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Comparision of red deer stomach in relation to different foraging habitat

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Summary

The aim of the study was to evaluate the stomach chambers of Zielonogorskie (Z) and Bieszczady (B) red deer (Cervus elaphus L. 1758) from different foraging habitats in South-West and South-East Poland. Thirteen calves, ten hinds and bulls were shot in Z and B, and examination of the carcasses indicated the substantial impact of foraging strategies in various habitats on polygastric parameters. Differences (P<0.05) in stomach content (SC), fresh and dry matter of stomach tissue (FSTM, DSTM) and total stomach area (TSA) were noted between the deer of Z and B. Additionally, some indexes (IA, IB) of FSTM, DSTM in relation to body mass (carcass weight, C) were relatively higher in each category of deer from the B region. Comparisons of ID (ratio DSTM to TSA), IE (DSTM to metabolic body mass - C0.75) and IF (TSA to C0.75) indicated a relatively thicker stomach tissue wall, and its larger overall area and volume of some stomach chambers in deer from the B vs. Z region.

The study indicates that the carrying capacity of habitats, and conditions such as the quality and abundance of plants (their structure and nutritional value) considerably influence modifications within the digestive system, and mainly the stomach chambers in polygastric wild ruminants.

Keywords: red deer (Cervus elaphus L.), stomach habitat

Wild ruminants show morphological adaptation to the utilization various habitat (4, 9, 11, 17). Although, many researchers from all over the world have reviewed scientific knowledge of their gastrointestinal tract carefully, the studies are continued on detailed comparison of the digestive system dependent upon an ecology condition (habitat) (1, 2, 5, 10, 11, 16).

Precisely examined and described some aspects of the anatomy and physiology of gastrointestinal tract, metabolism of digestion nutrients and general digestive problems as well as nutrition ecology in mammals have allowed to recognize evolutionary steps of the ecophysiological adaptation and diversification of ruminants (4, 5, 7, 9, 10, 13, 17). Also, some of wild herbivores are or/and could be an important bioindicators of human environments, because they are keystone species in many ecosystems (8, 9). Thus, knowledge of various habitats could have a significant influence on the digestive principle parameters in wild mammals. A habitat carrying capacity (condition) is causing increase population, decrease or remain stable, too (14). A key and primary factors are adaptive to feeding ecology, food quality and availability, but also recognized selectivity by wild mammals became basis of classification herbivorous provided by Hofmann (9). According to this verification, ruminants are related to three morphophysiological feeding types such as concentrate selectors (browsers), grass and roughage eaters (grazers) and intermediate, opportunistic, mixed feeders (9, 17). Concentrate selectors have a relatively lower digestive tract than grazers, however selectors and mixed feeders have tendency to larger hindguts in relation to rumen size and smaller rumen relatively to body size (17). Typical selector (ex. roe deer) possesses small rumen and less developed omasum and a larger liver. In a consequence more available nutrients passage to markedly larger lower digestive tract (bypass). The further studies (1, 3-5, 7, 11, 16) focuses on dietary structural type, classification of diet in different environments, the role of spatial and temporal variation in herbivore, vegetation abundance, size of bite, foraging behavior, which could explain different diet consumption and the morphometric correlation data with feeding type and body mass (weight) in mammals.

Importance of polygastric parameters (stomach chambers structure, size ex.) in the relation to their function as well as significant aspects of feeding strategy in habitat lead to undertake further research on wild ruminants. In specific ecological condition, feeding carrying capacity of habitat dependent upon plant quality, abundance and availability, in some particular way respect wild herbivores nutrition strategy and can promote animal stomach advantageous to the adaptation.

Population density of red deer (*Cervus elaphus* L.) in Poland has been spread out widely in the whole country (12). However, there are determinable differences between individuals of various habitat regions in the country (12). This study focus on some detailed differences in red deer stomach characteristics parameters, being affected by consuming various categories of food and such the response of feeding behaviors in various habitats.

Material and methods

Thirty-three red deer (*Cervus elaphus* L.) stomachs, including thirteen calves, ten hind and bulls were shot in the winter time (November-January), in the South-West and South-East of Poland, respectively Zielonogórskie (Z) and Bieszczady (B) region. The body mass (carcass) of deer was weighed after they had been shot, disemboweled and the internal organs had been removed.

Before any measurement was taken each stomach had removed the fat and fascia. The reticulum was divided along with the reticulo-rumen and the reticulo-omasum vent. The omasum and omasum-abomasum vent were excised from the abomasum. Each stomach chamber was weighed together with its contents. Then, the contents was removed, the stomach chambers was precisely rinsed away in water, and lightly dried with the blotting paper. Cleaned stomach chambers were weighed again to the nearest gram. Subsequently, each stomach chamber area was measured after the individual chamber was spread out on paper and drawn the shape and surface. The area was measured by using the planimetria. Then, each chamber was dried for six days at 60°C and weighed again.

Data were subjected to analysis by the ANOVA procedure (19). The significant differences between means were determined by t-test of Student.

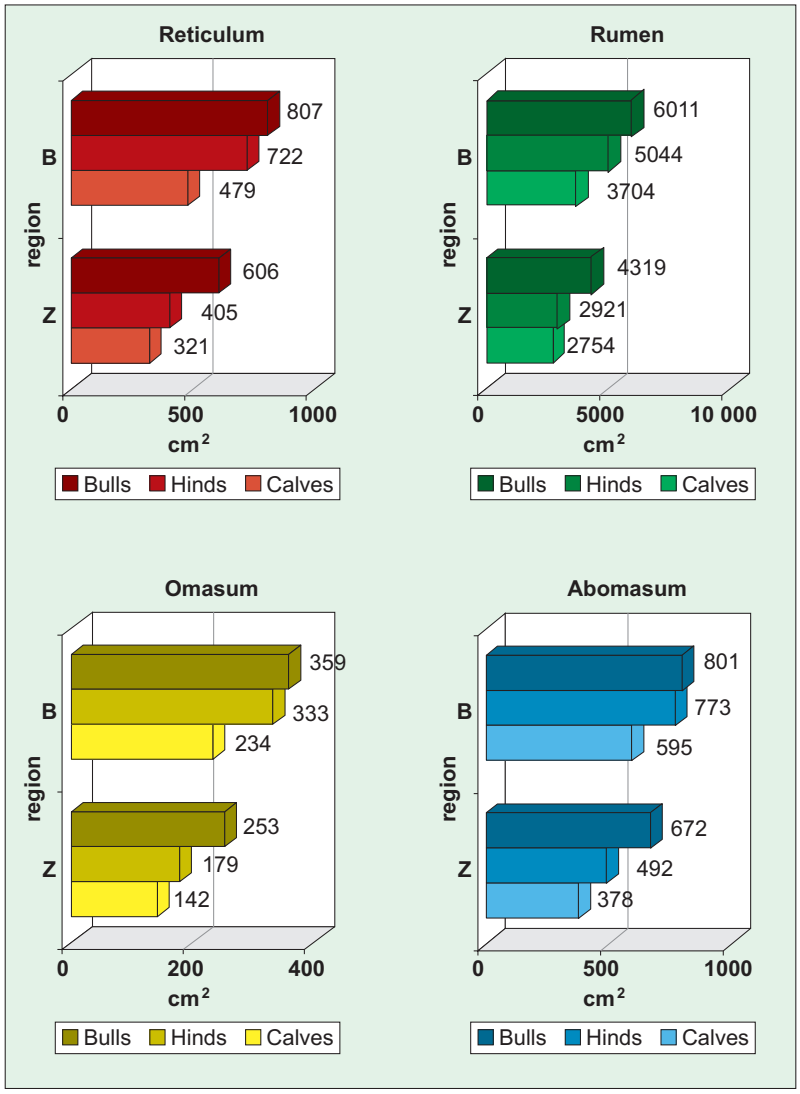

Fig. 1. Stomach chamber area (SCA, cm²) of red deer from Zielonogórskie (Z) and Bieszczady (B) region (between Z and B, P < 0.05)

Results and discussion

As red deer is classified into mixed or intermediate feeders, their morphology and physiology is adaptive to the consumption and digestion both browse and graminaceous plants material (diet) (4, 5, 9). However, feeding ecology seems to have substantial impact on the optimal strategies of foraging by particular individuals, because red deer besides other wild ruminants is depend upon food carrying capacity of a forest habitat (3, 4, 6, 7, 9, 10, 16). Therefore, even slight vegetation quality changes and/or their availability affect substantially animal body size (mass) and condition (13). Moreover, body mass (weight) of deer is a major determinant of survival individuals and their reproductive performance (13, 14). Variable topography of habitat influence on the access to nutritious food, too. Thus, it can caused physiomorphological variation of digestive system between individuals of deer. Our research support some of the earlier studies concerning principles of foraging behavior of ruminants that specializing on segregation different diets and interact with the food availability in various ecosystems condition (5, 7, 14).

Significant differences ($p < 0.05$) were found among stomach parameters in the most cases in calves, hinds and bulls of Zielonogórskie (Z) and Bieszczady (B) region (fig. 1, tab. 1, 2). Stomach content (SC), fresh and dry matter of stomach tissue mass (FST_M and DST_M) were higher ($p < 0.05$) in calves and hinds from B region indicating on better foraging ecology and behavior strategy in this habitat. Similarly, SC, FST_M and DST_M had bigger values in bulls of the B area (tab. 1). It suggests the variation in the composition of plant material consumed by deer in this region as well as the optimal strategies for the consumption and digestion such diets were higher and more efficient in B in comparison to Z habitat. Lower DST_M in deer from Z indicates on lower stomach fatness resulted in poorer deer body condition.

Also, markedly larger rumen (fig. 1, tab. 2) in each group of deer from Bieszczady is closely linked with

Tab. 1. Comparison of stomach parameters in deer of Zielonogórski (Z) and Bieszczady (B) region

Specification	Calves		Hinds		Bulls	
	Z	B	Z	B	Z	B
Stomach content – SC (g)	6179^a	9599^b	7623^a	15914^b	14573	18988
Fresh stomach tissue mass – FST_M (g)	1438^a	2046^b	1940^a	3559^b	3194^a	4643^b
Dry matter of stomach tissue mass – DST_M (g)	210^a	352^b	322^a	666^b	484^a	879^b
Total stomach area – TSA (cm^2)	3593^a	5012^b	3997^a	6873^b	5852^a	7980^b
Water content in stomach tissue – WCST (%)	85.6^b	82.7^a	82.8^b	81.0^a	84.9^b	81.3^a
I_A $FST_M/C \times 100$	3.5	3.57	3.50^a	3.57^b	3.63^a	4.01^b
I_B $DST_M/C \times 100$	0.485^a	0.610^b	0.556^a	0.755^b	0.543^a	0.763^b
I_C TSA/C (cm^2/kg)	83.4	88.8	77.4	71.1	68.0	70.2
I_D DST_M/TSA (g/cm^2)	0.060^a	0.071^b	0.079^a	0.096^b	0.083^a	0.110^b
I_E $DST_M/C^{0.75}$ (g/$kg^{3/4}$)	12.34^a	16.9^b	14.85^a	22.73^b	16.59^a	24.90^b
I_F $TSA/C^{0.75}$ (cm/$kg^{3/4}$)	212.2	243.3	206.1^a	236.2^b	207.7^a	229.9^b

Explanations: a, b – P<0.05 (between Z and B); I_A, I_B, I_C, I_D, I_E, I_F – indexes; C – carcass

the anatomical form and optimal function of stomach, leading to more efficient digestion of the types of plant consumed by deer (5, 7, 9, 10). This can explain and support the earlier study on abilities for selective particle retention, which are physiological consequences of ruminant diversification (4, 7). Relatively the largest rumen area (fig. 1) to the other stomach chamber was in each group of animal both in Z and B region. Although, the rumen tissue weight (DST_M, tab. 2) increased with body mass and age (according to physiology and anatomy of adult individuals) it cannot necessary cause total stomach and rumen volume enhance in the relation to metabolic body mass of deer (tab. 1). It could resulted in an increased of the wall thickness. Usually, the relative stomach and rumen area are inversely proportional to body weight (9, 17). I_C index (tab. 1) presented stomach volume confirmed it.

Index I_A, I_B was higher in calves, hinds and bulls of Bieszczady but I_C were higher only in calves and bulls of the B area (tab. 1). Whereas, in hinds the relation of total stomach volume relatively to carcass mass (I_C) were opposite, lower. This reflects that smaller body size allometry of adult female, taking relatively lager bites appears to reach an asymptote at a lower plant biomass than does males (1-3, 7). Differences among each stomach size in individual groups of deer are related to females and males various sexual segregation, activity patterns and variation in the use of spatial habitats (2, 14). The highest rumen chamber and SC in total stomach was found in bulls of B (fig. 1, tab. 1, 2) support thesis that male foraging on the worse quality food intake it more. This lead to differences in body size (mass) (1, 6). The highest I_C index (stomach volume) in calves of Bieszczady is responded on differences in forage types, their spatial distribution, abundance and segregation (selectivity) by deer. It may be explain by prolonged access (to newly emerged plants, during early summer too) to favorable, enhanced quality forages at high elevation. It seems to reflect animal's adaptation to specific mountain habitat (2, 14). In consequences this provide to important differences between individuals inside the same species but in various an environment (habitat Z vs. B) (tab. 1, 2). Although anatomical adaptation of red deer to mixed feeder category are appreciated, related capacities for the processing food seems to demonstrate difference in various habitat (2, 3, 5, 6, 8). Thus, diet choice or feeding type can influence passage rate of food and can cause deer body size changes (4, 5, 7). It has been suggested by Mysterud el al. (14), that enhanced forage quality at high elevation is positively correlated with the proportion of high altitude habitat. Thus, it can lead to the prediction that deer body mass (weight) are highest in regions with the highest diversity of different altitudes (14). Our result supported such postulates.

Indexes I_D and I_E as relative to metabolic body mass ($C^{0.75}$) of deer, indicate on thicker stomach wall tissue

Tab. 2. Indexes of stomach chambers in deer of Zielonogórskie (Z) and Bieszczady (B) region

I_E $DST_M/C^{0.75}$	Calves		Hinds		Bulls	
g × $(kg^{0.75})^{-1}$	Z	B	Z	B	Z	B
Reticulum	0.98^a	1.42^b	1.28^a	1.60^b	1.14^a	1.71^b
Rumen	9.48	11.56^b	10.93^a	16.89^b	12.80^a	18.85^b
Omasum	0.84^a	1.95^b	1.07^a	2.13^b	1.07^a	2.19^b
Abomasum	1.08^a	1.95^b	1.49^a	2.13^b	1.59^a	2.15^b
DST_M g						
Reticulum	16^a	29^b	28^a	49^b	33^a	60^b
Rumen	160^a	241^b	232^a	492^b	373^a	666^b
Omasum	14^a	41^b	27^a	63^b	30^a	78^b
Abomasum	20^a	40^b	34^a	63^b	49^a	75^b
WCST %						
Reticulum	84.8^b	81.7^a	82.9^b	80.6^a	85.0^b	80.5^a
Rumen	85.2	83.5	82.1	81.3	84.5^b	81.6^a
Omasum	86.5^b	80.7^a	82.5^b	79.7^a	87.6^b	81.9^a
Abomasum	84.5^b	80.5^a	83.1^b	80.0^a	84.3^b	78.4^a

Explanations: a, b – P < 0.05 (between Z and B); dry matter of stomach tissue mass – DST_M, g; water content in stomach tissue – WCST, %

and its heavier mass in each category of deer (calves, hinds and bulls) living in mountains ecosystem (B), and bull had them the supreme. Both relation of DST_M to $C^{0.75}$ and total stomach area (TSA) to the metabolic body mass ($C^{0.75}$) were enhanced in deer of this region (B). Relatively (to total stomach) smaller the omasum in bulls can indicate on lower food mass passage by this chamber in comparison to hind (tab. 2). Also, it suggests that developed bigger forestomach (heavier and with wider surface) is interacted with food supply. Stomach chambers seems like are able adjust to utilize more efficiently the chemical composition of vegetation, including secondary plant compounds both of browse and graminaceous in certain ecosystems (3, 4, 6, 7, 14, 17). The results suggest tendency in deer of Z region to comparatively faster food passage rate than in deer of B. It means that due to shorter retention of some nutrients like fibrous particles in fermentation chambers, deer of Z digested less efficiently. It support Clauss and Lechner-Doll (3) postulates. The selectivity factor (size of particle retention in rumen) seems has absolute impact on passage rates in mixed feeders such deer (1, 2). However, the selective particle retention does not necessary increase together with body (mass) weight of animal (3). Illius and Gordon (11) described the allomatric relationship between body mass and particle mean retention time in ruminants (3, 7).

The fresh boreal site of Zielonogórski habitat with predominate of coniferous sprouts, frutescent and monocotyledonous plants has poorer (biomass) carrying capacity mainly due to the lack of browsers foliation, herbs and/or forbs in forest litter (15). Whereas, mountain forest habitat of Bieszczady provide much richer biomass, consisting of various vegetation (plants) with high nutritional value both in the winter and during the vegetation seasons. Higher potential carrying capacity of B habitat is resulted in bigger varieties of plants material both mono and dicotyledonous, herbs, evergreen blackberries, shrubs, browses and their access to deer (15, 18). Also, in poor foraging habitat (Z) animals have to expense more energy on foraging, to be able to support their nutritional requirements. It resulted in slower grow rate in calves (smaller size, mass) and lighter body size in adult individuals, as well as lower energy reserves in lactating hinds, usually also, a smaller amount of energy (fat - protein) reserves in gain bulls (17).

Individual stomach chambers were the supreme in bulls and the lowest in calves, thus in individuals being in the most critical situation of food foraging in winter (fig. 1, tab. 2). However, each of them (chambers) was higher in deer of B site. The relative tissue mass of each stomach chamber calculated on metabolic body mass (I_E index, tab. 2) were the lowest in calves and the highest in bulls independently of habitat (Z and B). Lower individual DST_M indexes of stomach chambers in deer of Z indicate on substantial impact of habitat and poorer foraging ecology in this region. Those data are supported by WCST index being increased in deer of Z (tab. 1, 2). Higher TSA in bulls of B and food content (SC) in their stomach confirm (reflects) postulates of foraging activities and strategy of male (1, 2, 6, 13). It is evidence on niche of food resources and existing the integration in dietary structure type, their nutritional values and their consumption. There are relatively higher in bull of B habitat.

In conclusion, the ecological condition such as, abundance and wide variety of vegetation both browses and graminaceous, associated with food availability substantially affect digestive system anatomy by the modification of stomach chambers in deer. Thus, individuals are adapted to the optimal foraging strategy and the utilization of food more efficiently in mountain ecosystem of Bieszczady in comparison to Zielonogórskie area.

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