THE CHARACTERISTICS OF GREAT CRESTED NEWT TRITURUS CRISTATUS' BREEDING PONDS

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PROJECT REPORT

"Protection of *Triturus cristatus* in the Eastern Baltic region"
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INTRODUCTION

Since 1989, approximately 4,000 ponds have been dug and restored in Denmark, 3,800 of which are situated in more or less open landscapes and 200 in the forest. Half of the Danish ponds have been dug with the aim to improve the landscape for amphibians in general, and another half to improve the breeding conditions of rare and endangered amphibian species *Pelobates fuscus, Hyla arborea, Rana dalmatina, Triturus alpestris and Bombina bombina*.

Triturus cristatus still remains quite a widespread species in Denmark – although the species has not been provided with custom-made breeding ponds, it can often be found living with *Pelobates fuscus, Hyla arborea, Triturus alpestris, Bombina bombina* and *Rana dalmatina*. Thus, *Triturus cristatus* benefits from the improvement of the habitat conditions of those species. Nevertheless, it is necessary to examine the effectiveness of colonisation of *Triturus cristatus* into those ponds and what effect these ponds have on the conservation of *Triturus cristatus*.

As *Triturus cristatus* is a target species of LIFE-nature project "Protection of *Triturus cristatus* in the Eastern Baltic region", the ponds' investigation was specially tailored to the demands of this particular species. Although the general principles in restoring and creating *Triturus cristatus* breeding ponds are commonly known, current habitat restoration has not paid much attention to such matters as the location of pond clusters in respect to the rest of the landscape, optimal pond density, the structure of a meta-population and its restoration. The pond inventory and the evaluation of occupation of the dug and restored ponds, as was done in the frame of the investigation reported here, provides new knowledge that helps to determine which water bodies *Triturus cristatus* prefers, what the key characteristics of those ponds are, how densely the water bodies should be situated, which structure and type of ponds is characteristic of a viable meta-population, and in which surrounding they can best be situated.

The investigation and evaluation of dug and restored ponds in Denmark was carried out in four different landscape types: in forest, semi-natural habitats, mosaic landscape with extensive agriculture and on a territory with intensive agriculture. Those areas (except the land with intensive agriculture) are the reference areas for *Triturus cristatus*' habitat creation and protection in Finland and Estonia (and subsequently for Latvia and Lithuania) in the frame of the above-mentioned LIFE project. Moreover, the investigation was carried out in landscapes, representing the four basic *Triturus cristatus* habitat types in Denmark. Denmark is in the centre of the range of *Triturus cristatus* in North European Lowland, close to other countries with similar habitats, climate and land use, such as Germany, England, the Netherlands, Belgium, Northern France and Western Poland. However, results gained in the intensive agriculture areas are also becoming relevant for Baltic countries in the current years, as the agriculture there is intensifying after joining the EU. The investigation of ponds was carried out in cooperation with experts from Denmark, Estonia, Finland, Germany and the Netherlands.

DESCRIPTION OF THE SPECIES

Although the investigation and evaluation of dug and restored ponds was specially tailored to the demands of *Triturus cristatus*, the habitat demands of two other *Triturus* species (*T. vulgaris* and *T. alpestris*), as well as *Pelobates fuscus,* were taken into account and compared with the demands of *Triturus cristatus*.

Triturus cristatus

Triturus cristatus has a dark brown body with black spots and conspicuous white tubercles on the sides and legs. The underside is usually yellow or orange with a variable pattern of black blotches that tend to be more numerous anteriorly. The throat is dark with white stippling. Breeding males have a pale whitish or bluish stripe along the middle of the tail, one on each side, while females have an orange line along the lower edge of the tail. The skin is obviously warty in texture. Breeding males develop a jagged crest along the body and tail and this is deeply indented at the base of the tail, a feature by which it is easy to distinguish *Triturus cristatus* from *Triturus vulgaris*, as the latter does not have this interruption in the crest. Females can attain a total length of about 160 mm and males usually reach a length of 14-15 cm (Edgar and Bird 2006).

Triturus cristatus is predominantly nocturnal during both its terrestrial and aquatic phases. This nocturnal tendency is more pronounced than in the smaller species of European newts, in which active breeding often occurs during the day, especially in shady ponds (Edgar and Bird 2006). It spends an average of five months of the year in water (Arntzen and Wallis 1999).
Triturus cristatus hibernates on land. Newly emerged juveniles live on land until they reach sexual maturity, a process that takes two to three years, after which they return to water to breed (Edgar and Bird 2006).

Triturus vulgaris

Triturus vulgaris is a small, smooth-skinned newt. It often has a characteristic ventral pattern. The belly of the newt is typically bright orange or yellow with well-developed dark spots, which usually extend onto the throat. Breeding females are brown or yellow-brown above, often with small dark spots. Breeding males develop large dark spots above the side and a continuous crest on the tail and body. The lower edge of the tail is usually orange with a light bluish streak above. Terrestrial animals have dry velvety skin and are paler than in the aquatic phase. *Triturus vulgaris* is very widespread and the most common newt over much of its range. It is more terrestrial than any other species of European newts. On land, it occurs in a wide variety of damp habitats (Arnold and Burton 1980).

Triturus alpestris

Triturus alpestris is a medium-sized newt, females reach up to about 12 cm including the tale; males are smaller. It is usually identifiable by distinctive colouring: dark above with uniformed deep yellow or red belly. Males are grey, bluish to blackish above, usually

with darker markings and they have a fine chequered white-black line on the centre of the back. Females are often more brown and more uniform, but they have a marble pattern on the upper part of the body. They frequently have numerous small spots along the flank, often set on a light ground in males. The belly is almost always unmarked, but sometimes they have little black spots in the throat region. The skin of terrestrial animals is velvety (smooth or granular in water). Breeding males have a low, smooth-edged yellowish crest, barred or spotted with black (Arnold and Burton 1980).
Triturus alpestris is very aquatic and nearly always in or near water. The species occurs commonly in woodlands (Arnold and Burton 1980).

Pelobates fuscus

Pelobates fuscus is a plump, smooth-skinned toad with large eyes and vertical pupils. It has a large pale-coloured spade on the hind foot, which is more or less fully webbed, and a well-marked lump on top of the head just behind the level of the eyes. Adults are up to about 8 cm, but usually smaller. Males tend to be smaller than females. The colour of the upper side is extremely variable: grey, pale-brown, yellowish or whitish with darker brownish markings. Sides and sometimes also the back often have small orange spots. Eyes are golden, orange or coppery. The specimens often smell strongly of garlic (Arnold and Burton 1980).
Pelobates fuscus is a nocturnal toad, not emerging until after sunset, particularly active in wet weather. During the breeding season it is partly diurnal. Breeding males produce a repeated clicking, ‘c’lock-c’lock-c’lock, under water (Arnold and Burton 1980). They are very terrestrial amphibians. The terrestrial habitat normally has patches of open sand.

INVESTIGATION AREA

The investigation was carried out in five Danish counties: Vejle, Viborg, South Jutland, Fynen and West Zealand. The majority of the investigated ponds were situated in Vejle and Viborg counties, and only some additional ponds were inventoried in the rest of the counties.

Intensive agriculture and the deciduous beach woodlands on clay soils dominate the eastern part of Vejle County. The western part is dominated mainly by intensive agricultural land on mixed sandy and clay soils. There are also deciduous woodlands, coniferous plantations, heath and grasslands present in the county.
Viborg County is dominated by intensive agriculture on a mixture of sandy and clay soils. Other habitats consist of deciduous woodlands, coniferous plantations, heaths and grasslands.

The investigation area in South Jutland County consists of deciduous woodlands on clay soils. Additional 8 ponds were investigated in agricultural areas on clay soils in West Zealand County and Fynen County.

Management strategies for habitat improvement

In the frame of local amphibian protection and habitat improvement, active management has been carried out in the investigated areas. The management strategies of small water bodies in the three counties where the largest number of ponds was investigated (Vejle, Viborg and South Jutland) have been rather different. In Vejle, the management of small water bodies has been targeted directly at those ponds and areas where *Pelobates fuscus* and *Hyla arborea* were present. The selection of sites for management has been based on expert visits and yearly monitoring programs of amphibians. In South Jutland County, the same methods have been used, but the target species has been *Triturus alpestris*. In Viborg County, the management of small water bodies has been carried out in the areas where *Pelobates fuscus* was found during surveys in 1992 and 1996, but the ponds for management have not been pointed out by herpetological experts there, as it was done in Vejle and South Jutland counties.
In Fynen and West Zealand counties, no special pond management has been carried out in the areas where the investigation took place.

METHODS

Selection of investigated sites

The investigation and evaluation of dug and restored ponds in Denmark was carried out in four different landscape types: in the forest, in semi-natural habitats, in mosaic landscape with extensive agriculture and on a territory with intensive agriculture. These activities took place in five counties: Vejle, Viborg, South Jutland, Fyn and West Zeland (see Annex 1). Moreover, in Vejle and Viborg counties, aquatic habitat management (restoration and digging of small water bodies) has been carried out especially for *Pelobates fuscus* and *Hyla arborea*. Also, the conditions in those counties could be described as typical to Denmark in terms of soil types (clay, sand peat) and habitat types in the surrounding of the water bodies.

The ponds chosen for this investigation were all situated in the areas where *Triturus cristatus* populations were detected in 2004 and/or 2005, and where the pond management (restoration and digging) began in the period from 1992 to 1996. The exact ponds selected for the investigation were ponds where *Triturus cristatus* was found (during 1990–2005) or that had been restored or dug since 1992. Ponds in South Jutland County were included only because, in addition to two other newt species, *Triturus alpestris* also occurs in this county.

Altogether 210 ponds were investigated; out of these, 90 ponds were restored or dug anew in the period from 1992 to 2002. The majority of the ponds were chosen from Vejle County (N =124) and Viborg County (N = 63).

Data collection

An international group of herpetological experts from Denmark, Estonia, Finland, Germany and the Netherlands carried out the investigation in late June-July, 2004–2005. Only in South Jutland County the ponds were investigated in August 2005. The main method for investigating amphibians in the ponds was dipnetting of larvae. At least 10 catches were made in different parts of each pond. If *Triturus cristatus* larvae were not caught after 10 dip-netting attempts, but the water quality was good and there was also suitable soft-leaved vegetation in the pond, some additional caches were made. Thus, the presence of the species in the pond was mainly determined by the presence of larvae. Nevertheless, in several cases some adult newts were also caught. A special form for each pond was filled out (see Annex 2) featuring data on the physical characteristics of the pond, water quality, sediment, vegetation, amphibian species in the pond, as well as the habitats in the surroundings of the investigated pond.

Data analysis

The gathered data was analysed by means of data mining that summarises the data and presents the main patterns. It meets this target by listing the relations between all the values in each field and the dependent variable. The method employs an evolutionary algorithm that segments numeric fields in an optimal way and displays the relation between each interval and the value under analysis. The results are presented by the association rules, which are formulated as “if-then” sentences.
In addition to data mining the hypotheses of the researchers were checked using the Chi-square test.
Median smoothing was used to find the description of the typical pond among all of the ponds and the ponds with the habitat of *Triturus cristatus*. Comparing these descriptions gives us additional insight to what kind of environment *Triturus cristatus* prefers.

RESULTS

1. Physical parameters of the breeding ponds

1.1. Size of the pond

The sizes of investigated ponds were in the range of 14 m^2 up to 11,550 m^2. Most of the ponds were smaller then 700 m^2 (Table 1). Within the smaller ponds (14 m^2–672 m^2), a very high occupancy of *Triturus cristatus* (74%) was recorded in the ponds ranging between 124 m^2 and 198 m^2. In general, the ponds ranging between 124 m^2 and 672 m^2 had a 56%-occupancy of *Triturus cristatus*, the ponds below 124 m^2 had occupancy of 40% and the ponds bigger than 672 m^2 had occupancy of 39%. The size of the ponds with the highest occurrence of *Triturus cristatus* was generally between 124 m^2 and 672 m^2 (χ^2 = 8.38, p = 0.0038).

Table 1. Size of the investigated ponds in relation to the occurrence of *Triturus cristatus*

Pond category	Pond size (m^2)	Number of investigated ponds	Presence of *Triturus cristatus* (%)
14–672 m^2	< 124	39	40
	124-198	23	74
	124-672	77	56
> 672 m^2	> 672	71	39

1.2. Maximum depth of water

The maximum depth of water in the ponds was estimated in three intervals: 0–0.5 m; 0.5–1 m and more than 1 m. *Triturus cristatus* was found mainly (in 54% of the cases) in the ponds where the maximum depth of water was 0.5–1 m. The total number of such ponds was 93. In ponds deeper than 1 m (N = 52), *Triturus cristatus* was found in 55% of the cases. *Triturus cristatus* was also found (in 43% of the cases) in the ponds with shallow water (maximum depth up to 0.5 m; N = 21). As the investigation of ponds was carried out mainly in June and July, the water table of the ponds was probably lower than in spring when the eggs were laid.

1.3. Slopes

In the cases where the pond was completely flat (inclination 0°), the occupation of *Triturus cristatus* was rather low (27%). Although *Triturus cristatus* was present in 53% of the ponds with slopes from 2° up to 90°, it preferred ponds with slopes 20°- 40° and tended to avoid ponds with slopes steeper than 40° ($\chi^2 = 6.39$, $p = 0.012$).

1.4. Zones with shallow water

Looking at the area of shallow water (up to 50 cm) in the ponds, it became obvious that the ponds without any shallow water (N = 62) did have a significantly lower occupancy of *Triturus cristatus* (27.4 %) than ponds with at least 0.1 m of shallow water zone (N = 148; occupied by *Triturus cristatus* 55.4 %; $\chi^2 = 13.73$, $p = 0.0002$). Where the zone of shallow water was larger, it was more likely to find *Triturus cristatus* larvae in the pond ($\chi^2 = 6.95$, $p = 0.008$; table 2).

Table 2. Size of shallow water zone (≤ 50 cm) in the ponds in relation to the occurrence of *Triturus cristatus*

Shallow zone (m^2)	Number of investigated ponds	Presence of *Triturus cristatus* (%)
0–28	84	34.5
32–70	24	54.2
72–110	30	56.7
114–150	13	53.8
151–190	9	55.6

The area of shallow water in the pond was also estimated as a percentage of the total pond area. In 73 ponds, the zone of shallow water was below 6 % of the total and

Triturus cristatus was found only in 28.8% of such cases (Table 3). The highest occupation of *Triturus cristatus* (66.1%) was recorded in the ponds with 26% to 70% of shallow water. Thus, the situation is most optimal for *Triturus cristatus* when the shallow water covers 25% to 70% of the total area of the pond ($\chi^2 = 15.75$, p = 0.0001).

Table 3. Percentage of shallow water zone (≤ 50 cm) in relation to the occurrence of *Triturus cristatus*

Area of shallow water (%)	Number of investigated ponds	Presence of *Triturus cristatus* (%)
< 6	73	28.8
7–25	43	55.8
26–70	56	66.1
73–100	38	44.7

Additionally, the location of the shallow water zone was analysed in the ponds. The analyses revealed that the presence of shallow water area in all parts of the pond had significant connection to the presence of *Triturus cristatus* in the pond. If the zone of shallow water was more than 1 m wide, in the western part of the pond, the probability to find *Triturus cristatus* in this pond was statistically significant ($\chi^2 = 4.03$, p = 0.045). It was also important to have more than 1 m wide shallow water zone in the southern ($\chi^2 = 4.65$, p = 0.031), eastern ($\chi^2 = 6.16$, p = 0.013), and particularly northern ($\chi^2 = 10.09$, p = 0.0015) part of the pond. In 138 ponds, the width of shallow water in the northern part of the pond was 0 to 1.2 m, and *Triturus cristatus* occupied 39% of such ponds (Table 4). If the shallow zone in the northern part was 1.5 to 6 m wide, the occurrence of *Triturus cristatus* was 65.5%. The conditions seem to be more optimal for *Triturus cristatus* if the zone of shallow water is at least 1.50 m wide in the northern part of the pond.

Table 4. Width of the shallow zone (≤ 50 cm) in the northern part of the pond in relation to the occurrence of *Triturus cristatus*

Width of shallow zone	Number of investigated ponds	Presence of *Triturus cristatus* (%)
0–1.2 m	138	39.1
1.5–6 m	60	65.5
7–30 m	12	50.0

2. Geology and water quality

2.1. Sediment

The sediment recorded in the ponds was clay, mud, sand or peat. *Triturus cristatus* was found in 64% of the ponds with sandy bottom (Table 5). The ponds with clay bottom had *Triturus cristatus* in 58% of the cases. The species was found in the ponds with muddy bottom in 44% of cases and in the ponds with peat sediment only in 24% of cases. *Triturus cristatus* occurs mainly in ponds with sandy or clay bottom, compared to ponds with muddy or peaty sediment ($\chi^2 = 9.64$, p = 0.0019).

Table 5. Sediment of pond bottom in relation to the occurrence of *Triturus cristatus*

Bottom sediment	Number of investigated ponds	Presence of *Triturus cristatus* (%)
Sand	22	64
Clay	71	58
Mud	80	44
Peat	37	24

2.2. Water clarity and colour

The clarity and colour of water in each investigated pond was noted. The main categories to describe this parameter were the following: clear, brown (which is often caused by humus rich sediment), muddy or algae-green.
117 ponds with clear water had *Triturus cristatus* in 57.3 % of the cases. When the water was muddy, brown or algae-green, *Triturus cristatus* was found only in 30–37% of the cases (N = 93). *Triturus cristatus* obviously prefers ponds with clear water instead of ponds with unclear water ($\chi^2 = 10.86$, p = 0.0010).

3. Surrounding habitats

3.1. Buffer zone

The width of the buffer zone around the pond was measured. The buffer zone was defined as an area of any type of habitat around the pond, except cultivated land. It became obvious that *Triturus cristatus* preferred ponds with such a buffer zone. The analysis showed that *Triturus cristatus* occurred only in 35 - 37% of the ponds that had a buffer zone up to 5 m around the ponds (N = 132). If the buffer zone was wider than 5 m, the species was present in 60 to 80% of the ponds (N = 86). The conditions are definitely most optimal for *Triturus cristatus* if the buffer zone is more than 5 m wide on all sides of the pond ($\chi^2 = 15.02$, p = 0.0001).

3.2. Terrestrial habitat within a 50 m radius around the pond

The habitat complexes within a 50 m radius around the pond were analysed and compared to the occurrence of *Triturus cristatus* in the ponds (see Table 6). In 85 cases, deciduous forest was present within a 50 m radius around the pond and *Triturus cristatus* was found in 58.8% of those ponds. In 124 cases there was no deciduous forest within a 50 m radius around the pond and the occupancy of *Triturus cristatus* was only 39.5%. *Triturus cristatus* preferred the presence of deciduous forest in the surroundings of the pond ($\chi^2 = 6.92$, p = 0.0085).

Coniferous forest was present within a 50 m radius in 33 cases; 69.7% of those ponds were occupied by *Triturus cristatus* (Table 6). In the 176 cases were coniferous forest did not occur within a 50 m radius around the pond, *Triturus cristatus* was found in 43.2% of the cases. *Triturus cristatus* preferred coniferous forest in the surroundings of the pond ($\chi^2 = 7.84$, p = 0.0051).

Densely vegetated type of shrub was present within a 50 m radius around the pond in 62 cases and *Triturus cristatus* occurred in 38.7% of these ponds (Table 6). In 147 cases there was no shrub recorded within a 50 m radius around the pond and the occurrence of *Triturus cristatus* was 51%. The analyses did not reveal any significant preferences by *Triturus cristatus* concerning the presence or absence of shrub within the 50 m surroundings the pond ($\chi^2 = 2.65$, $p = 0.1$).

The presence of deadwood within 50 m surrounding the pond was noted in 16 cases and *Triturus cristatus* was found in 68.8% of those ponds (Table 6). In 193, cases no deadwood was found within the 50 m surrounding the pond and *Triturus cristatus* occurred in 45.6% of those cases. Even if *Triturus cristatus* seemed to prefer ponds with some deadwood in the surroundings, this did not turn out to be statistically significant ($\chi^2 = 3.11$, $p = 0.078$).

Fields were present in 105 cases within a 50 m radius around the pond and *Triturus cristatus* occupied the ponds in 51.4% of the cases (Table 6). The fields were not present in 104 cases and the occurrence of *Triturus cristatus* was 43.3%. The occurrence of fields in the surroundings of the ponds did not have any statistically significant impact on the presence of *Triturus cristatus* ($\chi^2 = 1.40$, $p = 0.2$).

Grassland occurred in 68 cases within a 50 m radius and *Triturus cristatus* was found in 58.8% of those cases (Table 6). In 141 cases, grassland was not present within a 50 m radius and *Triturus cristatus* occurred in these ponds in 41.8% of the ponds. *Triturus cristatus* preferred the presence of grassland within a 50 m radius around the pond ($\chi^2 = 5.31$, $p = 0.021$).

Grazing in the surroundings of the ponds was also observed. Two types of grazing were taken into account:
1) extensive grazing without any use of agrochemicals;
2) intensive grazing with the use of fertilisers and/or pesticides.
There were 26 ponds situated in the area with extensive grazing within a 50 m radius of the pond, and *Triturus cristatus* occurred in 65.4% of these ponds (Table 6). Intensive grazing within a 50 m radius around the pond was recorded in 21 cases, and *Triturus cristatus* occurred in 38.1% of these ponds. In 140 cases, the area within a 50 m radius of the pond was not grazed and the occurrence of *Triturus cristatus* was 49.3%. *Triturus cristatus* preferred ponds with extensive grazing within a 50 m radius around the pond, rather than ponds surrounded with intensively grazed areas or areas without any grazing ($\chi^2 = 3.87$, $p = 0.049$).

Urban areas occurred in the surroundings of the ponds in 30 cases and *Triturus cristatus* was found in 50% of such situations (Table 6). In 146 cases there were no urban areas within a 50 m radius of the pond and *Triturus cristatus* occurred in 46.9% of these situations. *Triturus cristatus* tended to be rather neutral to the presence or absence of urban areas in the surroundings of the ponds ($\chi^2 = 0.10$, $p = 0.8$).

Table 6. Different habitat types within a 50 m radius of the investigated ponds in relation to the occurrence of *Triturus cristatus*

Habitat type	Number of investigated ponds	Presence of *Triturus cristatus* (%)
Deciduous forest within 50 m	85	**58.8**
No deciduous forest within 50 m	124	39.5
Coniferous forest within 50 m	33	**69.7**
No coniferous forest within 50 m	176	43.2
Dense shrub within 50 m	62	38.7
No dense shrub within 50 m	147	51.0
Deadwood within 50 m	16	**68.8**
No deadwood within 50 m	193	45.6
Fields within 50 m	105	51.4
No fields within 50 m	104	43.3
Grassland within 50 m	68	**58.8**
No grassland within 50 m	141	41.8
Extensive grazing, no agrochemicals, within 50 m	26	**65.4**
Intensive grazing within 50 m	21	38.1
No grazing within 50 m	140	49.3
Urban areas within 50 m	30	50.0
No urban areas within 50 m	146	46.9

The results of our investigation indicated that the habitat complex within a 50 m radius around the pond is essential for *Triturus cristatus*. Extensively grazed areas, coniferous forest, deciduous forest and grassland in general were the favoured habitats for *Triturus cristatus*. The presence of deadwood within a 50 m radius around the pond also had a positive effect on *Triturus cristatus*. On the other hand, intensively grazed grasslands within a 50 m radius around the pond where unfavourable habitats for *Triturus cristatus*. Fewer ponds were also occupied when there was no deciduous forest in the close, 50-metre surroundings of the pond. Urban areas, shrub, and fields in the surroundings of the ponds did not have any significant influence on the occurrence of *Triturus cristatus*.

3.3. Terrestrial habitat in the radius of 50 to 500 m around the pond

The habitats recorded in the radius further than 50 m away from the pond and up to 500 m around the pond were deciduous and coniferous forest, urban areas, grasslands and fields. The presence of the above-mentioned habitats further than 50 m from the pond did not have any influence on the occurrence of *Triturus cristatus* ($\chi^2 = 0.12$, $p = 0.7$).
The terrestrial habitats further than 50 m from the pond had minimum influence on the occurrence of *Triturus cristatus* compared to the habitat features within a 50 m radius around the ponds.

3.4. Distance between the pond and the forest

Distance between the pond and the forest was also analysed. In 82 cases, the pond was situated in the forest or directly on the edge of the forest. In these cases *Triturus cristatus* occurred in 47.6% of the ponds. In 41 cases the pond was 2 to 80 m away from the forest, and *Triturus cristatus* occurred in 68.3% of such ponds. In 41 cases the distance between the pond and the forest was 100 to 400 m, and *Triturus cristatus* was present in 48.8% of such cases. In 45 cases, the forest was situated 450–2,000 m from the pond and the occurrence of *Triturus cristatus* was down to 26.7%.

It can be concluded that in most cases it is favourable for the *Triturus cristatus* population that forest is nearby, 2 to 80 m away from the aquatic habitat ($\chi^2 = 7.10$, $p = 0.0077$). The rate of *Triturus cristatus* occupancy in the ponds falls as distance from the forest increases. At the same time, it is not the most optimal case if the pond is situated inside the forest, with trees on the edges.

3.5. Other ponds within 100 m

Other ponds were recorded within a 100 m range from the analysed pond only in 13 cases. In 7 cases, only one pond was situated in this area and the occurrence of *Triturus cristatus* was 71.4%. In 6 cases, there were 3 to 5 ponds within a 100 m range of the analysed pond, and *Triturus cristatus* was found in 50% of those cases. For all 13 cases, when there were other ponds present within 100 m from the analysed pond, the occupancy of *Triturus cristatus* was an average of 61%. In comparison, in 196 cases there were no other ponds within 100 m from the analysed pond, and *Triturus cristatus* occurred in 46.4% of those cases.

Based on the few examples in this study, *Triturus cristatus* seemed to prefer ponds that are situated in clusters. Nevertheless, the small set of data (N = 13) did not allow us to get any statistically significant results of this analysis.

3.6. Distance between the breeding pond and other ponds

In addition to the above-mentioned, cases where the adjacent ponds were found further than 100 m from the investigated pond were analysed. The distances taken into account were more than 100 m and up to 200 m (N = 13), 200 to 500 m (N = 11) and 500 to 800 m (N = 9). Unfortunately, this analysis did not give any relevant results, which might be explained by the small set of data available.

4. Biotic factors

4.1. Shade provided by trees over the pond

Shade provided by trees over the pond was recorded in five different categories: 0%, 25%, 50%, 75% and 100% shade. If there was no shade over the pond, *Triturus cristatus* was found in 48.9% of the ponds (Table 7). If shade covered 25% of the pond surface, the occurrence of *Triturus cristatus* was 49%. In ponds with 50%, 75% or 100% shade cover, the occurrence of *Triturus cristatus* was 53.8%.

Based on the data available, it seemed that the presence or absence of shade over the pond surface and its extent did not have any influence on the occurrence of *Triturus cristatus* (χ^2 = 0.05, p = 0.8). Nevertheless, it must be noted that only a few ponds had 75% or 100% shade.

Table 7. Presence of *Triturus cristatus* in relation to the extent of shade over the water surface

Shade (%)	Number of investigated ponds	Presence of *Triturus cristatus* (%)
0	94	48.9
25	49	49.0
50, 75 or 100	26	53.8

4.2. Vegetation

The vegetation present in the ponds was divided into four groups:

1. Vegetation higher than 1 m
2. Vegetation lower that 1 m
3. Floating vegetation
4. Submerged vegetation

The percentage of the coverage of each group was estimated and recorded in the field.

It was analysed whether the height of the vegetation influenced the presence of *Triturus cristatus* in the ponds or not, and which type of vegetation is preferred by newts and which not. Finally, the dominating species of floating and submerged vegetation in the ponds were analysed, since newts need both type of plants for egg-laying as well as for larvae forage.

4.2.1. Vegetation higher than 1 m

In ponds with no vegetation higher than 1 m, the occurrence of *Triturus cristatus* was 48.3% (Table 8). In 48.0% of the cases the species was found in the ponds where vegetation higher than 1 m covered 10% of the surface. If this particular vegetation cover was more than 10% of the pond surface, the presence of *Triturus cristatus* declined and the species was found only in 37.5% of the cases. Nevertheless, the occurrence of *Triturus cristatus* had not significant association with presence of high vegetation in the pond (χ^2 = 0.99, p = 0.3).

Table 8. Vegetation higher than 1 m in the pond in relation to the occurrence of *Triturus cristatus*

Vegetation higher than 1m	Number of ponds investigated	Presence of *Triturus cristatus* (%)
None	60	48.3
Less than 10% of water	75	48.0
More than 10% of water	32	37.5

4.2.2. Vegetation lower than 1 m

In the cases where the vegetation less than 1 m tall was not found in the ponds at all, the presence of *Triturus cristatus* was 32% (Table 9). As this vegetation cover started to increase, the occurrence of *Triturus cristatus* also rose. In ponds where vegetation less than 1 m tall covered 10% of the surface, *Triturus cristatus* was present in 49.5% of the cases. When vegetation covered 25% of the pond surface, the presence of the species was the highest (63%). *Triturus cristatus* preferred the presence of vegetation lower than 1 m in the ponds ($\chi^2 = 4.89$, p = 0.027).

Table 9. Vegetation lower than 1 m in the pond in relation to the occurrence of *Triturus cristatus*

Vegetation lower than 1m	Number of ponds investigated	Presence of *Triturus cristatus* (%)
None	34	32.0
Less than 10% of water surface	91	49.5
25% of water surface	27	63.0
50% of water surface	30	56.7

4.2.3. Low vegetation on the edges of the pond

Low vegetation on the edges of the pond is important for newts, particularly in terms of egg-laying. *Mentha sp.*, *Myosotis scorpioides* and *Callitriche sp.* have been used by *Triturus cristatus* for egg-laying. *Mentha sp.* was absent in 60 ponds, and *Triturus cristatus* was found only in 33.3% of such ponds (Table 10). In the ponds where *Mentha sp.* was present, the occurrence of *Triturus cristatus* was 63.6%.

If *Myosotis scorpioides* was not present in the pond, *Triturus cristatus* occurred in 34% of the cases. If *Myosotis scorpioides* occurred with a maximum cover of 1% of the pond, the presence of *Triturus cristatus* was 50%. Moreover, if *Myosotis scorpioides* covered 1 to 10% of the pond area, *Triturus cristatus* occurred in 66.7% of the cases.

Callitriche sp. grows often on the edge of the pond but can also occasionally grow further out among the submerged vegetation. If *Callitriche sp*. did not occur in the pond, the presence of *Triturus cristatus* was 33.3%. If *Callitriche sp*. did grow in the ponds, *Triturus cristatus* occurred in 53.3% of such water bodies. In general, it was more likely to find *Triturus cristatus* in the ponds with low vegetation present, than in ponds without low vegetation on the edges of the pond ($\chi^2 = 12.01$, p = 0.0005).

Table 10. Presence of plants that are regularly used for depositing eggs in relation to the occurrence of *Triturus cristatus*

Presence/absence of plant species and its cover	Number of investigated ponds	Presence of *Triturus cristatus* (%)
No *Mentha sp.*	60	33.3
Mentha sp.	22	63.6
No *Myosotis scorpioides*	53	34.0
Myosotis scorpioides max 1%	52	50.0
Myosotis scorpioides max 1–10%	9	66.7
No *Callitriche sp.*	60	33.3
Callitriche sp. max 1–10%	15	53.3

4.2.4. Floating vegetation cover

Floating vegetation cover was estimated in terms of its percentage of water surface in each pond. *Triturus cristatus* occurred in 70% of the ponds where floating vegetation covered 50% of the water surface (Table 11). The ponds where floating vegetation formed 25% of the water surface had *Triturus cristatus* in 59% of the cases. If the floating vegetation covered 100% of the water surface, the presence of *Triturus cristatus* was 56%. In most of the investigated ponds, floating vegetation covered 10% of the water table. In such ponds, *Triturus cristatus* occurred in 52% of the cases. Ponds without floating vegetation had *Triturus cristatus* in 32% of the cases. Thus, *Triturus cristatus* preferred ponds with floating vegetation to ponds without floating vegetation ($\chi^2 = 5.87$, $p = 0.015$).

Table 11. The coverage of floating vegetation in relation to the occurrence of *Triturus cristatus*

Coverage of floating vegetation (%)	Number of investigated ponds	Presence of *Triturus cristatus* (%)
100	18	56
50	27	70
25	22	59
10	62	52
0	28	32

4.2.5. Composition of floating vegetation

Glyceria fluitans often occurred among the floating vegetation in the ponds. In 36 cases there were no *Glyceria fluitans* in the ponds and *Triturus cristatus* occurred in 27.8% of these ponds. Even if *Glyceria fluitans* was present to the maximum extent of only 1% of vegetation cover (N = 36), *Triturus cristatus* occurred in 61% of theses ponds. If *Glyceria fluitans* covered 1% to 10% of the area of water surface (N = 60), *Triturus cristatus* occurred in 50% of the cases. *Glyceria fluitans* covered more than 10% in only 18 cases, and in 72.2% of those cases *Triturus cristatus* occurred. The results of this study showed that *Triturus cristatus* preferred ponds with this plant species as opposed to ponds without it ($\chi^2 = 9.36$, $p = 0.0022$).

Potamogeton natans like *Glyceria fluitans* is a typical plant species forming floating vegetation in small ponds. In the 33 cases where there was no *Potamogeton natans*, *Triturus cristatus* occurred in 24.2 % of such ponds. In the 105 cases *Potamogeton natans* was a part of the floating vegetation cover in the pond, *Triturus cristatus* occurred in 54.4% of the cases. Thus, *Triturus cristatus* preferred ponds with *Potamogeton natans* compared to ponds without this plant species ($\chi^2 = 9.10$, $p = 0.0026$).

4.2.6. Submerged vegetation

Submerged vegetation was missing in 69 ponds and in these cases the occurrence of *Triturus cristatus* was 44.9%.
Where the submerged vegetation coverage was 10% of the pond area (N = 75), *Triturus cristatus* occurred in 48% of the cases. In the cases where the submerged vegetation covered 25%, 75% or 100% of the pond area (N = 32), *Triturus cristatus* was found in 61.1% of such ponds. Even though *Triturus cristatus* seemed to prefer ponds that had submerged vegetation coverage of more than 25%, it did not have any significant influence on the occurrence of *Triturus cristatus* compared to the ponds without submerged vegetation ($\chi^2 = 1.38$, $p = 0.2$).

5. Other fauna

5.1. Fish

35 ponds out of all investigated ponds (N = 210) had fish in them. *Triturus cristatus* was found in 99 ponds and only in one single pond *Triturus cristatus* was present together with fish. In this case it was an adult newt, not larvae. In general, if there were fish in the ponds, *Triturus cristatus* did not occur ($\chi^2 = 33.06$, $p < 0.0001$).

5.2. Amphibians

In addition to *Triturus cristatus*, the presence of other amphibian species was recorded during the inventory in each examined pond. Those species were *Triturus vulgaris, Triturus alpestris, Pelobates fuscus, Hyla arborea, Rana temporaria, Rana arvalis* and *Bufo bufo*.
Analyses were conducted to discover the relation between the occurrence of *Triturus cristatus* and the other two *Triturus* species *Triturus vulgaris* and *Ttriturus alpestris*, as well as *Pelobates fuscus*.

5.2.1. Triturus vulgaris

Triturus vulgaris was found in 136 (64.8%) ponds out of all 210 investigated ponds.
In 64% of the cases (N = 87), *Triturus vulgaris* coexisted with *Triturus cristatus* and in 36% (N = 49) of the cases they did not coexist.

In the case of *Triturus vulgaris*, the presence of shallow water in the pond was essential. The sediment of the ponds was preferably sand or clay and the water had to be clear.
Triturus vulgaris preferred ponds with floating vegetation covering at least 10% out of the total water surface. *Potamogeton natans* and *Glyceria fluitans* often occurred in the ponds with *Triturus vulgaris*. A large coverage of submerged vegetation (25–100%) was preferred to a lower coverage ($\chi^2 = 5.45$, p = 0.019).

Extensive grazing in the surroundings of the pond had a positive effect on the occurrence of *Triturus vulgaris*. Another positive feature was the distance between the pond and the forest being between 2 to 150 m, instead of the pond being situated directly in the forest or more than 150 m away from the forest. Grassland, coniferous and deciduous forest within a 50 m radius around the pond had a positive effect on the occurrence of *Triturus vulgaris*. Shrub within a 50 m radius around the pond had a slightly positive effect as well. Urban area and field within a 50 m radius around the pond as well as the occurrence of deadwood was rather neutral in relation to *Triturus vulgaris*.
The existence of a buffer zone around the pond was important. It must be at least 5 m wide, but in 80.2% of the cases (N = 86), the buffer zone was even wider (up to 200 m).

5.2.2. Triturus alpestris

Triturus alpestris was found in 13 ponds (87%) out of the 15 water bodies that were investigated in South Jytland County. In 84% of the cases (N = 10), *Triturus cristatus* was found in the same ponds with *Triturus alpestris* and in 75% of the cases (N = 9), all three newt species were found in the same pond.

Triturus alpestris tended to occur in smaller ponds than *Triturus cristatus*. In 12 cases out of 13, *Triturus alpestris* was found in the ponds with an area of 13 m^2 – 124 m^2. The largest pond where the species was found was 186 m^2. Most of the ponds were covered with floating vegetation, which in 53.8% of the cases (N = 7) was dominated by *Lemna minor*. In 6 cases, *Potamogeton natans* was present in the ponds. *Glyceria sp.* was also found in the ponds (N = 9), but always to a smaller extent (not more than 10%) than the other above-mentioned species.
All the ponds in which *Triturus alpestris* was found were situated in deciduous forest. They were covered by shade to the extent of at least 25%, and the bottom of the ponds consisted of either clay or mud. The water in the ponds was clear (50%) or muddy (50%). Vegetation taller than 1 m was not usually found in the ponds. Submerged vegetation was often missing. If it was present, the main species were *Hottonia palustris* and *Potamogeton pectinatus*.

5.2.3. Pelobates fuscus

At least 75 investigated ponds occurred within a 5 km range of the areas where *Pelobates fuscus* was distributed. *Pelobates fuscus* larvae were found only in 7 ponds. The larvae of *Pelobates fuscus* and *Triturus cristatus* coexisted in 5 ponds out of 7 (71.4%). Unfortunately, the analyses did not give any relevant results, which might be explained by the small set of data available.

6. Management of the ponds

During the investigation, *Triturus cristatus* was found in 99 ponds out of 210. The species occurred in 16 (25.4%) out of 63 ponds in Viborg County, in 10 (66.7%) out of 15 ponds in South Jutland County and in 68 (54.8%) ponds out of 124 in Vejle County. Our study revealed that there is a relatively low probability of finding *Triturus cristatus* in the ponds in Viborg County compared to the ponds in Vejle or South Jutland counties ($\chi^2 = 16.44$, $p = 0.0001$).

6.1. Ponds without management

Ponds without any conservation management were also analysed. The ponds that are defined as not managed are the ponds that conservation authorities have not dug or restored in the landscape. Those are simply ponds in the landscape, which can be natural depressions or ponds artificially created (cattle watering ponds, ponds dug for hunting, marl or peat ponds) by local people. In total, our inventory included 108 such ponds. *Triturus cristatus* was found in 38% of such ponds. In Viborg County, there were 48 ponds without conservation management, and the presence of *Triturus cristatus* was 20.8%. 45 ponds in Vejle County were without management, and *Triturus cristatus* was found in 47% of such ponds.

6.2. Restoration of ponds

A number of ponds have been restored with the purpose of improving mainly the breeding conditions of *Pelobates fuscus* and *Hyla arborea.* Among all investigated ponds, the number of restored ponds was 53. *Triturus cristatus* occurred in 58.5% of restored ponds. The greatest number of restored ponds (N = 39) was found in Vejle County, and 14 restored ponds were found in Viborg County. In Vejle County, *Triturus cristatus* occurred in 25 restored ponds (64%) and in Viborg County, the species was found in 6 restored ponds (43%).

In Viborg County, a relatively larger number of *Triturus cristatus* was in the restored ponds than in ponds without any management (targeted at the improvement of the breeding conditions of amphibians). *Triturus cristatus* was found in 43% of the restored ponds and in 21% of the ponds without any management (N = 48).

In Vejle County, also a relatively larger number of *Triturus cristatus* was found in restored ponds than in ponds without management. The species occurred in 64% of the restored ponds and in 47% of the ponds without any management (N = 45). In both counties it was more likely to find *Triturus cristatus* in the restored ponds than in ponds without any conservation management ($\chi^2 = 5.20$, $p = 0.023$).

6.3. New dug ponds

A number of ponds were dug with the purpose to improve the breeding conditions of *Pelobates fuscus* and *Triturus cristatus*. During the pond investigation, a total 47 new dug

ponds were inventoried in Vejle, Viborg and South Jytland counties. *Triturus cristatus* was found in 58% of all the newly dug ponds.
The amount of new dug ponds was 38 in Vejle County, 8 in South Jutland County and only 1 in Viborg County.
In Vejle County, 53% (N = 20) of the new dug ponds were colonised by *Triturus cristatus*; in South Jutland County, 63% (N = 5) were colonised, and in Viborg County, the only existing new dug pond was not colonised by *Triturus cristatus*.

The results showed that in general, within 5 to 10 years after the pond digging more than half of the ponds were colonised by *Triturus cristatus*. In all counties it was more likely to find *Triturus cristatus* in the new dug ponds than in ponds without any conservation management (χ^2 = 5.13, p = 0.024). In general, comparing the presence of *Triturus cristatus* in managed and unmanaged ponds, the species occurs more likely in managed than unmanaged ponds (χ^2 = 7.53, p = 0.0061).

DISCUSSION

Physical parameters of the ponds

The inventory of small water bodies in four Danish counties showed that *Triturus cristatus* could occur in very small ponds (14 m^2) but also in rather large ones (11,550 m^2). The highest perceptual occurrence was in the ponds with an area between 124 m^2 and 672 m^2. The reasons for lower occurrence in ponds below 124 m^2 can be explained by the fact that in small ponds the space for a complete habitat complex is not always available. The habitat complex consists of areas with shallow water with egg-laying plants, deeper water where adults can hide in daytime and an area of open water or open water between floating vegetation, where the larvae can hunt for prey. In the ponds with the size of 124 m^2 up to 672 m^2, there is probably enough space for all three life stages of *Triturus cristatus*: eggs, larvae and adults.

In ponds larger than 672 m^2, the occurrence of fish starts to be more common. The negative correlation between the abundance of embryos of newts and the pond size has been observed (Sztatecny *et al.* 2004). Joly *et al*. (2001) have also detected a negative relationship between pond area and the abundance of newts. Pond area has also been shown to adversely affect survival, growth rate, and mass at metamorphosis of anuran tadpoles. The increase of pond size is related to the increase of the incidence of predators (Pearman, 1993). *Triturus cristatus* is vulnerable to predatory fish, as the larvae tend to swim in open water, rather than staying on the bottom or concealed in vegetation like other newt species. A range of carnivorous invertebrates and waterfowl such as ducks also eat the larvae (Edgar and Bird 2006). Fish exclude the breeding of *Triturus cristatus* (Joly *et al.* 2001). Moreover, larger ponds have a larger possibility to become eutrophicated since they might be a part of a water course/ditch/drainage system and thereby receive nutrient rich water more easily.

The results of this inventory showed that *Triturus alpestris* tended to occur in much smaller ponds (13 m^2 – 124 m^2) than *Triturus cristatus*. *Triturus vulgaris* was found in larger ponds, but never in very large ponds, such as those of 11,550 m^2, where *Triturus cristatus* was found.

A relatively larger number of *Triturus cristatus* was recorded in ponds with a maximum depth of over 0.5 m, compared to ponds with less deep water. *Triturus cristatus* was not found in completely flat ponds (slopes 0°); it preferred ponds with 20° slopes and tended to avoid ponds with slopes steeper than 45°. At the same time, the existence of shallow water (max depth 0.5 m) near the edges of the ponds was crucial for *Triturus cristatus*. The species occurred mainly in the ponds were the zone of shallow water formed 26–79% of the total surface area. Shallow water in the pond is important for the growth of the typical egg-laying plants. Furthermore, the importance of shallow water in the breeding ponds might be connected to the embryonic and larval development of the newts. The larvae of *Triturus cristatus* usually develop more rapidly in shallow and warmer water than in deeper and cooler water. Moreover, our study showed that a zone with shallow water, at least 1.50 m wide, in the northern part of the breeding pond was essential for *Triturus cristatus.* Although the presence of shallow water in all parts of the pond influenced the occurrence of *Triturus cristatus*, having a shallow water zone towards the north played the most important part. The importance of shallow water towards the north can be explained by the possible need for the warmest water for the rapid egg and young larvae development. The northern side of the pond is often most exposed to the sun.

Geological and water quality parameters

The pond bottom should preferably have a mineral character (sand or clay) instead of an organic one (mud or peat). A similar preference has also been recorded in the United Kingdom, where the species is most numerous in clay areas, and in the Netherlands where most of *Triturus cristatus* populations occur in clay or loam soil (Edgar and Bird 2006).

In our study *Triturus cristatus* was mainly found in the ponds with clear water, compared to ponds with muddy, brown or algae-green water. This phenomenon can be explained by the breeding habit of the newt because the adults need clear water to display. The clear water is also important for foraging, both for adults and larvae. Brown water also has often enough good visibility for adults to display and adults/larvae to feed. Still, brown water can sometimes be too acid for the development of eggs and can be less productive with food organisms. The muddy and algae-green water are both negative because of bad visibility and poor water quality. Oxygen content is often too low in such ponds for the hatching of eggs and development of larvae. Mineral soils (clay and sand) might be related to clear water, whereas muddy and peaty soils might cause brown, algae-green and muddy water. Drainage pipes leading water into ponds, steep slopes with run-off, organic garbage on pond edges and the presence of fish can spoil the clarity of water. All these influences can create muddy, algae-green or brown water even in ponds on clay soils.

Pond surroundings

The investigation showed that the surroundings of the ponds within 50 m influenced the presence of *Triturus cristatus* more than the surroundings further than 50 m away. It can be explained by the fact that *Triturus cristatus* does not exhibit long distance migratory behaviour (Edgar and Bird 2006). Also, Jehle (2000) has found that more than 50% of adult newts leaving breeding ponds utilised refuges within 15 m of the water and that 95% could be found within 50 m of the pond. The maximum distance covered by newts in that study was 95 m, although Kupfer (1998) has recorded movements between 230 and 1,290 m in a more open agricultural landscape. Work on juveniles has found that they may disperse up to 860 m from the pond after metamorphosis, with the average distance moved being 254 m (Kupfer and Kneitz 2000). Another reason why the quality of the first 50-m zone around the pond plays an important role in the occurrence of *Triturus cristatus* could be that land use within a 50 m radius around the pond has the biggest influence on water quality and thereby the reproduction possibilities for *Triturus cristatus*.
The presence of forest (deciduous or coniferous), deadwood or extensively grazed grasslands within a 50 m radius around the pond had a positive influence on *Triturus cristatus*. At the same time, the presence of intensively grazed grasslands exhibited a negative influence. The presence of scrub, urban areas, fields and other types of grasslands around the pond had a neutral effect on the occurrence of *Triturus cristatus*. Nevertheless, in France the cultivated fields around *Triturus cristatus* ponds have had a negative effect on the presence of the species (Joly *et al*. 2001).

Buffer zones of at least 5 m of uncultivated land around the ponds had a positive effect on the occurrence of *Triturus cristatus* compared to buffer zones below 5 m. The investigation of *Triturus cristatus* ponds carried out in France (Joly *et al*. 2001) showed that the existence of uncultivated buffer zones between ponds and forest was important. Moreover, newts preferred the ponds with a larger angle (sector) of the buffer zone towards the forest – the larger the angle was, the better (Joly *et al*. 2001). Our investigation showed that *Triturus cristatus* preferred ponds that were situated rather close to the forest. 68.3% of the ponds that were 2–80 m away from the forest had *Triturus cristatus* in them.

Based on the few examples in this study, *Triturus cristatus* seemed to prefer ponds that are situated in clusters (meaning that other ponds are found within a 100 m radius in an area of about 100 ha around the investigated pond). Nevertheless, the small set of data did not allow us to draw any statistically significant results from the analysis. In France, it has been found that the vicinity of other ponds within 50 ha from *Triturus cristatus* ponds has produced a positive effect (Joly *et al*. 2001).

Flora and shade

The results of our investigation at Danish sites do not reveal a relationship with the extent of shade in the pond. Most of the ponds investigated had 25%, 50% and 75% shade, and no effect on occurrence of *Triturus cristatus* was recorded. As very few ponds had 100% shade, it might be that those very shaded ponds had some negative effect on *Triturus* *cristatus*. The study carried out in France (Joly *et al.* 2001) showed that intermediate shade coverage was favoured by *Triturus cristatus*, but in Denmark it was different. It could be the case that this relatively northern species does benefit from some shade in the southern part of the distribution range.

There was a clear relation between the amount of floating vegetation and the presence of *Triturus cristatus* larvae. *Triturus cristatus* found an intermediate amount of floating vegetation (cover of 50%) more optimal than the ponds with less or more floating vegetation cover. Furthermore, the analysis of low vegetation around the edges of the pond showed that *Triturus cristatus* favours ponds with such vegetation over ponds without it. At the same time, the presence or absence of submerged vegetation in the pond did not have any significant influence on the occurrence of *Triturus cristatus*. Nevertheless, the species tended to prefer ponds that had submerged vegetation cover of more than 25%. In France, *Triturus cristatus* preferred ponds with intermediate shade and floating vegetation (Joly *et al.* 2001). The preference of intermediate vegetation cover by this newt species fits to with investigation and can be explained by larval behaviour. The larvae need both: the floating vegetation cover to hide and open water to hunt its prey.

In Denmark, the coverage of swamp vegetation less that 1 m high was an advantage compared to no such vegetation. In contrast, the presence of vegetation taller than 1 m, covering more that 10% of the pond, had a negative impact on the presence of *Triturus cristatus* compared to the situation where this type of vegetation covered less than 10% of the pond. This can be explained by the fact that tall vegetation begins to shadow the pond and thus makes the water cold. Moreover, vegetation taller than 1 m often includes *Typha latifolia*, *Typha angustifolia* or *Phragmites australis*, which means that these tall and nutrient-demanding plants often grow in ponds that have been exposed to eutrophication from households or nutrients coming from fields. Thus, tall vegetation can indicate eutrophication of the pond.

Aquatic vegetation provides a food source for prey organisms, refuge from predators, and a substrate for egg-laying. The egg-laying plants whose presence was recorded in our investigation were *Glyceria fluitans, Myosotis sp., Callitriche sp., Mentha sp.* and *Potamogeton natans*. *Myosotis scorpiodes, Glyceria fluitans* and various *Callitriche* species are particularly favoured by *Triturus cristatus* for egg-laying (Edgar and Bird 2006). In their studies, Miaud (1995) and Sztatecny *et al.* (2004) have noted the particular importance of *Glyceria fluitans* as a substrate for egg-laying.

Our study showed that *Triturus cristatus* preferred ponds with floating vegetation, particularly with *Potamogeton natans* and *Glyceria fluitans* compared to ponds without those plant species. If *Myosotis sp.* or *Mentha sp.* occurred in the pond, there was a bigger probability to find *Triturus cristatus* in the pond. Those two species grow in the zone of shallow water in the pond, which means that the existence of such a shallow zone is essential in the breeding ponds of *Triturus cristatus*. However, beyond a certain plant density indicating an advanced stage of succession, ponds become unsuitable for newts, as aquatic space gets restricted and drying probability increases (Oldham *et al*. 2000).

Other fauna

Fish were present in the pond in 35 cases, and in all those cases there were no larvae of *Triturus cristatus* found in the ponds. The adult *Triturus cristatus* occurred only in one out of the 35 ponds with fish. Fish exclude the breeding of *Triturus cristatus* because the larvae have a pelagic behaviour and are thus exposed to predators (Joly *et al.* 2001, Sztatecny *et al.* 2004, Edgar and Bird 2006).

Other amphibians

During the investigation, the larvae or adults of 7 amphibian species were recorded. These species were *Triturus vulgaris, Triturus cristatus, Triturus alpestris, Pelobates fuscus, Hyla arborea, Rana temporaria, Rana arvalis* and *Bufo bufo*.

Pelobates fuscus larvae occurred only in 7 ponds. Interestingly, in 71% of these ponds the larvae of *Pelobates fuscus* and *Triturus cristatus* coexisted. This indicates that these two species often occur together and that species management actions can be targeted at both species simultaneously. However, the predatory character of *Triturus cristatus* adults should be taken into account while designing the pond. The coexistence of *Triturus cristatus* and *Hyla arborea* larvae was also noted in several cases in ponds that were managed for the conservation of *Hyla arborea*.

This investigation did reveal some differences in the habitat demands of *Triturus* species in Denmark. *Triturus alpetris* was only found in very small ponds with an area of less than 200 m^2 that were always situated inside deciduous forest. It seems like *Triturus alpetris* cannot occur in open landscapes in Denmark.
Triturus vulgaris was found in 65% of the investigated ponds and was always a more common species than *Triturus cristatus* in all investigation areas. This indicates that *Triturus vulgaris* is more flexible in terms of habitats and has a wider niche both in aquatic and terrestrial habitats. *Triturus vulgaris* often coexisted with *Triturus cristatus* in the same ponds (64%). In the case of *Triturus vulgaris*, the statistics did not reveal such specific habitat demands as were noticed for *Triturus cristatus*, especially in terms of aquatic habitat. Nevertheless, the existence of shallow water and the presence of submerged vegetation (25% to 100%) was essential for *Triturus vulgaris*. In terms of terrestrial habitat, it was preferable to have deciduous and coniferous forest, shrub or extensive grazing within a 50 m radius around the pond. A buffer zone of at least 5 m in width was also favoured compared to the situations without a buffer zone or with one of less than 5 m.

Pond management

The management of ponds (restoration and digging new ponds) had a positive effect on amphibians in all counties: Vejle, Viborg and South Jutland. There was a significantly higher probability to find *Triturus cristatus* in ponds where some management was done than in ponds without any management. Thus, it was concluded that it is positive for *Triturus cristatus* and amphibians in general to restore ponds or dig some new ones, compared to doing nothing. The restoration and creation sets the succession stage of the pond back to the beginning stage. The occurrence of *Triturus cristatus* is dependent on the succession stage of the pond rather than the occurrence of suitable patches of habitats (Sztatecny *et al.* 2004). Therefore, pond management (restoration and digging new ponds) should be planned over a longer period in order to secure a set of ponds with different succession stages in one area.

CONCLUSIONS

Triturus cristatus occurs in a wide range of pond and landscape types in Denmark. The species was found in 99 out of 210 investigated ponds; however, this investigation points out some key parameters that seem to be more important than others.
It can be concluded that the following parameters are positive to the occurrence of *Triturus cristatus*; when planning the management of aquatic and terrestrial habitat, attention should be paid to the following parameters:

Aquatic habitat

- Although all ponds with a size larger than 10 m^2 can function as *Triturus cristatus* breeding sites, it is often an advantage if pond size is between 124 m^2 and 672 m^2.

- There must be a zone of shallow water (with a width of 1.5 m or more) in the pond and it should preferably be present in the northern part of the pond.

- In most cases, but not always, it is an advantage if there is a deeper part in the pond (deeper than 0.5 m).

- The slopes toward the pond should be at an angle of more than 0° (preferably not over 45°).

- The bottom of the pond should consist of clay or sand instead of peat or mud.

- Water should be clear or brown-clear instead of brown-unclear, algae-green or muddy.

- There should be no inlets and agricultural run-off should be very reduced in order to limit eutrophication of the pond and optimise the clarity of the water.

- The presence of egg-laying plants such as *Glyceria fluitans, Myosotis sp., and Callitriche sp.* in the pond is essential for the occurrence of *Triturus cristatus*.

- *Triturus cristatus* prefers ponds with a floating vegetation cover of about 50% of the pond surface, rather than ponds with very little or total coverage (100%) of floating vegetation.

- Swamp vegetation should preferably consist of plants less than 1 m high. If swamp vegetation consists of plants more than 1 m high, the coverage of those plants should not exceed 10% of the pond surface.

- Shade over the pond does not have a negative impact on the species, as long as it covers less than 75% of the surface.

Terrestrial habitat

- There should be a buffer zone of at least 5 m wide, preferably more, of uncultivated land around the pond.

- The presence of forest (deciduous or coniferous), deadwood or extensively grazed grasslands within a 50 m radius around the pond has a positive influence on the occurrence of *Triturus cristatus*.

- *Triturus cristatus* had a higher occurrence in the ponds that were situated between 2 and 80 m away from the forest, rather than in ponds pond situated inside the forest or more than 80 m away from the forest.

- There should be at least one additional pond within a 100 m radius around a *Triturus cristatus* breeding pond, forming a small pond cluster.

Fauna

- *Triturus cristatus* breeds almost exclusively in water bodies without fish.

- *Triturus cristatus* can breed in the same ponds with *Triturus alpestris, Triturus vulgaris, Pelobates fuscus*, *Hyla arborea*, *Rana temporaria*, *Rana arvalis* and *Bufo bufo*.

Management

- The newt will colonise well-designed new ponds in areas with populations of *Triturus cristatus* sooner or later, depending on the strength of the populations.

- It is preferable to restore ponds instead of doing nothing in order to improve the breeding conditions of *Triturus cristatus* and increase their population.

- In general, *Triturus cristatus* benefits from the restoration and creation of ponds in Danish landscapes instead of doing nothing.

- Besides using well-known pond restoration and digging techniques, the above-mentioned positive parameters for the aquatic and terrestrial habitats should be taken into account in order to achieve successful habitat management at *Triturus cristatus* breeding sites.

NB! Natural ponds in a landscape with special habitat communities, rare and isolated flora and fauna should not be restored if the restoration can result in an elimination of such habitats and species.

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