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„Dispersal and migration in yellow-bellied toads,
Bombina variegata“

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1 Introduction

In terrestrial vertebrates, including amphibians there are two different types of movements: dispersal and migration, which can be subdivided into short-distance and long-distance movements. Dispersal is described as nondirectional and random movements of individuals from natal sites to new sites (Heinz et al. 2006, Semlitsch 2008) whereas migration is described as bidirectional movements that mostly occur periodically such as movements towards and away from breeding sites (Semlitsch 2008, Osbourn 2012). Furthermore, dispersal and migration can be influenced by many aspects such as population density, habitat quality, abiotic and biotic factors (Hartel 2008, Semlitsch 2008, Osbourn 2012).

Explosive breeders such as the Common Toad (*Bufo bufo*) and the Moor Frog (*Rana arvalis*) migrate synchronized in large numbers across terrestrial habitats towards breeding sites. These breeding migrations between habitat patches are usually long-distance movements. Prolonged breeders, however, which have an extended breeding season, make repeatedly short-distance movements between closely located water bodies (Wells 2007).

Nathan et al. (2008) proposed that movement activities of amphibians are subdivided into four basic components affecting the movement of individuals: internal state, motion capacity, navigation capacity and external factors. In many pond-breeding amphibians juveniles are considered to be the primary dispersal stage, moving more or less randomly through terrestrial habitats (Gollmann & Gollmann 2005, Semlitsch 2008, Osbourn 2012). While juveniles are more vagile, dispersing from natal sites to new sites, adults often remain philopatric (Breden 1987, Berven & Grudzien 1990, Gollmann 2005). Movement implicates costs for amphibians such as predation, loss of energy and water loss. Especially newly metamorphosed and juvenile amphibians are highly vulnerable to predation and desiccation as they encounter new habitats (Osbourn 2012). The majority of individuals that survive the primary dispersal stage will return to their natal ponds after reaching sexual maturity, and a small number of individuals will disperse to new sites (Osbourn 2012). This

small number of dispersing individuals plays an important role in maintaining population dynamics (Semlitsch 2008, Osbourn 2012).

The movement of juveniles into terrestrial habitats, however, is hard to detect. Osbourn (2012) subdivided juvenile movement of pond-breeding amphibians into three fundamental phases with different goals: (1) the pre-departure phase, (2) the initial juvenile movement phase, and (3) the home range establishment phase. In the initial phase newly metamorphosed amphibians increase their energy reserves while waiting for optimal movement conditions. After metamorphosis juveniles emerge from their natal ponds and establishing of a home range starts. Movement of juveniles usually ends when a home range is established, but they may disperse to new breeding sites.

Pond-breeding amphibians show high site fidelity to natal sites and tend to return to those in later years (Berven & Grudzien 1990, Gollmann & Gollmann 2005, Gamble et al. 2007, Jacob et al. 2009). Philopatry, just as movement activity, depends on several factors such as distribution of favourable breeding sites, environmental conditions, life stage and fitness (Berven & Grudzien 1990, Barandun & Reyer 1998, Semlitsch 2008).

Fitness and energy stores of amphibians are analysed with body condition indices (BCI) (Băncilă et al. 2010, MacCracken & Stebbings 2012, Osbourn 2012) based on the relationship between body mass and a linear measure of body size. The BCI is an important tool to analyse the fitness and the reproductive potential of an individual (Green 2001), and has been used in different contexts of conservation and population biology. Parameters such as habitat quality, life stage, seasons, altitude, feeding, and movement direction affect the BCI (Lowe et al. 2006, Băncilă et al. 2010, MacCracken & Stebbings 2012).

The movement activity of juvenile and adult yellow-bellied toads (*Bombina variegata*), a temporary pond breeder, has often been studied (Beshkov & Jameson 1980, Kapfberger 1984, Abbühl & Durrer 1996, Gollmann & Gollmann 2000, Gollmann 2005, Gollmann & Gollmann 2005, Hartel 2008). As prolonged breeders the breeding season lasts from April to September, and breeding migrations are not as conspicuous as in other pond-breeding amphibians. Due to the proximity of hibernation, estivation and aquatic breeding sites, breeding migrations of *B. variegata* are described as short-distance movements (Glandt 1986). During the activity period females show continuous egg development and hence are able to spawn multiple times (Seidel 1988, Sy & Grosse 1998). They typically breed in shallow, unshaded, and temporary aquatic sites with no vegetation and high risk of drying up. While yellow-bellied toads show long life expectancies (Seidel 1992), their aquatic sites are usually ephemeral. Due to the high fluctuation of abiotic and biotic factors of aquatic sites, females show a risk spreading strategy, which is the ability to spawn several times during the season and at different sites (Buschmann 2002).

At the beginning of the activity season adult toads are predominantly found at aquatic sites, while juveniles arrive later (Niekisch 1990, Miesler & Gollmann 2000). During summer yellow-bellied toads, especially juveniles and females that are not sexually active can be found either at breeding sites or resting habitats (Möller 1996). As a pioneer species yellow-bellied toads are able to efficiently explore and colonize new aquatic sites (Seidel 1988, Niekisch 1990, Hartel et al. 2007). Movement activities are influenced by environmental conditions. Due to the risk of water loss, toads time their movements to correspond with rainfall (Hartel 2008). Newly metamorphosed toads abandon their breeding sites and do not return in the same year (Hoss 1994). While juveniles move considerable distances in the first 2-3 years of the postmetamorphic life (Gollmann & Gollmann 2000, 2005), adults are often found in the same habitat or even at the same site over years (Seidel 1988, Barandun 1995, Gollmann & Gollmann 2012). Nevertheless, dispersal does not exclude the possibility that some individuals return to natal sites (Barandun & Reyer 1998).

To examine the movement activity of yellow-bellied toads, the study area was visited in 2010 and 2011 from April to September. For better analyses of movements, data of a previous study in Großkrottenbach (Gollmann 2005) were included.

The research questions addressed in this study were:

- (1) Do yellow-bellied toads prefer certain habitats? Is the use of habitats related to life stage or sex? Which habitats are predominantly used for breeding?
- (2) Is the body condition of yellow-bellied toads affected by sex, seasons, altitude, and movement activity?
- (3) Does the movement activity of juvenile and adult yellow-bellied toads differ?
- (4) Do metamorphs leave their natal sites after metamorphosis? If so, what distances do they cover? Do they return to their natal sites?

2 *Materials and Methods*

2.1 *Background*

The present study is based on previous data of B. Gollmann and G. Gollmann who studied the population ecology of yellow-bellied toads in Großkrottenbach (Gollmann 2005). The aim of previous investigations was to gather information about population dynamics of *B. variegata* with focus on size structures, reproduction, movements, and population densities to propose guidelines and recommendations for habitat management. The area was visited annually (2002-2005) on five to six days from May to September. From 2006 to 2009 B. Gollmann and G. Gollmann visited the area sporadically. On 28 August 2008 a high number of metamorphs ($n = 405$) of *B. variegata* was registered at the site 1, which is located in a forest glade and consisted of a network of water-filled wheel ruts and puddles that were spring-fed.

Birgit Gollmann and Günter Gollmann reported that yellow-bellied toads in Großkrottenbach predominantly bred in newly created, shallow, and temporary water bodies that were unshaded (Gollmann 2005). More permanent aquatic sites tended to be unsuitable for breeding because of co-occurring competitors and predators. Breeding was observed at seven sites over a period of four years (Gollmann 2005). At the site 1 breeding was most successful, especially in 2008. Cleared sites, forest glades, forest aisles, and forest roads represented potential locations for aquatic sites of yellow-bellied toads. Activity of wild boars and forestry work created new sites, or maintained sites. Newly created water bodies such as water-filled wheel ruts were suitable for breeding and were quickly colonized by *B. variegata*. The population size was estimated with the Petersen method modified by Chapman. It was the highest in 2002 and decreased over the years (Tab. 1). Over a period of four years the mean movement distance, measured as the greatest distance between two capture points, was 113 m. No differences were found between the movement distances of males and females. Some individuals covered distances greater than 1000 m and for many toads site fidelity was observed.

Table 1. Population estimates of yellow-bellied toads in Großkrottenbach from 2002 to 2005 (Gollmann 2005).

Year	Population size \pm SE			
	total	males	females	juveniles
2002	406 \pm 26	165 \pm 13	142 \pm 24	110 \pm 13
2003	339 \pm 47	146 \pm 28	111 \pm 19	77 \pm 31
2004	327 \pm 22	131 \pm 10	165 \pm 19	34 \pm 8
2005	285 \pm 26	102 \pm 12	161 \pm 23	20 \pm 4

In the present study the area was expanded (Fig. 1) with the aim to document movements of yellow-bellied toads, especially those of juveniles, which were first registered as metamorphs in 2008. Therefore the area around the previous study area was scanned for possible water bodies used by *B. variegata*.

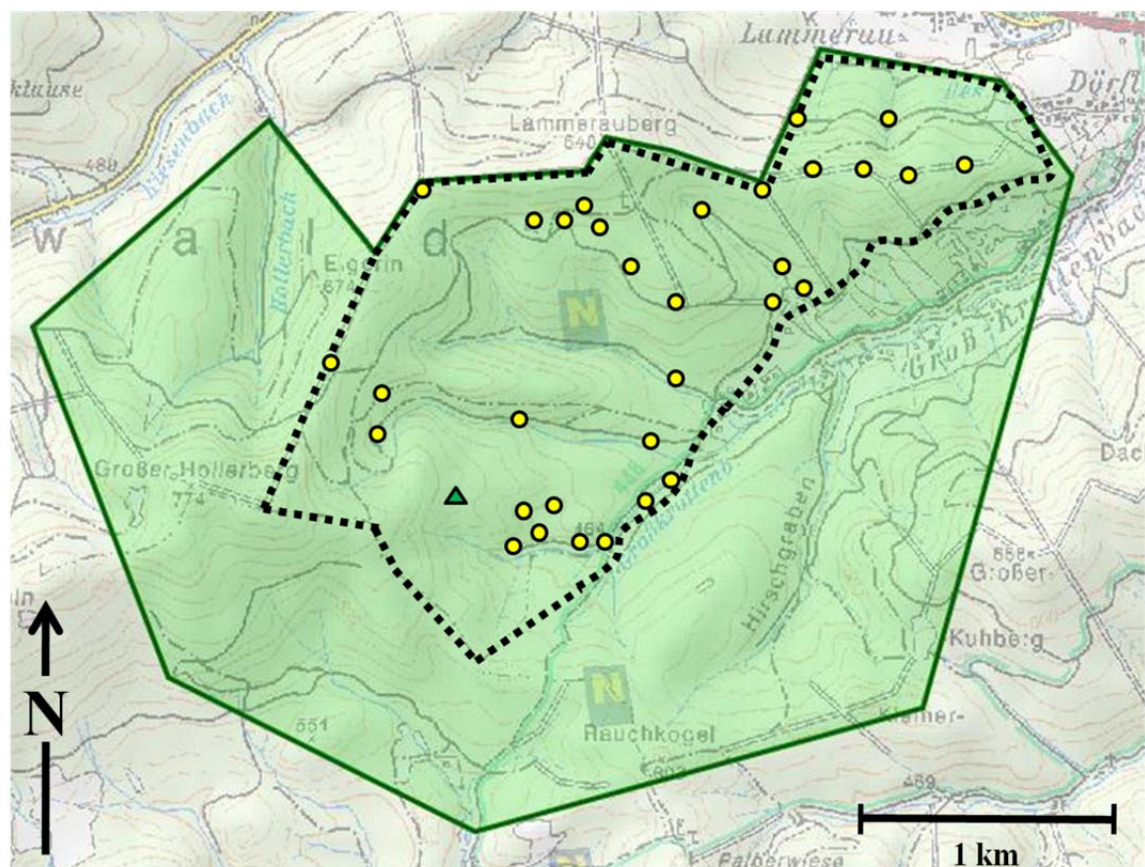


Figure 1. Map of Großkrottenbach (online NÖ atlas 4.0 – atlas.noel.gv.at). The dotted line shows the study area including all sites (○) where toads were recorded from 2002-2009 (Gollmann 2005; G. Gollmann, personal communication). The solid line shows the extended area that was investigated in the present study (2010-2011). The green triangle represents site 1 where breeding had been most successful, especially in 2008.

2.2 Study area

The data were collected in the biosphere park Wienerwald (Lower Austria) in Klausen-Leopoldsdorf, near Großkrottenbach (48°05'17.6" N, 16°00'53.9"; 374 m a. s. l.) on a forested area. The study area is located in a valley of the Vienna Woods and belongs to the flysch zone (Sandstone Vienna Woods). The forest is mixed deciduous, containing European Beech (*Fagus sylvatica*) as a major species. Furthermore, growths of hornbeam, maple, ashes, and pines are present. The major part of the forest in the study area is managed by the ÖBf (Österreichische Bundesforste AG). Forestry work includes building and graveling of forest roads, local clear-cuts and logging, creation and maintenance of forest aisles, and wildlife management. The agricultural use of fields in Großkrottenbach has become rare. Meadows and grasslands are predominantly used for hay production or grazing by horses and highland cattle. Populations of wild boars and red deer are present. The brook Großkrottenbach is formed in the valley and flows northeastwards into the river Schwechat. Man-made ponds in pastures are used for fishing and by cattle. In flat areas the flow of water is managed through drainage and roadside ditches. The valley is surrounded by several mountains: Hirschenstein (785 m) and Großer Hollerberg (774 m) in the northwest; Eigerin (674 m), Lammerauberg (648 m) and Großer Kuhberg in the northeast and Rauchkogel (603 m) in the southeast.

2.3 Data collection

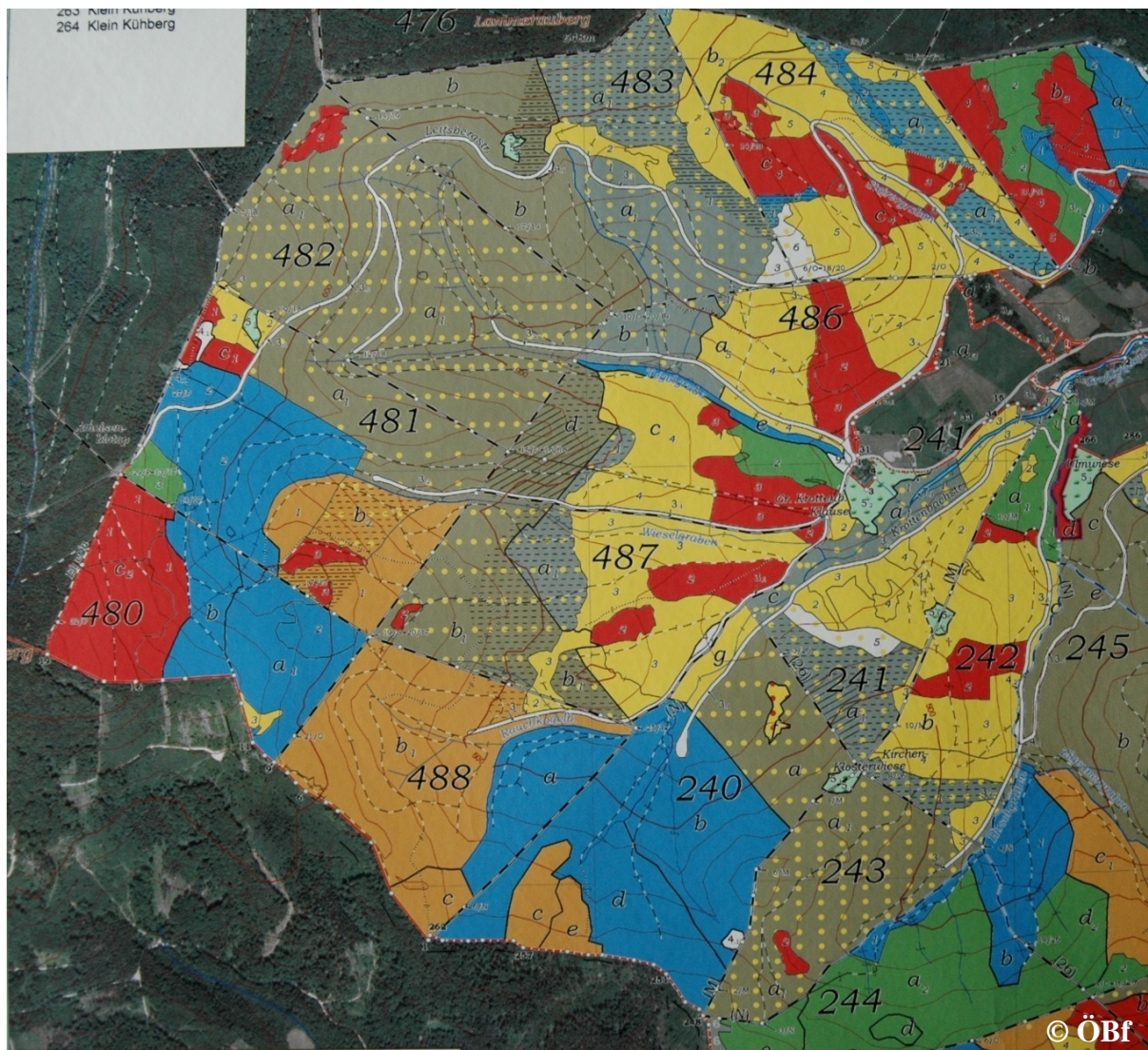
Fieldwork was conducted in 2010 and 2011 during the activity period of *B. variegata*. In 2010 the study area was visited on 20 days between 30 April and 11 September, in 2011 on 6 days between 11 June and 24 September (Tab. 2). All sites that were known from previous years were visited again and included in the present study if still existent. To explore the area for new sites different routes were chosen. At each visit all known sites that were located on the chosen route were sampled when toads were present. At each site all observed toads were captured. The ventral colour pattern of each toad was photographed. The snout vent length (SVL) was measured to the nearest 0.1 mm with callipers and the body mass (BM) was recorded with a pocket balance (TEE 150-1, max 150 g, d = 0.1 g, Kern & Sohn GmbH - Balingen, Germany). All toads were released immediately after measurements were taken. The sex was identified by presence of nuptial pads of males, while toads without nuptial pads and a length of at least 38 mm were recorded as females. All other toads below 38 mm were considered juveniles. For identification of recaptured toads pattern mapping was used (Gollmann & Gollmann 2011).

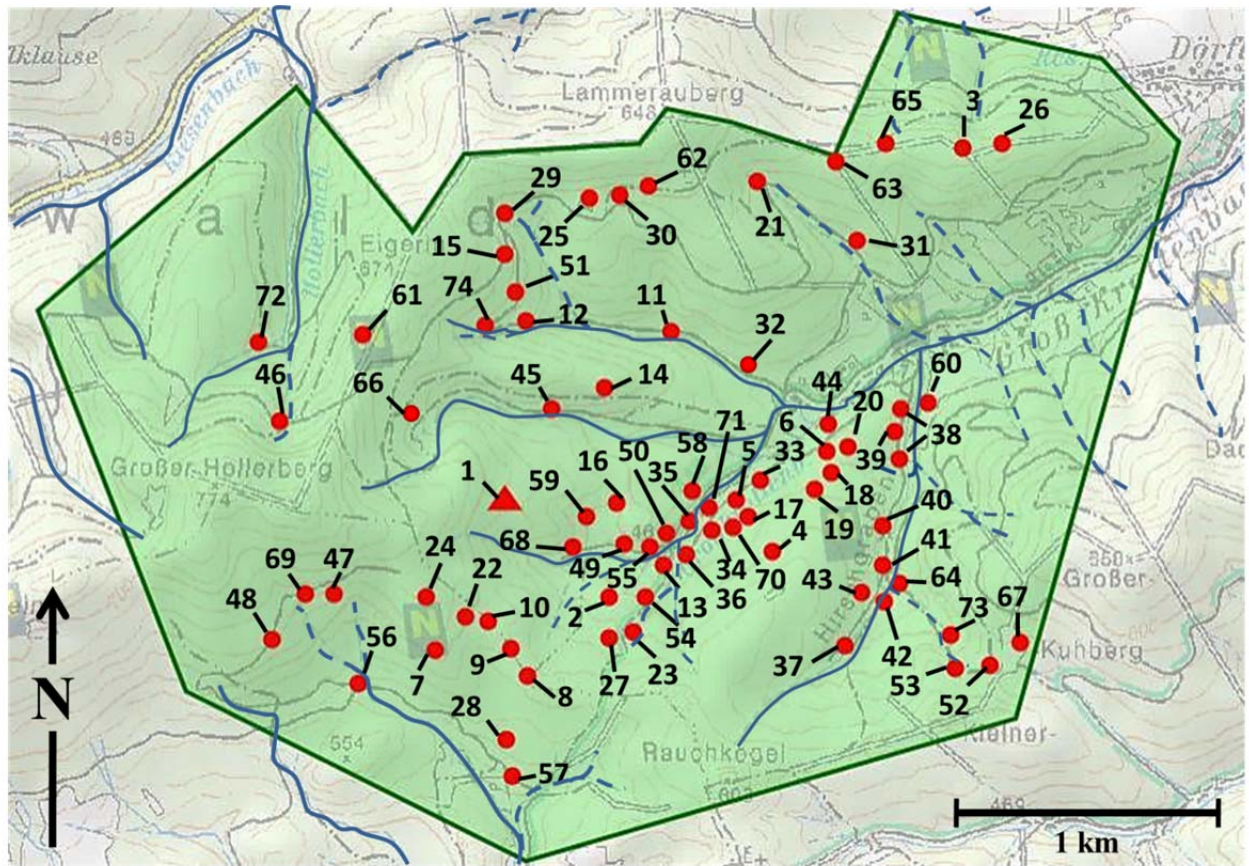
Table 2. Dates on which the area was visited, number of captured toads (n), and registered sites during investigations in 2010 and 2011.

Date	n	Sites
2010-04-30	58	487 A, 487 D oben, 487 M, 488 Y, 483 F, 483 sch, 483 H, 484 I, 484 J, 484 K, 484 N, 484 R, 486 Q
2010-06-06	85	241 a, 240 b, 240 c, 240 e, 240 x, 240 f, 240 g, 241 h, 241 i, 241 j, 241 k, 242tr, 242 tr 1, 242 m, 245 n, 245 n2, 245 o, 245 op, 241 p, 245 q, 51 r, 241 s
2010-06-26	74	481 u, 479 v, 488 Y, w, x, z, 488 yy, 488 D unten, 484 KT
2010-07-04	5	481 u, 486 Q
2010-07-09	51	488 D unten, 487 D oben
2010-07-12	51	488 D unten, 488 Y, z
2010-07-13	27	487 j, 487 i, 488 D unten, 488 yy, 479 v, 479 w, 481 o, 481 f, 481 u
2010-07-14	58	487 j, 488 D unten, b, r, z
2010-07-16	41	487 j, 487 B, 488 D unten, 488 yy, 488 nn 7/N, 488 2a, 488 2b, 488 2bo, 488 Y, 488 zw
2010-07-17	30	481 u, 486 t, 482 s, 482 so, 482 su, 482 x, 487 j, 487 B, 488 D unten, 488 yy, 488 zw, 488 nn 7/N
2010-07-19	42	240 wa, 240 Ti1, 240 Te1, 488 nn 7/N, 488 2b, 488 2bo, 488 D unten, 488 yy, z, b
2010-07-21	85	240 wa, 240 Ti1, 488 nn 7/N, 488 2b, 488 2bo, 487 j, 488 D unten, 487 D oben, 487 B, 488 yy, b, r
2010-07-22	27	51 r, 242 tr, 242 tr1, 245 n2, 245 n3, 245 u, 245 o, 245 ol
2010-07-23	20	481 u, 483 sch, 482 su, 487 j, 488 D unten, 488 yy
2010-07-26	9	481 u, 487 j, 488 D unten, 488 yy
2010-08-21	49	242 tr, 242 tr1, 51 r, 240 wa, 487 j, 488 yy
2010-08-22	28	240 wa, 240 ww, 240 Ti1, 488 nn 7/N, 488 2a, 488 2b, 488 2bo, 487 j, 487 D oben
2010-08-25	45	487 j, 488 D unten, 488 yy, 488 Y, b, r
2010-08-29	7	481 u, 479 v, 481 o, 240 wa, 488 yy
2010-09-11	33	487 A, 240 Ti1, 488 2a, b, r, n, nw, no, 240 wa
2011-06-11	108	240 wa, 488 nn 7/N, 488 2b, 487 B, 487 D oben, 488 yy, 488 Y, r
2011-07-07	74	242 tr, 242 tr1, 245 n, 245 n2, 245 op, 245 u, 263 s, 245 o, 51 r, 240 d, 240 f, 240 ww, 487 A
2011-08-01	23	487 A, 487 j, 488 yy, 488 Y, 487 zw, 240 ww
2011-08-07	193	487 A, 487 j, 487 D oben, 487 M, 488 Y, 481 o, 482 ra, 483 sch, 483 H, 484 I, 484 J, 484 K, 484 KT, 484 N, 479 v
2011-09-04	46	484 R, 482 ra, 479 v, 488 Y, w, z, 487 B, 487 A
2011-09-24	5	487 D oben, 488 Y, 488 nn 7/N

2.4 Definition and mapping of sites

Maps (scale 1:10.000) of Großkrottenbach (provided by ÖBf) were used for orientation in the field (Fig. 2). These maps included aerial photographs, information about forest age, forest aisles, and boundary stones, which facilitated orientation and made precise mapping possible. The aerial photographs were searched for open areas such as meadows, roads, forest glades and aisles to detect potential habitats of *B. variegata* (Fig. 3). Sites where yellow-bellied toads were observed were either defined as a single water body, or a network of various water bodies that were closely located to each other. All sites were classified by sea levels and categorized into five different types of water bodies: D – roadside ditches, P – ponds, PU – puddles, R – runlets, and WR – wheel ruts (Fig. 4, Tab. 3). The size and depth of each water body was measured. Water bodies were further categorized into: (1) temporary or permanent water bodies, (2) stagnant or running waters, (3) three categories of water depths (< 10 cm, 10-20 cm, > 20 cm), and (4) unshaded, partly shaded and shaded sites. Water bodies where eggs, tadpoles, or metamorphs occurred were registered as breeding sites. Attributes such as presence of aquatic vegetation, shading, cohabitating amphibians, and reptiles were observed and registered.





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Figure 4. Map of the study area in Großkrottenbach (online NÖ atlas 4.0 – atlas.noel.gv.at) including all sites ($n = 74$) that were visited in 2010 and 2011.

Table 3. Recording sites of *B. variegata* (Nr. – number of sites, site –coding of sites, WB – type of water body: D – roadside ditches, P – ponds, PU – puddles, R – runlets, WR – wheel ruts; SL – meters above sea level).

Nr.	Site	WB	SL (m)	Nr.	Site	WB	SL (m)
1	488 Y	PU, WR, R	567	38	242 tr, tr1	D	427
2	488 zw	WR	539	39	242 m	D	430
3	484 K	P, PU, WR	540	40	245 n	D	453
4	240 c	WR	483	41	245 n2	D	456
5	240 b	WR	460	42	245 op	D	462
6	241 h	WR	463	43	245 q	D	463
7	r oben, unten	WR	558	44	241 s	D	454
8	488 nn 7/N	WR	571	45	481 u	D	500
9	488 2a	WR	566	46	479 v	D	654
10	488 2b	WR	566	47	w	D	647
11	486 t	WR	475	48	x	D	633
12	482 s	WR	542	49	488 D unten	D	480
13	240 wa	WR	467	50	487 i	D	465
14	487 zw	WR	543	51	482 so	D	560
15	482 ra	WR	580	52	245 ol	D	538
16	487 D oben	PU, WR	499	53	245 o	D	535
17	240 g	PU	464	54	240 ww	D	477
18	241 i	PU	466	55	487 B	D	478
19	241 j	PU	468	56	n	D	536
20	241 k	PU	459	57	nw	D	510
21	484 R	D	516	58	487 A	PU, WR, R	455
22	488 2bo	PU	566	59	487 M	R	516
23	240 Ti1	PU	523	60	51 r	P	427
24	b	PU	639	61	481 o	P	663
25	483 F	PU	595	62	483 H	PU	598
26	484 KT	P	520	63	484 I	P	568
27	240 Te1	PU	523	64	245 n3	P	455
28	no	PU	524	65	484 J	P	541
29	482 x	D	587	66	481 f	PU	658
30	483 sch	D	585	67	263 s	PU	536
31	484 N	D	465	68	488 yy	PU	498
32	486 Q	D	457	69	z	R	616
33	241 a	D	456	70	240 d	R	466
34	240 e	D	462	71	487 j	R	464
35	240 x	D	467	72	479 w	R	584
36	240 f	D	478	73	245 u	R	525
37	241 p	D	477	74	482 su	R	550

2.5 Data analysis

Statistical analyses were performed using Microsoft® Excel® 2007, IBM® SPSS® 16.0 with α set at 0.05. The scaled mass index was analysed using R 2.15.3 with Rstudio version 0.97.

2.5.1 Identification of recaptures

For identification of yellow-bellied toads and the detection of recaptures the photographed ventral pattern of each individual was compared with photographs taken earlier in the season and of previous years (Fig. 5). Additionally, the photos were analysed with the pattern extraction and matching software Wild-ID 1.0.



Figure 5. Change of the ventral pattern of a yellow-bellied toad (nr. B1030) that was captured as a juvenile in 2008 and 2009 and recaptured as a male in 2010.

2.5.2 Total counts, recaptures and population size (2010-2011)

To analyse the frequency of recaptures between juveniles, males, and females a Kruskal-Wallis H test was used. The grouping variables were juveniles, males, and females and the dependent variables were the number of recaptures. Population size was estimated with the Petersen method modified by Chapman (Donnelly & Guyer 1994). The total number of all identified individuals, captured in 2010, was subsumed as first capture (r) and the total number of all identified individuals, captured in 2011, as second capture (n). The population was assumed to be ‘closed’, which means that there were no gains (births and immigrations) and losses (deaths and emigration). To minimise the rate of gains, metamorphs of both years were excluded from the calculations.

$$\hat{N}_c = \frac{(r + 1)(n + 1)}{m + 1} - 1$$

r...number of identified individuals (first capture – 2010)

n...number of identified individuals (second capture – 2011)

m...number of recaptures (in 2010 and 2011)

To calculate the standard error of population size, the formula by Seber (1970) was used:

$$SE_{\hat{N}_c} = \left[\frac{(r + 1)(n + 1)(r - m)(n - m)}{(m + 1)^2(m + 2)} \right]^{\frac{1}{2}}$$

2.5.3 *Snout vent length (SVL) and body mass (BM)*

2.5.3.1 *Size structure*

For comparison of the size structure of yellow-bellied toads the measurements of the first capture of 2010 and 2011 were used. All metamorphs were included. For correlation analyses between SVL and BM a Pearson correlation was used. To analyse the difference of SVL and BM between males and females, data of 2010 and 2011 were pooled together and a Mann-Whitney U test was calculated. The grouping variables were 'males' and 'females' and the dependent variables were data of body measurements. To test if there were significant interactions between SVL and BM in males and females between 2010 and 2011, a two-way ANOVA was used. Therefore 'sex' and 'years' were used as independent variables and SVL and BM as dependent variables.

2.5.4 *Growth*

2.5.4.1 *2010-2011*

To analyse the relationship of SVL and BM on growth of juveniles, males, and females, a linear regression was calculated. For SVL and BM data of the first capture (2010) and for growth, the difference of data from 2011 and 2010 were used. To detect differences in the increase of SVL between juveniles, males, and females an ANOVA was used. To analyse the increase of BM between juveniles, males, and females a Kruskal-Wallis H test was used.

2.5.4.2 *Metamorphs of 2008*

The growth of metamorphs, first captured in 2008, was defined as the difference of SVL of the last capture (2010/2011) and SVL of the first capture (2008). For analysis of the relationship between SVL and growth a linear regression was used.

2.5.5 Scaled mass index (SMI)

The body condition was calculated with the scaled mass index (SMI) using residuals from a standardized major axis regression (Peig & Green 2009, 2010). The SMI was calculated for each individual according to the following equation:

$$\hat{M}_i = M_i \left[\frac{L_0}{L_i} \right]^{b_{sma}}$$

To improve the linearity of SVL and BM, the data were ln-transformed. The scaling exponent b_{sma} was estimated by a standard major axis regression of lnBM and lnSVL using data of the first capture of each individual. The arithmetic mean of the SVL of all individuals ($n = 831$) of the first capture was taken as L_0 , M_i and L_i represent the raw data of BM and SVL. The resulting SMI scores were analysed by sex, season, months, altitude, and movement activity using parametric (ANOVA) and non parametric tests (Kruskal-Wallis H test and Mann-Whitney U test) to identify significant differences between the SMI and these factors. To test for homogeneity of variance a Levene test was used. To analyse statistically significant differences within groups a post-Hoc test (Tukey-HSD test) was chosen. For comparison between different methods of calculating body condition the scaling exponent b was further analysed with an ordinary least squares (OLS), a reduced major axis (RMA), and a major axis (MA) regression.

2.5.5.1 Relation of the SMI to sex, season, months, altitude and movement activity

To compare the SMI between juveniles, males, and females data of the first capture ($n = 831$) of each individual were used. To analyse the relationship between SMI and months in each season all captures ($n = 1273$) were partitioned by years (2010, $n = 826$; 2011, $n = 447$) and categorized by months (April-September). To analyse the relationship between SMI and altitude the data of all captures ($n = 1273$) were pooled together. For comparison of the SMI and the movement activity individuals were subdivided in 'mover' and 'stayer'. Movers ($n = 76$) were defined as individuals that changed sites at least once. Stayers ($n = 138$) were defined as individuals that were captured

and recaptured at the site of first capture. The SMI was calculated for movers and stayers at two capture points ('start' and 'end'). In the case of movers data of SVL and BM of the most distant capture points were used. For individuals that were captured more than once, at either the 'start' or 'end', the first capture was counted. In the case of stayers data of the first and the last capture were used.

2.5.6 SMI in 2010 and 2011

For comparison of the SMI in 2010 and 2011 a two-way ANOVA was calculated. Therefore 'month' and 'years' were defined as independent variables and the SMI as dependent variable.

2.5.7 Movement activity

The movement distances of yellow-bellied toads were defined as the greatest observed distance between two capture points (Herrmann 1996). To measure the movement distances, sea levels, and geographic coordinates, all sites were registered on the map and further analysed with the online NÖ atlas 4.0 (atlas.noel.gv.at). The dispersal rate was calculated as the standard deviation of the movement distance (Szymura & Barton 1986).

2.5.7.1 Movement (2010-2011)

To compare the movement distances between juvenile, male, and female yellow-bellied-toads a Kruskal-Wallis H test was chosen. For analysis of the relationship between SVL (independent variable) at the first capture and the greatest covered movement distance (dependent variable) of juveniles, males, and females a linear regression was used.

2.5.7.2 Movement of metamorphs (2008)

To analyse the relationship between SVL and movement distance of former metamorphs a linear regression was used. As independent variable the SVL at the first capture was chosen. For the dependent variable the movement distances were chosen. The sex of 11 former metamorphs could

be assigned over the years. For comparison of the relationship of the movement distances between sexes an ANOVA was used.

2.5.7.3 Comparison of movements of juveniles and adults (2008-2011)

For comparison of movements of juvenile and adult yellow-bellied toads, movement distances of individuals that were first captured in 2008 and/or 2009 and recaptured in 2010 and/or 2011 were used and a Mann-Whitney U test was calculated.

3 Results

3.1 Types of registered water bodies

3.1.1 Ponds (P)

Ponds were mostly unshaded, bigger than 300 x 100 cm, and deeper than 20 cm (Fig. 6). The water surface was often covered by macrophytes (Fig. 7).



Figure 6. Site 61 (13 July 2010).



Figure 7. Site 60 (22 July 2010).

Site 3. 484 K (540 m a. s. l., 400 x 220 x 33 cm)

A pond containing a lot of leaf litter. The banks were flat and without any aquatic vegetation. On 30 April 2010 tadpoles of *Rana* sp. were found. Puddles and wheel ruts were closely located to this pond.

Site 26. 484 KT (520 m a. s. l., 350 x 100 cm)

A small pond in a forest aisle closely located to water-filled wheel ruts. On 7 August 2010 larvae of the Alpine Newt *Ichthyosaura alpestris* were found.

Site 60. 51 r (427 m a. s. l., 1200 x 400 x 100 cm)

A pond located on the meadow Ulmwiese that was used as a feeding ground for Highland cattle. The banks were shallow and the terrestrial vegetation was dominated by rushes and sedges. The water surface was mainly covered with water lilies, and the banks were covered with algae. Another pond (1300 x 500 x 110 cm), located on the same meadow, was not used by *B. variegata* in 2010

and 2011. The banks were much steeper, without any aquatic vegetation and the bottom had clay as a substrate. On 6 June 2010 larvae of *I. alpestris* were found.

Site 61. 481 o (663 m a. s. l., 2500 x 1400 x 200 cm)

A big pond without fish located in a forest glade. The bottom was very muddy and the whole pond was surrounded by rushes. The eastern side of the pond was closer to the forest and the banks were grown over with blackberry shrubs. At the southern end the pond was very shallow and fell dry in 2010 and 2011. In August, 2010 the meadow and the bank vegetation was mowed. Close to the pond there were wet wheel ruts in the forest at which once two adult yellow-bellied toads were found. These captures were included into this site. On 13 July 2010 larvae of *I. alpestris* were found and on the way up to the pond numerous metamorphosed tadpoles of the Common Frog *R. temporaria* occurred.

Site 63. 484 I (568 m a. s. l., 320 x 300 x 110 cm)

A clay pond located in a forest aisle. The water was murky and without any aquatic vegetation. On 30 April 2010 larvae of *I. alpestris* and tadpoles of *Rana* sp. were found.

Site 64. 245 n3 (455 m a. s. l., 500 x 450 x 80 cm)

A pond situated alongside the road. The banks were steep and had collapsed on 22 July 2010. The pond was partly shaded and contained no aquatic vegetation.

Site 65. 484 J (541 m a. s. l.)

A pond located in a forest glade. The banks were shallow and the bottom muddy and partly covered with leaves. On 30 April 2010 spawn of *B. bufo* and larvae of *I. alpestris* were found.

3.1.2 Puddles (PU)

Puddles were water-filled depressions with a water depth of 10-20 cm, flat banks, and little aquatic vegetation (Fig. 8). Some puddles were shaded, but most were sun-exposed. Wallows of wild boars were defined as puddles as well (Fig. 9).



Figure 8. Site 16 (24 September 2011).



Figure 9. Site 1 (12 July 2010).

Site 1. 488 Y (567 m a. s. l.)

A network of four puddles and several water-filled wheel ruts located in a forest glade. Three main puddles were spring-fed and connected with each other. The fourth (120 x 70 x 16 cm) was not connected with the other puddles. The bottom of all puddles was muddy and no aquatic vegetation occurred. On 26 June 2010 metamorphs of *Rana* sp. and larvae of *I. alpestris* were found. All water bodies were partly shaded. The wheel ruts were surrounded by rushes and partly covered with *Lemna* sp. and algae.

Site 16. 487 D oben (499 m a. s. l., 180 x 30 x 20 cm)

A network of unshaded water bodies located on an area that had been cleared in the winter before 2002. There were several patchily distributed water-filled depressions on a swampy ground and one bigger permanent puddle, which was partly covered by a shrub and surrounded by rushes and blackberry shrubs.

Site 17. 240 g (464 m a. s. l., 80 x 50 x 4 cm)

A small puddle without any aquatic vegetation located on a meadow close to a bigger pond.

Site 18. 241 i (466 m a. s. l., 80 x 40 x 8 cm)

A puddle in a forest glade with clay as a substrate. The banks were partly covered with algae and were surrounded by grassy plants (*Carex demissa*).

Site 19. 241 j (468 m a. s. l., 120 x 60 x 7 cm)

A water-filled puddle of clay located in a forest glade without any aquatic vegetation.

Site 20. 241 k (459 m a. s. l., 100 x 40 x 5 cm)

A clayey puddle close to a forest glade without any aquatic vegetation.

Site 22. 488 2bo (566 m a. s. l., 400 x 140 x 9 cm)

A puddle located in a forest aisle. In 2010 the water level was very low and in 2011 the puddle completely dried up.

Site 23. 240 Ti1 (523 m a. s. l., 80 x 30 x 6 cm)

A shaded water-filled puddle formed by the uprooting of a tree, located on an area with several uprooted trees. These puddles were filled with water and leaf litter. The ground was partly swampy and overgrown with rushes and ferns. On July 19 and July 21, 2010 larvae of *I. alpestris* were found.

Site 24. b (639 m a. s. l., 260 x 100 x 10 cm)

A water-filled depression located in a forest glade. The puddle was surrounded by rushes and *Carex*. The water surface and the bottom were partly covered with algae.

Site 25. 483 F (595 m a. s. l., 110 x 60 x 12 cm)

An unshaded puddle located on a meadow. The banks were surrounded by grass and no aquatic vegetation occurred. Metamorphs of *Rana* sp. were found on 30 April 2010.

Site 27. 240 Tel (523 m a. s. l., 190 x 180 x 10 cm)

A water-filled depression, which originated from an uprooted tree. This puddle was filled up with leaf litter and located in a swampy area, which was covered with rushes and ferns.

Site 28. no (524 m a. s. l., 380 x 20 x 12 cm)

A puddle located in a forest glade. The water of the puddle was murky, the banks were full of rushes, and the area surrounding this puddle was covered with broken twigs.

Site 58. 487 A (455 m a. s. l., 120 x 40 x 11 cm)

Unshaded puddles located at a feeding ground, which was used by wild boars. The site was located close to a forest road. The area surrounding the feeding ground consisted of water-filled depressions located on a wet and marshy ground with a number of puddles, which were created out of wheel ruts. These water bodies were covered with *Lemna* sp., no other aquatic vegetation occurred. On 30 April 2010 spawn of *Rana* sp. was found.

Site 62. 483 H (598 m a. s. l., 170 x 120 x 16 cm)

A shaded, spring-fed puddle which was surrounded by blackberry bushes and located in the forest. There was no aquatic vegetation and the bottom was covered with leaf litter.

Site 66. 481 f (658 m a. s. l., 130 x 50 x 8 cm)

A water-filled puddle, which was used by wild boars to wallow. The site was shaded and located close to a feeding ground.

Site 67. 263 Schlachtwiese (536 m a. s. l., 170 x 50 x 9 cm)

A muddy depression covered with grass, which was used by wild boars to wallow and located on the east side of the meadow Schlachtwiese.

Site 68. 488 yy (498 m a. s. l.)

A number of wet depressions located in the vicinity of a feeding ground. A bigger puddle was shaded and covered with algae. The ground was muddy and partly covered with grass.

3.1.3 Roadside ditches (D)

Roadside ditches were located close to gravel roads and were predominantly unshaded water bodies. The water of roadside ditches was either stagnant or running and the banks were often overgrown with rushes or sedges. There was no aquatic vegetation, except at the site 30, which was covered with reed (Fig. 10). These roadside ditches were used for drainage of roads (Fig. 11).



Figure 10. Site 30 (23 July 2010).



Figure 11. Site 38 (6 June 2010).

Site 21. 484 R (516 m a. s. l., 210 x 90 x 11 cm)

A roadside ditch totally filled up with leaf litter. Right next to this ditch there was another ditch where no toads were found. Both water bodies were partly shaded.

Site 29. 482 x (587 m a. s. l., 80 x 60 x 10 cm)

A roadside ditch that was partly shaded, full of broken twigs, and without any aquatic vegetation.

Site 30. 483 sch (585 m a. s. l., 300 x 200 x 34)

A deep, partly shaded roadside ditch overgrown with reed, which was part of a driveway culvert. At one side the bank was very flat, muddy, and free of vegetation. On the other side, where the culvert pipe transfers the water in the ditch, the bank was steep.

Site 31. 484 N (465 m a. s. l.)

A roadside ditch with a muddy bottom and without any aquatic vegetation.

Site 32. 486 Q (457 m a. s. l., 100 x 70 x 10 cm)

A roadside ditch located next to a wood pile. The whole bottom was covered with detritus.

Site 33. 241 a (456 m a. s. l., 80 x 40 x 11 cm)

A roadside ditch with gravel as a substrate and a weak current. On 6 June 2010 tadpoles of *Rana* sp. were found.

Site 34. 240 e (462 m a. s. l., 60 x 30 x 7 cm)

A roadside ditch with clay as a substrate and without any aquatic vegetation.

Site 35. 240 x (467 m a. s. l., 50 x 23 x 5 cm)

A very shallow roadside ditch that was covered with grass.

Site 36. 240 f (478 m a. s. l., 40 x 30 x 15 cm)

A small but deep roadside ditch with clay as a substrate. The water was murky, full of leaf litter, and without any aquatic vegetation.

Site 37. 241 p (477 m a. s. l., 210 x 50 x 13 cm)

A roadside ditch located on a logging road in a forest glade. The banks were surrounded by grassy plants. The soil was muddy.

Site 38. 242 tr (427 m a. s. l., 180 x 150 x 25cm) and 242 tr 1 (425 m a. s. l., 220 x 170 x 18 cm)

Two big drainage ditches beside a forest road. The banks were very steep, muddy, and without any aquatic vegetation. The bottom of the ditch was covered with detritus. On 6 June 2010 an adult Common Frog (*R. temporaria*) was found.

Site 39. 242 m (430 m a. s. l.)

A roadside ditch closely located to a stream with gravel and clay as a substrate and without any aquatic vegetation.

Site 40. 245 n (453 m a. s. l., 140 x 30 x 5 cm)

A roadside ditch with gravel as a substrate, the bottom was covered with leaves.

Site 41. 245 n2 (456 m a. s. l., 400 x 80 x 15 cm)

A big roadside ditch totally covered with leaf litter. The banks were shallow, but at the center the ditch was very deep. On 6 June 2010 spawn of *Rana* sp. was found.

Site 42. 245 op (462 m a. s. l., 80 x 30 x 12 cm)

A roadside ditch with some rushes growing up from the bottom and all around the ditch. The substrate was a mixture of soil and gravel. The banks were covered with leaf litter.

Site 43. 245 q (463 m a. s. l., 400 x 220 x 70 cm)

A deep roadside ditch used for drainage. The banks were very steep and densely overgrown. The water was murky. On 6 June 2010 spawn of *Rana* sp. was found.

Site 44. 241 s (454 m a. s. l., 150 x 100 x 8 cm)

Reed has overgrown this partly shaded roadside ditch. The water surface was covered with an algae layer.

Site 45. 481 u (500 m a. s. l., 140 x 80 cm)

A shallow roadside ditch with a weak current located at the beginning of a forest aisle. Rushes surrounded the banks. The area near the ditch was wet, muddy, and covered with leaf litter.

Site 46. 479 v (654 m a. s. l., 100 x 40 x 6 cm)

A long roadside ditch with some water-filled depressions and another ditch with a water depth of 1.5 m (120 x 45 x 18 cm). The former was very shallow and the bottom was totally covered with leaf litter. The latter was used as a road ditch culvert, partly filled with water and the banks were steep. The bottom was covered with some big stones, leaf litter and gravel. During the season 2010 this ditch fell dry. On 26 June 2010 tadpoles of *Rana* sp. were found in the deeper ditch.

Site 47. w (647 m a. s. l., 60 x 40 x 8 cm)

A roadside ditch, which had gravel and soil as a substrate, was covered with algae, and without any aquatic vegetation.

Site 48. x (633 m a. s. l. 80 x 30 x 5 cm)

A roadside ditch located in a forest aisle with gravel and soil as a substrate. The bottom was covered with some leaves.

Site 49. 488 D unten (480 m a. s. l.)

A roadside ditch surrounded by various little puddles. The soil close to the ditch was muddy with patches of grass.

Site 50. 487 i (465 m a. s. l., 600 x 40 cm)

A roadside ditch surrounded by various little puddles. Crawfish hid between the stones. At the end of the ditch the banks were very shallow and water flowed across a gravel road and ended up in a basin.

Site 51. 482 so (560 m a. s. l., 60 x 40 x 5 cm)

A shallow roadside ditch without any aquatic vegetation.

Site 52. 245 o1 (538 m a. s. l., 400 x 60 x 10)

A roadside ditch overgrown with grass and a muddy bottom.

Site 53. 245 o (535 m a. s. l.)

A roadside ditch overgrown with grass and rushes. The terrestrial vegetation surrounding the ditch was dense.

Site 54. 240 ww (477 m a. s. l., 130 x 40 x 4 cm)

A shaded roadside ditch, which was located parallel to the end of a road (Krottenbachstraße). Grass grew from the muddy bottom.

Site 55. 487 B (478 m a. s. l.)

A roadside ditch with running water. The location was partly shaded.

Site 56. n (536 m a. s. l.)

A long roadside ditch located on the hiking path 488. The water was very shallow.

Site 57. nw (510 m a. s. l., 110 x 50 x 4 cm)

A roadside ditch located on the hiking path 488 without aquatic vegetation. The water was very shallow.

3.1.4 Runlets (R)

Runlets were fed by streams or springs, had water depths lower than 10 cm, and were mostly unshaded (Fig. 12). They ran across forest roads or forest soil and some ended up in a basin (Fig. 13). Runlets often created small puddles with a little current. The area around runlets was either overgrown with rushes and sedges, covered with leaf litter or without any vegetation.



Figure 12. Site 73 (22 July 2010)



Figure 13. Site 71 (14 July 2010).

Site 59. 487 M (516 m a. s. l.)

A partly shaded runlet which originated from a spring located in the forest. The ground was muddy with some small water-filled depressions and covered with leaves and grass.

Site 69. z (616 m a. s. l.)

A weak runlet located close to a forest road. The whole area surrounding this runlet was overgrown with rushes and partly covered with algae, the soil was dry and stony with some bigger twigs.

Site 70. 240 d (466 m a. s. l.)

A runlet located in the forest. The area was swampy with little water-filled depressions, which were covered with twigs, stones, and leaf litter.

Site 71. 487 j (464 m a. s. l., 100 x 60 x 13 cm)

A runlet across the forest road, which originated from the roadside ditches above (487 i, 487 B). The runlet flowed into a basin and ended up in a roadside stream. During the season in 2010 the runlet sometimes dried up and in 2011 the runlet fell completely dry.

Site 72. 479 w (584 m a. s. l.)

A runlet which was fed by the stream Hollerbach and located on a forest road. The ground was covered with gravel and no vegetation occurred.

Site 73. 245 u (525 m a. s. l.)

A runlet across the road with a weak current and some deeper water-filled depressions. The ground surrounding the runlet was muddy and without any vegetation.

Site 74. 482 su (550 m a. s. l., 60 x 70 x 7 cm)

A streamlet across a forest road. The ground was stony and muddy including single puddles of calm water.

3.1.5 *Wheel ruts (WR)*

Water-filled wheel ruts were created by forestry vehicles and were predominantly located close to forest aisles and logging roads (Fig. 14). They were temporary aquatic sites with a water depth of 0-20 cm. The water often was murky and without any aquatic vegetation (Fig. 15).



Figure 14. Site 12 (17 July 2010).



Figure 15. Site 6 (6 June 2010).

Site 2. 488 zw (539 m a. s. l., 120 x 40 x 8 cm)

A muddy, completely shaded wheel rut located on a forest road. The ground was covered with leaf litter and twigs and was used by boars to wallow.

Site 4. 240 c (483 m a. s. l., 80 x 30 x 6 cm)

A water-filled wheel rut alongside a forest aisle with clay as substrate. The water was murky and without any aquatic vegetation.

Site 5. 240 b (460 m a. s. l., 70 x 33 x 10 cm)

A water-filled wheel rut closely located to an uprooted tree. Most of the surface was covered with emergent plants such as rushes and sedges. The location was unshaded and the soil consisted mostly of clay and silt.

Site 6. 241 h (463 m a. s. l., 60 x 30 x 7 cm)

A network of four clayey water-filled wheel ruts without any terrestrial or aquatic vegetation located in a forest glade.

Site 7. r oben (558 m a. s. l.) and r unten (544 m a. s. l.)

The whole length of the wheel rut was about 230 meters. The upper part of the site was partly shaded and shallow. The wheel rut was spring-fed and showed a weak current. The streambed was covered with stones, gravel, twigs, and leaf litter. The sides were covered with grass and rushes. Downhill there were deeper and calmer pools in the rut. The area beside this wheel rut was overgrown with reed and rushes.

Site 8. 488 nn 7/N (571 m a. s. l., 460 x 80 x 9 cm)

A water-filled wheel rut located in a forest aisle. The banks were covered with grass and the bottom was muddy.

Site 9. 488 2a (566 m a. s. l., 400 x 120 x 12 cm)

A water-filled wheel rut located in a forest glade without any aquatic vegetation. Grass was growing from a muddy bottom.

Site 10. 488 2b (566 m a. s. l., 370 x 60 x 10 cm)

A water-filled wheel rut. Parallel to this site there was another wheel rut, which was overgrown with grass and of the same size.

Site 11. 486 t (475 m a. s. l., 200 x 90 x 7 cm)

A water-filled wheel rut which was located on a logging road and filled with mud.

Site 12. 482 s (542 m a. s. l.)

A broad and wet wheel rut located on a logging road. The site was shaded and muddy.

Site 13. 240 wa (467 m a. s. l., 80 x 50 x 15 cm)

A deep water-filled wheel rut located on the hiking path 488. The bottom was muddy and covered with leaves. The banks were overgrown with grass.

Site 14. 487 zw (543 m a. s. l., 140 x 40 x 6 cm)

A water-filled wheel rut located on a forest road. The bottom of the rut was muddy, covered with leaf litter and grass.

Site 15. 482 ra (580 m a. s. l., 110 x 40 x 3 cm)

A water-filled wheel rut alongside a forest road without any aquatic vegetation. On 7 August 2011 the rut was full of newly metamorphosed toadlets. A month later the wheel rut completely dried up.

3.2 Total counts, recaptures and population size (2010-2011)

During this study 834 individuals were identified, of which 327 toads were recaptured. In total 1276 captures were achieved (Tab. 4, Tab. 5). In 2010 and 2011 a total of 107 metamorphs (< 20 mm) were recorded. The number of captured males was higher than those of females (Fig. 16).

Table 4. Total number of first captures and recaptures of male (m), female (f), and juvenile (j) yellow-bellied toads in 2010 and 2011.

Year	Number of first registered toads	Number of recaptures	
		2010	2011
2010			
m	176	81	43
f	110	56	25
j	264	123	44
2011			
m	79	—	22
f	64	—	31
j	141	—	14

Table 5. Frequency (F_r) of visits at which toads could be captured and number (n) of individuals at each site – juveniles (j), males (m), and females (f). The number of captured toads of 2010 and 2011 was summed up.

Nr	Site	F_r	n	j	m	f	Nr	Site	F_r	n	j	m	f
1	488 Y	10	92	38	31	23	38	242 tr + tr1	4	33	22	5	6
2	488 zw	2	1	0	0	1	39	242 m	1	3	1	1	1
3	484 K	2	10	0	6	4	40	245 n	2	24	9	9	6
4	240 c	1	11	8	2	1	41	245 n2	3	1	0	0	1
5	240 b	1	9	3	4	2	42	245 op	2	3	3	0	0
6	241 h	1	2	0	2	0	43	245 q	1	1	0	0	1
7	r oben + unten	5	70	45	14	11	44	241 s	1	1	0	0	1
8	488 nn 7/N	7	7	0	4	3	45	481 u	7	8	6	1	1
9	488 2a	3	5	0	3	2	46	479 v	4	10	5	2	3
10	488 2b	5	8	4	3	1	47	w	2	7	3	1	3
11	486 t	1	1	1	0	0	48	x	1	5	4	1	0
12	482 s	1	1	0	0	1	49	488 D unten	12	16	12	2	2
13	240 wa	7	29	14	11	4	50	487 i	1	1	1	0	0
14	487 zw	1	1	0	0	1	51	482 so	1	1	0	1	0
15	482 ra	2	89	83	4	2	52	245 ol	1	1	0	0	1
16	487 D oben	7	97	32	38	27	53	245 o	3	2	1	1	0
17	240 g	1	5	3	2	0	54	240 ww	3	6	1	3	2
18	241 i	1	3	1	2	0	55	487 B	5	9	7	1	1
19	241 j	1	7	3	1	3	56	n	1	2	1	1	0
20	241 k	1	1	1	0	0	57	nw	1	4	3	1	0
21	484 R	2	8	6	2	0	58	487 A	6	30	7	13	10
22	488 2bo	4	4	2	1	1	59	487 M	2	2	0	1	1
23	240 Ti1	4	4	1	2	1	60	51 r	4	30	1	21	8
24	b	5	8	3	5	0	61	481 o	3	10	1	8	1
25	483 F	1	7	3	3	1	62	483 H	2	6	0	2	4
26	484 KT	1	11	0	5	6	63	484 I	2	2	0	1	1
27	240 Te1	1	1	1	0	0	64	245 n3	1	2	1	1	0
28	no	1	7	1	4	2	65	484 J	1	4	0	1	3
29	482 x	1	4	1	1	2	66	481 f	1	1	1	0	0
30	483 sch	3	9	4	2	3	67	263 s	1	2	0	2	0
31	484 N	2	10	0	6	4	68	488 yy	13	13	13	0	0
32	486 Q	1	5	3	1	1	69	z	4	25	13	8	4
33	241 a	1	2	2	0	0	70	240 d	1	4	1	3	0
34	240 e	1	6	6	0	0	71	487 j	12	10	10	0	0
35	240 x	1	1	1	0	0	72	479 w	1	2	1	0	1
36	240 f	2	8	3	3	2	73	245 u	1	5	3	1	1
37	241 p	1	2	0	1	1	74	482 su	2	2	1	0	1

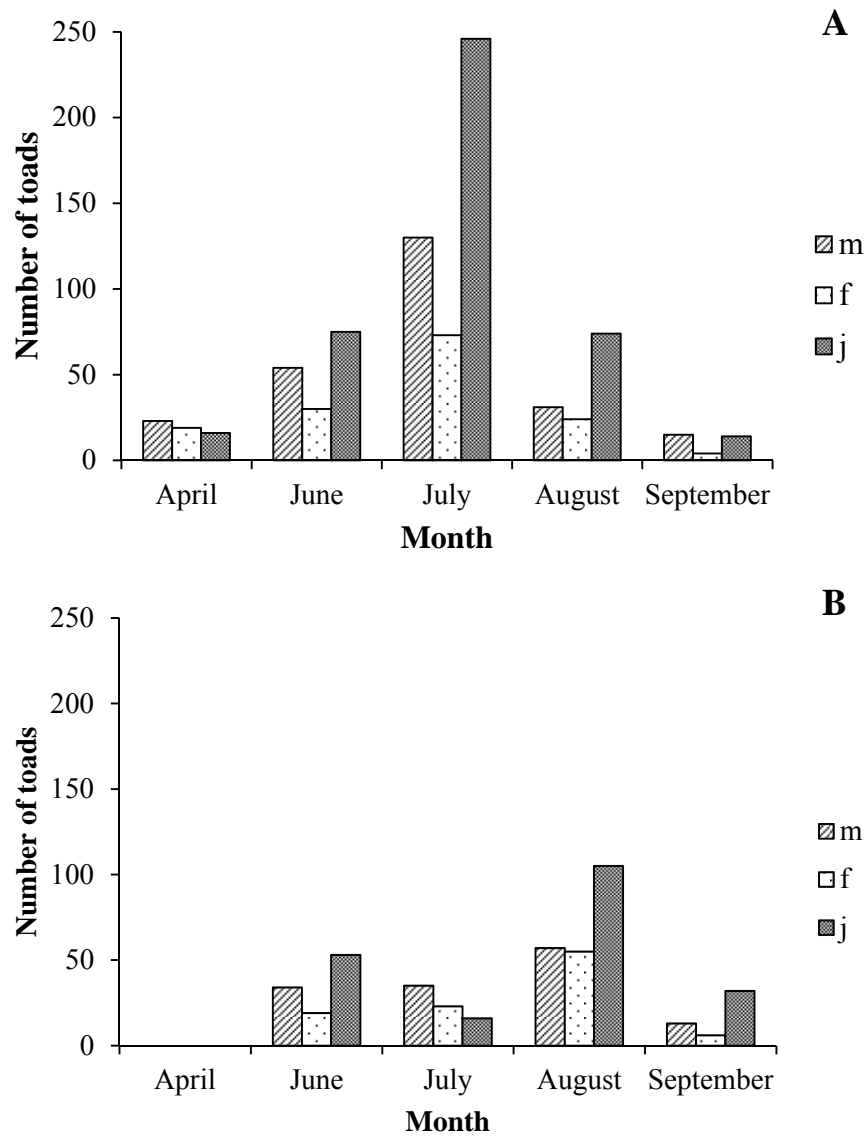


Figure 16. Monthly numbers of captured males ($n = 255$), females ($n = 174$), and juveniles ($n = 405$) in 2010 (A) and 2011 (B). In April 2011 the study area was not visited. The first capture of individuals is shown.

The majority of all individuals were captured only once. A total of 39% of toads were recaptured more than once (Tab. 6). The frequency of recaptures did not significantly differ between juveniles, males, and females (Kruskal-Wallis H test, $\chi^2 = 9.4545$, $n = 834$, $df = 2$, $p > 0.05$). The population size of the studied area in Großkrottenbach was 565 ± 9 (SE) and was estimated with the Petersen method modified by Chapman.

Table 6. Recapture frequency of all individuals (n = 834) during 2010 and 2011.

Sex	Frequency of recaptures							
	0	1	2	3	4	5	6	7
m (255)	151	52	30	14	5	2	0	1
f (174)	86	62	15	6	3	0	2	0
j (405)	269	73	30	11	11	9	2	0

3.2.1 Recaptured toads first registered in previous years (2002-2009)

In 2010 and 2011 a number of 153 individuals of previous years was recaptured (Tab. 7). More than 50% of these individuals had been first captured in 2008 and 2009.

Table 7. Recaptures of individuals first captured by B. & G. Gollmann in 2002-2009.

First capture	Number of recaptured toads	
	2010	2011
2002	12	13
2003	7	7
2004	11	3
2005	1	4
2006	2	0
2007	4	5
2008	29	13
2009	33	9

3.3 Number and distribution of sites used by *B. variegata*

At 74 sites yellow-bellied toads were observed (Fig. 17). The sites were distributed along an altitudinal range of 425 m to 663 m. The majority of these sites were man-made water bodies.

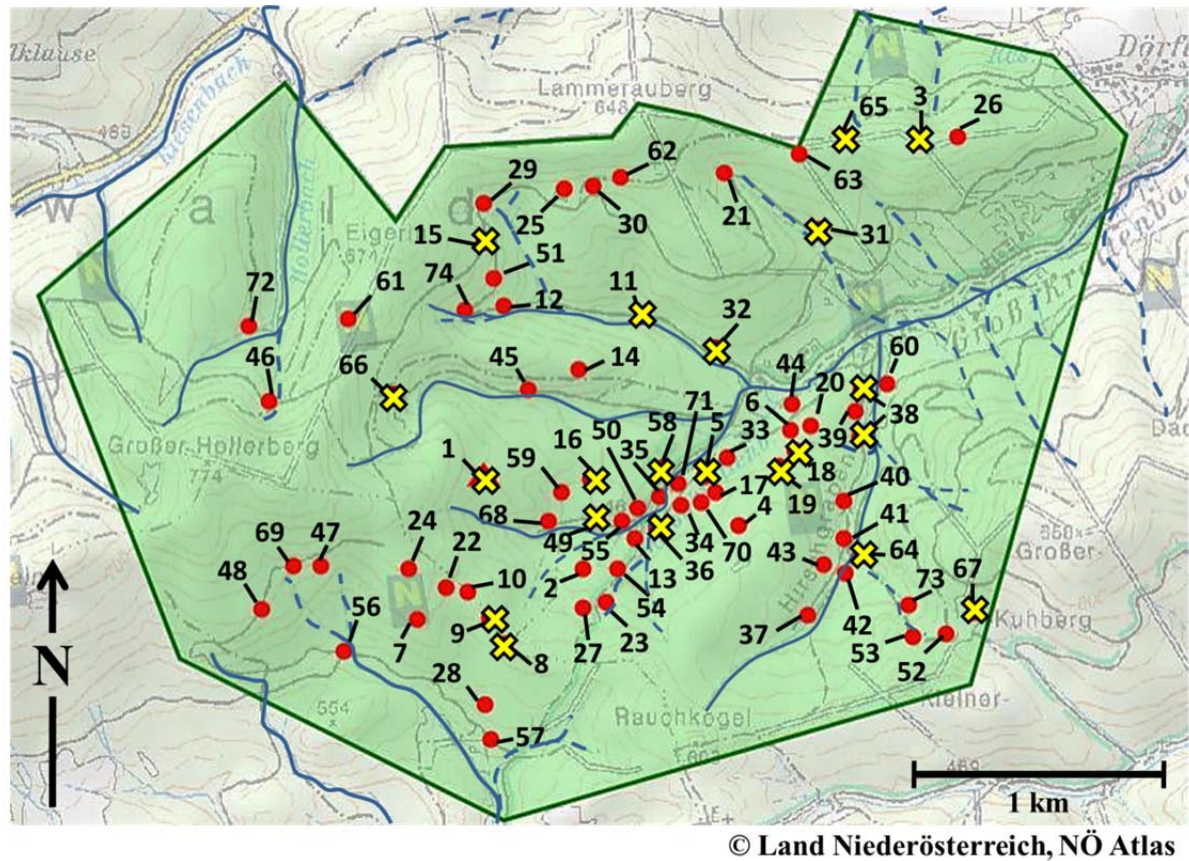


Figure 17. Map of the study area in Großkrottenbach (online NÖ atlas 4.0 – atlas.noe.gv.at) with all water bodies (○) and breeding sites (x) where yellow-bellied toads were observed. Blue lines show brooks < 5 m.

3.3.1 Abiotic factors of sites

Most of the registered sites were temporary, stagnant, and unshaded water bodies with water depths lower than 10 cm (Fig. 18).

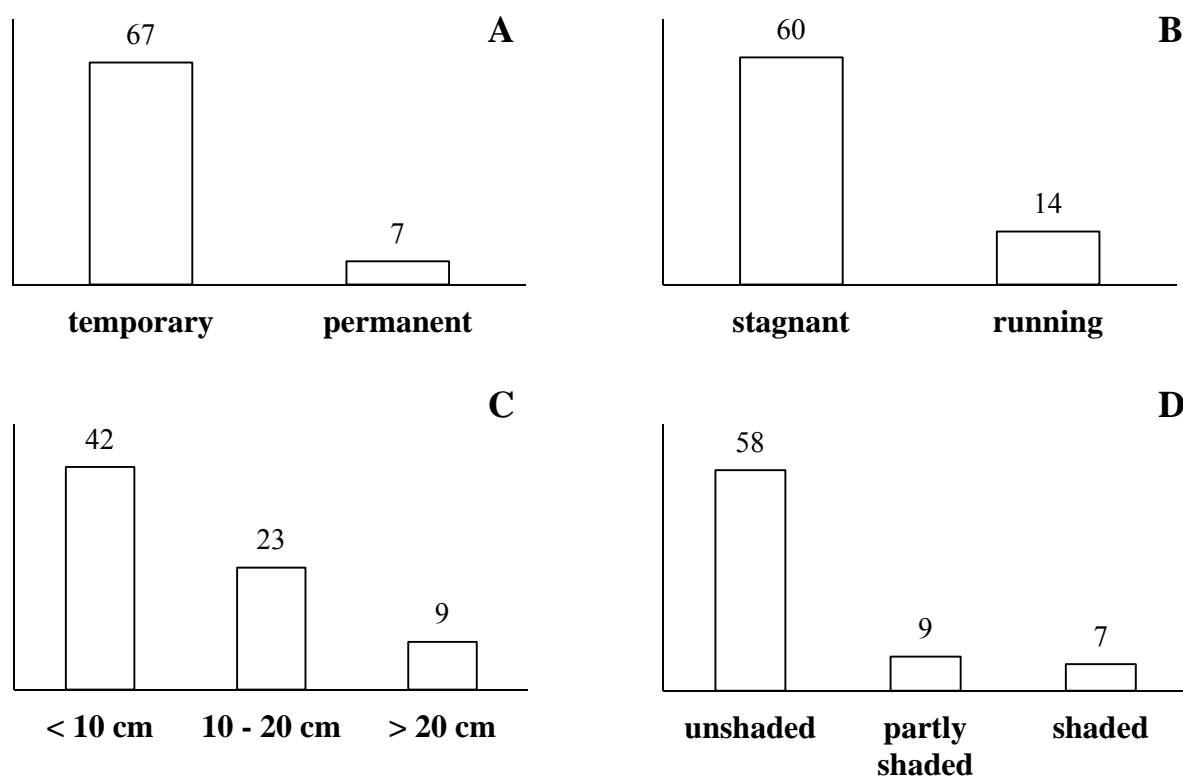


Figure 18. Abiotic factors of all registered sites (n = 74). They were categorized as follows: (A) temporary vs. permanent, (B) stagnant vs. running, (C) water level, and (D) unshaded, partly shaded and shaded.

3.4 Breeding sites

At 20 sites breeding of *B. variegata* was observed (Fig. 19). Each type of water body was used for breeding except for runlets. Sites where eggs, tadpoles, or metamorphs occurred were registered as breeding sites (Tab. 8).

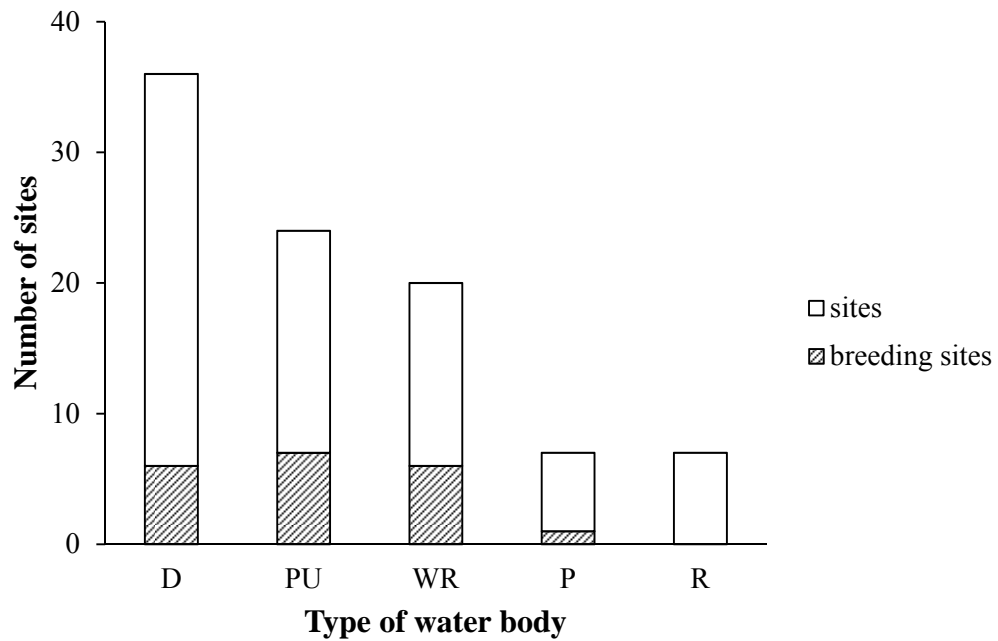


Figure 19. Number of different types of water bodies (n = 74) and breeding sites (n = 20) where yellow-bellied toads were found (D – roadside ditches, P – ponds, PU – puddles, R – runlets, WR – wheel ruts). Sites where various types of water bodies occurred the most dominant were chosen for classification.

Table 8. Breeding sites of *B. variegata* and presence (+) or absence (-) of eggs (E), tadpoles (T), and metamorphs (M) at each site.

Nr.	Site	Water body	E	T	M	Date
36	240 f	D	+	–	–	2010-06-06
38	242 tr	D	+	+	–	2010-06-06
38	242 tr1	D	+	+	–	2010-07-22
31	484 N	D	–	+	+	2011-08-07
32	486 Q	D	+	–	–	2010-07-04
49	488 D unten	D	+	–	–	2010-07-19
64	245 n3	P	–	+	–	2010-07-22
18	241 i	PU	+	–	–	2010-06-06
19	241 j	PU	+	+	–	2010-06-06
67	263 s	PU	+	–	–	2011-07-07
66	481 f	PU	–	+	–	2010-07-13
1	488 Y	PU, WR	+	+	+	2010-06-26
			–	+	+	2010-07-12
			–	+	+	2010-07-16
58	487 A	PU	+	+	–	2011-08-07
16	487 D oben	PU	+	+	–	2010-07-09
			–	+	+	2010-07-21
			–	+	+	2010-08-22
5	240 b	WR	+	–	–	2010-06-06
15	482 ra	WR	–	–	+	2011-08-07
9	488 2a	WR	–	+	–	2010-07-16
8	488 nn 7/N	WR	–	+	–	2010-07-16
7	r oben	WR	–	–	+	2010-07-22
7	r unten	WR	–	–	+	2010-07-22

3.4.1 Abiotic factors of breeding sites

Breeding predominantly occurred in shallow water bodies with a water depth of 0-20 cm (Fig. 20). Only one pond (nr. 64) with a depth of 80 cm was used for breeding. Sites where breeding was observed were predominantly stagnant water bodies, but sometimes roadside ditches with running water were used as well. All breeding sites were mainly unshaded, free of dense aquatic vegetation, and man-made habitats.

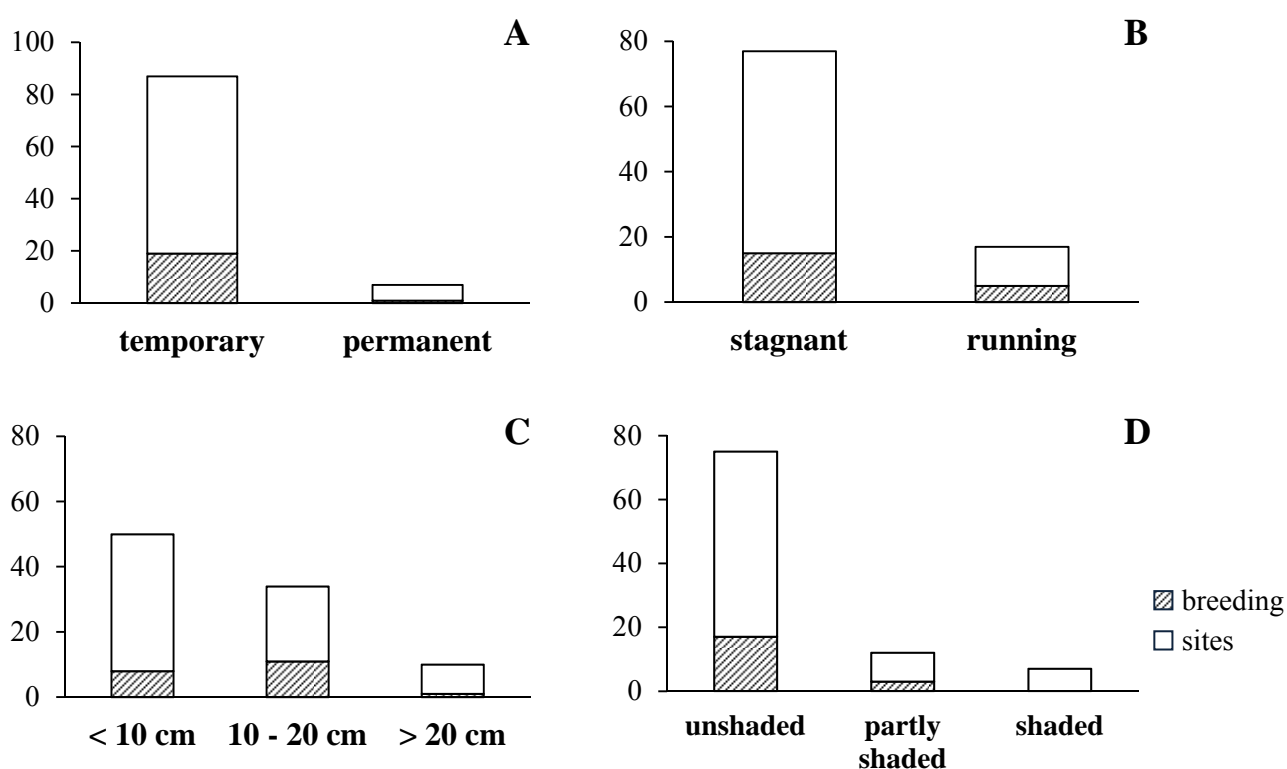


Figure 20. Abiotic factors of breeding sites. They were categorized as follows: (A) temporary vs. permanent, (B) stagnant vs. running, (C) water level, and (D) unshaded, partly shaded, and shaded.

3.4.2 Altitude

Breeding occurred in water bodies that were distributed at an altitudinal range from 427 m to 658 m (Fig. 21). Most types of water bodies were found at lower altitudes.

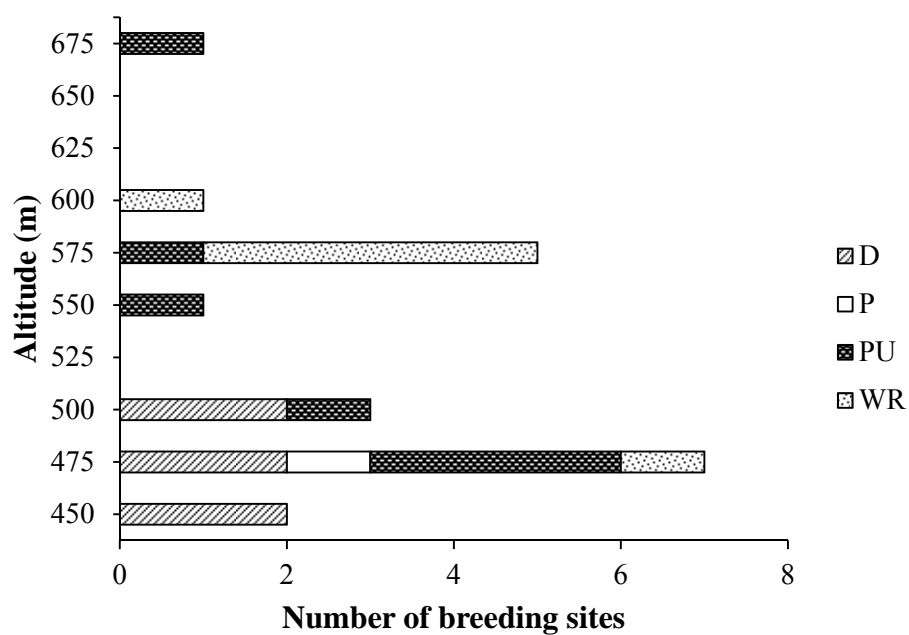


Figure 21. Altitudinal distribution of different types of water bodies that were used as breeding sites (D – roadside ditches, P – ponds, PU – puddles, R – runlets, WR – wheel ruts). Sea levels were categorized into intervals of 25 m (450 m: 426-450 m).

3.5 *Habitat use*

To analyse the habitat use, data of all captured toads were used and all metamorphs were included. Juveniles and adults were found in all types of water bodies (Fig. 22), predominantly in wheel ruts, roadside ditches and puddles. In ponds the number of captured juveniles was lower than those of adult toads. A higher number of juveniles was found in runlets.

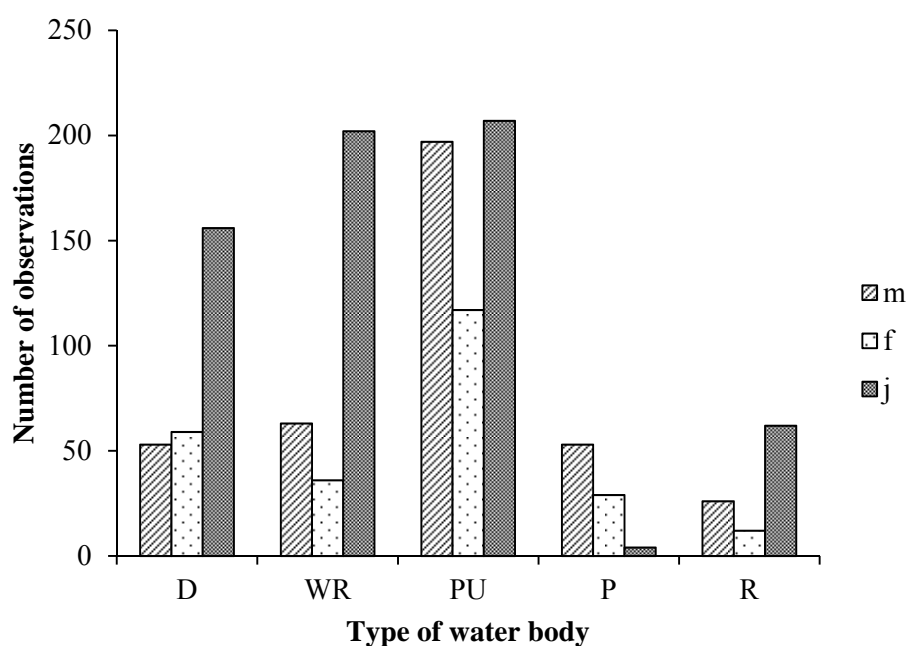


Figure 22. Different types of water bodies where juvenile and adult yellow-bellied toads ($n = 1276$) were observed. D – roadside ditches, P – ponds, PU – puddles, R – runlets, WR – wheel ruts.

3.5.1 Abiotic factors

Juveniles were mostly captured in temporary and unshaded water bodies with a depth of 0-20 cm. They were observed in stagnant water bodies as well as in runlets with puddles of calm water. Fewer juveniles were found in deeper water bodies. Most adults were observed in permanent and unshaded water bodies with a water depth of 10-20 cm. Runlets were also used by adults, but not as often as by juveniles (Fig. 23).

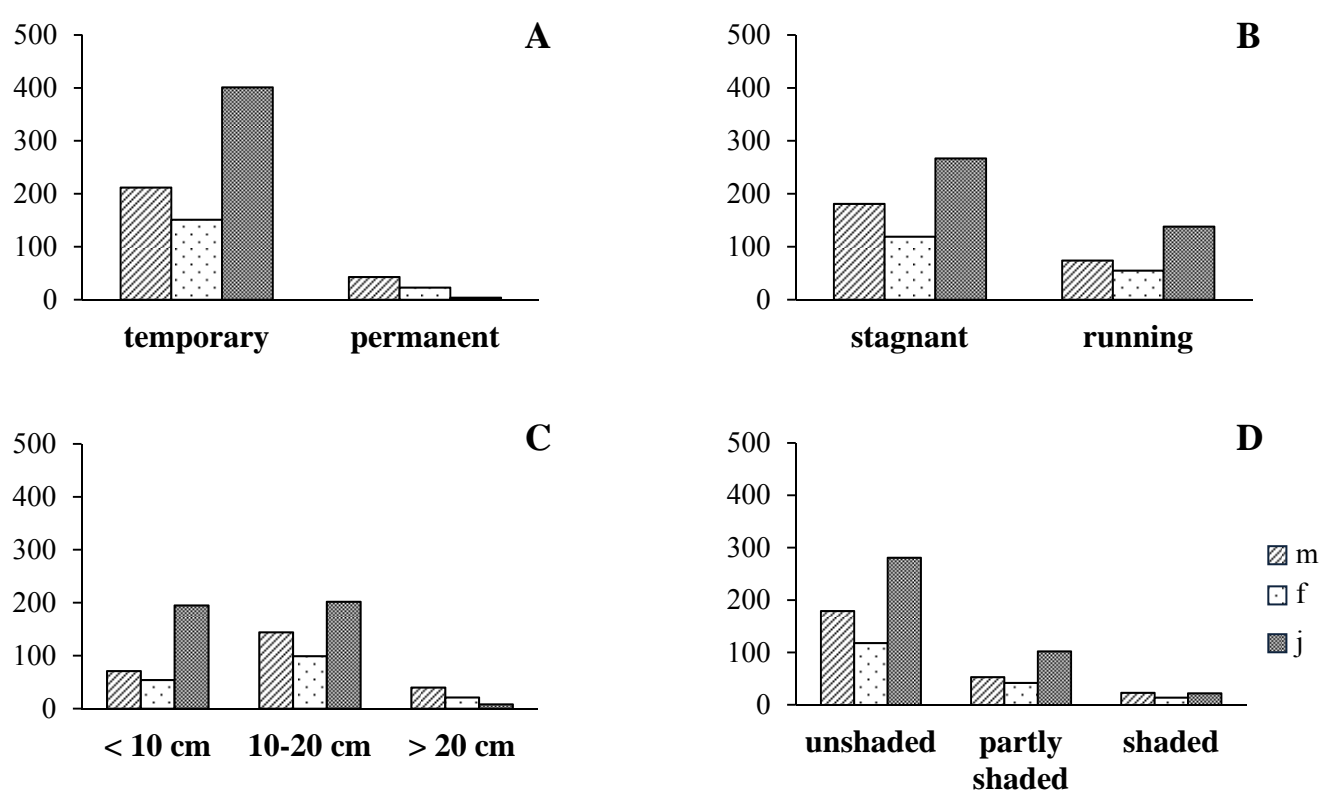


Figure 23. Habitat use by juvenile and adult yellow-bellied toads (n = 834). They were categorized as follows: (A) temporary vs. permanent, (B) stagnant vs. running, (C) water level, and (D) unshaded, partly shaded, and shaded.

3.5.2 Altitude

Of all individuals found, 39% were captured at an altitudinal range of 475-500 m and 37% at 575-600 m (Fig. 24). The number of captured individuals decreased at higher altitudes.

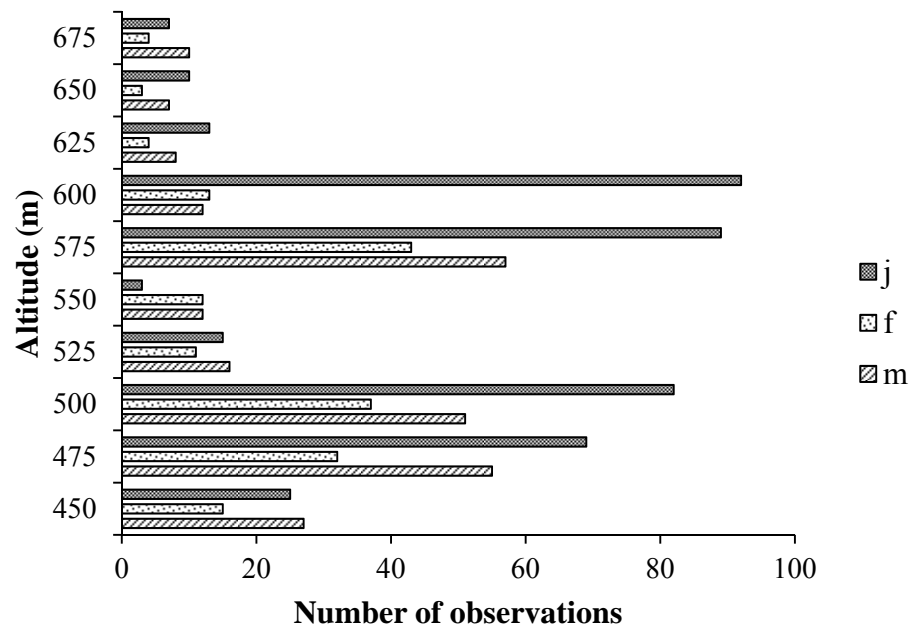


Figure 24. Altitudinal distribution of observations of juvenile and adult yellow-bellied toads ($n = 834$). Sea levels were categorized into intervals of 25 m (475 m: 451-475 m).

3.6 Snout vent length (SVL) and Body mass (BM)

3.6.1 Size structure

Size classes, reaching from 14 mm to 54 mm, were represented in 2010 and 2011 (Fig. 25). In 2010 mainly juveniles and small adult toads were captured. In 2011 more metamorphs ($n = 85$) were found compared to 2010. Big adult toads (> 50 mm) were captured in both seasons.

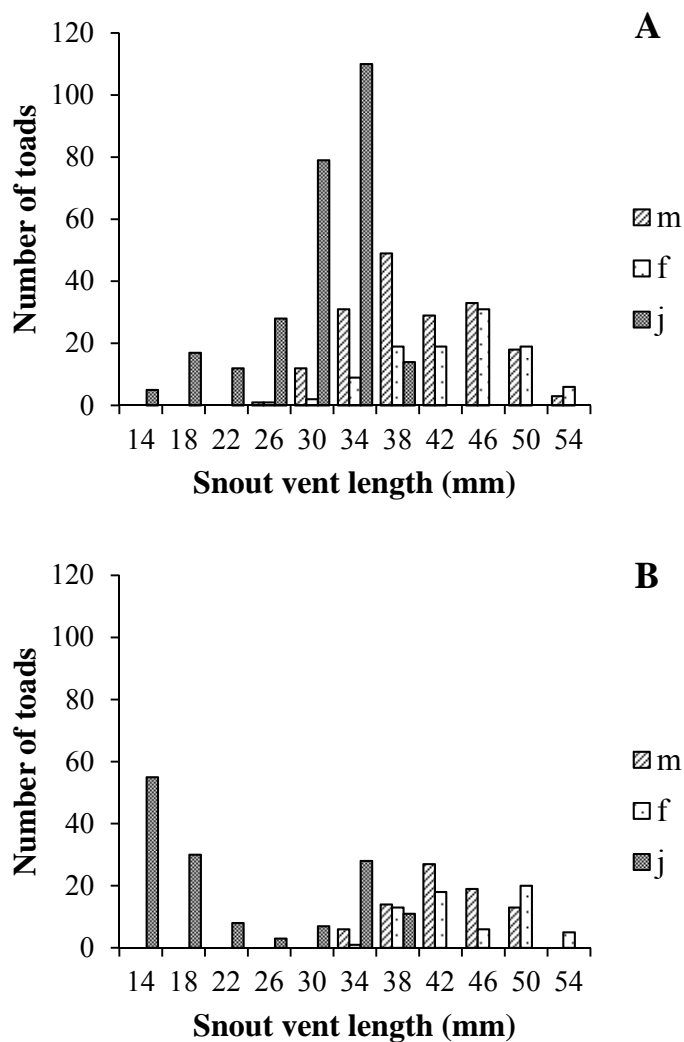
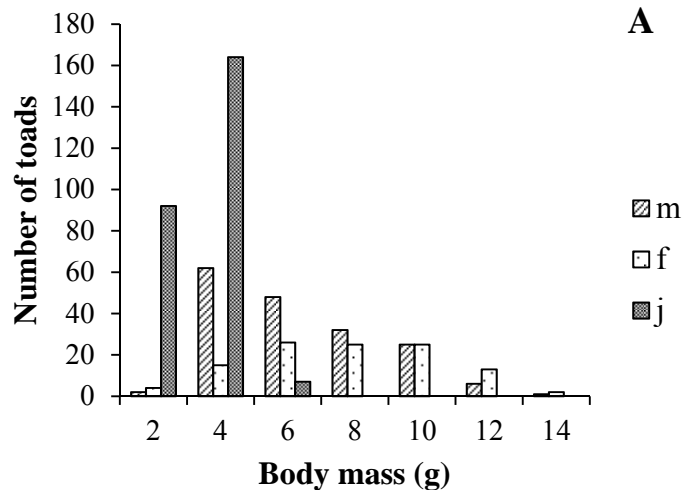
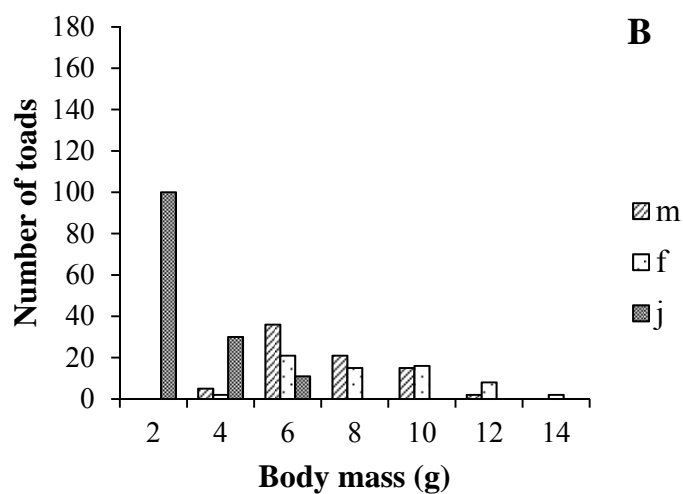


Figure 25. Size structure of toads (2010: $n = 549$, 2011: $n = 283$) captured in 2010 (A) and 2011 (B). Snout vent length was categorized in classes with intervals of 4 mm (e.g. category 14 mm: 12.1-16 mm). All registered metamorphs (< 20 mm) were included. Two females were excluded because of missing SVL.

Body mass classes, reaching from 2 g to 14 g, were represented in both seasons (Fig. 26). In 2010 a higher number of heavy juveniles and light adults was registered than in 2011. Especially in 2010 a high number of light males was registered. The distribution of heavy adults was similar in both seasons.



A Figure 26. Body mass (g) of toads (2010: n = 549, 2011: n = 284) captured in 2010 (A) and 2011 (B). Body mass was categorized in classes with intervals of 2 g (e.g. category 2 g: 0-2 g). All registered metamorphs (< 20 mm) were included. One juvenile was excluded because of missing BM.



B

In both seasons the mean SVL and BM were higher in females than in males (Tab. 9). All recaptures were excluded and measurements of SVL and BM of the first capture of toads were used. Two female individuals and one juvenile were excluded, because of missing SVL or BM (n = 831). The relationship between SVL and BM was curvilinear in both seasons (Fig. 27, Fig. 28). The correlation between SVL and BM was positive in both years (Pearson correlation 2010: $r = 0.912$, $n = 548$, $p < 0.05$; 2011: $r = 0.949$, $n = 283$, $p < 0.05$).

Table 9. Mean snout vent length (SVL in mm) and body mass (BM in g) of yellow-bellied toads (n = 831). Data of the first capture were used for analysis. Three individuals (two females, one juvenile) were excluded because of missing SVL or BM. All metamorphs were included.

Sex	2010		2011	
	BM \pm SD	SVL \pm SD	BM \pm SD	SVL \pm SD
m (248)	5.6 \pm 2.3	40.6 \pm 5.5	6.5 \pm 1.8	43.1 \pm 4.6
f (157)	7.4 \pm 2.5	45.1 \pm 4.7	7.6 \pm 2.4	44.9 \pm 5.0
j (426)	2.4 \pm 1.0	30.6 \pm 5.3	1.4 \pm 1.5	22.2 \pm 9.3

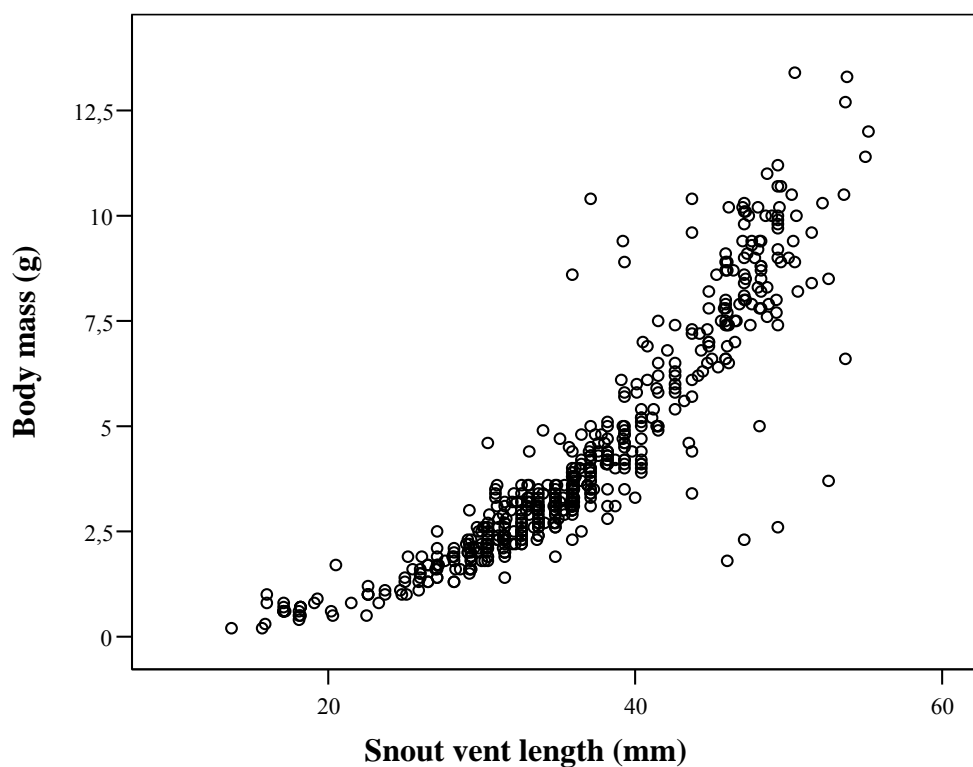


Figure 27. Relationship between snout vent length (mm) and body mass (g) in yellow-bellied toads captured in 2010 (n = 548). Two individuals were excluded because of missing SVL.

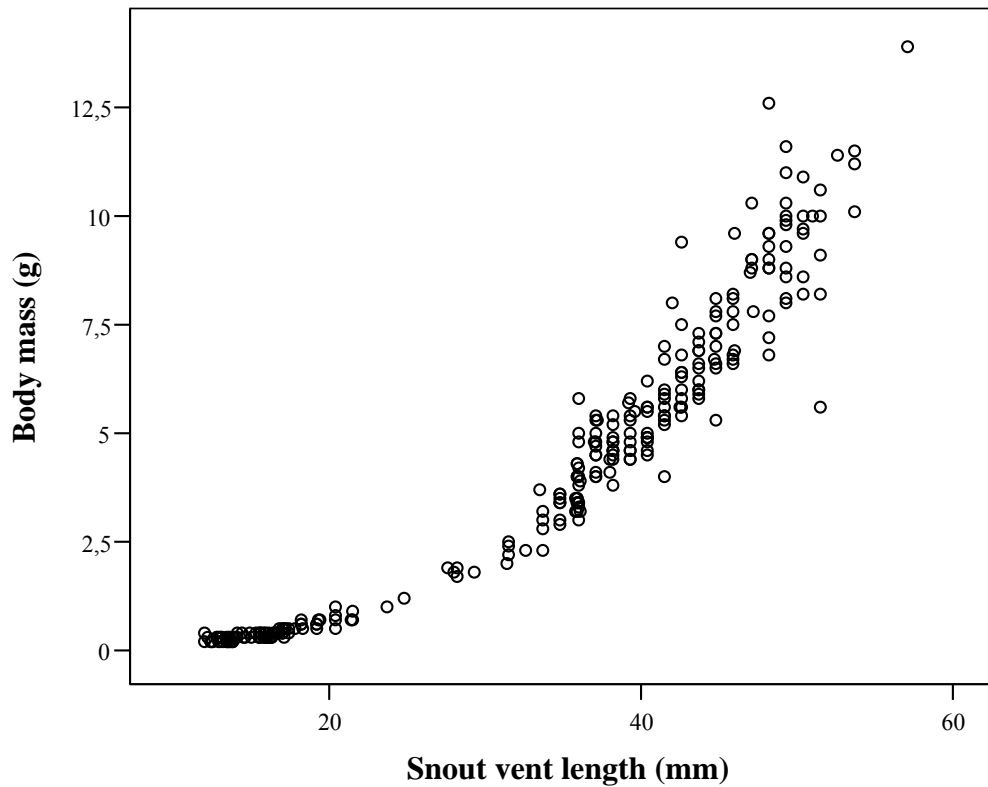


Figure 28. Relationship between snout vent length (mm) and body mass (g) in yellow-bellied toads captured in 2011 (n = 283). One individual was excluded, because of missing BM.

Females were significantly longer (males: n = 248, females: n = 157; Mann-Whitney: U = 11830, $p < 0.05$) and heavier (males: n = 248, females: n = 157; Mann-Whitney: U = 11614, $p < 0.05$) than males. In 2011 males and females were longer and heavier than in 2010 (Tab. 10, Tab. 11). Juveniles were longer and heavier in 2010 than in 2011.

Table 10. Two-way ANOVA of SVL (dependent variable) partitioned by sex and year (independent variables).

Source	SS	df	MS	F	P-value
Year	118.626	1	118.626	4.612	< 0.05
Sex	881.324	1	881.324	34.266	< 0.05
Year*sex	167.787	1	167.787	6.524	< 0.05
Error	10313.764	402	25.720		
Total	754906.883	405			

Table 11. Two-way ANOVA of BM (dependent variable) partitioned by sex and year (independent variables).

Source	SS	df	MS	F	P-value
Year	21.453	1	21.453	4.213	< 0.05
Sex	210.889	1	210.889	41.414	< 0.05
Year*sex	16.086	1	16.086	3.159	> 0.05
Error	2041.999	402	5.092		
Total	19504.541	405			

3.7 Growth

3.7.1 2010-2011

3.7.1.1 Snout vent length (SVL)

Snout vent length and growth were negatively correlated (Pearson correlation $r = -0.624$, $n = 99$, $p < 0.05$). Growth was high, when SVL was low (Fig. 29, Tab. 12). Significant differences were found in growth between juveniles, males, and females (Tab. 13). Growth was higher in juveniles than in males and females. The mean increase of SVL was 4.7 mm per year.

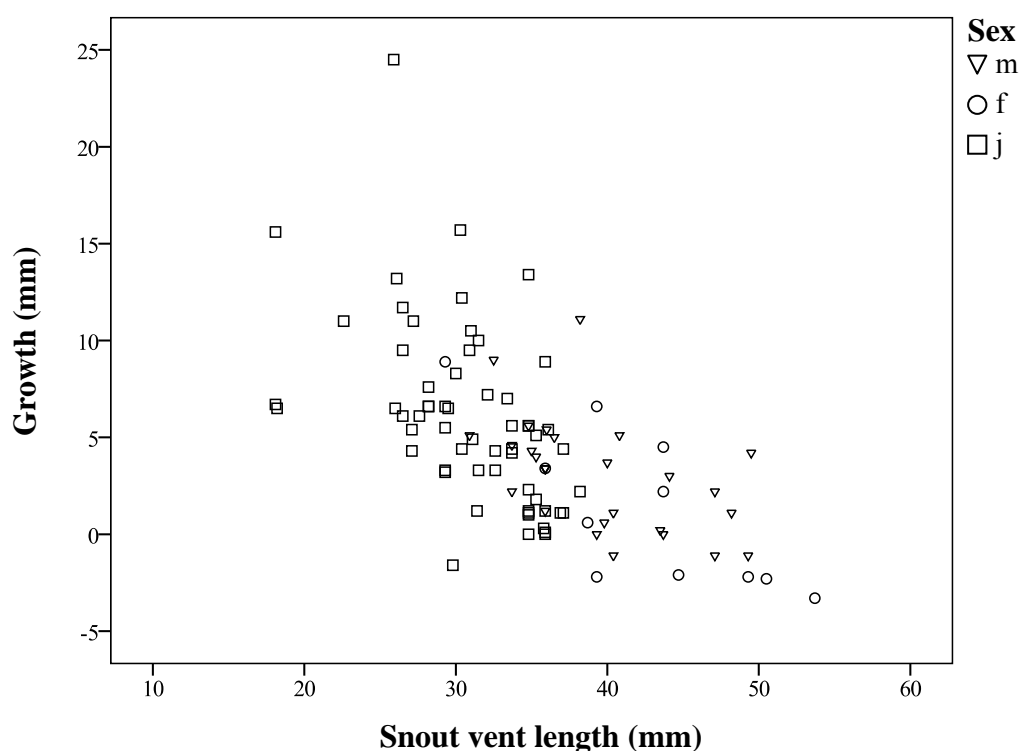


Figure 29. Correlation of growth and SVL (2010) in male ($n = 33$), female ($n = 19$), and juvenile ($n = 47$) yellow-bellied toads from 2010 to 2011. Growth is defined as difference between SVL of last capture (2011) and SVL of first capture (2010).

Table 12. Linear regression of growth (2010-2011) on SVL (2010) of juveniles, males, and females.

Model	SS	df	MS	F	P-value	R ²
Regression	779.0560533	1	779.0560533	61.759	< 0.05	0.39
Residual	1223.6094013	97	12.6145299			
Total	2002.6654545	98				

Table 13. ANOVA of growth (SVL) in juveniles, males, and females and comparison of means with the Tukey-HSD test (means with the same letter are not significantly different at $p < 0.05$).

Source	SS	df	MS	F	P-value
Between groups	305.721186	2	152.860593	8.648	< 0.05
Within groups	1696.944268	96	17.676503		
Total	2002.665455	98			
Sex		n		Means (\pm SE)	
Juveniles		60		6.003 (± 0.6052) ^a	
Males		28		3.057 (± 0.5495) ^{ab}	
Females		11		1.282 (± 1.2504) ^b	

3.7.1.2 Body mass (BM)

Body mass and growth were negatively correlated (Pearson correlation $r = -0.452$, $n = 99$, $p < 0.05$).

Growth was higher in individuals with low body mass (Fig. 30, Tab. 14). Significant differences were found between juveniles, males, and females. Growth was higher in juveniles than in males and females (Tab. 15). The mean increase of BM was 1.4 g per year.

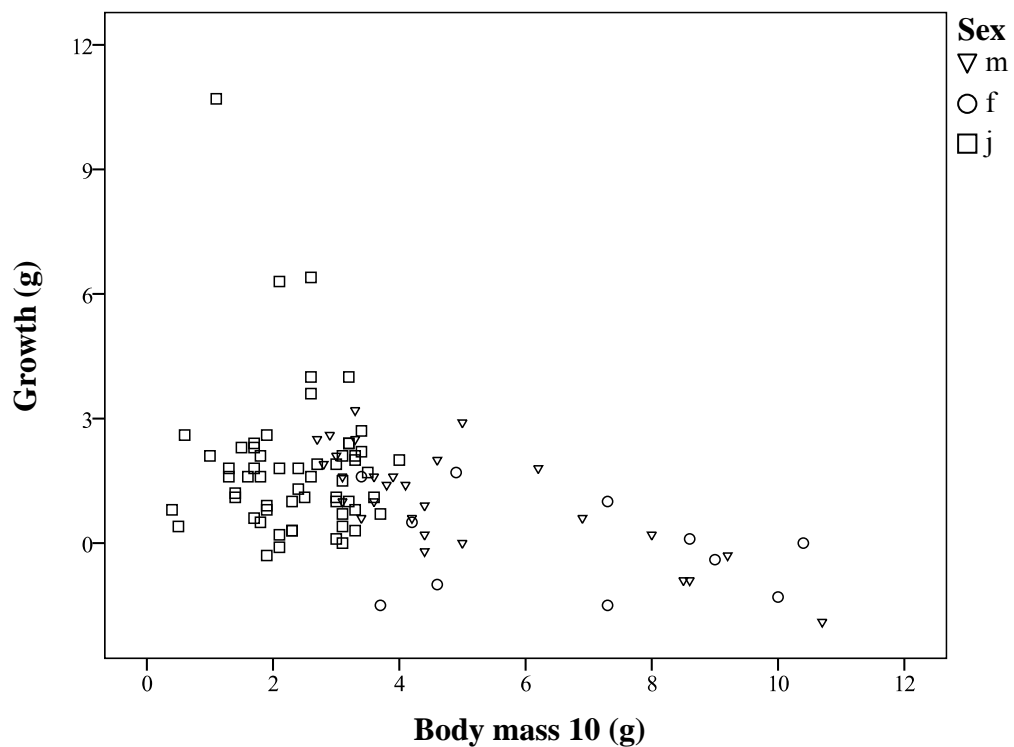


Figure 30. Correlation of growth and BM (2010) in male ($n = 33$), female ($n = 19$), and juvenile ($n = 47$) yellow-bellied toads from 2010 to 2011. Growth was defined as difference between BM of last capture (2011) and BM of first capture (2010).

Table 14. Linear regression of growth (2010-2011) on BM (2010) of juvenile, male, and female yellow-bellied toads.

Model	SS	df	MS	F	P-value	R ²
Regression	55.3222224	1	55.3222224	24.873	< 0.05	0.20
Residual	215.7488888	97	2.2242153			
Total	271.0711111	98				

Table 15. Kruskal-Wallis H test of growth (BM) between juveniles, males, and females and comparison of means with the Tukey-HSD test (means with the same letter are not significantly different at $p < 0.05$).

Source	χ^2	df	P-value
Sex	14.296	2	< 0.05
	n	Means (\pm SE)	
Juveniles	60	1.787 (\pm 0.2251) ^a	
Males	28	1.071 (\pm 0.2356) ^{ab}	
Females	11	-0.072 (\pm 0.3568) ^b	

3.7.2 *Metamorphs of 2008*

A year after metamorphosis (2008) the mean increase of SVL measured was 10.7 mm and 2.9 mm from 2009 to 2010 (Fig. 31, Tab. 16). No significant relationship between SVL and growth was found (Pearson correlation $r = -0.286$, $n = 35$, $p > 0.05$; Fig. 32, Tab. 17).

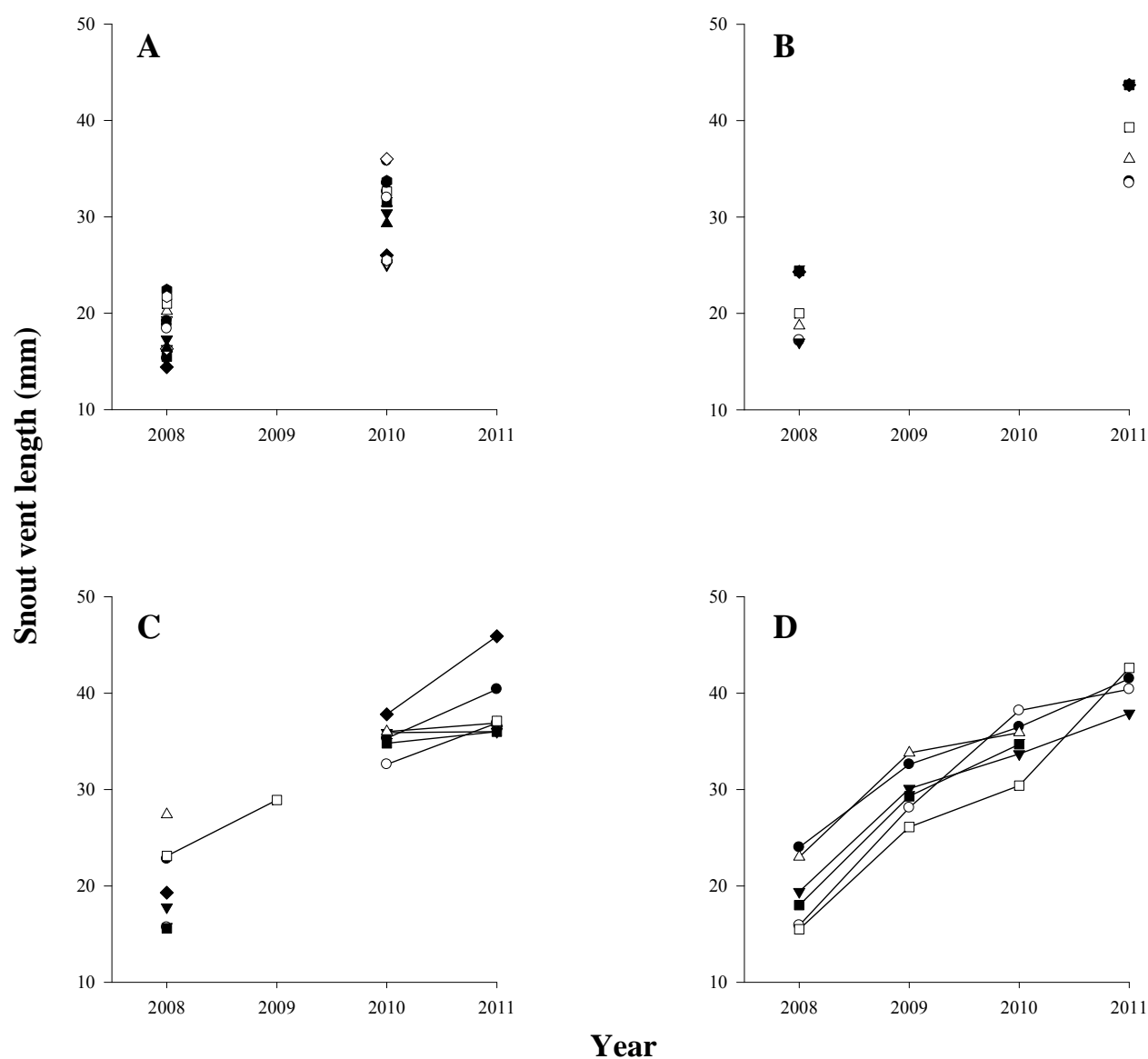


Figure 31. Growth (SVL) of metamorphs ($n = 35$) first captured in 2008 and recaptured in 2009 ($n = 7$), 2010 ($n = 27$), and 2011 ($n = 18$). A and B – two years missing, C – one year missing year, D – consecutive years.

Table 16. The mean SVL and growth of metamorphs (n = 35) first captured in 2008 and recaptured in 2010 and 2011.

	2008	2009	2010	2011
Mean SVL (mm)	19.1	29.8	32.7	39.2
Mean growth (mm)/year		10.7	2.9	6.5

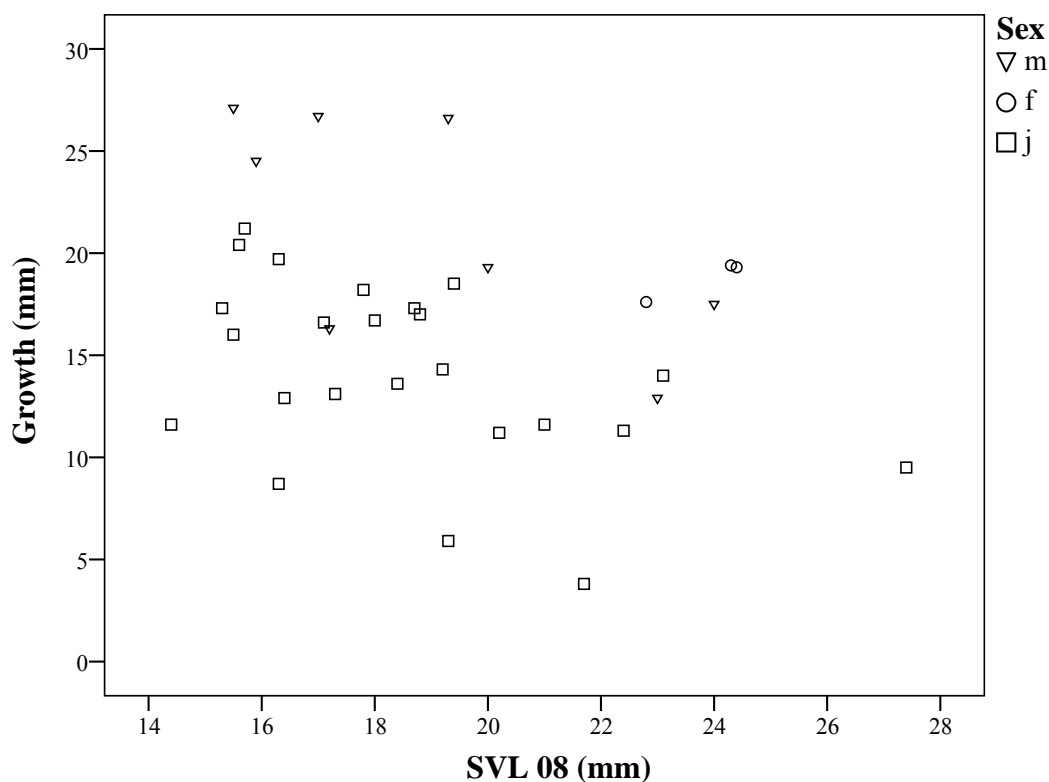


Figure 32. Correlation of growth and SVL in metamorphs of 2008 (n = 35). Growth was defined as the difference between SVL of last capture (2010/2011) and SVL of first capture (2008). The sex of 11 individuals could be assigned over the years.

Table 17. Linear regression of growth on SVL of metamorphs first captured in 2008.

Model	SS	df	MS	F	P-value	R ²
Regression	82.1393460	1	82.1393460	2.935	> 0.05	0.08
Residual	923.6903683	33	27.9906172			
Total	1005.8297143	34				

3.8 Body condition– Scaled mass index (SMI)

Because of the curvilinear relationship between BM and SVL, data were ln-transformed (Fig. 33). The linear body measurement (SVL) of all individuals was standardized to $L_0 = 35.1273165$, which represented the mean SVL of all individuals. The scaling exponent b_{sma} was 2.833912. Only minor differences were found between calculations of the scaling exponent using different methods (Tab. 18).

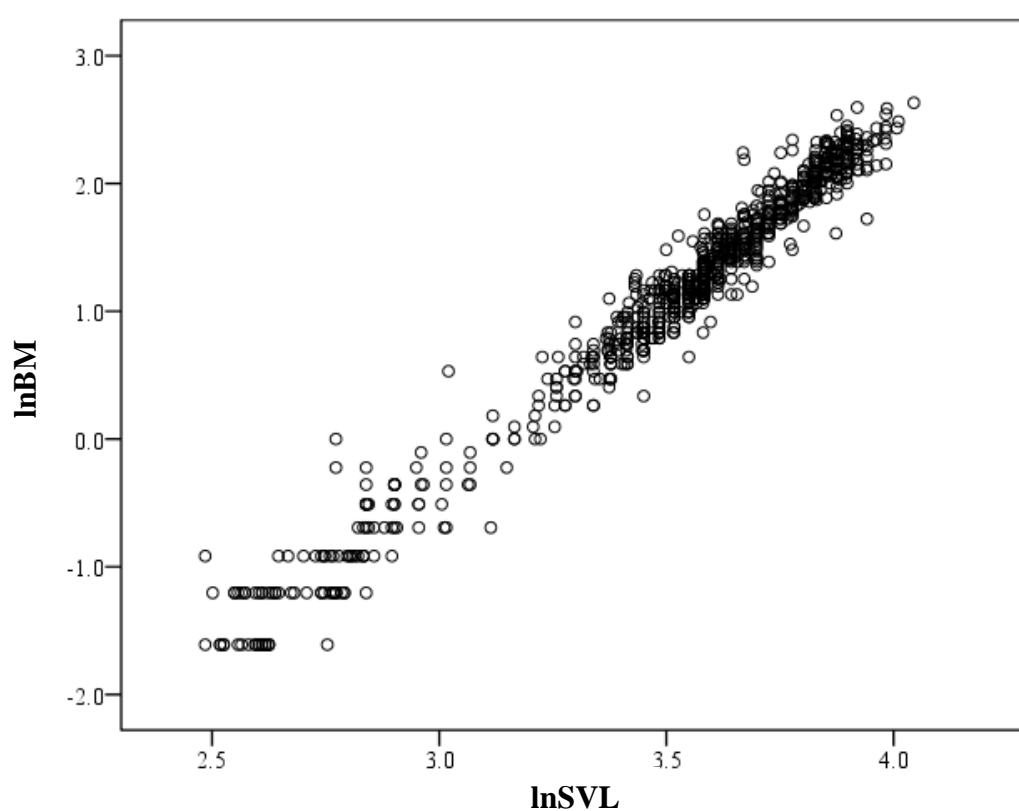


Figure 33. Relationship between the ln-transformed body mass (BM) and the snout vent length (SVL) in yellow-bellied toads ($n = 831$).

Table 18. Results of the scaling exponent calculated with a standard major axis (SMA), an ordinary least squares (OLS), a reduced major axis (RMA), and a major axis (MA) regression.

Method	SMA	OLS	RMA	MA
Scaling exponent (b)	2.833912	2.787969	2.835845	2.870321

3.8.1 Sex

No statistically significant differences were found between SMI and sex (Fig. 34, Tab. 19).

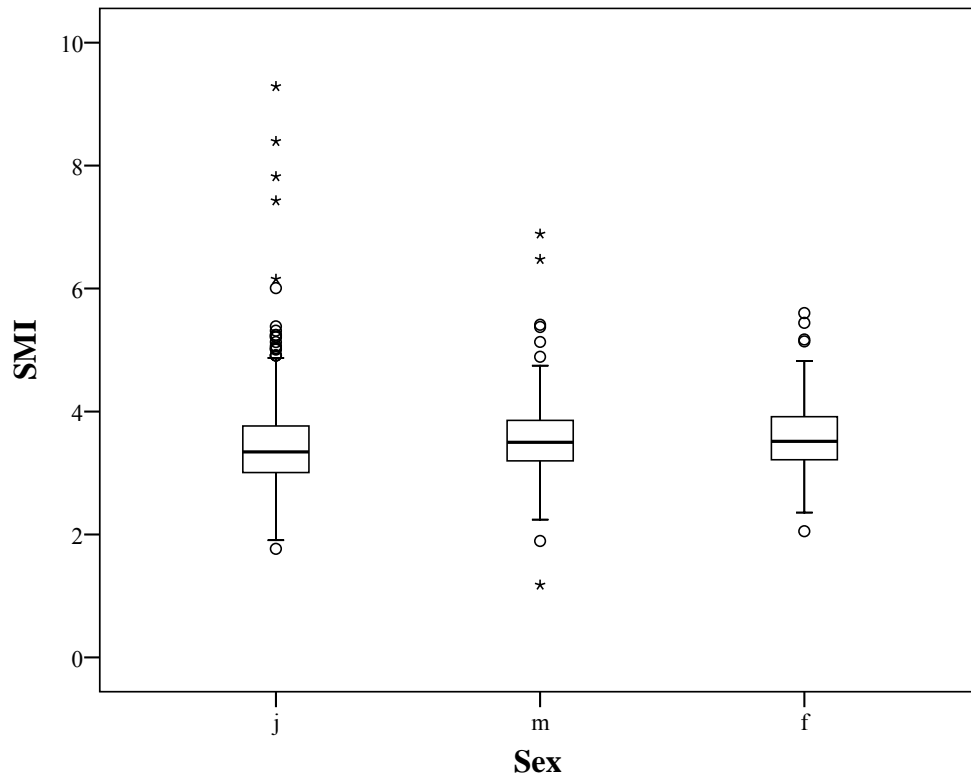


Figure 34. Relationship of the scaled mass index (SMI) between juveniles (n = 404), males (n = 255), and females (n = 172).

Table 19. ANOVA of the scaled mass index (SMI) between juvenile, male, and female yellow-bellied toads.					
Source	SS	df	MS	F	P-value
Between groups	1.4703344	2	0.7351672	1.506	> 0.05
Within groups	404.1659997	828	0.4881232		
Total	405.6363341	830			

3.8.2 Month

3.8.2.1 Season 2010

The SMI was calculated for all captured individuals ($n = 826$) and partitioned by sex and months (Fig. 35). Differences in the SMI between months were significant (Tab. 20). No significant differences were found in the SMI of juveniles between months (Kruskal-Wallis H test, $\chi^2 = 33.057$, $n = 424$, $df = 4$, $p > 0.05$). In the case of males (Tab. 21) and females (Tab. 22) there were statistically significant differences. In both sexes the SMI was the highest in June and September.

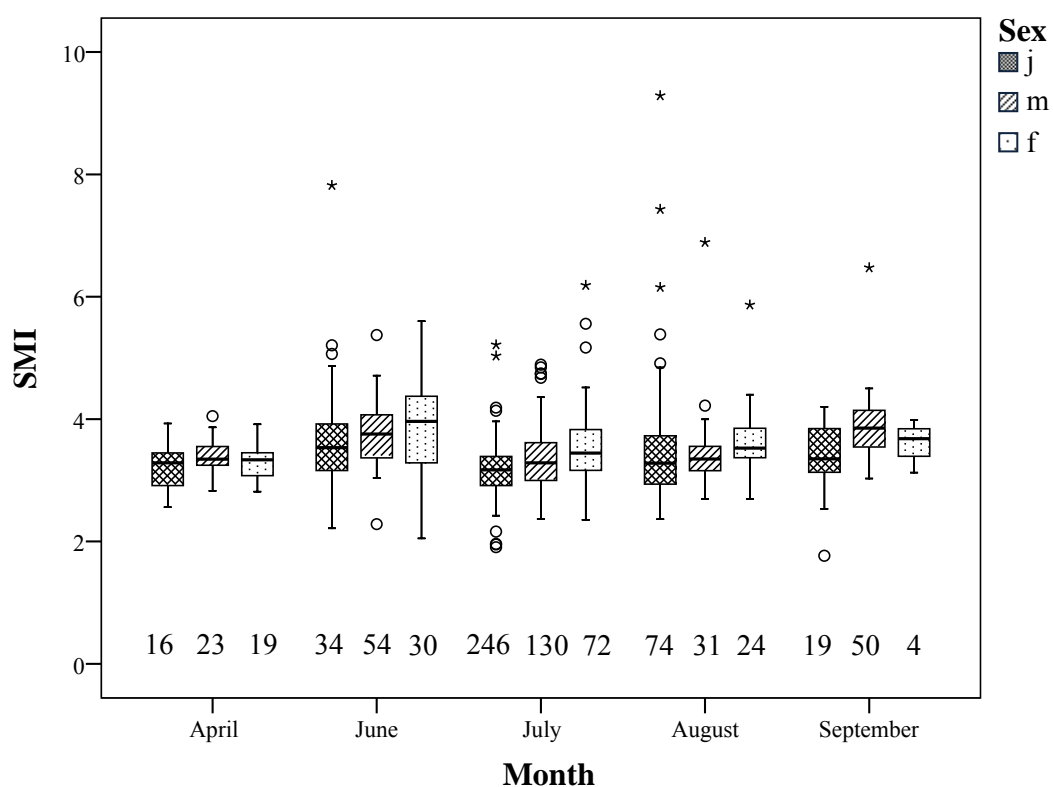


Figure 35. Relationship between the scaled mass index (SMI) and months in juvenile, male, and female yellow-bellied toads ($n = 826$) in 2010. Numbers indicate n .

Table 20. Kruskal-Wallis H test of the scaled mass index (SMI) between months in 2010 and comparison of means with the Tukey-HSD test (means with the same letter are not significantly different at $p < 0.05$).

Source	χ^2	df	P-value
Among months	80.0337	4	< 0.05
Month	n	Means (\pm SE)	
June	158	3.709 (\pm 0.0535) ^a	
September	33	3.665 (\pm 0.1306) ^a	
August	129	3.590 (\pm 0.0819) ^a	
April	58	3.313 (\pm 0.0433) ^b	
July	448	3.281 (\pm 0.0231) ^b	

Table 21. Kruskal-Wallis H test of the scaled mass index (SMI) of males between months in 2010 and comparison of means with the Tukey-HSD test (means with the same letter are not significantly different at $p < 0.05$).

Source	χ^2	df	P-value
Among months	40.3321	4	< 0.05
Month	n	Means (\pm SE)	
September	15	3.997 (\pm 0.2059) ^a	
June	54	3.761 (\pm 0.0701) ^{ab}	
August	31	3.471 (\pm 0.1288) ^{bc}	
April	23	3.386 (\pm 0.0649) ^{bc}	
July	130	3.334 (\pm 0.0432) ^c	

Table 22. ANOVA of the scaled mass index (SMI) of females between months in 2010 and comparison of means with the Tukey-HSD test (means with the same letter are not significantly different at $p < 0.05$).

Source	SS	df	MS	F	P-value
Between groups	4.4421354	4	1.1105339	2.946	< 0.05
Within groups	54.2901746	144	0.3770151		
Total	58.7323100	148			
Month	n	Means (\pm SE)			
April	19	3.299 (\pm 0.0667) ^a			
June	30	3.880 (\pm 0.0701) ^b			
July	72	3.471 (\pm 0.1295) ^{ab}			
August	24	3.634 (\pm 0.1258) ^{ab}			
September	4	3.618 (\pm 0.1792) ^{ab}			

3.8.2.2 Season 2011

The SMI was calculated for all captured individuals ($n = 447$) and partitioned by sex and months (Fig. 36). There were significant differences in the SMI between months (Tab. 23). The SMI was the highest in August and September. Significant differences were found in juveniles between months (Tab. 24). In the case of males (Tab. 25) and females (Tab. 26) there were no statistically significant differences.

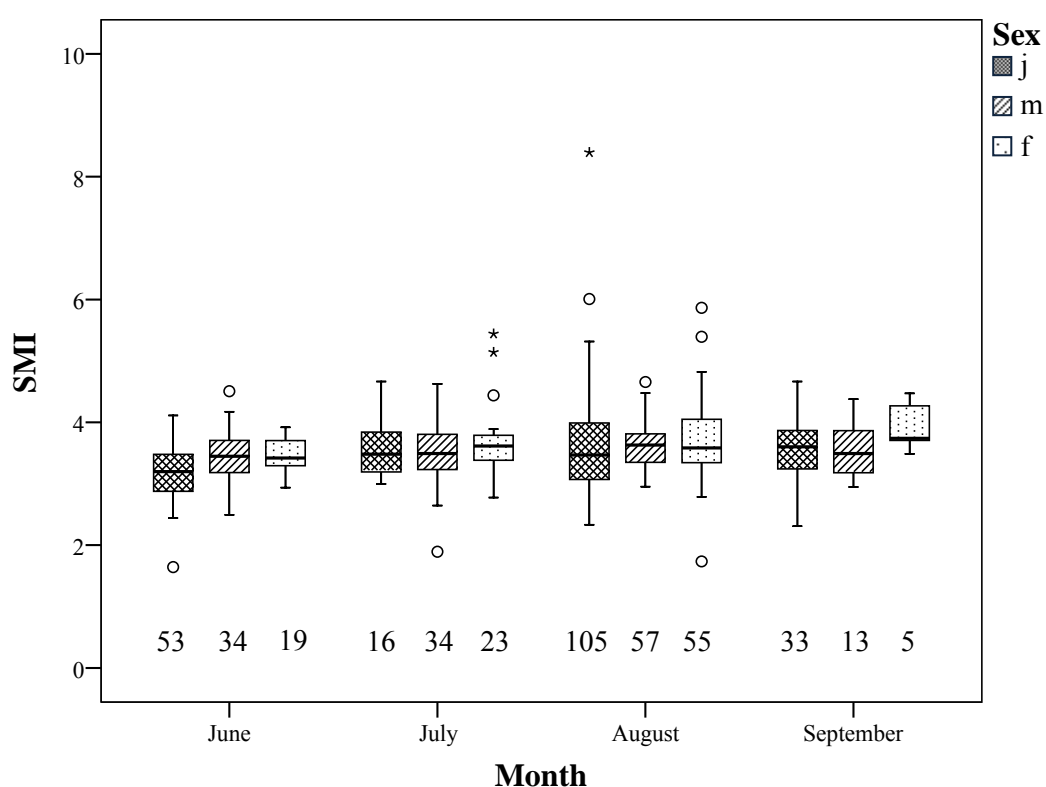


Figure 36. Relationship between the scaled mass index (SMI) and months in juvenile, male, and female yellow-bellied toads ($n = 447$) in 2011. Numbers indicate n.

Table 23. Kruskal-Wallis H test of the scaled mass index (SMI) between months in 2011 and comparison of means with the Tukey-HSD test (means with the same letter are not significantly different at $p < 0.05$).

Source	χ^2	df	P-value
Among months	23.9490	3	< 0.05
Month	n	Means (\pm SE)	
August	217	3.643 (\pm 0.0469) ^a	
September	50	3.618 (\pm 0.0759) ^a	
July	74	3.556 (\pm 0.0626) ^a	
June	106	3.309 (\pm 0.0399) ^b	

Table 24. Kruskal-Wallis H test of the scaled mass index (SMI) of juveniles between months in 2011 and comparison of means with the Tukey-HSD test (means with the same letter are not significantly different at $p < 0.05$).

Source	χ^2	df	P-value
Among months	18.3179	3	< 0.05
Month	n	Means (\pm SE)	
August	105	3.649 (\pm 0.0826) ^a	
September	32	3.603 (\pm 0.0101) ^{ab}	
July	16	3.547 (\pm 0.1143) ^{ab}	
June	53	3.171 (\pm 0.0559) ^b	

Table 25. ANOVA of the scaled mass index (SMI) of males between months in 2011.

Source	SS	df	MS	F	P-value
Between groups	0.7562190	3	0.2520730	1.417	> 0.05
Within groups	24.0236244	136	0.1779528		
Total	24.7798434	139			

Table 26. ANOVA of the scaled mass index (SMI) of females between months in 2011.

Source	SS	df	MS	F	P-value
Between groups	1.1181561	3	0.3727187	1.134	> 0.05
Within groups	32.2188134	98	0.3287634		
Total	33.3369695	101			

3.8.3 SMI in 2010 and 2011

There was a significant interaction between the effects of month and year on the SMI (Tab. 27).

Multiple comparison of SMI means showed that differences in June and July were statistically significant (Fig. 37, Tab. 28).

Table 27. Two-way ANOVA of the scaled mass index (SMI, dependent variable) partitioned by month and year (independent variables).

Source	SS	df	MS	F	P-value
Year	0.150	1	0.150	0.391	> 0.05
Month	6.703	3	2.234	5.825	< 0.05
Year*month	15.161	3	5.054	13.175	< 0.05
Error	462.999	1207	0.384		
Total	15195.993	1215			

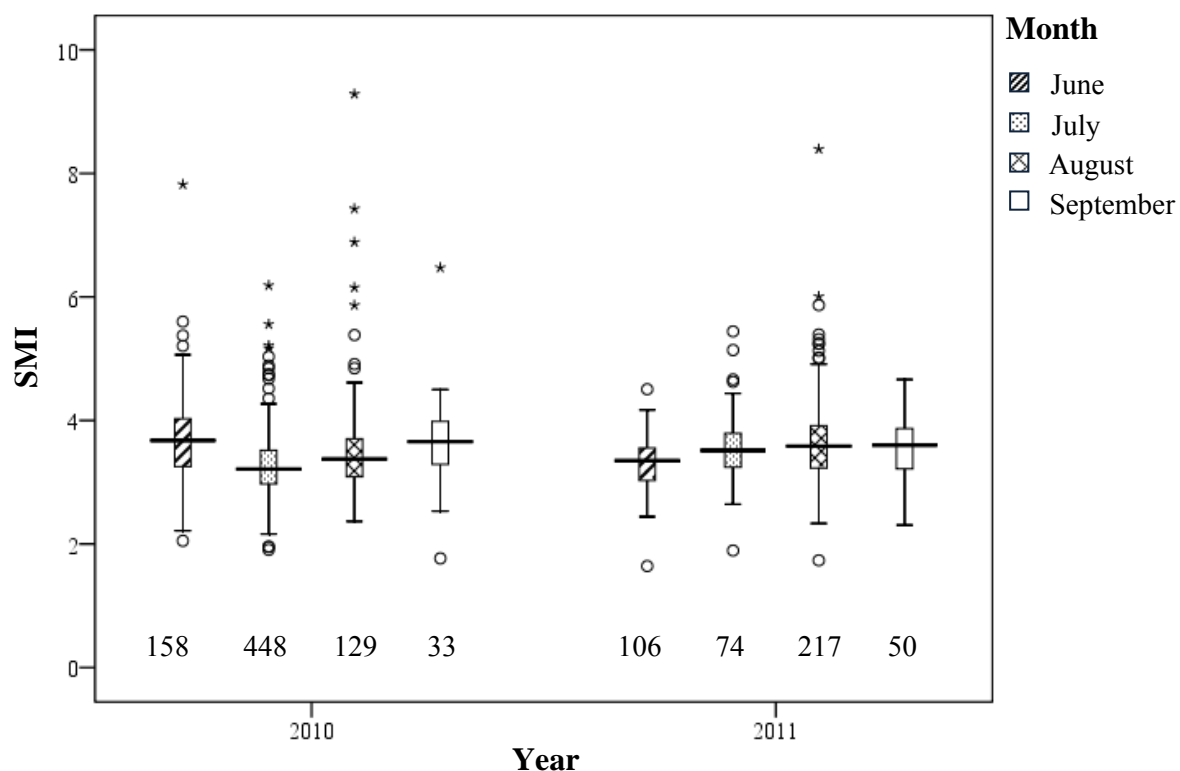


Figure 37. Comparison of the scaled mass index (SMI) between 2010 and 2011. April is excluded, because in April the study area was only visited in 2010. Numbers indicate n.

Table 28. Comparison of the scaled mass index (SMI) means of different months in 2010 and 2011.

Source	n	2010	n	2011	P-value
		Means (\pm SD)		Means (\pm SD)	
June	158	3.709 (\pm 0.6724)	106	3.309 (\pm 0.4111)	< 0.05
July	448	3.281 (\pm 0.4890)	74	3.556 (\pm 0.5390)	< 0.05
August	129	3.590 (\pm 0.9313)	217	3.643 (\pm 0.6907)	> 0.05
September	33	3.665 (\pm 0.7502)	50	3.618 (\pm 0.5365)	> 0.05

3.8.4 Altitude

The SMI was calculated for all captured toads ($n = 1273$) in 2010 and 2011 (Fig. 38). No statistically significant differences were found between the SMI and altitude in juveniles, males, and females (Kruskal-Wallis H test, $\chi^2 = 2.5351$, $n = 1273$, $df = 2$, $p > 0.05$).

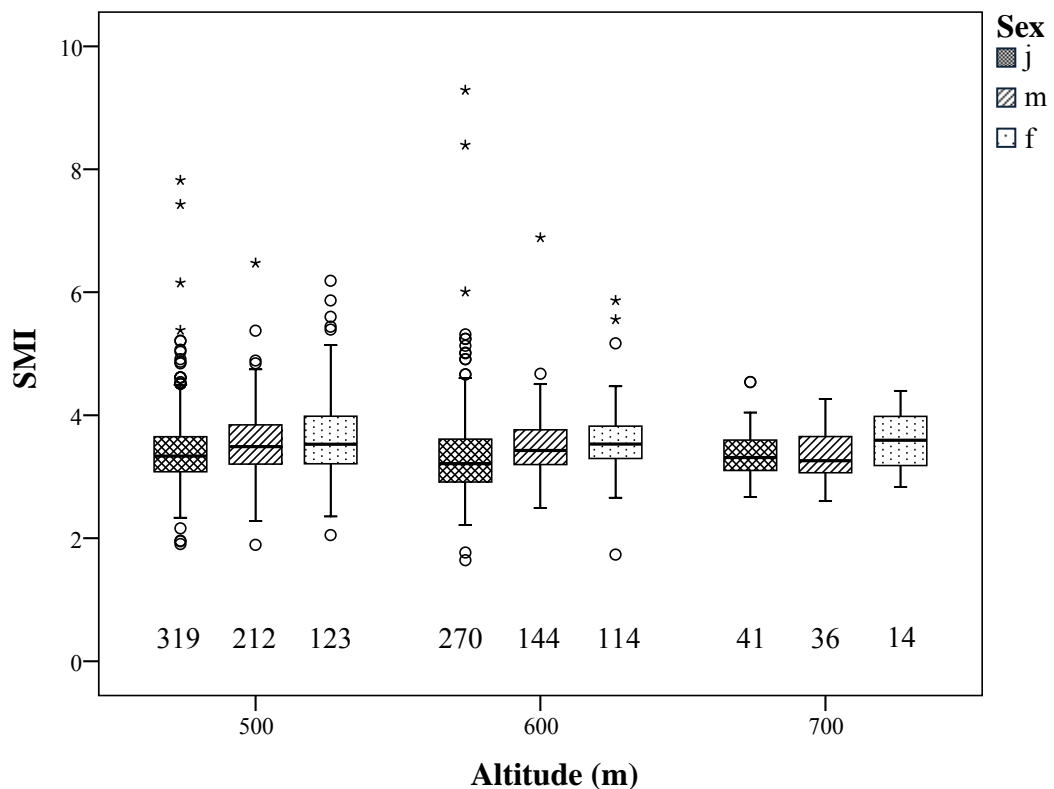


Figure 38. Relationship between the scaled mass index (SMI) and altitude in juvenile, male, and female yellow-bellied toads ($n = 1273$). Sea levels were categorized into intervals of 100 m (500 m: 400-500 m). Numbers indicate n.

3.8.5 Movement

3.8.5.1 Mover

No significant differences were found in the scaled mass indices between two capture points of movers (Fig. 39, Tab. 29).

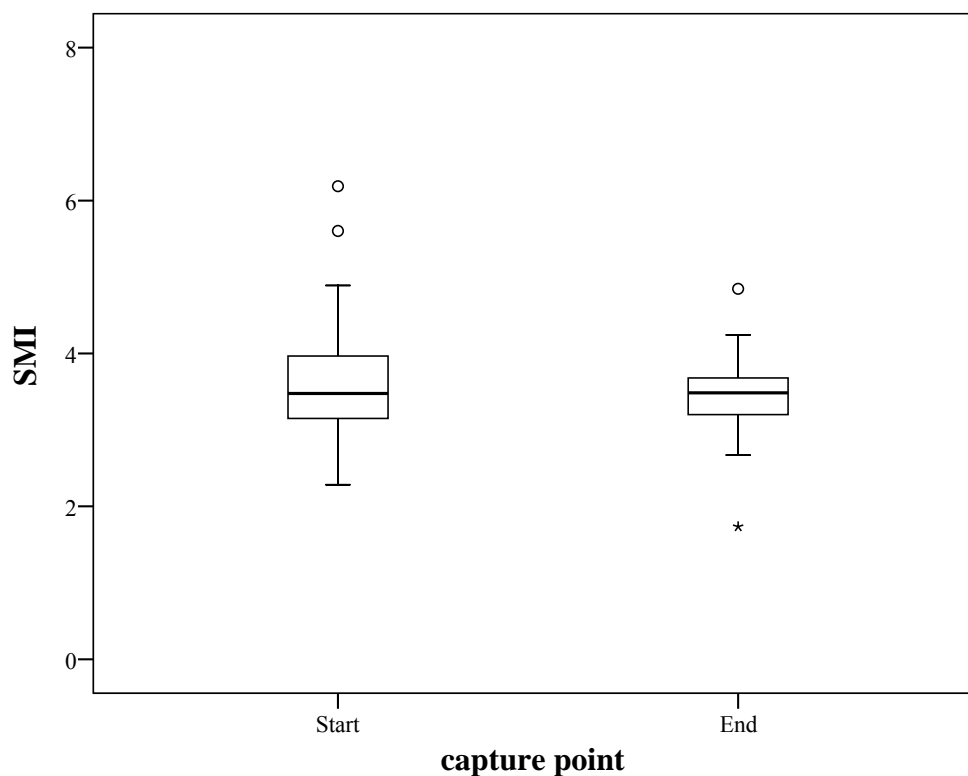


Figure 39. Comparison of the scaled mass indices (SMI) of movers between the two most distant capture points (n = 76).

Table 29. ANOVA of the scaled mass indices (SMI) of movers between two capture points (start – end).

Source	SS	df	MS	F	P-value
Between groups	0.9126554	1	0.9126555	2.720	> 0.05
Within groups	50.3261716	150	0.3355078		
Total	51.2388270	151			

3.8.5.2 Stayer

No significant differences were found in the scaled mass indices between two capture points of stayers (Fig. 40, Tab. 30).

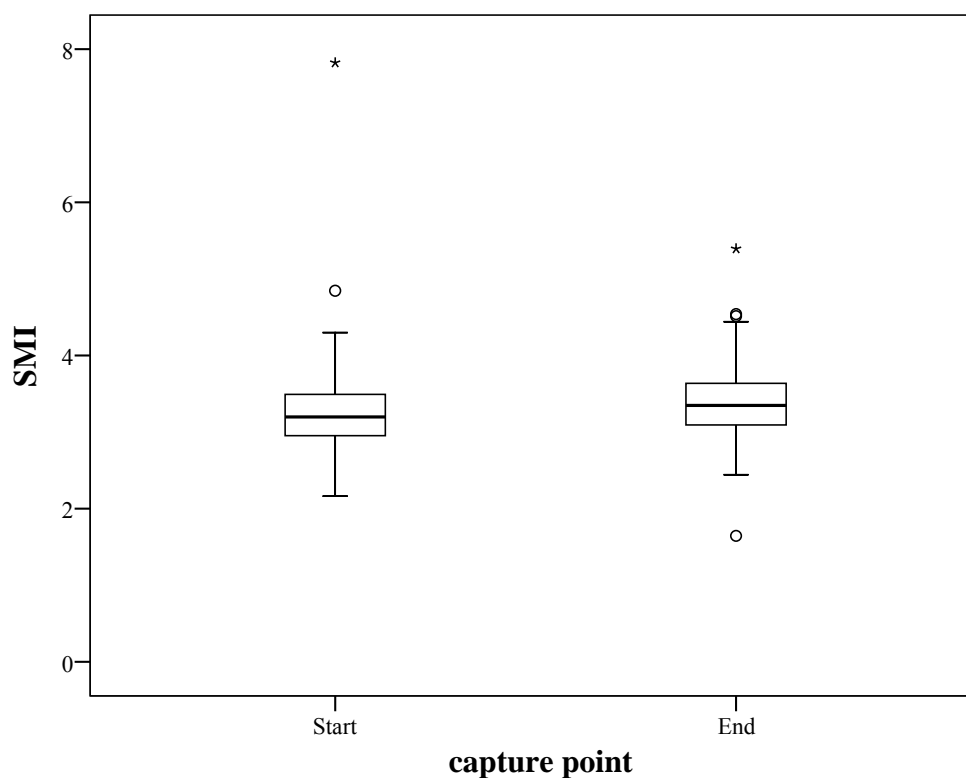


Figure 40. Comparison of the scaled mass indices (SMI) of stayers between the first and the last capture (n = 138).

Table 30. ANOVA of the scaled mass indices (SMI) of stayers between two capture points (start – end).

Source	SS	df	MS	F	P-value
Between groups	0.9041807	1	0.9041807	3.499	> 0.05
Within groups	70.8089001	274	0.2584267		
Total	71.7130817	275			

3.9 Movement activity

3.9.1 Movement (2010-2011)

Of 834 individuals 214 toads were recaptured at least once, of these individuals 138 toads were found at the site of first capture and 76 toads changed the sites. These individuals covered distances between 108 m and 1153 m (Tab. 31). The annually dispersal rate was 234 m.

Table 31. Mean movement distances between the most distant sites covered by male, female, and juvenile yellow-bellied toads (n = 214) captured in 2010 and 2011.

Sex	Movement distance (m)				
	Mean	SD	Median	Min	Max
m (n = 66)	170	271	0	0	1113
f (n = 40)	131	239	0	0	950
j (n = 108)	115	207	0	0	1153

The maximum observed distance was 1153 m, which was covered by a juvenile (Fig. 41). No statistically significant differences were found between the movement distances of juveniles, males, and females (Kruskal-Wallis H test, $\chi^2 = 0.5671$, n = 214, df = 2, $p > 0.05$).

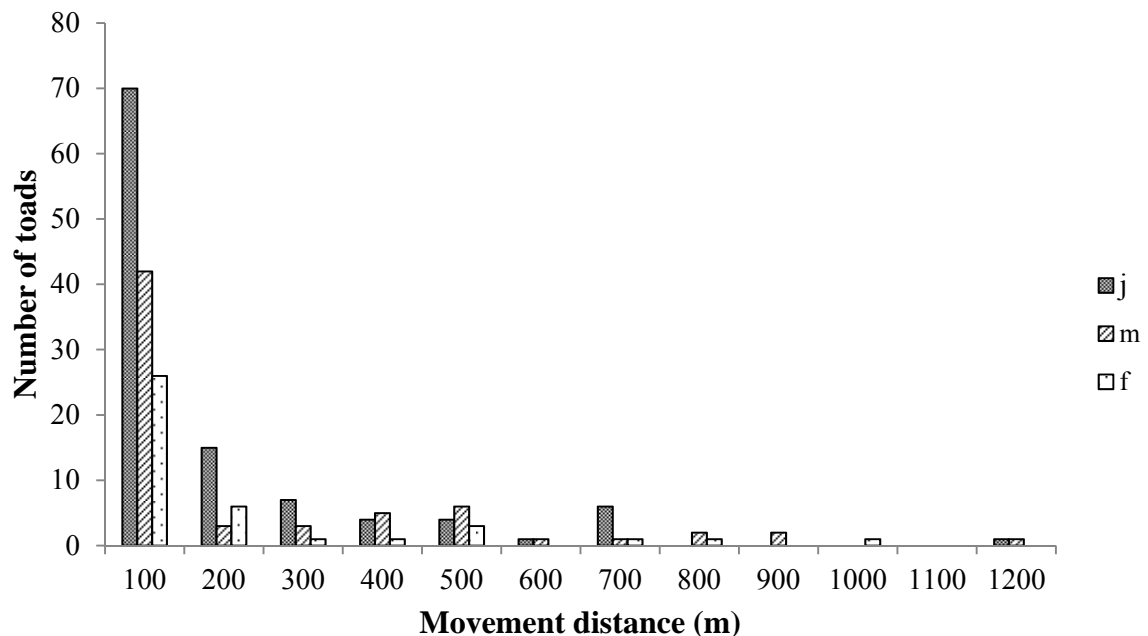


Figure 41. Movement distances covered by juvenile, male, and female yellow-bellied toads (n = 214) captured and recaptured in 2010 and 2011. Distances are categorized in classes with intervals of 100 m between each class (e.g. class 100 m: 0-100 m).

The relationship between SVL and the movement distances of juveniles was not statistically significant (Tab. 32).

Table 32. Linear regression of distance on SVL of juvenile yellow-bellied toads.

Model	SS	df	MS	F	P-value	R ²
Regression	45556.79	1	45556.79	1.069	> 0.05	0.01
Residual	4518603.62	106	42628.34			
Total	4564160.41	107				

In the case of males the relationship between SVL and the movement distances was not statistically significant (Tab. 33).

Table 33. Linear regression of distance on SVL of male yellow-bellied toads.

Model	SS	df	MS	F	P-value	R ²
Regression	191932.59	1	191932.59	2.691	> 0.05	0.04
Residual	4564774.50	64	71324.60			
Total	4756707.09	65				

In females the relationship between SVL and the movement distances was not statistically significant (Tab. 34).

Table 34. Linear regression of distance on SVL of female yellow-bellied toads.

Model	SS	df	MS	F	P-value	R ²
Regression	30256.47	1	30256.47	0.522	> 0.05	0.01
Residual	2201797.31	38	57942.03			
Total	2232053.78	39				

3.9.2 Movement of metamorphs (2008)

In 2008 high numbers of metamorphs were recorded. Out of 447 metamorphs, 405 were first registered at site 1. In 2010 and 2011 a number of 35 individuals were recaptured of which three individuals were first captured at site 68. Over the years the sex of 11 individuals (eight males and three females) could be assigned (Fig. 42). These metamorphs covered distances between 0 m and 3042 m (Fig. 43, Tab. 35) and the dispersal rate, calculated as the standard deviation of movement distances over a period of four years, was 617 m per generation. The overall mean movement distance of these metamorphs, irrespective of sex, was 690 m. There were no significant differences between the mean movement distances of juveniles, males, and females (Tab. 36).

While 7 metamorphs were found at the site of first capture, 28 metamorphs had moved to new sites. Of all metamorphs eight individuals changed the site more than once and two individuals returned to their natal site (Fig. 44).

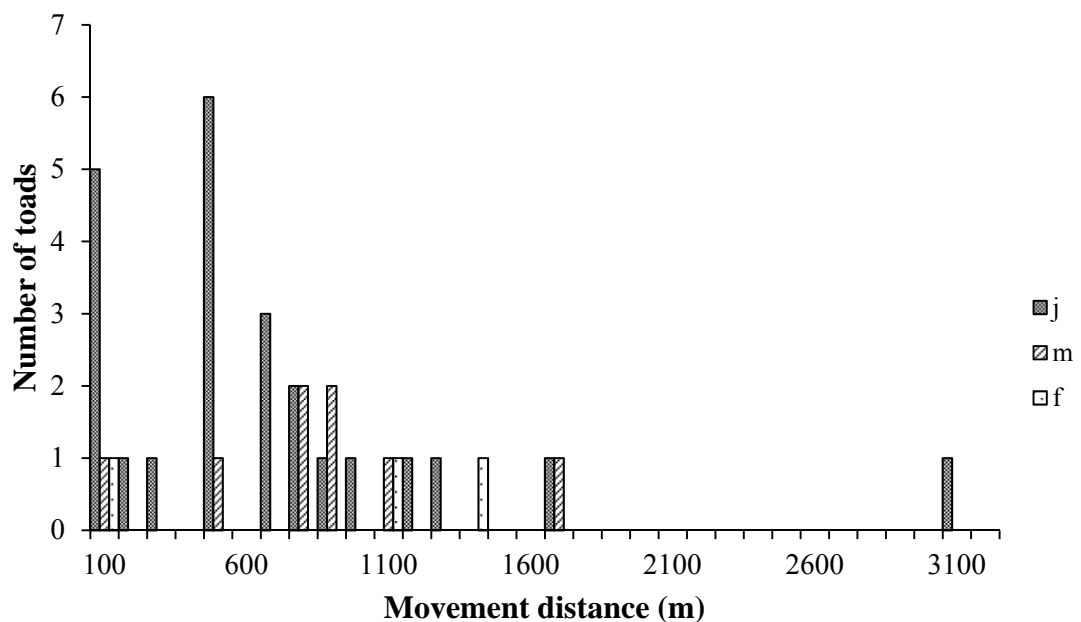


Figure 42. Movement distances of metamorphs (n = 35) captured in 2008 and recaptured in 2010 and 2011. The sex of 11 individuals could be assigned (eight males, three females). Distances are categorized in classes with intervals of 100 m between each class (e.g. class 100: 0-100 m).

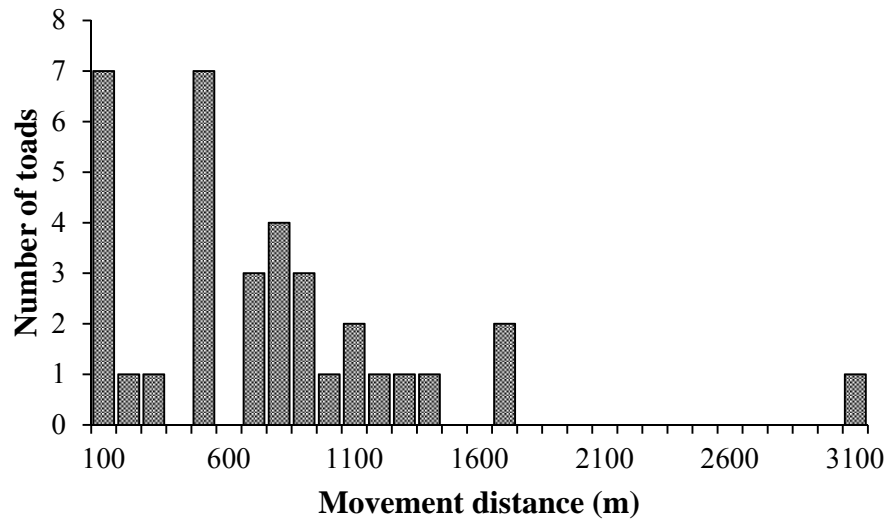
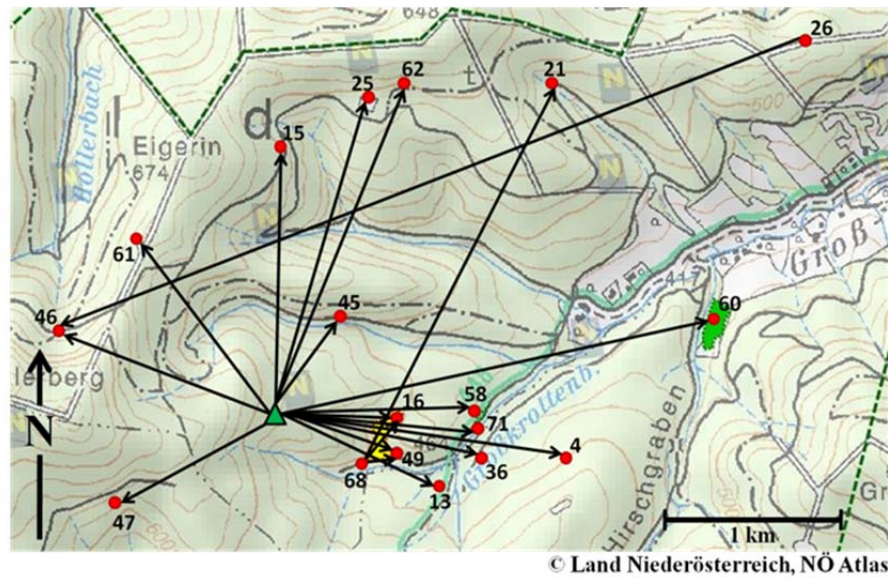


Figure 43. Movement distances of metamorphs ($n = 35$) first captured in 2008 at site 1 (Δ) and site 68. Solid lines represent the greatest covered distances between two capture points. The distances 1-13, 1-15, 1-16, 1-36, 1-45, 1-49, and 1-61 were covered more than once. The yellow area shows an open area (cleared in the winter before 2002), the green area shows the meadow Ulmwiese.

Table 35. Mean movement distances of the most distant sites covered by metamorphs first captured in 2008. During the study period the sex of 11 individuals could be determined. A number of seven toads remained at the natal site.

Sex	Movement distance (m)				
	Mean	SD	Median	Min	Max
m ($n = 8$)	795	480	796	0	1691
f ($n = 3$)	805	720	1028	0	1388
j ($n = 24$)	640	662	469	0	3042

Table 36. ANOVA of the mean movement distances of former metamorphs (2008) partitioned by sex.

Source	SS	df	MS	F	P-value
Between groups	187270	2	93635.098	0.235	> 0.05
Within groups	12734856	32	397964.262		
Total	12922126	34			

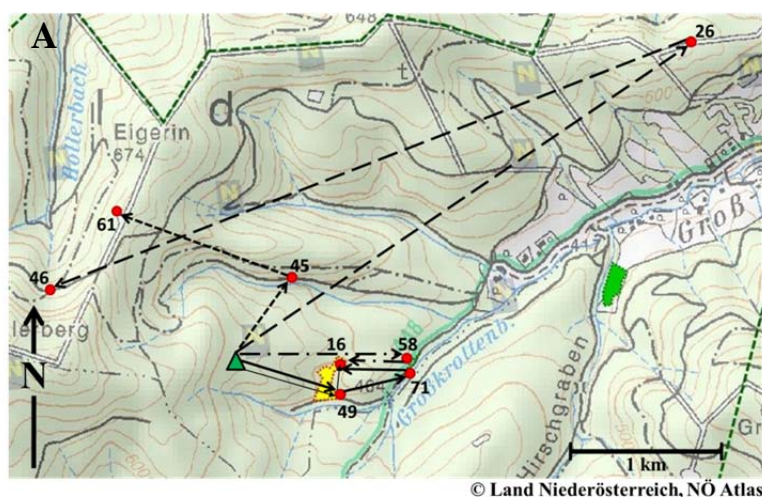
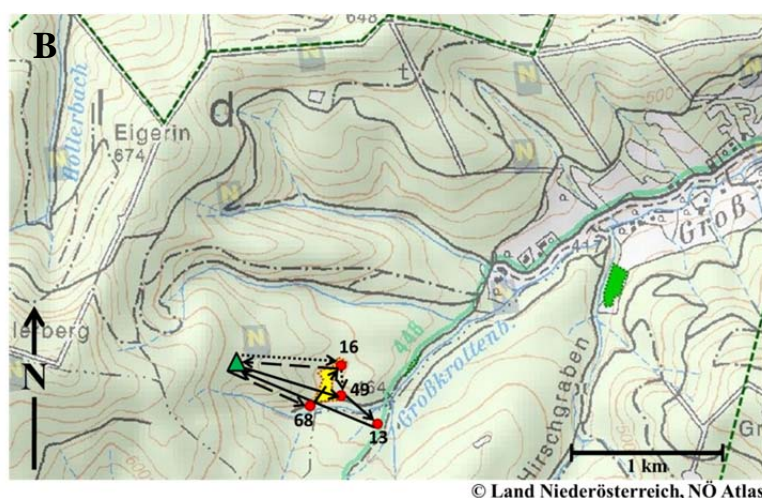


Figure 44. Observed paths of metamorphs (n = 8) that changed the site more than once. For a better distinction paths are shown on separate maps (A, B).

A date

- 28/08/08, 04/07/10, 07/08/11
- — 28/08/08, 26/06/10, 07/08/11
- · — 28/08/08, 12/08/09, 09/07/10
- 28/08/08, 19/07/10, 07/08/11
- 28/08/08, 12/07/10, 14/07/10, 07/08/11



B date

- 28/08/08, 12/08/09, 11/06/11
- — 28/08/08, 12/08/09, 09/07/10, 11/06/11
- 28/08/08, 30/04/10, 21/08/10, 11/06/11

There was no statistically significant relationship between SVL and the movement distances of metamorphs (Tab. 37).

Table 37. Linear regression of distance on SVL of metamorphs first captured in 2008.

Model	SS	df	MS	F	P-value	R ²
Regression	49204.03	1	49204.03	0.126	> 0.05	0.004
Residual	12872922.54	33	390088.56			
Total	12922126.57	34				

3.9.3 Comparison of movements of juveniles and adults (2008-2011)

Juveniles ($n = 71$) covered distances between 0 m and 3042 m. Adults ($n = 13$) covered distances between 0 m and 1225 m (Fig. 45). The mean movement distance of juveniles was 505 m and of adults 280 m. No statistically significant differences were found between the mean movement distances of juveniles and adults (juveniles: $n = 71$, adults: $n = 13$; Mann-Whitney: $U = 316$, $p > 0.05$).

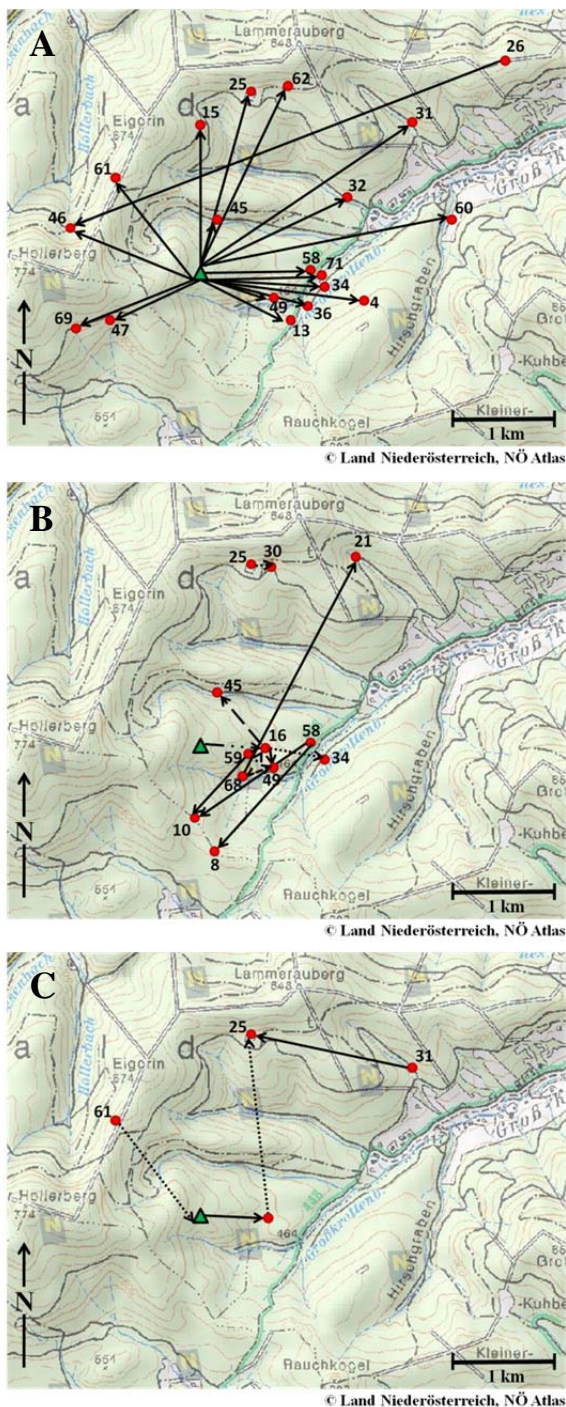


Figure 45. Comparison of movement distances between juvenile (A, B; $n = 71$) and adult (C; $n = 13$) yellow-bellied toads first captured in 2008 or 2009 and recaptured during 2010 and/or 2011. For a better distinction, movement distances of juveniles are shown on separate maps.

4 Discussion

4.1 Habitat use

Yellow-bellied toads predominantly were observed in roadside ditches and water-filled wheel ruts. These water bodies were most frequently registered in the study area apart from runlets and ponds. In man-made habitats yellow-bellied toads are typically found in such types of water bodies (Sy & Grosse 1998, Gollmann & Gollmann 2012). In Romania Hartel et al. (2011) reported that yellow-bellied toads performed better in water bodies with short hydroperiods, and were more successful in temporary water bodies than other amphibians. In Großkrottenbach up to 80-90% of registered water bodies used by *B. variegata* were temporary, stagnant, unshaded, and shallow. Only 8% of individuals, of which four individuals were juveniles, were found in ponds. In habitats with high numbers of different kinds of water bodies amphibians tend to move opportunistically between aquatic sites (Hartel et al. 2011). Hartel (2008) reported that yellow-bellied toads moved more frequently and covered greater distances in years with more precipitation.

More juveniles than adults were observed in runlets probably because these water bodies were used as stepping-stones and corridors for dispersal (Gollmann & Gollmann 2012, Osbourn 2012). Furthermore, the low water level, the current and the stony soil of runlets were not suitable for reproduction and thus these water bodies were not used by adults. The water depth of most water bodies was lower than 20 cm, only 11% of aquatic sites were deeper.

Due to the patchy distribution of water bodies and the high number of juvenile and adult individuals in puddles, wheel ruts and roadside ditches it is likely to be that these aquatic sites were used by juveniles as well as adults as stepping-stones for dispersal and migration.

The low number of juveniles in ponds can be explained by the presence of predators. Larvae and adult individuals of *I. alpestris* and *R. temporaria* were found co-occurring with yellow-bellied toads in ponds, which are both potential predators of *B. variegata* (Gollmann & Gollmann 2012). Adult Fire Salamanders (*S. salamandra*) were observed in terrestrial habitats, but were not found in the same water bodies as *B. variegata*. Habitats of yellow-bellied toads were closely located to streams, which serve as breeding habitats of *S. salamandra* (Nöllert & Nöllert 1992). Reptiles such as the Slow Worm *Anguis fragilis* and the Grass Snake *Natrix natrix* were found close to water bodies. Szczerbak & Szczerban (1980) found several yellow-bellied toads in the stomach of *N. natrix*. Kapfberger (1982) reported of water frogs that fed on metamorphosed yellow-bellied toads. The risk of predation through aquatic insects, reptiles, and amphibians is more notable for tadpoles and metamorphs of *B. variegata* than for juveniles and adults. Due to their skin toxin yellow-bellied toads have few predators (Gollmann & Gollmann 2012).

Up to 80% of individuals were found at altitudes of 475-500 m and 575-600 m, which correlated with the distribution of breeding sites at these altitudes, but no distinct pattern in the altitudinal distribution of juvenile and adult toads was found. The high number of individuals found at these altitudes may have depended on a higher frequency of visits. Sites at lower altitudes were visited more frequently than those of higher altitudes. Furthermore, no suitable water bodies were found at higher altitudes.

The bottom of nearly all water bodies was covered with silt or clay and in some cases covered with detritus and grass. In the presence of predators (*A. fragilis*, Dytiscidae – personal observations) or investigators toads immediately used the muddy bottom as shelter, which was also observed by Niekisch (1990). The density of aquatic vegetation in water bodies varied, but the majority exhibited little or no aquatic vegetation, which is typical for newly created and temporary water bodies. While juveniles were more often observed close to banks, adults were predominantly observed floating on the water surface or on swimming macrophytes. Osbourn (2012) reported that

juvenile amphibians often wait in water bodies close to banks for suitable conditions (e.g. rain) to move and described it as ‘wait mode’.

Human impact has caused original habitats of *B. variegata* such as wet meadows, swamps, and lentic meanders of streams to disappear gradually. Thus yellow-bellied toads were forced to adapt to new habitats and started using water bodies, which are man-made and mostly temporary. Forestry being the main factor for change in habitats in Großkrottenbach should be regulated, even though it is important for the creation of new habitats. A major part of this regulation would include reducing the frequency of vehicle activity during the breeding season, in order for toads to have fewer disturbances. Due to the fragmented habitats of *B. variegata*, the temporary character and patchy distribution of their water bodies, and the fact that they are pioneer species the model of a metapopulation, as described by Hanski & Simberloff (1997), seems to be appropriate for the studied population in Großkrottenbach. According to this model, metapopulations are subdivided into a number of patchily distributed subpopulations where local extinctions, recolonizations and movements between patches occur. Open areas that are closely located to forest edges with networks of patchily distributed and different types of water bodies, are ideal habitats for yellow-bellied toads (Gollmann et al. 2012).

4.1.1 Breeding sites

Except for runlets, at all other types of registered water bodies breeding was observed, which probably can be explained by low levels of water and the current in runlets. In pond 64, which was free of aquatic vegetation, tadpoles and metamorphs were found. In other ponds no breeding was observed. Hartel et al. (2011) found that yellow-bellied toads were more common and reproductively successful in temporary water bodies, which corresponds with findings of this study.

Breeding sites were found at an altitudinal range of 427-658 m. Most different types of breeding sites were found between 450 m and 475 m. Fewer breeding sites were found on higher grounds (altitudes starting from 575 m up to 675 m) probably because of lower amount of open areas and lower activity of forestry vehicles at these altitudes.

In the previous study (Gollmann 2005) reproduction was most successful at site 1 and 16. In 2010 and 2011 at both sites breeding was observed – eggs, tadpoles, and metamorphs were found. Site 1 was a network of different water bodies, natural and man-made, that were spring-fed. Site 16 had been cleared before 2002 and consisted of many water bodies on a swampy ground. At both sites some water bodies were prevented from silting up, enlarged, and created by the use of wild boars.

In the year 2011 a high number of metamorphs ($n = 76$) were registered at the breeding site 15. This water body completely dried up after one month. Drying up of water bodies is the most frequent factor that causes mortality in yellow-bellied toads (Seidel 1988, Gollmann & Gollmann 2012). On the one hand, shallow water bodies are important because at such sites water quickly warms up and provides suitable conditions for the development of eggs and tadpoles (Barandun et al. 1997). On the other hand, the risk of drying up is high. The ability of yellow-bellied toads to reproduce multiple times during the activity period (Barandun et al. 1997, Di Cerbo & Biancardi 2012, Gollmann & Gollmann 2012) increases the chance of successful breeding.

In total the breeding success in Großkrottenbach could not be documented in detail at all 20 breeding sites because of the ephemerality of water bodies, possible migration, and dispersal of metamorphosed toadlets (Barandun & Reyer 1998, Gollmann 2005). Furthermore, the sites were visited at different intervals.

4.1.2 *Resting sites*

In Großkrottenbach *B. variegata* used temporary and permanent water bodies as resting habitats. Adults especially used unshaded ponds as resting habitat with high levels of bank and aquatic vegetation and water bodies with possibilities to hide. Juveniles were seldom observed in such water bodies. Many juveniles were found in shallow, shaded, and unshaded water bodies such as runlets and water-filled wheel ruts. Some water bodies fulfilled conditions for both, breeding and resting sites, which was also described by Miesler & Gollmann (2000).

4.2 *Size structure*

Sexual size dimorphism has been observed in many amphibian species (Wells 2007). In most cases females are longer than males (Seidel 1988, Di Cerbo & Biancardi 2012). The size differences between males and females can be caused by many factors such as selection (Wells 2007), variation in climatic conditions (Liu & Li 2010), and differences in breeding costs (Woolbright 1983). In some amphibians males are bigger than females. This is known as reversed sexual dimorphism (Di Cerbo & Biancardi 2012). In some anurans sexual dimorphism does not occur (Smith & Roberts 2003). In yellow-bellied toads the difference in size between males and females is not very distinct, but there are notable differences in the length of hind limbs – those of males are longer than those of females (Gollmann & Gollmann 2012).

In Großkrottenbach size classes of 14-54 mm and body mass classes of 2-14 g were represented. Offspring of previous years as well as metamorphs of present years, small adults, and big adults (> 46 mm) were registered. The number of juveniles was higher than those of big adults.

Low numbers of big and old adults and high numbers of metamorphs and juveniles are typical of man-made habitats (Gollmann et al. 2012). In such influenced habitats turnover rates are usually high (Kapfberger 1984). In a long-term study of *B. variegata* Seidel (1992) reported that toads have high survival rates and are able to reach the age of 15 years and more. He further reported of a population in Lower Austria which predominantly consisted of adult toads (Seidel 1988). On the contrary, in the present study nearly 50% of the population were juveniles.

In 2010 and 2011 the mean snout vent length and body mass was higher in females than in males. The mean snout vent length of adult yellow-bellied toads was about 40-45 mm, which has been reported of many populations of *B. variegata* (Gollmann et al. 2012). The mean snout vent length of a population in Romania was about 40-42 mm (Băncilă et al. 2010). In Großkrottenbach the longest male measured was 53.7 mm long and weighed 12.7 g, the longest female measured was 57.1 mm long and weighed 13.9 g. In the Lainzer Tiergarten, a nature reserve in the Vienna Woods, Miesler & Gollmann (2000) reported that on average females were about 3 mm longer than males. Seidel (1988) found that female yellow-bellied toads were longer and heavier than males as well. In Switzerland Abbühl & Durrer (1993) reported that the body mass was minimal higher in female than in male yellow-bellied toads. In studies by Frick (2002), Gollmann (2005) and Băncilă et al. (2010) no significant differences in size of male and female yellow-bellied toads were found. The high body mass in females probably was linked to the production of eggs during the breeding season.

4.3 Growth

4.3.1 2010-2011

Growth of yellow-bellied toads was negatively correlated to the snout vent length and the body mass. The mean growth was 4.7 mm per year, which coincides with the results (5.6 mm per year) found in the previous study (Gollmann 2005). In the Lainzer Tiergarten the mean growth per month of juvenile yellow-bellied toads (SVL of 20-32 mm) was $4.2 \text{ mm} \pm 1.3 \text{ mm}$ (SD) and of adults (SVL of 32-40 mm) $2.6 \text{ mm} \pm 0.5 \text{ mm}$ (Miesler & Gollmann 2000). In general the growth of individuals was quite different – some individuals grew slower than others or not at all, which was also observed by Gollmann (2005) in Großkrottenbach.

4.3.2 Metamorphs of 2008

The mean increase of the snout vent length was the highest a year after metamorphosis (2008) and the lowest from 2009 to 2010. This result confirms that growth of yellow-bellied toads is the highest during the first 1-2 years (Miesler & Gollmann 2000, Gollmann & Gollmann 2005, Gollmann & Gollmann 2012). Niekisch (1990) reported that the snout vent length in metamorphs of *B. variegata* increased by approximately 2-5 mm per month. In the present study the mean growth of metamorphs, a year after metamorphosis, was 10.7 mm and thus noticeably lower than results of Niekisch (1990) showed.

If conditions are good, metamorphs can reach a body size of up to 30 mm after their first hibernation (Gollmann & Gollmann 2012). In the present study the mean snout vent length of metamorphs was 29.8 mm, a year after metamorphosis. The low increase of the snout vent length from 2009 to 2010 is probably due to different capture dates during the season. In 2009 the area was visited in August, while in 2010 the area was visited already in April. In general growth in metamorphs varies a lot and depends on the date of metamorphosis, size at metamorphosis, and environmental conditions (Gollmann & Gollmann 2012).

4.4 *Scaled mass index (SMI)*

4.4.1 *Sex*

No significant differences were found in the SMI between juveniles, males, and females. In Romania Băncilă et al. (2010) compared the Residual Index (R_i) between juvenile and adult yellow-bellied toads. They calculated the body condition with residuals from an ordinary least squares regression (OLS) and also found no significant differences in the body condition index between life stages. To compare these results the scaling exponent b was calculated with a standard major axis regression, an OLS, a reduced major axis, and a major axis regression – only minor differences were found.

4.4.2 *Months – Season 2010*

Statistically significant differences in the SMI were found between sexes in different months of the season. The SMI of males and females was higher in June, August, and September compared to April and July. In the case of juveniles no differences were found. In April the SMI was probably lower, because individuals had depleted all their energy reserves during hibernation. In June the SMI increased due to their increased activity. In July, during the peak of breeding, most of the gathered reserves have already been used for reproduction which resulted in lower SMI's. In August the SMI differed between sexes, the SMI of males was lower than those of females. While females typically leave the breeding sites after spawning and move to resting sites (Gollmann & Gollmann 2012), males usually remain at breeding sites, calling. At resting sites females are no longer disturbed by males and probably have more time for foraging. In September the SMI was high in both sexes probably due to the restored reserves for hibernation. In Romania Băncilă et al. (2010) found higher body conditions during spring and summer than in autumn. This result could have been influenced by many factors such as altitude, environmental conditions, and appearance of offspring at the end of the activity period.

4.4.3 Months – Season 2011

Significant differences were found between months – the SMI was higher in July, August, and September than in June. In April the study area was not visited. The differences were only statistically significant in juveniles. The SMI was the highest in August and the lowest in June. Because juveniles are not sexually mature, they do not use their energy reserves for breeding, which probably explains why the SMI was higher in July.

4.4.4 SMI in 2010 and 2011

The comparison of 2010 and 2011 showed significant differences in the SMI in June and July – the SMI was higher in June, 2010 than in 2011, and higher in July, 2011 than in 2010. These results may have been influenced by the differences of investigation in years resulting in great differences between sampling sizes.

4.4.5 Altitude

No differences were found in the SMI at different altitudes probably due to the proximity of sites in the studied population and because differences in altitudes were not that high. In Romania Băncilă et al. (2010) found that yellow-bellied toads had higher body conditions at lower altitudes. Longer periods of cold temperature, at higher altitudes, probably had an influence on the activity and body condition of yellow-bellied toads in Romania (Băncilă et al. 2010). Pooling data of three different populations at different altitudes may have affected their results.

4.4.6 Movement activity

For movers and stayers no SMI differences were found between two capture points. The mean SMI of movers was minimally lower after moving (start: 3.6, end: 3.4). For stayers the SMI was minimally higher (start: 3.3, end: 3.4). In contrast to stayers, movers probably moved because of better body conditions or because of changing environmental conditions, which would explain the lower SMI after moving. In the case of stayers the SMI was higher at the end, which indicates that their site was suitable and no energy was depleted for moving. Though stayers were found at the same site it does not implicate that they did not move at all.

4.5 *Movement*

4.5.1 *Movement (2010-2011)*

In the present study more than 60% of recaptured toads were found at the site of first capture. Of these toads 50% were juveniles. Adult yellow-bellied toads tend to stay at the site of first capture over years. Gollmann & Gollmann (2012) recaptured yellow-bellied toads over a period of six years at the site of first capture. In displacement experiments Barandun & Reyer (1998) reported that adult yellow-bellied toads remained at the same site over three years and even returned after displacement of 8 m to 420 m away from natal sites. This raises the question why adult individuals should leave their sites when habitat quality is suitable and breeding successful. A main factor, apart from environmental conditions, habitat quality and population densities, that influences the movement activity of toads is the distribution, abundance, and connectivity of water bodies. In Großkrottenbach water bodies were patchily distributed and sometimes closely located to each other, which probably favored movements. Gollmann et al. (2012) reported that yellow-bellied toads are more likely to move if water bodies are closely located to each other. Forestry work in Großkrottenbach and the accompanying creation of new water bodies may also have promoted repeated short-distance movements between water bodies, because yellow-bellied toads are known to quickly colonize newly created water bodies (Niekisch 1990, Hartel et al. 2007, Gollmann et al. 2012).

The mean movement distance measured for males was 170 m and 131 m for females. The low mean movement distances of adults and the fact that 50% of recaptured adults remained at their sites indicates that yellow-bellied toads in Großkrottenbach were partly philopatric. The maximum observed movement distance of males was 1113 m and in the case of females 950 m. In Romania Hartel (2008) reported that the movement distance of female yellow-bellied toads was positively related to body size and suggested that longer females are more experienced and efficient in

locating new water bodies. In the present study no statistically significant relationship was found between the snout vent length and the movement distances in juveniles, males, and females.

Previous studies have shown that juveniles tend to be more vagile and show little site fidelity (Beshkov & Jameson 1980, Gollmann & Gollmann 2012, Osbourn 2012). Within a year Niekisch (1990) recaptured single juveniles 850 m away from the site of the first capture. In the following year 10 other metamorphs were found 600-800 m away from the site of the first capture.

From 2010 to 2011 the mean movement distance of juveniles measured was 115 m, which did not significantly differ from the mean movement distance of adults and was no indication that juveniles represent the main dispersal stage. The maximum observed movement distance of juveniles was 1153 m. In Germany (Lower-Saxony) the maximum observed movement distance of juvenile yellow-bellied toads covered within a year was only 203 m (Jacob et al. 2009). In Großkrottenbach the calculated dispersal rate for all individuals was 234 m per year, which is consistent with studies of *B. variegata* by Szymura & Barton (1986) – the dispersal rate was 250 m per year and was calculated as standard deviation of distance travelled over one year. The irregular and low frequency of investigation of the study area, especially in 2011, probably affected the results. To better analyse long-distance movements of yellow-bellied toads in Großkrottenbach the study area has to be enlarged and to be investigated more intensive and more frequently.

4.5.2 *Movement of metamorphs (2008)*

The maximum observed distance covered by a juvenile was 3042 m, which shows that juveniles are able to cover considerable distances. The dispersal rate estimated for former registered metamorphs was 617 m per generation and was calculated as the standard deviation in distance. In a hybrid zone in west Cracow Szymura & Barton (1986) estimated a dispersal rate of 890 m per generation, which was calculated as the standard deviation in distance between parent and offspring and was inferred from allele frequencies. Though different methods were used calculating the dispersal rate, remarkable similarity in results of both studies was found, which is impressive, because usually the opposite is the case.

Gollmann & Gollmann (2005) suggested that benefits of early dispersal may be gaining knowledge about the landscape and resources to optimize growth and reproduction in later years. Although seven toads were found at natal sites over a period of four years it is not certain that they did not change the sites at all. It is possible that they moved and returned to their natal sites after dispersal (Kapfberger 1984) or conditions at site 1 suited them perfectly. Gollmann & Gollmann (2005) suggested that dispersal probably depends on habitat quality – metamorphs in unsuitable habitats are more likely to move to new sites than those in habitats with suitable conditions. This could not be observed in the present study, because conditions at site 1, referring to the availability, hydroperiod, and proximity of different kinds of water bodies, had been suitable over the years. In 2008 high numbers of metamorphs were registered at site 1 (Gollmann 2005), which probably favored dispersal because of high conspecific densities, resulting in increased competition. In many species it has been observed that movement can be affected by population densities (e.g. Léna et al. 1998, Berven 2009).

The movement activity of metamorphs in the present study supports the suggestion of Gollmann & Gollmann (2000) that juveniles move considerable distances in the first 2-3 years of the postmetamorphic life. Gollmann & Gollmann (2005) observed that metamorphs of *B. variegata* repeatedly returned to natal sites in later years.

In the present study 80% of recaptured metamorphs ($n = 35$) left their natal sites and dispersed to new sites over a period of four years. Two individuals returned to their natal sites after dispersal. The mean movement distance of metamorphs, irrespective of sex was 690 m, which supports the assumption that some probably have left the study area. Nevertheless 8% of former registered metamorphs were recaptured even though metamorphs are highly susceptible to predation and desiccation during movements in terrestrial habitats (Semlitsch 2008, Osbourn 2012).

Gollmann & Gollmann (2012) reported that juvenile yellow-bellied toads tend to disperse through terrestrial habitats, and do not return to their natal sites within the season. In the Lainzer Tiergarten Gollmann & Gollmann (2012) recaptured metamorphs, which had already moved 600 m away from their natal site, just a month after metamorphosis. In displacement experiments juvenile yellow-bellied toads did not return to former sites (Niekisch 1990).

Pond-breeding amphibians typically time their movements to coincide with rainfall (Hartel 2008). If conditions are not suitable for moving, it is most likely that they orientate towards near-pond temporary refuges, which are used as stepping-stones (Osbourn 2012). Furthermore, new habitats are usually colonized by juveniles and subadults (Niekisch 1990). In the present study 47% of juveniles were captured at runlets and water-filled wheel ruts, which were probably used as stepping-stones during dispersal.

5 *Conclusions*

Juvenile and adult yellow-bellied toads in Großkrottenbach used the same types of water bodies. Runlets and wheel ruts were mainly used by juveniles and ponds mainly by adults. For breeding all types of water bodies were used except of runlets. The body condition index was higher in autumn than in spring and summer and was not affected by sex, altitude, or movement activity. In the years 2010 and 2011 no differences in the movement distances between juveniles and adults could be found. Over a period of four years 80% of recaptured former metamorphs dispersed from their natal to new sites.

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8 Abstracts

8.1 English abstract

In 2010 and 2011 a capture-recapture study on the Yellow-bellied Toad, *Bombina variegata* (Linnaeus, 1785) was conducted in a forested area in Großkrottenbach (Lower Austria). This study is based on data of a previous study by Gollmann (2005). A total of 834 individuals were identified and nearly half of the population consisted of juveniles ($n = 405$). Up to 90% of sites where toads were observed were man-made, temporary, unshaded, and stagnant water bodies. The most common types of water bodies in the studied area were water-filled wheel ruts, roadside ditches, and puddles. Only 8% of individuals were found in ponds. Adults predominantly used ponds and juveniles predominantly used runlets. Most of the juveniles were captured in wheel ruts and most adults in puddles. Spawning occurred in 20 water bodies, especially in ditches, wheel ruts, and puddles. The snout vent length (SVL) and the body mass (BM) was on average higher in females than in males. The scaled mass index was not affected by sex, altitude, and movement activity, but differed between months – it was higher in autumn than in spring and summer. Of metamorphs first captured in 2008, a total of 80% left their natal sites. The dispersal rate of metamorphs was 617 m per generation. The maximum observed distance of 3042 m over a period of four years was covered by a former metamorph. For individuals captured between 2010 and 2011 the annual dispersal rate was 234 m. The maximum observed distance covered by juveniles was 1153 m, 1113 m by males and 950 m by females. Site fidelity was found for more than 60% of these toads. No differences in the movement activity of juvenile and adult yellow-bellied toads were found.

8.2 *Deutsche Zusammenfassung*

In den Jahren 2010 und 2011 wurde in einem Waldgebiet in Niederösterreich, Großkrottenbach eine Fang-Wiederfang-Studie an Gelbbauchunken durchgeführt. Diese Studie basiert auf Daten einer Vorstudie von Gollmann (2005). Es konnten 834 Individuen identifiziert werden und der Anteil an Juvenilen in der Population war hoch ($n = 405$). Mehr als 90% der Gewässer wo Unken angetroffen wurden, waren künstlich, temporär, besonnt und stehend. Die am häufigsten vorgefundenen Gewässertypen im Untersuchungsgebiet waren wassergefüllte Wagenspuren, Straßengräben, und Pfützen. In Teichen wurden nur 8% der Individuen gefunden. Teiche wurden überwiegend von Adulten verwendet und Rinnsale von Juvenilen. Die meisten Juvenilen wurden in Wagenspuren und die meisten Adulten in Pfützen angetroffen. Fortpflanzung konnte in 20 Gewässern nachgewiesen werden, v.a. in Straßengräben, Wagenspuren und Pfützen. Weibchen waren im Durchschnitt größer (SVL) und schwerer (BM) als Männchen. Der Body condition index (SMI) war im Herbst höher als im Frühling und Sommer und wurde nicht durch Geschlecht, Seehöhe oder Wanderaktivität beeinflusst. Metamorphlinge, welche erstmals 2008 registriert wurden, haben zu 80% ihre Geburtsgewässer verlassen. Ihre Ausbreitungsrate betrug 617 m pro Generation. Die beobachtete Maximaldistanz, über einen Zeitraum von vier Jahren, betrug 3042 m und wurde von einem ehemaligen Metamorphling zurückgelegt. Die Ausbreitungsrate von Individuen, welche zwischen 2010 und 2011 gefangen wurden, betrug 234 m. Die beobachtete Maximaldistanz von Juvenilen betrug 1153 m, von Männchen 1113 m und von Weibchen 950 m. Standorttreue konnte in mehr als 60% dieser Individuen nachgewiesen werden. Es konnten keine Unterschiede in der Wanderaktivität von juvenilen und adulten Gelbbauchunken gefunden werden.

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