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Seasonal changes in the weight and composition of the liver of the willow grouse (Lagopus lagopus) in the far north of Finland[1]

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The fresh weight of the liver was determined in 199 willow grouse (*Lagopus lagopus*) shot in the far north of Finland within three years. There were no age-related differences in the fresh weights of the livers. They showed remarkable seasonal variation, the highest values being recorded in summer and the smallest in late winter. The fresh weights of the female livers increased from February-March to April-May, but those of the males did not, whereas those of the male livers were higher than those of the females in November-March. The liver/net body weight ratio of adult birds was highest in summer and lowest in February-March, while that of young males was higher than that of adult males in September-October. The glycogen content was higher in September-October than in any other periods. No differences in water and protein content were found between the livers of the willow grouse killed in autumn and winter.

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1. Introduction

Although the functions of the avian liver for digestion, protein, fat and carbohydrate metabolism and the detoxication of metabolites are well known (see review in Sturkie 1976), practically nothing is known about the seasonal changes in the size of the liver, although this is potentially possible in view of the functions mentioned and the storage propensity of the liver. The observation that seasonal changes do in fact occur in the lengths of the small intestine and caeca of the willow grouse (*Lagopus lagopus* L.) (Pulliainen & Tunkkari 1983) led the authors to continue their studies in order to determine whether similar changes take place in the dimensions of other internal organs in this species. The purpose of the present paper is to provide data on the liver.

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2. Material and methods

A total of 199 willow grouse were shot in the districts of Inari, Savukoski and Salla in the far north of Finland within a period of three years, from February 1981 to February 1984. They were refrigerated as soon as possible and sent to Oulu, where they were weighed (without crop contents). The birds were sexed and aged according to Bergerud et al. (1963) and Myrberget (1974). Both fresh and dry weights of the livers were recorded (dried at 80° C on an aluminium plate for 2 days). Glycogen and protein were determined from fresh samples of the birds killed in autumn and winter. The former determinations were carried out after Siu et al. (1970) and the latter by the Kjeldahl method. The coefficient 6.25 was used for calculating the amount of (crude) protein.

3. Results

The main results obtained were as follows:

1) There were no age-related (2-3 months old and older) differences in the fresh weights of the livers in the birds studied. Consequently no distinctions of age are made here.

2) Statistically significant seasonal variations were recorded in the fresh weights of the livers of

both male ($F=4.11$, $P<0.01$, $df_1=4$, $df_2=114$) and female ($F=3.64$, $P<0.01$, $df_1=4$, $df_2=77$) willow grouse. The highest fresh weights were found in summer and the smallest in late winter (Fig. 1). The fresh weights of the female livers increased from February-March to April-May, but those of the males did not, whereas those of the male livers were higher than those of the females in November-January ($t=2.25$, $P<0.05$, $df=23$) and February-March ($t=2.84$, $P<0.01$, $df=54$).

3) The liver/net body weight ratio of both sexes of adult birds was highest in summer and lowest in February-March, while that of young males was higher than that of adult males in September-October ($t=3.18$, $P<0.01$, $df=37$). No corresponding difference was recorded among the females ($t=0.73$, ns, $df=43$).

4) The glycogen content was higher in September-October than in any other periods (Table 1). No differences in water and protein content were found between the livers of the willow grouse killed in autumn and winter.

Table 1. Glycogen, protein and water content of the liver of the willow grouse killed in Finnish Lapland in autumn and winter.

Season	Mean±*SE*	*n*	*t*-test	
Glycogen (mg/g)				
Sept-Oct	8.27±1.22	63	5.11***	4.75***
Nov-Jan	1.88±0.28	14	1.00^{ns}	
Feb-March	2.29±0.30	24		
Protein (% of dry weight)				
Sept-Oct	78.08±0.82	14	0.19^{ns}	
Nov-Jan	77.77±1.42	10		
Water (%)				
Sept-Oct	71.92±0.17	45	1.46^{ns}	
Feb-March	71.57±0.17	24		

4. Discussion

Morse (1975) assumes that interactions over food sources are most important in leading to adaptive radiation in birds, while according to Magnan (1910), the liver is smallest in relative terms in carnivores and granivores and largest in piscivores and insectivores. The frugivorous waxwing (*Bombycilla garrulus*) appears to have a relatively large liver, which it needs for rapid metabolism and probably also as a detoxication organ (Pulliainen et al. 1981, Eriksson & Nummi 1983).

The present data (Fig. 1) shows that the fresh weight of the liver may vary considerably from one season to another. Two questions arise here. What in fact happens in the liver, and what causes it?

It is known that the liver can serve as a store for lipids and glycogen (Ziswiler & Farner 1972). The present data show that the water and protein content of the liver remains unchanged from autumn to winter, while changes take place in its glycogen content (Table 1). Earlier changes in glycogen levels have been recorded as occurring in the liver and muscle during the embryonic life and various growth phases of the chick (Freeman 1969), but they are now seen to take place during juvenile and adult life, too. The absolute amounts of glycogen in the liver, even when they are at their maximum in autumn, are, however, so small that they explain only a very small fraction of the variation in the fresh weight of the liver. The explanation may thus lie either in the fat content or in the amount of liver tissue or it is some kind of hypertrophy.

The weight of the liver and its glycogen content were here found to increase in summer and autumn (Fig. 1, Table 1) simultaneously with an increase in the length of the small intestine (Pulliainen & Tunkkari 1983). The latter is necessary in order to increase the absorptive surface of the intestine at a time when the willow grouse eats considerable amounts of berries, from which it mainly utilizes the flesh (especially sugars). It may be that the high incidence of sugars and other carbohydrates in the diet of the willow grouse results in the storage of glycogen, a reserve polysaccharide, in its liver. This liver glycogen is then either catabolized or turned over, producing glucose, which diffuses into the blood. This blood glucose is subsequently taken up by the muscles and used to synthesize muscle glycogen. The high standard deviation recorded here for the glycogen content in September-October (9.65) as compared with that recorded in winter (1.47) also indicates the active role the liver is playing in the process of glycogen storage during the former period. In this process a great amount of liver tissue can be considered to be beneficial.

The weight of the liver of the male willow grouse was found to be higher on average than that of the female in November-March (Fig. 1). This difference may be solely due to a corresponding difference in the total net weight of the birds,

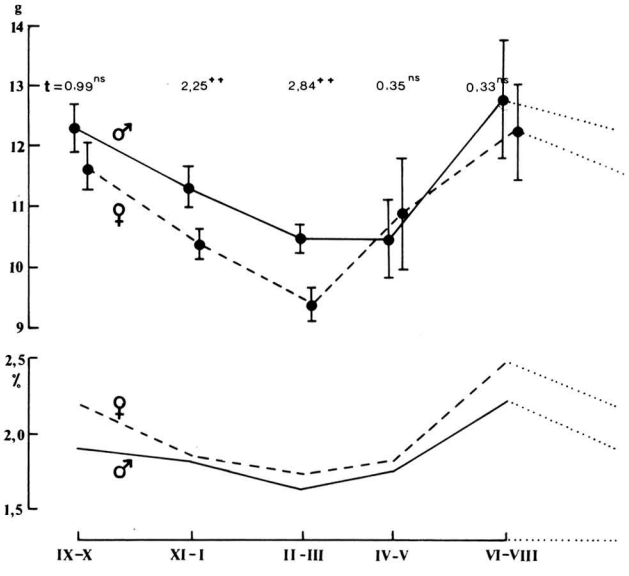

Fig. 1. Seasonal changes in the fresh weight of the liver (g, mean ± *SE*) and the proportion of the fresh weight of the liver of the net body weight (%, lower curves) of the willow grouse killed in Finnish Lapland (*t*-values indicate statistical significance of the differences in the fresh weights of the livers between the sexes).

the males being heavier than the females (Pulliainen 1968, 1976). At this time of year the composition of the food intake of these birds is very unvarying, with no differences occurring between the sexes (Pulliainen & Iivanainen 1981).

The fresh weights of the female livers increased from February-March to April-May, but those of the males did not. This may be due to the fact that the liver synthesizes proteins for the eggs. On the other hand, the males consume a lot of energy for display activities in the spring, which may be reflected in "condition indices" such as the weight of the liver.

The young males have relatively heavier livers than the old males in September-October. The former are still growing at that time, so that intensive metabolism and a large liver are needed. Very young willow grouse also have relatively large hearts and long intestines compared with those of the adult birds (unpubl. data). It is not worth maintaining internal organs of too large a size during the adult life.

The space available in the abdominal cavity of the willow grouse accommodates a certain amount of variation in the size of the internal organs. The use of this facility, which has been verified in the case of the lengths of the small intestine and caeca (Pulliainen & Tunkkari 1983), and the weight (size) of the liver (this study) must similarly be of adaptive significance in the life of these non-migratory birds under severe northerly conditions.

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