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Tadpoles in the diet of otters – an overlooked prey item in the diet of a riparian predator?

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Abstract. Understanding the diets of predators, prey selection and their impact on prey populations is pivotal to investigations on the ecology of predator and prey species. In this study, we observed a hand-reared European otter (*Lutra lutra*) foraging in the wild, in order to identify the type of prey captured by the predator. The study was carried out between March and June 2001 in a diverse range of natural otter habitats in Białowieża Forest (NE Poland). We found that tadpoles represented an important part of the otter's diet in June, when their frequency of occurrence and biomass reached 38% and 11%, respectively. During spring, tadpoles were less common than other types of prey, such as adult amphibians, fish, or aquatic Coleoptera. Otter diet varied among months and there were differences in the main prey type captured among water body types. Our results highlight the need to develop methods that enable the identification of tadpoles and other cryptic seasonal food items in riparian predator diets.

Key words: predator diet composition, *Lutra lutra*, amphibians

Introduction

To understand predator ecology, knowledge of diet composition, prey selection and trophic interactions is essential. Classical methods of studying the diet composition of predator species include scat, pellet and gut content analyses, direct observation of wild animals, feeding site surveys, and prey remains counts (Litvaitis 2000). Several approaches have been developed to analyse dietary data: frequency of occurrence, relative frequency of occurrence, relative volume, percentage biomass, and relative energy content of food items consumed (Goszczyński 1974, Cumberland et al. 2001, Ruehe et al. 2003, Zabala & Zuberogoitia 2003, Bojarska & Selva 2012, Smiroldo et al. 2019a). All these methods of studying diet composition have some biases and limitations (Litvaitis 2000). For instance, in scat, pellet and gut contents analyses, birds and insects in the diet are often overestimated compared to other food items that are more digestible. Similarly, the 'frequency of occurrence' method overestimates the share of small prey in the diet compared to the 'percentage biomass' approach (Cumberland et al. 2001). Actual biomass intake is estimated based on conversion

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factors, linear regression or extrapolation from the number of prey (Goszczyński 1974, Weaver 1993, Bartoszewicz & Zalewski 2003, Zalewski 2007). Using conversion factors or estimating relative volume ratio also produces biased estimates (Ruehe et al. 2003, Ruhe et al. 2008). Furthermore, none of the classical methods mentioned above includes the analysis of prey types that are consumed whole (or almost whole) and digested completely and, therefore, leave none or few remains in scats or pellets. However, these prey items could potentially represent a substantial proportion of consumed biomass, especially during pulses or periods of high abundance of such prey. Observations of foraging by hand-reared animals in natural environments can be a valuable tool to identify cryptic food items and may supplement an otherwise incomplete picture of a predators' diet in the wild. In spite of this method being criticized as artificial (Wallmo et al. 1973), it may be the only realistic way to identify neglected but potentially important food items, and to improve and complement traditional diet studies.

The European otter (*Lutra lutra*) is a riparian predator inhabiting vast parts of Europe and Asia. It inhabits mostly freshwater (rivers, lakes, artificial fish ponds, water reservoirs) and coastal habitats (Kruuk 1995). The diet of the otter consists of many prey types, mainly fish, amphibians, reptiles, and occasionally birds, small mammals and molluscs (Clavero et al. 2003, Lanszki & Molnar 2003, Gorgadze 2013, Smiroldo et al. 2019a, b). Otters track pulses of food resources and otter diet varies seasonally as prey availability changes over time (Clavero et al. 2003). Prey abundance, particularly in harsh winters and summer droughts during cub-rearing, has important consequences for otter population density (Ruiz-Olmo et al. 2001, Sulkava et al. 2007). Otters give birth in various months, but most commonly in April and May (Sidorovich 1991, Ruiz-Olmo et al. 2002). Consequently, prey abundance at this time and in subsequent months is crucial for the successful rearing of cubs. Identifying the whole spectrum of prey types consumed by otters, particularly in this period, is valuable in improving our understanding of the population dynamics and general ecology of the species.

In this study, we observed a hand-reared animal foraging in natural otter habitats in Białowieża Forest (NE Poland), with the goal of helping identify hitherto unrecognised food items in the diets of otters. Our focus was to identify the presence of small or sporadic prey that are rarely detected using traditional diet analysis methods, but that might be potentially important in certain periods. We analysed the monthly variation in otter diet in riparian habitats of this lowland deciduous forest, with special attention to otter diet during the spring.

Material and Methods

From March to June 2001 a hand-reared otter (8-10 months old) was directly observed hunting in natural riparian habitats in Białowieża Forest (NE Poland). The otter was found in the wild, orphaned and still nursing, in mid-summer. The required permit (DLOPiKog.-4201-368/2000) was obtained for keeping and handling the otter, which was fed solid food ground into a paste (mostly fish and also meat) as soon as possible, and later, whole dead fish. We never fed the otter with frogs, beetles or any other type of natural prey. The otter was kept from late autumn in an outside enclosure in the village of Teremiski where it had access to a small swimming pool and a sleeping refuge. Every day, the keepers (N. Selva and A. Wajrak) walked the otter for approximately 2 h (about 5 km) through natural otter habitats: a valley with a medium-sized river (the River Łutownia), open grassland with an artificial pond without fish, and an ash-alder forest. The otter was able to walk and swim freely, closely followed by the keepers, which permitted the observation of hunting attempts and the accurate identification of the type of prey caught. The otter was fed only after the walk and, therefore, hunted readily for prey. The otter was not trained to hunt and obtained hunting skills through predation attempts. A record was made of all prey captured by the otter during daily walks.

Overall, 203 prey were captured by the otter during 113 walks. The results are presented as frequency of occurrence (percentage of caught prey). From these data the percentage biomass of each prey category was calculated by multiplying the frequency of occurrence of each prey category by its average body size and calculating the percentage of its biomass. The average body sizes used for these calculations were: 18 g for frogs, 1.5 g for tadpoles, 15 g for fish, 1 g for aquatic Coleoptera, 2 g for gastropods and 10 g for other prey (Semlitsch & Reyer 1992, Brzeziński et al. 1993, Zalewska & Zalewski 2019, A. Zalewski unpublished data).

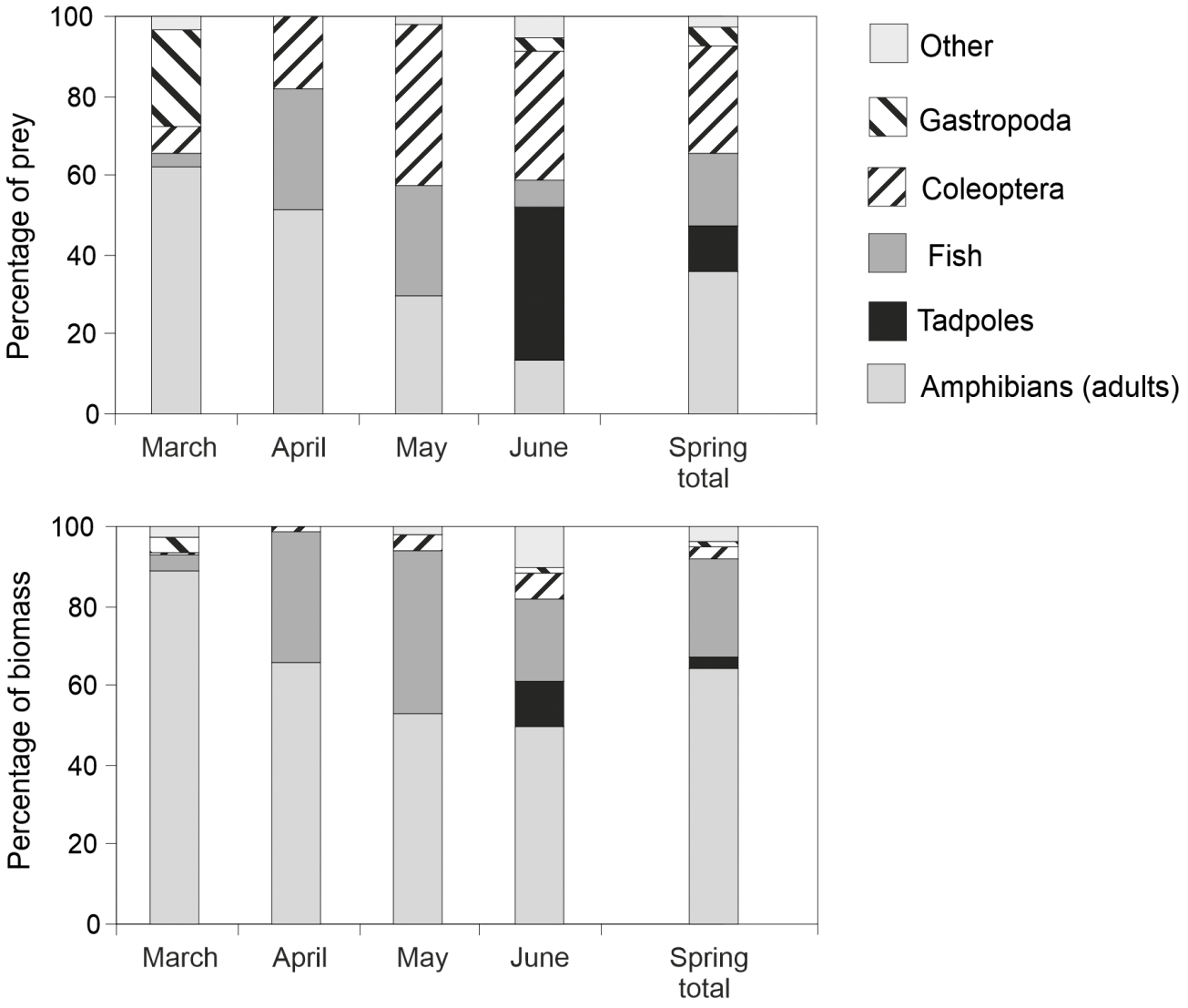

Fig. 1. Monthly variation in the frequency of occurrence of prey categories (as a percentage of prey caught) and in the percentage of biomass consumed by a hand-reared otter in aquatic habitats in Białowieża Forest (NE Poland).

Wild otters inhabit all the habitats where the hand-reared otter was observed foraging (Sidorovich et al. 1996) and wild otters were encountered during daily walks. In Białowieża Forest, otter density is on average 2.2 individuals per 10 km, with medium-sized rivers supporting a larger number of individuals than smaller rivers (Sidorovich et al. 1996).

Results

During spring, adult amphibians, fish and Coleoptera were the most important food items (Fig. 1). These types of prey constituted 80.3% of all prey items caught by the otter. Adult amphibians captured by the otter included brown frogs (*Rana temporaria, R. arvalis*), green frogs (*Rana esculenta* complex), newts (*Triturus* sp.) and tree frogs (*Hyla arborea*). Although there were few unsuccessful predation attempts, toads (*Bufo bufo*) were not killed as prey, but were scavenged. Fish caught included roach (*Rutilus rutilus*), mud loach (*Misgurnus fossilis*), and gudgeon (*Gobio gobio*). The most frequent Coleoptera identified were water beetles (*Hydrophilus caraboides* and *Dytiscus marginalis*). Tadpoles and gastropods (mostly freshwater snails, e.g. *Planorbis* spp.) were taken less often and constituted 12% and 18% of caught prey, respectively. Other prey included chicks and eggs of passerines, and earthworms, caught close to the river bank. All prey categories were also scavenged, i.e. not only killed by the otter, but were consumed when found already dead.

The composition of prey types caught by the otter varied significantly over consecutive months (Fig. 1; $\chi^2 = 88.2$, $p < 0.001$, df = 5). Adult amphibians and gastropods were more frequently taken in March, when they were mostly inactive. The percentage of adult amphibians

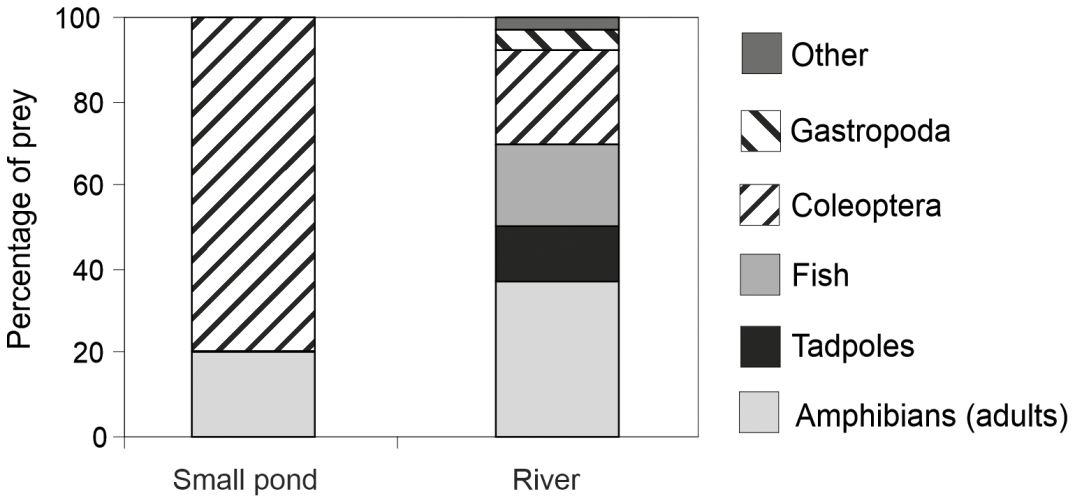

Fig. 2. Variation in the composition of prey caught by a hand-reared otter in the main aquatic habitats of Białowieża Forest (NE Poland). Sample size: pond 35 prey, river 168 prey.

decreased from March to May-June, while the share of fish and aquatic Coleoptera (Hydrophilidae and Dytiscidae) increased in April and May. Tadpoles and Coleoptera constituted a large proportion of the prey taken in June and the percentage of tadpoles increased up to 38% (Fig. 1). During this period, the otter consumed about 15 and 35 tadpoles on each walk. The proportion of biomass of each prey category also varied between consecutive months (Fig. 1). Adult amphibians and fish constituted a large proportion of the consumed biomass (on average 64.3% and 24.7% respectively). Tadpoles represented 11.4% of the biomass consumed by the otter in June. Other prey constituted less than 4% of consumed biomass (Fig. 1).

The composition of prey caught by the otter also varied among the different water bodies (Fig. 2; $\chi^2 = 116.5$, $p < 0.001$, df = 5). In the pond, the otter caught only aquatic Coleoptera and adult amphibians, whereas in the river, prey composition was more diverse and included all types of prey. Despite the fact that the time taken by the otter to hunt in the pond was twice as long, the number of prey items was lower in the pond (35 prey) than in the river (168 prey).

Discussion

Our study demonstrates the potential importance of tadpoles in the spring diet of otters, particularly during specific periods. To our knowledge, tadpoles have never been described previously in the diet of otters in Białowieża Forest or from other locations (Jędrzejewska et al. 2001, Smiroldo et al. 2019b). We are also not aware of any studies providing evidence of tadpole consumption by other species of aquatic carnivores, such as the American mink *Neovison vison* or polecat *Mustela putorius* (Jędrzejewska & Jędrzejewski 1998, Jędrzejewska et al. 2001). Reviews of otter diet have highlighted the importance of amphibians, mostly frogs and toads, but always in their (sub)adult phase; tadpole consumption has hitherto never been reported (Jędrzejewska et al. 2001, Clavero et al. 2003, Georgiev 2008, Krawczyk et al. 2016, Smiroldo et al. 2019b). Similarly, newts are rarely mentioned from otter diet analysis. However, we documented cases and in some areas they seemed to be an important food item (Parry et al. 2015). The relatively high contribution of tadpoles to the diet of the otter during the period of high tadpole abundance (June), may reflect food resource tracking by the otter and potentially implies that tadpoles may be an important food resource for wild otters during that time.

In Europe, the diet of otters varies widely among habitats, seasons, and geographical locations (see review by Jędrzejewska et al. 2001). In most habitats, crayfish, fish, and amphibians are the dominant prey items. In areas with a low abundance of crayfish, otters feed more on fish, and where fish are also scarce, supplement their diets primarily with amphibians (Jędrzejewska et al. 2001, Smiroldo et al. 2019a). Our data, based on a novel approach involving natural prey capture in the wild by a hand-reared otter, is in agreement with results based on spraint analysis from Białowieża Forest, which also show that during spring and summer the diet of otters comprises mainly fish, frogs, and water beetles (*Dytiscus* sp.) (Jędrzejewska et al. 2001). Our results show that these three types of prey were eaten by the hand-

reared otter in comparable ratios. In medium-sized rivers, however, amphibians dominated over fish. Invertebrates constituted a low proportion of consumed biomass, but they are often taken as prey (representing a high proportion by frequency of occurrence). Spraint analysis has also shown that birds are a supplementary food item for otters in Białowieża Forest (Jędrzejewska et al. 2001). Only flightless chicks were caught by the hand-reared otter. On a few occasions, the otter unsuccessfully tried to hunt ducks.

Our results revealed wide variation in the otter's diet over the spring months and these data closely track the seasonal availability of foods. In May, amphibians which are more abundant in rivers due to the onset of breeding (Juszczyk 1987), dominated in the diet. During the subsequent two months, the proportion of amphibians captured by the otter gradually decreased, as most brown frogs and toads shifted to a terrestrial habit. During these months the otter switched to feeding more on fish and water beetles. In June, the otter began consuming a large proportion of tadpoles. During this month, tadpole body length increases up to 100 mm and the tadpoles can weigh up to 3 g (Juszczyk 1987, Semlitsch & Reyer 1992), which was large enough to be caught by the otter. This observation suggests that tadpoles could be an important alternative food for otters, despite the fact that they are available only in June. A further question is whether tadpoles are consumed by wild otters during that period. The peak of otter pup birth occurs in April and May (Sidorovich 1991). Tadpoles are most abundant in June and may, therefore, represent a crucial food item for females with cubs and/or for young and inexperienced individuals, like our hand-reared otter. Otters have to learn hunting techniques, e.g. for toads or fish (Carss 1995) and tadpoles might represent easily-captured prey for young individuals that have yet to acquire the necessary skills to hunt more difficult and evasive prey types. The assessment of the impact of otters (or other riparian predators) on amphibian populations based on otter diet composition has hitherto only considered adult amphibians (Jędrzejewska & Jędrzejewski 1998) and predation of larval stages has been an overlooked aspect of their ecology.

In many natural ecosystems, like the Białowieża Forest or Doñana National Park, small prey play an important role in the diet of otters. For example, in Doñana National Park small fish species, such as *Gambusia* (weight of about 1 g), are one of the main otter food items (Adrian & Delibes 1987). Otters also consume amphibian eggs and small juvenile and subadult frogs (Georgiev 2008, Smiroldo et al. 2019b). The importance of small prey may have been overlooked in many studies (Carss & Elston 1996), despite being abundant during specific periods. Despite their small size, tadpoles are a reliably abundant resource that is available annually and may constitute an important resource and warrants further investigation as a component of the diet of otters.

Our observations highlight the need to develop methods to improve the identification of tadpoles in riparian predator scats or spraints. In the case of the European badger (*Meles meles*), it was not until a researcher developed a method for estimating the number of earthworms that they consumed, that the real importance of this food item in the diet was fully recognised (Kruuk 1989). In the case of otters an approach might be to experimentally feed captive otters with tadpoles and to subsequently analyse their spraints to identify and quantify the occurrence of amphibian chondrocranium. Our results are in accordance with data on otter diets obtained through traditional techniques. The method used in this study, albeit derived from the behaviour of a single captive individual, allowed us to identify a potential component of the diet of otters, which would otherwise have been overlooked.

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