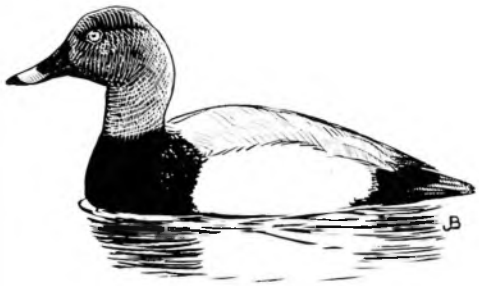
Body composition of starved Tufted Ducks *Aythya fuligula*, Pochards *A. ferina* and Little Grebes *Tachybaptus ruficollis*



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Fresh winter mass of eleven Tufted Ducks, nine Pochards and four Little Grebes, which died in the wild most likely from starvation, are compared with data from birds in normal condition. Fat content, dry and lean dry mass were recorded by standard procedures. All starved specimens had lost 26–56% of normal fresh mass. The mean water content of the starved birds was 76–79%, lean dry mass accounted for 96–98% of dry mass, total fat made up 2.2 to 3.5% of dry mass. When estimating body condition and survival time without food intake, these values of non-metabolized tissue have to be taken into account.

Birds wintering in northern latitudes generally increase in mass as they accumulate body reserves to survive periods of severe weather and reduced food availability (Newton 1969, King 1970, Evans & Smith 1975, Davidson 1981, Baldassare *et al.* 1986). Estimations of body condition and calculations of the potential survival time without food intake are usually based on the amount of fat and protein which may be mobilised (Wishart 1979, Piersma 1984, Miller 1986).

Fat reserves are measured either directly by carcass analysis or indirectly by estimations based on body mass and body dimensions (Piersma 1984, Gauthier & Bédard 1985, Perdeck 1985). Both methods require a knowledge of the quantity of structural fat and non-metabolizable protein, which are unavailable as an energy source.

In this study, the fat and lean dry mass of Tufted Ducks *Aythya fuligula*, Pochards *A. ferina* and Little Grebes *Tachybaptus ruficollis* which had died from starvation have been analysed. As material from starved birds is not readily available, the data are presented in detail and compared with ducks of normal winter mass.

Material and Methods

Eleven starved (6 males, 5 females) and four non-starved (3 males, 1 female) Tufted Ducks, nine starved (4 males, 5 females) and three male non-starved Pochards and four starved Little Grebes (2 males, 2 females) were available. The starved specimens were found dead on the River Rhine below the Lake of Constance (Switzerland) on 11, 13 and 22 March 1986 during a cold spell. The non-starved ducks were found dead on 5 February 1987 at the Rhine near Basle, and analyses by the Toxicological Institute of Zürich revealed an acute poisoning leading to an almost instantaneous death. We received the carcasses of the poisoned ducks without viscera, liver, heart, stomach, and three specimens without their heads.

Wing-length (maximum chord) was measured, the specimens plucked and divided into the following parts: head (including 4 cm of the neck), the flight muscles M. pectoralis major, M. supracoracoideus, if available, viscera (empty), stomach (empty), liver, heart and the remaining carcass without sternum.

All these parts were dried to constant mass at 70°C. Fat was extracted in a Soxhlet apparatus with petroleum-ether as a solvent (Jenni & Jenni-Eiermann 1987). Phospholipids, which make up the bulk of structural fat are removed to a greater extent by a chloroform-methanol mixture than by the solvent we used (Dobush *et al.* 1985). We preferred petroleum-ether, because it extracts hardly any non-lipid material and is therefore suited to estimate the protein content more accurately (Dobush *et al.* 1985). The water content was calculated as the difference between fresh and dry mass, fat as that of dry and lean dry mass (LDM).

The dry mass and the length of sternum and keel were taken as a measurement of body size. Keel-length was measured with calipers on the ventral side of the sternum from the caudal end of the keel to the cranial tip, "sternum-length" on the dorsal side from the caudal end (same point as above) to the cranial base of the keel.

Results

Starved birds

(i) Body-mass and body-composition

The starved specimens of the two duck species had lost 26–40% and the Little Grebes up to 56% of normal winter mass (Table 1). The body composition of the three species is almost identical (Tables 2–4). The percentage of water differs in the various parts between 69–81% according to the amount of structural fat. The water content is low in organs with a high amount of structural fat (e.g. nervous tissue, cell membranes), as lipids in fatty tissues are stored with only 15% water in cytosol (Jungermann & Möhler 1980). The LDM made up for 87–100% of dry mass. The fat extracted may be defined as structural, non-metabolized fat. Most of the fat is found in the head and carcass (80% in Tufted Ducks and Pochards, 73% in Little Grebes), whereas only traces could be found in the muscular tissues, the two breast muscles, heart and stomach.

(ii) Sexual differences and body size

The measurements of wing-length of our sample (Table 5) agree with more representative data which show a size difference of 7–9 mm between the sexes in Tufted Ducks and Pochards (Bauer & Glutz 1969). Sternum- and keel-length as well as its dry mass are significantly smaller in female Tufted Ducks than in male (Table 5).

In accordance with their smaller size, the body mass of the starved female Tufted Ducks are significantly lighter than those of the males ($P = 0.025$, Table 1). Fresh mass, dry mass and LDM of the separate body parts show the same trend (Table 2), with a significant difference for head (fresh, dry mass and LDM) and stomach (dry mass, LDM). In the Pochards, the mean values of the females are lower (Table 1), but no significant differences are found in keel or sternum measurements (Table 5), the fresh, dry and LDM of the body parts (Table 3). The same applies for the total amount of fat in both species.

Wing-, keel- as well as sternum-length of all Tufted Ducks correlate significantly with the entire fresh mass, explaining 41%, 48% and 51% respectively, of the variation (Table 6). The amount of structural fat is expected to increase with body size but no significant correlation of the entire fat with any of the body measurements was found in Tufted Ducks. The correlation between all three body measurements and total LDM showed a positive trend but no significant result. For the Pochards no significant correlation between size and mass could be demonstrated.

Comparison of starved and non-starved ducks

The small sample of Tufted Ducks and Pochards of normal mass does not justify a separate comparison of male and female.

Table 1. Mean body mass (g) of ducks and grebes with standard deviation and sample size. Normal mass during January (*), December–February in the Camargue, France (**), December–January, Switzerland (***).

		Starved March 86	Normal February 87	(Bauer & Glutz 1969)
Tufted Duck	Male	485 ± 25(6)	823 ± 83(3)	729 ± 77(100)*
	Female	440 ± 31(5)	725 (1)	681 ± 83(200)
Pochard	Male	616 ± 24(4)	963 ± 65(3)	849 (119)**
	Female	595 ± 62(5)		807 (202)
Little Grebe	Male	145, 145		256 ± 28(5)***
	Female	127, 145		308, 315

Table 2. Mean mass of body parts (g) of starved Tufted Ducks with standard deviation. Sex differences were tested by t-test, * = $P<0.05$. Sample size: 6 male, 5 female.

		Fresh mass	Dry mass	LDM	Fat
Carcass[a]	Male	217.85 ± 17.1	61.26 ± 3.0	59.91 ± 2.9	1.35 ± 0.70
	Female	200.14 ± 17.9	57.04 ± 3.5	55.98 ± 3.4	1.06 ± 0.29
Head incl. neck	Male	45.68 ± 5.7	12.69 ± 1.6	12.09 ± 1.5	0.60 ± 0.10
	Female	38.54 ± 3.3*	10.99 ± 0.6*	10.41 ± 0.6*	0.58 ± 0.06
M. pectoralis major[b]	Male	21.04 ± 3.9	4.14 ± 0.8	4.14 ± 0.8	0.01 ± 0.01
	Female	18.56 ± 2.4	3.79 ± 0.5	3.75 ± 0.5	0.04 ± 0.04
M. supra-coracoideus[b]	Male	3.01 ± 0.4	0.63 ± 0.1	0.63 ± 0.1	0.00
	Female	2.81 ± 0.1	0.56 ± 0.0	0.55 ± 0.0	0.02 ± 0.03
Heart	Male	5.70 ± 1.4	1.22 ± 0.3	1.22 ± 0.3	0.00
	Female	5.93 ± 0.4	1.26 ± 0.1	1.25 ± 0.1	0.01 ± 0.02
Stomach	Male	30.82 ± 5.6	8.06 ± 1.4	8.00 ± 1.4	0.06 ± 0.04
	Female	26.69 ± 2.5	6.48 ± 0.5*	6.43 ± 0.5*	0.05 ± 0.05
Liver	Male	11.69 ± 3.0	2.67 ± 0.7	2.57 ± 0.7	0.09 ± 0.03
	Female	11.67 ± 1.9	2.53 ± 0.4	2.42 ± 0.4	0.11 ± 0.03
Viscera	Male	31.15 ± 7.3	6.31 ± 1.6	6.10 ± 1.6	0.20 ± 0.09
	Female	37.64 ± 7.6	9.12 ± 3.1	8.85 ± 3.0	0.27 ± 0.08
Total[c]	Male	485.2 ± 24.8	104.6 ± 7.4	102.2 ± 7.4	2.32 ± 0.78
	Female	439.9 ± 31.0	98.4 ± 6.7	96.2 ± 6.7	2.19 ± 0.52

[a] Body mass minus all partial masses listed, feather and sternum mass.
[b] Left side only.
[c] Totals include both sides of breast muscle. Totals of dry mass, LDM and fat exclude dry feather mass (32.8 ± 2.9).

Table 3. Mean mass of starved Pochards (4 male, 5 female). See Table 2.

		Fresh mass	Dry mass	LDM	Fat
Carcass[a]	Male	299.03 ± 7.8	81.84 ± 3.7	79.91 ± 3.5	1.92 ± 0.48
	Female	278.82 ± 20.7	76.90 ± 4.4	75.30 ± 4.4	1.60 ± 0.23
Head incl. neck	Male	68.21 ± 4.7	19.66 ± 0.9	18.80 ± 0.8	0.86 ± 0.18
	Female	60.42 ± 6.5	17.59 ± 2.1	16.77 ± 2.0	0.82 ± 0.04
M. pectoralis major[b]	Male	22.47 ± 4.4	4.48 ± 0.9	4.43 ± 0.9	0.05 ± 0.04
	Female	24.52 ± 3.6	5.11 ± 0.8	5.06 ± 0.7	0.05 ± 0.02
M. supra-coracoideus[b]	Male	3.44 ± 0.6	0.69 ± 0.1	0.68 ± 0.1	0.01 ± 0.02
	Female	3.67 ± 0.5	0.74 ± 0.1	0.73 ± 0.1	0.01 ± 0.01
Heart	Male	8.67 ± 2.0	1.83 ± 0.6	1.82 ± 0.6	0.01 ± 0.01
	Female	7.52 ± 1.2	1.52 ± 0.3	1.51 ± 0.3	0.02 ± 0.01
Stomach	Male	34.95 ± 9.9	8.99 ± 2.5	8.87 ± 2.5	0.13 ± 0.11
	Female	34.19 ± 4.6	8.35 ± 1.1	8.27 ± 1.1	0.08 ± 0.05
Liver	Male	14.10 ± 3.8	3.05 ± 1.1	2.84 ± 1.1	0.22 ± 0.18
	Female	14.16 ± 0.8	3.02 ± 0.2	2.84 ± 0.2	0.18 ± 0.08
Viscera	Male	37.86 ± 8.0	7.34 ± 2.3	7.07 ± 2.2	0.27 ± 0.11
	Female	35.51 ± 5.8	6.85 ± 1.6	6.63 ± 1.6	0.22 ± 0.07
Total[c]	Male	616.2 ± 24.0	136.0 ± 6.7	132.5 ± 6.0	3.52 ± 0.98
	Female	595.2 ± 61.9	128.9 ± 7.3	125.9 ± 7.4	3.01 + 0.36

[a] Body mass minus all partial masses listed, feather and sternum mass.
[b] Left side only.
[c] Totals include both sides of breast muscles. Totals of dry mass, LDM and fat exclude dry feather mass (41.8 ± 3.1).

The differences between the starved and normal ducks, however, are so large, that they cannot be explained by sexual differences. The fresh, dry and fat mass of all body parts analysed of both duck species are significantly lower in the starved group (Table 7, 8). Compared with normal Tufted Ducks, the starved birds show no more than 1–13% of the amount of fat. The protein level is also very low. The LDM of the breast muscles weighs about one third (38% M. supracoracoideus, 27% M. p. major) of the LDM in the non-starved ducks. The LDM of the carcass is reduced by 30% and even the LDM of the head is reduced by 17%.

The decrease in mass of the Pochards is similar to that of the Tufted Ducks: the amount of fat varies between 2% (M. p. major) and 13% (head) of that in normal ducks. The LDM is reduced to 35% in M. supracoracoideus and 26% in M. p. major, whereas carcass and head lost 28% and 22% respectively, of their LDM.

Table 4. Data from four starved Little Grebes. See Table 2.

		Fresh mass	Dry mass	LDM	Fat
Carcass[a]	Male	81.73, 81.53	24.56, 24.72	24.14, 24.10	0.42, 0.62
	Female	68.22, 81.05	21.53, 24.14	20.93, 23.59	0.60, 0.55
Head incl. neck	Male	9.77, 9.30	2.82, 2.65	2.62, 2.42	0.20, 0.23
	Female	8.68, 9.46	2.51, 2.73	2.36, 2.63	0.15, 0.10
M. pectoralis major[b]	Male	3.26, 3.01	0.72, 0.68	0.72, 0.64	0.00, 0.04
	Female	1.43, 2.13	0.30, 0.46	0.30, 0.43	0.00, 0.03
M. supra-coracoideus[b]	Male	0.55, 0.44	0.12, 0.10	0.12, 0.07	0.00, 0.03
	Female	0.32, 0.43	0.07, 0.10	0.07, 0.08	0.00, 0.02
Heart	Male	2.87, 2.32	0.66, 0.55	0.66, 0.52	0.00, 0.03
	Female	2.05, 2.78	0.49, 0.58	0.49, 0.55	0.00, 0.03
Stomach	Male	4.55, 4.29	1.14, 1.46	1.14, 1.42	0.00, 0.04
	Female	3.10, 4.63	0.79, 1.20	0.79, 1.16	0.00, 0.04
Liver	Male	7.78, 6.44	2.06, 1.69	2.04, 1.63	0.02, 0.06
	Female	6.02, 9.39	1.63, 2.50	1.57, 2.29	0.06, 0.21
Viscera	Male	8.30, 8.21	1.89, 2.01	1.86, 1.88	0.03, 0.13
	Female	8.31, 8.84	1.74, 1.92	1.68, 1.81	0.06, 0.11
Total[c]	Male	145.9 , 144.8	35.3 , 35.2	34.2 , 33.4	0.66, 1.24
	Female	126.5 , 145.3	29.9 , 34.7	28.6 , 33.0	0.87, 1.15

[a] Body mass minus all partial masses listed, feather and sternum mass.
[b] Left side only.
[c] Totals include both sides of breast muscles. Totals of dry mass, LDM and fat exclude dry feather mass (10.3 ± 1.0).

Table 5. Means of body measurements with standard deviation and sample size of starved Tufted Ducks and Pochards. p = probability in t-test for sexual differences of means.

	Male	Female	p
Tufted Ducks			
Wing-length (mm)	206.5 ± 2.4 (6)	203.6 ± 3.2 (5)	n.s
Keel (mm)	84.47 ± 1.6 (6)	80.46 ± 2.0 (5)	0.006
Sternum (mm)	68.25 ± 0.9 (6)	65.76 ± 1.5 (5)	0.008
Sternum (g)	2.82 ± 0.1 (6)	2.32 ± 0.2 (5)	0.004
Pochards			
Wing-length (mm)	220.5 ± 3.3 (4)	214.0 ± 1.9 (5)	0.007
Keel (mm)	88.30 ± 1.4 (4)	87.42 ± 2.8 (5)	n.s.
Sternum (mm)	70.58 ± 1.5 (4)	70.20 ± 1.9 (5)	n.s.
Sternum (g)	2.97 ± 0.3 (4)	3.00 ± 0.3 (5)	n.s.

Discussion

Body composition of starved ducks

The amount of fat, which was not metabolized by the starved ducks, is less than 1% of their body mass. Similar results were obtained in starved Willow Grouse *Lagopus lagopus* (Brittas & Marcström 1982), Lapwings *Vanellus vanellus* and Oystercatchers *Haematopus ostralegus* (Marcström & Mascher 1979), Coots *Fulica atra* (Visser 1978) and Great Crested Grebes *Podiceps cristatus* (Piersma 1984). A similar decrease of LDM as in our Tufted Ducks (39%) and Pochards (38%) was also found in starved Lapwings and Oystercatchers (45%), Coots (46%) and Great Crested Grebes (44%). This mass decrease is expected to be caused by a catabolism of muscle protein (Visser 1978). During prolonged starvation the protein catabolism is reduced to a more economic level, but increases again in the final critical stage of starvation (Le Maho 1984). This does not necessarily coincide with the depletion of the fat reserves. It has been shown that this final protein exhaustion was started before or after the fat reserves were fully depleted (Le Maho *et al.* 1981, Robin *et al.* 1988). In cold weather, death from starving may be due to hypothermia without depleting all

Table 6. Least squares linear regression of size measurements on fresh mass of starved Tufted Ducks (n = 11). a = intercept, b = regression coefficient, r = correlation coefficient with probability (p).

Size measurement	a	b	r	p
Wing-length	179.5	0.055	0.640	0.034
Keel-length	58.0	0.053	0.690	0.019
Sternum-length	51.0	0.035	0.712	0.014

Table 7. Mean mass (g) with standard deviation of starved (n = 11) **and normal** (n = 4, for head n = 2) **Tufted Ducks.** The data of both groups do not overlap and are significantly different. n = normal, s = starved.

		Fresh mass	Dry mass	LDM	Fat
Carcass[a]	n	303.37 ± 44.2	136.34 ± 39.4	83.45 ± 11.2	52.89 ± 40.8
	s	209.80 ± 18.9	59.34 ± 3.8	58.12 ± 3.6	1.22 ± 0.5
Head incl. neck	n	53.41 ± 0.3	18.28 ± 0.7	13.67 ± 0.4	4.60 ± 1.1
	s	42.43 ± 5.9	11.92 ± 1.5	11.32 ± 1.4	0.59 ± 0.1
M. pectoralis major[b]	n	55.14 ± 6.0	17.09 ± 3.6	14.48 ± 1.4	2.60 ± 2.6
	s	19.91 ± 3.4	3.98 ± 0.7	3.96 ± 0.7	0.02 ± 0.0
M. supracoracoideus[b]	n	6.42 ± 0.9	1.71 ± 0.2	1.55 ± 0.3	0.15 ± 0.1
	s	2.92 ± 0.3	0.60 ± 0.1	0.59 ± 0.1	0.01 ± 0.0

[a] Body mass minus all partial masses, feather and sternum mass.
[b] Left side only.

Table 8. Mean mass (g) with standard deviation of starved (n = 9) **and normal** (n = 3, for head n = 2) **Pochards.** See table 7.

		Fresh mass	Dry mass	LDM	Fat
Carcass[a]	n	401.27 ± 59.6	170.02 ± 9.8	108.05 ± 14.4	61.97 ± 5.2
	s	287.80 ± 18.7	79.10 ± 4.6	77.35 ± 4.5	1.74 ± 0.4
Head incl. neck	n	83.00 ± 7.5	28.78 ± 1.7	22.53 ± 2.2	6.25 ± 0.5
	s	63.88 ± 6.8	18.51 ± 1.9	17.68 ± 1.9	0.84 ± 0.1
M. pectoralis major[b]	n	67.28 ± 7.2	20.73 ± 2.0	18.35 ± 2.7	2.37 ± 0.8
	s	23.61 ± 3.9	4.83 ± 0.9	4.78 ± 0.8	0.05 ± 0.0
M. supracoracoideus[b]	n	8.04 ± 0.3	2.23 ± 0.0	2.05 ± 0.1	0.18 ± 0.0
	s	3.56 ± 0.5	0.72 ± 0.1	0.71 ± 0.1	0.01 ± 0.0

[a] Body mass minus all partial masses, feather and sternum mass.
[b] Left side only.

reserves. While fat reserves will normally be depleted also under cold weather conditions, this might not be the case for protein reserves (Davidson & Clark 1985). We assume that fat reserves in our starved birds are completely or almost completely depleted because we found only traces of fat, consistent with other studies (see above). Although muscle atrophy was very apparent, we cannot be sure that all possible protein has been catabolised. Moreover, it is not known whether the starved ducks could have recovered from a critical minimum mass if environmental conditions had changed before their death (Ash 1964, Vepsäläinen 1968).

Size dependence of lean body mass

Tufted Ducks and Pochards are sexually dimorphic in size and mass. A significant relationship between linear body measurements and fresh lean body mass could also be demonstrated in Tufted Ducks. Other studies demonstrate a relationship between wing-length and lean dry mass, e.g. in starved American Wigeon *Anas americana* (Wishart 1979) and moderately fat Bramblings *Fringilla montifringilla* (Jenni & Jenni-Eiermann 1987). Relationships between body measurements or body mass and lean dry mass of fat birds or of birds of different physiological states are difficult to establish, because protein reserves, water content and mass of organs may vary (Davidson 1983, Jenni & Jenni-Eiermann 1987). The structural fat of both species does not correlate with wing-, sternum- or keel-length. Wishart (1979) also did not find a relationship between structural fat and size in American Wigeons. The fat reserves of the non-starved Tufted Ducks and Pochards (without organs) amounted to about 63 and 73 g respectively. The average structural fat forms 3% and 3.7% in Tufted Ducks and Pochards respectively, of the normal amount of winter fat. A size dependent variation in structural fat with a range of about 2.3 g (Tufted Ducks) and 1.5 g (Pochards) could therefore be neglected.

When estimating fat and protein reserves of non-starved Tufted Ducks and Pochards, the amount of structural fat and non-metabolized protein should be subtracted from the total. Provided the same solvent is used (cf. Dobush *et al.* 1985) and assuming similar depletion of protein, the data of this study might be used.

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