VARIATIONS IN BODY WEIGHT, FAT-FREE WEIGHTS AND FAT DEPOSITION OF STARLINGS IN NEW ZEALAND

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SUMMARY: The effects of age, sex and season on the live weight and weight of liver, ether-extractable fats, fat-free weight and gizzard contents were examined for starlings in Canterbury, New Zealand.

Starling live weights varied with age and with the seasonal deposition or mobilization of fat and other stored foods. In spring and summer, non-breeding first-year birds carried relatively more fat than adults. However, adults probably feed more successfully than younger birds as when the activities of both groups were similar (autumn and winter), adults were heavier and had relatively more fat.

Dimorphic patterns also existed. In adults these probably resulted from divisions of labour prior to and during breeding.

INTRODUCTION

The omnivorous diet and flock feeding behaviour of the starling *(Sturnus* v. *vulgaris* L.) has given it a beneficial reputation in non-cropping farming areas (Pfabe and Szypula-Gador 1964, Russell 1971) while it has been considered a pest in viticultural (Szijj 1956), cherry (Kalmbach 1922) or cereal growing regions (Dunnet 1956, Bailey 1966). In New Zealand published information on starlings is largely anecdotal. Current local research is concentrated on the use of manipulated starling populations in insect control programmes. However, in the light of foreign published research an adequate knowledge of the birds local ecology seems essential before any manipulation of its numbers is commenced.

This paper forms part of a study of starling ecology on farmlands in Canterbury, New Zealand. It describes differences in the seasonal condition of both first year and adult birds of both sexes, using the following carcass variates:

(a) live weight
(b) liver weight
(c) the weight of ether-extracted "fats" (fats, paraffins, waxes and alcohols).
(d) the weight of fat-free tissues, and
(e) gizzard content weight.

Change in condition is correlated with rates and periods of high mortality and likely reproductive success, while being a function of the seasonal variation of calorific intake. As individual food reserves are mobilised at different levels of physiological stress, only consideration of several variates will give a real understanding of the birds total physical well-being.

The study area of West Melton is near the centre of the Canterbury Plains (43°30'S, 172°20'E); an extensive area of flat land characterised by low rainfall (58-76 cm annually), warm summers with occasional hot north west fohn winds to above 30°C and cool winters with frequent frosts and occasional snow. Farming consists largely of the production of livestock and mixed cash crops, particularly cereals, with frequent stock fodder crops.

METHODS

Approximately 40 birds were shot each month between 1000 and 1500 hours daily from April 1969

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to March 1970. On collection carcasses were sexed, aged by hackle feather measurements (Coleman 1973) and weighed (=live weight) to the nearest 0.1 g. Subsequently the liver, gonads, gizzard contents and perivisceral fat depot were removed and weighed separately to the same degree of accuracy.

For birds collected in March, June, September, and December, representative months of each season, the fat extractable by petroleum ether (B.P. 40-60°C) was measured by methods similar to those described by Rogers and Odum (1964) and Bamford (1970). Each carcass, with plumage intact but minus the intestine, gizzard contents, liver, perivisceral fat depot and gonads was finely minced in a laboratory "Waring" blender. The intestine, minus visible fat, was discarded because of errors arising from the presence of food. The minced remains were dehydrated in an oven at 60 ± 1°C to establish dry weights. The fats were subsequently extracted by three successive 10 min. boilings in petroleum ether. After each boiling the solvent was filtered, and after the third filtration the samples were again dehydrated and weighed. This gave the weight of dry fat-free tissues and, by subtraction, ether extracted fat. As a check on extraction methods, 10 carcasses were boiled a fourth time. Within the limits of the equipment used, no further weight was lost.

The perivisceral fat depot, a discrete entity underlying the viscera adjacent to the rectum, was used to provide an estimate of the total weight of fat for each bird. The latter, comprising the ether extracted fat plus the perivisceral fat depot, was regressed on the weight of the perivisceral fat depot. The equations for each month were:—

March	$Y = 0.406 + 0.490\ X$
June	$Y = 0.665 + 0.173\ X$
September	$Y = 0.486 + 0.442\ X$
December	$Y = 0.384 + 0.638\ X$

These regressions were tested for significance by analysis of variance techniques (Sokal and Rohlf 1969, Ch. 14.5) and all had Fs ratios indicating a significance level of $p<0.001$. For birds collected in other months of the same season, the weight of total fat was estimated from the weight of the perivisceral fat depot using these equations.

Seasonal variation in the "live" weight of birds, their livers, gizzard contents, estimated total fat and fat-free tissues, was analysed by single classification analysis of variance techniques (Sokal and Rohlf, op. cit, Ch. 9). Where overall seasonal significance occurred Gabriels' sum of squares simultaneous test procedure (SS-STP; Sokal and Rohlf, op. cit, p. 237) was used to test differences amongst the seasonal means. SS-STP analyses rank sample means in decreasing magnitude (see results) such that means not covered by two lines and enclosed by the range of any one line are significantly different.

Fat-free body weights of starlings other than those whose fat-free weights were determined by fat extraction, were obtained by subtracting the estimated total fat weight from the measured live weight. The variation in the fat content of all the starlings collected, relative to body weight, was examined indirectly by regressing live weights on fat-free body weight. The regressions were compared using analysis of covariance techniques (Snedecor and Cochran 1967).

Variation with age and sex of the same carcass variates was tested subsequently using single classification analysis of variance.

Statistical significance was determined at the 0.05 probability level and denoted by * where $0.01<p<0.05$, ** where $0.001<p<0.01$ and *** where $p<0.001$.

RESULTS

Live weight

The live weights of adult starlings were greatest in winter and least in summer; a trend typical of birds (Baldwin and Kendeigh 1938). There was no significant seasonal variation of live weight in adults. Males decreased from 90.48 ± 0.896 (S.E.) to 84.94 ± 1.310 g and females from 83.54 ± 1.230 to 81.07 ± 1.309 g from winter to summer. These changes compare with mid-winter maxima for adult male and female starlings in North America of 87.42 ($N \approx 2000$) and 82.24 ($N \approx 1000$) respectively (Hicks 1934). Live weights of first year Canterbury birds followed the patterns shown by local adults. These were comparable with starlings in Scotland (Dunnet 1956). Summer weights of females were significantly lower than the spring and winter weights and for males, the summer weight differed from that of all other seasons, i.e.,

Mean live weight (g)

	Spring	Winter	Autumn	Summer
First year females	81.2	80.2	79.9	72.8
First year males	87.1	85.4	83.5	76.2

Male starlings were heavier than females of similar age (Table 1). Adults differed significantly in their aggregate means but first year birds differed only in spring as they approached adult weight. Adults on average were heavier than first years; significant differences occurring between females in summer, and between males in summer and winter. Starlings of both sexes were smallest in summer following fledging, but close to adult weight by the subsequent autumn.

TABLE 1. *Analyses of variance of the live weights of starlings with sex and age.*

Season	Mean Live weights (g) Male	Female	Degrees of Freedom	Fs	Level of significance
		a. Sex			
		Adult birds			
Yearly Mean	88.01	82.14	1,194	55.06	***
		First year birds			
Autumn	83.54	79.92	1,25	3.454	n.s.
Winter	85.37	80.22	1,14	2.509	n.s.
Spring	87.10	81.19	1,14	5.860	*
Summer	76.17	72.79	1,15	1.556	n.s.
		b. Age			
		Males			
	Adult	First year			
Autumn	84.94	83.54	1,36	0.235	n.s.
Winter	90.48	85.37	1,49	5.390	*
Spring	87.75	87.10	1,48	0.131	n.s.
Summer	87.40	76.17	1,22	47.300	***
		Females			
	Adult	First year			
Autumn	81.58	79.92	1,31	1.230	n.s.
Winter	83.54	80.22	1,35	1.272	n.s.
Spring	82.22	81.19	1,37	0.284	n.s.
Summer	81.07	72.79	1,24	9.944	**

Liver Weight

Liver weights varied seasonally. Trends amongst sex and age groups were similar, with the livers of all birds significantly heavier in winter than in autumn. First year males also showed significant summer differences, i.e.,

Intact Liver Weights (g)

	Winter	Spring	Summer	Autumn
Adult females	3.27	3.07	2.84	2.72
Adult males	3.61	3.25	3.21	2.89
	Winter	Summer	Spring	Autumn
First year females	3.48	3.27	3.25	2.55
	Winter	Spring	Autumn	Summer
First year males	3.87	3.11	3.05	2.98

Adult males had heavier livers than adult females; differences being significant in winter and summer (Table 2). Patterns amongst first year birds were less regular although significant autumnal differences were recorded. Age differences were not established, but livers of first year starlings generally were as heavy or heavier than those of adults.

TABLE 2. *Analyses of variance of fresh liver weights of starlings with sex and age.*

Season	Mean Live weights (g) Male	Female	Degrees of Freedom	Fs	Level of significance
		a. Sex			
		Adult birds			
Autumn	2.89	2.72	1,21	0.866	n.s.
Winter	3.61	3.27	1,71	4.510	*
Spring	3.25	3.07	1,70	1.151	n.s.
Summer	3.21	2.84	1,27	4.289	*
		First year birds			
Autumn	3.05	2.55	1,17	4.503	*
Winter	3.87	3.48	1,14	1.586	n.s.
Spring	3.11	3.25	1,13	0.258	n.s.
Summer	2.98	3.27	1,14	1.201	n.s.
		b. Age			
		Males			
	Adult	First year			
Autumn	2.89	3.05	1,24	0.792	n.s.
Winter	3.61	3.87	1,51	1.205	n.s.
Spring	3.25	3.11	1,48	0.193	n.s.
Summer	3.21	2.98	1,23	1.286	n.s.
		Females			
	Adult	First year			
Autumn	2.72	2.55	1,14	0.597	n.s.
Winter	3.27	3.48	1,34	0.535	n.s.
Spring	3.07	3.25	1,35	1.159	n.s.
Summer	2.84	3.27	1,18	3.280	n.s.

Total fat weight

Total fat varied seasonally. Trends were similar for each sex and age category, with average total fat maximal in winter and minimal in summer following the fledging or breeding of first year and adult birds respectively. Winter fat, in general, was significantly greater than in any other season, i.e.,

Total Fat (g)

	Winter	Spring	Autumn	Summer
Adult females	7.24	5.87	4.28	4.05
Adult males	7.51	4.93	3.71	3.49
First year females	5.68	3.99	3.65	3.14
First year males	7.39	4.42	3.64	3.19

Total fat did not differ significantly with either sex or age (Table 3). However, first year females generally had less fat than adult females or like-aged males. Conversely, adult females frequently had more fat than adult males.

The relative fat content of birds of different ages varied seasonally (Fig. 1, A-D). Unfortunately, high sample variances of one or both age groups limited analyses of covariance comparisons. Even so, in autumn and winter (Fig. 1, A and B) it appeared that lower fat-free weights and hence greater total fat were attained by adult starlings compared with younger birds of the same body weight. Conversely, in spring and summer (Fig. 1, C and D) first year birds appeared to have higher fat-free and lower total fat weights than similar sized adults.

TABLE 3. *Analyses of variance of the total fat of starlings with sex and age.*

Season	Mean Total fat (g) Male	Female	Degrees of Freedom	Fs	Level of significance
a. Sex					
Adult birds					
Autumn	3.71	4.28	1,40	1.434	n.s.
Winter	7.51	7.24	1,69	0.156	n.s.
Spring	4.93	5.87	1,69	2.592	n.s.
Summer	3.49	4.05	1,31	2.706	n.s.
First year birds					
Autumn	3.64	3.65	1,20	0.002	n.s.
Winter	7.39	5.68	1,14	4.426	n.s.
Spring	4.42	3.99	1,14	1.124	n.s.
Summer	3.19	3.14	1,14	1.058	n.s.
b. Age					
Males					
	Adult	First year			
Autumn	3.71	3.64	1,35	0.057	n.s.
Winter	7.51	7.39	1,49	0.011	n.s.
Spring	4.93	4.42	1,48	0.471	n.s.
Summer	3.49	3.19	1,23	0.139	n.s.
Females					
	Adult	First year			
Autumn	4.28	3.65	1,25	0.891	n.s.
Winter	7.24	5.68	1,34	3.742	n.s.
Spring	5.87	3.99	1,35	2.730	n.s.
Summer	4.05	3.14	1,22	2.456	n.s.

Fat-free weight

Fat-free weights of adult starlings were greatest in summer and spring, and least in autumn for males and in winter for females, but seasonal differences were not significant, e.g., males varied from 83.77 ± 0.980 to 80.87 ± 1.249 g and females from 77.42 ± 0.934 to 75.44 ± 0.888 g. Conversely, first year birds were significantly lighter in summer than in spring (females) or autumn and spring (males), i.e.,

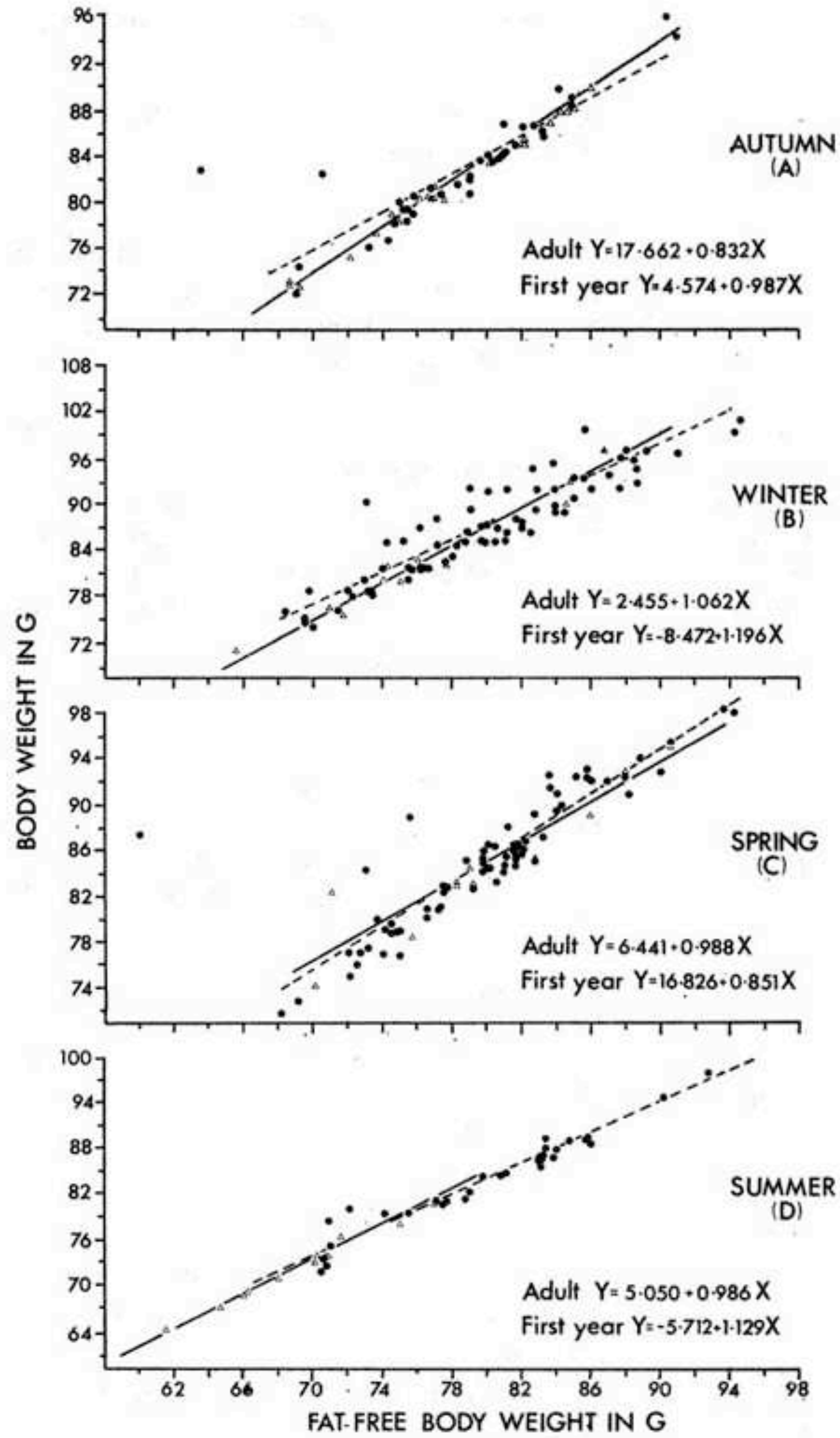

FIGURE 1. *Seasonal regression analyses of body (live) weight on fat-free body weights of adult (—●—) and first-year starlings (—△—).*

Mean Fat-free Weights (g)

	Spring	Autumn	Winter	Summer
First year females	77.2	75.2	74.7	68.5
First year males	81.8	80.5	78.0	72.6

The fat-free weights of male starlings were greater than those of females of similar age, with adults differing significantly in their annual aggregate means, and first year birds in autumn (Table 4). Adult fat-free weights were greater than those of first year birds throughout the year, with males differing significantly in summer and winter and females in summer.

TABLE 4. *Analyses of variance of the fat-free weights of starlings with sex and age.*

a. Sex

Season	Mean Fat-free weights (g) Male	Female	Degrees of Freedom	Fs	Level of significance
		Adult birds			
Yearly Mean	82.42	76.12	1,188	81.026	***
		First year birds			
Autumn	80.53	75.17	1,20	7.166	*
Winter	78.00	74.66	1,14	1.482	n.s.
Spring	81.80	77.24	1,14	2.735	n.s.
Summer	72.61	68.45	1,14	3.209	n.s.

b. Age

	Adult	First year			
		Males			
Autumn	80.87	80.53	1,32	0.039	n.s.
Winter	82.99	78.00	1,49	6.851	*
Spring	82.99	81.80	1,48	0.345	n.s.
Summer	83.77	72.61	1,23	56.615	***
		Females			
Autumn	76.24	75.17	1,25	0.207	n.s.
Winter	75.44	74.66	1,34	0.153	n.s.
Spring	77.42	77.24	1,35	0.340	n.s.
Summer	77.13	68.45	1,22	10.848	**

Gizzard content weight

The weight of the wet gizzard contents of adult-plumaged birds was greatest in autumn and least in summer. SS-STP analysis using Duncan's multiple range test with an intuitive modification for unequal sample sizes (see Bancroft 1968, p. 109) revealed significant seasonal variation, i.e.,

Autumn	Winter	Spring	Summer
1.760	1.643	1.545	1.430

The weight of the wet gizzard contents was independent of age and sex. Adults on average appeared to ingest more food items than juvenile birds (123.6 : 84.6; N = 20 for each age category), with differences approaching significance ($Fs = 2.09$, $0.05<p<0.1$; $F(0.05) = 2.12$). The discrepancy between the weight and numbers of ingested food probably results from variations in the hygroscopic qualities and breakdown rates of age-specific starling foods.

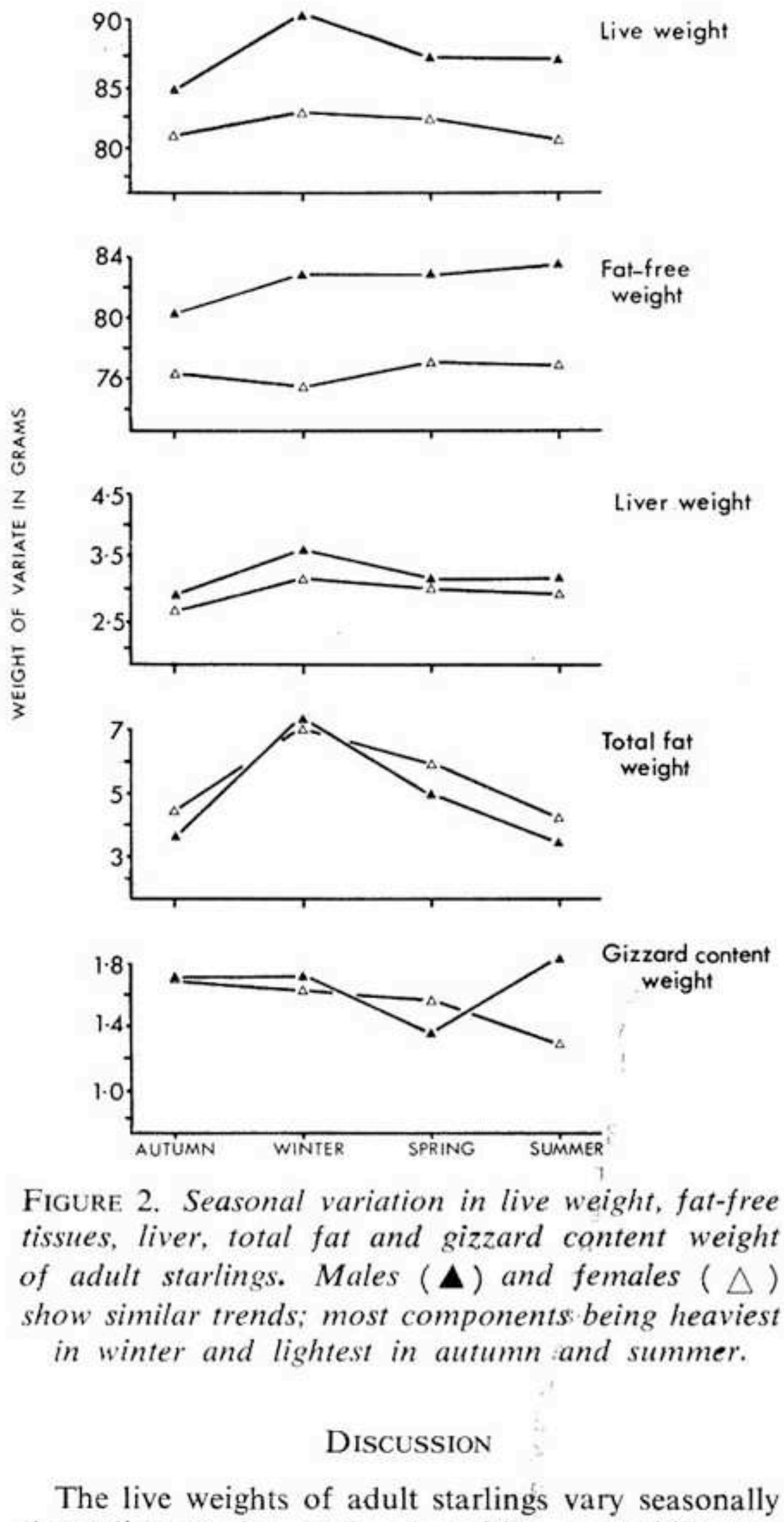

FIGURE 2. *Seasonal variation in live weight, fat-free tissues, liver, total fat and gizzard content weight of adult starlings. Males (▲) and females (△) show similar trends; most components being heaviest in winter and lightest in autumn and summer.*

DISCUSSION

The live weights of adult starlings vary seasonally depending on the regular deposition or mobilisation of fat and analogous stored products (Fig. 2). Increases in total fat were matched by increases in liver weight; the latter due to changes in stored glycogen, fat, protein and water (Ljunggren 1968). The liver serves as a food storage organ and increases in liver weight especially when coincident with increases in total fat, must be indicative of periods when the bird is consuming food in excess of its immediate requirements.

Seasonal decreases in live weights, food storage organs and depots, varied in timing and magnitude with sex. Males, though heavier than females, lost 5.3% of their mid-winter live weight by the start of laying. On the other hand, females lost 3.5% of their winter weight by the end of the nestling period; a rate of loss less than half that of males and apparently due to the division of labour of the two sexes prior to and during breeding. Males select and defend nest sites before laying commences (Coleman 1972), but females spend longer periods at the nest following laying and convert considerable liver reserves into egg yolk (Bellairs 1964). Both activities result in partial inanition and, as suggested by Baldwin and Kendeigh (1938), partly determine the observed losses in weight of liver and fat depots.

Relative fat content varied with the age of starlings. Although heavy birds generally had large fat reserves and vice versa, medium-sized birds were not so predictable, largely because of age differences. In comparison with older birds, those in juvenile plumage in summer had relatively large fat reserves, due to intensive feeding by parents before and after leaving the nest. Likewise, first year birds in spring had large reserves, as generally they did not breed. Conversely, adults in spring and summer had relatively low fat reserves apparently because of the intensive activities of breeding. In autumn and winter this pattern changed. Adults had relatively greater fat reserves than younger birds, which suggests that when the activities of all birds were similar, adults fed more successfully. This has also been shown for wood pigeons *Columba palumbus* (Lack 1966, p. 185).

The fat-free tissues of adult Canterbury birds did not show significant seasonal variation, which agrees with the findings of Connell, Odum and Kale (1960) for a range of passerine species. Conversely, much of the seasonal variation in live weights of migrant and non-migrant passerines has been reported to result from variations in fat-free tissues metabolized following the seasonal depletion of fat reserves (see Newton 1969, Child 1969, Fry, Ash and Ferguson-Lees 1970, Barnett 1970).

Seasonal variations in the stored "food" reserves of Canterbury birds may point to seasonal differences in feeding rates (as shown for starlings in North America, see Hart 1962) or in calorific requirements. It is not necessarily indicative of variations in food availability; some mammals lay down fat during periods of comparative food shortage (Flux 1971). Seasonal variations in the weight of gizzard contents are influenced by distinct seasonal food components which vary markedly in their calorific content (Coleman 1972). It is possible that the calorific intake, as well as the weight of food taken, may vary seasonally. This would not necessarily be indicated by increased food reserves, e.g., during breeding, as increased activity and a subsequent moult preclude the deposition of reserve foods. Ljunggren (1968) similarly considered that live and fat weights of the wood pigeon in Sweden were determined by the quality not quantity of their food, with large quantities of food low in caloric value being taken during "lean" periods of the year.

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