North-Western Journal of Zoology, Vol.1, pp. 31-39

The trophic spectrum of a *Triturus cristatus* (Laurentus 1768) population from Plopiş Mountains area (Bihor County, Romania)

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Abstract. Crested newts eat mainly invertebrates, but may also ingest vegetal particles, Amphibian eggs or shed skins. Besides the shed skins of conspecific individuals, we have also identified shed skins of *Bombina variegata*, and even of *Lacerta agilis*. Due to the particular morphology of the habitat, the coming of the warm season brings about differences in the accessibility of different prey categories from one part to another of the Şinteu pond. This difference in the trophic offer causes modifications in the trophic spectrum, the adoption of the "sit-and-wait" feeding strategy, an increase in the number of empty stomachs, and indicates a decrease in the preying capacity of newts that prepare to leave the aquatic environment. Quantitatively, the most important prey taxa to the studied population are tadpoles and Nematocera larvae.

Introduction

Amphibians are vertebrates at the higher levels of the trophic pyramid (Cogălniceanu et al 2000). Because they inhabit both aquatic and terrestrial ecosystems, they hold a special position in the trophic chains (Burton & Likens 1975). Crested newts are aquatic during the first part of their active period, after which they become terrestrial and nocturnal (Fuhn 1960). The study of the feeding behavior is absolutely necessary for the understanding of the species ecology (Hodar 1997), and for this reason many studies on the trophic spectrum of crested newts (*Triturus cristatus*) have been conducted during the last few years in Bihor County (Covaciu-Marcov et al 2001a; 2002 a, b, c, d). Previous studies on the subject lack from Romanian literature (Cogălniceanu & Andrei 1992, Andrei & Torok 1997). In the present paper we intended to study the trophic spectrum of a *Triturus cristatus* population from Şinteu village (Plopiş Mountains), where no such studies have been previously carried out.

Materials and Methods

We have analyzed the trophic spectrum of a crested newt population from a permanent pond situated near the Aleşd – Zalău road, close to Şinteu village, from the high part of the Plopiş Mountains. The pond is relatively large, being 15 m long, 5 m wide, and approximately 1 m deep. It has rich aquatic vegetation, a silt substrate, and is continually recharged by a nearby spring.

The study was carried out from April to June 2003, during which time we analyzed the stomach contents of 490 newts, captured on 5 different occasions. The newts were captured by dredging of the silt substrate or of the water mass. The stomach contents were extracted by the stomach washing method (Joly 1987, Cogălniceanu 1997), with the help of a syringe equipped with a thin perfusion pipe. After that, the newts were released. The samples were collected in airtight test tubes, preserved in 4% formaldehyde, and then analyzed under the binocular microscope. The identification of prey items up to the Order and Family levels was made by examining also the scientific literature (Radu & Radu 1967, Ionescu et al 1971, Crişan & Mureşan 1999, Crişan & Cupşa 1999). A more accurate identification is not relevant for the purpose of this study (Mescherski 1997).

We analyzed the following parameters of the trophic spectrum: 1. The taxonomic classification of the prey items. 2. The variation in the maximum and medium number of preys per *Triturus cristatus* individual. 3. The relative abundance of a certain prey taxon in the total number of identified preys (the fraction between the number of preys belonging to a certain prey taxon and the total number of preys). 4. The frequency with which newts ate a certain prey taxon (the fraction between the number of newts that ate the certain prey taxon and the total number of newts). 5. The belonging of prey taxa to the aquatic or terrestrial environment and the relative abundance of preys from the two environments.

Results and Discussions

In the stomach contents of the *Triturus cristatus* population from Şinteu we have identified a number of 5041 animal prey items that were narrowed down to 30 prey categories. We have also identified other animal, vegetal or mineral particles.

A number of the studied *Triturus cristatus* individuals had empty stomachs when they were captured. The percent of empty stomachs was 4,61 at the beginning of April (fig. 1), null at the end of May, and it rose again in June, but not to the April level. This variation is due to the life-cycle of crested newts. When they enter the water for reproduction they adapt to the aquatic environment, and after the eggs are laid, they leave the water and readapt to the terrestrial life. Besides the differences in the newts' individual ability to capture preys, the difference between the number of newts with empty stomachs at the start and at the end of the aquatic period can be explained by other factors also. One of the causes may be the increase in the animal biomass due to higher temperatures of the habitat. Thus, at the beginning of April, the potential preys are few, while in June, the small sized fauna's abundance offers the newts numerous occasions to capture preys, even if their ability to capture them is probably lower. The presence of individuals with empty stomachs was previously pointed out in the literature with reference to several Amphibian species, including crested newts (Covaciu-Marcov et al 2001a, 2002a, b, c, d, 2003, Cristea et al. 1972, Houston 1973).

Triturus cristatus is a predacious species (Fuhn 1969), which as all Amphibians, consume mobile preys (Zimka 1966). Still, it is known that crested newts may accidentally consume vegetal items, usually algae, and that not all the animal preys are mobile, the newts occasionally eating egg-clutches or Amphibian' shed skin also (Covaciu-Marcov et al 2001a, 2002a, b, c, d).

The vegetal contents that we have identified (fig. 1) are represented by fragments of aquatic plants, usually algae, and only sporadically by terrestrial vegetation. The high percent of newts that ate vegetal items (65,71%), and the extremely big difference between this value and that of the percent of newts that ate only vegetal items (1,63%) may be explained by the fact that vegetal fragments were accidentally ingurgitated along with the target prey (Whitaker et al. 1977). There are still newts that ate only vegetal items, fact due probably to the mistaking of vegetal elements of the surrounding environment for potential preys (Covaciu-Marcov et al 2000, 2003). Despite the fact that there are several Amphibian species that have a vegetarian diet (da Silva 1989), it is generally considered that vegetal prey items reach the Amphibian stomachs by accident, the phenomenon having been traced in a large number of Amphibian species: *Bombina bombina* (Sas et al 2003), *Rana arvalis* (Covaciu-Marcov et al 2001b), *Rana perezi* (Hodar et al 1990), *Rana ridibunda* (Covaciu-Marcov et al 2000, Vancea et al 1961), *Rana temporaria* (Houston 1973), *Triturus cristatus* (Dolmen & Koksvik 1983).

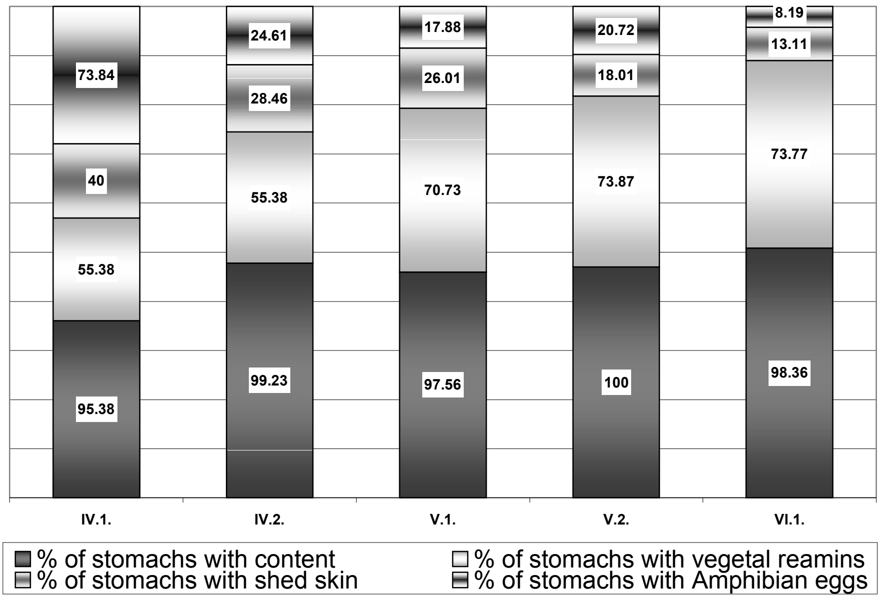

Figure 1 The amount of stomachs with content, vegetal remains, shed-skin and Amphibian eggs

During April and the first part of May, three of the studied newts had mineral items in their stomachs: little pebbles or ground particles (fig. 1). The most likely accidental presence of the mineral particles in the trophic spectrum of crested newts confirms the fact that newts are prone to ingurgitate items of different nature than animal, along with their targeted prey. This appears to be verified also by the fact that mineral elements disappear from their diet in the second part of their aquatic period. At this time, aquatic vegetation becomes more luxuriant and therefore obliges the newts to hunt in the water mass, and not only at the bottom of the pond, even if they are predominantly benthonic (Dolmen & Koksvik 1983). This way, the probability to ingurgitate mineral particles becomes very small. The presence of mineral particles in Amphibian stomachs was previously recorded in literature also (Vancea et al. 1961, Sas et al. 2003).

Animal food, other than that represented by mobile preys that newts detect using their sight, can be identified by them with the help of smell (Cogălniceanu et al. 2000). The egg-clutches or shed skins of Amphibians, present in the stomach contents of newts (fig. 1) indicate the procurement of food by smell. Along with Amphibian shed skins, in one stomach content we have identified *Lacerta agilis* shed skin fragments, this being a premiere in the trophic spectrum of crested newts. By eating their own shed skin or that of other individuals of the population, a recycling of epidermal proteins takes place (Weldon et al. 1993). This phenomenon has been observed in several Amphibian species (Sas et al. 2003, Gunzburger 1999, Guidali et al. 1999). Generally, Amphibians eat their own shed skins or that of other individuals of the species, fact that justifies the idea of epidermal proteins recycling. In the case of the Şinteu population, some of the newts ate shed skins of yellow-bellied toads (*Bombina variegata*). The eating of shed skins of a different species is a premiere, suggesting a certain form of predatory behavior, the yellow-bellied toads also eating their own shed skins (Sas et al. 2003). In the population studied by us, the number of newts that ate shed skins decreased continually with the advance of the warm season. The higher values recorded at the beginning of the aquatic period are probably due to the scarcity of other potential preys.

Table 1 The number of analyzed samples; The total number of preys; The average and the maximum number of prey individuals / stomach; The amount of aquatic and terrestrial preys

	IV.1.	IV.2.	V.1.	V.2.	VI.1.	Total
No. of analyzed samples	65	130	123	111	61	490
Total number of preys	288	1238	597	1337	1581	5041
Average number of prey individuals / stomach	4,64	9,59	4,97	12,04	26,35	10,45
Maxim number of prey individuals / stomach	59	50	17	54	211	211
% of aquatic preys	96,53	99,36	96,82	91,54	97,92	96,42
% of terrestrial preys	3,47	0,64	3,18	8,45	2,08	3,57

The high percent of newts that ate Amphibian eggs at the beginning of April (fig. 1) is due to the abundance of *Rana dalmatina* and *Rana temporaria* egg-clutches in the habitat at that time. After the retreat of brown ranids, the persistence of eggs in the trophic spectrum of newts is due to the presence of other Amphibians: newts, yellow-bellied toads (*Bombina variegate*) and green frogs (*Rana ridibunda*). Crested newts have also consumed their own eggs during the egg-laying period, cannibalism being a feature encountered in other Amphibian species as well (Sin et al 1975, Loman 1979). The eating of Amphibian eggs may be considered as a highly profitable activity, due to the abundance of egg-clutches and the small effort needed to obtain this type of food (Covaciu-Marcov et al. 2002d).

Table 2 The amount and the frequency of the prey items depending the period

	Amount					Frequency				
	IV.1.	IV.2.	V.1.	V.2.	VI	IV.1.	IV.2.	V.1.	V.2.	VI
Nematoda	-	-	0,16	-	-	-	-	0,16	-	-
Oligochaeta Lumbricida	1,04	0,16	-	0,59	0,12	1,04	0,16	-	0,59	0,12
Crustacea Ostracoda	-	-	0,50	-	2,02	-	-	0,50	-	2,02
Crustacea Cladocera	-	-	-	-	40,29	-	-	-	-	40,29
Crustacea Copepoda	1,04	-	-	-	0,18	1,04	-	-	-	0,18
Gasteropoda	2,08	0,16	0.67	0,44	-	2,08	0,16	0.67	0,44	-
Araneida	-	-	-	-	0,12	-	-	-	-	0,12
Miriapoda Diplopoda	-	-	0,16	-	0,12	-	-	0,16	-	0,12
Colembola	-	0,16	0,50	4,11	-	-	0,16	0,50	4,11	-
Ephemeroptera - imago	-	-	1	0,07	0,37	-	-	1	0,07	0,37
Ephemeroptera - larva	0,34	3,55	13,40	0,22	4,11	0,34	3,55	13,40	0,22	4,11
Odonata - larva	5,20	0,96	16,75	2,39	0,44	5,20	0,96	16,75	2,39	0,44
Homoptera Cicadinea	0,34	-	0,16	-	-	0,34	-	0,16	-	-
Homoptera Aphidinea	-	-	-	0,07	-	-	-	-	0,07	-
Heteroptera	-	0,08	-	0,74	0,.63	-	0,08	-	0,74	0,.63
Coleoptera Satfilinida	-	-	-	0,07	-	-	-	-	0,07	-
Coleoptera Curculionida	-	-	-	0,07	-	-	-	-	0,07	-
Coleoptera Dytiscus imago	-	-	0,16	0,14	0,06	-	-	0,16	0,14	0,06
Coleoptera undet..imago	1,04	0,08	0.67	6,73	0,88	1,04	0,08	0.67	6,73	0,88
Coleoptera Dytiscus larva	8,33	1,85	0,33	1,94	2,59	8,33	1,85	0,33	1,94	2,59
Coleoptera larva ter.	-	-	0,16	0,37	-	-	-	0,16	0,37	-
Lepidoptera - larva	-	0,16	-	0,07	0,06	-	0,16	-	0,07	0,06
Diptera Nematocera imago	0,34	-	0,33	0,14	0,12	0,34	-	0,33	0,14	0,12
Diptera Nematocera larva	3,12	6,54	62,14	80,40	47,50	3,12	6,54	62,14	80,40	47,50
Diptera Brachicera imago	-	0,08	0,50	0,14	0,06	-	0,08	0,50	0,14	0,06
Diptera Brachicera larva	0,34	0,16	-	0,44	-	0,34	0,16	-	0,44	-
Hymenoptera Formicida	0,34	-	0,16	-	0,18	0,34	-	0,16	-	0,18
Hymenoptera undet.	-	-	-	0,07	-	-	-	-	0,07	-
Amphibia - tadpoles	76,04	85,70	1,17	0,29	-	76,04	85,70	1,17	0,29	-
Amphibia – Triturus vulgaris	0,34	0,32	1	0,44	0,06	0,34	0,32	1	0,44	0,06

The largest part of preys captured by crested newts is represented by mobile Invertebrate preys, while the Vertebrates held very low consumption rates (tab. 2). The importance of a certain prey taxon to the crested newts is established on basis of that prey type percent relative to the total number of preys eaten, and of the frequency with which that prey taxon was eaten by crested newts.

In what concerns the most important prey taxa in the diet of crested newts, both as abundance and frequency, tadpoles were the most common prey during the beginning of the study period, and Nematocera larvae replaced them towards the end of the study period. Crested newts are opportunistic (Covaciu-Marcov et al 2002d) the importance of a prey taxon to them depending on its abundance, mobility, and size. Therefore, the potential prey must be abundant, mobile and have an appropriate size for the newt to swallow it. The high mobility of brown ranid tadpoles in May is compensating differently, to all other prey taxa, by size and abundance. The same thing happens with Nematocera larvae in May and June, when they have the highest profitability by number, mobility and size.

In mountain ponds, that are usually small, the feeding habits of newts are largely influenced by the optimum equilibrium between temperature and precipitation, situation that does not apply to our study habitat, that is of larger size and has permanent recharge through a spring. The average number of preys per newt at the first sampling is only of 4,64, this result being one of the consequences of lower temperatures at the beginning of April. During the first three samplings we have observed an increase in the number of captured prey categories as well as in the captured preys per newt. This is due to the increase in the animal community diversity along with the increase in ambient temperature on one side, and to the better agility of newts. The high mortality, the increase in size, and the higher mobility of brown ranid tadpoles is the reason why the average number of captured preys per newt decreased towards the end of April and the beginning of May. The relatively high number of preys per newt (26,25) in June is largely due to Cladoceran crustaceans from the genus *Daphnia*.

The maximum number of preys per newt decreases until the first half of May, and then it increases in June up to a value that is higher than the one recorded in April. The lowest maximum prey number per newt, 17, recorded at the beginning of May, is established by the highest monthly abundance of large-sized preys, newts eating 100 Odonata larvae, 80 Efemeroptera larvae, and 6 individuals of *Triturus vulgaris*. In June we recorded the highest number of preys per newt (211) that was induced by the numerical explosion of Cladoceran crustaceans.

At every sampling event, when checking in a decreasing order the values of prey abundance and consumption frequency, we noticed a correlation between abundance and frequency of preys by type (Tab. 4 and 5), as follows: up to the fifth prey category at the first sampling from April (tadpoles, Ditiscidae larvae, Odonata larvae, Nematocera larvae, and aquatic gasteropods), up to the forth category of preys at the second sampling (tadpoles, Nematocera larvae, Efemeroptera larvae, and Ditiscidae larvae), up to the third prey category at the first sampling from May (Nematocera larvae, Odonata larvae and Efemeroptera larvae), up to the second prey category at the second sampling from May (Nematocera larvae and terrestrial Coleopterans). Finally, at the last sampling, Nematocera larvae held the first place both as abundance and frequency. The continuing decrease, from five to one, of prey categories up to which the correlation persists between the abundance and frequency of predator newts shows that situations where a prey taxon, even if accounting for a large number of consumed preys, was eaten by few newts, are common. In June, for example, on the second place in what concerns the abundance, are crustaceans (42,50 %), as for the frequency, Efemeroptera larvae hold the second place (47,54 %). This inadvertence in the given situation is due to Daphnia: 7 newts ate 637 Daphnia individuals, while the 65 Efemeroptera larvae were eaten by 29 newts. The explanation for the increase in the number of situations where a prey taxon has a low consumption rate even if it holds a high rank from the total number of captured preys is the difference in food availability between different parts of the pond. The possibility of capturing aquatic preys from another pond is null, due to the fact that there are no other ponds nearby. Due to differences in the shape of the shore and the different depth from one place to another of the pond, the aquatic vegetation developed differently along with the progress of the warm season. The animal community developed under the same pattern. The assumed low mobility of crested newts when capturing prey toward the end of the aquatic period, indicates a shift towards the "sit-and-wait" feeding strategy.

Some researchers pointed out that large Amphibian species have eaten fish, other amphibians or mammals (Sampedro et al. 1986, Covaciu-Marcov et al. 2000). In the trophic spectrum of the crested newts, the only vertebrate remains that we observed were amphibian tadpoles, amphibian eggs and other smaller newts (Covaciu-Marcov et al. 2002). In the stomach contents of the studied population, we identified 18 individuals of *Triturus vulgaris*. The numeric difference between the eaten newts from April and May is due to their reduced presence in the pond immediately after the cold season. The only *Triturus vulgaris* prey item eaten in June, along with the increase in the number of empty stomachs found, tends to confirm that, when they prepare to leave the pond, crested newts are less capable of catching preys.

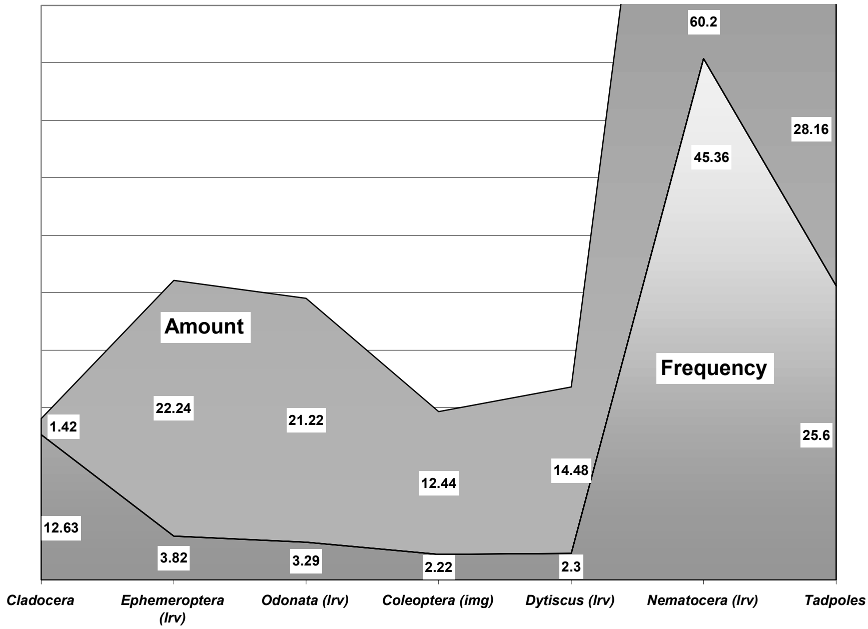

Figure 2 The amount and the frequency to the whole period of the most important preys

From the 5041 prey items eaten by crested newts, 96,42 % were aquatic, while the rest came from the terrestrial environment. The number of terrestrial preys evolved antagonistically to the average number of preys per newt throughout the entire study period, with one exception only (second half of May). The terrestrial coleopterans, 92 in number at the end of May, have raised the percent of terrestrial preys to 8,42, influencing thus the average number of preys per newt. Taking into account that the average number of preys per newt from the beginning of April and from May is smaller due to the lack of aquatic preys (because of lower temperature in the first situation, and of the decrease in tadpole availability in the second situation), we may conclude that newts rely more on terrestrial preys when they lack from the aquatic environment.

Conclusions

Crested newts eat mainly invertebrates, but may also ingest vegetal particles, Amphibian eggs or shed skins. Besides the shed skins of conspecific individuals, we have also identified shed skins of *Bombina variegata*, and even of *Lacerta agilis*. Due to the particular morphology of the habitat, the coming of the warm season brings about differences in the accessibility of different prey categories from one part to another of the Şinteu pond. This difference in the trophic offer causes modifications in the trophic spectrum, the adoption of the "sit-and-wait" feeding strategy, an increase in the number of empty stomachs, and indicates a decrease in the preying capacity of newts that prepare to leave the aquatic environment.

Quantitatively, the most important prey taxa to the studied population are tadpoles and Nematocera larvae. The decrease in number, the increase in size, and the more and more rapid movements of brown ranids tadpoles caused an increase in the percent of terrestrial preys between the end of April and the beginning of May. The percent of terrestrial preys was also high at the beginning of the aquatic period because aquatic preys were scarce, but the highest percent of terrestrial preys were caught during the second half of May. The largest number of large sized preys was recorded at the beginning of May, when Odonata larvae, Efemeroptera larvae and smaller newts (*Triturus vulgaris*) were de dominant preys.

Acknowledgements I would like to thank the anonymous reviewers for the valuable comments on the draft of this paper.

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Received 1 December 2005; Accepted 29 April 2005