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Food composition of a breeding population of the endemic Anatolia newt, *Neurergus strauchii* (Steindachner, 1887) (Caudata: Salamandridae), from Bingöl, Eastern Turkey

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Abstract. The study presents data on the food composition of a breeding population of the Anatolia newt *Neurergus strauchii* (Steindachner, 1887), from Bingöl, Turkey. A total of 953 prey items were determined in the food contents of 46 individuals (18 males and 28 females) examined in the study. Insecta (63%) and Malacostraca (35%) constitute 97% of the food composition by number. While the most frequently encountered prey groups in the diet are Diptera (87%), Amphipoda (85%), *Neurergus* eggs (74%), and Coleoptera (37%), the comparison of food composition by volume is Amphipoda (40%), *Neurergus* eggs (41%), and Diptera (10%) respectively. No significant difference in food niche was observed between the sexes. The species generally fed on aquatic, poor-flying or slow-moving invertebrates.

Keywords. Ecology, diet, trophic niche, dipterans, amphipods, oophagy.

INTRODUCTION

Understanding the feeding relationships in amphibian communities is of fundamental interest to herpetologists and ecologists due to their key role in aquatic ecosystems (Hirai and Matsui, 1999). Quantitative information about the role of amphibians in ecosystems is extremely important, particularly in their capacity as consumers in both aquatic and terrestrial habitats (Whiles et al., 2006). Furthermore, determining their feeding relationships in this trophic network is an essential step to understand the life cycle of the species and population fluctuations, as well as to develop successful conservation strategies (e.g., Duellman and Trueb, 1986; Cogălniceanu et al., 2001; Solé and Rödder, 2010).

The Middle Eastern newt genus *Neurergus* comprises five stream-dwelling species [*Neurergus strauchii* (Steindachner 1887), *N. barani* Öz 1994, *N. crocatus* Cope 1862, *N. kaiseri* Schmidt 1952, and *N. microspilotus* (Nesterov 1916)] distributed in Anatolia, Iran, and Iraq (Leviton et al., 1992; Papenfuss et al., 2009; Sparreboom, 2014; Rancilhac et al., 2019). The Anatolia Newt, *N. strauchii*, is endemic to eastern Turkey (Schmidtler and Schmidtler, 1970; Öz, 1994; Tok et al., 2016; Yıldız et al., 2018). Due to its narrow area of occupancy, which is less than 2000 km^2, its fragmented distribution, and habitat destruction, the species is listed as vulnerable in the IUCN Red List of Threatened Species (Papenfuss et al., 2009).

While *N. strauchii* inhabits small, cool mountain streams at altitudes between 950 and 1900 m above sea level, it overwinters on land not far from streams under stones and in burrows (Schmidtler and Schmidtler, 1970; Başoğlu et al., 1994; Bogaerts et al., 2012). Being semi-aquatic salamanders adapted to a high-elevation climate,

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adult Anatolia newt emerge from hibernation in early spring and thereafter migrate into streams that form during or after snowmelt where they will mate and breed (Bogaerts et al., 2010; Schneider and Schneider, 2010).

The species is widely studied with respect to distribution (e.g., Schmidtler and Schmidtler, 1970, 1975; Yıldız et al., 2018) and taxonomy (e.g., Steinfartz et al., 2002; Pasmans et al., 2006; Özdemir et al., 2009; Olgun et al., 2016; Rancilhac et al., 2019). Unfortunately, there are still limited data on its ecology (e.g. Schneider and Schneider, 2010; Bogaerts et al., 2006, 2010, 2012). Whilst limited information is available regarding the food habits of *Neurerus* species in captive (Bogaerts et al., 2012) and natural populations (Farasat and Sharifi, 2014), there are no data on the food habits of *N. strauchii* in nature. Therefore, the present study aimed to determine the food habits of a breeding population of the Anatolia newt from Bingöl, Turkey.

MATERIAL AND METHODS

In the study, the ingested food items of 46 aquatic adults (18 males and 28 females) collected between mid-May and early June 2014 from Soğukpınar Village in Genç – a district of Bingöl, Turkey (38°42'N, 40°27'E, 1,075 m a.s.l.) were examined. The newts were caught by hand and using fish nets in a small stream flowing into the Murat River between 07.00 and 13.00. Following capture, the sex of each individual was recorded and secondary sexual characters, snout-vent length (distance from the tip of the snout to the cloaca, SVL) and total length (from the cloaca to the tip of the tail, TL) were measured by using a caliper with a precision of 1 mm and recorded. Within an hour following capture, the stomach contents were extracted in field by flushing the stomach with pressurized water. The obtained food contents were preserved in a 70% ethanol solution for further analysis (Solé and Rödder, 2010; Çiçek, 2011).

The food contents were identified to the least inclusive possible taxonomic level. Vegetal materials, sand and small pebbles were also encountered in the food contents of four individuals (frequency of occurrence, F% = 8.7%). However, we concluded that these materials had most likely been ingested accidentally during foraging and were not regarded as food. The following parameters of dietary items were recorded: frequency of occurrence (the frequency of newt stomachs containing a particular prey type, F%), numeric proportion (the number of a particular prey item type relative to all prey items, N%), and volumetric proportion (the volume of a particular prey item as a percentage of all prey items, V%). The prey volume was calculated using an ellipsoid formula (Dunham, 1983): $V = 4/3\pi\ (L/2)\ (W/2)^2$, where V is the prey volume, L is the length of prey item, and W is the width of prey item. To determine the relative importance of each prey category in the diet of the species, the Index of Relative Importance (IRI, Pinkas et al., 1971) was calculated using the following formula: IRI = (N % + V %) F %, where N % is the numerical proportion of each prey item in the diet; V % is the volumetric proportion of each prey item in the diet; and F % is the relative frequency of occurrence of prey. The higher value indicates the greater importance of a particular prey item in the overall dietary composition.

Trophic niche overlap was calculated using Pianka's index (O, 1973). This index ranges from 0 (no similarity) to 1 (identical). Food-niche breadth was determined using Shannon's index (H, Shannon, 1948). All niche calculations were made using "EcoSimR vers. 1.0" package (Gotelli et al., 2014) in R vers. 3.6.1 (R Core Team, 2019). The sexes were compared by t-test, and Mann-Whitney U tests were performed using the Deducer statistical package (Fellows, 2012) in the same version of R. Mean values are provided with their standard deviations.

RESULTS

The average *Neurergus strauchii* body length (SVL) was 70.3 ± (SD) 2.84 mm (range = 63-75 mm) for males and 71.2 ± 3.01 mm (65-77 mm) for females. The average total length (TL) was determined as 146.8 ± 7.08 mm (134-159 mm) in males and 148.3 ± 5.77 mm (136-158 mm) in females. No statistically significant difference was observed between the sexes in terms of their sizes (SVL, t = 0.983, P = 0.332; TL, t = 0.016, P = 0.987).

In the food content of 46 individuals, a total of 953 prey items, with body lengths ranging from 3 to 55 mm, were determined with a median number of 18 (range = 1-50) dietary items per individual. The median number of prey items was 16 (1-50) for males and 17.5 (1-39) for females. While the number of prey items was slightly greater in females, there was no significant difference between the sexes (Mann-Whitney U test, Z = -0.452, P ≤ 0.652).

Among the prey taxa shown in Table 1, the highest frequency of occurrence (F% > 30%) in the food composition was observed for Diptera (87%), Amphipoda (85%), *Neurergus* eggs (74%), and Coleoptera (37%). Diptera (46%) and Amphipoda (34%) were the most abundant prey groups (N% > 20%). The greatest prey volumes (V% = 20%) were accounted for by Amphipoda (40%) and *Neurergus* eggs (41%). More active prey items such as adult Diptera, Coleoptera, Hemiptera, Lepidoptera, and Orthoptera were less frequently encountered in the food contents. Larval prey accounted for 36% of dietary items in number, 93% in frequency, and 10% in volume in the total food content. Vegetal fragments (e.g., leaves, roots, and seeds) and inorganic material were observed in 4.4% of the newts and were considered to have been ingested accidentally during foraging. In addition, the presence of shed-skin remains was detected in the diet of two individuals (F% = 4.4%). Amphipoda (IRI = 6827), Diptera (5386), *Neurergus* eggs (3739) and Coleoptera (318) were the most important prey categories in Anatolia newts (Table 1).

Table 1. The food composition of 46 (18 males and 28 females) *N. strauchii* individuals from Eastern Anatolia, Turkey. F: Frequency of occurrence, N: Numeric proportion, V: Volumetric proportion, IRI: Index of Relative Importance.

Prey Taxa	F (%)			N (%)			V (%)			IRI
	Females	Males	Overall	Females	Males	Overall	Females	Males	Overall	
MOLLUSCA: GASTROPODA	8 (28.6%)	1 (5.6%)	9 (19.6%)	10 (1.7%)	1 (0.3%)	11 (1.2%)	62 (0.9%)	4 (0.1%)	67 (0.6%)	29.9
Lymnaeidae	6 (21.4%)	-	6 (13.0%)	7 (1.2%)	-	7 (0.7%)	48 (0.7%)	-	48 (0.4%)	14.8
Planorbidae	2 (7.1%)	1 (5.6%)	3 (6.5%)	3 (0.5%)	1 (0.3%)	4 (0.4%)	15 (0.2%)	4 (0.1%)	19 (0.2%)	3.8
ANNELIDA: CLITELLATA	3 (10.7%)	-	3 (6.5%)	3 (0.5%)	-	3 (0.3%)	124 (1.7%)	-	124 (1.1%)	8.9
Lumbricidae	3 (10.7%)	-	3 (6.5%)	3 (0.5%)	-	3 (0.3%)	124 (1.7%)	-	124 (1.1%)	8.9
ARTHROPODA	28 (100%)	18 (100%)	46 (100%)	567 (97.8%)	372 (99.7%)	939 (98.5%)	7069 (97.4%)	4543 (99.9%)	11612 (98.4%)	55801.7
Chilopoda	-	1 (5.6%)	1 (2.2%)	-	1 (0.3%)	1 (0.1%)	-	4 (0.1%)	4 (<0.1%)	0.3
MALACOSTRACA: ISOPODA	2 (7.1%)	2 (11.1%)	4 (8.7%)	2 (0.3%)	5 (1.3%)	7 (0.7%)	45 (0.6%)	48 (1.0%)	92 (0.8%)	13.2
Oniscidae	2 (7.1%)	2 (11.1%)	4 (8.7%)	2 (0.3%)	5 (1.3%)	7 (0.7%)	45 (0.6%)	48 (1.0%)	92 (0.8%)	13.2
MALACOSTRACA: AMPHIPODA	26 (92.9%)	13 (72.2%)	39 (84.8%)	163 (28.1%)	-	328 (34.4%)	2530 (34.9%)	-	4763 (40.4%)	6827.3
Gammaridae	26 (92.9%)	13 (72.2%)	39 (84.8%)	163 (28.1%)	165 (44.2%)	328 (34.4%)	2530 (34.9%)	2233 (49.1%)	4763 (40.4%)	6827.3
INSECTA	26 (92.9%)	18 (100%)	44 (95.7%)	402 (69.3%)	201 (53.9%)	603 (63.3%)	4494 (61.9%)	710.8 (15.6%)	1872.8 (15.9%)	20301.5
ORTHOPTERA	1 (3.6%)	-	1 (2.2%)	1 (0.2%)	-	1 (0.1%)	6 (0.1%)	-	6 (0.1%)	0.3
EPHEMEROPTERA	4 (14.3%)	1 (5.6%)	5 (10.9%)	11 (1.9%)	4 (1.1%)	15 (1.6%)	24 (0.3%)	10 (0.2%)	34 (0.3%)	20.2
HEMIPTERA	3 (10.7%)	4 (22.2%)	7 (15.2%)	7 (1.2%)	6 (1.6%)	13 (1.4%)	21 (0.3%)	26 (0.6%)	47 (0.4%)	26.8
Notonectidae	3 (10.7%)	4 (22.2%)	7 (15.2%)	7 (1.2%)	6 (1.6%)	13 (1.4%)	21 (0.3%)	26 (0.6%)	47 (0.4%)	26.8
HYMENOPTERA	-	1 (5.6%)	1 (2.2%)	-	1 (0.3%)	1 (0.1%)	-	1 (<0.1%)	1 (<0.1%)	0.2
Formicidae	-	1 (5.6%)	1 (2.2%)	-	1 (0.3%)	1 (0.1%)	-	1 (<0.1%)	1 (<0.1%)	0.2
COLEOPTERA	10 (35.7%)	7 (38.9%)	17 (37.0%)	21 (3.6%)	15 (4.0%)	36 (3.8%)	167 (2.3%)	402 (8.8%)	569 (4.8%)	317.9
Coleoptera sucul	4 (14.3%)	1 (5.6%)	5 (10.9%)	14 (2.4%)	4 (1.1%)	18 (1.9%)	88 (1.2%)	20 (0.4%)	108 (0.9%)	30.5
Coleoptera larva	6 (21.4%)	5 (27.8%)	11 (23.9%)	7 (1.2%)	10 (2.7%)	17 (1.8%)	79 (1.1%)	364 (8.0%)	443 (3.8%)	132.4
Carabidae	-	1 (5.6%)	1 (2.2%)	-	1 (0.3%)	1 (0.1%)	-	18 (0.4%)	18 (0.2%)	0.6
LEPIDOPTERA	3 (10.7%)	4 (22.2%)	7 (15.2%)	4 (0.7%)	4 (1.1%)	8 (0.8%)	11 (0.1%)	20 (0.4%)	31 (0.3%)	16.8
Lepidoptera indet.	1 (3.6%)	2 (11.1%)	3 (6.5%)	2 (0.3%)	2 (0.5%)	4 (0.4%)	1 (<0.1%)	5 (0.1%)	6 (<0.1%)	3.1
Lepdoptera larvae (indet.)	2 (7.1%)	2 (11.1%)	4 (8.7%)	2 (0.3%)	2 (0.5%)	4 (0.4%)	10 (0.1%)	15 (0.3%)	25 (0.2%)	5.5
DIPTERA	24 (85.7%)	16 (88.9%)	40 (87.0%)	298 (51.4%)	143 (38.3%)	441 (46.3%)	933 (12.9%)	251 (5.5%)	1184 (10.0%)	5385.9
Diptera adult	2 (7.1%)	1 (5.6%)	3 (6.5%)	5 (0.9%)	2 (0.5%)	7 (0.7%)	37 (0.5%)	1 (<0.1%)	38 (0.3%)	6.9
Chironimid Larvae (indet.)	18 (64.3%)	11 (61.1%)	29 (63.0%)	116 (20.0%)	34 (9.1%)	150 (15.7%)	390 (5.4%)	104 (2.3%)	495 (4.2%)	1256.4
Culicidae	8 (28.6%)	6 (33.3%)	14 (30.4%)	90 (15.5%)	25 (6.7%)	115 (12.1%)	347 (4.8%)	57 (1.3%)	404 (3.4%)	471.5
Culicid larvae	17 (60.7%)	10 (55.6%)	27 (58.7%)	87 (15.0%)	82 (22.0%)	169 (17.7%)	159 (2.2%)	89 (2.0%)	248 (2.1%)	1164.1
AMPHIBIA: CAUDATA	18 (64.3%)	16 (88.9%)	34 (73.9%)	60 (10.3%)	28 (7.5%)	88 (9.2%)	3332 (45.9%)	1548 (34.0%)	4880 (41.3%)	3738.6
Neurergus eggs	18 (64.3%)	16 (88.9%)	34 (73.9%)	60 (10.3%)	28 (7.5%)	88 (9.2%)	3332 (45.9%)	1548 (34.0%)	4880 (41.3%)	3738.6
Total number of prey items	28	18	46	580	373	953	7255	4548	11803	

The food niche breadth (Shannon's index) was low and quite similar between the sexes (1.62 for males and 1.34 for females). The food spectrum of the newts yielded a moderate niche breadth based on the index value. Prey composition was quite similar between the sexes (Pianka's niche overlap index, 0.68), indicating the use of similar microhabitats for foraging. Despite small differences in percentages, no statistically significant differences were found between the sexes with respect to food contents.

DISCUSSION

Adult *Neurergus* newts mainly feed on aquatic prey items in their larval stages (e.g., Kutrup et al., 2005; David et al., 2009; Covaciu-Marcov et al., 2010; Kopecký et al., 2012; Farasat and Mozafar, 2014). The close relative of *N. strauchii*, *N. microspilotus* predominantly feeds on benthic macroinvertebrates, mainly Mycetophilidae, Baetidae, Corbiculidae, Gammaridae, and Lumbricidae (Farasat and Mozafar, 2014). In this study, the most frequent prey items of Anatolia newts were dipterans, amphipods, coleopterans, and their own eggs, whereas the greatest prey volume was attributable to amphipods, *N. strauchii* eggs, and dipterans. The dietary components of Anatolia newts are similar to those of other species of newts (Farasat and Mozafar, 2014). The utilization of amphibian eggs as food is beneficial for several reasons, one of them being the low energy consumption needed for a large volume of food (Denoël and Demars, 2008). The sampling was done during the breeding period of the species and there were many egg clutches in the study area. Eggs were identified in the food contents of 34 individuals (74%). The consumption of amphibian eggs has also been recorded in other newt species (Covaciu-Marcov et al., 2010; Kopecky et al., 2012; Farasat and Mozafar, 2014), though Farasat and Mozafar (2014) reported *N. microspilotus* to consume its own eggs at a lower rate. Our observation in the field showed that the prey spectrum in the environment of the species was limited and that the easily obtained eggs could substitute for potential prey requiring greater foraging effort. It has been shown that in captivity, *N. strauchii* will eat a wide variety of food items offered, even dead unnatural food items, such as slices of liver and octopus (Bogaerts et al., 2012). This means that they are certainly able to identify and eat non-moving foods like an egg in their natural habitats. Under poor environmental conditions, this could be an effective strategy to avoid starvation.

There were no sex-specific differences detected in the food composition of *N. strauchii* in Anatolia. This also coincides with many studies on the same issue reporting that there is no difference between the sexes (e.g., Covaciu-Marcov et al., 2010; Farasat and Mozafar, 2014). This indicates that both sexes use the same habitat for foraging. However, some species (e.g. *Lissotriton vulgaris*, *Lissotriton montandoni*, *Triturus cristatus* group) exhibit sex-specific differences in the feeding strategy and a certain level of trophic selectivity (Covaciu-Marcov et al., 2002, 2010) depending on newt size variation (David et al., 2009; Covaciu-Marcov et al., 2010).

Data suggest that amphibians exhibit two modes for foraging: sit-and-wait foraging and active foraging. While actively foraging, amphibians wander around the environment in search of prey, thus spending considerable energy in the search phase but little energy in the capture phase of foraging (Vitt and Caldwell, 2014). They mostly encounter and consume non-moving or slow-moving prey items (Pianka, 1966) and generally use their visual and olfactory senses while foraging (Vitt and Caldwell, 2014). Their food niche breadth is rather narrower than that of sit-and-wait predators (Perry and Pianka, 1997). Having its diet based mainly on composed slow-moving aquatic invertebrates, the Anatolia newt could be considered an active forager.

As stated in the study, the Anatolia newt's food items comprise slow-moving aquatic invertebrates, particularly aquatic dipterans, amphipods, and coleopterans, as well as their own eggs. There is no significant difference in food composition between the sexes. The species is an active predator usually feeding on poor-flying or non-flying prey items. It has low food niche breadth, mostly limited to the classes Insecta and Malacostraca. The abundance of these prey taxa in habitats might potentially indicate streams habitable by the Anatolia newt within its range. The data on the biology and ecology of the Anatolia newt are still insufficient to identify the ecological pressures on populations. Unfortunately, further studies are necessary to determine its ecology, habitat, and distribution pattern.

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