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Assessing the Use of Artificial Hibernacula by the Great Crested Newt (*Triturus cristatus*) and Smooth Newt (*Lissotriton vulgaris*) in Cold Climate in Southeast Norway

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Abstract: Construction of artificial overwintering habitats, hibernacula, or newt hotels, is an important mitigation measure for newt populations in urban and agricultural areas. We have monitored the use of four artificial hotels built in September 2011 close to a 6000 m^2 breeding pond in Norway. The four hotels ranged from 1.6 to 12.4 m^3 and were located from 5 to 40 m from the breeding pond. In 2013–2015, 57 Great Crested Newts (*Triturus cristatus*) and 413 Smooth Newts (*Lissotriton vulgaris*) spent the winter in the hotels. The proportions of juveniles were 75% and 62%, respectively, and the hotels may be important to secure recruitment. Knowledge on emigration routes and habitat quality for summer use and winter hibernation is important to find good locations for newt hotels. The study documented that newts may survive a minimum temperature of −6.7 °C. We recommend that newt hotels in areas with harsh climate are dug into the ground in slopes to reduce low-temperature exposure during winter.

Keywords: *Triturus cristatus*; *Lissotriton vulgaris*; climate; hibernacula

1. Introduction

Large piles of rubble, rocks, rotting trees, log piles, and earth banks with mammal burrows and ground fissures present, are good hibernation and refuge sites for both European newts [1–4] and for American salamanders (Genus *Ambystoma* [5–8]). In urban areas, basements and other openings in buildings and constructions are also used for hibernation [9,10]. Newts choose hibernacula up to 80 cm below ground, and individuals of different species and stages are found together [4].

Great Crested Newts show high fidelity to terrestrial habitats and overwintering locations [11–13]. When newts leave a breeding pond, they usually travel in straight lines and seem to move towards favorable habitat patches in the vicinity [3,8,14–19]. Most individuals hibernate less than 300 m from the breeding pond. However, individuals have been observed as far as 1300 m from the nearest breeding pond [3,4,8,15,16,20].

In urban and agricultural areas, access to suitable hibernation sites may be restricted due to buildings, infrastructure, and agricultural practice. Construction of artificial hibernacula to improve the terrestrial habitat for amphibians and reptiles is therefore often an effective mitigation measure [1,2]. However, there are few studies assessing the benefits of such measures [21–23]. Characteristics of the overwintering site may impact both survival and when spring migration to the breeding pond is initiated. The animal's position with respect to depth in the soil, whether the wintering place is sun exposed or not, and how long it is covered by snow or frozen soil have a major impact on metabolism and thus the risk of dehydration and mortality due to frost damage. Such differences may affect the intensity and duration of spring migration, since some individuals may have to start the migration prematurely due to adverse winter conditions and consumption of energy reserves [24].

In the northernmost part of their distribution, low temperatures represent an extra challenge when constructing newt hotels, and factors such as depth and design must be considered. The advantage of overwintering deeper in the ground is that the temperature is relatively constant compared to surface overwintering, which provides only vegetation or snow cover as shelter. In addition, the probability that the temperature will fall to harmful levels decreases, and physiological stress from dehydration is reduced when hibernating deeper underground. The disadvantage of deep caves is that the average temperature during the hibernation will be higher and energy reserves will therefore cease earlier [24]. Another important consideration is choosing optimal locations in relation to both the pond and the surroundings.

The principal aim of the current study was to determine if Great Crested Newts, *Triturus cristatus*, and Smooth Newts, *Lissotriton vulgaris*, would use artificial hibernacula under the relatively harsh climatic conditions in Norway.

2. Materials and Methods

2.1. Study Area

The study pond and surrounding area in Lier municipality, Buskerud County, Southeastern Norway (UTM WGS84 33N 0236699 33S 6630232) is severely impacted by human use and is dominated by agriculture, private homes, and infrastructure (Figure 1). The breeding pond Lahelldammen (30 m a.s.l. (metres above sea level)) has an area of 6050 m^2, a maximum depth of 4 m and a volume of 13,000 m^3. Mean annual air temperature is 5.0 °C and mean annual precipitation is 860 mm. Mean monthly air temperatures in March, April and May are −1.0, 3.9 and 10.1 °C, respectively [25]. The 0.392 km^2 area within 300 m from the pond is used for agriculture (33%), roads (6%) and housing (17%) (GIS-based Geograhical Information Systems) analysis of FKB map (a Norwegian central common map database) from the Norwegian Mapping Authority). Forest and nature-like areas constitute 44% of the area. Only 29% of the area is easily accessible for newts due to the presence of two roads (Røykenveien and Grimsrudveien) with high motor traffic, and a nearby river. Approximately 10% of the area may be characterized as "well suited" newt habitat. The pond is a breeding site for the Great Crested Newt, the Smooth Newt, the common frog, *Rana temporaria,* and the common toad, *Bufo bufo*. The local road around Lahelldammen is used by only 0–6 cars per hour at night during migration and is therefore well suited to observing newt crossings. Based on a mark–recapture study [26], the average annual *T. cristatus* population was estimated (Chapman estimator, Appendix A) at 1156 (95% CI = 738–1573) mature individuals for the years 2012–2015, and 79% migrated outside the road around Lahelldammen. For *L. vulgaris*, no estimates of population size exist; however, based on the ratio between *T. cristatus* and *L. vulgaris* captured, *L. vulgaris* population was estimated to include approximately 7600 mature individuals.

Figure 1. Map of the pond at Lahelldammen (UTM WGS84 33N 0236699 33S 6630232) in Southeastern Norway, with the four newt hotels (dots, nos. H1–4), zones (North, East, South and West), and the route for observation (Lahelldammen road). The distribution (gray) areas of Great Crested Newt (Tc right) and Smooth Newt (Lv left) in Norway are given in the maps in the upper part of the figure. The red point shows the location of Lahelldammen.

2.2. The Newt Hotels

To increase access to suitable hibernation sites close to the pond, four different newt hotels were constructed in September 2011 (Figure 2). The hotels were placed in different sections in the surroundings of the pond (Figure 1). Three of the hotels were placed between the pond and the road encircling the pond (Lahelldammen) and one just outside this road. The hotels were completed at the end of the emigration period and only one *L. vulgaris* was registered in the hotels in spring 2012. To record the use of the hotels, data were collected systematically in the spring in three consecutive years from 2013–2015.

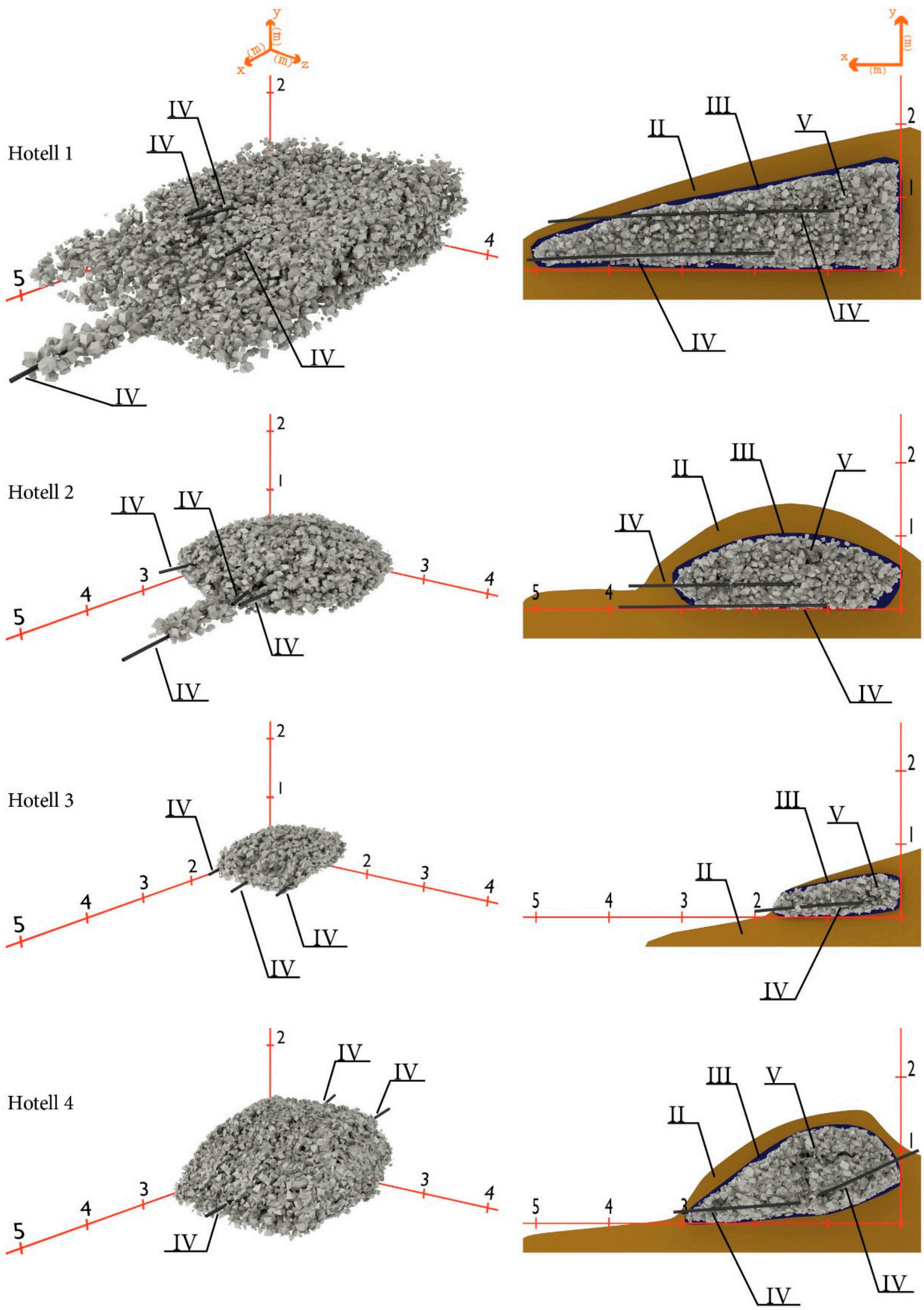

Figure 2. Sketches of the hotels. Hotel 1 = 12.4 m^3, Hotel 2 = 4.1 m^3, Hotel 3 = 1.7 m^3 and Hotel 4 = 4.2 m^3. II = soil, III = geotextiles, IV = drainage pipes, V = stones 2–30 cm diameter.

The newt hotels were constructed in accordance with Froglife's guidance in *Great Crested Newt Conservation Handbook* [2] and Reference [1], but with a slightly different design adapted to the harsh climate in Norway. The core of the newt hotels consisted of stones (hornfels) from 2–30 cm in diameter (Figure 2, Appendix B). Rock mass was covered with permeable geotextile fiber fabric and a layer of soil. Each hotel had three to four drain pipes (12 cm diameter with 1.6 cm holes every 30 cm) from the core to the outside were the newts could enter the hotels. All hotels were dug into ground consisting of clay, with proper drainage to prevent water accumulation (see Appendixs B and C for more details and pictures of the hotels and the construction).

Hotel 1 was located 13.0 m from the pond in a sloping grass-covered hill (Figure 1, Appendix B). The hotel was dug 1.6 m into the ground, with a 0.6 m soil layer on top (Figure 2). A 6.0 m long 0.40 m × 0.40 m rock-filled channel was placed from the hotel towards the pond, and the end was not covered with soil in order for it to function, together with the drainage pipes, as the hotel entrance. The total volume of rubble for the hotel and channel was 12.4 m^3 and 1.0 m^3, respectively.

Hotel 2 was located 36.0 m from the pond in a flat park area. The hotel was dug 1.0 m into the ground and total height was 1.7 m of which the stone masses constituted 1.0 m. The hotel was covered with soil. A 35.0 m long 0.5 m × 0.5 m rock-filled channel with a drainage pipe went from the hotel towards the pond. This pipe served as entrance and wintering area. The total volume of rubble for the hotel and the channel was 4.4 m^3 and 5.6 m^3, respectively.

Hotel 3 was located 8.0 m from the pond in a slope with birch. Total height was 1.0 m, with rubble constituting 0.7 m. The front towards the pond was open and not covered with soil. The total volume of rubble for the hotel was 1.6 m^3.

Newt Hotel 4 was located 15.0 m from the pond in a slope just across the road on solid ground. The hotel was dug 0.5 m into the ground and the total height was 1.5 m. The total volume of rubble for the hotel was 4.3 m^3.

2.3. Monitoring Methods

Using a flashlight at night [27,28], we observed spring immigrations to the pond (2013–2015) and autumn emigrations (2013) to hibernation localities on the 500 m-long and 5 m-wide paved road (Lahelldammen road) that encircles the pond. We recorded species, sex and stage (juvenile and adult) for all individuals. The road was split into four sections representing the directions North, East, South and West. The number of observation rounds each night ranged from 0 to 15, starting approximately one hour after sunset. When conditions were unfavorable, i.e. cold weather or more than a week since the last rainfall, we did not perform surveys. When the numbers of newts observed were low (<5 individuals), only two observation rounds were performed. Spring immigration to the pond was observed during 97 nights (380 rounds) and autumn emigrations during 30 nights (60 rounds).

Circular guide fences with fall traps on the inside (https://www.grube.de/kroetenschutzzaun-75-120/) were used in spring to catch newts leaving the hotels [29,30]. Outside Hotels 2 and 4, 1.0 m keep nets were mounted at the opening of the drainage pipes. The traps were checked once or twice each night and emptied at 08:00 a.m., and species and stage (juv. and ad.) determined. In 2015, a random sample of Smooth Newt was measured (mm) from snout to tail tip (total length).

The temperature was logged every two hours during the hibernation phase with five HOBO Pendant Temperature data loggers (http://www.onsetcomp.com/products/data-loggers/ua-004-64) with a specified accuracy to ±0.53 °C. One temperature logger was placed 1.5 m above the ground outside Hotel 3, and one in a drainage pipe at the core of each hotel. The temperature was measured from October 15 to April 15 in 2013–2015.

3. Results

There were few days with temperatures below freezing in the hotels, but with 2012/13 and Hotel 4 as exceptions (Table 1). In 2012/13 the winter temperature was lower than normal and mean and minimum temperatures registered were −2.7 °C and −22.0 °C, respectively. The numbers of days with temperature below zero in 2013 for Hotels 2, 3 and 4 were 88, 36, and 93 days, respectively. In 2015, temperatures below zero were registered in all hotels for at least a few days due to a cold December without snow cover.

Overall, 4900 Great Crested and Smooth newts were observed during the spring immigration and 186 during the autumn emigration. The number of migrating Great Crested Newts observed on the road was highest in the East and South in spring, and lowest in the West (Table 2). A similar pattern was observed for Smooth Newts. In autumn the pattern was different, with more juvenile Great Crested Newts being observed in the North and West. Very few Smooth Newts and adult Great Crested Newts were observed here.

In total, 14 adult Great Crested and 155 adult Smooth newts and 301 juveniles of both species were caught (Table 3). A total of 57 Great Crested and 413 Smooth newts were observed in the hotels during spring (Table 3). Numbers of individuals during the three consecutive years increased by 81% for the Great Crested Newt and by 65% for the Smooth Newt. The frequencies of juveniles observed in the hotels and in the pond were similar (Tables 2 and 3). The frequencies of juveniles were 51, 72 and 60% for the three years. Most individuals were caught at Hotels 3 (184) and 4 (185), and fewest at Hotel 1 (40) and Hotel 2 (61). The length distribution of Smooth Newts in 2015 shows that younger age groups are represented (Figure 3). The relatively low proportion of the smallest (30–50 mm), which is the youngest cohort (0+), is probably due to poor recruitment in 2014. In June to September in 2014 Lahelldammen had only 20% water volume compared to a normal year due to agricultural irrigation.

Table 1. Temperature (Minimum temperature °C = Min, Average = Av, Standard deviation = SD) and number of days with temperature below zero in the core of Hotels 1–4 and outside the hotels (Outdoor) during October 15 to April 15, 2013–2015.

Place	2012/13				2013/14				2014/15			
	Min	Av	SD	No. of Days below Zero	Min	Av	SD	No. of Days below Zero	Min	Av	SD	No. of Days below Zero
Hotel 1	1.2	3.2	2.1	0	0.0	3.4	1.9	0	−0.5	4.1	2.5	2
Hotel 2	−2.5	2.2	3.4	88	−0.6	3.7	2.2	1	−0.3	3.2	2.9	1
Hotel 3	−0.8	2.2	2.7	36	0.9	4.1	2.1	0	−1.1	3.6	2.5	2
Hotel 4	−6.9	0.8	3.7	93	−1.7	4.0	2.7	3	−2.8	3.4	3.4	23
Outdoor	−22.0	−2.7	4.8	148	−13.4	2.4	5.0	86	−15.0	2.0	5.3	93

Table 2. Number of adults (Ad.) and juveniles (Juv.) of Great Crested *Triturus cristatus* (Tc) and Smooth *Lissotriton vulgaris* (Lv) newts observed per meter on the road around the Lahelldammen pond during spring and autumn for sections North, East, South and West in 2013 (see Figure 1). The lengths of the sections are shown in parentheses, and the total numbers of individuals observed (Total No.) are given.

Species	Season	North (130 m)	East (90 m)	South (150 m)	West (130 m)	Total No.
Tc Ad.	**Spring**	0.49	0.58	0.65	0.23	254
Tc Juv.		0.05	0.04	0.04	0.01	18
Lv Ad.		3.52	4.15	5.37	0.79	1740
Lv Juv.		0.02	0.00	0.00	0.00	2
Tc Ad.	**Autumn**	0.00	0.00	0.00	0.00	0
Tc Juv.		0.43	0.20	0.24	0.38	162
Lv Ad.		0.02	0.00	0.02	0.02	9
Lv Juv.		0.04	0.02	0.02	0.05	15

Table 3. Numbers of adults (Ad.) and juveniles (Juv.) of Great Crested *Triturus cristatus* (Tc) and Smooth *Lissotriton vulgaris* (Lv) newts observed outside Hotels 1–4 in 2013–2015. The total numbers are given, with the numbers in H1, H2, H3 and H4 provided in parenthesis.

Year	Tc		Lv		Total
	Ad.	Juv.	Ad.	Juv.	Ad. + Juv.
2013	3 (0, 2, 1, 0)	19 (0, 1, 17, 1)	29 (1, 10, 13, 5)	30 (0, 0, 29, 1)	81 (1, 13, 60, 7)
2014	7 (6, 0,1, 0)	15 (3, 2, 1, 9)	35 (2, 8, 18, 7)	90 (0, 18, 2, 70)	147 (11, 28, 22, 86)
2015	4 (1, 2, 0, 1)	9 (2, 2, 5, 0)	91 (6, 7, 33, 45)	138 (19, 9, 64, 46)	242 (28, 20, 102, 92)
Total	**14**	**43**	**155**	**258**	**470**

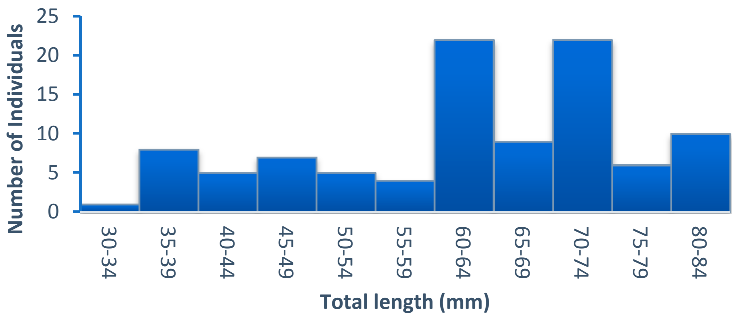

Figure 3. Length distribution of Smooth Newts observed at hotels in 2015 (No. of individuals = 99).

4. Discussion

Our experiences from three seasons with newt hotels were positive and showed that they can serve as a good measure to support both Great Crested and Smooth newt populations. Fifty-seven Great Crested Newts and 413 Smooth Newts used the hotels for hibernation. The ratio between the number of Great Crested and Smooth newts using the hotels was close to the population estimates for the two species. The newts' use of the hotels increased throughout the period, while the number of breeding individuals in Lahelldammen remained stable. The proportion of juveniles varied between 51% and 72% during the period, probably reflecting the variation in recruitment between years. The use of the hotels by Great Crested and Smooth newts increased faster and was more extensive than previously observed [21,22].

The location of the hotels probably impacted the degree to which they were used for hibernation. Hotel 2 was placed in the migration route for animals overwintering in the East, while Hotel 1 was placed at the edge of a forest in the West, where relatively few migrating individual adult newts, but relatively many juvenile Great Crested Newts, have been recorded. Hotels 3 and 4 were located in the woods to the West, with few records of migrating adults and juveniles. These two hotels have probably the best location in terms of habitat quality for summer use and winter hibernation [4,15,31].

Newts hibernate close to a breeding pond if local refuges and food are abundant in habitat adjacent to the pond [32]. Adult newts are known to return to the same hibernating locality and this implies that newts leave and enter the pond in the same area or route year after year [32]. The variation in migration distances from a few meters up to 1300 m probably reflects an adaptive flexibility in response to site-specific variation in habitat conditions [3,4,15,16,20,33].

The construction of hotels was similar to those used in the United Kingdom [1,2], but dug below ground level and with a thicker cover to avoid frost.

The winter temperature in southern Norway is low and measured down to −22.0 °C outside the hotels in 2013. Newts hibernating on the ground only covered by leaves may suffer high mortality if the snow cover is lacking in this area. The temperature inside the hotels was higher than outside, even though minimum temperature in Hotel 4 was −6.9 °C in 2013. The temperatures were measured at the lowest point inside each hotel, with only a thin stone layer below. The hotels probably support microhabitats that are warmer than the temperatures registered. Except for 2013, temperatures within the hotels were above freezing during winter. Both Great Crested Newts and Smooth Newts may survive this temperature as examples of both species were caught outside the hotel in spring. Newts may tolerate lower winter temperatures than frogs [34,35], and some newt species may survive slow cooling down from 0 to −6 °C [36]. A slow cooling in combination with the osmotic pressure and glycerol in the body fluids may involve only extracellular freezing without intracellular formation of ice crystals. The minimum temperature varied between the hotels, and did probably depend on the construction, with Hotels 1 and 2 having the highest minimum temperature. These hotels were dug into the ground in a slope and this is probably favorable in the harsh climate.

5. Conservation Implications and Recommendations

The Great Crested Newt population has experienced decline in many European countries [37,38], whereas the Smooth Newt is still widespread and locally abundant [39–42]. Many newt species are listed as endangered [43], and methods to improve their habitat and survival are important. Newt hotels may substantially improve conditions for newts in urban and agricultural areas. The hotels in this study were used shortly after construction, and when hibernation space is bottleneck this will enhance the newt population.

The choice of location is important to ascertain the effect of newt hotels quickly and optimally. If located close to the pond, migration distance, predation and desiccation risk during migration are reduced [32,44]. It is also important to avoid road crossings or other obstacles that may increase mortality. Additionally, it should be considered that newts, both adults and juveniles, tend to be oriented towards forests when leaving the pond [17].

The choice of hotel location must take into account the cause of population decline, whether it is due to road constructions or other infrastructure measures, or whether it is due to the need for habitat improvements in natural habitats. In both cases, knowledge is required of migration routes and hibernation facilities as well as the important population regulation factors.

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Conflicts of Interest: The animals were captured with permission from the Directorate for Nature Management (ref. 2012/3515 ART–VI–ID). The authors declare no conflicts of interest.

Appendix A

Year-specific population size estimates were based on capture–mark–recapture data, using the Chapman estimator:

$$\hat{N} = \frac{(K+1)\,(n+1)}{k+1} - 1$$

where K is the marked individuals at the first capture occasion, n is total individuals captured at the second capture occasion and k is the number of marked individuals at the second capture occasion. The variance was calculated as:

$$\text{Var}\,(\hat{N}) = \frac{(K+1)(n+1)(K-k)(n-k)}{\frac{(k+1)^2}{(k+2)}}$$

Appendix B

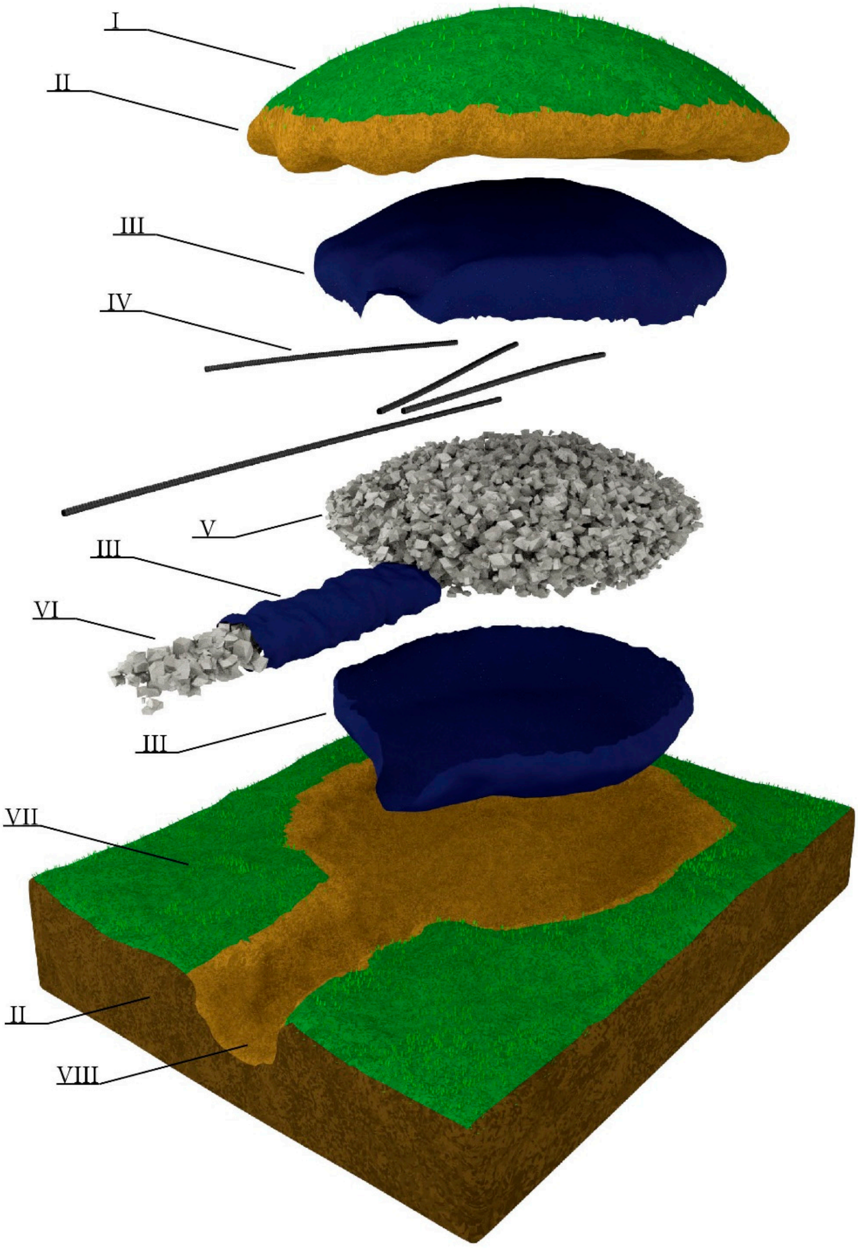

Figure A1. 3D model showing the different layers of Hotel 2. I & VII = vegetation, II = soil, III = geotextiles, IV = drainage pipes, V = stones 2–30 cm diameter, VI = rock-filled channel, VIII = drainage channel.

Appendix C

Figure A2. Photos of excavator at work during construction of Hotel 2 (**top left**), drainage pipes, geotextiles and rocks of Hotel 1 (**top right**), and final result of Hotel 1 (**mid left**), Hotel 2 (**mid right**), Hotel 3 (**bottom left**) and Hotel 4 (**bottom right**).

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