

**Food of adult diving beetles *Colymbetes fuscus* (LINNAEUS, 1758) and
C. striatus (LINNAEUS, 1758) (Coleoptera: Dytiscidae) in the Zehlau
Peatbog and in oxbow lakes and fens (the Biebrza Marshes)**

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ABSTRACT. The study involved the analysis of the foregut content of 120 adult specimens of *Colymbetes fuscus* and *C. striatus* collected in aquatic habitats in the Biebrza Marshes (Poland) and the Zehlau Peatbog (Russia). The gut content comprised animals (including eggs of aquatic invertebrates), plants and detritus. Larvae of Ephemeroptera were common in beetles from the Biebrza Marshes. The gut content also included Dytiscidae, Cladocera, Chironomidae and other Diptera, Copepoda, other insects, other Coleoptera aquatica, Heteroptera, Acari, Ostracoda, Culicidae and *Asellus aquaticus*. In the Zehlau Peatbog, both of the beetle species fed predominantly on the larval stages of Chironomidae (Diptera). The gut content also included adult terrestrial insects and spiders.

KEY WORDS: predation, diving beetles, the Zehlau Peatbog, the Biebrza Marshes, Dytiscidae.

INTRODUCTION

Predation is one of the dominant antagonistic relationships integrating a biocoenosis. In spite of the availability of a rich literature relating to food consumed by predatory insects, our knowledge of the diet of Dytiscidae is still scarce. It is the larval stages of these beetles that seem to have been examined the most thoroughly (JOHANSSON & NILSSON 1992, YOUNG 1967, YOUNG & SPERLING 1986, PEARMAN 1995, LE LOUARN & CLOAREC 1997, GAUTAM & GOUTAM 2006, INODA 2012).

Field observations of the predatory behaviour of diving beetles have been carried out by, for example, SAILER & LIENK (1954), KÜHLHORN (1961), JAMES (1965), LEE (1967), ROBERTS et al. (1967) and YOUNG (1967). Results of studies based on the analysis of the content of intestines or proventriculi are also available. They concern mainly small and medium species (DETTNER et al. 1986, DEDING 1988, HICKS 1994, BOSI 2001, KEHL & DETTNER 2003). The diets of representatives of the family Dytiscidae have been analysed in laboratory conditions, although according to some authors, laboratory results can be at variance with what happens in the natural environment (LINDBERG 1944, JOHNSON & JAKINOVICH 1970, SWAMY & RAO 1974, BISHT & DAS 1979, IDEKER 1979, BOSE & SEN 1985).

The objective of this study was to compare the composition of diets of *Colymbetes fuscus* (LINNAEUS, 1758) and *C. striatus* (LINNAEUS, 1758) from two different localities, namely, fens in the Biebrza Marshes, distinguished by a highly diverse aquatic fauna of hydrobionts, and peatbogs in the Zehlau Peatbog, where the aquatic fauna was dominated by predaceous beetles and water bugs and the larvae of acenotropine moths.

FIELD LOCALITIES

The Biebrza Marshes, situated in the Biebrza National Park, constitute a unique complex of lowland wetlands with an area of 100 km², covering the valleys of the Rivers Biebrza and Narew. A system of oxbow lakes, lying predominantly in the Biebrza valley, is a particularly interesting component of the hydrographic network. The oxbow lakes in which the beetles were captured are eutrophic water bodies inhabited by an extremely rich and diverse fauna (PALCZYŃSKI 1988).

The Zehlau Peatbog is located in the Kaliningrad Oblast, approximately 34 km north of the Polish border. More than 25 km² in area, it includes over 200 dystrophic water bodies. The largest ones have an area of approximately 1 ha. The hydrobiological study carried out in May 1997 revealed that the local aquatic fauna was dominated by predaceous beetles and water bugs, as well as. The other groups of hydrobionts were present in small numbers (CZACHOROWSKI 1997).

MATERIALS AND METHODS

The material was collected in the Biebrza Marshes (Poland) and in the Zehlau Peatbog (Russia). The Biebrza Marshes are located at 53°31'N, 22°59'E and the Zehlau Peatbog is located at 54°32'N, 20°18'E.

Colymbetes fuscus has a length of approximately 16-18 mm, and a relatively convex body, distinctly rounded on the edges. It usually inhabits small water bodies largely overgrown with aquatic plants. Due to its wide ecological tolerance, the beetle can colonise both peatbog and eutrophic water bodies. The eggs are laid primarily in ephemeral puddles and vernal pools with grassy vegetation. The larval stages emerge in April and May. *C. striatus* is of a similar size and lives in the same habitats as *C. fuscus*. Larval stages of both species are typically encountered together (GALEWSKI & TRANDA 1978).

The material was collected by means of bottle traps (VOLKOVA et al. 2013) in May 1997 and preserved in 70% alcohol at the Department of Ecology and Environment Protection of the University of Warmia and Mazury in Olsztyn; it was deposited in coll. Biesiadka. The traps were submerged in water without access to air. As a result, the beetles died. The material was retrieved 12 hours after the traps had been set (VOLKOVA et al. 2013). The material was analysed in 2012. A total of 120 specimens (Tab.) belonging to two species was randomly selected and the foreguts were dissected under a binocular microscope (MST 132 Edu BK). One microscope slide was prepared from each specimen. 100 specimens obtained in the Biebrza Marshes and 20 from the Zehlau Peatbog were analysed.

The contents of each specimen (number in Tab.) were immersed in a droplet of glycerine, placed in glycerine on a microscopic slide, enclosed with a cover glass and analysed under a XJS 400 microscope. One hundred slides were prepared for each of the species obtained from the Biebrza Marshes, and 20 for each of the species from the Zehlau Peatbog. The diversity of the diet of the two beetle species from different environments was analysed using the Fisher test (Statistica 2010). The results were analysed at a significance level of 0.05, and two hypotheses were tested: H_0 – the diet of *C. striatus* and *C. fuscus* from the Biebrza Marshes and the Zehlau Peatbog is the same; H_1 – the diet of *C. striatus* and *C. fuscus* from the Biebrza Marshes and the Zehlau Peatbog is different.

The percentage diversity of food was calculated from the number of proventriculi in which food was identified. The percentage of animal material, plant material, other and detritus (Tab.) was calculated from the number of food items examined. The percentage contribution of particular organisms to the diet of diving beetles was calculated on the basis of their numbers in the intestinal content analysed. Such a methodology was applied in the light of the results relating to animal and plant material as well as detritus. While it is easy to determine the numbers of consumer organisms in animal material, it is impossible to do so in the case of plant material and detritus.

The items were identified from the remains of head capsules, mandibles, maxillae, eyes etc. and whole bodies in the case of Cladocera etc.

Animal and plant fragments and detritus were identified by means of a reference collection. This was produced by collecting and identifying all the organisms constituting

the beetles potential prey. The items were macerated to a state resembling the fragments in the foreguts, and microscopic slides were made of each item.

Table. Items in the proventriculi of *Colymbetes fuscus* and *C. striatus* (n – number of Coleoptera individuals. The insect fragments are mostly from larvae; the figures in brackets relate to parts from imagines).

Taxon	the Biebrza Marshes		the Zehlau Peatbog	
	<i>C. fuscus</i> n=50	<i>C. striatus</i> n=50	<i>C. fuscus</i> n=10	<i>C. striatus</i> n=10
Animal material				
Cladocera	10	10	1	–
Ostracoda	1	–	–	–
Copepoda	6	2	1	–
<i>Asellus aquaticus</i> (LINNAEUS, 1758)	1	–	–	–
Ephemeroptera	5 (3)	9 (1)	–	1
Heteroptera	2	2	–	–
Dytiscidae	10 (2)	9	1	1
Other Coleoptera aquatica	5	3	1	1
Trichoptera	–	–	–	1
Chironomidae	9	1	2	2 (1)
Culicidae	–	1	1	1
Other Diptera	5	4	1	–
Other insects	4	6	1	1
Acari	–	1	–	–
Araneae	–	–	–	1
Skeletal tissue	24	11	10	8
Plant material				
Filamentous algae	1	3	–	–
Mosses	–	–	1	1
Other plant parts	–	–	–	1
Seeds	1	–	–	–
Detritus				
–	2	3	1	–
Other				
Eggs	–	11	–	–
Empty foreguts				
–	1	1	–	–

RESULTS

The most numerous component in the foreguts of *Colymbetes fuscus* and *C. striatus* were animal organisms (84%), predominantly insects. Apart from larval stages, a few adults were found. Eggs of aquatic invertebrates were also identified (7.1%), and there were small proportions of plants (5.1%) and detritus (3.8%). No gastric content was found in 2 specimens (Tab.).

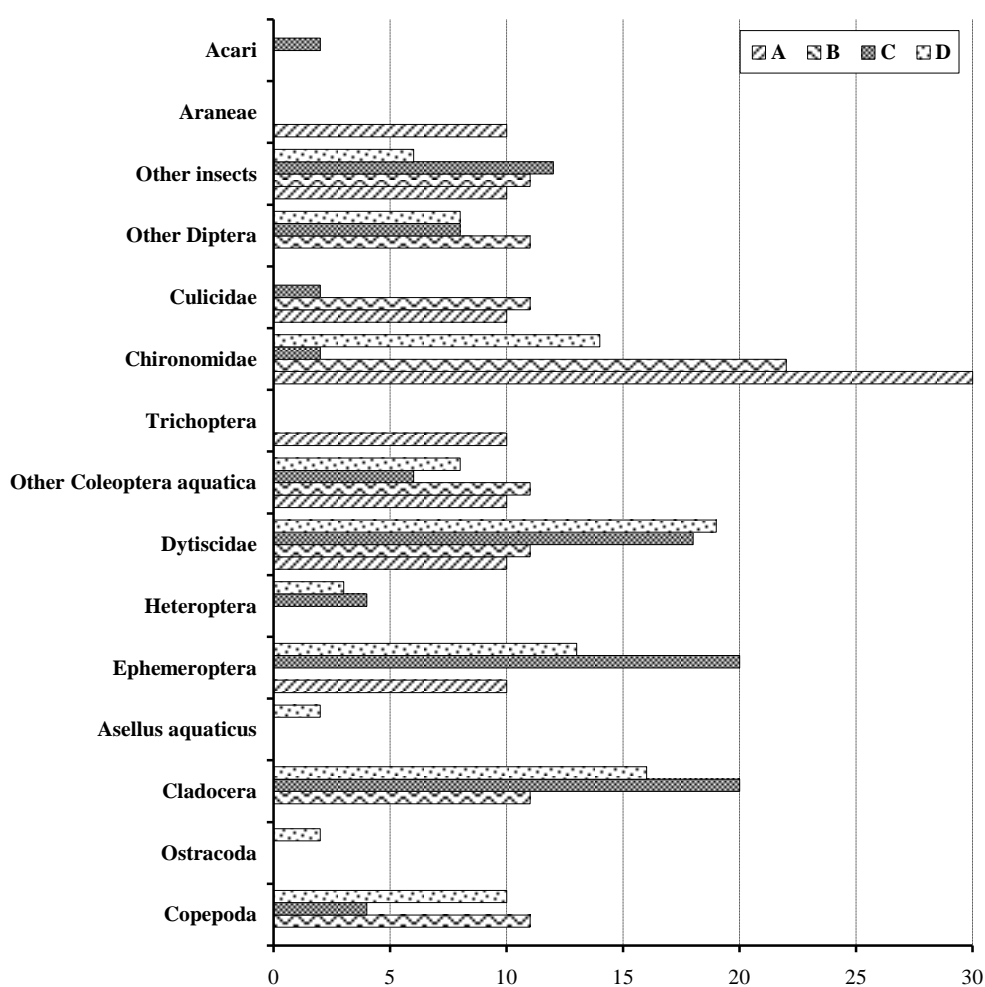


Fig. Percentage share of different food items in the foregut of *Colymbetes fuscus* and *C. striatus* (animal contents). A – *C. striatus* in the Zehlau Peatbog, B – *C. fuscus* in the Zehlau Peatbog, C – *C. striatus* in the Biebrza Marshes, D – *C. fuscus* in the Biebrza Marshes.

The food ingested by the populations of *C. fuscus* and *C. striatus* from the Zehlau Peatbog contained more plant material and detritus. The population in the Biebrza Marshes ingested more adult forms of insects and striated muscle tissue (Fig.).

C. striatus more numerously consumed larval stages of Ephemeroptera and Culicidae and also adult forms of Acari and Araneae. The diet of *C. fuscus* contained Ostracoda, *Asellus aquaticus*, Cladocera and Copepoda. Moreover, the latter species consumed more adult Ephemeroptera and water beetles from the family Dytiscidae (Fig.).

The diet of diving beetles from the Biebrza Marshes comprised 13 taxa of animal organisms. Larval stages of Ephemeroptera and Chironomidae, also adult beetles from Dytiscidae and Cladocera, were consumed in the highest numbers. Larval stages of Culicidae, and adult forms of Acari, Ostracoda and *Asellus aquaticus* were eaten only sporadically. *C. striatus* ingested larval stages of Ephemeroptera and adult forms of Cladocera in the greatest abundance, while *C. fuscus* preferred chironomid larvae, water beetles from the family Dytiscidae and Copepoda. The diet of *C. striatus* was also found to include larval stages of Culicidae and adult forms of Acari, which were absent from the diet of *C. fuscus*. The diet of *C. fuscus* also contained Ostracoda and *Asellus aquaticus* (Fig.).

The diet of Coleoptera inhabiting the Zehlau Peatbog consisted of 11 taxa of organisms, dominated by larval stages of Chironomidae. Whereas *C. striatus* consumed larval stages of Trichoptera, Ephemeroptera and adult forms of Araneae, *C. fuscus* ingested other Diptera, Cladocera and Copepoda (Fig.).

The results of the Fisher test for *Colymbetes striatus* and *C. fuscus* from the Biebrza Marshes and the Zehlau Peatbog for particular animal organisms constituting the diet of the beetles are as follows: Ephemeroptera – 1.0; Culicidae – 1.0; Chironomidae – 0.76; other Diptera – 1.0; Dytiscidae – 1.0; other Coleoptera aquatica – 1.0; other insects – 1.0; Cladocera – 1.0; Copepoda – 1.0.

According to the Fisher test, there is no difference in the dietary composition between the two species in the two localities.

DISCUSSION

Predators in the littoral environment include piercing sucking insects and shredders. Dytiscidae imagines are shredders (ZARET 1980). They are able to ingest prey of substantially different sizes – from meiofauna to prey only slightly smaller than themselves. Shredders can also feed on organisms protected by thick integuments, e.g. a chitinous cuticle. In this case, the effectiveness of hunting and feeding depend more on the size and strength of their own mandibles and thickness of cuticles of the prey than on the relative body size of the predators and prey (ZARET 1980). This is reflected in the considerable

variability in the size of food of the *Colymbetes* species analysed here. They are capable of ingesting small planktonic crustaceans and beetles with chitin cuticles, as well as winged terrestrial insects.

This situation is confirmed by LUNDKVIST et al. (2003), who demonstrated experimentally the existence of correlations between the size of the larval forms of Culicidae and their selection by Dytiscidae imagines. In spite of the prevalence in the diet of *Colymbetes* sp. of animal food (with a particular preference for insects), fragments of plant tissues were also consumed. Plants parts in the proventriculi of Dytiscidae were also reported by DEDING (1988), KEHL & DETTNER (2003) and BOSI (2001). According to DEDING (1988), plants constitute a dietary supplement. They may have such a function in situations of long periods of starvation. It is also probable that the plants were ingested incidentally together with animal food.

Body fragments suggesting the ingestion of imagines of flying terrestrial insects were also frequently encountered. According to DEDING (1988), adult Diptera falling on to the water surface become an additional source of food in conditions of insufficient nutrition. Adult Diptera are particularly easy to capture while they are laying eggs in the vicinity of water bodies (DEDING 1988). Consequently, they make up a large proportion in the diet of both *Colymbetes* species. The presence of a spider in the diet of a single specimen suggests random selection of prey. Its consumption may have resulted from the conditions occurring in dystrophic water bodies. A low taxonomic diversity of potential prey forces predators to ingest incidentally encountered organisms.

Ephemeroptera seemed to be the preferred prey of both species recorded in the Biebrza Marshes, but a different situation occurred in the Zehlau Peatbog, where the preferred food constituted the ponderous larval stages of Chironomidae.

The results of a laboratory experiment in which beetles from the species *Rhantus sikkimensis* REGIMBART, 1899 were fed chironomid larval stages of various sizes were somewhat different. It turned out that the predators were more likely to choose slightly larger prey (GAUTAM & GOUTAM 2006). In the case of the ponderous larval stages of Chironomidae, the situation is at variance with the concept of ZARET (1980). This could be due to the restriction under laboratory conditions of factors determining prey selection. Relating experimental results to natural conditions is very difficult. Hence there is an urgent need for studies on Dytiscidae imagines in the natural environment, where food selection is determined by a large number of factors.

Cladocerans were common in the diet of water beetles from the Biebrza Marshes. It is interesting that in the course of evolution, planktonic animals have developed specific adaptations protecting them from predation. In cladocerans, protection against getting eaten takes the form of a transparent body that is invisible to potential predators, irrespective of their locomotor abilities (KOPERSKI 1999). In littoral habitats, potential swimming prey is

usually smaller, and provides a smaller energy yield *per capita* as food than the majority of available benthic or rather inactive animals. The significant contribution of prey with high locomotor abilities (e.g. plankton) in the diet of predators is therefore related to a considerable decrease in the weight of consumed food (KOPERSKI 1997). This fact is a perfect explanation for such large amounts of ingested Cladocera.

In both the species recorded in the Biebrza Marshes and the Zehlau Peatbog, larval forms of Dytiscidae water beetles make up a substantial proportion of their diet. Adult forms of the insects are also encountered. It is worth noting that in freshwater environments, where long food chains are the norm and cannibalism is common, predators frequently consume each other.

It is also worth emphasising that hardly any food preferences can be identified in the extreme conditions occurring in dystrophic water bodies, peatbogs, or peat pits. Life in such habitats forces organisms to develop certain adaptations related to obtaining food (BOSI 2001). It may also be a reason why imagines and juvenile forms of Dytiscidae are hunted. Moreover, terrestrial organisms drowning in water become a source of food for Dytiscidae, including beetles, spiders, or those falling on to the water surface, like dragonflies and Diptera. This was confirmed by DEDING (1988), who pointed out the occurrence of remains of aphids and chironomid imagines in the intestines of Dytiscidae.

A large proportion of the bodies of other prey items remain undigested because of the presence of chitin structures. After digesting the soft body parts of the prey, head capsules, legs, head appendages, wing cases, setae and parts of post-abdomens are left over. In the majority of cases, they are strongly fragmented. Single sclerites and their entire groups also occur. This fact is confirmed by DEDING (1988) and KEHL & DETTNER (2003). These authors observed undigested, strongly fragmented, chitinous parts of insect bodies left over in proventriculi. It is interesting that prey items that could be used by predators to a maximum degree are frequently unavailable to them.

Even though many experimental studies of predation in diving beetles have been carried out, there is a need for more field research in order to gain deeper insight into this problem.

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