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Habitat preferences of Little Bitterns *Ixobrychus minutus* breeding in wetlands embedded in an urban habitat matrix: a case study from Vienna, Austria

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Abstract

The Little Bittern *Ixobrychus minutus* is an endangered species with priority conservation status at a European level. The causative factors threatening the species are predominantly of anthropogenic nature, including habitat fragmentation and destruction, as well as disturbance through human recreational activities. Therefore, the Little Bittern population in and around the city of Vienna is remarkable in two respects: (1) many breeding pairs occupy territories located in areas of relatively high anthropogenic disturbance; (2) many breeding sites are situated at isolated and very small water bodies. To shed light on this apparent contradiction, the current study investigated the habitat requirements of Little Bitterns in the state of Vienna. To measure habitat suitability, the study first compares the characteristics of occupied vs. unoccupied water bodies in 2006. Secondly, the study compares 2006 data with previously published records in order to analyse continuity of occupancy as a measure of habitat quality. Results show that even water bodies with small reed bed areas (0.07 ha) are occasionally used by the Little Bittern as a breeding habitat in Vienna. However, the probability of colonisation and the number of territories rise with increasing reed bed area: For a reed bed area in Vienna to have a 50% chance of attracting Little Bitterns to breed, it must be no smaller than 0.65 ha. The degree of isolation of water bodies from water bodies with Little Bittern occurrence did not significantly influence their likelihood of colonization. Similarly, human disturbance was not found to have any detectable effect on the occurrence of Little Bitterns. The city of Vienna shows the largest known breeding population of Little Bittern in Austria. Therefore it is still essential to protect even small existing reed beds.

Keywords: Little Bittern, *Ixobrychus minutus*, habitat fragmentation, habitat isolation, habitat requirements, conservation, Vienna

Zusammenfassung

Die Zwergdommel *Ixobrychus minutus* ist eine europaweit gefährdete und prioritär geschützte Art. Die Gefährdungsfaktoren sind primär anthropogener Natur wie Lebensraumzerschneidung und –zerstörung sowie Störung durch Freizeitaktivitäten. Deshalb ist das Vorkommen der Zwergdommel im Wiener Stadtgebiet aus zweierlei Hinsicht bemerkenswert: (1.) Viele Brutpaare besetzen Territorien in Bereichen mit einem relativ hohen Grad an anthropogener Störung und (2.) bei vielen Gewässern handelt es sich um Bruthabitate, die hochgradig isoliert und sehr kleinräumig sind. Angesichts dieses scheinbaren Wiederspruchs soll die vorliegende Studie die Habitatansprüche der Zwergdommel in Wien untersuchen. Als Maß für die Eignung als Bruthabitat wurden zuerst die Eigenschaften von besiedelten zu nicht besiedelten Gewässern im Untersuchungsjahr 2006 verglichen. Weiters wurden die 2006 erhobenen Daten mit früher publizierten verglichen um die Kontinuität der Besetzung als Maß für die Habitateignung heranzuziehen. Die Ergebnisse zeigten, dass selbst Gewässer mit kleinen Schilfflächen (0,07 ha) gelegentlich von der Zwergdommel als Bruthabitat in Wien genutzt werden. Die Wahrscheinlichkeit der Besetzung und die Zahl der Territorien erhöhen sich jedoch mit steigender Gewässer- und Schilffläche. Für eine 50%ige Eignung eines Wiener Gewässers als Bruthabitat muss es eine Schilffläche von mindestens 0,65 ha aufweisen. Der Grad der Isolation eines Gewässers von Gewässern mit einem Vorkommen der Zwergdommel wirkte sich nicht auf die Wahrscheinlichkeit der Besiedlung aus. Genauso konnte kein signifikanter Einfluss anthropogener Störung auf das Vorkommen der Zwergdommel nachgewiesen werden. Da die Stadt Wien das größte bekannte Brutvorkommen der Zwergdommel in Österreich aufweist, ist der Schutz selbst kleiner vorhandener Schilfbestände von großer Bedeutung.

Introduction

The Little Bittern *Ixobrychus minutus* is an endangered species with priority conservation status at a European level. It breeds in one of the habitats most seriously threatened by human activities – wetlands (Millennium Ecosystem Assessment 2005). The European breeding populations suffered a large decline between 1970–1990. Although they appeared to be stable or even showed increasing numbers during 1990–2000 across much of the species' European range, they have not yet recovered to its former level (BirdLife International 2004). Threats include high mortality at stopover sites on migration and in wintering grounds in the Sahel due to severe draughts, as well as loss and deterioration of habitats driven by intensification of agriculture and other land uses (Bauer *et al.* 2006; BirdLife International 2010).

The most significant factors threatening populations of the Little Bittern in its breeding areas are loss of habitats through (1) destruction or deterioration of water bodies and riparian vegetation (including reed beds) as a consequence of construction activities, fishing, swimming etc., (2) intensive commercial use of water bodies such as frequent reed cutting and fish farming, (3) drying up of shallow water areas, for example through drainage, receding ground water levels or river regulation measures and (4) eutrophication leading to poor visibility through algal blooms, thereby decreasing access to prey, and changes in the food web (Bauer *et al.* 2006).

Large parts of the species' former distribution have been abandoned completely since the end of the 1960s. Since the 1990s, regional populations have stabilized at low levels or have increased slightly (BirdLife International 2004). In some areas, even more marked increases and recolonizations have been observed (Bauer *et al.* 2006). In Austria, Little Bittern populations are concentrated in two areas – Lake Neusiedl (60-120 territories in 2006; Dvorak 2009) and Vienna (ca. 38-60 breeding territories, Sabathy 1998; for current distribution see Wichmann *et al*. 2009). The Little Bittern population in the city of Vienna and its margins is remarkable in two respects: (1) many breeding pairs occupy territories located in areas of relatively high anthropogenic disturbance, and (2) many breeding sites are situated at isolated and very small water bodies (Sabathy 1998). In view of the endangered status of the Little Bittern in Europe and the anthropogenic nature of the causative factors, the Viennese population is therefore of particular interest.

For these reasons, this study investigated the habitat requirements of Little Bitterns in Vienna. To identify important habitat features, the study compares occupied vs. unoccupied water bodies in 2006. Subsequently, the breeding records from 2006 are compared with previous records published by Sabathy (1998) in order to analyse continuity of occupancy as a measure of habitat quality. In particular, we analysed effects of water body and reed bed size, water body isolation, water quality and human disturbance on the occurrence of the Little Bittern. In Vienna the Little Bittern occurs even at very small water bodies (minimum area: 0.3 ha) when at least some small reed beds (minimum area: 0.03 ha) are present (Sabathy 1998). We analysed how the likelihood of occurrence is affected by these water body parameters. Furthermore, colonization of water bodies may depend on their isolation from other suitable breeding sites. Also, human disturbance by anglers or through other recreational activities may decrease the quality of water bodies as breeding sites, although the species´ occurrence even at water bodies in densely populated areas of Vienna (Sabathy 1998) indicate that it appears to be rather robust against human disturbance. Finally water quality parameters (visibility through water and the content of phosphorus and chlorophyll-a) could influence the occurrence of the Little Bittern at water bodies in Vienna by influencing the prey density and/or availability. All these variables may affect habitat quality, thereby influencing the suitability of water bodies as breeding habitat and the temporal stability of colonization.

Methods

Study area

The study area comprises 59 water bodies within the borders of the state of Vienna. Sites were selected based on Sabathy’s (1998) Little Bittern survey in 1995-98. Only some of these water bodies located in the western part of Vienna (Wienflussstaubecken-West, Grünauer Teich and Wilhelminenberg / Teich Nord) were not studied due to time constraints. However, no definite records from the breeding season exist from one of these excluded sites (Sabathy 1998). The locations of the selected study sites are illustrated in Figure 1.

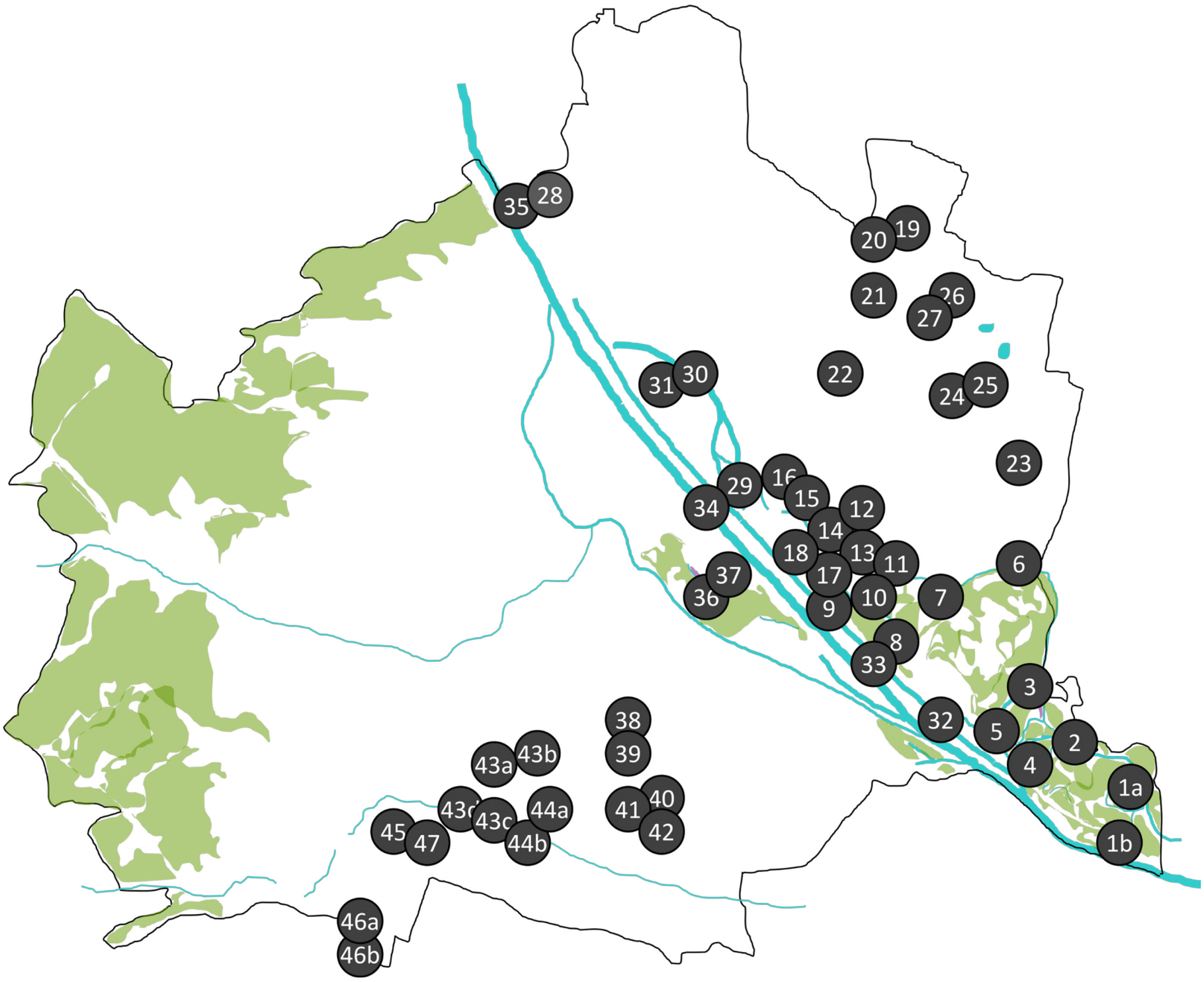


Figure 1. Location of study sites. Forest areas are marked green, water bodies are indicated blue. The bold blue line separating the territory of Vienna in a western and eastern part represents the Danube river. For site abbreviations see Appendix 1. Sometimes water bodies located closely to each other (with individual letter codes a, b etc.) are not indicated individually in the map (compare Appendix 1).

Survey of Little Bitterns

Little Bitterns were recorded according to the method described in Sabathy (1998) and the recommendations in Südbeck *et al.* (2005). Methods therefore consisted of recording calling males, sightings, foraging flights, and calls of juveniles. In order to ensure comparability with Sabathy's (1998) results, no nest searches were undertaken and no song playback was used. The standard observation period per site and visit was 10 min. Observations at larger water bodies took longer, as the observer walked all around the perimeter.

A total of 59 surveyed water bodies were visited between 19 April and 14 September 2006 (for detailed time survey schedule see Table 1). The majority of water bodies were visited between four and five times (34% and 63% of water bodies, respectively); and two sites (3%) were visited 3 times (Appendix 1). Dates of individual visits to study sites and individual Bittern records are listed in Appendix 1 and 2, respectively.

Table 1. Time schedule of the five survey periods in 2006.

Survey	**Period**
1	19 April – 9 May
2	10 May – 30 May
3	31 May – 28 June
4	29 June – 2 August
5	7 August – 14 September

The first visit of the selected wetlands was scheduled for the last 2 weeks of April in order to allow adequate recording of other water birds. While the earliest recorded arrival date of the Little Bittern in Vienna is 17 April (Sabathy 1998), the main breeding season does not start until mid-May. Therefore, individual birds observed in April or early May might be migrants on a stopover. Repeated visits to study sites until August were necessary to estimate the reproductive success of breeding pairs. Sabathy's (1998) earliest records of juvenile Little Bitterns date from late June.

Recorded habitat variables

In total 10 habitat parameters were measured, estimated or extracted from available sources as completely as possible (compare Appendix 2). The following six habitat parameters were measured for all study sites using digitized aerial photographs analysed with ArcView 3.3 (ESRI):
(1) Total area of reed beds (m^2)

(2) Area of the largest continuous reed bed patch (m^2).

(3) Shape of total reed bed area quantified as a ratio of its perimeter (m) and total area (m^2).

(4) Isolation of water body (m): Distance (shore to shore) to nearest water body with a Little Bittern record.

The extent of human disturbance was quantified as follows:

(5) Fishing allowed or prohibited.

(6) Swimming allowed or prohibited.

Finally, water quality parameters were extracted from the "Report on the water quality of standing water bodies in Vienna – sampling period 1993-2001" (Zoufal *et al.* 2002):

(7) Visibility through water [m]

(8) Total phosphorus [µg/l]

(9) Chlorophyll–a [µg/l]

Statistical analysis

Pearson correlations were used to test for multicollinearity of the parametric water body variables (1) total reed bed area, (2) area of largest connected reed bed, (3) reed bed shape, (4) water body isolation, (5) vertical visibility through water, (6) phosphorus content and (7) Chl-a content. For further analyses only variables were selected, which were not significantly related to each other (compare result section). Univariate logistic regression models were used to test for effects of the remaining habitat variables on the occurrence of Little Bitterns.

Fisher exact tests were calculated to test if the two categorical variables for human disturbance, bathing activities and fishing, affected the frequency of Bittern occurrence. To test if parametric variables which proved to significantly affect Bittern occurrence at water bodies differ between categories of non-parametric variables for human disturbance (bathing allowed of prohibited) a t-test was calculated.

Subsequently, we calculated Generalized Linear Models (GLMs) (with binomial error distribution and log-link function) including all selected habitat variables and all possible subsets to test for effects on Little Bittern occurrence. The resulting GLMs were ranked according to their AICc values. The GLMs calculated for all water bodies (N = 59) did not consider the variable vertical visibility through water because measurements were not available for all water bodies.

The GLMs calculated for all water bodies for which data on vertical visibility through water were available (N = 28) did not consider the variable fishing activities because visibility measurements were not available for water bodies where fishing activities are prohibited (only one exception).

To test if reed bed area and isolation of water bodies from other colonized water bodies differ between water bodies colonized only infrequently (only recorded during one survey period), regularly (recorded during two survey periods) or continuously by Little Bitterns, one-way ANOVAs were calculated. We further tested if colonization frequency of water bodies was affected by fishing activities or by swimming activities using Chi-square tests.

GLMs (with multinomial error distribution and log-link function) were used to evaluate effects of human disturbance (bathing waters vs. non-bathing waters) and total reed bed area on the stability of Little Bittern occurrence at water bodies (0 – no records, 1 – recorded in 1 year, 2 – recorded in >1 years). Again, resulting models were ranked according to their AIC values.

A Spearman rank correlation was calculated to test for a relationship between total reed bed area and the maximum number of territories recorded between 1995 and 2006.

We used t-tests to test for differences in maximum territory density between bathing and non-bathing waters and between fishing activity only considering colonized water bodies. Subsequently, a GLM with normal distribution error and log-link function was calculated to evaluate effects of the water body parameters reed bed area shape, fishing activity and bathing water on territory density.

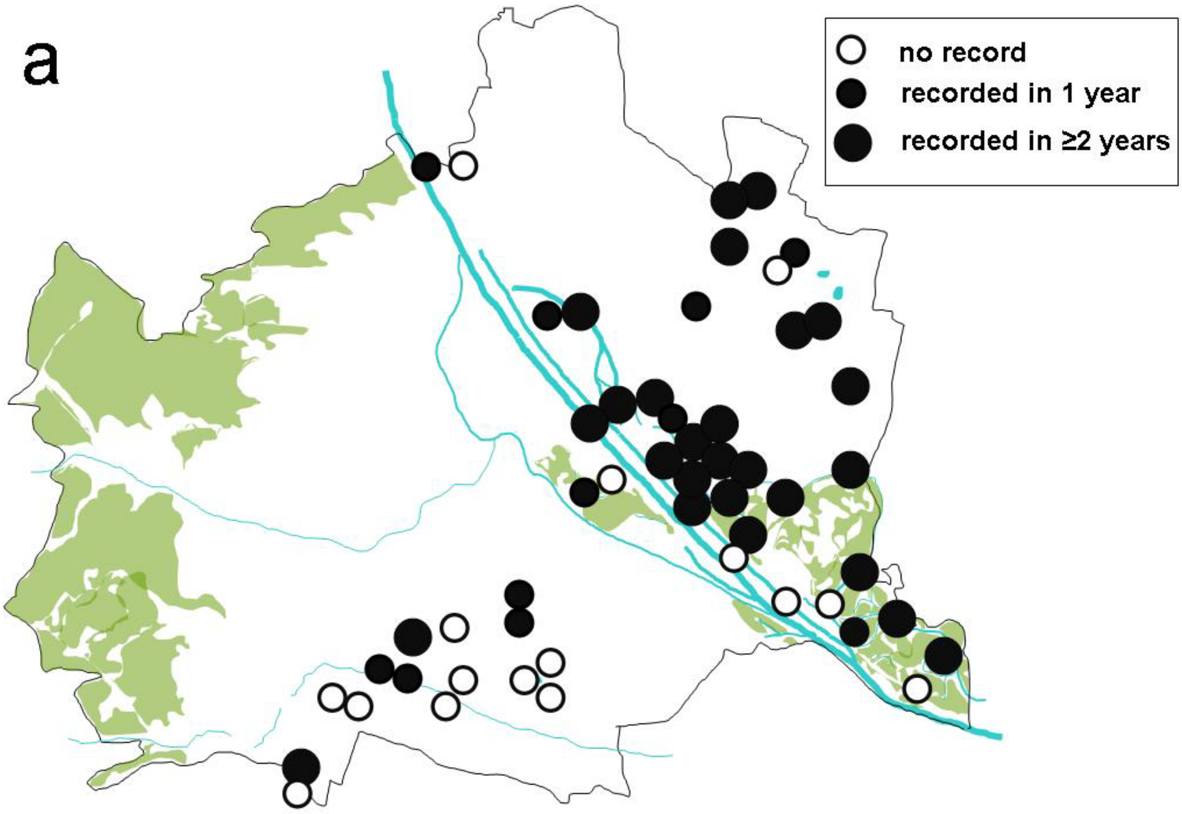
A linear regression model was used to describe the relationship between density of Little Bittern territories and reed bed shape.

All analyses were carried out with the program Statistica 7.1 (StatSoft 2005). When data were not normally distributed, adequate data transformations were used to achieve normal distribution.

Results

Historical and present distribution of the Little Bittern in Vienna

The occurrence of the Little Bittern in Vienna was analysed combining data from three different surveys: (1) 1995-1998 (Sabathy 1998), (2) 2001-2002 (Dvorak 2003) and (3) 2006 (this study). The map shows that the Viennese population centres on the water bodies north-east of the Danube. The majority of these water bodies were permanently colonized (Fig. 2a) and highest territory numbers per surveyed water body were recorded in this area (Fig. 2b). In the southern part of Vienna, Little Bitterns were recorded more than once only at two large water bodies (Fig. 2a).



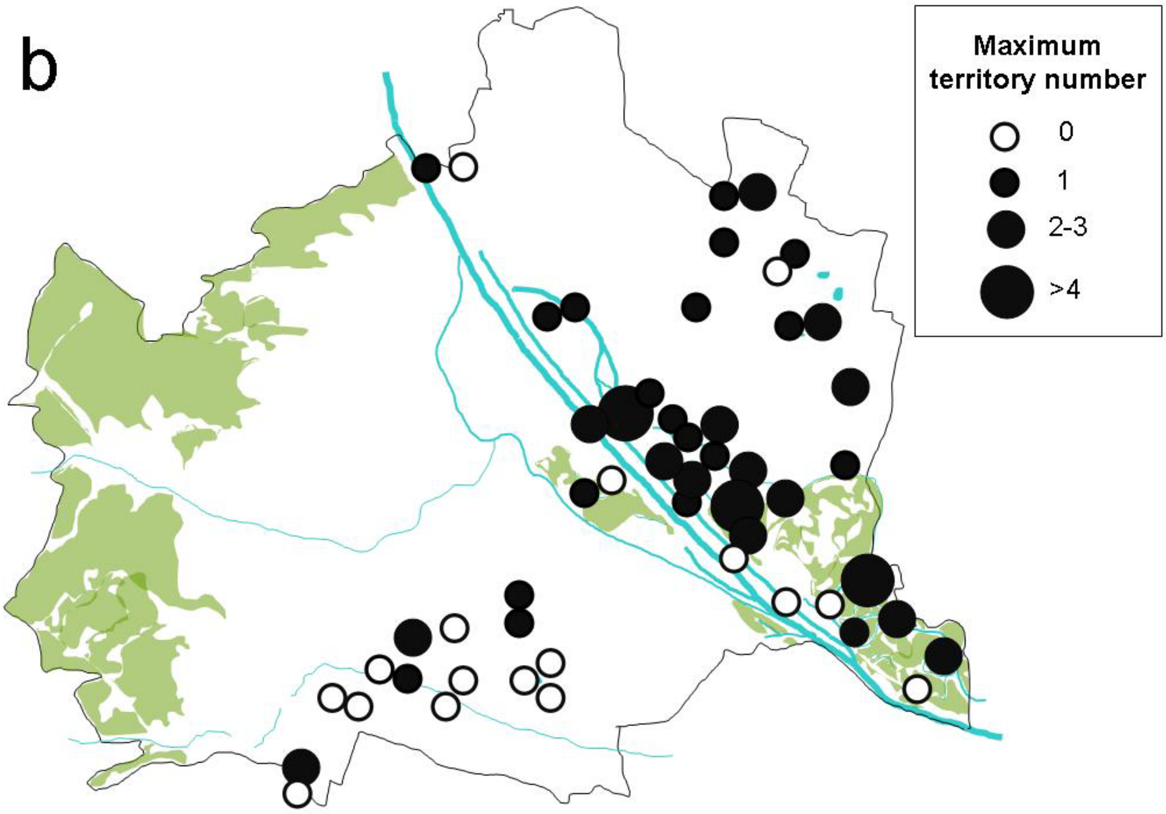


Figure 2. Study area indicating surveyed water bodies, (a) the number of years with records and (b) the maximum number of territories of Little Bittern *Ixobrychus minutus* in Vienna

recorded during the survey periods 1995-1998 (Sabathy 1998), 2001-2002 (Dvorak 2003), and 2006 (own data).

Habitat preferences of the Little Bittern

Correlations were calculated to test for multicollinearity of parametric water body variables. Because total reed bed area was strongly correlated with the area of the largest reed bed patch and reed bed shape, we only considered total reed bed area in further analyses. Furthermore, visibility through water was negatively correlated with phosphor and Chl-a concentration (Table 2). Because visibility through water represent the variable directly influencing prey detectability, we only considered this variable in all further analyses.

Table 2. Results of Pearson correlations between the parametric water body parameters (1) total reed bed area, (2) area of largest connected reed bed, (3) reed bed shape, (4) water body isolation, (5) vertical visibility through water, (6) phosphorus content and (7) Chl-a content.

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
(2)	**$r = 0.85$ $p < 0.001$**					
(3)	**$r = -0.67$ $p < 0.001$**	**$r = -0.82$ $p < 0.001$**				
(4)	$r = -0.49$ $p = 0.016$	**$r = -0.52$ $p = 0.004$**	$r = 0.30$ $p = 0.116$			
(5)	$r = 0.14$ $p < 0.476$	$r = 0.33$ $p = 0.091$	$r = 0.14$ $p = 0.468$	$r = -0.19$ $p = 0.328$		
(6)	$r = -0.19$ $p = 0.321$	**$r = -0.54$ $p = 0.003$**	$r = 0.29$ $p = 0.132$	$r = 0.26$ $p = 0.184$	**$r = -0.61$ $p = 0.001$**	
(7)	$r = -0.262$ $p = 0.178$	**$r = -0.51$ $p = 0.006$**	$r = 0.27$ $p = 0.163$	$r = 0.35$ $p = 0.070$	**$r = -0.79$ $p < 0.001$**	**$r = 0.78$ $p < 0.001$**

Univariate logistic regression models were used to test for effects of total reed bed area, isolation of water bodies from colonized ones and visibility through water on the occurrence of Little Bitterns in 2006. Only total reed bed area significantly affected the species' occurrence (Table 3). The likelihood of Bittern occurrence increased significantly with increasing reed bed area (Fig. 3). The calculated logistic regression curve predicts a 50 % likelihood of Little Bittern occurrence for a total reed bed area of ca. 6500 m^2 (= 0.65 ha).

Table 3. Results of univariate logistic regressions testing for effects of three parametric water body variables on the occurrence of Little Bittern in 2006. The number of surveyed water bodies was 59, except for the visibility through water for which data from only 28 water bodies were available for analysis. Significant results are printed bold.

Variable	Results of logistic regressions	
	χ^2	***P***
log (total reed bed area)	**18.16**	**<0.001**
log (isolation of water body)	2.96	0.086
visibility through water (m)	0.54	0.461

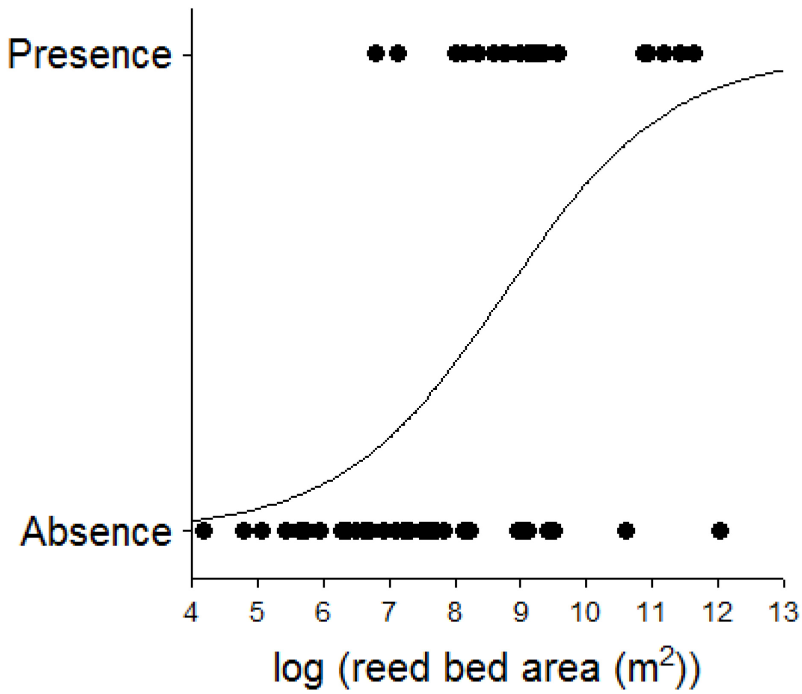


Figure 3. Logistic regression curve describing the increasing likelihood of Little Bittern occurrence at water bodies with increasing total reed bed area only considering records of the own survey in 2006.

Furthermore, we tested if two categorical variables for human disturbance, bathing activities and fishing, affected the occurrence of Little Bitterns. Fishing activities did not affect the occurrence of Little Bittern (Fisher exact test: p = 0.386). Bitterns were recorded at 47.0% of the water bodies where fishing was allowed (N = 46) and at 46.2% of the water bodies where fishing was prohibited (N = 13). Remarkably, bitterns occurred with a higher likelihood at water bodies where swimming was allowed (Fisher exact test: $p = 0.018$). A total of 61.5% of water bodies (N = 26) where swimming was allowed were colonized by Little Bitterns, while the species was only recorded at 21.2% of the water bodies where swimming was prohibited (N = 33).

The higher likelihood of Bittern occurrence at bathing waters is not caused by larger reed bed areas at this type of water bodies. Indeed, reed bed areas [ha] were significantly smaller at bathing (log (x+1) transformed area values; mean ± SD = 0.52 ± 0.47) than non-bathing waters (1.23 ± 1.09; t-test: $t = 2.89$, $p = 0.007$).

Generalized linear models (GLMs) including all selected habitat variables and all possible subsets were calculated and ranked according to their AICc values to test for effects on the occurrence of Little Bittern. GLMs calculated for all 59 water bodies did not consider the variables vertical visibility through water because measurements were not available for all water bodies. The two best models included total reed bed area and the two variables for human disturbance ($AIC_c = 62.86$; AIC_c weight = 0.44) and total reed bed area and swimming activities ($AIC_c = 63.59$; AIC_c weight = 0.27). All other models performed worse ($AIC_c > 65.16$; AIC_c weight < 0.14).

GLMs calculated for all 28 water bodies for which data on vertical visibility through water were available did not consider fishing activities because visibility measurements were not available for water bodies where fishing activities are prohibited (only one exception). The best model included the variables total reed bed area and swimming activities ($AIC_c = 30.58$; AIC_c weight = 0.35). All other models performed worse ($AIC_c > 32.80$; AIC_c weight < 0.12).

Temporal stability of occurrence

Total reed bed area differed significantly between water bodies where Bitterns were recorded with different annual frequency (one-way ANOVA: $F_{2,33} = 4.09$, $p = 0.026$). Water bodies for which Bitterns were recorded over a 3 years period are characterized by higher total reed bed areas than water bodies with records over one or two years (Fig. 4). Permanently colonized water bodies were characterized by an average total reed bed area of ca. 3 ha. However, even water bodies with a total reed bed area of ca. 0.07 ha were occasionally colonized (compare Appendix 2).

Isolation of water bodies from other colonized water bodies did not differ between more permanently colonized and less colonized water bodies (one-way ANOVA: $F_{2,33} = 1.83$, $p = 0.177$).

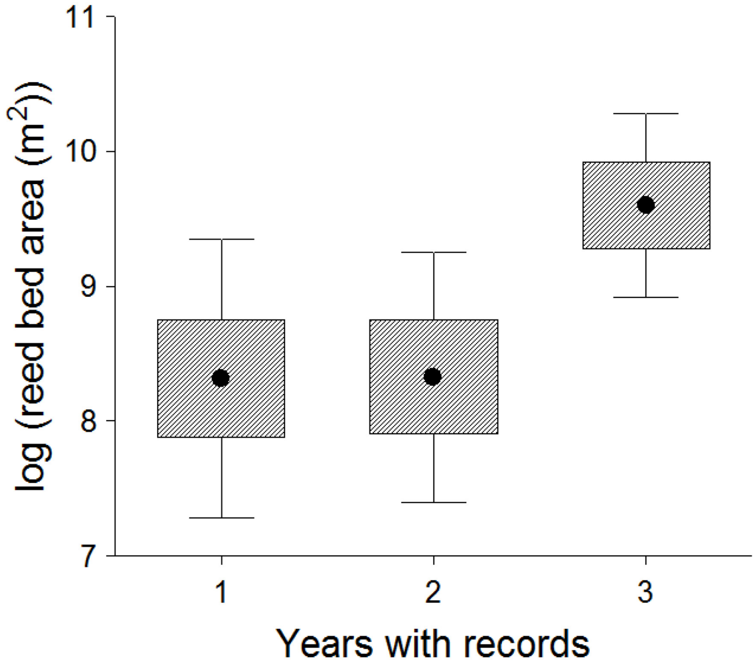


Figure 4. Mean reed bed area ± SE (box) and 95% CI (whiskers) of water bodies with different number of years with Little Bittern records.

Colonization frequency of water bodies was either affected by fishing activities (Chi-square test: $\chi^2 = 2.13$, df = 2, $p = 0.345$) nor by swimming activities ($\chi^2 = 1.41$, df = 2, $p = 0.495$).

When testing for the effects of the variables total reed bed area and swimming allowed or prohibited on the stability of occurrence, again the model with both variables proved to have the highest information content and both variables were included in the best selected model according to AIC (Tab. 4).

Tab. 4. Results of GLMs which test for the effects of human disturbance (bathing waters vs. non-bathing waters) and total reed bed area [m^2] (log x-transformed) on the stability of occurrence (0 – no records, 1 – recorded in 1 year, 2 – recorded in >1 years) of Little Bittern. Models are ranked according to Akaike information criterion (AIC).

Variables included	**df**	**AIC**	***P***
reed bed area, human disturbance	2	57.60	<0.001
reed bed area	1	64.74	<0.001
human disturbance	1	72.75	0.001

Effects of water body variables on territory density

Also the maximum number of territories recorded for the considered water bodies within a single year proved to be positively related to total reed bed area (r_s = 0.68, p < 0.001; Fig. 5).

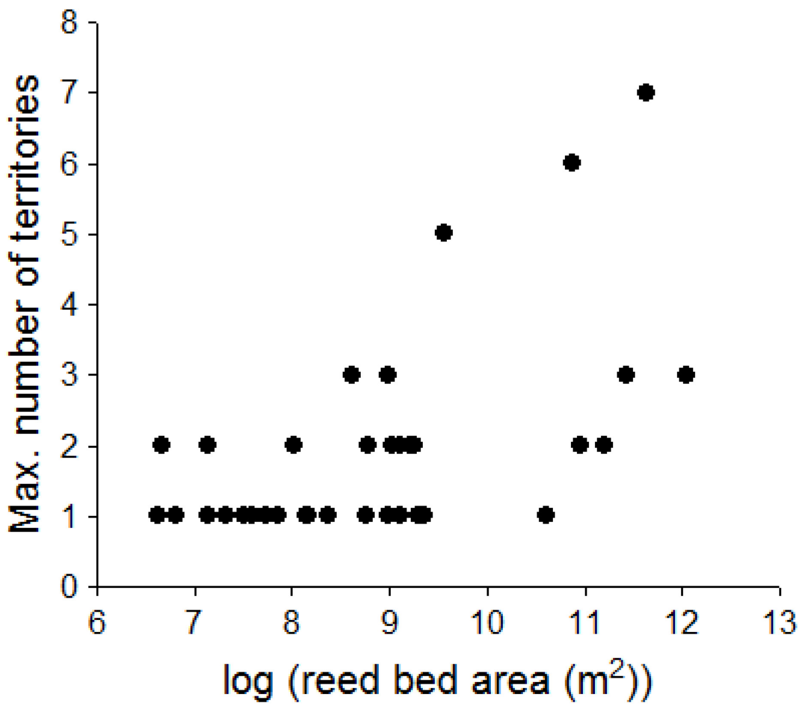


Fig. 5. Relationship between maximum numbers of Little Bittern territories recorded per year at individual water bodies between 1995 and 2006 and total reed bed area.

Subsequently, we calculated the maximum territory density for all water bodies only considering reed beds as potentially suitable habitats. The mean territory density (± SD) at colonized water bodies was 4.14 (± 5.16) territories per ha reed bed area. Territory density (log x transformed) of colonized water bodies differed significantly between bathing and non-bathing waters (t test: t_{34} = -2.44, p = 0.020). At non-bathing waters a mean territory density (log x transformed) of 0.88 (± 0.77), while at bathing waters it was 1.52 (± 0.71). Territory density also differed significantly between fishing and non-fishing waters (t_{34} = 3.68, p < 0.001); at fishing waters higher mean territory densities (log x transformed data; 1.53 ± 0.74) than at non-fishing waters (0.54 ± 0.29) were found.

Then, a GLM was calculated to test for the effects of water body parameters reed bed area shape, fishing activity and bathing water on territory density (multiple r = 0.79, multiple r^2 = 0.62, $F_{3, 32}$ = 17.23, p < 0.001). Only the reed bed shape index had a highly significant effect on territory density (Tab. 5). The shape index for the reed bed areas proved to have a particularly strong effect on territory density. Territory density increased with increasing shape index (Fig. 6). The importance of the ratio reed bed circumference to reed bed area as an explanatory variable for territory density was also supported by a GLM testing for the effects of bathing and fishing activities as well as reed bed shape index on territory density. Only the later proved to significantly affect territory density (Tab. 5).

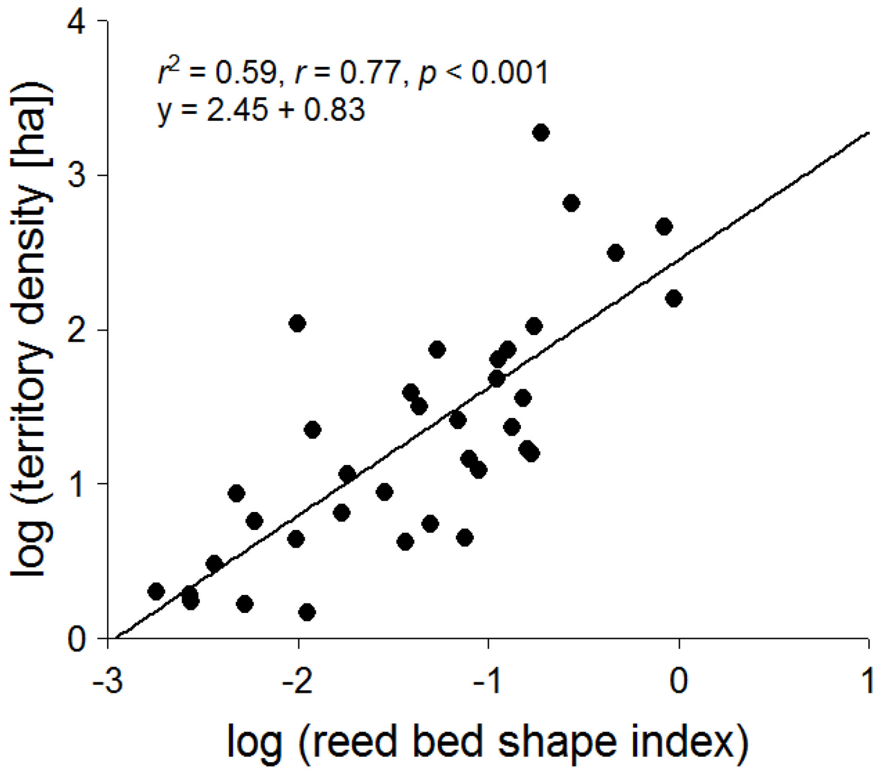


Fig. 6. The relationship between density of Little Bittern territories and reed bed shape described by a linear regression model.

Tab. 5. Results of GLMs testing for effects of reed bed shape (circumference reed bed area/redbeed area) on territory density.

Variable	**df**	**MQ**	***F***	***P***
Constant	1	20.66	80.74	<0.001
Fishing activity	1	0.34	1.34	0.254
Bathing water	1	<0.01	<0.01	0.983
Reed bed shape index	1	7.11	27.80	<0.001
Error	32	0.26		

Discussion

Historical and present distribution of the Little Bittern in Vienna

A total of 37 breeding territories of Little Bitterns were found in Vienna during the course of this study in 2006. With the Austrian population estimated at 150-300 breeding pairs (Bauer et al. 2005), the Viennese population therefore represents between 12% and 25% of the national total – a large proportion, given the small area and high human population density of the city. The population count of 37 territories agrees well with the lowest estimate published by Sabathy (1998), whose three-year study estimates the Viennese population at 38-60 breeding territories. This may suggest a stable population at the lower level, or, more likely is due to the fact that the current study only extended over one breeding season. Sabathy's (1998) higher figure of 60 breeding territories is a sum of the maximum number of territories per water body over three years. Compared to our study, a very similar population size of 37 breeding territories was also found in Vienna in the years 2001 and 2002 (Dvorak 2003), further emphasizing that the Little Bittern population in Vienna might have been stable within the last decade.

Habitat preferences

Little Bitterns breed at the edges of ponds, lakes and other water bodies with flooded reed beds consisting of reeds (*Phragmites*) and bulrush (*Typha*). Wet reed beds with scattered trees (e.g. *Salix* and *Alnus*) or shrubs are also commonly used as nesting sites. Fish ponds and gravel pits with plenty of emergent vegetation are colonized occasionally when sufficiently large reed bed areas are available. In general, the species requires reed beds in shallow standing or slowly flowing water, with a layer of old collapsed reeds which is important for nest construction (Bauer & Glutz von Blotzheim 1966, Voisin 1991, Beiche 1979).

In our study area, the probability of colonisation of water bodies and the number of territories rose with increasing reed bed area. A 50% chance of containing a Little Bittern territory was reached by reed beds larger than 0.65 ha, but even smaller reed beds (0.07 ha) were occasionally used as a breeding habitat. Sabathy (1998) published estimates of 0.3 ha as a minimum size of water bodies, and of 0.03 ha as a minimum size of reed bed. The results are, therefore, slightly different but at the same order of magnitude. In comparison, in Central Italy only wetlands larger than 1 ha with reed beds of at least 0.13 ha size were colonized by Little Bitterns (Benassi et al. 2009, Benassi & Battisti 2011).

Our results indicate that the Little Bittern is apparently highly tolerant of human disturbance. Fishing activities did not prove to affect the occurrence of Little Bittern and, remarkably, the species occurred with a higher likelihood at water bodies where swimming was allowed. Similarly, on a fish pond in Oberschlesien, 41 % of a number of 89 nests were found only 3 to 10 m from roads or places where people walk through for fishing (Cempulik 1994). However, Weggler et al. (2005) emphasized that breeding sites of the Little Bittern in wetland reserves in Switzerland were located predominantly in areas of low or no human disturbance indicating that disturbance may potentially affect the suitability of reed beds as breeding sites.

In our study area, the higher likelihood of Bittern occurrence at bathing waters was not caused by larger reed bed areas at this type of water bodies. In fact, reed bed areas were significantly smaller at bathing than non-bathing waters. Therefore, it remains unclear what factors are responsible for this result. Perhaps Little Bitterns may benefit from a lower predator density and consequently a lower predation risk at water bodies more frequently visited by humans. Animals may remain in disturbed areas because the costs of moving to a new location are too high, food resources are more abundant or predation risk is lower than at alternative sites (Gill 2007).

Temporal stability of occurrence

The attractiveness of individual reed bed areas for breeding birds can be remarkably constant between years, although the individuals occupying them are changing almost annually, as documented for the Great Reed Warbler (*Acrocephalus arundinaceus*) (Bensch & Hasselquist 1991, Bensch et al. 2001). Therefore, a continuous occupation – in contrast to water bodies only infrequently colonized – may indicate a high habitat quality. In our study, reed bed area differed significantly between water bodies where Bitterns were recorded with different annual frequency. Water bodies from which Bitterns were recorded in two or more years are characterized by higher total reed bed areas, water bodies with no records by smaller reed bed areas. In this study temporal stability of occurrence was also found to be significantly greater at bathing waters than at non-bathing waters. As mentioned above the reasons for this pattern remain unclear.

A study on the breeding biology of the Little Bittern on fish ponds in Oberschlesien during the years from 1982 to 1989 showed a high population fluctuation, which may have been partially caused by the mowing of reeds and destruction of some breeding sites in the years 1985-1986 (Cempulik 1994). However, such effects are probably of minor importance for the population in Vienna. During the survey period we did not recognize any mowing activity or other destructive disturbances of reed beds.

Effects of water body variables on territory density

Of the water body parameters reed bed area shape, fishing activity and bathing water, only the reed bed shape index had a highly significant effect on territory density. In a Swiss study the Little Bittern preferred nesting sites within the reed bed close to the open water (Braschler 1961). This may explain that territory density increased with increasing shape index in the Viennese study. Also for the Great Reed Warbler the spatial heterogeneity of reed beds (quantified by reed edge length) increased attractiveness for the establishment of territories (Bensch et al. 2001).

Edge effects can penetrate up to ca. 15 m into the reed bed and cause a great spatial variation in structural and microclimatic variables across the edge, which inevitable affects the occurrence of animals species (Báldi 1999).

Additionally to the likelihood of Little Bittern occurrence, also the maximum number of territories recorded at water bodies proved to be positively related to total reed bed area. In the Ebro Delta (NE Spain) 60.9 % of the Little Bittern established their nests at more than 30 m from the closest adjacent nest, although there were adequate nesting patches available at closer distances (Pardo-Cervera et al. 2010). A larger reed bed area may present a higher probability for building a territory for the Little Bittern as a mainly solitary breeder.

Our results indicate that the degree of isolation of colonized water bodies had no significant influence on their suitability as a breeding habitat for Little Bitterns in Vienna. Also a study on bird species richness in reed bed islands at Lake Velence (Hungary) indicated no or only a very weak effect of the distance between reed patches on birds (Báldi & Kisbenedek 2000).

Implications for conservation

The city of Vienna shows the largest known breeding population of Little Bittern in Austria (Dvorak 2003). The current population size seems to be stable at a lower level. Nevertheless it is still essential to protect the existing reed beds, even small ones, to preserve the population of Little Bitterns in Vienna. Also other species may benefit from the conservation of small reed beds. For example, the Great Reed Warbler (*Acrocephalus arundinaceus*), the Reed Warbler (*Acrocephalus scirpaceus*), Water Rails (*Rallus aquaticus*) and Coots (*Fulica atra*) settle for only 0.01 to 0.1 ha reed bed area, and for the Spotted Crake (Porzana *porzana*), the Little Crake (*Porzana parva*), Great Crested Grebe (*Podiceps cristatus*) and Marsh Harriers (*Circus aeruginosus*) 0.1 to 1 ha is sufficient (Ostendorp 1993; see also Báldi 2004). Consequently, a wide range of other species related to freshwater habitats may benefit from conservation measures aiming to maintain a stable population of Little Bitterns in Vienna.

Although the population trend in Europe appears to be decreasing, it is not sufficiently rapid to currently classify the Little Bittern as Vulnerable (BirdLife International 2010). While in several regions of Central Europe the number of breeding pairs declined significantly over the last decades (Bavaria, Germany: Weixler 2008; Baden-Württemberg, Germany: Hölzinger et al. 2007), in others populations even increased (Switzerland: Weggler 2005). A continuous monitoring of the population in Vienna is therefore highly recommended so we may contribute to our understanding of regional differences in the species' population and the underlying factors wich cause these trends.

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Appendix 1

Field work schedule

Site	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5
I. Untere Lobau					
01a. Kühwörter Wasser	8 May	26 May	28 Jun.	28 Jul.	
01b. Gänsehaufenwasser	8 May	26 May	28 Jun.	28 Jul.	
02. Mittelwasser	9 May	26 May	28 Jun.	25 Jul.	
03. Eberschüttwasser + Lausgrundwasser	5 May	30 May	27 Jun.	1 Aug.	
04. Arm südlich Eberschüttwasser	9 May	30 May	27 Jun.	1 Aug.	
05. Oberes Lausgrundwasser-West	5 May	30 May	27 Jun.	1 Aug.	
II. Obere Lobau					
06. Großenzersdorfer Arm-Nord	28 Apr.	25 May	19 Jun.	24 Jul.	
07. Oberleitner Wasser	28 Apr.	25 May	19 Jun.	24 Jul.	
08. Panozzalacke/Fasangartenarm	28 Apr.	24 May	17 Jun.	18 Jul.	1 Sep.
09. Dechantlacke	28 Apr.	22 May	16 Jun.	20 Jul.	21 Aug.
III. Mühl-/Schiller-wasserbereich					
10. Mühl-/Tisch-wassergebilde	28 Apr.	24 May	16 Jun	20 Jul.	6 Sep.
11. Unteres Mühlwasser/W Lobaugasse	28 Apr.	24 May	16 Jun.	20 Jul.	6 Sep.
12. Unteres Mühlwasser/W Biberhaufenweg	21 Apr.	20 May	14 Jun.	17 Jul.	29 Aug.
13. Unteres Mühlwasser/W Binsenweg	21 Apr.	20 May	14 Jun.	11 Jul.	28 Aug.
14. Unteres Mühlwasser/westlich Tamariskengasse	21 Apr.	20 May	14 Jun.	11 Jul.	28 Aug.
15. Unteres Mühlwasser/westlich Kanalstraße	21 Apr.	20 May	13 Jun.	11 Jul.	28 Aug.
16. Oberes Mühlwasser	21 Apr.	20 May	13 Jun.	10 Jul.	28 Aug.
17. Alte Naufahrt	21 Apr.	22 May	17 Jun.	18 Jul.	21 Aug.
18a. Schillerwasser und Großes Schilloch	21 Apr.	22 May	14 Jun.	17 Jul.	29 Aug.
18b. Kleines Schilloch	21 Apr.	22 May	14 Jun.	17 Jul	29 Aug.
18c. Gewässer SW Kierschitzweg	21 Apr.	22 May	14 Jun.	17 Jul.	29 Aug.
18d. Arm NW Kierschitzweg	21 Apr.	22 May	14 Jun.	17 Jul.	29 Aug.
IV. Wien-Nord					
19. Großer Süßenbrunner Teich(Transportbetonteich)	24 Apr.	10 May	7 Jun.	5 Jul.	10 Aug.
20. Kleiner Süßenbrunner Teich (Meiergrube)	24 Apr.	10 May	7 Jun.	5 Jul.	10 Aug.
21. Biotop Rautenweg	24 Apr.	10 May	7 Jun.	6 Jul.	10 Aug.
22. Badeteich Hirschstetten	24 Apr.	11 May	6 Jun.	4 Jul.	9 Aug.
23. Teich Eßling (Himmelteich)	26 Apr.	11 May	6 Jun.	4 Jul.	9 Aug.
24. Großer Teich südlich Breitenlee (Krcalgrube 1)	26 Apr.	11 May	6 Jun.	4 Jul.	9 Aug.
25. Kleiner Teich südlich Breitenlee (Krcalgrube 2)	26 Apr.	11 May	6 Jun.	4 Jul.	9 Aug.
26. Rußwasser	24 Apr.	10 May	12 Jun.	6 Jul.	7 Aug.
27. Peischerwasser	24 Apr.	10 May	12 Jun.	6 Jul.	7 Aug.
38. Schönungsteich	27 Apr.	18 May	8 Jun.	3 Jul.	14 Aug.
V. Alte Donau					
29. Alte Donau und Kaiserwasser	21 Apr.	20 May	13 Jun.	10 Jul.	22 Aug.
30. Arm SW Obere Alte Donau (Schießstattlacke)	21 Apr.	19 May	9 Jun.	7 Jul.	11 Aug.
31. Irissee (Donaupark)	21 Apr.	19 May	9 Jun.	7 Jul.	11 Aug.
VI. Donauinsel/Pater					
32. Donauinsel bei km 3 (Schwalbenteich)	2 May	29 May	21 Jun.		
33. Donauinsel bei km 5 (Hüttenteich)	2 May	29 May	21 Jun.		
34. Tritonwasser	2 May	29 May	21 Jun.	2 Aug.	4 Sep.
35. Neue Donau /N (bei km 18.5)	2 May	18 May	8 Jun.	3 Jul.	14 Aug.

36. Lusthauswasser	27 Apr.	23 May	20 Jun.	19 Jul.	16 Aug.
37. Krebsenwasser	27 Apr.	23 May	20 Jun.	19 Jul.	16 Aug.
VII. Wien-Süd					
38. Teich-Nord im Laaer Wald (Butterteich)	19 Apr.	12 May	31 May	31 Jul.	
39. Teich-Süd im Laaer Wald (Blauer Teich)	19 Apr.	12 May	31 May	31 Jul.	
40a. Nördliche Teiche Laaer Berg (Erholungspark Oberlaa) Südlichster	19 Apr.	12 May	31 May	31 Jul.	
40b. Nördliche Teiche/Laaer Berg (Erholungspark Oberlaa) 1.Mittlerer	19 Apr.	12 May	31 May	31 Jul.	
40c. Nördliche Teiche/Laaer Berg (Erholungspark Oberlaa) 2.Mittlerer	19 Apr.	12 May	31 May	31 Jul.	
40d. Nördliche Teiche/Laaer Berg (Erholungspark Oberlaa) Nördlichster	19 Apr.	12 May	31 May	31 Jul.	
41. Westlicher Teich/Laaer Berg (Erholungspark Oberlaa) Seerosenteich	19 Apr.	12 May	31 May	31 Jul.	
42. Südöstlicher Teich/Laaer Berg (Kurpark Oberlaa) Schilfteich	19 Apr.	12 May	31 May	31 Jul.	
43a. Großer Wienerbergteich	19 Apr.	17 May	2 Jun.	30 Jun.	23 Aug.
43b. Kleiner Lehmteich östl. Gr. Wienerbergteich		17 May	2 Jun.	30 Jun.	23 Aug.
43c. Teich-Südwest/Wienerberg (O/Stierofenteich)	19 Apr.	17 May	2 Jun.	30 Jun.	11 Sep.
43d. Teich-Südwest/Wienerberg (W/Kastanienalleeteich)	19 Apr.	17 May	2 Jun.	30 Jun.	11 Sep.
44a. Teich-Südost/Wienerberg	19 Apr.	17 May	1 Jun.	10 Jul.	11 Sep.
44b. Bendateich	19 Apr.	16 May	1 Jun.	29 Jun.	15 Aug.
45. Steinsee	19 Apr.	16 May	1 Jun.	29 Jun.	15 Aug.
46a. Teich östlich Brunn am Gebirge	19 Apr.	15 May		10 Jul.	14 Sep.
46b. Kleiner Teich östlich Brunn am Gebirge	19 Apr.	15 May		10 Jul.	14 Sep.
47. Rückhaltebecken Inzersdorf	19 Apr.	16 May	1 Jun.	29 Jun.	15 Aug.

Appendix 2

Water body parameters and breeding pairs of Little Bittern (*Ixobrychus minutus*) in Vienna in 1995–1998 (Sabathy 1998), 2001–2002 (Dvorak 2002, where * denotes data by E. Sabathy from 2001 (LIFE Project)), and 2006 (own data).

Explanations:
n/a – not applicable, i.e. water body was not visited in this time period
Water body parameters: 1 – total area of reed beds [ha], 2 – largest continuous area of reed bed [ha], 3 – total circumference of reed beds [m], 4 – isolation (=distance (shore to shore) to nearest water body with a Little Bittern record) [m], 5 – fishing allowed (0 = no, 1 = yes), 6 – swimming allowed (0 = no, 1 = yes), 7 – vertical visibility through water [m], 8 – total Phosphorus [µg/l], 9 – Chlorophyll–a [µg/l],]

Water Body	Water body parameters									Number of territorries		
	1	2	3	4	5	6	7	8	9	1995-1998	2002	2006
I. Untere Lobau												
1a. Kühwörther Wasser	16.9	15.1	24099	2	1	0	>2.3	31	3	1-3	3*	0
1b. Gänsehaufen-wasser	1.4	1.1	2041	5	0	0				n/a	n/a	0
2. Mittelwasser	9.2	9.1	7026	2	0	0				1-2	3*	1-2
3. Eberschütt- und Lausgrundwasser	11.4	7.3	9933	9	1	0				4-7	3*	1
4. Arm südlich Eberschüttwasser	4.0	2.2	4122	7	0	0				0-1	0	0
5. Oberes Laus-grundwasser-West	1.2	1.2	1140	80	0	0				0	n/a	0
II. Obere Lobau												
6. Großenzersdorfer Arm-Nord	0.2	0.2	203	15	1	1				1	1*	0
7. Oberleitner Wasser	7.3	7.3	5665	15	0	0				1	2	1-2
8. Panozzalacke/ Fasangartenarm	5.7	5.7	3653	220	1	1	1.0	22	10	1	2	2
9. Dechantlacke	0.3	0.2	631	307	1	1	2.5	19	3	1	1	0
III. Mühl-/Schiller-wasserbereich												
10. Mühl-/Tisch-wassergebilde	5.3	1.7	5697	9	1	0				2-5	4	4-6
11. Unt. Mühlwasser/ westl. Lobaugasse	0.9	0.3	3021	13	1	1	1.2	23	8	1-2	1	1
12. Unt. Mühlwasser/ westl. Biberhaufenweg	0.6	0.4	2034	17	1	1	>0.8	21	5	1	2	1-2
13. Unt. Mühlwasser/ westl. Binsenweg	0.6	0.3	1366	2	1	1	1.9	32	7	0-1	1	0-1
14. Unt. Mühlwasser/ W Tamariskengasse	0.3	0.2	1439	2	1	1	1.9	32	7	1	1	0
15. Unt. Mühlwasser/ westl. Kanalstraße	0.4	0.1	2000	17	1	1				0	n/a	1
16. Oberes Mühlwasser	1.1	0.3	3560	28	1	1				1	1	1
17. Alte Naufahrt	0.3	0.2	1440	9	1	1	2.0	23	7	1-2	1	1
18a. Schillerwasser und Großes Schilloch	0.8	0.2	3759	60	1	1	1.4	67	11	1-2	2	0
18b. Kleines Schilloch	0.2	0.2	538	19	1	0	1.5	22	6	0	0	0

18c. Gewässer SW Kierschitzweg	0.006	0.006	51	94	1	0				0	0	0
18d. Arm NW Kierschitzweg	0.05	0.02	323	33	1	0				0	0	0
IV. Wien-Nord												
19. Großer Süßenbrunner Teich (Transportbetonteich)	1.0	1.0	3556	289	1	1	3.7	10	2	1-2	2	2
20. Kleiner Süßenbrunner Teich (Meiergrube)	0.6	0.6	629	289	1	1				1	0	1
21. Biotop Rautenweg	1.1	0.9	1508	943	0	0				1	1	1
22. Badeteich Hirschstetten	0.2	0.1	885	1544	1	1	1.3	17	4	1	0	0
23. Teich Eßling (Himmelteich)	1.1	0.8	1860	1425	0	0	>2.6	8	2	1	1	2
24. Großer Teich südlich Breitenlee (Krcalgrube1)	0.1	0.07	1227	187	1	1	2.7	8	1	1	1	0-1
25. Kleiner Teich südlich Breitenlee (Krcalgrube 2)	0.1	0.04	727	187	1	1	1.3	22	5	1	0	1-2
26. Rußwasser	0.07	0.06	696	1336	1	1	2.4	13	3	1	0	0
27. Peischerwasser	0.07	0.03	557	293	1	1	2.5	9	5	0	n/a	0
28. Schönungsteich	0.14	0.12	403	449	1	0				0	n/a	0
V. Alte Donau												
29. Alte Donau und Kaiserwasser	1.4	0.8	3695	357	1	1				4-6	2	1
30. Arm SW Obere Alte Donau (Schießstattlacke)	0.3	0.3	514	380	1	1				n/a	n/a	0-1
31. Irissee (Donaupark)	0.9	0.9	2484	380	0	0				1	0	0
VI. Donauinsel/Prater												
32. Donauinsel bei km 3 (Schwalbenteich)	0.1	0.07	260	1330	0	0				0	n/a	0
33. Donauinsel bei km 5 (Hüttenteich)	0.03	0.02	157	357	0	0				0	n/a	0
34. Tritonwasser	0.08	0.04	384	357	0	0				1-2	1	0
35. Neue Donau /N (bei km 18.5)	0.8	0.6	1355	4818	1	1				1	0	0
36. Lusthauswasser	1.2	0.6	2769	1383	1	0				1	0	0-1
37. Krebsenwasser	0.03	0.03	168	235	1	0				0	n/a	0
VII. Wien-Süd												
38. Teich-Nord im Laaer Wald (Butterteich)	0.2	0.1	764	263	1	0	1.1	27	59	0-1	0	0
39. Teich-Süd im Laaer Wald (Blauer Teich)	0.18	0.13	516	263	1	0	1.5	12	4	1	0	0
40a. Nördliche Teiche Laaer Berg/Südlichster	0.03	0.01	266	1800	1	0	0.5	178	83	0	n/a	0
40b. Nördliche Teiche Laaer Berg/1.Mittlerer	0.06	0.03	183	1686	1	0	0.5	178	83	0	n/a	0
40c. Nördliche Teiche Laaer Berg/2. Mittlerer	0.01	0.007	102	1598	1	0	0.5	178	83	0	n/a	0
40d. Nördliche Teiche Laaer Berg/Nördlichster	0.02	0.007	127	1434	1	0	0.5	178	83	0	n/a	0
41. Westlicher Teich Laaer Berg (Erholungspark Oberlaa)	0.06	0.03	395	1557	1	0	0.8	79	49	0	n/a	0
42. Südöstlicher Teich Laaer Berg (Schilfteich, Kurpark Oberlaa)	0.08	0.08	308	2348	1	0	0.8	86	56	0	n/a	0
43a. Großer Wienerbergteich	0.8	0.4	3564	215	1	0	0.5	45	6	1-2	1	1-3
43b. Kleiner Teich östl. Gr. Wienerbergteich	0.02	0.02	111	163	1	0				n/a	n/a	0

43c. Teich-Südwest/ Wienerberg (O/Stierofenteich)	0.1	0.05	648	56	1	0				0	n/a	0-1
43d. Teich-Südwest/ Wienerberg (W/Kastanienalleteich)	0.2	0.2	1084	56	1	0				1	0	0
44a. Teich Südost/Wienerberg	0.1	0.1	475	117	1	0				n/a	n/a	0
44b Bendateich	0.02	0.02	82	328	1	0	>3	127	2	n/a	n/a	0
45. Steinsee	0.2	0.2	301	1484	1	1	2.3	26	5	0	n/a	0
46a. Teich östlich Brunn am Gebirge	0.5	0.2	2239	4910	1	1				1-3	n/a	1-2
46b Kleiner Teich östlich Brunn am Gebirge	0.4	0.4	1578	62	1	1				n/a	n/a	0
47. Rückhaltebecken Inzersdorf	0.2	0.2	685	977	0	0				0	n/a	0
Sum										38-60	37	24-38

Lebenslauf

Ausbildung:

09/1996 – 06/2001	Höhere Bundeslehranstalt für wirtschaftliche Berufe Ausbildungsschwerpunkt: Umweltökonomie
10/2001 – 11/2013	Diplomstudium Biologie an der Universität Wien Studienrichtung Ökologie
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