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Basking activity pattern of the European pond turtle, *Emys orbicularis* (Linnaeus, 1758) in Babat valley (Gödöllő, Hungary)

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Abstract

The populations of the widespread European pond turtle and their numbers are decreasing in Hungary and other European countries. Knowledge of basking habits, along with other biological characteristics of the species, could be important to preserve the European pond turtle. The purpose of our research was to assess the seasonal and daily basking activity of the European pond turtle, and the effects of weather parameters on sun-basking, for which no prior data exist for Hungary. Our study was carried out in the area of a dammed valley pond system at Gödöllő (Hungary) over two years. The results showed that the seasonal peak of the turtles' basking (the highest number of observed sun-basking turtles) was in the spring. When using a finer time scale (1.5-hour intervals), we found that daily activity peaks were earlier in the spring and summer (11:00–12:30 h) than in autumn (12:30–14:00 h). Based on three measured temperatures (air temperature in shade and sunlight, water temperature), the number of basking turtles positively correlated with temperatures and varied seasonally; the optimal temperature ranges also shifted during the year. In the spring and autumn, turtles started sun-basking at lower temperatures than in the summer. We observed the narrowest optimal temperature ranges in the summer as well. Based on a Principal Component Analysis of weather parameters, low humidity and high air temperature created optimal basking conditions, whereas high humidity, and low air and water temperatures had an adverse effect.

Key Words

freshwater turtle, meteorological factors, optimal temperature, sun-basking activities, visual observation

Introduction

In turtles (like in other reptiles and amphibians) maintaining proper body temperature by sun-basking influences multiple characteristics such as growth and development, intensity of metabolism, movement, nutritional and reproductive activity, behaviour, the possibility to colonize new habitats and successful defence against predators (Vitt and Caldwell 2014).

The importance of sun-basking is demonstrated by the distribution of freshwater turtles within potential habitats, which is primarily defined by their microhabitat parameters and the presence of optimal basking sites (Luiselli 2008).

The European pond turtle *Emys orbicularis* is a widespread species (Fritz 2003), but some European and Hungarian populations have shown a considerable decline in recent decades (Farkas and Sasvári 1999; Fritz and Chiari 2013). Hence, biological characteristics of the species, including basking activity, require extensive research to provide the information to apply proper conservation measures.

The European pond turtle utilises both aquatic and terrestrial habitats, but is essentially aquatic (Lanza 1983; Ficetola et al. 2004). It leaves the water only for basking, egg laying, or migrating to new water bodies. Its annual

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activity depends on site-specific climatic conditions, but in Central Europe it starts between the end of February and early April (Novotený et al. 2004; Mazanaeva and Orlova 2004; Vamberger and Kos 2011) and increases significantly (Cadi et al. 2004; Ayres and Cordero 2007; Cadi et al. 2008; Pupins and Pupina 2009; Vamberger and Kos 2011). The turtles spend the active months after the breeding season (egg laying usually in May–July) feeding and basking (Vamberger and Kos 2011). In August their activity starts to decline, from September on the basking activity decreases considerably, but turtles only start hibernation when the water surface freezes (Dall'Antonia et al. 2001; Cadi et al. 2004; Mazanaeva and Orlova 2004; Cadi et al. 2008; Vamberger and Kos 2011).

Although the turtles' need for thermo-regulation has been well established, the sun-basking activity of *E. orbicularis* in relation to the weather conditions was investigated only in a few cases: in one outdoor terrarium in Latvia (Pupins and Pupina 2009), in experimental ponds in France (Cadi and Joly 2003), and under natural conditions in Italy (Capula et al. 1994; Dall'Antonia et al. 2001, Ficetola et al. 2004).

There is no published information about turtle basking activity in connection with weather parameters in Hungary yet. Some studies give general information on turtle seasonal activity but not on basking activity (Dely 1983, Péchy and Haraszthy 1997, Farkas 2000). However, the implications of our study can extend beyond Hungary. Knowledge of the European pond turtle's basking activity pattern in Central Europe can aid in the species' conservation by optimizing the spatial and temporal design of conservation interventions to minimize potential disruptions to an affected population.

The purpose of our research was to assess the seasonal and daily pattern of the basking activity of the European pond turtle around the pond system of Babat valley, Hungary. Thus, our study set out to determine: (1) whether seasons affect the number of observed basking turtles, (2) if there are differences in sun-basking activity within the day (part of the day) and (3) what daily activity peaks are observed on a finer timescale (1.5-hours), and (4) whether a relationship can be detected between air temperature measured in sunlight and shade along with the water temperature and basking activity, (5) whether optimal temperature ranges and seasonal deviations could be identified, and (6) if there is a combined effect of measured and estimated weather parameters on sun-basking activity.

Materials and methods

Study area

We carried out our study in the area of the Babat valley pond system located on the outskirts of the town of Gödöllő (47°36′N, 19°22′E), about 30 km northeast of Budapest (Fig. 1). The size of the pond system was originally 10 ha (Dövényi 2010), but at the time of the study, due to water management and expansion of reeds (*Phragmites* sp.), the total open surface had decreased to about 7.6 ha. The study area is located in a valley extending from the northwest to the southeast, with an average altitude of 300 m above sea level (Dövényi 2010). Out of the original 11 ponds, the dams between ponds 1. and 2. as well as 3. and 4. were demolished a few decades ago, which created larger ponds. The whole surface of pond 5. was covered with reeds, but was sampled. The utilisation of the ponds by people and the number of potential basking sites for turtles in the ponds were different.

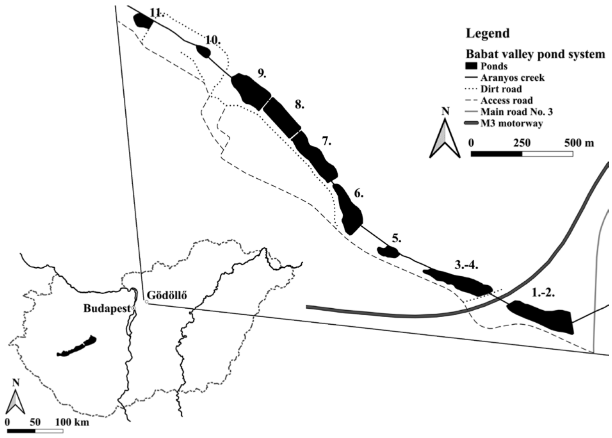

Figure 1. Location of the study area.

Surveys

The surveys were carried out in 2015 and 2016 in three seasons when turtles are actively sun-basking: in the spring (mid-April to mid-May), summer (July), and autumn (September). We counted all turtles and did not discriminate between sex, age or size. We observed only sun-basking turtles at basking places, so these data were recorded as "number of basking turtles".

We chose to utilise visual observations as the optimal method for this large lake system in order to maximise the number of turtles we could observe, while maintaining low costs (compared to other methods such as data loggers for example) (Dall'Antonia et al. 2001; Mosimann and Cadi 2004). Before data collection we planned the survey routes on the ponds' edges and the places of observing points from where we could achieve almost full visual coverage of each pond. Pond edges covered with reeds were observed from the opposite side of the pond; we could not observe the inside of the dense reeds but it was unlikely there were basking turtles there. There were different types of basking sites: fallen tree trunks and branches in the water, broken *Typha* sp. and reed stems, shorelines and embankments in each pond.

We spent 5 survey days per season per year, for a total of 15 survey days at each ponds. We divided each survey day into three parts of the day: morning 8:00–11:30 h, midday 11:30–15:00 h, and afternoon 15:00–18:30 h. Each pond was visited once in each of the three parts of the day per survey day. Overall, we carried out 45 observations (on the 15 survey days) each year. The duration of observation at each pond took 10–25 minutes, depending on the perimeter size of open water and their accessibility. The sequence of pond visits was planned prior to the field work in a way that resulted in visits dispersed through the seasons and parts of the day (in a full factorial arrangement). Over the two years we carried out 90 observations at each ponds, for a total of 810 observations at the whole pond system.

Our priority was to minimise the disturbance to turtles during the observations. We used binoculars to observe the sun-basking turtles. The approach to the ponds' edges and the observation points were carried out as silently and carefully as possible, and the observer kept adequate distance from the basking turtles (10–15 m). We achieved minimal disturbance by moving between ponds on a service road, running about 20–50 m parallel to the whole pond system. All observations were conducted by the same observer (Erdélyi, G.), not only to minimise disturbance, but also to limit observer bias.

We recorded the weather parameters in the middle of each 10–25 minutes observation at each pond. Abrupt changes in weather conditions were not registered during those times, except on two occasions when it rained; we repeated these surveys at later days.

We measured air temperature (in sunlight = T_{sun}; in shade = T_{shade} at 0.5 m height) and relative humidity (RH) for all parts of the day in both years; additionally in 2016 we obtained water temperature (T_{water}; at 10 cm depth near the coast) and dew point (with TFA Malibu 30.3053 wireless digital thermometer). Furthermore, we estimated the wind force on the Beaufort scale (0 – calm, 2 – light breeze, 3 – gentle breeze, 4 – moderate breeze, 6 – strong breeze), the cloud cover (0 – none, 1 – some clouds, not covering the sun, 2 – some clouds covering the sun, 3 – not dense, but continuously cloudy, 4 – dense clouds), and the presence of sunshine (0 – none, 1 – occasionally, 2 – continuous, 3 – strong sunshine).

Data handling and statistical analyses

The summarised numbers of observed basking turtles per survey day, season and year at the whole pond system were grouped in the larger 3.5-hours periods (three parts of the day) and also at a finer time scale (seven 1.5-hours periods per day), based on the start/end time of each observation. The summarised data were analysed for the effect of year, season, the part of the day and the finer time scale period on the turtle basking activity patterns (first independently of the year and the season, and secondly according to season).

The summarised numbers of basking turtles were compared to the actual measured temperature values per year and season in order to detect the effect of current temperatures on basking activity. The cumulated numbers of observed basking turtles belonging in the actual measured temperature values per seasons (independently of the effect of year) were used to determine the temperature range of basking activity. We define the optimal temperature range for basking activity as the presence of 80% of the cumulated number of all observed turtles. The effects of weather parameters on the number of observed basking turtles in 2016 were analysed independently of year, season and pond.

Statistical analyses were performed with the R statistical program 3.3.3. (R Development Core Team 2017). As the activity data did not follow a normal distribution and was over-dispersed compared to a Poisson distribution, we analysed it with the negative binomial regression model of the MASS package (Venables and Ripley 2002). Two complex weather variables were created with a Principal Component Analysis (PCA), thus the first two principal components were used as explanatory variables in the statistical models. The following variables were used in the PCA: T_{sun}, T_{shade}, T_{water}, the dew point, RH values, and for the 2016 data – the estimated weather parameters (wind force, presence of sunshine, cloud cover). The effect of the two complex weather variables (first two principal components) on basking activities was tested by the negative binomial model.

Results

Number of observed basking turtles in the two years

We observed a total of 3016 basking turtles during the study. In 2015 there were 1212 observed turtles, and in 2016: 1804.

Differences in the summarised number of all observed basking turtles within the 3.5 hours period at the whole pond system in 2015 and 2016 (Fig. 2) were significant with the negative binomial model (z- = 3.852, p < 0.001).

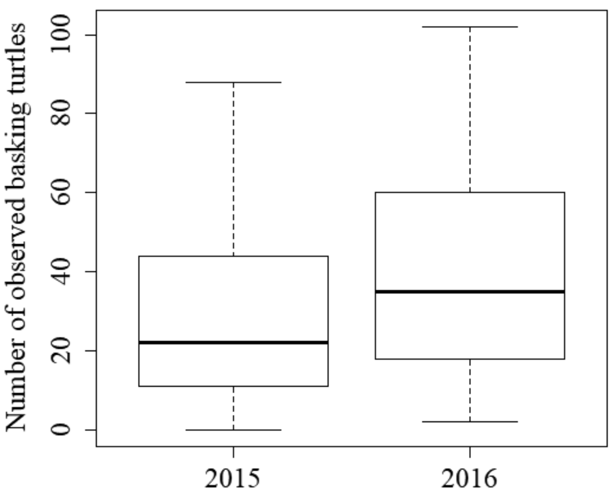

Figure 2. Differences of the summarized number of turtles within the 3.5 hours period in 2015 and 2016. The band inside the box is the median. The bottom and the top of the box are the first and third quartile. The ends of the whiskers are the minimum and maximum excluding outliers. Open circle: outlier (more than 3/2 times of the upper or lower quartile).

Effects of season on the number of observed basking turtles

The number of observed basking turtles summarised within the 3.5 hours period was the highest in the spring; significantly fewer turtles were observed in autumn (z = -8.813, p < 0.001) for both years. There was no significant difference between the number of turtles observed in spring and summer (z = 0.421, p = 0.674) (Fig. 3). There was no significant interaction between years and seasons (summers-years interaction: z = -1.774, p = 0.076; autumns-years interaction: z = 0.228, p = 0.819).

Part of the day basking activity pattern

There was a significantly higher number of observed basking turtles at midday compared to the morning (z = 3.488, p < 0.001). The difference in the morning and afternoon period was also significant (z = -2.749, p = 0.006), but there were lower numbers in the afternoon than in the morning (Fig. 4). There was no significant interaction between any combination of season and daytime activity.

Finer time scale basking activity pattern

The cumulative number of observed basking turtles per 1.5-hours interval (both years and all seasons), i.e. the peak of basking activity, was highest between 11:00 and 12:30 h. There was a slight difference in the seasonal breakdown. Based on the cumulative turtle numbers, the observed basking turtles showed an activity peak in the spring and summer between 11:00 and 12:30 h, while in autumn the activity peak was between 12:30 and 14:00h (Fig. 5).

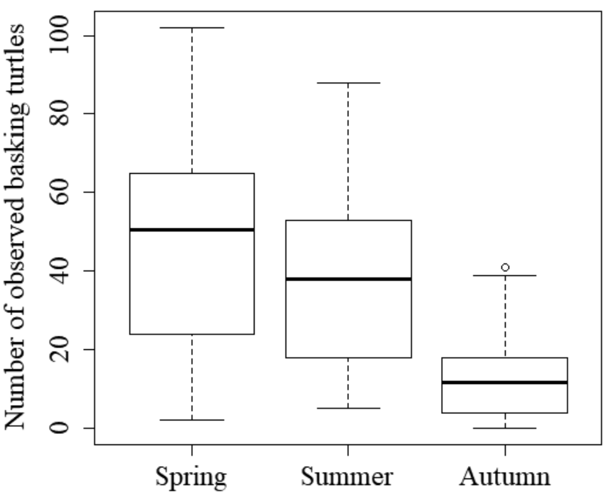

Figure 3. Box-plot of seasonal trends of the summarized number of turtles within the 3.5 hours period (2015–2016).

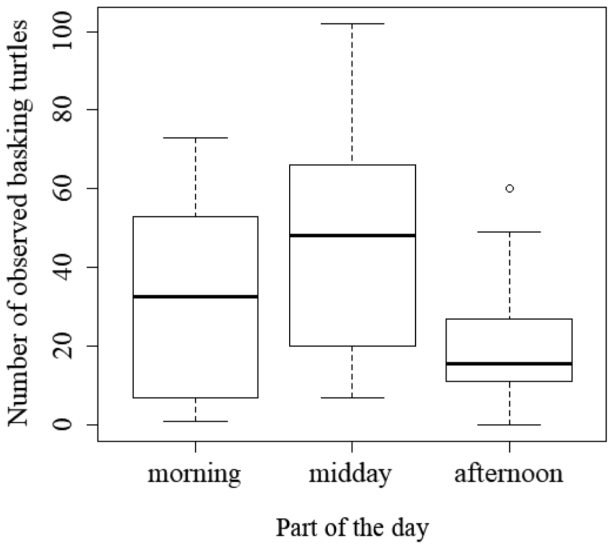

Figure 4. Box-plot of summarized number of turtles within the free 3.5 hours period (2015–2016).

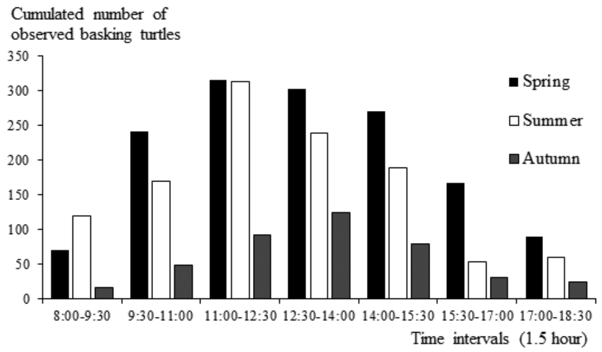

Figure 5. Turtles' basking activity seasonally in a finer time scale. Based on the cumulated number of turtles within 1.5 hours periods (2015–2016).

The effect of current temperature on basking activity

According to the negative binomial model, during the survey, taking into account all temperature data (T_{sun}, T_{shade}, T_{water}), the summarised number of observed basking turtles increased as temperature increased (z = 6.195, p < 0.001). When temperature types were analysed separately, the number of observed basking turtles decreased with the increase of T_{sun} (z = -2.452, p = 0.014). There was no significant difference between the effect of T_{shade} and T_{water} (z = 1.797, p = 0.072). This decrease in numbers occurred from the inflection temperature value (T_{sun}: 35 °C, T_{shade}: 27 °C, T_{water}: 26 °C) (Fig. 6).

Optimal basking temperature ranges

The lowest T_{shade} at which sun-basking started in the spring was 9 °C. In summer the turtles were observed even at 33 °C. The optimal T_{shade} ranges were narrower in

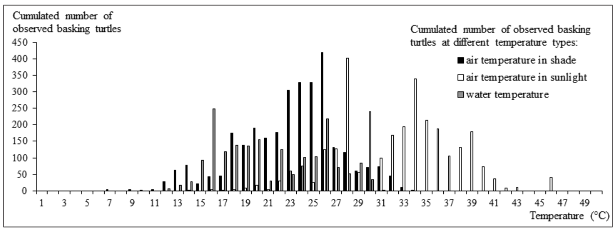

Figure 6. Cumulated number of observed basking turtles at the current temperature values (T_{sun}, T_{shade} and T_{water}) (2015–2016).

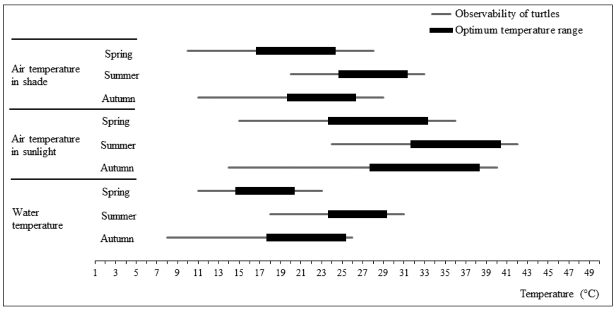

Figure 7. The effect of T_{sun}, T_{shade} and T_{water} values on the observability of turtles and seasonal differences in the ranges of their optimum zones (2016).

summer (7 °C, 25–31 °C) and autumn (7 °C, 20–26 °C) than in spring (8 °C, 17–24 °C). Taking into account the T_{sun}, the lowest temperature at which turtles began basking was 15 °C in spring and 14 °C in autumn (Fig. 7). In summer, turtles were present at basking sites only above 24 °C, and they stayed there even at 42 °C. In spring and autumn, the optimal T_{sun} range showed wider intervals than in summer. The optimal T_{sun} range was 24–33 °C in spring, 32–40 °C in summer, and 28–38 °C in autumn. The initiation of basking activity seemed to be less influenced by cooler T_{water} in spring and autumn, as turtles started basking at 11 °C in spring and at 8 °C in autumn. However, in the summer, turtles did not bask when T_{water} was above 31 °C. The optimal T_{water} range when most of the turtles were basking, similarly to the optimal range of T_{sun}, appeared to be the narrowest in summer. It seemed that temperature values, i.e. sunlight, shade, and water, likewise showed the widest optimal range in autumn, when most of the turtles were basking.

The combined effects of weather parameters

If the five measured and three estimated weather parameters were considered, the first two principal components explained 65.3% of the variance (Table 1). According to the negative binomial model, the increase of the second axis's values (p = -4.240, z < 0.001) correlated negatively with the number of turtles. On this axis, the wind force (-0.359), the presence of sunshine (0.353), cloud cover (-0.643) and RH (0.489) had a strong effect. Cloud cover and high RH were unfavourable to sun-basking. If only

Table 1. Results of the Principal Component Analysis of measured and estimated weather parameters in 2016.

Weather factors	1. axis	2. axis		Eigen values
Wind force	0.184	-0.359	1. axis	3.576
Intensity of sunshine	-0.204	0.353	2. axis	1.649
Cloud cover	0	-0.643	3. axis	1.321
Air temperature in the shade	-0.485	-0.200	4. axis	0.725
Air temperature in sunlight	-0.456	-0.171	5. axis	0.304
Water temperature	-0.467	-0.113	6. axis	0.252
Dew point	-0.488	0.111	7. axis	0.151
Relative humidity	-0.149	0.489		

Table 2. Results of the Principal Component Analysis of measured weather parameters in 2016.

Weather factors	1. axis	2. axis		Eigen-values
Air temperature in the shade	-0.506	0.254	1. axis	3.342
Air temperature in sunlight	-0.480	0.254	2. axis	1.193
Water temperature	-0.489	0	3. axis	0.278
Dew point	-0.504	-0.309	4. axis	0.166
Relative humidity	-0.144	-0.878		

the five measured weather parameters were considered, the first two components of the PCA explained 90.7% of the variance (Table 2). The increase of the second axis's values correlated positively to the number of turtles (z = 4.283, p < 0.001) based on the negative binomial model. The T_{shade} (0.254), T_{sun} (0.254), and RH (-0.878) had a strong effect on this axis. The dry and warm weather was most suitable for the turtles' sun-basking.

Discussion

Annual, seasonal and daily basking activity pattern

We found a significant difference in the summarised number of observed basking turtles between the years 2015 and 2016 (Fig. 2), which we assume was caused by differences in weather conditions. Compared to 2016, the daily maximum temperatures in Hungary in the year 2015 fluctuated more, especially in the spring and summer, which we think was less favourable for turtles basking. The presumably more favourable weather increased the number of basking turtles in 2016.

While there were no significant differences in the number of observed basking turtles between the seasons in the two years, the effect of year (under different weather conditions) did not influence the seasonal basking activity of turtles. After a sun-basking activity peak in spring (when the highest number of basking turtles was observed in the whole pond system), it decreased in the following seasons (Fig. 3). Novotený et al. (2008) in Slovakia found that in spring the sun-basking activity of the European pond turtles is high. In Italy, Ficetola et al. (2004) also observed more basking turtles in April and May than in October, but the difference was not significant. In Slovenia, Vamberger and Koss (2011) observed the highest activity (the highest observational success) in spring, maybe due to low vegetation then. These results corroborate our findings.

In autumn, decreasing temperatures may have reduced the number of observed sun-basking turtles (Fig. 3). These findings confirm the results of surveys conducted in many different areas of Europe: in Russia (Mazanaeva and Orlova 2004), in Spain (Ayres and Cordero 2007; Alacros et al. 2008), in Latvia (Pupins and Pupina 2009) and in Slovenia (Vamberger and Kos 2011; Vamberger et al. 2017).

We observed turtles' activity peak around midday, between 11:00 and 12:30h throughout the study (Fig. 4). These findings are identical to results presented in Italy (Capula et al. 1994; Lebboroni and Cecchini 2005), in Russia (Mazanaeva and Orlova 2004), in Spain (Ayres and Cordero 2007) and in Latvia (Pupins and Pupina 2009). In contrast, in France Cadi and Joly (2003) found the highest basking activity in the early morning hours (7:00 to 11:00h) during an experiment, but it may be related to non-natural conditions. In Italy, Di Trani and Zuffi (1997) and Dall'Antonia et al. (2001) observed two daily activity peaks: in the morning and afternoon. In Latvia, Pupins and Pupina (2009) reported similar data under natural weather conditions, but in an experimental outdoor terrarium. The difference in activity peak that we observed (later in autumn than in spring and summer) may be a result of the seasonal variation of the incidence angle of the sun. Cadi and Joly (2003) in France, and Ficetola et al. (2004) and Vignoli et al. (2015) in Italy reported that sun-basking turtles choose basking sites to utilise as much heat as possible depending on the incidence angle of the sun.

The effects of temperature

The combined analysis of water and air temperature data showed that in cases of rising temperature up to an inflection value, the number of observed basking turtles increased too, corroborating results by Pupins and Pupina (2009).

In our surveys the increasing T_{sun} showed the highest effects on the fluctuation of observed basking turtles' number (Fig. 6). The number of observed basking turtles decreased above an inflection temperature value, likely because they spend much less time basking to achieve optimal body temperature.

In contrast to our results of turtles observed only in full sun exposure, Kleewein (2015) reported thermoregulation in the shade and semi-shade too. His study was performed in Austria under near natural conditions, where the European pond turtles were placed with 12 different species together. At our pond system only one alien species (*Trachemys scripta elegans*) was rarely observed, so *E. orbicularis* do not need to use semi-shaded and shaded basking sites for their thermoregulation because of interspecific competition (Cadi and Joly 2003).

The seasonal variations in the optimum ranges for the different temperature types, the seasonal differences within the minimal temperatures when turtles started basking, and the maximum temperature values when turtles had been basking that we observed can be explained by the difference in activity shown to achieve optimal body temperature (Lebboroni and Cecchini 2005; Macchi et al. 2008; Kleewein 2015).

The combined effect of weather parameters

We established two parameter groups that were favourable (higher T_{sun} and T_{shade} and low RH) and unfavourable (high RH, low T_{water} and T_{air} and rising wind force) for turtles' basking (Table1, 2). Pupins and Pupina (2009) analysed the relationship between separate weather parameters and the number of basking turtles independently in Latvia, concluding that mostly intensive sunshine and high temperature increased basking activity, while rain and high humidity reduced it; this corresponds to our results. Mazanaeva and Orlova (2004) in Russia observed that turtles rarely leave the water on cloudy and rainy days. Ficetola et al. (2004) in Italy did not find a significant relationship between sun exposure and numbers of basking turtles, while Macchi et al. (2008) showed a high correlation between duration of basking and light intensity in Italy. Also in Italy, Vignoli et al. (2015) found that sun exposure is one of the most important factors in basking site choice.

Conclusions

We recommend visual counts as a useful tool in studies on basking activity. We confirmed for the first time in Hungary that *E. orbicularis* shows defined seasonal and daily sun-basking activity patterns. The finer time scale data can be utilised in planning monitoring methods, including adjusting timing of observations. To optimise work input, we recommend surveying during the spring season and the midday period to maximise the number of observed basking turtles.

While the effect of T_{sun} differed the most from the other two temperature data, recording the T_{sun} may be the most important during surveys. Because there was no significant difference between the effects of T_{water} and T_{shade} on the pattern of sun-basking, we think it is enough to measure only one of them. Utilising the information provided by official weather forecasts (T_{shade}, wind strength, sun intensity, RH) could be useful to plan surveys within the next few days. Any management work concerning the European pond turtle's habitats should be timed to minimise the disturbance to basking turtles, for which our results of turtles' sun-basking patterns could be used.

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