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Weights and fat in Lapwings Vanellus vanellus and Oystercatchers Haematopus ostralegus starved to death during a cold spell in spring

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Weights and fat levels in body and liver in six Lapwings and six Oystercatchers starved to death during a cold spell in spring were investigated. Compared with control groups the starved Lapwings and Oystercatchers had 46 and 38% lower total weights respectively. Fat-free dry weights were 45 and 35% lower whereas body fat was drastically reduced by 92 and 91% in the starved groups. Proportional water content was remarkably constant, 71–72% in both species and in normal as well as starved birds. There was an appreciable reduction of dry liver mass which only to a minor part depended on a depletion of liver fat. The reduction of total fat-free dry body is supposed to depend mainly on a mobilization of muscle protein as an energy source when the fat depots are depleted. The reduction of liver dry mass is partly unexplained. It is inferred that such drastic emaciation in birds is uncompatible with life even if environmental conditions are changed before the death of the birds.

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1. Introduction

Most studies on weights and fat levels in birds have been performed during migratory and wintering periods when environmental conditions have been essentially normal. Comparatively few records concerning the effect of extraordinary stress factors on migratory birds are available. In extremely exhausted migrants which have crossed large water areas abnormally low total and fat-free weights have been recorded, indicating that not only fat but also other tissue such as muscle protein may be used for fuel when the fat reserves are depleted (Voous 1957, Nisbet et al. 1963, Odum et al. 1964 and others).

In migrating or wintering passerines starved to death during periods of cold weather and shortage of food drastic total body weight reductions amounting to 35–55% have been recorded. Under similar circumstances, birds of prey such as Kestrels *Falco tinnunculus* and Goshawks *Accipiter gentilis* have lost about 30–35% of normal weights at death and average weight losses of 35–45% have been recorded in several wader species (Harris 1962, Ash 1964, Vepsäläinen 1968, Creutz and Piechocki 1970, Morrison 1975). Canada Geese *Branta canadensis* starved to death as a result of impaction of the oesophagus by dry, unpalatable foods had lost 43–46% of their normal weight (Hanson 1962). In comparing the calculated weight losses some caution is warranted because the "normal" weight levels used may vary between different workers. Especially in migratory birds appreciable seasonal weight variations occur which must be taken into consideration. An evaluation of weight changes in a collected sample of birds against yearly mean values or values from a different season of the year may be misleading.

Between 9–23 April, 1966 an extremely hard cold spell with frost and snow prevailed in South Sweden. Many early migrants had arrived and most Lapwings and Oystercatchers had already occupied their breeding places and had started breeding activities. Thus they were physiologically in an early breeding phase and did not react to the sudden cold weather with a reversed

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movement south- or southwestward as is otherwise commonly noted under such circumstances when the birds are still in a migratory phase. Because of snow and frost hardly any food at all was available for these birds. Especially Lapwings starved to death in large numbers resulting in a 87% reduction of the local populations on the south point of the island of Öland (Hjort and Larsson 1973). On middle Öland, about 90% of breeding populations was eliminated in several areas (Svensson 1966, own obs.). Edberg (unpubl.) collected appreciable numbers of dead Lapwings and Oystercatchers on the eastern part of middle Öland. For instance, 117 Lapwings and 18 Oystercatchers were found on one locality on 20 April. They were in a severely emaciated condition. In Skåne, reductions of local Lapwing populations by 70–80% were recorded by Svensson (1966). An extensive study on the effects of the same cold spring on Lapwing populations in Finland has been published by Vepsäläinen (1968).

The purpose of this paper is to present some data concerning weights and fat levels in body and liver in Lapwings and Oystercatchers which were starved to death and collected in Runsten parish on the eastern coast of Öland in 1966 and to compare the results with analyses of birds in a normal condition. Though the material is too small for analysis by statistical methods some interesting effects of the prolonged starvation period on the 1966 birds are clear from the results presented.

For comparison with the present results, some unpublished data on liver weights and liver fat content in Goshawks and domestic chicks are referred to in the Discussion section.

2. Material and methods

Six dead Lapwings and six dead Oystercatchers collected in Runsten parish on the east coast of middle Öland by R. Edberg on 20 April, 1966, were analysed at the Inst. of Zoophysiology at Uppsala University for weights, fat levels in body and liver etc. Snow was falling on the day before these specimens were collected. As they were not covered with snow it can be inferred that they had succumbed during the preceding night. Cold weather (±0°C) was still prevailing. Thus the bodies collected were in a fresh and unchanged condition.

In order to compare the results with data on unstressed birds in a normal condition, equal numbers of the same species were collected at Ottenby on the south point of Öland on 27 March and on 1 April 1975 (Lapwings) and on 1 and 3 April 1975 (Oystercatchers) by R. von Schultz. Thus these birds were collected about 3 wk earlier than the dead ones in 1966.

All specimens were analysed by the same method as described earlier by us (Mascher and Marcström 1976). The liver was taken out of the body and analyzed separately, but for the purpose of computing total contents of fat and water the body was considered as a whole. The stomach was emptied in the birds of 1975 in order to achieve a closer comparison with the 1966 groups of birds which had no stomach content at all.

Testes and ovaries are included in the total weights. In the 1966 groups, there were no developed eggs but two of the Lapwings in 1975 had complete eggs in the oviduct. The weight of the eggs and their lipid content will affect the total weights and fat levels in these birds to a certain extent but this is unimportant for the general results presented in this paper.

No clear trend could be ascertained as concerns possible differences in total weights and body fractions between males and females, but the material is too small for a closer comparison. Both sexes are included in the further calculations.

3. Results

3.1. Gonad measures and weights

Testes and ovaries were measured and weighed but in some specimens from 1975 these organs were injured and impossible to separate from the body. In four male Lapwings of 1966 the testes weighed 0.5–0.7 g whereas two males collected in 1975 had testes weighing 0.7 and 0.8 g respectively. One male Oystercatcher which was collected in 1966 had a testis weight of 0.4 g whereas the testes of three males in 1975 weighed below 0.3 g.

The ovary weights in two Lapwing females collected in 1966 were 0.3 and 0.6 g. Two females from 1975 had almost completely developed eggs in the oviduct. However, the ovaries were injured in all but one of the 1975 birds and could not be adequately separated and weighed or measured. The ovaries of five female Oystercatchers in 1966 ranged between 0.1–1.0 g whereas three females of the control group had ovary weights between 0.3–0.7 g.

3.2. Total weights and fat-free dry weights

Mean total weights were 120 g lower in the starved Lapwings and 186 g lower in the starved Oystercatchers compared to the control groups. This corresponds to a proportional reduction of body mass by 46 and 38% respectively. Fat-free dry weights were 25 g lower in the starved Lapwings and 38.6 g lower in the starved Oystercatchers, which corresponds to similar proportional reductions by 45 and 35% (Tabs 1–3).

3.3. Fat content

In the control groups of both species the mean proportion of total body fat was about 9–10% of body weight and the fat proportion in dry body mass was near 30%. The corresponding mean total fat content in absolute figures was 26 g in the Lapwings and 45.4 g in the Oystercatchers (Tabs 1–2).

Tab. 1. Means and ranges of total weights and body fractions in the control group and starved group of Lapwings. Figures in g where not otherwise stated.

	Control group (n = 6)	Starved group (n = 6)
Total body	260.1 (232.6–309.1)	139.9 (135.0–145.5)
Dry body	81.8 (71.5–101.5)	32.7 (30.2– 34.0)
Fat-free dry body	55.8 (51.5– 64.0)	30.8 (28.2– 31.9)
Total body fat	26.0 (17.8– 41.5)	2.0 (1.8– 2.3)
Total body fat%	9.8 (7.4– 14.0)	1.4 (1.2– 1.7)
Dry body fat %	31.1 (24.6– 40.9)	5.9 (5.4– 6.9)
Water in fat-free body %	71.0 (70.3– 72.2)	72.0 (70.6– 73.4)
Liver, total	9.0 (7.6– 11.7)	2.5 (2.1– 2.8)
Liver dry mass	2.6 (2.2– 2.7)	0.7 (0.6– 0.8)
Liver, fat-free dry mass	2.1 (1.8– 2.6)	0.6 (0.5– 0.7)
Liver fat	0.6 (0.4– 0.7)	0.1 (0.07– 0.12)
Liver fat in dry mass %	20.8 (17.2– 23.4)	12.2 (9.3– 15.8)
Water in fat-free liver mass %	75.5 (73.5– 76.5)	76.4 (75.6– 77.5)

Tab. 2. Means and ranges of total weights and body fractions in the control group and starved group of Oystercatchers. Figures in g where not otherwise stated.

	Control group (n = 6)	Starved group (n = 6)
Total body	494.0 (472.2–539.2)	308.0 (291.9–324.0)
Dry body	154.8 (134.4–173.7)	74.8 (69.3– 78.6)
Fat-free dry body	109.4 (100.7–126.7)	70.8 (65.3– 74.3)
Total body fat	45.4 (22.0– 73.1)	4.0 (3.8– 4.3)
Total body fat %	9.3 (4.3– 15.3)	1.3 (1.3– 1.4)
Dry body fat %	28.8 (16.4– 42.1)	5.4 (4.8– 5.7)
Water in fat-free body %	71.1 (70.6– 72.1)	71.9 (70.0– 73.5)
Liver, total	14.1 (11.1– 16.7)	5.7 (5.0– 7.1)
Liver dry mass	4.1 (3.1– 4.8)	1.5 (1.2– 1.9)
Liver, fat-free dry mass	3.3 (2.6– 3.9)	1.3 (1.1– 1.7)
Liver fat	0.8 (0.5– 1.0)	0.2 (0.15– 0.22)
Liver fat in dry mass %	18.3 (16.5– 20.2)	12.4 (10.6– 13.7)
Water in fat-free liver mass %	75.0 (73.2– 75.9)	75.9 (74.2– 78.4)

In the starved birds of both species body fat was reduced to an extremely low level. Mean fat proportions of total body weights were as low as 1.4% in the Lapwings and 1.3% in the Oystercatchers with corresponding fat proportions in dry body amounting to 5.9 and 5.4% respectively. The average total body fat content was only 2.0 g in the Lapwings and 4.0 g in the Oystercatchers (Tabs 1–2). The corresponding mean proportional reduction of total body fat compared with the control groups was 92% in the Lapwings and 91% in the Oystercatchers (Tab. 3).

Tab. 3. Mean loss in per cent of total weight and body components in birds starved to death compared with control birds in normal condition. n = 6 in all groups.

	Lapwings	Oystercatchers
Total body weight	46	38
Fat-free dry body weight	45	35
Fat-free dry liver weight	71	60
Total body fat	92	91
Liver fat	83	75

3.4. Water content in body and liver

The proportion of water in fat-free body mass averaged 71–72% in both species groups under normal as well as under extreme starvation. There was an appreciable loss of water in the starved birds but this depended on the general loss of body mass as the water proportion was unaltered (Tabs 1–2). The proportional water content in fat-free liver mass averaged slightly larger, i.e. 75–76.4% with a trend to somewhat larger water content in the livers of the starved birds.

3.5. Liver weights and fat

Mean liver weights in the starved birds of both species averaged only about one third of normal liver weights as compared to the control groups (cf. Tabs 1–2). Fat-free dry liver masses were 71% lower in the Lapwings and 60% lower in the Oystercatchers (Tab. 3). Mean total liver fat was reduced from 0.6 g in the control group of Lapwings to 0.1 g in the starved group, a reduction from the normal level by 83%. The corresponding figures in the Oystercatcher groups were 0.8 and 0.2 g fat, a reduction by 75% (Tabs 1–3). Obviously, liver components other than fat and water were appreciably reduced, but further details cannot be analysed from the present data. In the control groups the fat level in dry body mass exceeded the liver fat level but in the starved groups the proportion of fat in the body was lower than in the liver.

4. Summary and discussion

According to the data on gonad weights, the males and females of both year groups and species were in a reproductive phase. The material and the differences are too small for an adequate comparison of the normal and starved groups.

The lipid level of about 9–10% of total body weight in the control groups of both species indicate small residues of migratory fat as non-migratory levels of about 4–6% should be expected in accordance with earlier studies on passerines as well as on waders (e.g. Odum 1960, Johnston 1966, Mascher and Marcström 1976). One of the control Oystercatchers had only 5% fat indicating a postmigratory phase.

The total weights of Lapwings starved to death are in fairly close conformance with results published by other authors as summarized in Tab. 4. The figures by Creutz and Piechocki average 15–20 g lower. The total weight reduction appears smaller in the studies by Harris (1962), Ash (1964) and Vepsäläinen (1968) because these authors calculated with lower normal weight levels. It should be noted that the "normal" total weight is subject to considerable seasonal variation, especially in long-distance migrants which put on large fat depots during the migratory periods. An adequate comparison requires that the groups of birds studied are collected in the same season of the year and that they are in the same physiological phase. In the present study, the control groups were collected somewhat earlier in the spring season than the birds starved to death and possibly had somewhat larger fat residues than would be expected two or three weeks later. On the other hand, most of them were taken at about the same time of the year as the extraordinary climatic stress began to exert its influence on the 1966 birds.

As concerns Lapwings, total weights below 110–135 g seem to be uncompatible with life (Tab. 4). The weight loss recorded in the present study includes a loss of fat-free dry weight by 25 g or 45% and a very drastic reduction of total body fat from a normal level at the end of the migratory period of about 26 g to only 2 g, i.e. a reduction by no less than 92%. Such drastic emaciation as a result of starvation is perhaps not compatible with recovery even if environmental conditions are changed before the death of the birds (cf. Ash 1964 and Vepsäläinen 1968). At which level of emaciation recovery would in fact be possible is unknown. Jordan (1953) found that starving Mallards *Anas platyrhynchos* which had lost about 44% of their normal total weight could still survive. This figure agrees closely with the present data on Lapwings starved to death (Tab. 3).

No relevant literature data have been available to us concerning weight loss under similar circumstances in Oystercatchers. The present results indicate that minimum total weights range about 290–320 g. There was a fat-free dry body reduction by 38.6 g or 35% and a total body fat loss from a normal level in the end of the migratory season of about 45.5 g to 4 g, a reduction by 91%.

There are strong reasons to assume that many bird species exposed to stress situations including food deprivation derive their main energy output from breakdown of fat which yields more than twice as much energy per gram than protein. Concluding from data on small passerines by Farner et al. (1961) the carbohydrate reserves are comparatively small amounting to only one per cent or less of the total weight (cf. Newton 1968) and are used up quickly. When the fat depots are

Tab. 4. Total weights (g) in starved Lapwings. Means and ranges are given.

Author		Starved birds	n	Normal birds	n	Calculated weight reduction
Ash (1964)		133.7 (116.0–146.3)	6	201.6 (180–226.5)	14	67.9
Harris (1962)	♂	140.5 (136–145)	2	210	1	69.5
	♀	128 (124–131)	3	–		
	total	134.2 (124–145)	6			
Vepsäläinen (1968)	♂	137 (111–155)	7	205.3 (191–226.5)	8	68.3
	♀	134 (123–149)	7	196.7 (180–210)	6	62.7
Creutz and Piechocki (1970)	♂	118 (106–132)	3	210.1 (174–259)	24	92.1
	♀	126.6 (117–137)	5	240.2 (205–281)	8	113.6
Present study		139.9 (135.0–145.5)	6	260.1 (232.6–309.1)	6	120.2

Tab. 5. Decrease of body weight, liver weight and lipid content in normal and starved (no food, water ad lib.) Goshawks. In the normal groups, means and standard errors of means are given.

		Body weight (before starvation)	Body weight decrease, %	Liver weight g	Liver lipids g	Liver lipids % of liver wet weight
Normal groups	♂♂	864.3±30.1	–	15.1±2.7	0.64±0.1	4.22±0.2
7 ♂♂, 7 ♀♀	♀♀	1428.9±66.3	–	30.1±2.8	1.17±0.1	3.90±0.2
Starved group	♂	1060	51.3	6.3	0.18	2.8
n = 3	♂	985	42.8	8.2	0.23	2.9
	♀	1260	43.0	7.1	0.19	2.7

Tab. 6. Weight and lipid content of liver in fed and starved (no food, water ad lib.) domestic chicks. Means and standard errors of means are given.

	Wet weight g	Dry substance g	Dry substance %	Lipids g	Liver lipids % of liver wet weight	Liver lipids % of liver dry weight	Water in fat-free substance %
Fed group n = 8	6.38±0.30	1.81±0.09	28.32±0.21	0.214±0.013	3.35±0.07	11.84±0.30	71.6
Starved group n = 9	2.00±0.14	0.54±0.02	26.85±0.66	0.041±0.003	2.04±0.06	7.61±0.34	74.5

emptied there is an increase in the utilization of protein as an additional energy reserve which is displayed in an accelerated loss of fat-free dry body mass (cf. Odum et al. 1961). On the other hand, Hanson (1962) and Newton (1968) claimed that fat mobilization is always accompanied by utilization of protein as well. Further, some recent studies indicate that a certain reduction of muscle protein may occur during regular migratory flights over longer distances. Evans and Smith (1975) found 13% lower weights of pectoral muscles in adult Bar-tailed Godwits *Limosa lapponica* which had presumably crossed the North Sea on autumn migration and were caught at Lindisfarne, Northumberland. Though they were newly arrived their fat indices were not exceptionally low. These authors also pointed out that migratory birds utilize muscle protein in order to maintain protein metabolism rather than as a general source of energy, i.e. when fat reserves are still available to meet the main energy requirements. However, in other bird species muscle protein may be more important as a source of energy. Brittas (unpubl.) found that protein in Willow Grouse *Lagopus lagopus* was almost as important an energy reserve as the fat depots. No doubt, a metabolization of muscle protein accounts for most of the fat-free dry body reduction recorded in the present study, but the pectoral or other muscles were not separately examined.

There was a considerable reduction of total liver mass in the starved groups of both species. Compared with the control groups, liver fat was reduced by 83% in the Lapwings and 75% in the Oystercatchers. The proportional liver fat loss was somewhat lower than in the body as a whole. It is remarkable that non-fat liver tissue was appreciably reduced too. The fat-free dry liver mass was 1.5 g or 71% lower in the starved Lapwings and 2 g or 60% lower, on average, in the starved Oystercatchers.

In an unpublished study on Goshawks one of us (VM) found that total liver weights in seven normal males and seven normal females averaged 15.1 and 30.1 g respectively, whereas the mean liver weight of three starved specimens ranged between 6.3 and 8.2 g. Liver lipids averaged 0.64 and 1.17 g in the two normal sex groups and ranged between 0.18–0.23 g in the starved specimens (Tab. 5). The combined loss of fat and water cannot account for the remarkable reduction of liver weight in the starved group. An appreciable loss of fat-free dry liver substance no doubt must occur. Other unpublished data collected by VM concerning domestic chicks show a more distinct picture since liver dry weights were analysed in addition to fat content (Tab. 6). In a group of 26 d old chicks which were starved for 5 d, liver fat was reduced by on average 81% compared to a control group, but fat accounted for only 0.17 g or 13.4% of the total reduction of liver dry mass by 1.27 g. Concluding from data on small passerines by Baggott (1977), liver glycogen depots amount to less than one per cent of the total liver weight, and can only account for a negligible proportion of such weight losses which are of a magnitude by far exceeding the well-known diel and seasonal variations in liver weights reported in several studies (e.g. Oakeson 1953, Fisher and Bartlett 1957, Farner et al. 1961, Baggott 1977). Hanson (1962) has pointed out that a reduction of liver mass occurs during situations of metabolic stress, and has shown that liver weights are remarkably low in female Canada Geese during the period of egg-laying. However, he did not analyse liver fat and fat-free dry mass separately. The nature of the drastic fat-free dry liver mass reduction in severely starved birds as reported in the present study is still unclear.

The proportional water content in fat-free body tissue was practically unaffected by the starvation stress and accompanying drastic emaciation of the Lapwings and Oystercatchers studied. The constant proportion of water in fat-free body is in accordance with the earlier study by us on resting Dunlins *Calidris alpina* on the island of Öland (Mascher and Marcström 1976, cf also Odum et al. 1964). In fat-free liver mass the water content averaged somewhat larger than in the fat-free body tissue. The study on domestic chicks earlier referred to (Tab. 6) showed the same general picture concerning water content in fat-free liver substance. It should be noted, that though there was a total deprivation of food, the birds had unlimited access to water. Thus, in accordance with Newton and Evans (1966) no abnormal retention of body fluid was found as was supposed by Mackay (1965) to occur as a result of food deprivation.

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