the barbs in the same plane as the vane (Wishart 1969). Measurements were taken to the nearest 0.02 mm by sliding the feather into a tapering aperture varying from 1.5 mm to 4.5 mm, as described by Robertson (1985). Feather lengths were also measured to the nearest 0.1 mm when the feather was flattened and straightened.

Using measurements of body weight, tarsus length, head length, spur length, ratios of body weight to tarsus length and head length and proximal primary feather diameters and lengths, statistical comparisons of means of groups of known-age individuals were made based on the student's t-test. Subsequently, these data were used in a discriminant function analysis (Sokal and Rohlf 1981, Green 1982). A discriminant function analysis seeks the single linear combination of all or some of the measured variables that best discriminates between groups. The function can assign a probability of an individual being in each group (Green and Theobald 1989). Unknown individuals can then be assigned to previously defined groups.

A series of multivariate discriminant function analyses were determined using SYSTAT (Wilkinson 1990). Feather variables and all morphological variables were examined and reduced through a forward stepwise procedure to achieve the smallest subset of predictors that correctly classified the maximum number of individuals.

We used 988 pheasants in the analysis. Of these 752 were of known age and 236 were of unknown age. Data were analysed as two separate groups for both sexes because in 1988-1990 neither head length nor spur length in males were measured. The birds were split into 2 groups based on the year they were caught: -

Group 1 - pheasants caught in 1988-1990

Group 2 - pheasants caught in 1991-1995

Before doing this analysis data from the known-age birds was randomly split such that two-thirds (503 birds) were assigned to a predict group and one-third (249 birds) to a test group. The predict group was used to compute the discriminant function and the test group was used to cross-validate the function using a separate group of known-age birds.

Since the data were collected over a number of different years and to account for any year effect, the forward stepwise procedure was initially run without the year variable. Once the predictor variables were determined the stepwise was then re-run adding in the year variable. This enabled us to assess whether adding year made a significant improvement to the prediction accuracy of the model, and to determine the change in prediction accuracy.

Results

Morphological characteristics

We assessed the normality of the independent variables, grouped by sex and age. All were normally distributed except body weight in juveniles.

Table 1: Comparison of morphological variables and feather measurements for male and females adult and juvenile pheasants collected during spring 1988-1995, Dorset, southern England. The last column shows the success rate of prediction accuracy of age from a discriminant function analysis upon each individual variable alone.

	Adults		Juveniles			
	n	Mean ± SD	n	Mean ± SD	P^a	Level of prediction accuracy
Males						
Body weight	46	1581.63 ± 102.43	254	1459.65 ± 123.48	***	70%
Tarsus length	49	72.5 ± 2.36	256	71.7 ± 2.85	n.s.	56%
Head length	42	77.28 ± 2.59	169	75.79 ± 2.33	***	62%
Primary shaft diameter	46	3.62 ± 0.16	240	3.21 ± 0.19	***	87%
Primary shaft length	46	17.91 ± 0.57	197	16.48 ± 0.66	***	88%
Maximum spur length	41	23.53 ± 1.99	168	20.25 ± 1.76	***	82%
Ratio of body weight to tarsus length	46	21.86 ±1.30	252	20.37 ± 1.52	***	70%
Ratio of body weight to head length	39	20.78 ± 1.34	167	19.27 ± 1.55	***	69%
Females						
Body weight	85	1198.06 ± 99.68	331	1137.36 ± 106.14	***	62%
Tarsus length	87	63.94 ± 2.72	333	63.34 ± 2.7	n.s.	55%
Head length	73	68.56 ± 1.92	306	67.92 ± 2.3	*	58%
Primary shaft diameter	80	3.33 ± 0.17	315	2.86 ± 0.19	***	89%
Primary shaft length	80	16.23 ± 0.59	265	14.89 ± 0.61	***	87%
Ratio of body weight to tarsus length	84	18.77 ± 1.47	330	17.96 ± 1.62	***	60%
Ratio of body weight to head length	71	17.56 ± 1.39	305	16.74 ± 1.44	***	63%

[a] Student's t-test ($* = P < 0.05, *** = P < 0.001$).

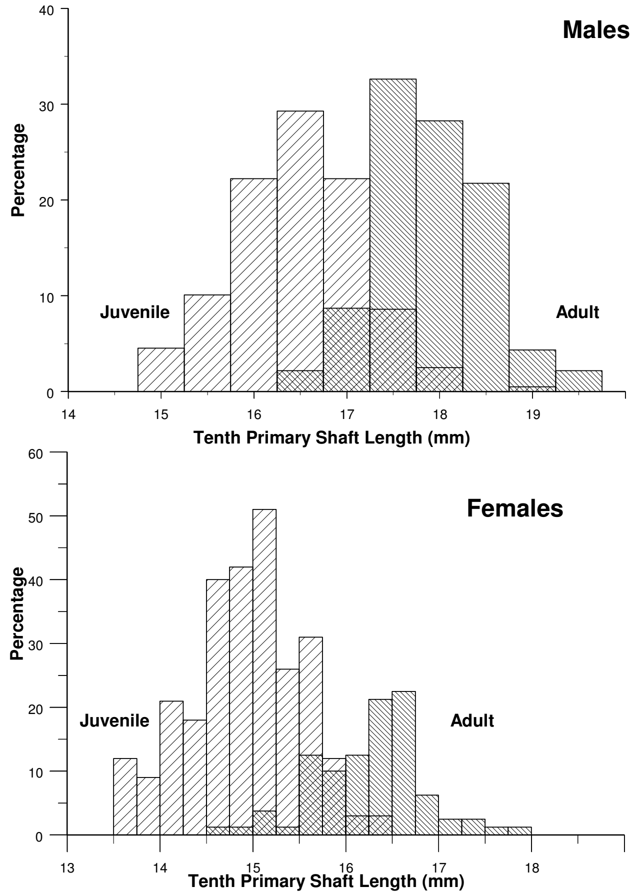

Figure 1: Frequency distribution of proximal primary feather lengths from male and female pheasants caught during spring 1988-1995, Dorset, southern England. The dark hatched area show where the adult and juvenile values overlap.

Consequently log (body weight) was used in subsequent analyses.

Comparison of means for all the morphological variables and feather measurements for each sex showed that adults had higher values than juveniles, with the exception of tarsus length in both sexes (Table1). However there was considerable overlap between adults and juveniles in some measures. The frequency histograms of the two feather measurements and spur length in males showed the smallest degree of overlap between the ages (Figs 1, 2, and 3).

Table 1 also shows the actual level of accuracy of prediction for all the morphological variables and the two feather measurements taken individually. For both sexes the feather data provided the highest level of prediction accuracy.

Multivariate discrimination

Table 2 shows the results of the discriminant function analysis showing the smallest subset of predictor variables that best discriminates between the ages. The change in prediction accuracy is shown as more variables were selected by the model. As described in Methods, some morphological variables were not measured in the early years of the study and so the data were analyzed separately as Group 1 (1988-1990) and Group 2 (1991-1995).

In all cases the feather variables were important predictors, especially proximal primary shaft diame-

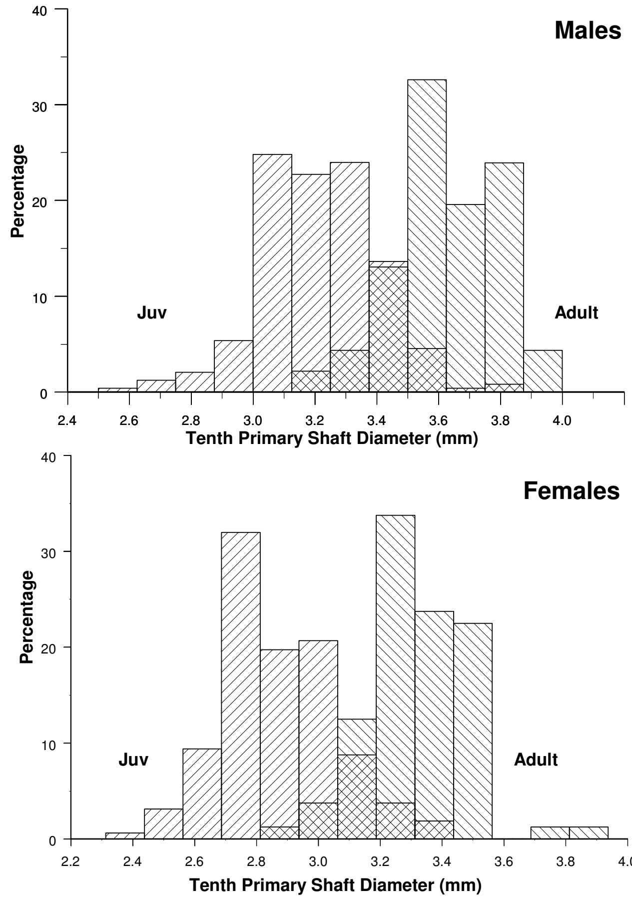

Figure 2: Frequency distribution of proximal primary feather shaft diameters from male and female pheasants caught during spring 1988-1995, Dorset, southern England. The dark hatched area show where the adult and juvenile values overlap.

ter. In males spur length, where measured, was also shown to be important.

The variable year was shown to have no effect on the accuracy of prediction in both groups of males and in Group 1 females but it was selected in the forward stepwise of Group 2 females (years 1991-1995), where it improved the accuracy of prediction by 3%. In the initial stepwise where all the measured variables were included and year was excluded, the log(body weight) variable was selected for Group 2 females. However, when the stepwise procedure was re-run using the selected variables and including year, log(body weight) was dropped but year was then selected, suggesting that the two variables are highly correlated. We examined this and found that body weight did vary between years for this group of females, (F_4 = 4.063, $P < 0.01$).

Cross validation

The test group of known-age birds was used in cross validation to check the accuracy of the discriminant function. Table 3 shows the classification success of both the test group and the predict group of birds from each of the two year categories for both sexes.

In all cases the classification accuracy of the test group was similar to that of the predict group used to compute the original discriminant function.

After cross validation, the discriminant functions

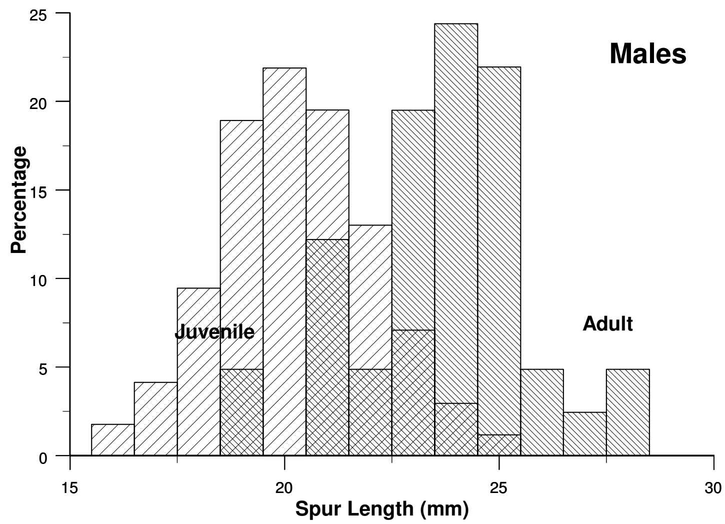

Figure 3: Frequency distribution of maximum spur length of male pheasants caught during spring 1988-1995, Dorset, southern England. The dark hatched area show where the adult and juvenile values overlap.

were then used to predict the age class of 236 previously unknown-age individuals for which feather and morphological data were collected (Table 4). The analysis assigned each bird a probability of being in each of the 2 age groups. The bird was given the age of the group with the higher probability value. As shown in the table, a small percentage of birds could not be aged because they were either borderline with almost equal probability of being assigned to the adult or juvenile group or they had missing values for some variables and their data were excluded from the analysis.

Discussion

In this study the comparison of means of the morphological variables and the two feather measurements showed there was considerable overlap between adults and juveniles. This indicated how difficult it would be to accurately age a proportion of the birds using any one variable alone. Discriminant function analysis has been shown to provide a suitable method of highlighting the key variables important in predicting the age of pheasants. From our results both feather measurements, proximal primary shaft diameter and proximal primary shaft length, were important predictor variabales, especially primary shaft diameter. This was true for both sexes but in males we found that spur length was also an important predictor variable. Including other morphological variables did not significantly improve the accuracy of ageing in either males or females.

We achieved greater accuracy of ageing in males (98%) compared to females (94%). In particular we found reduced accuracy of prediction in the Group 1 females which may partly be due to the small sample size used in the analysis. In the early years of the study we had missing values for some of the measured variables. In the analysis all data from an individual where there was not a complete set of variables was omitted. Therefore, in some cases where for example the feather length was not recorded because the feather tip was broken, all data from that individual bird was excluded from the analysis, thereby reducing the sample size.

Our findings are similar to those of Greenberg et al. (1972) who studied wild pheasants in Illinois. They assessed the use of proximal primary feather diameter and length measurements as an ageing

Table 2: Variables selected in multivariate discriminant function analysis to predict the age of a known-age sample of pheasants. Classification success shows the change in accuracy of prediction at each step in the forward stepwise model. Data were collected from pheasants caught in spring 1988-1995, Dorset, southern England.

	Step	Variables	Canonical discriminant functions	Classification success (%)
Males				
	0	constant	-32.214	
1988-1990	1	primary shaft diameter	4.996	95%
n = 63	2	primary shaft length	0.919	**98%**
	0	constant	-25.855	
1991-1995	1	primary shaft diameter	3.69	93%
n =148	2	spur length	0.215	94%
	3	primary shaft length	0.556	**95%**
Females				
1988-1990	0	constant	-23.286	
n =30	1	primary shaft diameter	7.228	**83%**
	0	constant	-25.438	
1991-1995	1	primary shaft diameter	3.644	89%
n =262	2	primary shaft length	0.925	91%
	3	year	0.283	**94%**

technique. Pheasants were captured in autumn and winter and separated into juvenile and adult age classes on the basis of bursal depths. The level of accuracy achieved by Greenberg et al. (1972) was similar to that found in this study, varying from 92-98% in males and 90-92% in females. They found that including the lengths of the proximal primaries did not improve the level of ageing accuracy and they did not include any other morphological variables in their analysis. They did not assess the age of birds beyond January-February.

The variable year did not affect the accuracy of

Table 3: Prediction success in ageing a subset of a known-age pheasants (test group) using previously defined discriminant functions derived from a separate sample of known-age pheasants (predict group). Data were collected from pheasants caught in spring 1988-1995, Dorset, southern England.

		Predict group classification success (%)	Test group classification success (%)
Males	Group 1	98%	91%
	Group 2	95%	95%
Females	Group 1	83%	92%
	Group 2	94%	96%

Table 4: Predicted age of unknown-age pheasants using discriminant function analysis. Borderline birds could not be accurately assigned an age group and unclassified birds had missing values for one of the required parameters. Data were collected from pheasants caught in spring 1988-1995, Dorset, southern England.

		Predicted Adult	Predicted Juvenile	Borderline	Unclassified
Males	Group 1 n = 44	14 (32%)	23 (52%)	0	7 (16%)
	Group 2 n = 46	6 (13%)	34 (74%)	1 (2%)	5 (11%)
Females	Group 1 n = 35	6 (17%)	21 (60%)	2 (6%)	6 (17%)
	Group 2 n = 111	19 (17%)	77 (69%)	3 (3%)	12 (11%)

prediction in either group of males or in Group 1 females but it did have an effect on the results from the Group 2 females. Body weight was initially selected as a predictor variable in this group but was dropped when year was included, suggesting high correlation between the two variables. Further analysis showed that female body weight did vary between years, particularly in juveniles. This may reflect food availability in different years and nutritional status of the females. From 1992 onwards the hand-reared pheasants on the study area were bought as six-week old poults from game farms and put directly into release pens on the farm. Prior to this the pheasants were bought as one day-old chicks hatched at the game farm from eggs collected from hens on the study area They were hand-reared in pens on the study area and released into the wild at six-weeks old. This difference in management practice between years together with variation in the genetic stock of the birds from the game farm could also contribute to the year effect shown in the females.

When applying discriminant analysis to pheasants it is important to note that birds from different areas may show regional variation in morphological characteristics. This could affect the accuracy of the ageing technique. Therefore, pheasants that are to be aged should ideally be from the same population as those birds used to determine the final discriminant equation. This was also suggested by Robertson et al. (1985). Several other studies have also found variation in mean size of primaries from different pheasant populations, and have concluded that to accurately age unknown birds, feather measurements from known-age birds from the same population should be used (Greenberg et al. 1972, Goransson 1982). As already mentioned above, there is also the potential for variation in populations as a result of different management practices. The quality and quantity of food available to birds is one factor, but differences in habitat and climate could also influence morphological variables, such as feather size.

It is also possible that variation in morphological and feather measurements may be due to the origin of the birds, and where possible, this should be taken into account. Sage et al. (2001) found body weight differences in spring between females of wild origin compared to those of hand-reared origin. In their study pheasant eggs from both a wild pheasant area and from an area populated by hand-reared pheasants were collected. The chicks were then hatched, intensively-reared and released together under identical conditions such that the only difference between the two groups of birds was their genetic origin. The scientists found that wild birds weighed less than those originating from hand-reared birds, but there were no differences in tarsus length and head length between the groups. In contrast Hill and Robertson (1988) found no difference in body weight between populations of wild and hand-reared hen pheasants measured in spring. Wishart (1969) compared measurements of shaft diameter and shaft length of proximal primaries from hatchery reared and wild pheasants from the same region. No differences were found between the groups.

It was not possible to test the effect of origin on the measured variables in the data set used in this study because the sample size of known-age juvenile and adult birds reared in the wild by their natural parent was too small. It was therefore assumed that there were no differences in either the morphological or feather data collected from the wild and hand-reared birds on the study area. The justification for this assumption is that the wild group were likely to be the offspring of previously hand-reared birds, and therefore were not genetically different from the hand-reared group itself. Also, there was a history of pheasant rearing and releasing over several decades on the land surrounding the study area and so, any truly wild birds that may once have been in the area would have undoubtedly interbred with free-living hand-reared birds.

Management Implications

The results from this study suggest that pheasants can be accurately aged using length and diameter measurements of their proximal primary feathers together with spur length measurements in males. The advantages of using this method for ageing are that large samples of data can be collected quickly and easily, no expensive equipment is needed and, unlike some methods, it can be used on live birds. Wildlife managers will also find it a valuable method as it is applicable throughout the year and not confined to autumn and early winter.

It is important, however, that researchers are aware of potential year, origin and site effects when using this technique. The pheasants used in this study were either hand-reared in origin or were the offspring of previously hand-reared birds. It is possible that different results would have been obtained if sampling from a population of wild birds reared naturally by their mother with no influence of hand-rearing. This should be taken into account, although studies by Wishart (1969) and Hill and Robertson (1988) suggested there were no differences in feather and morphological measurements of wild and hand-reared birds. However, to reduce the likelihood of these factors having an effect, when applying the model the discriminant function equation should be derived using data from a sample of known-age birds taken from the same population as those to be aged.

Being able to age birds accurately will greatly enhance our understanding of pheasant biology. From a management point of view it may be valuable to determine the ratio of old to young birds in the bag during the shooting season. More importantly being able to distinguish between first-year and older birds in spring allows the age structure of a breeding population to be established. By means of individually marking birds or using radiotelemetry detailed information can be collected on breeding behaviour, reproductive performance and survival of pheasants in relation to age (Woodburn 1999).

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