Zeitschrift für Feldherpetologie, Supplement 5: 1–6 #####2004
D. GLANDT & A. KRONSHAGE (Hrsg.): Der Europäische Laubfrosch

Characterization of tree frog (*Hyla arborea*) calling ponds in western Switzerland

JÉRÔME PELLET & SOPHIE HOEHN

(Laboratory for Conservation Biology, Institute of Ecology, Biology Building, University of Lausanne, CH-1015 Dorigny, jerome.pellet@ie-zea.unil.ch)

Charakterisierung von Rufgewässern des Laubfrosches (*Hyla arborea*) in der westlichen Schweiz

Eine Metapopulation des Laubfrosches (*Hyla arborea*) in der Westschweiz wurde im Frühling 2001 untersucht. Alle potenziellen Rufgewässer in einem Gebiet von 350 km² wurden nach rufenden Männchen abgesucht. An 29 von 111 Gewässern sind zwischen 1 und 250 Rufer nachgewiesen worden. Die meisten dieser Gewässer wiesen weniger als 12 Männchen auf. Gewässerparameter wurden auf drei unterschiedlichen Niveaus mit Hilfe von Feldanalysen und Geographischem Informationssystem (GIS) erhoben. Die erste Ebene umfasst die Parameter Wasserchemie und Weiherstrukturen. Die zweite Ebene befasst sich mit der Landnutzung in einem Umkreisradius von 30 m. Die dritte Ebene berücksichtigt Landschaftsfaktoren in einem größeren Umkreis (bis zu 2 km). Mittels GLM Analysen wurden Parameter zur Voraussage der Präsenz von Rufern gesucht. Vier signifikante Parameter erlauben 40 % der Abweichung der beobachteten Verteilung zu erklären. Urbanisation um den Teich hatte eine starke negative Auswirkung auf die Vorkommenswahrscheinlichkeit von rufenden Männchen. Direkte Sonneneinstrahlung war positiv korreliert mit der Zahl der Rufer. Höhere Leitfähigkeit des Wassers war mit einer kleineren Wahrscheinlichkeit eines Vorkommens verbunden. Je weiter weg die nächst gelegene zweispurige Straße, desto größer war die Wahrscheinlichkeit, dass Rufer präsent waren. Unsere Resultate zeigen, dass Präsenz oder Fehlen von rufenden Männchen von Faktoren verschiedener geographischer Ebenen beeinflusst werden.

Schlüsselbegriffe: *Hyla arborea*, Gewässerwahl, GLM Analysen, Leitfähigkeit, Sonnenlicht, Straßennetz, geografische Reichweite, Schweiz.

Abstract

A tree frog (*Hyla arborea*) metapopulation in western Switzerland was studied during spring 2001. All potential calling ponds in an area of 350 km2 were searched for tree frog calling males. Twenty-nine out of 111 ponds sheltered between 1 and 250 callers. Most ponds were occupied by less than 12 males. Pond parameters were measured at three different levels using field analysis and a Geographical Information System (GIS). The first level was water chemistry and pond-associated measures. The second level was the surrounding land use in a 30 m buffer around the pond. The third level consisted of landscape indices on a broader scale (up to 2 km). Logistic regression was applied to identify parameters that can predict the presence of calling males in a pond. Response variable was the presence or absence of callers. Four significant parameters allowed us to explain about 40 % of the total deviance of the observed occupational pattern. Urbanization around the pond had a highly negative impact on the probability of presence of calling males. Hours of direct sunlight on the pond was positively correlated with callers. Higher water conductivity was associated with a lesser probability of species presence. Finally, the further the closest 2-lane road, the higher the probability of callers presence. Our results show that presence or absence of callers is influenced by factors acting at various geographical scales.

Key words: *Hyla arborea*, pond selection, logistic regression, conductivity, urbanization, sunlight, road network, spatial scales, Switzerland.

1 Introduction

Population decline has been studied by many authors (reviewed by BORGULA 1993) and have proved to be occurring at different geographic scales. Determinants influencing tree frog populations at the pond level are, among others, predation (TESTER 1990, BRÖNMARK & EDENHAMN 1994), competition (FOG 1988, PAVIGNANO et al. 1990, TESTER 1990), water pollution (STUMPEL & HANEKAMP 1986, TESTER 1990), eutrophication (FOG 1988), natural succession (TESTER 1990, GROSSE 1994, GEIGER 1995) or simply destruction (many authors). Terrestrial factors also seem to affect population status. Food availability (BORGULA 1990), traffic (BORGULA 1993), disturbances and reduction of suitable terrestrial habitat are the most cited causes (BORGULA 1990, TESTER 1990, STUMPEL 1993). At a larger scale, factors such as pond isolation (BORGULA 1990, TESTER 1990, EDENHAMN 1996, VOS 1999) proved to be of influence. The loss of landscape dynamics (BORGULA 1990) and/or disappearance of elements such as hedgerows or forest borders have been proposed as potentially influencing factors for many other amphibians species (KNUTSON et al. 1999, POPE et al. 2000, JOLY et al. 2001). It is more likely that a complex combination of these factors is affecting populations in a synergistic way.

This study investigates ponds, pond surroundings and local landscape patterns to establish a statistical model that can predict the presence or absence of tree frog calling males with a limited number of predictors readily available.

2 Methods

All ponds within the study area were searched for calling males at least 3 times during calling season (early April to early June 2001). All ponds with at least one calling male were defined as occupied.

The first level of pond description considers only the water itself and the pond vegetation. At this level, water conductivity and pH were measured using a HACH conductimeter (model 44600) and a METROHM pH-meter (model 691). For both, the final value is the mean of 3 measurements taken around the pond. Percentage of vegetation cover on the pond was estimated visually from the shore. Mean hours of direct sunlight on the pond was estimated with the help of a solar compass (calibrated for latitude 47 °N) positioned at the southernmost end of the pond. This procedure allows to visually estimate for any given month the hours of the day when the sun is obscured by tree, building or hills.

Tab. 1: Parameters measured and associated level of description.
Untersuchte Parameter und ihre Beschreibung.

Parameter	Description	Scale
AGRIC	percent of agricultural landuse in a 30 m buffer	2
ALTITUDE	altitude	1
BUSHES	percent of bushes in 30 m buffer	2
BUSHVEG	bushes overhanging the pond	1
CONDUCTIVITY	mean water conductivity (µS/cm)	1
COUNTPOND	number of ponds in 2 km buffer	3
COUNTSAT	number of satellite ponds in 30 m buffer	2
DEPTH	depth	1
DIST2FOREST	distance from nearest forest	3
DIST2POND	distance from the nearest pond	3
DIST2RIVERS	distance from nearest river	3
DIST2ROAD	distance from the nearest 2-lane road	3
DISTURBAN	distance from the nearest village	3
DISTURBEDLANDUSE	percent of disturbed landuse in 30 m buffer	2
DIVSAT	typological diversity of satellite ponds	2
ERECTEDVEG	erected vegetation cover over the pond	1
FISH	fish presence (yes/no)	1
FLOATINGVEG	floating vegetation cover	1
FOREST	percent of forest in 30 m buffer	2
GRAVELPITS	percent of gravel pits landuse in 30 m buffer	2
HYDRIC	water source (categorical)	1
LAKE	percent of lake in 30 m buffer	2
LENGTHROAD	total length of 2-lane roads in 2 km buffer	3
MARSH	percent marshes in 30 m buffer	2
MEADOWS	percent of meadows in 30 m buffer	2
PERIMETER	perimeter of the pond	1
PH	pH	1
QUANTRUBUS	categorical quantity of *Rubus sp.*	2
SHOREDEV	shore development index = PERIMETER/(2*sqrt(AREA*π)	1
SUN	hours of sunlight during mating season	1
SURFACE	surface	1
TREECOVER	tree cover over the pond	1
TYPEPOND	type of pond (categorical)	1
URBAN	density of urban landuse in a buffer of 30 m around the pond	2
WINTERDRYING	drying of the pond in winter 2000–2001 (yes/no)	1

The second level of pond characterization describes the surroundings of the pond in a 30 m buffer, the area that correspond to the potential daytime refuge of individuals (FOG 1993) during calling season. This set of parameters was computed via ground-proofed aerial photos interpretation. The third level is used to measure landscape parameters on a broader scale of 2 km. This last set of measures describes the part of the landscape that is potentially reachable by migrating tree frogs (FOG 1993, VOS 1999). Geographical data originated from vector translation of national 1 : 25 000 maps (VECTOR25) for which precision is estimated to 4 m (OFT 2000). Levels of description and predictors are described in Table 1. In total, 35 predictors related to 3 geographical scales were measured on the field or using a GIS.

The status of the ponds (occupied vs. empty) in a pond was analysed using logistic regression (SOKAL & ROHLF 1995). The procedure developed by HOSMER & LEMESHOW (1989) was used. It includes an univariate analysis, followed by parameter selection. Factors elimination was applied in a backwards stepwise fashion. Significance of the explained deviance of each of the predictors was tested in a 1 000 permutations on the response variable (GUISAN & ZIMMERMANN 2000, JABERG & GUISAN 2001).

Correlation analysis was made using a Spearman rank correlation (SOKAL & ROHLF 1995) at a 5 % confidence level.

3 Results and discussion

Results of the logistic regression are presented in Table 2.

The presence of waterproofed surfaces around the pond seems to have a negative impact on calling males presence. It might seem trivial that artificialized areas are unsuitable for tree frog, there can be two reasons for this. First, callers face the absence of suitable terrestrial habitat (the quality of which is here unknown). Second, it could be possible that the human presence accompanying urbanized areas have a direct impact on populations in a way that is not yet known. Either way, creating private ponds in urban areas may not necessarily be an effective way of establishing new tree frog choruses.

The insulation of the pond during reproductive season positively influences the presence of callers. This fact has already been demonstrated by many authors (STUMPEL & HANEKAMP 1986, FOG 1988, TESTER 1990, ZYSSET 1995, GROSSE & NÖLLERT 1994). The potential warming of the water and the faster development of the tadpoles (MORAVEC 1990) could lead to an earlier metamorphosis and thus reduces predation on tadpoles.

A negative impact of conductivity in Zealand Flanders was already highlighted by VOS & STUMPEL (1996). In their case, conductivity was highly correlated with chloride ions resulting from seawater flooding and seepage. In our study area, conductivity indirectly measures dissolved organic and mineral ions of another type. In gravel pits

Tab. 2: Results of logistic regression for calling sites selection by males of *Hyla arborea* in western Switzerland. Null deviance = 127.51; residual deviance =78.58; D^2 = 0.38. Variables are density of urban landcover in a buffer of 30 m around the pond (URBAN), hours of direct sunlight during mating season (SUN), conductivity (µS/cm) of the water (CONDUCTIVITY) and distance (m) from the nearest 2-lane road (DIST2ROAD).

Statistische Analyse der Wahl der Rufgewässer von *Hyla arborea* in der Westschweiz mittels logistischer Regression. Nulldevianz = 127,51; residuelle Devianz = 78,58; D" = 0,38. Folgende Variablen wurden für die logistische Regression benutzt: URBAN = bebaute Fläche innerhalb eines Kreise mit 30 m Radius um das Laichgewässer herum, SUN = die Anzahl Stunden mit direktem Sonnenschein während der Fortpflanzungssaison, CONDUCTIVITY = Leitfähigkeit (in µS/cm) und DIST2ROAD = die Distanz zur nächsten 2-spurigen Straße.

Variable name	Regr. coef.	SE	Expl. dev.	p (expl. dev.)
URBAN	-0.229	±0.108	21 %	<0.001
SUN	0.382	±0.123	12 %	<0.001
CONDUCTIVITY	-5.201	±1.723	8 %	0.005
DIST2ROAD	0.012	±0.005	8 %	0.006

and quarries on limestone bedrocks, conductivity is mainly due to dissolved Ca^{++}, HCO_3^- and CO_3^{2-}. In agricultural landscapes, high conductivity usually indicates a high nitrates (NO_3^-) load resulting from agricultural runoffs (TCHOBANOGLOUS & SCHROEDER 1985). This hypothesis is supported by the observed correlation between agriculture intensivity around the pond (AGRICULTURE) and measured conductivity (CONDUCTIVITY). A Spearman rank correlation between these 2 parameters showed significance with a correlation coefficient of $r_s = 0.303$ ($p < 0.05$). This tends to support the hypothesis that organic pollution via agricultural effluent can be high in such landscapes. The presence of effluents in water is potentially troublesome as it indicates that pesticides and herbicides are probably being washed from fields in the same way. The lethal effects of some of these organic chemicals on tree frog larvae have been studied by TESTER (1990) and could explain these results.

The proximity to roads showed a negative impact on the probability of presence of calling males. Whether it is because of direct mortality due to traffic (FAHRIG et al. 1995, FINDLAY & BOURDAGES 2000), although no casualties have been observed in potentially dangerous roads or because of some unknown indirect effect is unclear.

This model demonstrates that calling sites selection factors can be found at various geographical scales. Here, parameters related to the water body (CONDUCTIVITY, SUN), its surroundings (URBAN) and adjacent landscape (DIST2ROAD) proved significant. It suggests that many mechanisms affect the calling sites selection by males of tree frogs.

Acknowledgments

This work was funded by the Centre de Conservation de la Faune et de la Nature of the canton de Vaud and the MAVA Foundation. Thanks to SYLVAIN DUBEY who helped during the field work, SILVIA ZUMBACH for advice and to JOEL PARKER for valuable comments on an early version of the manuscript.

4 References

BORGULA, A. (1990): Naturschutzorientierte Untersuchungen beim Laubfrosch (*Hyla arborea* L.): Bestandesentwicklung, Laichhabitat, Verhalten während der Laichperiode, Gefährdung und Schutz. – Diplomarbeit Universität Bern, unveröff.

BORGULA, A. (1993): Causes of the decline in *Hyla arborea*. In: STUMPEL A. H. P. & U. TESTER (eds.): Ecology and Conservation of the European Tree Frog: 71–80. – Wageningen (IBN-DLO).

BRÖNMARK, C. & P. EDENHAMN (1994): Does the presence of fish affect the distribution of tree frogs (*Hyla arborea*)? – Conservation Biology 8: 841–845.

EDENHAMN, P. (1996): Spatial dynamics of the European tree frog (*Hyla arborea* L.) in a heterogeneous landscape. – Dissertation Universität Uppsala.

FAHRIG, L., J. H. PEDLAR, S. E. POPE, P. D. TAYLOR & J. F. WEGNER (1995): Effect of road traffic on amphibian density. – Biological Conservation 73: 177–182.

FINDLAY, C. S. & J. BOURDAGES (2000): Response time of wetland biodiversity to road construction on adjacent lands. – Conservation Biology 14: 86–94.

FOG, K. (1988): The causes of decline of *Hyla arborea* on Bornholm. – Memoranda Societa Fauna Flora Fennica 64: 122–123.

FOG, K. (1993): Migration in the tree frog *Hyla arborea*. In: STUMPEL A. H. P. & U. TESTER (eds.): Ecology and Conservation of the European Tree Frog: 55–64. – Wageningen (IBN-DLO).

GEIGER, A. (Hrsg.) (1995). Der Laubfrosch (*Hyla arborea* L.): Ökologie und Artenschutz. – Mertensiella 6.

GROSSE, W.-R. (1994): Der Laubfrosch. – Magdeburg (Westarp).

GROSSE, W.-R. & A. NÖLLERT (1993): The aquatic habitat of the European tree frog. In: STUMPEL A. H. P. & U. TESTER (eds.): Ecology and Conservation of the European Tree Frog: 37–46. – Wageningen (IBN-DLO).

GUISAN, A. & N. ZIMMERMANN (2000): Predictive habitat distribution models in ecology. – Ecological Modeling 135: 147–186.

HOSMER, D. W. & S. LEMESHOW (1989): Applied Logistic Regression. – New York (Wiley).

JABERG C. & A. GUISAN (2001): Modelling the distribution of bats in relation to landscape structure in a temperate mountain environment. – Journal of Applied Ecology 38: 1169–1181.

JOLY, P., C. MIAUD, A. LEHMANN & O. GROLET (2001): Habitat matrix effects on pond occupancy in newts. – Conservation Biology 15: 239–248.

KNUTSON, M. G., J. R. SAUER, D. A. OLSEN, M. J. MOSSMAN, L. M. HEMESATH & M. J. LANNOO (1999): Effect of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, U.S.A. – Conservation Biology 13: 1437–1446.

MORAVEC, J. (1993): Development and growth of *Hyla arborea*. In: STUMPEL A. H. P. & U. TESTER (eds.): Ecology and Conservation of the European Tree Frog: 29–36. – Wageningen (IBN-DLO).

OFFICE FÉDÉRAL DE LA TOPOGRAPHIE (2000): VECTOR 25: Le modèle du paysage numérique de la Suisse. – Wabern (OFT).

PAVIGNANO, I., C. GIACOMA, & S. CASTELLANO (1990): A multivariate analysis of amphibian habitat determinants in north western Italy. – Amphibia-Reptilia 11: 311–324.

POPE S. E., L. FAHRIG & H. G. MERRIAM (2000): Landscape complementation and metapopulation effects on leopard frog populations.– Ecology 81: 2498–2508.

STUMPEL A. H. P. & G. HANEKAMP (1986): Habitat and ecology of *Hyla arborea* in the Netherlands. In: Z. ROČEK (ed.): Studies in Herpetology. – Prague (Charles University).

STUMPEL, A. H. P. (1993): The terrestrial habitat of *Hyla arborea*. In: STUMPEL A. H. P. & U. TESTER (eds.): Ecology and Conservation of the European Tree Frog: 47–54. – Wageningen (IBN-DLO).

SOKAL, R. R. & F. J. ROHLF (1995): Biometry. – New York (Freeman).

TCHOBANOGLOUS, G. & E. D. SCHROEDER (1985): Water Quality. – Davis, Ca (Addison-Wesley).

TESTER, U. (1990): Artenschützerisch relevante Aspekte zur Ökologie des Laubfroschs (*Hyla arborea* L.). – Dissertation Universität Basel.

VOS, C. C. (1999): A Frog's Eye View on the Landscape. – Wageningen (University of Wageningen).

VOS, C. C., & A. H. P. STUMPEL (1996): Comparison of habitat-isolation parameters in relation to fragmented distribution patterns in the tree frog (*Hyla arborea*). – Landscape Ecology 11: 203–214.

ZYSSET, S. (1995): Einflussfaktoren auf Rufgewässerwahl und Fortpflanzungserfolg bei *Hyla arborea*. – Zürich (Swiss Federal Institute of Technology).