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„The European Green Toad (*Bufotes viridis*) in Donaufeld (Vienna, Austria): status and size of the population"

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Table of contents

Abstract 6
Introduction 7
Materials and Methods 9
  Study Area 9
  Monitoring 9
  Individual Identification 10
  Population Assessment 11
Results 14
Discussion 25
Conclusion 27
Outlook 27
References (Literature) 28
Appendix 32
Zusammenfassung 44

Abstract

The European Green Toad, *Bufotes viridis* (Laurenti, 1768) is a species with endangered populations, in Austria it is considered as vulnerable and in Vienna as critically endangered. This capture-recapture study aimed to assess the status and size of the population of *B. viridis* in the Donaufeld (Vienna, Austria). Over the course of this study, 79 individuals (66 males, 10 females, 3 juveniles) were captured. On each occasion the Body Mass (BM) and Snout-Vent-Length (SVL) of the captured toads as well as the sex were recorded. Additionally, a photo of the unique dorsal pattern of each captured individual was taken. For assessing the condition of the toads, the Fulton-Index was calculated, separately for each occasion. To identify the individuals, the program HotSpotter was used, an image recognition software. For the population-assessment a capture-recapture model in R was built by applying Jolly-Seber-Schwarz-Arnason (JSSA) models, using the package openCR. The estimated population-size was 113 individuals, with a confidence interval reaching from 86 to 144.

Furthermore, the development of tadpoles to toadlets (metamorphlings) was verified at the identified spawning-ground, documenting reproductive success.

Additionally, syntopy of the Green Toad and the Common Toad (*Bufo bufo*) was observed, even a rare mismatch-mating between the two species.

Key words: European Green Toad (*Bufotes viridis*), capture-recapture, population-size, population-status, syntopy, mismatch-mating, Donaufeld (Vienna, Austria)

Introduction

In general, more than 70% of all amphibian species in the world are in decline, this is mainly caused by five major factors: diseases, atmospheric change, environmental pollutions, habitat modification and invasive species (Hayes et al., 2010).

The European Green Toad, *Bufotes viridis* (Laurenti, 1768) is a species considered as vulnerable in Austria (Gollmann, 2007) and in Vienna as critically endangered (Tiedemann & Häupl, 1994). Furthermore, *B. viridis* is listed in the Annex IV of the European Council Habitats and Species Directive, that includes species for which specific protective measures must be taken (Council Directive 92/43/EEC).

The primary habitat of *B. viridis* are open steppes, with loose soil substrates and little vegetation (Stöck et al., 2008). *Bufotes viridis* is a thermophilic species and can therefore be found in highly urbanized areas and city centers, preferring to breed in shallow warmer temporary water bodies (Mazgajska, 1996). The Green Toad is able to populate heavily anthropogenically altered habitats like artificial water-basins (Csarmann, 2012). The Common Toad (*Bufo bufo*) in turn prefers wooded and more wet areas in its terrestrial life (Kuzmin et al., 1996).

The migration of amphibians is spatially limited to an approximate radius of 0,1-2,2 km (Kovar et al., 2009), if the local habitat is destroyed and there are not any suitable breeding ponds in the mentioned radius, the local population is very likely to go extinct (Mazgajska & Mazgajski, 2020).

The phenomenon of hybridization is widespread in nature (Mallet, 2005). Hybrids occur when two different species interbreed, resulting in genetic material being recombined (Schwenk et al., 2008). The divergence between the *B. viridis* and *B. bufo* has been estimated back to the Oligocene (Maxson, 1981). Climate change contributes to hybridization events by promoting an overlap of the breeding activities (Canestrelli et al., 2017). When the number of potential breeding sites and diversity is reduced in a certain area, a syntopy of previous allotopic populations can occur (Canestrelli et al., 2017).

Over the last decade several investigations of potential populations of *B. viridis* have been made throughout Vienna, from the outskirts to the inner districts. There are documented populations in Simmering (Staufer, 2018) and at the Rudolf-Bednar-Park (Heyer & Wappl, 2016). The outskirt areas of Vienna were examined in the year 2010 which included the following regions: Unterlaa, Albern, Breitensee, Süßenbrunn and Bisamberg (Csarmann et al., 2010).

This study uses capture-recapture methods to estimate the status and size of the population present at identified breeding sites in the Donaufeld. The presence of *B. viridis* was known only for a few years in the Donaufeld, but there was no investigation of the population up to this point. The collected data provide a foundation for further investigations and documents the presence of a population in this very diverse urban ecosystem. The population of *B. viridis* is already threatened by multiple planned construction projects. Therefore, data acquisition is very important, because it is unknown if the identified breeding sites will be maintained or saved in the future. As a result of the planned construction projects, the population can suffer dramatically or even go extinct.

Materials and Methods

Study Area

The area of interest is located in the 22nd District (Donaustadt) of Vienna (Austria) and is called Donaufeld (Fig.1). It is an agricultural area used by a variety of businesses like garden centers, small private farms and allotment garden areas. The study area is confined by three main roads: the “Donaufelderstraße” to the north, the “Nordmanngasse” in the middle and in the south with an alley called “An der Schanze”.

Monitoring

The data for this study were collected during the main breeding activity period of *Bufotes viridis* from April 22nd to July 19th, 2020. The area of interest was visited during the evening hours and in the night. First, I surveyed the area for suitable breeding habitats and monitored calls in the whole area. Once the breeding sites were identified I revisited them 2-3 times a week (Fig. A1-A4).

During each visit I collected the following data from all captured individuals, the Snout-Vent-Length (SVL), Body Mass (BM), sex and the detailed location where the toad was found. To keep the captured toads in temporarily safe custody, I used several plastic buckets.

The SVL was measured in millimeters using a plastic Vernier-caliper, correct to one decimal place. The BM of the toads was weighed in grams using a digital micro-scale (Model: Hoosiwee Präzision Taschenwaage, 1000 g), correct to one decimal place (Heyer & Wappl, 2016). To make the weighing process more efficient I placed a plastic measuring cup on the micro-scale and tared it, then I gently put the toad in the cup and read off the Body Mass. This prevented the toads from jumping away while weighing them and limited their ability to move, providing better results.

For taking pictures, I built a custom-made “photo-booth”. The “photo-booth” was made from a plastic box with in-glued shrink-wrapped millimeter paper. This saved a lot of time because the toads can’t jump away easily, and it gives you a rough estimate of the size of the toad without even having it measured yet. I used the camera of my phone (Resolution: 4608x3456, 16MP) to take pictures of the dorsal pattern of the toads for later ID determination. The rest of my equipment included a headlamp, writing tools and nets of various sizes.

For determining the sex, all individuals were examined looking at both morphological and behavioral features, those were the nuptial pads of the front legs, the distinct mating call of the males as well as the male exclusive release call (Heyer & Wappl, 2016).

In order to assess the condition of the individuals, the Fulton-Index was calculated for each identified individual using the equation $K=BM/(SVL^{3})*10^{5}$ (Băncilă et al. 2010).

In addition, I recorded tadpoles and metamorphlings (toadlets) (Fig. A5) at the identified breeding sites.

Individual Identification

For identifying the toads, I used the program HotSpotter (Crall et al., 2013). It is a recognition software which uses an algorithm for identifying images against a labeled database (Crall et al., 2013). Before the program can start the analysis, a Region of Interest (ROI) must be determined, the ROI is a manually specified rectangular, focused on the most distinctive body parts (Crall et al., 2013). In this case the dorsal region from the snout to the lower back including the parotid glands. I assumed that these individual dorsal patterns will not change over the course of my study (Patel & Das, 2020). Uploading the pictures in the database of HotSpotter creates so-called chips, which are used to compute the hotspots (unique individual features), shown as multi-colored ellipses (Crall et al., 2013; Patel & Das, 2020). The program provides a similarity score and ranks the chips from most similar to the least similar one (Patel & Das, 2020) (Fig. 2). A high score indicates a highly probable match, low scores indicate improbable matches (Crall et al., 2013). A successful identification was recorded, when two chips belonged to the same individual (Patel & Das, 2020).

Additionally, to the identification using HotSpotter, all the pictures were manually compared to avoid any bias or to miss any individuals.

Population Assessment

For an estimation of the population in the Donaufeld I used the statistical software R (R Core Team 2020). R is an open source environment and functional programming language for statistical data analysis (Widemann et al., 2013). Further, a user interface (UI) called RStudio (RStudio Team, 2020) was used. In R I used a capture-recapture (CR) model for open populations by applying Jolly-Seber-Schwarz-Arnason (JSSA) models (Iijima, 2020).

To estimate recapture probability (p), apparent survival (φ), Superpopulation size (SuperN) and entry probability (b) I used JSSA models in the package openCR (Efford, 2020). Recapture probability (p) is the probability of recapturing an individual, which has already been captured at a previous occasion (Schwarz & Arnason, 1996). Apparent survival (φ) describes the probability of an individual surviving and remaining in the population between sample times (Schwarz & Arnason, 1996). The Superpopulation size (SuperN) is the estimated total number of individuals that enter the system and survive until the next occasion (Schwarz & Arnason, 1996). Entry probability (b) is the number of individuals that enter after a specific sample time (Schwarz & Arnason, 1996).

Additionally, I used the parameters “Session” (a linear time dependency) and “t” (a non-linear time dependency, where each occasion is a categorical variable) (Efford, 2020). I used a model selection approach where I used a full model with constant superpopulation size (SuperN), but (linear and non-linear) time-varying for recapture-probability, apparent survival as well as entry probability.

Models were ranked using the corrected Akaike Information Criterion (AICc) (Anderson & Burnham, 1999), which is calculated by the openCR-package. Models which could not be computed or yielded a “possible maximation error” were excluded from my analysis.

Figure 1. Map of the investigated area highlighting (yellow pins) the two main breeding sites. Overview map (in the corner) taken from the site: https://stadtplanwien360.at/karte-bezirke-wien (modified).

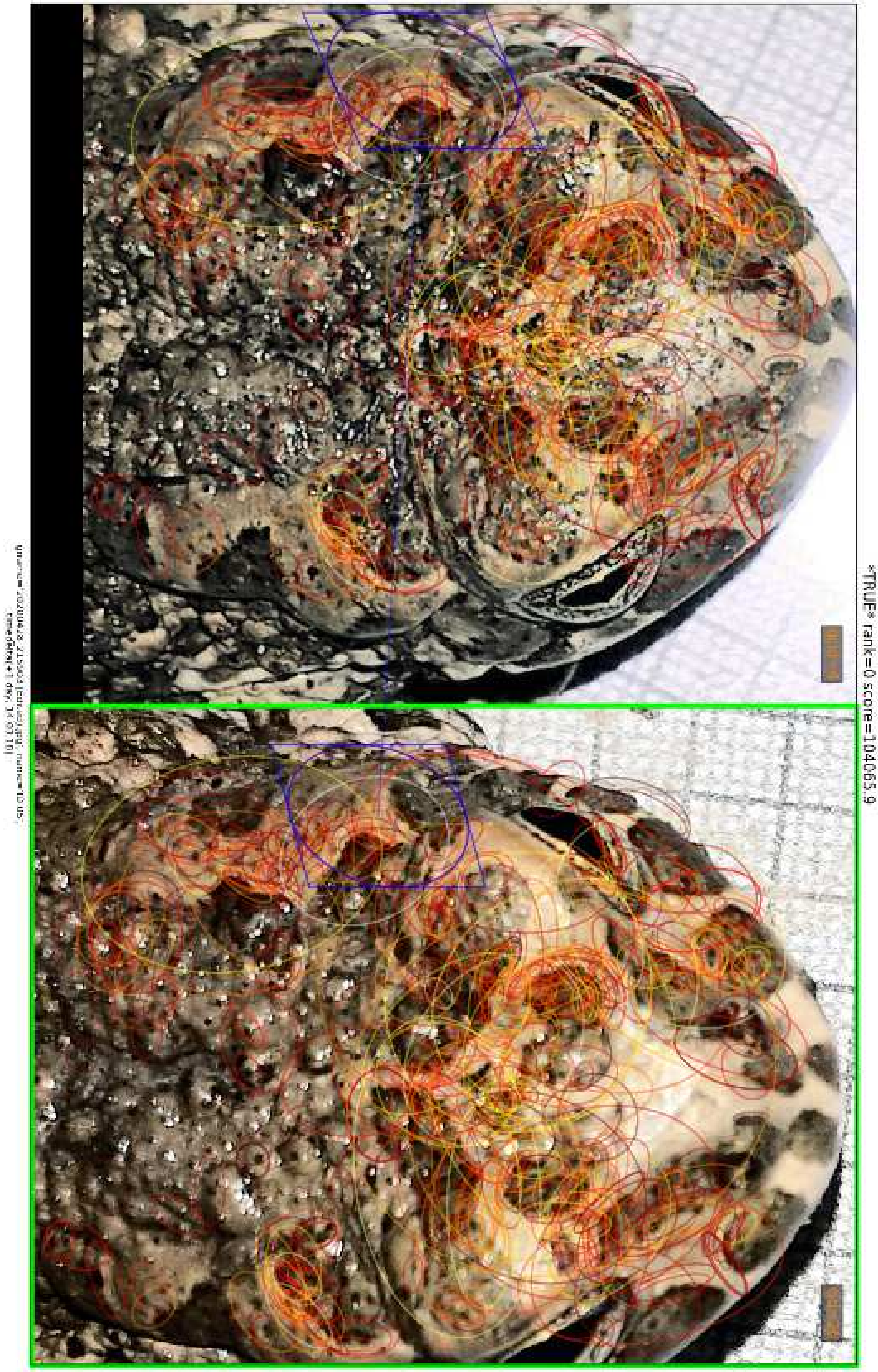

Figure 2. Example of a successfully identified toad using HotSpotter, highlighting the unique hotspots of the individual. The reference picture on the left is compared with the highest ranked matching picture with according score.

Results

Over the course of 30 days in the field, a total of 176 European Green Toads were captured, from which 79 individuals were identified. From the 79 individuals, 66 were males, 10 females and 3 juveniles. The recapture rate shows that the majority was only captured once (Fig. 3).

Most captures were made in the end of April to end of May. From June to the middle of July the captures were markedly less with a prominent peak on the 17th of June. The last capture was made on the 26th of June 2020, from there onward no more adult toads were found (Fig. 4).

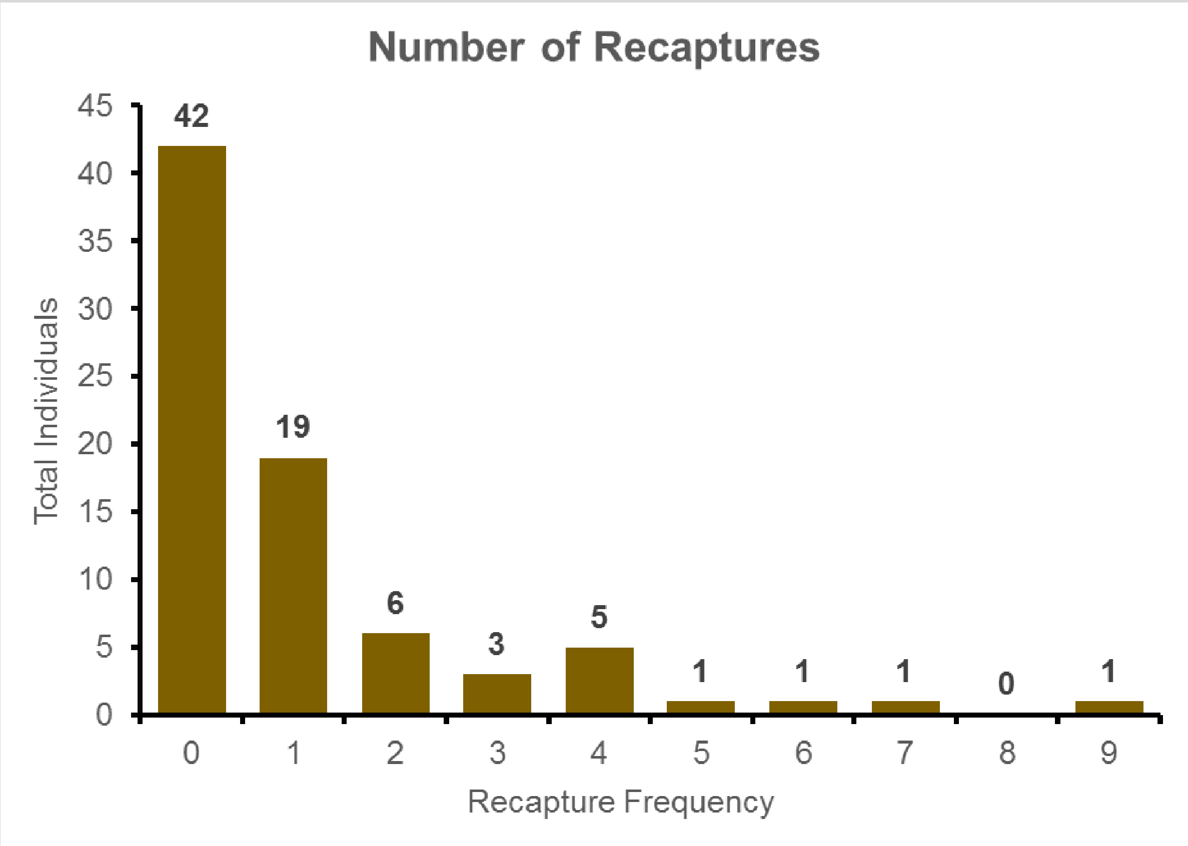

Figure 3: Recaptures: toads that have been caught multiple times.

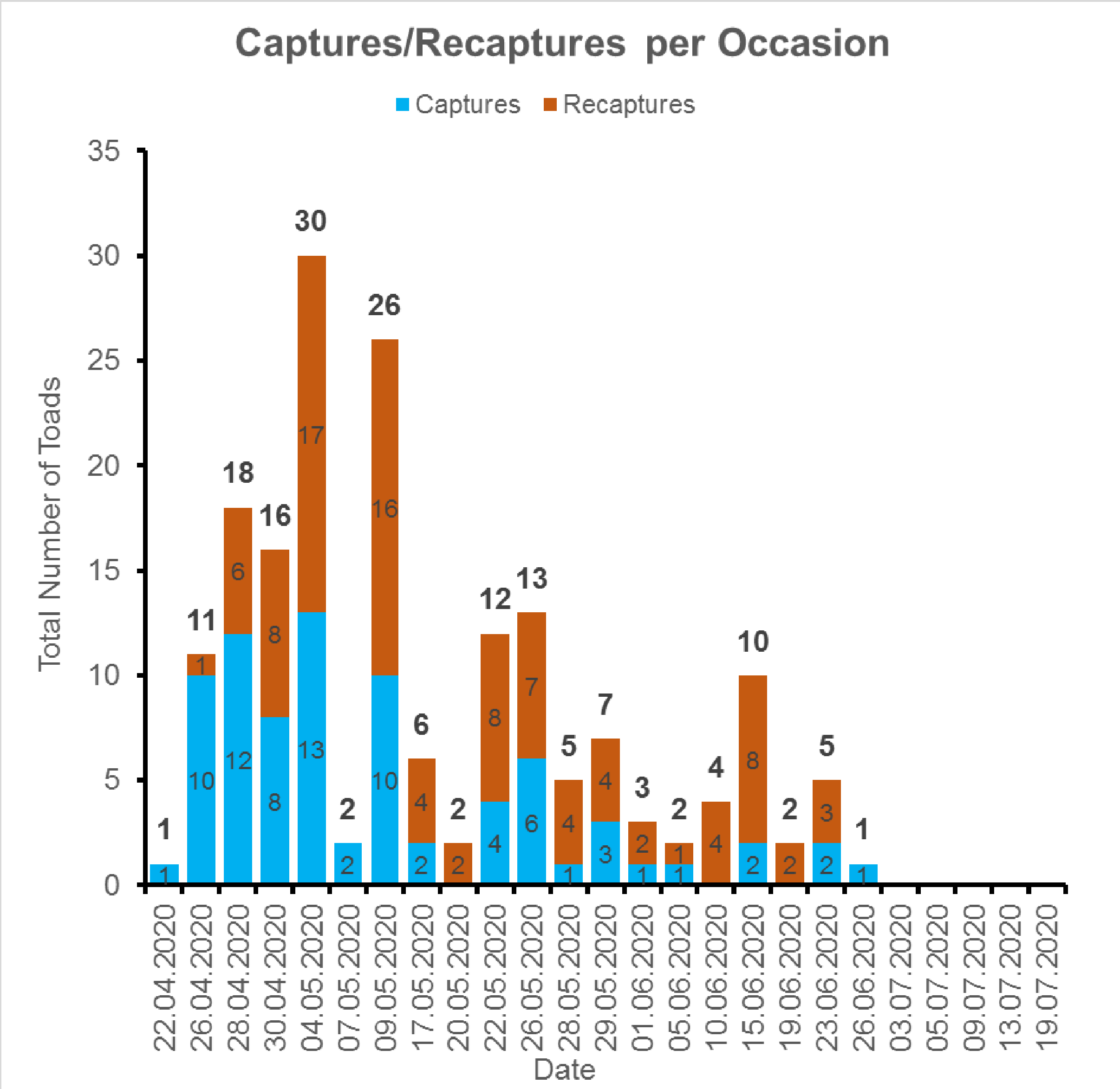

Figure 4: Number of toads captured on each sampling date. Captures: toads encountered for the first time at this day. Recaptures: toads that had already been captured at an earlier occasion.

The SVL of the males ranged from 40.0 mm to ≥ 80.0 mm, the majority of the captured males showed a size of 60.0 mm or more. The size of the females ranged from 70.0 mm to ≥ 80.0 mm, most of them were larger than 70.0 mm. The size of the juveniles ranged between 40 mm and 47 mm.

For the males (n = 66) the average SVL was 69.8 mm (standard-deviation of 5.5), for the females (n = 10) 77.2 mm (standard-deviation of 4.5) and for the juveniles (n = 3) 43.8 mm (standard-deviation of 2.8) (Tab. 1). Individuals, which were captured multiple times, had their mean values calculated and were assigned to the respective categories. Outlier values were not included in the analysis (Fig. 5).

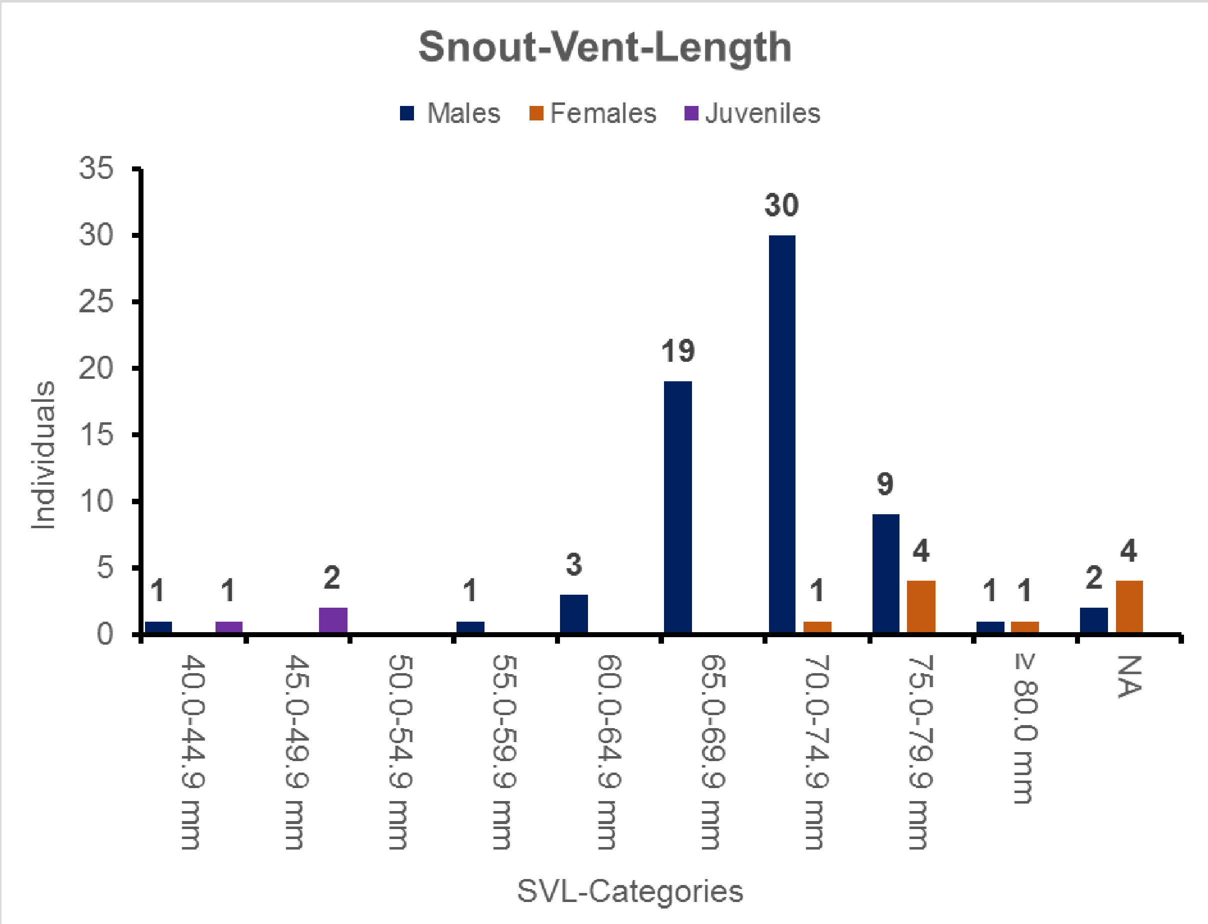

Figure 5: Size distribution of the captured toads in different categories divided by the sex. Individuals categorized as NA were not measured because they were engaged in Amplexus.

The BM of the males ranged from under 20.0 g to over ≥ 65.0 g, most of them weighed more than 30.0 g. Few captures were lighter than 30.0 g, but some males weighed 55.0 g or more. The BM of the females ranged from 40.0 g, to over 65.0 g, most of them weighed more than 40.0 g. The juveniles all weighed under 20 g. For the males (n = 66) the average BM was 40.30 g (standard-deviation of 7.4), for the females (n = 10) 51.05 g (standard-deviation of 10.8) and for the juveniles (n = 3) 10.08 g (standard-deviation of 1.1) (Tab. 2). Individuals, which were captured multiple times, had their mean values calculated and were assigned to the respective categories. Outlier values were not included in the analysis (Fig. 6).

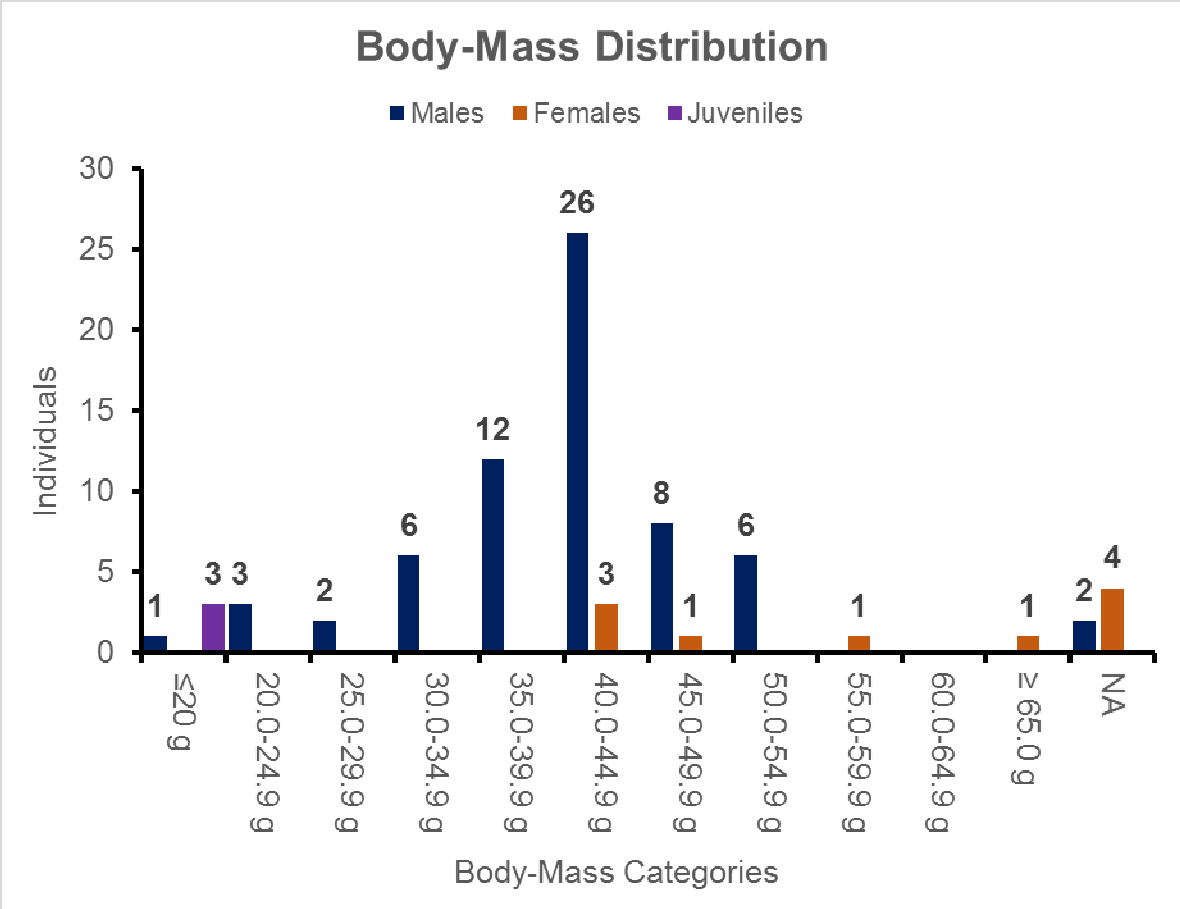

Figure 6: Body-mass distribution of the captured toads in several categories divided by the sex. Individuals categorized as NA have were not weighed because they were engaged in Amplexus.

The Fulton-Index was visualized using scatter plots for the females and juveniles (Fig. 7) and for the males (Fig. 8). If an individual was captured multiple times the Fulton-Index was calculated for each event separately. For the males (n = 66) the average Fulton-Index was 12.18 (standard-deviation of 2.8), for the females (n = 10) 8.61 (standard-deviation of 1.2) and for the juveniles (n = 3) 10.88 (standard-deviation of 0.99) (Tab. 3). Individuals whose condition could not be calculated are not included in the scatter plots. Outlier values were not included in the analysis. The abbreviation BV_DF_000x is *Bufotes viridis* (BV), Donaufeld (DF) and the correlated capture number.

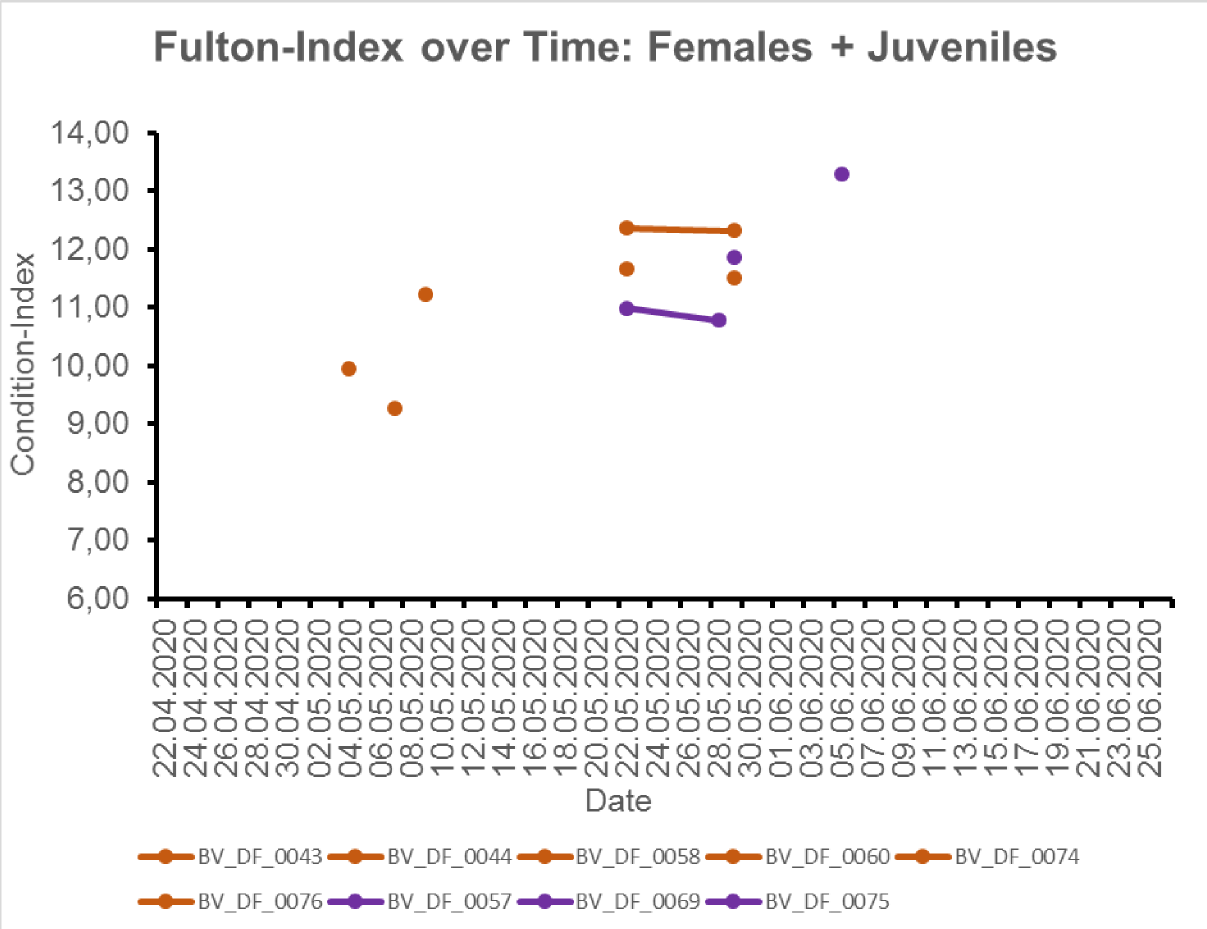

Figure 7: Fulton Index for each female (brown) and juvenile Individual (purple) per occasion. The lines show how the condition changed over the course of the field trips. Single dots show individuals that have been caught only once.

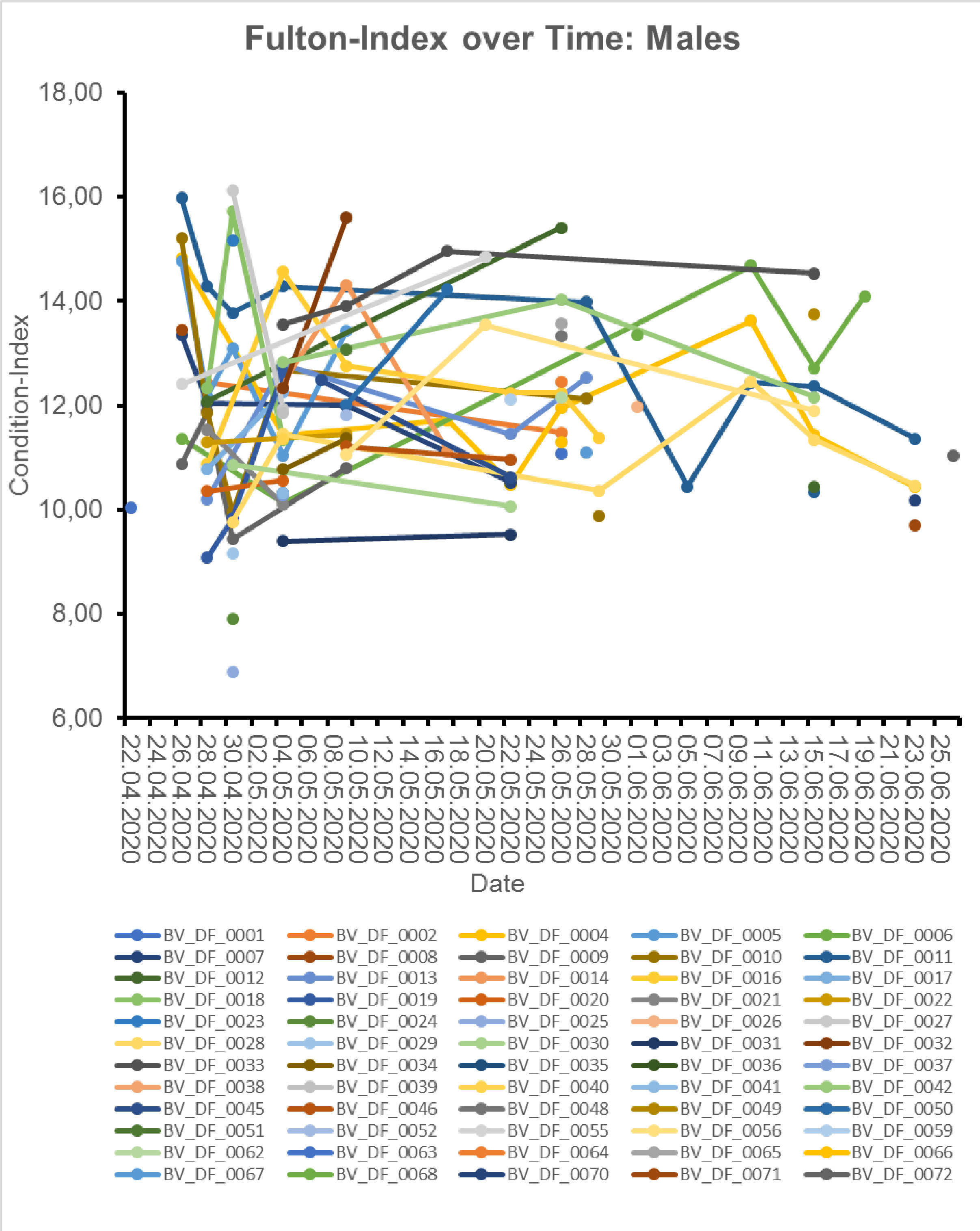

Figure 8: Fulton Index for each male Individual per occasion. The lines show how the condition changed over the course of the field trips. Single dots show individuals that have been caught only once.

The best supported model included the non-linear time dependency “t” and showed the following parameters: p~t phi~1 b~1 superN~1. The Superpopulation size (SuperN), apparent survival (phi) and entry probability (b) were calculated as non-time varying, while the recapture probability (p) was calculated as time varying. The estimated population-size was 113 individuals with a confidence interval reaching from 86 (lower confidence interval: lcl) to 144 (upper confidence interval: ucl). This model was chosen, because it has the best ranked AICc value without causing an error massage. Furthermore, it calculates on of the best potential predictions of the population-size was well as supporting my findings in the field. Other calculated models with better AICc values were discarded due to error massages while running.

Observations regarding the metamorphosis: From the beginning of May 2020 to the middle of June 2020, tadpoles of various amounts and different stages of development were observed. On May 5th, 2020 I documented the first big accumulation of young tadpoles (Fig. 9). At the beginning of June 2020, I recorded well developed tadpoles (Fig. 10). The first metamorphlings were recorded on June 15th, 2020, coming from the breeding-pond (Fig. 11).

Figure 9: High number of young tadpoles on May 5th, 2020.

Figure 10: Well developed tadpoles on June 1st, 2020.

Figure 11: Metamorphlings coming from the breeding-pond on June 15th, 2020.

Furthermore, a mismatch-mating between a female Common Toad (*Bufo bufo*) and a male European Green Toad was observed. This rare event was encountered on April 30th, 2020 (Fig. 12). Additionally, an amplexus between two Common Toads was encountered, close where the mismatch-mating (Fig. 13) was observed. All recorded captures of common toads are listed below (Tab. 4).

Table 4: Summary of the data from the captured Common Toads.

Date	**time**	**Location**	**Body-Mass**	**SVL**	**Photo-number**	**Sex**	**Comment**
April 28th,2020 (Tuesday)	09:00pm	An der Schanze 23 (Brombeerland) on the street	42 g	72 mm	20200428_210220	M	*Bufo bufo* (Common Toad)
April 30th,2020 (Thursday)	09:29pm	Location 1	x	x	20200430_213045	M+F	Amplexus, Mismatch-Mating Female: *Bufo bufo* Male: *Bufotes viridis*
April 30th,2020 (Thursday)	09:32pm	Location 1	x	x	20200430_213245	M+F	Amplexus, both Common Toads

Figure 12: Mismatch-mating of a female Common Toad and a male Green Toad.

Figure 13: Amplexus between two Common Toads.

Discussion

The population size of the European Green Toad in the Donaufeld has been surveyed for the first time and my results show a population of at least 86 individuals. The population assessment based on capture-recapture, provided an estimate of 113 toads (confidence interval of 86-148). This represents a population in excellent condition (Schnitter et al., 2006). In Vienna a population with more than 100 individuals is considered as large (Staufer, 2018).

The 76 adult individuals show a large majority of males (n = 66) with 86.8%, the females (n = 10) with only 13.2%, the corresponding sex ratio is 6.6:1. The overabundance of males could be explained, that they stay at the spawning-waters the whole breeding-season, while females only come to the spawning-waters to lay their eggs and emigrate immediately afterwards (Sinsch et al., 2008). The males and females reach sexual maturity after 2 respectively 3 years, this may result in a season with a male overabundance (Sinsch et al., 2008). Furthermore, as soon as the males arrive at the breeding-waters they begin emitting their distinctive mating call and release-calls, making them easier to detect (Sinsch et al., 2008).

The analysis of the Fulton-Index showed no clear trends, some individuals started with a better condition and others were in markedly lower condition. The condition of the males fluctuates noticeably. The average condition of the females was markedly poorer, this could indicate that the females have recently spawned (Mazgajska & Mazgajski, 2020). To assess the condition of the individuals in the Donaufeld, long term observations will be needed, for now the overall condition cannot be clearly determined.

The main activity lasted from early May to the beginning of June with peaks on May 4th (n = 30) and May 9th (n = 26), 2020. On these days exclusively I captured a total of 56 individuals. On June 15th was another peak of 10 individuals, after this occasion, I made very few additional captures. The last toad was captured on June 26th, 2020. After that I encountered no more adult toads. This may indicate that the breeding season in the Donaufeld ends relatively abruptly and that the toads are coming in groups. A study of Sinsch, (1988) concerning the movement behavior during the breeding-season of male Natterjack Toads (*Bufo calamita*) showed a similar pattern, the males arrived in groups at the spawning-waters resulting in different calling periods (April-May; May-July) (Sinsch, 1988). An overlap of emigrat-

ing and immigrating toads might have caused the high abundance at the mentioned occasions. In the Donaufeld however no clear groups of males were distinguishable, several males were documented calling over a longer time period.
Additionally, I was able to document reproductive success from early stages of tadpoles to newly metamorphized toadlets. On multiple occasions (e.g. April 28th, April 30th, May 9th and May 26th, 2020) I was able to document a successful amplexus, further emphasizing the reproductive success of the local population.
I observed syntopy between the European Green Toad and the Common Toad. On April 28th, 2020 I found a solitary male Common Toad, two days later I documented a successful amplexus between Common Toads. For this location syntopy between *B. viridis* and *B. bufo* represents a novelty.
On April 30th, 2020 I witnessed a mismatch mating between a male Green Toad and a female Common Toad. Hybridization events are rare due to *B. bufo* being an explosive breeder early in the year and *B. viridis* being a prolonged breeder later in the year (Canestrelli et al., 2017). Furthermore, in syntopic areas the breeding activity is usually reported as asynchronous due to delayed breeding periods (Canestrelli et al., 2017). Hybridization events are rare since there are very little documented cases but the estimated number of unreported or undetected cases remains unknown (Canestrelli et al., 2017).
Looking at the data (Heyer & Wappl, 2016) gathered at the Rudolf-Bednar-Park and its surrounding areas in Vienna (Austria) the following comparisons can be made. The average SVL in 2016 for males (n = 80) was 64.92 mm and 68.83 mm for females (n = 31). In the Donaufeld the average SVL for males was 69.80 mm and 77.16 mm for females. At the Rudolf-Bednar-Park in 2016 the average body-mass for the males was 29.81 g and 37.31 g for the females (Heyer & Wappl, 2016). Compared to the Donaufeld the average body-mass for males was 40.30 g and 51.05 g for females. When looking at the Fulton-Index from (Heyer & Wappl, 2016) calculated in 2016 the following observations are made. The average Fulton-Index for males was 10.78 and 11.12 for females. In the Donaufeld the average Fulton-Index was 12.18 for males and 8.61 for females. Both males and females were markedly larger and heavier in the Donaufeld, this might indicate that the individuals are older since there is a positive correlation between age, SVL and body-mass (Kutrup et al., 2011). The Fulton-Index for males was higher in the Donaufeld but the females were in markedly poorer condition. Females in bad condi-

tion show a smaller reproductive effort and store less resources for growth, survival and future reproduction (Castellano et al., 2004).

Conclusion

The size of the population in the Donaufeld was bigger than anticipated. Compared to other populations the male toads were in good condition, the condition of the females was markedly poorer. The individuals in the Donaufeld were slightly larger and heavier than those at the Rudolf-Bednar-Park. The observation of different stages of tadpole development with young toads emerging from the spawning-waters, demonstrated reproductive success. The observed mismatch-mating between the Green Toad and Common Toad may indicate a delayed breeding period of *B. bufo*.

Outlook

Due to imminent construction work in the Donaufeld, it remains uncertain what will become of the population. The main breeding-grounds will soon be removed and the potentially hibernating toads in the large deadwood-pile behind Location 1 are endangered. To prevent a major loss of the population this deadwood-pile must be removed gently under supervision of experts and authorities. The surviving toads could be resettled to an adequate habitat, ideally in the vicinity of Vienna.

Therefore, further monitoring is recommended to document potential new individuals and in the best scenario a stable population, but this seems unlikely given the current circumstances.

References (Literature)

Anderson, D. R., Burnham, K. P. Understanding information criteria for selection among capture-recapture or ring recovery models. *Bird Study* **46**, S14–S21 (1999).

Băncilă, R. I., Hartel, T., Plăiaşu, R., Smets, J., Cogălniceanu, D. Comparing three body condition indices in amphibians: A case study of yellow-bellied toad *Bombina variegata*. *Amphibia-Reptilia* **31**, 558–562 (2010).

Canestrelli, D., Bisconti, R., Chiocchio, A., Maiorano, L., Zampiglia, M., Nascetti G. Climate change promotes hybridisation between deeply divergent species. PeerJ 5:e3072 (2017).

Castellano, S., Cucco, M., Giacoma, C. Reproductive investment of female green toads (*Bufo viridis*). *Copeia* 659–664 (2004).

Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora *OJ L 206, 22.7.1992, p. 7–50*

Crall, J. P., Stewart, C. V., Berger-Wolf, T. Y., Rubenstein, D. I., Sundaresan, S. R. HotSpotter-Patterned species instance recognition. in *Proceedings of IEEE Workshop on Applications of Computer Vision* 230–237 (2013).

Csarmann, E. Expertise zur Situation der Wechselkröte (*Bufo viridis*) am Nordbahnhofgelände in Wien – Natur und Naturschutz - Studien der Wiener Umweltschutzabteilung (MA 22) – 123: 1-18 (2012).

Csarmann, E., Ruzek, S., Waringer-Löschenkohl, A. Wechselkröten (*Bufo viridis*) in den Randgebieten von Wien. Im Auftrag der Magistratsabteilung 22 – Umweltschutz, Wien 2010 (2010).

Efford, M. G. openCR: Open population capture-recapture models. R package version 1.4.4. https://CRAN.R-project.org/package=openCR/ (2020).

Gollmann, G. Rote Liste der in Österreich gefährdeten Lurche (Amphibia) und Kriechtiere (Reptilia). In K. P. Zulka (Ed.), Rote Listen gefährdeter Tiere Österreichs, Teil 2: Kriechtiere, Lurche, Fische, Nachtfalter, Weichtiere. Wien: Böhlau (2007).

Iijima, H. A Review of Wildlife Abundance Estimation Models: Comparison of Models for Correct Application. *Mammal Study* **45**, 177–188 (2020).

Hayes, T. B., Falso, P., Gallipeau, S., Stice, M. The cause of global amphibian declines: A developmental endocrinologist's perspective. *Journal of Experimental Biology* **213**, 921–933 (2010).

Heyer, E., Wappl, C. Big City Life: Investigating the population of European green toads (*Bufotes viridis*) at the Rudolf-Bednar-Park (Vienna, Austria). Bericht des Projektpraktikums "Populationsbiologie heimischer Amphibien" (2016). https://www.wien.gv.at/umweltschutz/nachhaltigkeit/pdf/wappl-heyer-2016.pdf (last accessed February 20th, 2021, 8:40 pm)

https://stadtplanwien360.at/karte-bezirke-wien (last accessed February 20th, 2021, 8:30 pm) (modified)

Kovar, R., Brabec, M., Vita, R., Bocek, R. Spring migration distances of some central European amphibian species. *Amphibia Reptilia* **30**, 367–378 (2009).

Kutrup, B., Cakir, E., Colak, Z., Bulbul, U., Karaoglu, H. Age and growth of the green Toad, *Bufo viridis* (Laurenti, 1768) from an Island and a mainland population in Giresun, Turkey. *Journal of Animal and Veterinary Advances.* **10**, 1469–1472 (2011).

Kuzmin, S. L., Bobrov, V. V. & Dunaev, E. A. Amphibians of Moscow Province: distribution, ecology, and conservation. *Zeitschrift für Feldherpetologie* **3**, 19–72 (1996).

Mallet, J. Hybridization as an invasion of the genome. *Trends in Ecology and Evolution* **20**, 229–237 (2005).

Maxson, L. R. Albumin Evolution and Its Phylogenetic Implications in African Toads of the Genus Bufo. *Herpetologica* **37**, 96–104 (1981).

Mazgajska, J. Distribution of amphibians in urban water bodies (Warsaw agglomeration, Poland). *Ekologia Polska* **44**, 245–257 (1996).

Mazgajska, J., Mazgajski, T. D. Two amphibian species in the urban environment: changes in the occurrence, spawning phenology and adult condition of common and green toads. *European Zoological Journal* **87**, 170–179 (2020).

Patel, N. G., Das, A. Shot the spots: A reliable field method for individual identification of *Amolops formosus* (Anura, Ranidae). *Herpetozoa* **33**, 7–15 (2020).

R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/ (2020).

RStudio Team. RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/ (2020).

Schnitter, P., Eichen, C., Ellwander, G., Neukirchen, M., Schröder, E. Empfehlungen für die Erfassung und Bewertung von Arten als Basis für das Monitoring nach Artikel 11 und 17 der FFH-Richtlinie in Deutschland: - Berichte des Landesamtes für Umweltschutz Sachsen-Anhalt, Sonderheft 2. *Berichte des Landesamtes für Umweltschutz Sachsen-Anhalt* 3–4 (2006).

Schwenk, K., Brede, N., Streit, B. Introduction. Extent, processes and evolutionary impact of interspecific hybridization in animals. *Philosophical Transactions of the Royal Society B: Biological Sciences* **363**, 2805–2811 (2008).

Sinsch, U. Temporal spacing of breeding activity in the natterjack toad, *Bufo calamita*. *Oecologia* **76**, 399–407 (1988).

Sinsch, U., Schneider, H. Tarkhnishvili, D. N. *Bufo bufo* Superspezies – Erdkröten-Artenkreis, pp. 191-337. In: Grossenbacher, K. (ed): Handbuch der Reptilien und Amphibien Europas, Band 5/1 Anuren (2008).

Staufer, M. Schutzkonzept für die Wechselkröte (*Bufotes viridis*) in den Gemüseanbaugebieten der Simmeringer Haide, Wien – Grundlagenerhebungen und Maßnahmenvorschläge. – Unveröffentlichter Bericht im Auftrag der Wiener Umweltschutzabteilung – MA 22, Wien (2018).

Stöck, M., Roth, P., Podloucky, R., Grossenbacher, K. Wechselkröten unter Berücksichtigung von *Bufo viridis viridis* Laurenti, 1768; *Bufo variabilis* (Pallas, 1769); *Bufo boulengeri* Lataste, 1879; *Bufo balearicus* Böttger, 1880 und *Bufo siculus* Stöck, Sicilia, Belfiore, Lo Brutto, Lo Valvo und Arcuelo, 2008. In *Handbuch der Reptilien und Amphibien Europas, Band 5/II. Froschluche I* 413–498 (2008).

Tiedemann, F., Häupl, M. Rote Liste der in Österreich gefährdeten Kriechtiere (Reptilia) und Lurche (Amphibia). In J. Gepp (Ed.), Rote Liste gefährdeter Tiere Österreichs (Vol. 2, pp. 67-74). Graz: Styria Verlag (1994).

Widemann, B. T. Y., Bolz, C. F., Grelck, C. The functional programming language R and the paradigm of dynamic scientific programming (Position paper) (2013).

Appendix

Figure A1: Roped-Off pond (Location 1), found coming from the street “An der Schanze”.

Figure A2: Location 1 seen from a distance when standing on the street “An der Schanze”.

Figure A3: Artificially created pond (Location 2), found coming from the street “Nordmanngasse” when walking along an abandoned greenhouse (to the right) and a corn field (to the left).

Figure A4: Path to the artificially created pond (Location 2), viewed from the street “Nordmanngasse”.

Figure A5: Metamorphling (juvenile) compared to a 2-Euro Coin.

Table 1: Overview of the SVL for every Individual. The abbreviation for the letter "**M**" is "measurement" and represents an occasion where the individual was examined. Each measurement was taken in millimeters (mm) as well as the mean-value. Individuals that could not be measured are shown as "not available" (NA). A measurement was considered an outlier if it undershot or exceeded two times the standard-deviation calculated from the mean value. These values were marked with a star-symbol (*). The abbreviation BV_DF_000x is *Bufotes viridis* (BV), Donaufeld (DF) and the correlated capture number.

Individual	M1	M2	M3	M4	M5	M 6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0001	75									75	0,00
BV_DF_0002	68	71								69,5	1,50
BV_DF_0003	42									42	0,00
BV_DF_0004	77 (*)	73	74	76	72	70	74	76		74,1	1,99
BV_DF_0005	68	68	62	65	65					65,6	2,24
BV_DF_0006	72	73	66	71	65					69,5	3,26
BV_DF_0007	64	63	67	68						65,5	2,06
BV_DF_0008	71									71	0,00
BV_DF_0009	78	74	76	76						76	1,41
BV_DF_0010	66	70	69	71	73					69,8	2,32
BV_DF_0011	65	63	72	72	73	79	77	77	78	72,9	5,36
BV_DF_0012	69	64								66,5	2,50
BV_DF_0013	78	71	75	73						74,3	2,59
BV_DF_0014	73	69	75							72,3	2,49
BV_DF_0015	NA									NA	NA
BV_DF_0016	73	67	68	71	71	72				70,3	2,13
BV_DF_0017	73	73								73	0,00
BV_DF_0018	73	61	72							68,7	5,44
BV_DF_0019	73	69	70							70,7	1,70
BV_DF_0020	70	69								69,5	0,50
BV_DF_0021	55	57								56	1,00
BV_DF_0022	74	71								72,5	1,50
BV_DF_0023	63									63	0,00
BV_DF_0024	72									72	0,00
BV_DF_0025	67									67	0,00
BV_DF_0026	70									70	0,00
BV_DF_0027	54	66								60	6,00
BV_DF_0028	70	75 (*)	68	70	62 (*)	70	71			69,4	0,98

Individual	M1	M2	M3	M4	M5	M 6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0029	71									71	0,00
BV_DF_0030	62	70								66	4,00
BV_DF_0031	71	74								72,5	1,50
BV_DF_0032	67	62								64,5	2,50
BV_DF_0033	68	66	65	64						65,8	1,48
BV_DF_0034	69	67								68	1,00
BV_DF_0035	70									70	0,00
BV_DF_0036	73									73	0,00
BV_DF_0037	80									80	0,00
BV_DF_0038	73									73	0,00
BV_DF_0039	68									68	0,00
BV_DF_0040	73									73	0,00
BV_DF_0041	74									74	0,00
BV_DF_0042	70	68	72							70	1,63
BV_DF_0043	76									76	0,00
BV_DF_0044	78									78	0,00
BV_DF_0045	75	75								75	0,00
BV_DF_0046	65	65								65	0,00
BV_DF_0047	NA									NA	NA
BV_DF_0048	69									69	0,00
BV_DF_0049	72									72	0,00
BV_DF_0050	72	70								71	1,00
BV_DF_0051	68									68	0,00
BV_DF_0052	66									66	0,00
BV_DF_0053	NA									NA	NA
BV_DF_0054	NA									NA	NA
BV_DF_0055	64	66								65	1,00
BV_DF_0056	72	68	71							70,3	1,70
BV_DF_0057	46	47								46,5	0,50
BV_DF_0058	71									71	0,00
BV_DF_0059	69									69	0,00
BV_DF_0060	78	74								76	2,00
BV_DF_0061	NA									NA	NA
BV_DF_0062	75									75	0,00
BV_DF_0063	73									73	0,00
BV_DF_0064	74									74	0,00
BV_DF_0065	69									69	0,00
BV_DF_0066	77									77	0,00
BV_DF_0067	71									71	0,00

Individual	M1	M2	M3	M4	M5	M 6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0068	68									68	0,00
BV_DF_0069	40									40	0,00
BV_DF_0070	76									76	0,00
BV_DF_0071	75									75	0,00
BV_DF_0072	71									71	0,00
BV_DF_0073	63									63	0,00
BV_DF_0074	86									86	0,00
BV_DF_0075	45									45	0,00
BV_DF_0076	76									76	0,00
BV_DF_0077	75									75	0,00
BV_DF_0078	75									75	0,00
BV_DF_0079	NA									NA	NA

Table 2: Overview of each weighed Individual. The abbreviation for the letter "**M**" is "measurement" and represents an occasion where the individual was examined. Each measurement was taken in grams (g) as well as the mean-value. Individuals that could not be weighed are shown as "not available" (NA). A measurement was considered an outlier if it undershot or exceeded two times the standard-deviation calculated from the mean value. These values were marked with a star-symbol (*). The abbreviation BV_DF_000x is *Bufotes viridis* (BV), Donaufeld (DF) and the correlated capture number.

Individual	M1	M2	M3	M4	M5	M6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0001	41,5									41,50	0,00
BV_DF_0002	39,1	41,1								40,10	1,00
BV_DF_0003	21,4									21,40	0,00
BV_DF_0004	67,7 (*)	45,4	47,5	46	44,6	46,7	46,3	45,8		48,75	7,20
BV_DF_0005	46,4	38,3	31,2	30,3	36,9					36,62	5,80
BV_DF_0006	42,4	39,9	42,2	45,5	38,7					41,74	2,30
BV_DF_0007	35	30,1	36,1	33,1						33,57	2,30
BV_DF_0008	48,1									48,10	0,00
BV_DF_0009	51,6	48,2	41,4	47,4						47,15	3,70
BV_DF_0010	44,5	40,7	32,7	45,4	47,2					42,10	5,20
BV_DF_0011	43,9	35,7 (*)	51,4	53,3	54,4	51,5	56,8	56,5	53,9	50,82	6,40
BV_DF_0012	39,7	40,4								40,05	0,30
BV_DF_0013	47,5	45,7	48,3	48,8						47,57	1,20
BV_DF_0014	48,4	47	46,9							47,43	0,70
BV_DF_0015	NA									NA	NA
BV_DF_0016	42,3	43,8	40,1	43,8	43,8	42,5				42,71	1,30
BV_DF_0017	41,6	46,7								44,15	2,60
BV_DF_0018	48	35,7	42,3							42,00	5,00
BV_DF_0019	35,3	32,3	43,4							37,00	4,70
BV_DF_0020	35,5	34,7								35,10	0,40
BV_DF_0021	19,2	18,7								18,95	0,30
BV_DF_0022	46,5	41								43,75	2,80
BV_DF_0023	37,9									37,90	0,00
BV_DF_0024	29,5									29,50	0,00
BV_DF_0025	20,7									20,70	0,00
BV_DF_0026	41,1									41,10	0,00
BV_DF_0027	25,4	34,3								29,85	4,40
BV_DF_0028	33,5	48,3 (*)	39,2	38,9	38	35,9	36,3			38,58	4,40
BV_DF_0029	32,8									32,80	0,00
BV_DF_0030	25,9	34,5								30,20	4,30

Individual	M1	M2	M3	M4	M5	M6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0031	33,6	38,6								36,10	2,50
BV_DF_0032	37,1	37,2								37,15	0,10
BV_DF_0033	42,6	40	41,1	38,1						40,45	1,60
BV_DF_0034	35,4	34,2								34,80	0,60
BV_DF_0035	35,4									35,40	0,00
BV_DF_0036	43,6									43,60	0,00
BV_DF_0037	52,6									52,60	0,00
BV_DF_0038	45,9									45,90	0,00
BV_DF_0039	37,3									37,30	0,00
BV_DF_0040	44,2									44,20	0,00
BV_DF_0041	41,8									41,80	0,00
BV_DF_0042	44	44,1	45,4							44,50	0,60
BV_DF_0043	43,7									43,70	0,00
BV_DF_0044	44									44,00	0,00
BV_DF_0045	52,7	44,8								48,75	4,00
BV_DF_0046	30,8	30,1								30,45	0,40
BV_DF_0047	NA									NA	NA
BV_DF_0048	43,8									43,80	0,00
BV_DF_0049	51,3									51,30	0,00
BV_DF_0050	44,9	44,8								44,85	0,10
BV_DF_0051	41,1									41,10	0,00
BV_DF_0052	34									34,00	0,00
BV_DF_0053	NA									NA	NA
BV_DF_0054	NA									NA	NA
BV_DF_0055	38,9	35,7								37,30	1,60
BV_DF_0056	41,3	42,6	42,6							42,16	0,60
BV_DF_0057	10,7	11,2								10,95	0,30
BV_DF_0058	41,8									41,80	0,00
BV_DF_0059	39,8									39,80	0,00
BV_DF_0060	58,7	49,9								54,30	4,40
BV_DF_0061	NA									NA	NA
BV_DF_0062	51,3									51,30	0,00
BV_DF_0063	43,1									43,10	0,00
BV_DF_0064	50,5									50,50	0,00
BV_DF_0065	44,6									44,60	0,00
BV_DF_0066	51,6									51,60	0,00
BV_DF_0067	45									45,00	0,00
BV_DF_0068	42									42,00	0,00
BV_DF_0069	8,5									8,50	0,00
BV_DF_0070	44,7									44,70	0,00
BV_DF_0071	40,9									40,90	0,00

Individual	M1	M2	M3	M4	M5	M6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0072	39,5									39,50	0,00
BV_DF_0073	24,7									24,70	0,00
BV_DF_0074	73,2									73,20	0,00
BV_DF_0075	10,8									10,80	0,00
BV_DF_0076	49,3									49,30	0,00
BV_DF_0077	43,6									43,60	0,00
BV_DF_0078	44									44,00	0,00
BV_DF_0079	NA									NA	NA

Table 3: Overview of the Fulton-Index calculated for each examined Individual. The abbreviation for the letter “**M**” is “measurement” and represents an occasion where the individual was examined. The Fulton-Index was calculated correct to two decimal places, as well as the mean-value. Individuals whose condition could not be calculated are shown as “not available” (NA). A measurement was considered an outlier if it undershot or exceeded two times the standard-deviation calculated from the mean value. These values were marked with a star-symbol (*). The abbreviation BV_DF_000x is *Bufotes viridis* (BV), Donaufeld (DF) and the correlated capture number.

Individual	M1	M2	M3	M4	M5	M6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0001	10,04									10,04	0
BV_DF_0002	12,44	11,48								11,96	0,48
BV_DF_0003	28,88 (*)									28,88	0
BV_DF_0004	14,83 (*)	11,43	11,72	10,48	11,95	13,62	11,43	10,43		11,99	0,99
BV_DF_0005	14,76	12,18	13,09	11,03	13,43					12,89	1,25
BV_DF_0006	11,36	10,13	14,68	12,71	14,09					12,59	1,69
BV_DF_0007	13,35	12,04	12,00	10,52						11,98	1
BV_DF_0008	13,44									13,44	0
BV_DF_0009	10,87	11,89	9,43	10,80						10,75	0,87
BV_DF_0010	15,20	11,86	9,95	12,68	12,13					12,36	1,69
BV_DF_0011	15,98	14,28	13,77	14,28	13,98	10,44	12,44	12,37	11,36	13,21	1,61
BV_DF_0012	12,08	15,41								13,74	1,66
BV_DF_0013	10,20	12,77	11,45	12,54						11,74	1,02
BV_DF_0014	12,44	14,31	11,12							12,62	1,31
BV_DF_0015	NA									NA	NA
BV_DF_0016	10,87	14,56	12,75	12,24	12,24	11,38				12,34	1,17
BV_DF_0017	10,78	12,25								11,51	0,74
BV_DF_0018	12,34	15,72	11,33							13,13	1,88
BV_DF_0019	9,07	9,83	12,65							10,52	1,54
BV_DF_0020	10,35	10,56								10,45	0,11
BV_DF_0021	11,54	10,09								10,81	0,73
BV_DF_0022	11,29	11,45								11,37	0,08
BV_DF_0023	15,16									15,16	0
BV_DF_0024	7,90									7,90	0
BV_DF_0025	6,88									6,88	0
BV_DF_0026	11,98									11,98	0
BV_DF_0027	16,13	11,93								14,03	2,1
BV_DF_0028	9,76	11,45	12,46	11,34	15,94 (*)	10,46	10,36			11,68	0,88

Individual	M1	M2	M3	M4	M5	M6	M7	M8	M9	Mean Value	Standard Devia-tion
BV_DF_0029	9,16									9,16	0
BV_DF_0030	10,86	10,06								10,46	0,4
BV_DF_0031	9,39	9,52								9,45	0,06
BV_DF_0032	12,33	15,61								13,97	1,64
BV_DF_0033	13,55	13,91	14,96	14,53						14,24	0,54
BV_DF_0034	10,77	11,37								11,07	0,3
BV_DF_0035	10,32									10,32	0
BV_DF_0036	11,20									11,20	0
BV_DF_0037	10,27									10,27	0
BV_DF_0038	11,80									11,80	0
BV_DF_0039	11,86									11,86	0
BV_DF_0040	11,36									11,36	0
BV_DF_0041	10,31									10,31	0
BV_DF_0042	12,82	14,02	12,16							13,00	0,77
BV_DF_0043	9,95									9,95	0
BV_DF_0044	9,27									9,27	0
BV_DF_0045	12,49	10,62								11,55	0,94
BV_DF_0046	11,21	10,96								11,08	0,13
BV_DF_0047	NA									NA	NA
BV_DF_0048	13,33									13,33	0
BV_DF_0049	13,74									13,74	0
BV_DF_0050	12,02	14,22								13,12	1,1
BV_DF_0051	13,07									13,07	0
BV_DF_0052	11,82									11,82	0
BV_DF_0053	NA									NA	NA
BV_DF_0054	NA									NA	NA
BV_DF_0055	14,84	12,41								13,62	1,22
BV_DF_0056	11,06	13,54	11,90							12,16	1,03
BV_DF_0057	10,99	10,78								10,88	0,11
BV_DF_0058	11,67									11,67	0
BV_DF_0059	12,11									12,11	0
BV_DF_0060	12,36	12,31								12,33	0,02
BV_DF_0061	NA									NA	NA
BV_DF_0062	12,16									12,16	0
BV_DF_0063	11,08									11,08	0
BV_DF_0064	12,46									12,46	0
BV_DF_0065	13,57									13,57	0
BV_DF_0066	11,30									11,30	0
BV_DF_0067	11,10									11,10	0
BV_DF_0068	13,35									13,35	0

Individual	M1	M2	M3	M4	M5	M6	M7	M8	M9	Mean Value	Standard Deviation
BV_DF_0069	13,28									13,28	0
BV_DF_0070	10,18									10,18	0
BV_DF_0071	9,69									9,69	0
BV_DF_0072	11,03									11,03	0
BV_DF_0073	9,87									9,87	0
BV_DF_0074	11,50									11,50	0
BV_DF_0075	11,85									11,85	0
BV_DF_0076	11,23									11,23	0
BV_DF_0077	10,33									10,33	0
BV_DF_0078	10,43									10,43	0
BV_DF_0079	NA									NA	NA

Zusammenfassung

Die Wechselkröte, *Bufotes viridis* (Laurenti, 1768) ist eine bedrohte Art, in Österreich gilt sie als gefährdet und in Wien als stark gefährdet. Ziel dieser Fang-Wiederfang-Studie war es, den Status und die Größe der Population von *B. viridis* im Donaufeld (Wien, Österreich) zu erfassen. Im Rahmen dieser Studie wurden 79 Individuen (66 Männchen, 10 Weibchen, 3 Jungtiere) gefangen. Bei jeder Begehung wurde die Körper-Masse, die Kopf-Rumpf-Länge und das Geschlecht der gefangenen Kröten notiert. Zusätzlich wurde ein Foto des einzigartigen Rückenmusters von jedem gefangenen Individuum gemacht. Zur Beurteilung des körperlichen Zustands der Kröten wurde der Fulton-Index berechnet, separat für jede Begehung. Zur Identifizierung der Individuen wurde das Programm HotSpotter verwendet, eine Bilderkennungssoftware. Für die Populationsabschätzung wurde ein Fang-Wiederfang-Modell in R, unter der Verwendung von Jolly-Seber-Schwarz-Arnason (JSSA) Modellen erstellt, wobei das Paket openCR verwendet wurde. Die geschätzte Populationsgröße ergab 113 Individuen mit einem Konfidenzintervall, welches von 86 bis 144 reicht.

Weiters wurde die Entwicklung von Kaulquappen zu Jungkröten (Metamorphlingen) am identifizierten Laichplatz nachgewiesen, dies dokumentiert den Fortpflanzungserfolg.

Zusätzlich wurde eine Syntopie der Wechselkröte und der Erdkröte (*Bufo bufo*) beobachtet, sogar eine seltene Fehlpaarung zwischen den beiden Arten.