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Amphibian and reptile distribution in forests adjacent to watercourses

Fördelning av amfibier och reptiler i skogar runt vattendrag

Biology
D-level

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Abstract

Worldwide amphibians and reptiles are declining with habitat fragmentation and destruction as the primary cause. Riparian areas are important for the herpetofauna, but as land is converted to agriculture or harvested for timber the areas are diminishing. The aim of this study was to examine amphibian and reptile abundance in relation to distance from water and in relation to habitat characteristics, foremost per cent deciduous trees. The survey was conducted during spring at six different locations, with continuous forest along streams or rivers, outside of Karlstad, Sweden. Animals were searched along four lines parallel to the water and each study area was visited five times. Statistical analyses were made for grass snake (*Natrix natrix*), common lizard (*Lacerta vivipara*) and frogs with joined data of common frog (*Rana temporaria*) and moor frog (*R. arvalis*). As expected both reptiles were positively correlated with per cent deciduous trees, with the strongest significance for the common lizard. For grass snake there was also a difference between survey periods, which might reflect the importance of weather. Frogs revealed no trends to trees, but there was a significant difference for habitat characteristics like amount woody debris and per cent bare ground. None of the species were correlated with distance from water which was surprising, especially for the frogs which is more dependent on water than the reptiles. Grass snakes hunt in the water, but the common lizard has no such associations to the water, yet the latter did reveal a slight trend towards being more numerous closer to the water. The causes behind lacking correlation to distance from water may be many, but water characteristics seem very important. Many amphibians prefer warm and calm ponds over running water that in general are colder and likely to inhabit more predators. It was assumed that the amphibians breed in the streams or rivers, but it is possible that other water bodies may have served as breeding sites, which mean the starting point was incorrect.

Sammanfattning

Värden över minskar antalet amfibier och reptiler och den främsta orsaken anses vara habitatfragmentering och förstörelse. Strandnära områden är viktiga för herpetofaunan, men allt eftersom land konverteras till jordbruk eller avverkas för timmer minskar de områdena. Syftet med studien var att undersöka förekomsten av amfibier och reptiler i förhållande till avstånd från vatten och i relation till habitatets utformning, framför allt procent lövträd. Undersökningen genomfördes under våren på sex olika lokaler, med kontinuerlig skog längs med vattendrag, utanför Karlstad, Sverige. Djur letades utefter fyra linjer, parallella med vattnet, och varje lokal besöktes fem gånger. Statistiska analyser genomfördes för snok (*Natrix natrix*), skogsödla (*Lacerta vivipara*) och grodor, med gemensam data för vanlig groda (*Rana temporaria*) och åkergroda (*R. arvalis*). Båda reptilerna var som väntat positivt korrelerade till procent lövträd, med starkast signifikans för skogsödla. För snoken var det även skillnad mellan undersökningsomgång, vilket eventuellt avspeglar vädrets betydelse. Grodorna uppvisade ingen trend gentemot andel lövträd, men de hade signifikanta skillnader för habitatets struktur, som mängd ris och procent bar mark. Ingen av arterna var korrelerad med avstånd till vatten, vilket var förvånande, speciellt för grodorna eftersom de är mer beroende av vatten än vad reptilerna är. Skogsödlan är inte associerad till vatten som exempelvis snoken som jagar i vatten, ändå visade skogsödlan en svag trend till att vara mer talrik närmare vattnet. Bristen på korrelation till avstånd från vatten kan ha många bakomliggande orsaker, men vattnets karaktär verkar väldigt viktig. Många amfibier föredrar varma och stillsamma dammar över rinnande vatten som i regel är kallare och har fler predatorer. Det var antaget att amfibierna lekte i det rinnande vattnet, men det är möjligt att de lekte i andra vatten, vilket innebär att utgångspunkten var fel.

Introduction

Globally both amphibians (Alford and Richards 1999; Nyström et al. 2007) and reptiles (Gibbons et al. 2000 in Loehle 2005) are declining and with only a few exceptions do the European amphibians follow the same trend (Loman and Andersson 2007). The entire Swedish herpetofauna are protected and 12 out of a total of 19 species are considered threatened. One case of drastic decline is that of the common spadefoot (*Pelobates fuscus*) which over the past decades has reduced both in abundance and in the number of occupied ponds in Sweden (Berglund 1998 and Nyström et al. 2002 in Nyström et al. 2007). It is estimated that amphibians have an average annual mortality level up to 95% (Spellerberg 2002) and factors contributing to the global decline are many and do often work synergistically, like diseases, habitat fragmentation and destruction, predation, environmental acidity, toxins and changes in climate and weather (Alford and Richards 1999).

Habitat destruction and fragmentation are considered the most important factors for the amphibian decline (Alford and Richards 1999) and a literature review by Vos and Chardon (1998) revealed a negative effect of fragmentation for all amphibians in all landscapes examined, but there may be effects yet to discover. Disturbed habitats around ponds are less favored by male rana lemur (*Phyllomedusa tarsius*) than continuous forest and as they remain fewer days in disturbed habitats they are in general smaller as a result of the poorer habitat quality (Neckel-Oliveira and Gascon 2006). The effect of individual size on fitness is not investigated (Neckel-Oliveira and Gascon 2006), but smaller females of common frog (*Rana temporaria)* tend to produce smaller ova than larger females, which may be disadvantageous as there are greater risks associated with smaller ova (Gibbons and McCarthy 1986 in Neckel-Oliveira and Gascon 2006). The result of Johansson et al. (2007) suggests that larvae from continuous landscape have a higher fitness than those from fragmented landscapes.

The level of isolation can be regarded as the combination of distance between suitable habitats and the resistance of the landscape between the habitats (Vos and Chardon 1998). As species have different movement capability, habitat fragmentation affects them differently (Ficetola and De Bernardi 2004). Many amphibians and reptiles utilize resources separated in time and space, resulting in movements between aquatic and terrestrial habitats (Pauley et al. 2000). Land without cover, like clearcuts or agricultural land, is often avoided by amphibians and their dispersal become inhibited (Mazerolle and Desrochers 2005 in Nyström et al. 2007). As amphibians are relatively ground dwelling do even roads constitute an important barrier and Vos and Chardon (1998) has demonstrated that road density has a negative effect on pond occupancy of moor frogs (*Rana arvalis*). It has been recorded that road mortality during migrations of the common toad (*Bufo bufo*) can be as high as 45% (Spellerberg 2002)

The amphibian movement pattern are influenced by breeding type and a study of the Appalachian salamanders by Petranka and Smith (2005) revealed a significant difference in the use of microhabitats between terrestrial and aquatic breeders. While there were no trends for the terrestrial breeders, the abundance of aquatic breeders declined progressively with distance from water. Amphibian movements are also influenced by the individual size and females of the boreal toad (*Bufo boreas*) tend to move further upland than males, who are generally smaller than females (Goates et al. 2007). Smaller conspecifics of terrestrial breeders were more associated with water, which may be influenced by insufficient time to disperse for recently metamorphosed animals, or the fact that smaller individuals are more vulnerable to desiccation (Petranka and Smith 2005). Several studies have reported that amphibian activity may be influenced by weather conditions and an increase in activity during rainy periods have been documented in common frog, moor frog, pool frog (*Rana lessonae*) (Sjögren-Gulve 1998; Lomans 1979) and adult tailed frogs who remained in close proximity to the water during dry seasons and migrated further from the water during wet seasons (Noble and Putman 1931 in Gomez and Anthony 1996).

Riparian areas have characteristics of both terrestrial and aquatic ecosystems and there is a variety of definitions. According to Welsch et al. (2000) it can be summarized as a "three-dimensional ecotone of interaction that includes the terrestrial and aquatic ecosystems, that extends down into the groundwater, up above the canopy, outward across the floodplain, up to the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at a variable width." Riparian areas have unique properties which in general make them more structurally diverse than the rest of the landscape and they are often associated with a higher abundance and diversity of wildlife (Hannon et al. 2002). However riparian areas are vulnerable to perturbations (Pauley et al. 2000) and historically they have been managed for protection of aquatic species like mussels and fishes, and for the quality of drinking water (Petranka and Smith 2005). The importance of riparian areas to terrestrial species is becoming clearer and according to Ohmart and Anderson (1986 in Pauley et al. 2000) amphibians and reptiles are of more importance as indicators than mammals and birds in riparian ecosystems. Yet, research on riparian habitats has mainly focused on birds and mammals, while amphibians and reptiles have been overlooked. Information on hydrophilic snakes is very limited (Pauley et al. 2000) and studies of amphibians in riparian habitats have focused on pond-breeding species (Smith and Green 2005 and Cushman 2006 in Olson et al. 2007).

Information on reptile habitat preference is not comprehensive, the common lizard (*Lacerta vivipara*) has been found in dry, humid and wet habitats with either open or dense vegetation. It was generally more numerous in shady spots in open environments, in open spots in densely vegetated areas and on drier spots in humid habitats (Strijbosch 1988). The lizard preferred birch trees over pine trees, but showed most preference for shrubs over isolated trees, however the form of trees and bushes may be of more importance than the species as different shapes creates different gradients between sun and shade (Strijbosch 1988). Like the lizard does the grass snake prefer shrubs and bushes and even though the habitat covered less than one per cent of the study area in Madsen (1984) research, 87% of the grass snakes were located in dense stands of blackberry bushes (*Rubus fruticosus*) and/or blackthorn bushes (*Prunus spinosa*) in close proximity to stone fences.

The first objective is to examine reptile and amphibian abundance in relation to distance from water and expected results are to observe fewer animals with greater distance from the water. All Swedish amphibians are aquatic breeders (Spellerberg 2002), but some amphibians migrate to upland habitats. After spawning does the common toad migrate, sometimes up to 1600 m from the breeding pond, to the feeding area where they stay relatively locally restricted during the summer (Sinsch 1988). Many amphibians have been recorded to disperse great distances, see Semlitsch and Bodie (2003) for an extensive review. There will most probably be exceptions to the hypothesis since grass snake (*Natrix natrix*) is the only Swedish reptile that is associated with water (Karlsson and Jonsson 2005).

The second objective is to examine herpetofauna abundance in relation to characteristics of riparian and upland forests and expected result is to observe more animals in deciduous stands than in coniferous stands. Amphibians tend to prefer wet deciduous forests with stands of alder and ash, and were in Pikulik et al. (2001) study uncommon in drier mixed forest. The common toad was the only species inhabiting drier forests and though present in very small amount, it had the broadest habitat range.

Method

This report was intended to be incorporated in a larger study, an international cooperation on the faunal distribution in forests around streams and rivers. The survey was conducted between 5th May and 18th July. The activity of most amphibians and reptiles increase in May after the breeding period and some migrates to feeding habitats (Spellerberg 2002). As reptiles are heliothermic, they are active during the day whereas the amphibians are predominantly nocturnal (Spellerberg 2002). Juvenile amphibians tend to be more day active than adults, which might be explained by the fact that adult frogs prey on juvenile frogs (Loman 1979). Work in the field was conducted during day time.

Sampling design

Four lines parallel to the water were paced out at distances 10, 40, 70 and 100 m from the water (Fig. 1). The maximal length was where possible 400 m and each line were marked with ribbons every 20 m. Other aid in the survey was a walking stick, a net and a modified ruler to find, catch and measure the animals.

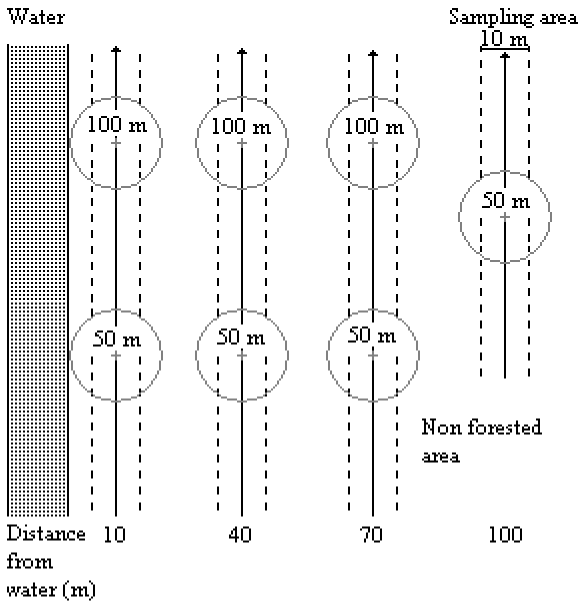

Fig. 1. Example of sample design of herpetofauna (within broken lines) and vegetation (within circle) in a study area.

Sampling of herpetofauna was made within the sampling area, five m on each side of the lines, and was based on visual search which included looking under logs, in leaf litter and under woody debris, without destroying the habitat. Each study area was sampled five times, on average 17 days apart (4-30 days apart), and all lines were walked once during each period. Every observation was determined to species, time and place (line and distance on line). Amphibians were captured and length was measured (snout to urostyle) before they were released on site.

Vegetation of the study areas was described every 50 m on each line within a ten m radius circle. Trees were counted by species and height, and a rough estimation was made of the degree of canopy cover. Species in the understory vegetation (mosses, lichen, herbs, ferns and half-bushes) were ranked, a low rank indicating a common species. Structure of the study area was described by the number of uprooted trees, standing dead trees and number of small and large fallen trunks on the ground (Table 1). Estimation was made of degree of bare ground, in this respect meaning no obvious vegetation which mostly comprise of leaf litter and layer of needles, and the amount of woody debris, scattered or in piles, were ranked from 1 (much woody debris) to 4 (no woody debris).

Study areas

Six locations with continuous riparian forest were selected at four different waters outside of Karlstad, Sweden (Fig. 2). The width and flow varies considerably between the waters, from a narrow brook that almost becomes stagnant (Torpnåret) to wide fast-flowing rivers like Klarälven and Norsälven. Study area Klarälven$_{SE}$ and Klarälven$_{SW}$ are at the floodplain of the river which makes the water run slower and become wider at some locations.

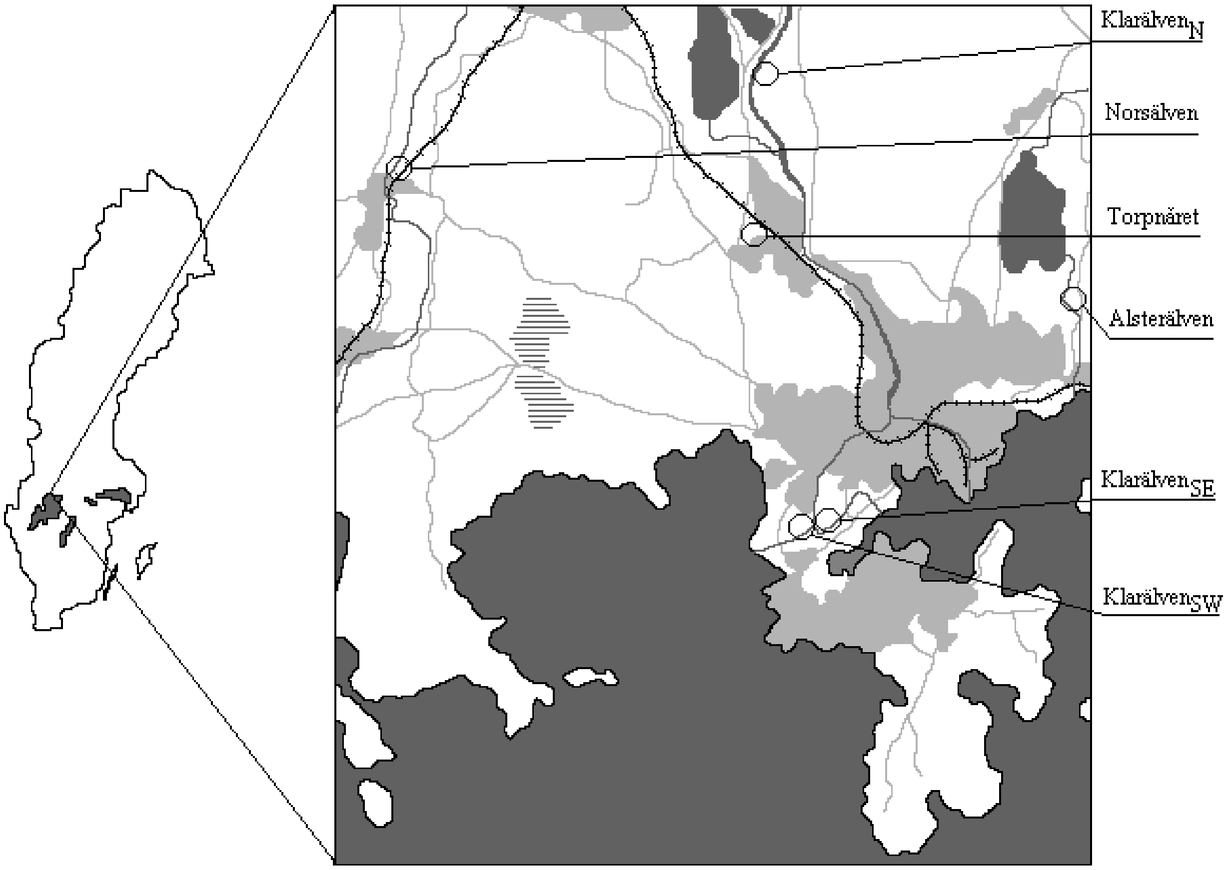

Fig. 2. Simple map over the study areas outside of Karlstad, with railroad (black), waters (dark grey) and cities and roads (light gray).

Klarälven$_{SE}$: Adjacent to the forest is wet pasture that is managed for birdlife and several paths run through the study area, making the whole area popular for recreation. Along the edge of the pasture runs a ditch and in connection is a small open area with wet and tufty ground, creating several small bodies of water. The forest consists mainly of birch (*Betula pubescens*) and along with the per cent bare ground, does the proportion increase further from the water. On the majority of bare ground is an extensive layer of leaves.

Klarälven$_{SW}$: The study area resembles that of Klarälven$_{SE}$ and is also popular for recreation, both on land where many paths run through the area, and on the water. Rowan (*Sorbus aucuparia*) is on average more numerous than birch and it declines further from the river. The most common species, grasses and half-grasses, follow the same trend while mosses, especially *Polytrichum commune,* increase with greater distance from the water. Bare ground is mostly composed of leaf litter and other sources of water are a pond in the middle of the area and a ditch that transects the lines to the east of the pond.

Torpnåret: To the north-west of the study area the water becomes almost stagnant, giving the water a muddy appearance. The study area is probably the most frequently visited, several large and small paths run through the area and a nearby kindergarten uses the forest during outdoor activities. Human-associated debris like mattresses, glass, large sheets of metal and different kinds of plastic, is scattered on the first line. The vegetation does on the first line resemble that of bog with plenty of moist loving herbs and mosses. The per cent deciduous trees is on the first line about 70%, which is 30% above average and species composition changes from osier and birch to rowan with increased distance to water. Overall is spruce (*Picea abies*) the most dominant tree species with plenty of seedlings.

Table 1. Summary of habitat characteristics displayed as average number or average per cent per vegetation zone. For each study area size and number of vegetation zones are given.

	Klarälven$_N$ 4.2 ha (28)	**Norsälven 4.2 ha (28)**	**Alsterälven 3.0 ha (22)**	**Torpnåret 4.2 ha (28)**	**Klarälven$_{SW}$ 3.08 ha (22)**	**Klarälven$_{SE}$ 1.92 ha (15)**
Tree species	4.18	3.61	3.91	4.93	3.71	3.67
Deciduous trees *	32.62%	46.19%	27.88%	39.96%	94.42%	92.69%
Canopy cover **	23.71%	51.04%	31.68%	48.82%	37.62%	47.00%
Moss species	2.68	4.21	5.05	5.36	3.82	2.73
Herb species	4.86	6.00	4.55	5.14	3.64	5.33
Fern species	0.93	2.07	0.91	1.07	0.59	0.67
Bare ground **	4.29%	21.43%	19.55%	30.18%	17.27%	15.33%
Woody debris **/***	3.64	2.14	2.45	3.43	3.64	3.40
Large and small trunks	0.96	4.29	1.64	4.11	4.36	1.80

* Excluding plants
** Quotas between study areas are considered more important than single rough estimations.
*** Rank: 1=high and 4=absent

Norsälven: There is an elevation of approximately 10-15 m, mainly at the river bank, but the terrain flattens somewhat to the north-east. Characteristic for the area is the many small ravines and ditches that indicate that the forest has been drained in the past. In the middle of the area are a few small pools of water. The ravines are more common in the south-west of the area and some of them become brooks closer to the river. Norsälven has the highest species richness of herbs and ferns and is on average the most diverse area, with plenty of grass, creeping buttercup (*Ranunculus repens*) and wood sorrel (*Oxalis acetosella*). Mosses common to the other areas are present but the most frequently observed moss is the moist-demanding *Minium* sp. The study area have the highest amount of woody debris and fallen trunks of all the study areas, and most of it exist in a corridor that transects the lines and so does the majority of the uprooted trees, giving the corridor a relatively complex structure.

Alsterälven: Adjacent on both sides and in the middle of the study area are ditches which contain water during rainy periods and the study area is narrowed by farmland on both sides. On the first line, to the east, are also some puddles and an extensive root system creating good refuges. The terrain is relatively hilly and there is an elevation of about 5-10 m. The ground vegetation is dominated by ordinary mosses and other common species are blueberry (*Vaccinium myrtillus*), grass and bracken (*Pteridium aquilinum*). The rating of canopy cover is affected by an old clearing, which is dominated by raspberry (*Rubus idaeus*), spruce seedlings and wood sorrel. There is also an overgrown road leading to the clearing.

Klarälven$_N$: The study area includes an old clearing with young birches, raspberry and grass which is distinctively different from the rest of the forest. There is also a clearing adjacent to the south of the area. The most common tree in the area is pine (*Pinus sylvestris*) and spruce, with the former dominating the first two lines. The per cent deciduous trees is reduces further from the water. In comparison to the other study areas, the forest can be considered less structural complex with few fallen trunks, standing dead trees, and little to no woody debris or uprooted trees. The understory vegetation is dense with ordinary mosses, bracken and blueberry.

Statistical analyses

Data was described and processed in Excel and one-way ANOVAs were made for each species separately (dependent variable) and eight independent variables. The distribution of amphibians and reptiles was first described through the variables; distance from water (line), study area and survey period. Thereafter a more elaborative description, independent on previous results, was made through the variables; proportion deciduous tree (10% classes), amount of woody debris (rank 1-4), amount of large and small fallen trunks (3 groups), proportion canopy cover (10% classes) and proportion bare ground (10% classes). In the statistical analysis each animal observation was joined with data from the closest vegetation zone and with the exception of study area, the variables did not distinguish between the six study areas and the information was fused together. Difference in vegetation and habitat structure were not considered in the analyses of the variable study area. Average observations are calculated between the survey periods. Multiple regressions (SAS 9.1 for Windows) with variables line, canopy cover and per cent deciduous trees were made to determine which of them explained the most of the variation.

Results

Most amphibians and reptiles are located in the south of Sweden and three species of amphibians were observed; common frog, moor frog and common toad (Table 2). Out of a total of 72 amphibian observations about 78% was captured, and the majority was most probably common frogs. However, due to the difficulty of species determination the data for common frog and moor frog was combined under frogs. No tadpoles were observed in any of the study areas, but about 200 m from Norsälven in small temporary pools in a clearing, tadpoles of unknown amphibians were observed a couple of times. A total of 36 reptiles were observed, including grass snake, common lizard and slow worm (*Anguis fragilis*). Due to low count of common toad and slow worm, they were excluded from further statistical analysis.

The weather during the whole study varied considerably between warm and sunny days to cooler days with rain and even hail. Despite the fact that for example 47% (about 38% of total count) of the frogs at Norsälven were observed during a rainy day (the fourth period) there was no significant difference between the survey periods. The weather was in general warmer and sunnier during the first half of the survey and about 93% of the grass snakes were observed during the first two survey periods and there was a significant difference between the periods (Fig. 3; Table 3).

Table 2. Summary of amphibian and reptile data, including total number of observations (n), average number for each survey period (X) and the standard deviation for each period (SD).										
	Frogs		Common toad		Common lizard		Grass snake		Slow worm	
	n	X (SD)	n	X (SD)	n	X (SD)	n	X (SD)	n	X (SD)
Alsterälven	11	2.2 (2.5)	0		0		0		0	
Klarälven$_N$	0		0		3	0.6 (0.5)	0		1	0.2 (0.4)
Klarälven$_{SE}$	1	0.2 (0.5)	0		9	1.8 (2.5)	3	0.6 (1.3)	0	
Klarälven$_{SW}$	0		0		9	1.8 (2.2)	8	1.6 (2.1)	0	
Norsälven	55	11 (8.7)	3	0.6 (0.9)	0		0		0	
Torpnåret	2	0.4 (0.9)	0		0		3	0.6 (0.9)	0	

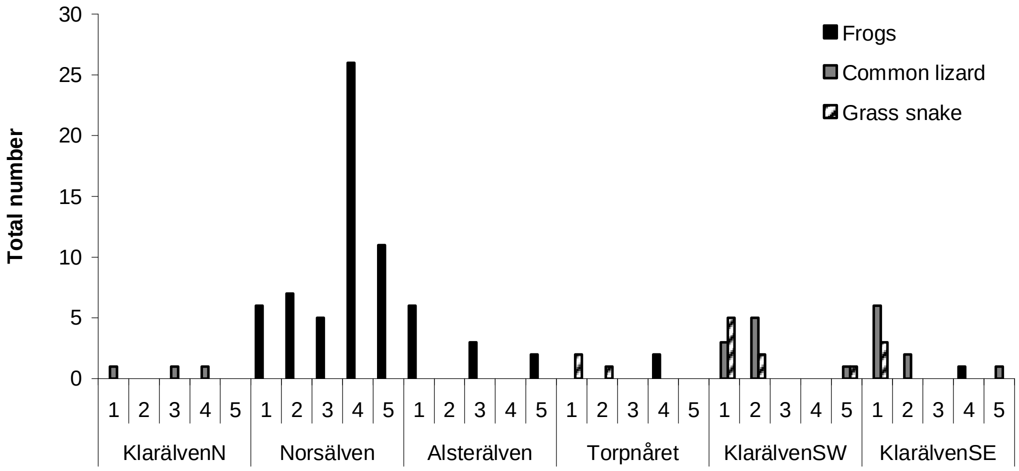

Fig. 3. Total number of observed frogs, lizard and snakes in different areas and survey periods.

Frogs were the only group with a significant difference between study areas (Fig. 4; Table 3) and 79.7% were observed at Norsälven (80.6% including the toads). The areas with the highest amphibian count, Norsälven and Alsterälven, had no reptile observations and almost half of all the reptiles were observed at Klarälven$_{SW}$.

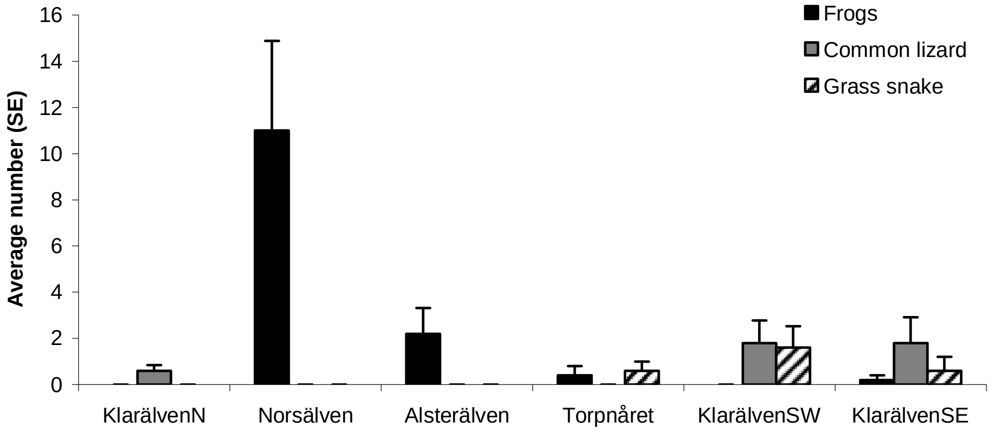

Fig. 4. Average number of observed animals per survey period in each study area.

Table 3. Summary of one-way ANOVAs. The results are presented irrespectively of interrelationship of the variables (see section Statistical analyses). Significant values are highlighted with bold typeface.

	F	df	p
Frogs			
Line	0.1992	3	0.8957
Study area	6.8416	5	**0.0004**
Survey period	0.4373	4	0.7804
Amount of woody debris	6.1101	3	**0.0057**
Canopy cover	1.8953	9	0.0808
Per cent bare ground	13.7847	9	**<0.005**
Per cent deciduous trees	1.0100	9	0.4484
Amount of fallen trunks	12.6986	5	**0.0011**
Common lizard			
Line	1.2911	3	0.3048
Study area	2.0893	5	0.1019
Survey period	1.3088	4	0.2939
Amount of woody debris	2.5979	3	0.0882
Canopy cover	1.7203	9	0.1161
Per cent bare ground	0.9988	9	0.4568
Per cent deciduous trees	3.3854	9	**0.0036**
Amount of fallen trunks	5.2320	5	**0.0232**
Grass snake			
Line	1.5344	3	0.2364
Study area	1.7159	5	0.1693
Survey period	2.8734	4	**0.0437**
Amount of woody debris	1.6522	3	0.2171
Canopy cover	0.8677	9	0.5610
Per cent bare ground	1.3989	9	0.2212
Per cent deciduous trees	2.4008	9	**0.0279**
Amount of fallen trunks	2.2147	5	0.1518

The first objective was to examine the animal abundance in relation to distance from water. About 57% of the common lizards and 47% of the grass snakes were found on the first line. None of the species examined were significantly correlated with distance from water, and frogs were the least associated with line (Fig. 5).

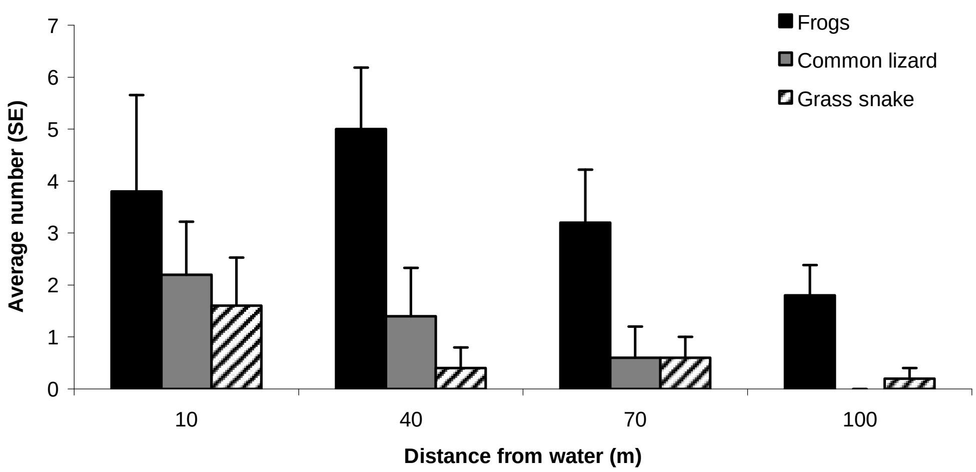

Fig. 5. Average number of observed animals per survey period on each line.

For a more comprehensive and profound study of distribution patterns, five variables of vegetation and habitat structure were tested irrespectively of study area, line and survey period. The second objective was to examine the animal abundance in relation to per cent deciduous trees and both common lizard and grass snake revealed a significant positive correlation (Fig. 6; Table 3). Multiple regression of the variables line, canopy cover and per cent deciduous trees revealed that per cent deciduous trees was the most important variable for the common lizard (multiple regression, t=3.54, p=0.0020) and the grass snake (multiple regression, t=2.98, p=0.0073) and the amount of variance explained was overall 49.3% and 40.2%, respectively. The correlation of tree cover was negative for both reptiles which indicate that they prefer more open habitats. However the abundance of both species was highest with medium canopy cover with 37.38±3.79 (SE) per cent for the common lizard and 37.14±5.66 (SE) per cent for the grass snake.

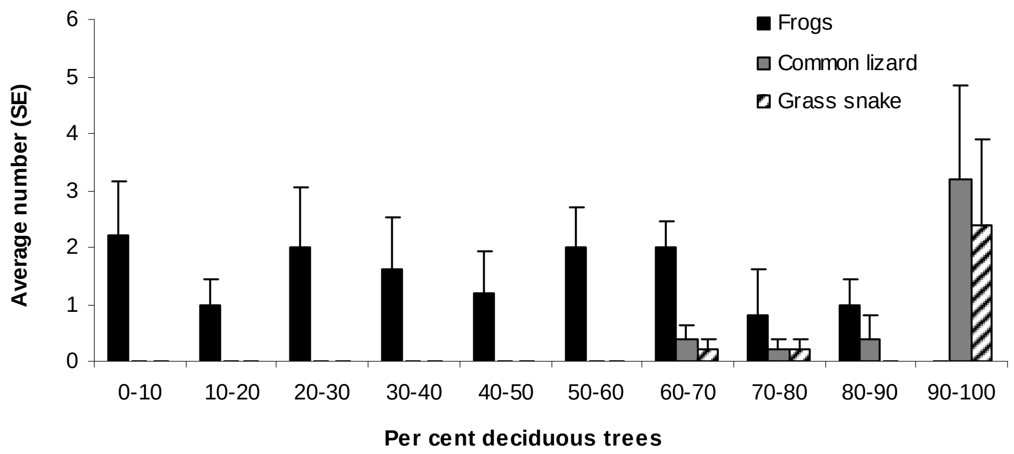

Fig. 6. Average number of observed animals per survey period in relation to per cent deciduous trees.

The difference in frog abundance in relation to per cent forest cover was almost significant, but the distribution pattern reveal no trend towards increased abundance with increased cover, quite the opposite the majority of observations were made in areas with more open stands. The tree cover explained the most of frog variance (multiple regression, t=7.75, p=0.0960), but in comparison with grass snake and common lizard, the variation explained was low, only 18%.

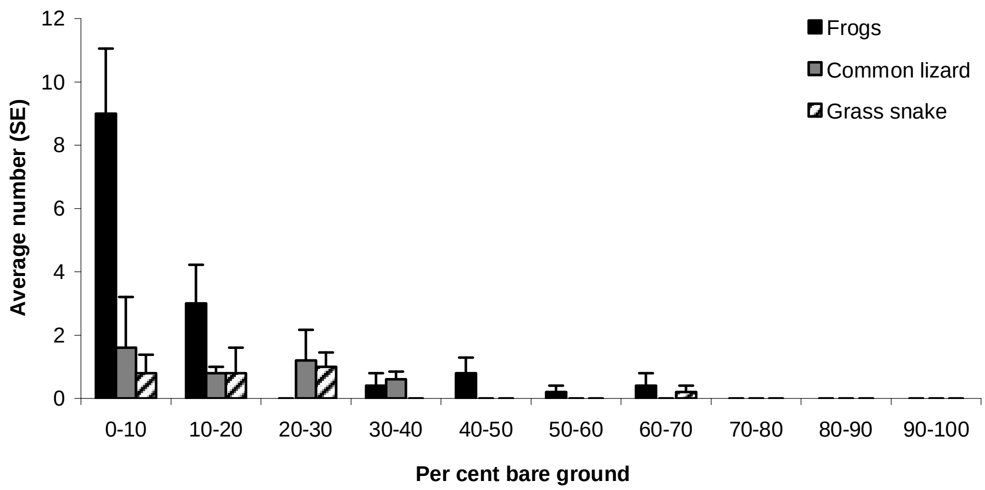

Fig. 7. Average number of observed animals per survey period in relation to per cent bare ground.

Ground characteristics are important for amphibians and about 77% of the frogs were observed in areas with 10% or less bare ground, resulting in a strong and significant negative correlation (Fig. 7; Table 3). There was also a strong significant difference between amount of woody debris (Fig 8; Table 3), but the correlation pattern is different from that of per cent bare ground and there was no obvious trend. The amount of woody debris was, although not significant, the second best explanation for common lizard and all 21 animals were observed in areas with little or no woody debris.

Fig. 8. Average number of observed animals per survey period in relation to amount of woody debris (1= high amount and 4=no woody debris).

Habitat structure was also examined through the amount of small and large trunks on the ground and there was a significant negative correlation for frogs and common lizard (Fig.9; Table 3).

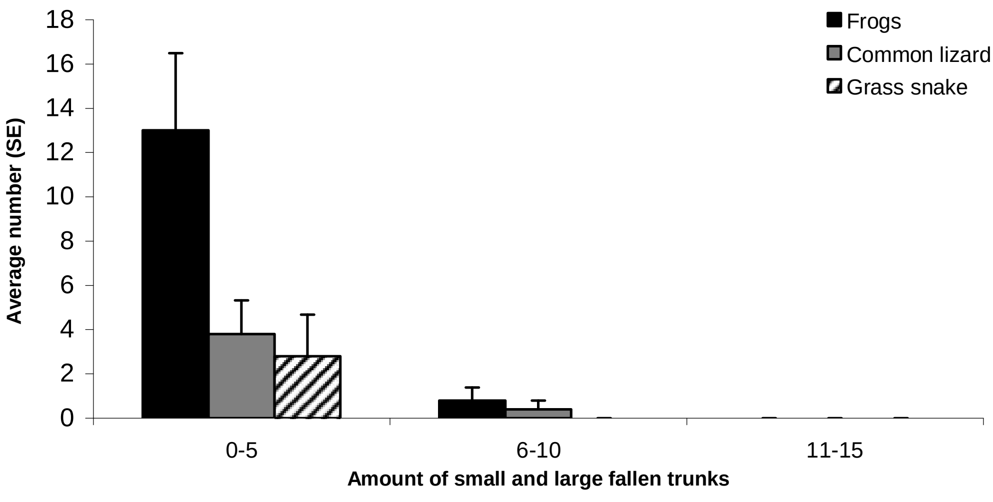

Fig. 9. Average number of observed animals per survey period and the amount of fallen trunks.

Discussion

Several gradients change with increased distance from water. In general, the day temperature increase while the relative daily humidity decrease (Olson et al. 2007), and both factors complicate respiration and indirect movement for amphibians further from the water. Numerous studies have revealed the relation between amphibian abundance and distance form water and similar result was expected on the first objective; higher abundance of amphibians and reptiles closer to the water. None of the reptiles and, most surprisingly, not even the frogs revealed a significant correlation. No salamanders were observed in this study. It is possible that correlation is more common amongst salamanders, foremost aquatic breeders as the results of Gomez and Anthony (1996) and Petranka and Smith (2005). Lung-less salamanders may also decline progressively with distance from water as they may be more sensitive to changes in moisture and temperature than other amphibians (Feder 1983 in deMaynadier and Hunter Jr 1998). Although the definition of riparian areas and the transition to upland areas was not considered in this study, Gomez and Anthony (1996) state that while species richness was similar between upland and riparian habitat for both amphibians and reptiles, reptile abundance was higher in upland habitats and amphibian abundance higher in riparian habitats.

The high percentage of grass snake and common lizard on the first line may have been affected by the low sampling number. There are some disadvantages with methods based on visual search and animals that did not move in response of my presence were most certainly missed. Many studies use pit-fall traps which reduce the errors associated with humans. Natural edge effects and paths may result in habitats being more open and therefore more warmer on the first line, conditions that positively may influence reptiles and negatively affect amphibians. When it comes to the lack of correlation between frogs and distance from water the starting point may be incorrect. This study is based on the assumption that amphibians breed in the streams and rivers of the study areas, which is not evident given the fact that many of them prefer sun exposed relatively calm ponds that have some sort of bottom vegetation (Karlsson and Jonsson 2005). For example, the common frog has the ability to utilise small temporary pools as breeding sites (Johansson, unpublished results in Johansson et al 2005). Running waters are in general colder and have a higher probability to have predatory fish, conditions that the common toad in general tolerates more than other species (Karlsson and Jonsson 2005). Over all there are many variables excluded in this study that may have affected the outcome. Ground chemistry, geomorphology, ground vegetation, human activity and water characteristics such as width and flow most probably influence the amphibian and reptile distribution. In Nyström et al. (2007) study on the common spadefoot water quality was more influential on reproductive success than the terrestrial surroundings, results that agree with other studies.

The second objective was to examine the abundance in relation to per cent deciduous trees and the expected result was higher abundance with increased proportion of deciduous trees. Several studies have revealed the importance of deciduous trees to amphibians (Spellerberg 2002; Pikulik et al. 2001; Rudolph and Dicksons 1990) but the abundance of amphibians in this study was not affected by the proportion of deciduous trees. The result from Gomez and Anthony (1996) study differs slightly from the others and while amphibian abundance was higher in deciduous forest the species richness was higher in coniferous forest. The reptiles were as expected significantly correlated with per cent deciduous trees, which are in line with the results of Strijbosch (1988), and the variable was the most important explanatory factor in the multiple regressions. Both common lizard and grass snake prefer shrub forest over pole forest (Gomez and Anthony 1996; Strijbosch 1988) but most important for heliothermic animals are habitats with spatial heterogeneity (Dent and Spellerberg 1987) and higher spatial heterogeneity have the potential to provide greater variety of prey and refuge from predators, than microhabitats with low diversity (Strijbosch 1988). Small and large trunks on the ground were examined as a simple estimation of the volume dead wood. The amount reflects the spatial heterogeneity, but none of the species were as expected positively correlated. Why the majority of animals were observed in areas with low count is uncertain, but too many fallen trunks may inhibit movements. The highest amounts of fallen trunks were found in coniferous forest and were relatively locally restricted with a reduction of ground vegetation as a result, which may have contributed to the lack of positive correlation for the reptiles and frogs, respectively. The result may also have been affected by the size, species and the stage of decomposition of the trunks.

Associated with deciduous trees are leaf litter and several studies state the importance of leaf litter to amphibian abundance (Spellerberg 2002; Sinsch 1988; Rudolph and Dicksons 1990; Ash 1997; deMaynadier and Hunter Jr 1998). It is used for hibernation and as refuge (Sinsch 1988) and it retains ground moisture and food (Ash 1997). Several amphibians are also positively correlated with the quality and quantity of litter and different types of litter are beneficial for different species, for example hardwood litter was more important for salamanders while aquatic ranids were significantly correlated with conifer litter (deMaynadier and Hunter Jr 1998). In this study the amount of woody debris was estimated, which is a form of litter. There was a strong significant difference for frogs and the amount of woody debris, however the abundance was not positive correlated to the amount, which might be explained by the same reason as for the fallen trunks, that too much woody debris inhibit movements. Woody debris retains ground moisture and makes good refuges, and it has been implied that woody debris, with other substrates, can mask the negative effect of thinning and harvesting for a couple of years (Kluber et al. 2008). deMaynadier and Hunter Jr (1998) point to the importance of age and diameter of the woody debris, with smaller and recently cut branches having less positive effects, and the synergistic effects of other variables. Other important habitat features are rot systems, stumps and proportion of snags which are important refuges (deMaynadier and Hunter Jr 1998), but garbage, as the one found at Torpnåret, may in a way also serve as hiding places and preserve moisture.

Extensive ground cover is also important for the herpetofauna, with positive correlations for many species (Rudolph and Dicksons 1990; deMaynadier & Hunter 1995 in deMaynadier and Hunter Jr 1998; deMaynadier and Hunter Jr 1998). All three species were mostly found in areas with low per cent of bare ground and the frogs showed a strong significant tendency to choose the more vegetated areas over the less. In the deciduous forest the bare ground consists mostly of leaf litter, which might have affected the outcome of per cent bare ground if the sampling number had been higher in those study areas.

Forest removal results in reduction of woody debris and drying of the litter (Ash 1997). Depending on forest type and latitude does the effect vary in time, for example does the amount of woody debris and leaf litter in pine-hardwood forest reduces for about 2-4 years and about 1-7 years, respectively, before the amount increases to post-harvest levels (Mattson et al. 1987, Shure and Phillips 1987 and Ash 1995 in Ash 1997). In general, amphibian abundance is lower in clearcuts than in forest habitats (Patrick et al. 2006), but partial harvest seem to have little or no effect on many amphibian species and Perkins and Hunter Jr. (2006) believe that up to 50% of the basal area may be harvested without any significant differences. It is however important to bear in mind the ecological time-lag, some species live long and reproduce with a few years apart. In combination with habitat features that can mask the effect of clearing, a study needs to span over a long period of time to reveal the long term effects on population-dynamics. The results of Patrick et al. (2006) states that amphibian abundance may be reduced in response to partial canopy removal.

There is a common consensus that a higher proportion of canopy cover is beneficial for the majority of amphibians, both for richness (Herrmann et al. 2005; Loehle et al. 2005; deMaynadier and Hunter

1995 in deMaynadier and Hunter Jr 1998) and for abundance (deMaynadier and Hunter Jr 1998; Patrick et al. 2006). The majority of frogs in this study were observed in more open stands, which do not agree with the research mentioned, but the result of Herrmann et al. (2005) study revealed that the forest cover was more influential on amphibian abundance between 100-1000 m from the water, than forest cover between 0-100 m and 1000-2000 m from the water. The weak explanation of frog variance in this study is similar to that of Herrmann et al. (2005) and even though they got a significant influence of forest cover on density and species richness of larval amphibians, the amount of variance explained was weak. Other researchers have documented that landscape variables alone account for relatively little per centage of the statistic variation (Herrmann et al. 2005) and the environmental variables in Ficetola and De Bernardi (2004) study explained only 17.5% of the variance.

Multiple regressions for common lizard and grass snake resulted in a negative value for canopy cover, which agree with other investigations. Loehle et al. (2005) examined the impact of basal area, which is often correlated with canopy cover, on reptile species richness and the result revealed higher richness with lower basal area which corresponds with the fact that more open habitats have warmer forest floors and probably more basking places, needed by heliothermic animals like reptiles. However the reptile abundance was not correlated with per cent forest cover, but as the results of other studies, where the majority of both common lizard and grass snake observed in areas that were not too opend nor too closed.

It has been demonstrated that both amphibians and reptiles are more abundant in wider (30-90 m) buffers than in narrower (0-25 m) buffers (Rudolph and Dickson 1990) and Semlitsch and Bodie (2003) conclude that amphibians need 159–290 m and reptiles 127–289 m buffer zones to incorporate all aspects of animal life history, but as mentioned the toad can migrate up to 1600 m from the breeding site (Sinsch 1988). In Sweden there are recommendations to leave trees and shrubs as buffer zones around waters, but there are no regulations defining the width and form of the zones (Zinko 2005). The results of a study conducted in three Swedish counties revealed the insufficient protection of streams, for example 70% of streams of 3-10 in width had buffers at clearcuts under 10 years of age, and out of these were only half of the buffers 10 m or more wide (Zinko 2005). It is estimated that edge effects of clearcuts influence the abundance of sensitive amphibians up to 25-35 m in the forest up to 11 years post-harvest (deMaynadier and Hunter Jr 1998). Since buffers are linear, with edge effect of both water and clearcut or agricultural land, the entire forest left as buffer can be considered as edge habitat, with no core habitat. It has been suggested by Pauley et al. (2000) that buffers to the riparian areas may be needed and not just buffer to the waters, to ensure ecological functions of the riparian areas. There are several aspects that make conservation efforts difficult, mainly for amphibians, so it is important to have a holistic perspective. It seems unrealistic to set a protection zone around waters, due to conflicts of interests for example between conservation and forestry. One main objective is to focus on quality rather than quantity of riparian habitats and identify hotspots and the first step would be to identify and collect information on the dynamics and natural history of the local herpetofauna to enable a customized solution suitable to that place.

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