Wing moult, body measurements and condition indices of Spur-winged Geese

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This is the first of a series of papers reporting results from a study of Spur-winged Geese *Plectropterus gambensis* at Barberspan, South Africa. These geese form a conspicuous element of the avifauna of sub-Saharan Africa, being the largest and most common of the so-called 'goose' species in the region. In spite of this and the fact that they are important gamebirds, very little about the biology of Spur-winged Geese has been published. Shewell (1959) and Douthwaite (1978) give general accounts of their habits in a farming area and a relatively pristine area, respectively. Douthwaite also gives detailed information on their traditional diet and Dean (1978) provides data on the annual flightless wing moult. Clark (1979, 1980) discusses the validity of the two races into which Spur-winged Geese are sometimes divided and summarizes what is known of the species' breeding biology.

Not surprisingly, the published data on body measurements of Spur-winged Geese are incomplete. Sample sizes are small (or not given) and appropriate statistical parameters have not been presented. Here we present data for various body measurements and discuss which are most suitable for use in calculating condition indices. We also give information on the annual flightless wing moult and discuss factors affecting its timing.

The study area

Barberspan (26°33'S, 25°36'E) is a shallow, alkaline lake in the south-western Transvaal, South Africa, where there is an Ornithological Research Station. The numbers of Spur-winged Geese at Barberspan reach a peak in winter when up to 2000 birds congregate there to moult and remain high until late spring when the birds disperse to breed (Skead & Dean 1977).

Methods

The data herein come from two sources. (1) 77 adult, moulting geese (36 males, 41 females) caught using walk-in traps during the Research Station's ringing programme between January 1969 and December 1974. These birds (two were included in Dean's (1978) sample) provided data on wing moult. (2) 57 adult male and 28 adult female geese shot between June 1980 and April 1982, provided further data on moulting (eight males and four females were in moult). In addition these birds were weighed and eight primary measurements and one derived measurement of structural size were determined.

- i) total length – tip of culmen to tip of tail with bird stretched out on its back.
- ii) wing length – from anterior protuberance on carpometacarpel with wing straightened.
- iii) wing bone – from protuberance to distal end of first phalanx of third digit.
- iv) tarsus length – from proximal end of articular sagittal grooves.
- v) tail length – from preen gland.
- vi) culmen length – premaxilla and nasal bones.
- vii) keel length.
- viii) spur length – entire spur on distal side.
- ix) body length – total length minus tail length.

Analysis of measurements

The data were analysed separately for the sexes. For each measurement, except body length, the mean and coefficient of variation were calculated as well as the 95% confidence limits of the population. Mean values for males and females were compared using Student's *t*-tests. For each sex correlation matrices were calculated using all eight structural

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measurements (not weight). This was done using a Statistical Analysis System (SAS) computer package. In addition, multiple correlation equations were calculated, correlating each one of the structural measurements with six of the other eight. Only six variables were used because total length and body length, and wing length and wing bone, are related measurements and so could not be put together in equations. Body length was used only when wing bone was the dependent variable and *vice versa*. A forward stepwise correlation procedure from the SAS computer package, maximizing R^2, was used for this analysis.

Analysis of moult

Most trapped birds were scored on the British Trust for Ornithology (BTO) moult card system (1= remiges missing or in pin, 4= remiges almost fully grown). A few geese trapped in 1973-74 and all shot birds were scored on a system with five growth classes (0= remiges missing, 5= remiges fully grown).

Some birds were recaptured frequently while moulting; from these the total duration of the wing moult was estimated. The time spent in each moult stage (i.e. class of remex growth) was also estimated, thus enabling calculation of when a bird in a particular stage of moult dropped its remiges. The mean dates when wing moulting was initiated in male and female geese were compared using a Mann-Whitney U test.

One male goose, first trapped and weighed on 7 May 1974, was reweighed 11 times subsequently as it progressed from moult stage 2 to 5. Simple linear regression was used to test whether this bird lost weight during the moult. Weights of the eight male and four female geese shot while moulting were known. These weights were adjusted to allow for differences in overall size of the birds, by dividing body weight of male birds by total length and that of females by body length. Spearman's rank correlation was used to test whether birds in later moult stages weighed less than those in earlier stages. Finally, for each sex the weights of moulting and non-moulting birds were compared using Student's *t*-tests.

Results

Moulting

Figure 1 shows that most Spur-winged Geese at Barberspan begin moulting during winter. The mean date of initiation of wing moult is three weeks earlier in male than female birds (16 June and 6 July, respectively); these dates are significantly different ($P < 0.001$). In each sex 84% of moulting begins over a period of two months, with 93% of the whole population moulting between May and July inclusive.

The dropping of the remiges lasts about one week (Shewell 1959; Dean 1978; pers. obs.). The period of remex growth and hardening (see Dean 1978) lasts about six weeks. Therefore the total period of flightlessness associated with moulting is about seven weeks. Five estimates (from five geese) of the duration of feather regrowth ranged from 37 to 46 days.

In spite of small sample sizes, there was a significant inverse correlation between stage of moult and body weight in female geese ($P=0.05$) and an almost significant one in male geese ($P=0.06$) using body weights adjusted for overall size. In both sexes moulting geese weighed at least 12% less than those not moulting, a significant difference in each case ($P < 0.001$). This figure underestimates the total amount of weight lost because the moulting sample includes birds in all moult stages, not just the final stage. A more realistic estimate is $\sim 20\%$ of initial weight. The single male weighed repeatedly during moult showed a significant loss of weight as moulting progressed ($y= 4598 - 28.7x$, $P<0.001$), losing 29g per day or about 25% of initial weight. It is possible that this bird lost more weight than normal because repeated capture often causes weight loss (Owen & Ogilvie 1979).

Body measurements

Generally male values were 15-22% larger than those of females for the primary structural measurements (Table 1) although there were two outliers, culmen length (11%) and spur length (32%).

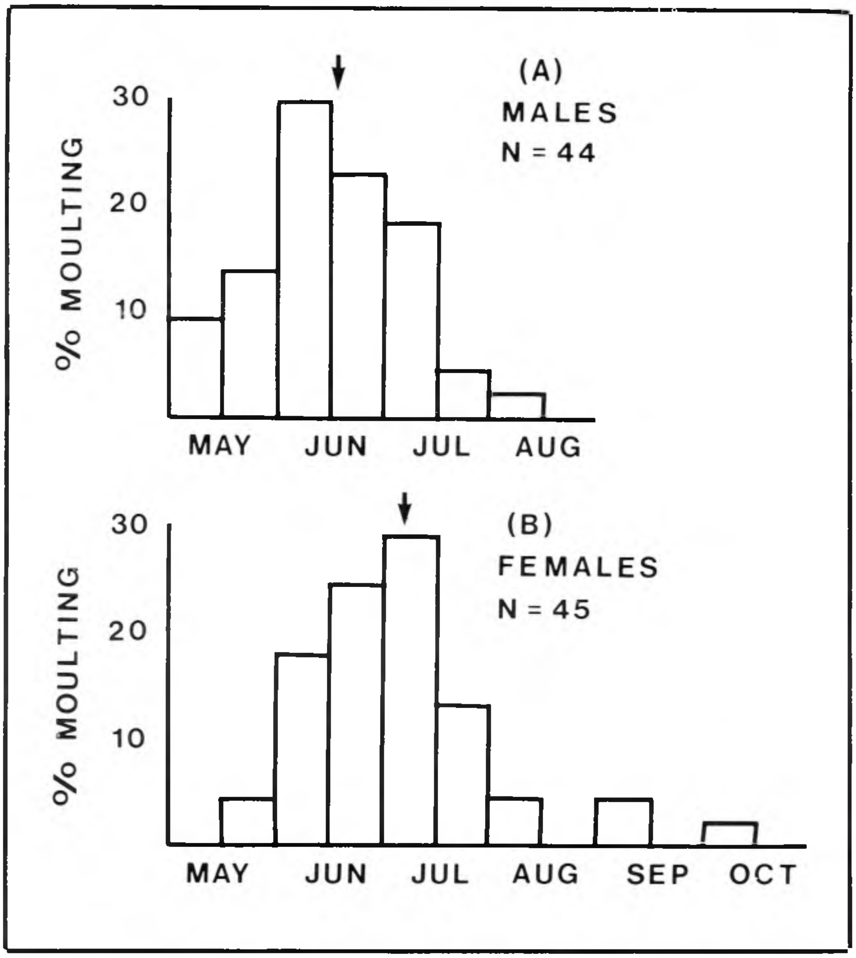

Figure 1. Date of initiation of wing moult in each sex. Percentage of moulting started in each half-month period is shown. Mean date of initiation is arrowed for each sex.

Males were on average 65% heavier than female geese. All these differences were significant ($P < 0.001$). Within a sex there was comparatively little variation in the structural measurements, except for spur length (Table 1). Weight is far more variable than the structural measurements (CV= 13% vs 4%). This is due to two factors. Firstly, the weight of an individual bird changes during the year (e.g. while moulting); this has an additive effect on the intrinsic variation in weight between birds. Secondly, this intrinsic variation itself is greater than for structural measurements because weight is a cubic measurement. If two birds differ in a linear measurement, such as total length, by 5%, their weights will differ by 16%.

Although Spur-winged Geese exhibit clear size dimorphism when mean measurements are compared, only total length and keel show a low level of overlap in their ranges (Table 1). These measurements may be useful adjuncts to cloacal examination (Taber 1969) in sexing birds even though, with both measurements, about five percent of birds will be classified wrongly.

Because the degree of correlation between two structural measurements is a measure of their concordance, it can be argued that the measurement which best estimates a bird's overall size is the one correlated with most other measurements. Total length and body length are correlated with the greatest number of other structural measurements (Table 2), and

Table 1. **Body measurements of male and female Spur-winged Geese.** Mean, 95% confidence limits (CL) of the population, coefficient of variation (CV) and sample size (N) are given as well as percentage by which male means are larger. Males are larger in all measurements (P<0.001) but only total length and keel show no overlap between sexes at 95% level.

	Weight (g)		Length (mm)		Wing (mm)		Bone (mm)		Tarsus (mm)	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
$\bar{X}$	5526	3352	981	842	517	449	148	126	115	96
$\pm$ 95% CL	6801–4251	4401–2303	1050–912	906–778	562–472	482–416	162–134	139–114	126–104	104–88
CV (%)	11.5	14.6	3.5	3.7	4.3	3.5	4.9	4.8	4.7	4.4
% diff	65		16		15		17		20	
N	58	34	60	28	52	24	56	23	60	28

	Tail (mm)		Culmen (mm)		Keel (mm)		Spur (mm)	
	♂	♀	♂	♀	♂	♀	♂	♀
$\bar{X}$	220	192	69	62	175	143	29	22
$\pm$ 95% CL	249–191	207–178	75–63	67–37	189–161	160–126	36–22	28–16
CV (%)	6.6	3.8	4.3	4.2	4.1	5.8	12.1	14.0
% diff	15		11		22		32	
N	48	22	52	23	52	23	59	27

Table 2. **Correlation coefficients for pairs of structural measurements.** Values for male birds appear in the upper right half of the table, those for females appear in the lower half.

Females	Length	Wing	Bone	Males Tarsus	Tail	Culmen	Keel	Spur	Body
Length		0.41**	0.45**	0.46*	0.63***	0.40**	0.61***	0.29*	0.92***
Wing	0.50*		0.39**	0.20	0.51***	0.04	0.24	0.17	0.37*
Bone	0.76***	0.54*		0.45***	0.25	0.21	0.52***	0.31*	0.56***
Tarsus	0.47*	0.51*	0.73***		0.33*	0.27	0.45***	0.25	0.51***
Tail	0.21	0.63**	0.05	0.15		0.13	0.23	0.51***	0.27
Culmen	0.01	0.08	0.39	0.30	0.13		0.26	0.15	0.47***
Keel	0.78***	0.46	0.56**	0.37	0.23	0.20		0.27	0.67***
Spur	0.03	0.11	0.31	0.22	0.48*	0.20	0.16		0.25
Body	0.97***	0.45	0.76***	0.59**	0.01	0.00	0.73***	0.00	

* P<0.05, ** P<0.01, *** P<0.001

therefore can be regarded as the best estimators of overall structural size. This is confirmed by the multiple correlation analysis (Table 3) where, for males, total length was the measurement accounting for most variation in the remaining structural measurements, i.e. the correlation equation with total length as the dependent variable had the largest R^2 – value (0.78). In female geese, body length and bone length accounted for an equal amount of variation (0.88); total length accounted for less but still adequately estimated overall size (0.74) (Table 3). The reason for different measurements in males and females accounting for most variation is found in Table 2. Although usually pairs of measurements that are well correlated in one sex are well correlated in the other, this is not always true. The relationships between structural measurements are not identical for male and female birds.

Although the most important structural measurements are total length and body length, several other also seem useful, in that they show a reasonable degree of concordance with other measurements. These are keel length, tarsus length, wing bone and perhaps tail length. Culmen length and especially spur length, do not appear to be useful estimators of other measurements or overall structural size. Wing length and tail length estimate one another well rather than overall size. Combined with the poor correlation between length of the wing bone and wing, this suggests that the length of a bird's feathers and the length of its bones are not closely tied. The significant correlations between spur length and tail length are surprising.

Discussion

Moulting

The data presented here support the earlier studies of Shewell (1959) and Dean (1978) who concluded that the flightless period associated with moulting in Spur-winged Geese at Barberspan is about seven weeks long. Shewell and Dean both used the rate of remex growth (knowing the length of the remiges) to calculate the period of flightlessness. Although this commonly used method can be validly applied to Spur-winged Geese and other waterfowl at Barberspan (Dean 1978), it ignores the possibility of birds flying before their remiges are fully grown. This occurs in many species of waterfowl, including Barnacle Geese *Branta leucopsis* (Owen & Ogilvie 1979) and Red-billed Teal *Anas erythrorhyncha* in some areas (Douthwaite 1976).

An unusual feature in the annual cycle of Spur-winged Geese is the delay of approximately eight weeks in males and six weeks in females before moulting begins after their breeding effort is finished. This appears to apply to the birds at all localities where they have been studied (Geldenhuys 1975; Dean 1978; Douthwaite 1978; this study), including the Cape where the birds breed in spring rather than summer (Geldenhuys 1975; Clarke 1980).

There is a surprising degree of synchrony in the moulting times of birds of the same sex. The biased sex ratio of approximately two males : one female (unpublished data and calculated from Douthwaite's (1978) sexed samples) results every year in many male birds not finding mates. This shortage of mates is exacerbated by some males being polygynous (Douthwaite 1978; Clark 1980). Thus, even in favourable years, more than half the adult males do not breed. The non-breeding population is increased in years of low rainfall when many paired birds fail to nest. But in spite of the large and variable number of non-breeding birds in any moulting population, the moulting season of Spur-winged Geese is well-defined, with a single peak for each sex, at all localities for which data are available. This strongly

Table 3. **R^2-values for multiple correlations of structural measurements for each sex.** The dependent variable was correlated against six other body measurements. Bone was used only when body was the dependent variable and *vice versa*. The single measurement best correlated with the dependent variable is also shown, provided the correlation is significant.

	Dependent variable								
	Length	Wing	Bone	Tarsus	Tail	Culmen	Spur	Keel	Body
Males									
R^2	0.78	0.35	0.45	0.50	0.58	0.33	0.33	0.47	0.61
best correlation	Tail	Tail	Size	Length[a]	Length	Length[a]	Tail	Length[a]	Keel
Females									
R^2	0.74	0.66	0.88	0.48	0.59	0.31	0.40	0.72	0.88
best correlation	Keel	Tail	Size	Wing	Wing	–	Tail	Length	Bone

[a] body would have given a better correlation if used.

suggests that there is no temporal separation between the moult of breeding and non-breeding geese of the same sex, such as occurs in many waterfowl species (e.g. Newton 1977).

Two events are crucial with respect to understanding the timing of wing moulting in Spur-winged Geese. These are the later moult of female birds and the delay between breeding and moulting. The lack of temporal separation between the moults of breeding and non-breeding birds can be explained as a consequence of the delay before moulting.

The later moult of female birds is most easily attributed to their longer involvement with the young. Although both parents may accompany broods for the first week or two after hatching, subsequently they are cared for only by female geese (Clarke 1980). It is general amongst waterfowl in which there is only maternal care of the young that males moult earlier than their partners.

The delay before moulting appears to be the result of two factors. Firstly, if a bird has bred its body reserves will be depleted (Raveling 1979) and must be replenished prior to moulting. Secondly, Spur-winged Geese inhabit areas with mild, comparatively unseasonal climates. There are no climatic constraints determining the date of the moult, which can be delayed past the time when sufficient body reserves have accumulated for moulting *per se* without a penalty being incurred. So we suggest the delay should be viewed as adaptation giving breeding birds a respite before moulting but acting on non-breeding birds as well because it is in no way disadvantageous. Some environmental cue, which acts differentiately on the sexes, must time moulting.

Measurements

Delacour (1959) recognized two races of Spur-winged Geese: *P.g. gambensis* in the 'north' and *P.g. niger* in the 'south'. Clark (1979) has provided convincing evidence that neither plumage characters nor other external features provide any basis for this. He decided that Spur-winged Geese are a monotypic species. During this study birds exhibiting the full species' range of plumage characters and external features were collected at Barberspan, in the breeding as well as the non-breeding season, thus supporting Clark's conclusion that the species is monotypic. So do the data on body measurements. There are no differences between the measurements of birds from Barberspan, those given by Clancey (1967) and those of McLachlan & Liversidge (1978) (all three sets from the *'niger'* race) and those of the *'gambensis'* race (Delacour 1959); the values fall within the 95% confidence limits of the Barberspan population. Although Delacour's weight range for 'normal' birds (4-6.7 kg) falls comfortably within the Barberspan range, the figure of 10 kg that he suggests birds occasionally attain, does not. We feel this figure should be regarded with extreme scepticism. In spite of hunters' stories to the contrary, it is difficult to conceive that Spur-winged Geese weigh much more than 7.5 kg.

In studies which involve monitoring weight changes in wild birds throughout the year, one is often unable to compare samples from different times because they contain birds of different structural sizes. This problem can be overcome by using condition indices, i.e. by correcting a bird's weight to allow for its overall structural size (Wishart 1979). A single measurement of structural size is generally used for this purpose (Owen & Cook 1977). Obviously the closer the measurement estimates overall structural size, i.e. in this study, the higher its R^2 value when it is the dependent variable in the multiple correlation analysis, the more useful the condition index will be. For Spur-winged Geese, total length is best correlated with overall size for male birds and body length is best for females. Therefore, these two measurements are the appropriate ones to use in calculating condition indices for male and female geese respectively. Because weight increases at a greater rate than length, it seems desirable to use the cube root of weight, instead of weight itself, as the numerator in the condition indices.

It is surprising that body length is not the best estimator of overall structural size in males. Intuitively one would expect it to be better than total length because it does not include the length of the tail. The length of the flight feathers is poorly correlated with bone size. Wing length, often used as a measure of body size (e.g. Owen & Cook 1977), does not estimate overall size of Spur-winged Geese particularly well. It also suffers the shortcoming that it cannot be applied to moulting waterfowl. If there are objections to using the total length or body length to calculate a condition index, length of the wing bone is a better measurement to use than wing length. It can be applied easily to moulting birds and better estimates overall size, presumably because it does not include length of the remiges.

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Summary

Data on wing moult and body measurements of Spur-winged Geese *Plectropterus gambenis* at Barberspan, South Africa, are given. The annual wing moult leaves the birds flightless for about seven weeks. Males begin moulting, on average, three weeks earlier than females. For 84% of birds of each sex moulting starts during a two-month period so that 93% of the population begins moulting in the period May to July. There is a delay of eight weeks in males and six weeks in females between the end of their breeding commitment and the beginning of moulting. The later moult of females relates to the longer periods they spend caring for the young. The overall delay before moulting represents a respite between the two most energetic events in the annual cycle. The geese lose ~20% of initial body weight while moulting.

Males are larger than females in all body measurements. It was found that total length best estimates overall structural size in males, and hence is the best measurement to use in a condition index. In females, body length (total length minus tail length) is more suitable. Length of feathers is not well correlated with length of bones, which probably explains why wing length estimates overall structural size poorly.

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