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Bryophagy in the groundhopper *Tetrix ceperoi* (Orthoptera: Tetrigidae): analysis of alimentary tract contents

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Abstract: Tetrigidae (Orthoptera) are known to feed on algae, lichens, mosses, small plants and detritus, but there are published only a few specific data about their food biology. We carried out a preliminary analysis of the food composition of species *Tetrix ceperoi* (Bolivar, 1887) by the dissection of the gut contents. At least four mosses species have been found to be a component of the diet of *T. ceperoi*: *Bryum argenteum*, *B. caespiticium*, *Ceratodon purpureus*, *Barbula* sp. (*B. convoluta* or/and *B. unguiculata*). The most frequent moss in gut of *T. ceperoi* was *Bryum caespiticium*, which was also the dominant moss on the locality with coverage of 70 %. Altogether, the presence of at least one fragment of one moss species has been detected in 89.7 % of specimens (94.4% of females and 85.7% of males), fragments of vascular plants (grasses) has been found in 20% of specimens (only females) and algae in 25% of specimens. Organic detritus was present in all specimens and occasionally some animal fragments have been found (sclerotised parts of unidentified beetle larvae). The average number of moss species detected simultaneously in gut content of one specimen was 1.5 in males and 2.0 in females, when the maximal number was four moss species

Keywords: food biology, bryophagy, bryophyte, groundhopper, *Tetrix ceperoi*, Tetrigidae, Orthoptera

Introduction

Tetrigidae (groundhoppers) are small, short-horned Orthoptera with an elongated pronotum, which covers the abdomen and hind wings (Kočárek et al. 2005). The fauna of the Czech Republic consist of only 7 species in one genus *Tetrix* (Kočárek et al. 1999, Holuša & Holuša 2002). Generally, Tetrigidae belong to the least-studied groups of Orthoptera (Hochkirch et al. 2006), when especially their ecological preferences and food biology is almost unknown. Most Tetrigidae are terricolous and inhabit marshy places, some are even semi-aquatic and good swimmers and divers (Podgornaya 1983, Paranjape et al. 1987). They are known to feed on algae, lichens, mosses, small plants and detritus, but there are published only a few concrete data about their food biology. In some species, as *Tetrix ceperoi* (Bolivar, 1887), the food preferences has not yet been studied in detail.

T. ceperoi is a West-Mediterranean species, which reaches the north-eastern edge of its range in Central Europe. In the Czech Republic, the species has been reported for the first time in 2002 (Holuša & Holuša 2002) and up to days we know only few localities in southern Moravia. It is mentioned as “near threatened“ in the current red-list of Orthoptera (Holuša & Kočárek 2005). *T. ceperoi* is restricted to damp, warm habitats, such as dune valleys, sand pits or heath ponds in the territory of the Czech Republic.

We carried out a preliminary analysis of the food composition by the dissection of the alimentary tract contents of *T. ceperoi*.

Material and methods

The groundhoppers have been collected in the sand pit near Bzenec-Přívov in SE Moravia (48°55'40.67"N, 17°16'47.37"E) 21.v.2007 and 8.vi.2007 and immediately stored in ethylalcohol. The locality is situated at the flat bottom of the abandoned part of the pit with sparse wood vegetation (*Populus tremula*, *Betula* sp. and *Pinus nigra* planted out during the revitalization) and high density of mosses. Together with the insects, the samples of all visually different terrestrial mosses have been collected, that were subsequently identified to 13 species (*Amblystegium serpens* (Hedw.) B.S.G., *Barbula convoluta* Hedw., *B. unguiculata* Hedw., *Brachythecium*

albicans (Hedw.) B.S.G., *B. rutabulum* (Hedw.) B.S.G., *B. velutinum* (Hedw.) B.S.G., *Bryum argenteum* Hedw., *B. bicolor* Dicks., *B. caespiticium* Hedw., *Ceratodon purpureus* (Hedw.) Brid., *Eurhynchium angustirete* (Broth.) T.J. Kop., *Funaria hygrometrica* Hedw., *Plagiomnium undulatum* (Hedw.) T.J. Kop.). Ground coverage of mosses had been evaluated by quadrat sampling. Ten quadrates (30 x 30cm) had been accidentally distributed in the area of study and the average coverage had been calculated based on the particular results (Fig. 1). Altogether, 21 males and 18 females of *T. ceperoi* have been used for dissections of their alimentary tract and the analysis of its content. The dissections have been made by the cutting of the abdomen cavity by thin forceps and taking out the oesophagus, crop and proventriculus. The permanent microscopic preparations of the alimentary tract content have been made with usage of Hoyer's solution (Anderson 1954). For the comparison and determinations of the tissue fragments in alimentary tract contents, the permanent microscopic preparations of the leaves of each moss species taken from the same locality have been made by the same method.

Results

At least four mosses species have been found to be a component of the diet of *T. ceperoi*: *Bryum argenteum*, *B. caespiticium*, *Ceratodon purpureus*, *Barbula* sp. (*B. convoluta* or/and *B. unguiculata*). In all samples there were presented also rhizoids and gemmae of these mosses. One sample of gut (male specimen) contained also gemmae of moss *Bryum moravicum* Podp., which is epiphytic species occurring also at the studied locality, but only on the bark of trees. The most frequent moss in gut of *T. ceperoi* was *Bryum caespiticium* (in gut of 88.9 % specimens – see Tab. 1), which was also the dominant moss at the locality with coverage of 70 % (see Fig. 1). The rest of species were represented frequently in diet of *T. ceperoi* (*Barbula* sp. – 33.3%, *Bryum argenteum* 27.8%, *Ceratodon purpureus* – 36.1 %) when were the densities at the locality (average coverage: *Barbula* sp. – 1.0%, *Bryum argenteum* 0.7%, *Ceratodon purpureus* – 1.0 %). Altogether, the presence of at least one fragment of one moss species has been detected in 89.7 % of specimens (94.4% of females and 85.7% of males), fragments of vascular plants (grasses) has been found in 20% of specimens (only females) and algae in 25% of specimens. Organic detritus was present in all specimens and occasionally some animal fragments have been found (sclerotised parts of unidentified beetle larvae). The average number of moss species detected simultaneously in gut content of one specimen was 1.47 (SD \pm 1.03) in males and 2.00 (SD \pm 0.84) in females, when the maximal number was four moss species (Fig. 2).

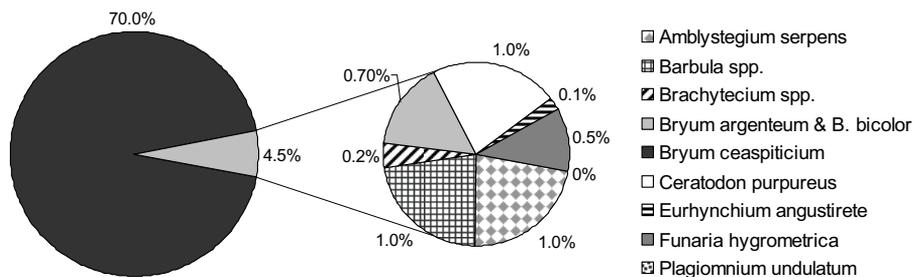


Fig. 1. Ground coverage of mosses at the studied locality in Bzenec-Přivoz (average of 10 squares 30x30cm). The rest to 100% were grasses, shrubs and trees.

Tab. 1. Frequency of individual moss species in gut contents of 39 specimens of *T. ceperoi*

Moss species	<i>T. ceperoi</i> specimens					
	♂(ind.)	♂(%)	♀(ind.)	♀(%)	Σ(ind.)	Σ(%)
<i>Barbula</i> sp. (<i>B. convoluta</i> or/and <i>B. unguiculata</i>)	6	31.6	6	35.3	12	33.3
<i>Bryum argenteum</i>	4	21.1	6	35.3	10	27.8
<i>Bryum caespiticium</i>	15	78.9	17	100	32	88.9
<i>Ceratodon purpureus</i>	6	31.6	7	41.2	13	36.1

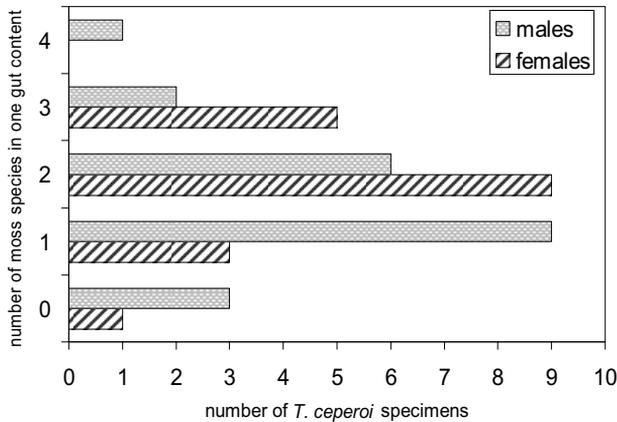


Fig. 2. Number of moss species simultaneously detected in gut content of each one individual of *T. ceperoi*

Discussion

Only several species of grasshoppers have been reported as moss consumers when the majority of observations were related to tetrigids. Verdcourt (1947) found in 80% of the fecal pellets of *Tetrix undulata* (Sowerby, 1806) and *T. subulata* L., 1758 the leaves of *Hypnum* and rhizoids and protonemata of a variety of mosses. Lock (1996) analyzed crop content of three specimens of *T. subulata* and found algae, detritus and grains of sand, and no traces of mosses or higher plants. But his sample was too small for generalizing. Diet of *T. undulata* studied Hodgson (1963). He observed feeding of the species on grasses (*Festuca rubra* L. and *Brachypodium sylvaticum* (Huds.) P. Beauv.) five times, on variety species of mosses (twenty-four times), on lichens and algae (eleven times), and on humus (thirty times). Besides that, he observed also feeding on the dead bush-cricket *Pholidoptera griseoaptera* (De Geer, 1773) in insectarium. Diet and feeding habit of *T. subulata* were studied by Hochkirch et al. (2000) in sand pit near Bremen in Germany. He found, that males were exclusively feeding on algae and mosses (*Brychythecium* cf. *rutabulum* (Hedw.) B.S.G.), while females also included grasses and forbs in their diet. Reynolds et al. (1988) studied the diet of two tropical tetrigids in Sulawesi. They observed the presence of mosses or vascular plants in crop contents in 82% of specimens of *Scelimena celebica* (Bolivar, 1887) and in 100% of specimens of *Diotarus pupus* Bolivar, 1887.

Generally, it has been shown that females of grasshoppers feed on plants richer in nutrients, since they have higher protein demands for egg production (Chapman & Sword

1997). Hochkirch (1999) observed that females feed more often than males. In our study, the crop contents of females were generally larger, as the number of moss species in crop and as well as the simultaneous occurrence of moss species in the diet. Fragments of vascular plants have been also found only in female's crops in our study similarly to observations of Hochkirch et al. (2000). The reason may be that females feed more vascular plants due to their higher protein amount. On the other hand, males might not be able to bite through leaves of grasses because they have smaller body size and consequently smaller mandibles (Hochkirch et al. 2000).

Very interesting result is detection of simultaneous occurrence of more moss species in one crop content in the majority of cases. There could be stated three main hypotheses for such feeding behaviour. At first, a mixed diet is generally advantageous for survival and development of grasshoppers compared to monotonous food (Champan & Sward 1997). At second, many mosses contain some toxic secondary metabolites (e.g. Zinsmeister et al. 1991, [Becker 1994](#), [Markham et al. 2006](#)), so the consumption of small amounts of different species decreasing the risk of poisoning. At third, the high number of moss species fed by one specimen during a short time can also reflect the high moving activity of groundhoppers and the high diversity of mosses at a small area. All the hypotheses need further examination by laboratory experiments.

Acknowledgements

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