



Quantification and explanation of the decline in the number of populations of common toad (*Bufo bufo*), in southern Switzerland.

Master thesis 2015



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ABSTRACT

In conservation biology, one of the main topics is the global loss of biodiversity. According to the researchers, this loss is caused by human activity and global change, which can have a negative effect qualitatively and quantitatively. Habitat quality is influenced by hydroperiods and quantitatively, homogenization of the habitat can have disastrous consequences on the populations of amphibians and their complex life cycle. The loss of long hydroperiods may affect negatively the fitness of amphibians and the homogenization may be caused by high urbanization rate, which fragments and destroys habitat. Often, however, the consequences are discovered and studied too late, and we realize that we have overlooked the important signs of decline.

In southern Switzerland (Ticino), a decline in number of populations of common toad (*Bufo bufo*) in the last decades was observed. Toad was no longer observed in many ponds considered breeding sites with cantonal importance. My goal was to understand what factors may explain decline of *B. bufo*, and if decline subsists. Results show that decline was confirmed, but the loss in number of populations came to a halt. Permanence of the pond, that is non-drying, is the most important factor that determines the occupation of the species. In addition, probability of occupancy is negatively affected by urbanization rate and rate of forest cover in covariance factors (radius buffer 500m). This may mean that the permanent breeding were common toad occurred, they are located on the limits of the agglomerates, where the forest is less dense. And also, that the severe drought in the last decades and urbanization, may have contributed to dry ponds, increase mortality, and to disappear populations.

Moreover, I investigated the occurrence of common toad as regards the update of data from the Swiss Amphibians Red List, in Ticino. The main purpose was to know if there is decline, turnover or increase of number of populations, after more than ten years. Factors were considered to explain probability of occupancy, and possible cases of extinction/colonization in ponds. Results show a pseudo turnover, with increase of occupancy in ponds and more cases of colonization than extinction. Again, permanency of pond affect positively occurrence of toad.

Finally, I believe that the situation of the common toad in Ticino is not critical, but we must continue to study the occupancy status of amphibians, to try to play in time conservation activities that might require a future decline.

Words: 397

Keywords: occurrence probability, *Bufo bufo*, decline, permanent pond, urbanization rate, forest cover, conservation biology, Switzerland.

INTRODUCTION

When the Earth loses more than three quarters of the species in a geologically short interval, paleontologists qualify a mass extinction. The mass extinction is characterized by the loss of global biodiversity. According to many researchers, the decrease of biodiversity is caused by the negative effects of human activity (Findlay and Houlihan, 1997; Barnosky et al., 2011). The negative effects are evident in the availability and quality of habitat. Availability and quality can be reduced by climate change or an homogenization of the landscape and therefore a loss of characteristics specific to the species. This loss is a precise case for species of amphibians, which show a complex life cycle, influenced on three levels (Cushman, 2006): breeding site, terrestrial habitats, meta-population structure. Amphibian populations have been declining during several decades (Alford and Richards, 1999; Houlihan et al., 2000; Stuart, et al., 2004). The causes of the decline may be global warming, which increases drought ponds and fluctuations in hydroperiods (Collins and Storfer, 2003; Hamer and McDonnell, 2008). Wetland hydroperiods can influence the distribution of amphibians (Babbitt et al., 2003; Werner et al., 2007). Wetlands isolated from other freshwater systems, as a river, are more vulnerable to drought, and in these areas the persistence of biodiversity is difficult (Brooks, 2009). The biodiversity of amphibians not only depends on the hydroperiod, but also by the larval development in the water. Thus less water and shorter hydroperiod can decrease the reproduction of a population and increase the probability of extinction (Walls et al., 2013). In addition, the probability of extinction may increase in relation to the association of macro-invertebrate predators of amphibians, which depend on the characteristics of pond (Walls et al., 2003). Moreover, characteristics of pond can be modified by the negative impact of urbanization. Urbanization can cause fragmentation, isolation and loss of habitat (McKinney 2006). This negative impact can be considered one of major cause of the natural ecosystem disturbance for amphibians (Sun and Naris, 2005; Baker and Richardson, 2006). Disturbance for amphibians is due to fragmentation-degradation of natural habitat (Houlihan and Findlay, 2003), increases mortality due to traffic (Schlupp and Podlousky, 1994), decreases the ability of dispersion and migration of amphibians (Gibbs, 1998b), decrease occupancy in breeding sites (Pellet et al., 2004b; Eigenbrod et al., 2008). In additional, decreases can be also due to local factors, such infectious diseases chytridiomycosis (Daszak, 2003) or depend on biotic/abiotic characteristics of the breeding site. Biotic/abiotic characteristics can influence amphibian occurrence (Van Buskirk, 2005) and determine breeding site selection (Indermaur et al., 2010). A widespread species, the Common toad (*Bufo bufo*), is in decline in some areas of Europe (Carrier and Beebee, 2003). According to Bonardi et al. (2011), in a study conducted for ten years in northern Italy, although some populations count more than thousand individuals, most of the populations of common toad declined. In additional, in 2010 and 2011, Maddalena & Mattei Roesli (2011), observed a decline in the number of populations of common toad in Ticino, Switzerland. To understand the decline observed by Maddalena & Mattei Roesli (2011), I have investigated the occurrence of common toad in breeding sites in Ticino. To investigate whether the number of common toad populations were declining, I done occupancy models proposed by MacKenzie et al. (2002) to analyze detection / non-detection data collected during 2014, in 46 breeding sites. In this breeding sites, I have calculated abiotic/biotic factors reflecting local condition and landscape

structure. In my study I selected four types of abiotic factors, that may affect the quality of the habitat and occurrence of the common toad: 1) the rate of urbanization and forest cover (Pellet et al., 2004b; Eigenbrod et al., 2008), 2) the percentage of the pond's area covered by the canopy, which can influence the survival of the larvae (Skelly et al., 2002; Thurgate and Pechmann, 2007), 3) if a breeding site is considered permanent or temporal, which is a specific choice of the species of amphibians (Werner et al., 2007), 4) the size of the population observed by Maddalena & Mattei Roesli in 2011, from which can depend occurrence in 2014. And one type of biotic factors: 1) the presence of fish (Van Buskirk, 2005). Fish that do not eat toad tadpoles because toxic, so considered competitors of other amphibian and facilitators of *B.bufo*. My goal was to understand what factors may explain decline of *B.bufo*, and if decline subsists. The hypotheses are that the occurrence depends on hydroperiods, because permanence of pond is a specific characteristic for breeding site selection of common toad (Indermaur et al., 2010) and that urbanization has a negative effect that may explain the decline.

In additional, during 2015, in my study I also investigated the occurrence of common toad as regards the update of data from the Swiss Amphibians Red List (VU red-list status, Schmidt and Zumbach 2005). To do this, I done multi-season occupancy model presented in MacKenzie et al. (2003) using detection / non-detection data. This data were that I have collected during 2015 in 44 ponds registered in the red list of Swiss amphibians and data collected in 2003-2004 from the same sites by Schmidt and Zumbach (2005). In this study, I have calculated abiotic factors reflecting local condition and landscape structure. I selected tree types of abiotic factors: the rate of urbanization and forest cover (Pellet et al., 2004b; Eigenbrod et al., 2008) and if a breeding site is considered permanent or temporal (Werner et al., 2007) as in 2014, and 3) the presence of common toad in the past, considered as site that was favorable in the past, therefore, that increases the likelihood of colonization and decrease extinction. The goal was to have a clear quantification of the state of occupation of the common toad in the ponds of the Red List, and check whether there has been a decline or a turnover of populations. Turnover may depend on the probability of colonization or extinction in ponds, which are not considered to be breeding sites of the common toad. In addition, I investigated if the abiotic variables may explain the probability of occurrence, detection, colonization and extinction. Hypotheses are similar to those written above, hoping to not see a decline in the ponds where in 2005 the common toad was present.

Finally, this study has the purpose to increase our knowledge on current situation of the occurrence of amphibians in Ticino, focusing on the current local situation of common toad (*Bufo bufo*), to implement the right measures of conservation biology.

MATERIALS AND METHODES

Study species

Biology of Bufo bufo

The focus species of the study is the common toad (*Bufo bufo* (L., 1758)). This species is currently declining (red-list status VU, Schmidt and Zumbach 2005) even if it is present everywhere in Switzerland.



Bufo bufo
(LINNAEUS, 1758)
(Common toad)
FAMILY: BUFONIDAE

Reproduction:
March-April

Altitude :
200m-1700m ASLM

Habitat :
Permanent pond, shore
of lake

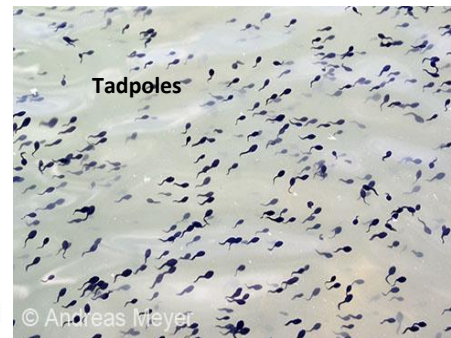
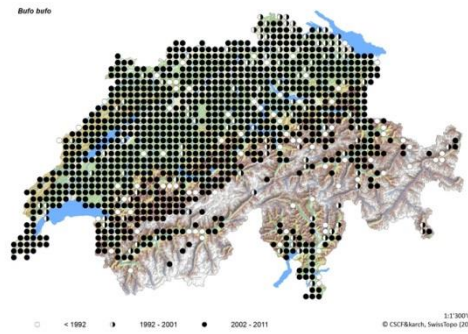


Figure1: The upper pictures show the distribution of the common toad in Switzerland (left) and the tadpoles (right). The lower pictures show a male and a female in amplexus (left) and an example of a pond inhabited by the species (right).

The common toad is an anuran of the family Bufonidae (Linnaeus, 1758). Adult males are smaller than females, and can reach a length of 6-7.5 cm, while females can reach lengths between 9.5 and 13 cm in the south of the Alps. *B. bufo* is a nocturnal species and feeds on small invertebrates. The male is the first to reach the breeding site, where it began his singing to attract females in early March. In early April-May begins the phase of terrestrial activity, which can last up to the end of October. Hibernation will last until February.

Currently, in Switzerland, the occurrence at the lowest altitude is located in Ticino, in the Magadino plain at an altitude of 200 m above sea level, and the highest is in the Berner Oberland, at a height of 2340 m above sea level. The species prefers large bodies of permanent water (Giacoma and Castellano, 2006). It can coexist with fish because eggs and larvae contain toxic substances that are secreted as protection from predators. With regard to activities outside of the breeding season, although it prefers forests, it can also be found in agricultural areas and mining sites, and in urban areas.

Data collection

The data collection was done from March to June 2014 and February to May 2015, divided into two distinct parts in the two years.

Quantifying the decline of the common toad

In 2010 and 2011, Maddalena & Mattei Roesli (2011), surveyed 73. From March 1 to April 30 2014, I re-surveyed 46 breeding sites (Figure 2) located in the canton of Ticino, Switzerland, randomly chosen from the 73 (12 of 73 discarded because compromised or under management). The choice of 46 breeding sites covering the entire territory in Ticino, it were chosen to maintain a standard percentage of presence-no presence, and it permitted to make a sufficient number of visits per breeding site. In the study conducted in 2010/11, in 46 of the 73 sites the common toad was present (63%). Maddalena & Mattei Roesli (2011) assigned every population to a size class category (Grossenbacher, 1988). I selected populations from all categories. The random choice of the 46 breeding sites has been divided into 17 sites where the presence of the common toad had not been seen recently, 9 in which the population appeared small (1-5 individuals), 9 in which the population was medium (5-50 individuals), 7 in which the population was large (51-200 individuals), 4 in which the population was very large (> 200 individuals). The study area in 2014 covers an area of about 950 km², from the north (Biasca) to the south (Stabio). The total area of the 46 breeding sites is 232.7 ha (2327 m²), the smallest has an area of 0.13 ha (1.3 m²) and the larger an area of 33.9 ha (339 m²). The station is located below sea level, is located at 200 meters ASLM, the upper one at 1100m ASLM.

Swiss Amphibian Red List – Current situation of Bufo bufo

In 2003 and 2004, Schmidt and Zumbach (2005) surveyed 49 sites in Ticino for the update of the Swiss amphibian Red List. During the second year of my study, from March 1 to April 30 2015, I re-surveyed 44 sites (5 excluded because they were dried or in management, all without occurrence of common toad) (Figure 2) to know the current occurrence of common toad and to produce the multi-season occupancy data required to estimate occupancy, colonization and extinction probabilities. In 14 of the 44 sites the common toad was present (31.81%) in 2005. The study area in 2014 covers an area of about 950 km², from the north (Biasca) to the south (Stabio). The station is located below sea level, is located at 196 meters ASLM, the upper one at 1110m ASLM.

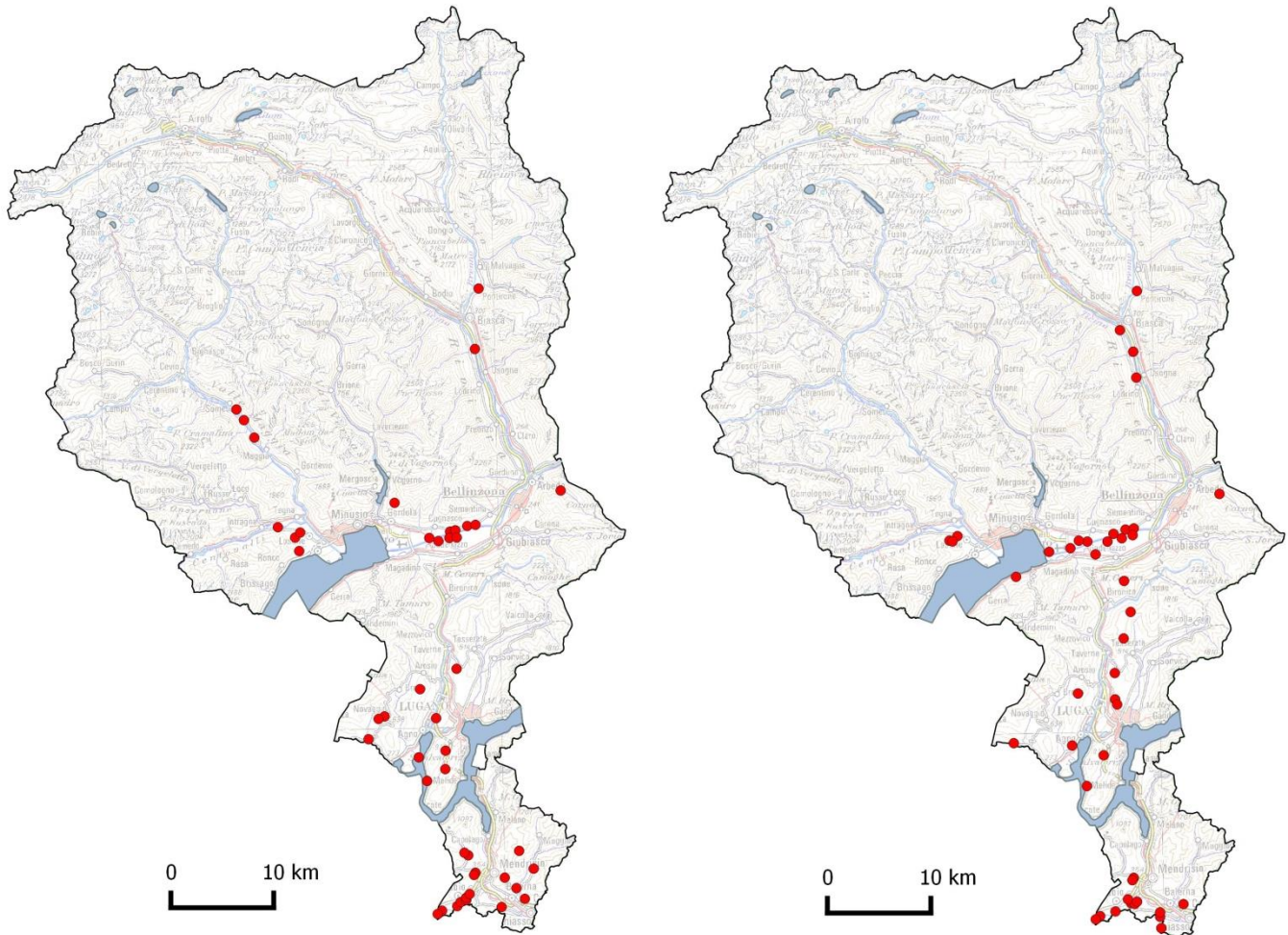


Figure 2: Map of canton Ticino (Switzerland). The red dots represent the study sites. The map on the left shows the 46 breeding sites monitored during 2014. The map on the right shows the 44 breeding sites monitored during 2015. In 22 cases, the ponds are the same.

Field methods

For data collection conducted during 2014 and also during 2015, for each breeding site, I decided to perform four visits (Schmidt, 2005; Pellet and Schmidt, 2005). Two at day (all carried out between 12:00 to 17:00, in the change to daylight saving time, start time visits is increase by 1h) and two at night (all carried out between the 18:30 to 01:00, in the change to daylight saving time, start time visits is increase by 1h). Data was collected during March and April, with a duration of 45 min for each visit approximately. The choice of the two month March and April, taking into account the biology of common toad, a species that ends hibernation very early. In 2014 also abundance of adults was observed (Grossenbacher, 1988). However, time constraints prevented that all sites can be visited four times (mean number of observations per site 2014: 3.17, mean number of observations per site 2015: 3.32).

For each stage of life of the common toad (embryo, larva, adult), the observation was carried out with visual encounter surveys (Crump and Scott, 1994) and call surveys (Pellet and Schmidt, 2005)

to collect detection / non-detection data. For each breeding site, tadpoles were captured using a net (Ferplast 20.5 x 53 cm).

Pond characteristics (Table1)

Occurrence and Abundance of B. bufo

Concerning the occurrence, during each visit to the breeding sites, I recorded the detection (= 1) or non-detection (= 0).

Concerning abundance, during each visit of breeding sites, I counted the number of adults to determine the population size class (Grossenbacher, 1988).

Pond permanency (Pm14 or Pm15)

I recorded conditions of breeding sites during visits between March and April as well as other visits during the months of July and August. A breeding site is considered permanent if it not dry during the breeding season and the metamorphosis of common toad. In addition, I also examined data from the Swiss Amphibian And Reptile Conservation Program (KARCH, Switzerland) about pond permanency.

Canopy cover (Ca14)

Estimated visually using KARCH model (Appendix Ca). For every percentage (10%, 20%, 30%, ..., 90%) corresponds the area covered by the canopy.

Fish present/absent (Fi14)

During each visit to the breeding sites, I recorded the detection/non-detection of fish (= 1 for the presence, = 0 for the absence) with a length of $\sim >10$ cm (Indermaur et al., 2010). An analysis of the data using occupancy models (MacKenzie et al. 2002) showed that fish were detected with high certainty and that no fish populations were missed.

Urbanization cover (Ur14 or Ur15) and Forest cover (Fo14 or Fo15)

I take land-use data from VECTOR25, the vector format of the 1:25000 topographical maps of Switzerland provided by the Swiss Federal Office of Topography (Swisstopo). The position accuracy is between 3-8 meters. we used the latest map (2010).

For each breeding site, we calculated a concentric buffer with a radius of 500 m (Zanini et al., 2008), for the percentage of forest cover (Eigenbrod et al., 2008) and the percentage of urbanization cover (Houlahan and Findlay, 2003; Stevens et al., 2004; Pellet et al., 2004b; Zanini et al., 2008). 500 meter representing the potential movement of amphibians in the air around the breeding site (Zanini et al., 2008).

Favorable or Not Favorable (Fav15)

For breeding sites studied in 2015, a pond is considered favorable (= 1) if in the past the common toad was present (historical data held by the KARCH), or not favorable (= 0).

Other amphibians

To determine the co-occurrence for each breeding site (data provided to KARCH), it was checked the detection (= 1) and the non-detection (= 0) of some species of amphibians. Of these species, two are urodeles: the spotted salamander (*Salamandra salamandra* (Linnaeus, 1758)) and the

Italian crested newt (*Triturus carnifex* (Laurenti, 1768)), while 5 are anurans: the agile frog (*Rana dalmatina* (Bonaparte 1840), the common frog (*Rana temporaria* (Linnaeus, 1758)), the Italian agile frog (*Rana latastei* (Boulenger, 1879)), the Italian tree frog (*Hyla intermedia* (Boulenger, 1882)), and the complex of green frogs consisting of the pool frog (*Pelophylax lessonae* (Camerano, 1882)) and the Edible frog (*Pelophylax esculentus* (Linnaeus, 1758)). These two species are able to hybridize and are distinguishable only by molecular analysis. For this reason, I decided to combine them as waterfrogs (Van Buskirk, 2005). Therefore, a total of 7 species. In fact, a visit was conducted in May, to have more data available for the species that ending hibernation later or for the sites located at high altitudes (e.g. *Hyla intermedia* or *Triturus carnifex*).

Process	Factor	Explanation	Sampling Interval	Measuring	Reference
Probability of occurrence	Y	Year (2014)			
	Y2	Year (2015)			
Pond characteristics 2014					
	Pm14	Pond permanence (1 or 0)	Annual	Visually	Houlahan, J.E., Findlay, C.S. (2003)
	Ca14	Canopy cover (%)	Seasonal (4 times)	Visually	Van Buskirk, J. (2005)
	Fi14	Fishes ~> 10 cm (1 or 0)	Seasonal (4 times)	Visually	Indermaur, L. et al. (2010)
	Fo14	Forest area 500m (%)	Once	VECTOR25	Eigenbrod, F. et al. (2008)
	Ur14	Urban area 500m (%)	Once	VECTOR25	Pellet, J. et al. (2004b)
	Ps11	Pop. size (n,s,m,l,v) ^o	once	KARCH ^{oo}	Grossenbacher, K. (1988)
Pond characteristics 2015					
	Pm15	Pond permanence (1 or 0)	Annual	Visually	Houlahan, J.E., Findlay, C.S. (2003)
	Fo15	Forest area 500m (%)	Once	VECTOR25	Eigenbrod, F. et al. (2008)
	Ur15	Urban area 500m (%)	Once	VECTOR25	Pellet, J. et al. (2004b)
	Fav15	Favorable or not (1 or 0)	Once	KARCH ^{oo}	/
Amphibians*					
		Presence of <i>Bubo bufo</i>	Seasonal (4 times)	Visually	
		Presence of <i>Rana temporaria</i>	Seasonal (4 times)	Visually	
		Presence of <i>Rana dalmatina</i>	Seasonal (4 times)	Visually	
		Presence of <i>Rana latastei</i>	Seasonal (4 times)	Visually	
		Presence of <i>Pelophylax sp.</i> **	Seasonal (4 times)	Visually	
		Presence of <i>Hyla intermedia</i>	Seasonal (4 times)	Visually	
		Presence of <i>Salamandra salamandra</i>	Seasonal (4 times)	Visually	
		Presence of <i>Triturus carnifex</i>	Seasonal (4 times)	Visually	

Table1: Factors used for predicting the probability of occurrence (2014) and occurrence/colonization/extinction (2015). ^o n=not recent obs. , s=small , m=medium , l=large , v=very large. ^{oo} Maddalena, T. and Mattei-Roesli, M. (2011). ^{ooo} KARCH (Center for the protection of amphibians and reptiles in Switzerland). *observation 2014-15 be done for KARCH. **Complex of green frog, *Pelophylax lessonae* and *Pelophylax esculentus*.

Statistical analysis

Data were analyzed in R, using the package *unmarked* (Fiske and Chandler 2011).

Quantifying the decline of the common toad

I used occupancy models to analyze detection / non-detection data collected during 2014 (MacKenzie et al., 2002). The analysis estimates site occupancy probabilities (ψ) when detection probabilities (p) are <1 . Explanatory variables can be used to explain occupancy and detection probabilities.

To do this, I have assembled a priori candidate models. These models contained the 6 explanatory variables (Table2), built on biological knowledge (Pellet et al., 2004b; Van Buskirk, 2005; Thurgate and Pechmann, 2007; Werner et al., 2007; Indermaur, 2010) and my own observations. I used AIC (Akaike's information Criterion) to rank models.

Swiss Amphibian Red List – Current situation of Bufo bufo

I used multi-season site occupancy models to analyze the detection / non detection data (MacKenzie et al., 2003). The analysis estimates initial occupancy (ψ), colonization (γ), extinction (ϵ) and detection (p). Covariates can be used to explain occupancy, extinction, colonization and detection probabilities.

First, I assembled a priori candidate models of probability of detention, containing none, one, two or three explanatory variables of 2015 (urbanization rate, rate of forest, site favorable or not). The models are based on biological knowledge and contained the 3 explanatory variables (Table3). I used explanatory variables to explain occupancy and colonization probabilities. Again, the model with the lowest AIC (Akaike's information Criterion) is considered to be the best explanation for the data.

I did not model the probability of extinction using the explanatory variables because only two extinctions were observed.

 Model covariates to quantify decline of common toad

1	pm14	15	pm14+fi14+fo14
2	ca14	16	pm14+fi14+ca14
3	fi14	17	pm14+fi14+ur14
4	fo14	18	pm14+fo14+ca14
5	ur14	19	pm14+fo14+ps11
6	ps11	20	pm14+fi14+fo14+ca14
7	pm14+fi14	21	pm14+fi14+ur14+ca14
8	pm14+fo14	22	pm14+fi14+fo14+ps11
9	pm14+ca14	23	pm14+fi14+ur14+ps11
10	pm14+ur14	24	pm14+fi14+fo14+ca14+ps11
11	fi14+ur14	25	pm14+fi14+ur14+ca14+ps11
12	ca14+fo14	26	pm14+fi14+ur14+fo14+ca11
13	fo14+ps11	27	pm14+fi14+ur14+fo14
14	pm14+fi14+ps11	28	pm14+ur14+fo14

Table2: A priori the explanatory variables to model the predicted occupancy of data collected at breeding sites to quantifying decline of common toad.

 Model covariates to establish declining or turnover of common toad

1	fo15	1	fav15
2	fav15	2	fo15
3	pm15	3	ur15
4	fav15+fo15	4	pm15
5	fav15+pm15	5	fav15+fo15
6	fo15+pm15	6	fav15+ur15
7	fav15+fo15+pm15	7	fav15+pm15
8	pm15+ur15	8	fo15+pm15
		9	ur15+pm15
		10	fav15+fo15+pm15
		11	fav15+ur15+pm15

Table3: A priori the explanatory variables to model the initial occupancy (left) and colonization (right) of data collected at ponds in 2015, to explain decline or turnover of common toad.

RESULTS

Quantifying the decline of the common toad

In 2014, common toad were observed at 30 of the 46 breeding sites (65.21%) (Appendix2). The presence of the common toad in breeding sites slightly increased from 63% in 2010-11 to approximately 65% in 2014. In 7 breeding sites where common toad was not observed during 2010-11, it was observed, while in 6 breeding sites where it was observed during 2010-11 (5 small population and 1 medium population), it was not observed anymore.

The best model had an Akaike weight of 46% (Appendix3). In this model, the probability of occupancy is best explained by pond permanence, urbanization cover and forest cover. Ponds permanency (Figure1) had a positive effect, while urbanization cover (Figure2) and forest cover (Figure3) had a negative effect. All three variables have significant effects (p -value <0.05) (Table3).

Parameter	Explanatory variable	Estimate	Std.Error	p-value
Occupancy	Intercept	5.06	3.06	<0.1
	Permanency (Pm14)	4.68	1.64	<0.005
	Urbanization cover (Ur14)	-12.26	5.63	<0.03
	Forest cover (Fo14)	-9.27	4.24	<0.03
Detection	Intercept	0.595	0.249	<0.02

Table3: Explanatory variables contained in the top ranked a priori occupancy from detection / non-detection data model 2014. Estimate, standard error, and p-value are shown.

The data collected during 2014 and analyzed, showing a probability of occurrence of the common toad equal to 7% ($\pm 8.9\%$) at the breeding sites considered temporary, while the probability of occurrence of the species is equal to 90% ($\pm 6.6\%$) in permanent breeding sites (Figure1).

The occurrence probability predicted on effect by urbanization cover decreases with increase in the proportion of urban coverage (Figure2).

The occurrence probability predicted on effect by forest cover decreases with increasing of forest cover (Figure3).

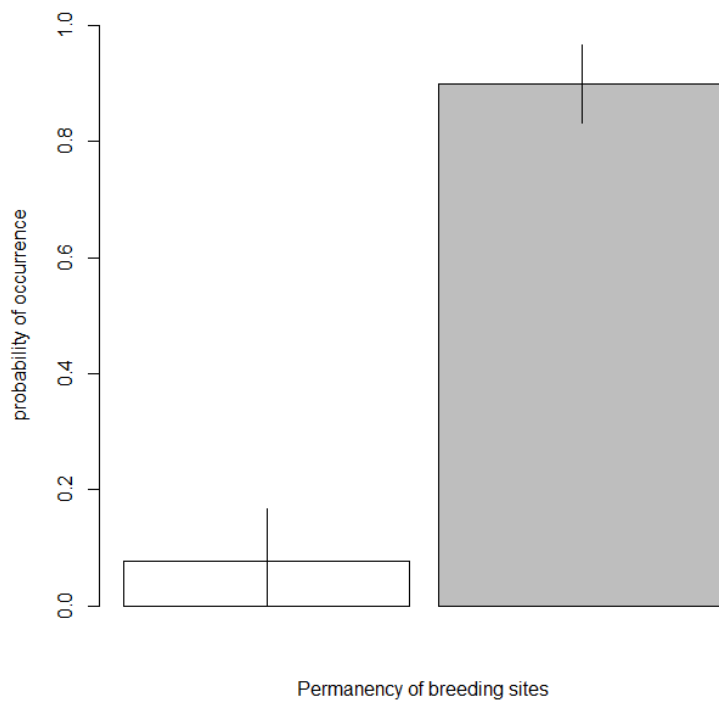


Figure1: The probability of occurrence, predicted by the best occupancy model, for not permanent breeding sites in white and for permanent breeding sites in gray. Standard error in vertical bars.

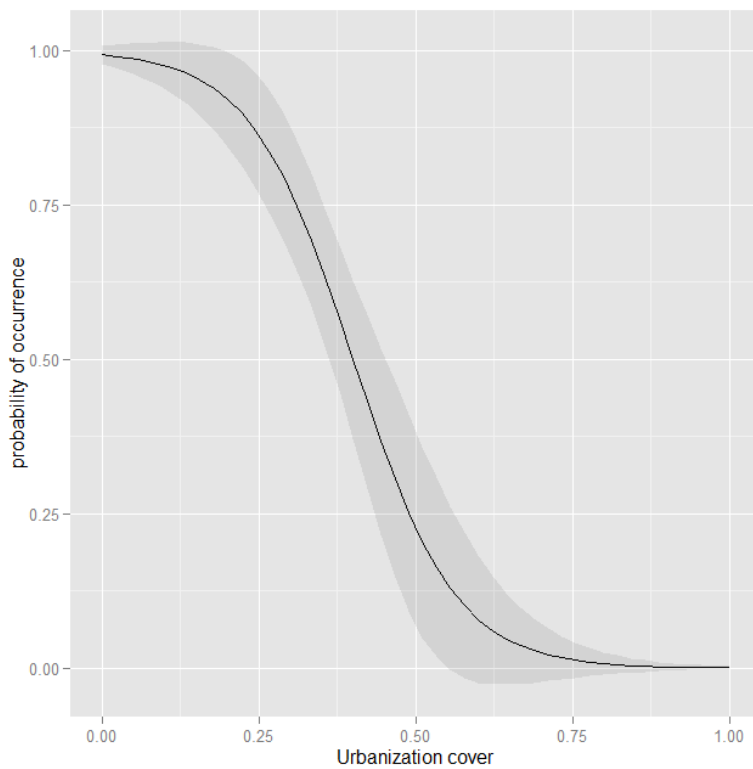


Figure2: The probability of occurrence, predicted by the best occupancy model, as a function of urban cover. The gray area represents the 95% confidence interval.

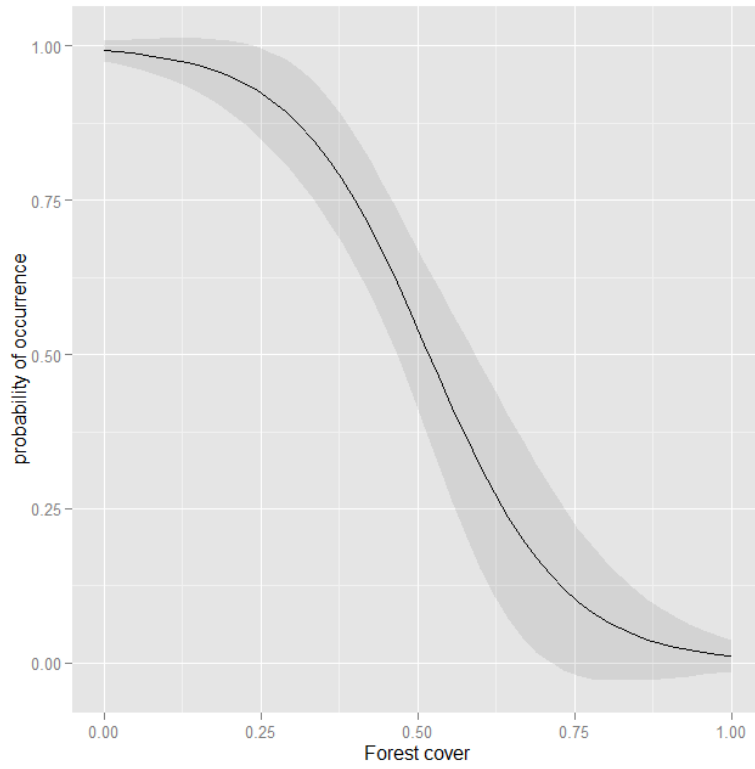


Figure3: The probability of occurrence, predicted by the best occupancy model, as a function of forest cover. The gray area represents the 95% confidence interval.

Swiss Amphibian Red List – Current situation of *Bufo bufo*

In 2003-04, common toad were observed at 14 of the 44 ponds (31.81%), while in 2015 they were observed at 19 (43.18%) (Appendix2). During 2015, were observed 7 cases of colonization (15.90%) and 2 cases of extinction (4.54%).

Of all the models built a priori, that best explains the multi-season data, represents 33% of the Akaike weight (Appendix3). In this model, occupancy probability is best explained by the permanency (p-value < 0.005) and urbanization cover of ponds, although urbanization cover has no significant effects (p-value = 0.1104). Ponds permanency had a positive effect, while urbanization cover had a negative effect.

The probability of colonization is best explained by the favorability of ponds and the percentage of forest cover, although these two variables have no significant effect (p-value > 0.05) and standard errors are very large (Table4).

Parameter	Explanatory variable	Estimate	Std.Error	p-value
Occupancy	Intercept	-2.4	1.06	<0.05
	Permanency	5.4	1.73	<0.005
	Urbanization	-7.69	4.82	0.1104
Colonization	Intercept	-7.76	29.3	0.791
	Favorability	11.07	29.5	0.707
	Forest cover	-13.87	14.5	0.338
Extinction	Intercept	-2.99	1.94	0.123
Detection	Intercept	0.088	0.21	0.675

Table4: Explanatory variables contained in the top ranked a priori multi-season occupancy model 2015. Estimate, standard error, and p-value are shown.

The predicted probability of occupancy in cases that the breeding sites are temporary is equal to 2.5% (\pm 2.9%), while for permanent breeding sites, the predicted probability of occupancy is equal to 85% (\pm 12.08%) (Figure4), and the variable explains the data in significant ways (p-value<0.005). Although the variable does not have a significant effect, I decided to show the effect of the urbanization cover on the occupancy (Figure5), because the p-value was low (=0.1104). The occurrence probability predicted on effect by urbanization cover decreases with increase in the proportion of urban coverage.

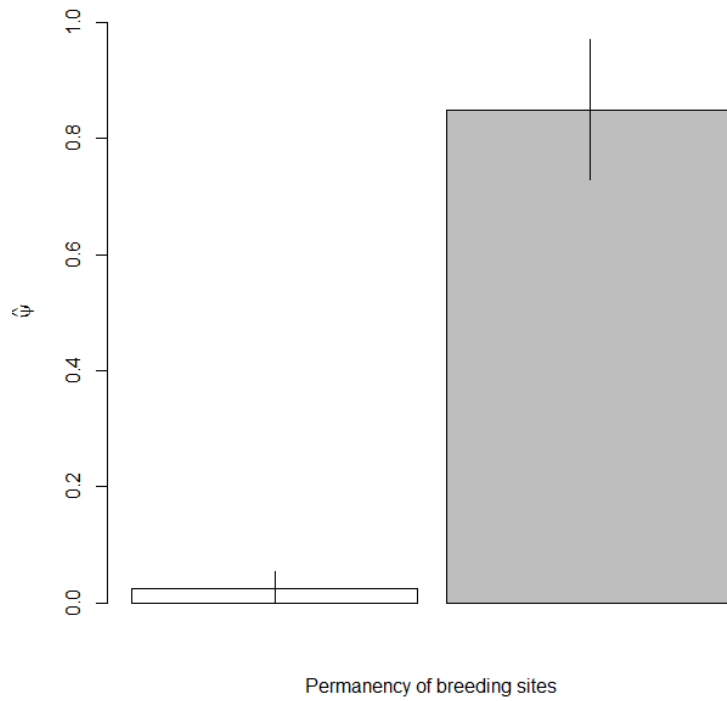


Figure4: The probability of occupancy (ψ), predicted by the best occupancy model, for not permanent breeding sites in white and for permanent breeding sites in gray. Standard error in vertical bars.

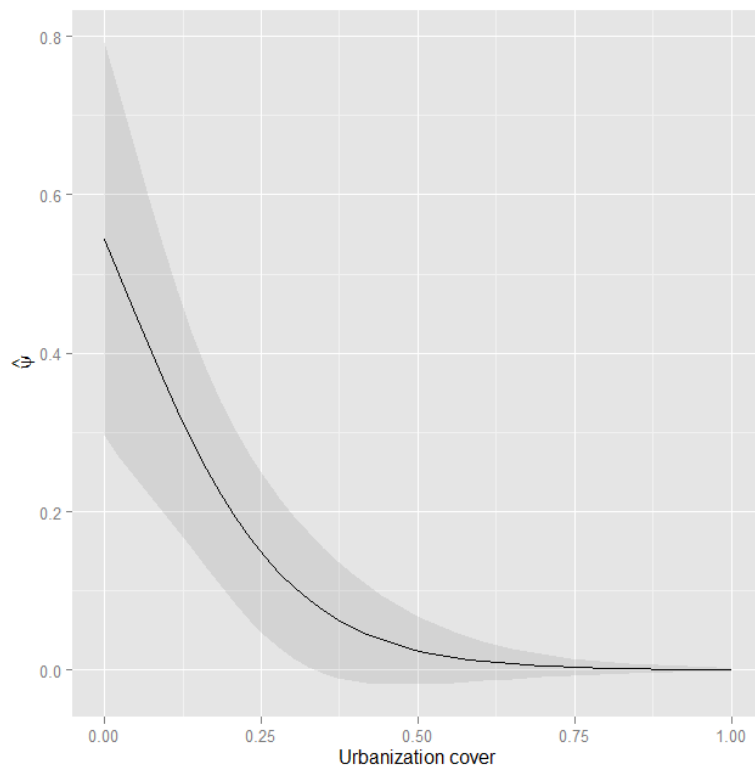


Figure5: The probability of occurrence (ψ), predicted by the best occupancy model, as a function of urban cover. The gray area represents the 95% confidence interval.

DISCUSSION

Quantifying the decline of the common toad

As expected, the decline registered in 2010/11 by Maddalena & Mattei Roesli (2011), for the last twenty years, it was also observed in this study. Although very large populations were observed and if the number of populations observed was slightly higher, the loss of populations was confirmed. The loss of populations however came to a halt. Regarding breeding sites observed in 2014, presence of common toad slightly increase and cases of detection / non detection occurred. This means that the species has re-colonized breeding sites where it had disappeared, and it became extinct in breeding sites where in 2011 it was present. In fact, of the 29 populations observed in 2014, 23 persist and 6 disappear. To these 23 population, must be added 7 populations detected in 2014, in breeding sites where in 2011 the detection was not made. The decline has stopped but the populations who persist in the breeding sites are less. This loss can be due by reduced quality and availability of habitat. This study indicates that a variables of habitat can determine the presence of the common toad in the local breeding sites (Table3). The results indicated that, in the wetlands studied, permanence of the pond has a positive effect on the occurrence of common toad in Ticino (Figure1), while forest cover and the rate of urbanization have a negative effect on the occupancy rate of common toad (Figure2 and 3). As confirmed by the literature (Indermaur et al., 2010), adults of *B. bufo* preferably used permanent ponds, large and deep. Moreover, large and warm ponds improved larvae of common toad performance and larvae grew quickly (Indermaur et al., 2009). Common toad performance may depend on habitat selection and niche-differentiation of the waterbody. This degree of niche-differentiation along environmental gradients (Van Buskirk, 2005; Indermaur et al., 2010) reduce mortality of common toad. In fact, the dead bodies of common toad are seen especially near the pond. Probably deep water can protect against flying predators, since common toad moves slowly compared to other amphibians, but this hypothesis should be investigated in permanent ponds. Permanent ponds are the waterbody more common in urban and suburban areas (Kentula et al., 2004b). Urbanization has negative effect on survival of amphibian's population (Findlay & Bourdages, 1999; Houlahan and Findlay, 2003; Pellet et al., 2004b; Eigenbrod et al., 2008), and results are in accord. Also, results show that forest cover has a negative effect on the occurrence of *B.bufo*. According to Indermaur et al. (2010), common toad is generalist respect to the cover of forest. The effect of forest cover is more difficult to investigate. According to several studies, toads (*Bufo bufo* & *Bufo americanus*) may show a negative association with forest cover (Gagné and Farhig, 2007; Eigenbrod et al., 2008) or a positive association with forest cover (Houlahan and Fidlay, 2003). Therefore the result of negative effect is not surprising. But importance of the negative effect of the high forest cover can be confusing, and not depend on the quality of the habitat but by the fact that in this study permanent ponds were less in areas away urban and suburban areas. So the low probability of occurrence with high forest cover may depend on the covariance of a high rate of urbanization. In fact, Ticino is one of the cantons in Switzerland with more forest cover and one of the most urbanized. In the plains where the urbanization rate is high, there are few trees or small forest. Near these small forests with medium urbanization rate, there are permanent breeding sites where the common toad is able to survive and have a fitness enough to occur.

Conversely, we do not find the common toad in ponds that dry early in the season, in fragmented and degraded habitats, where the traffic is high. Finally, according to the report on the climate in Ticino, in the last three decades, the rate of warming had a marked increase, recorded mainly at low altitudes and in the southern alpine. So ponds that dry early in the season and urbanization rate, they may be the cause of the decline in the ponds considered breeding sites in the past. Although it has no significant effect, it is interesting to note that the presence of fish is the variable that we found in the second model with the smallest AIC (Appendix 3). Fishes can have negative effects on populations of amphibians (Hecnar & M'Closkey, 1997) and are more likely in permanent ponds. The presence of fishes can show positive correlation with common toad occurrence (Van Buskirk, 2005; Indermaur et al., 2010) because larvae are toxic. Thus the presence of fish may decrease the number of amphibians competitors, and increase resource availability.

Swiss Amphibian Red List – Current situation of *Bufo bufo*

The study conducted in 2015 showed an increase of the occurrence of the common toad, in ponds recorded in the Red List. In these ponds, we don't observe a decline, but a "pseudo turnover", with 7 cases of re-colonization and 2 cases of extinction. Of 7 ponds with cases of recolonization, 4 were considered breeding sites, observed in 2014. Of 2 ponds with cases of extinction, one was considered a breeding site, observed in 2014. Of 7 ponds with cases of colonization, 5 are permanent ponds, two were managed to improve good condition for amphibians, and in this ponds all populations are small. However, the model that best explains multi-season data, shows a probability of extinction equal to 4%, a probability of colonization, in the case in ponds are considered not favorable less than 1%, and favorable equal to 19% (SE high). Favorability of ponds could show the possibility of turnover, in favor of the meta-population interpretation. In fact, local population of amphibians can be described as meta-population, which consists of a group of local populations in a wider habitat (Hanski, 1998). The size of the amphibian populations shows natural fluctuations, due to the variability of recruitment (Green, 2003; Beebee and Griffiths, 2005). Therefore, the decline of a local population may be common and a biotope which presents favorable abiotic and biotic characteristics, may promote colonization (Zanini et al., 2009). But colonization in meta-population interpretation, consist of the apparition of the species in the pond, from one population of the same wider habitat, and it is not the case of this study, beyond that in only one case. However, although dynamics of recolonization/extinction is uncertain, the effect of the variables can be interpreted, by comparing it with the probability of occurrence of adult toads in the ponds. Results show that probability of occurrence depends on the permanence of the pond. Moreover, that urban cover has a negative effect on occurrence. Therefore, we can write that longer hydroperiods influence common toad occurrence and can determine breeding site selection. Moreover, it is not surprising that the variables of forest cover and favorability, explains the probability of colonization, although the data are not significant and in the future, studies should be conducted to investigate this issue.

CONCLUSION, APPLICATIONS AND FUTURE WORKS

In 68 ponds visited during the two years of study, the common toad was observed at least once in 33 ponds (<50%). Assuming that the sites are checked in the list of cantonal importance and registered in the amphibian's red list, I do not consider the data as positive. However, the decline seems to have stopped, and this is a good news.

The main finding of my study is that occurrence probability of common toad depend by permanency of ponds, and that urban cover has a negative influence. This can be important 1) for monitoring in wetlands of populations of common toad, 2) for the management of the areas in which the species reproduces and 3) for the creation of areas with characteristics apposite for the selection of the breeding site and promote colonization.

Taking into account the constant decline in the number of amphibian populations observed throughout the world, the main future work is to monitor the occurrence and abundance of common toad, as well as other amphibians in Switzerland. In parallel with the work of monitoring, create new wetlands with favorable conditions, following studies that determine biotic/abiotic characteristics that can influence amphibian occurrence. Finally, find characteristics of permanent ponds that promote fitness and survival of common toad.

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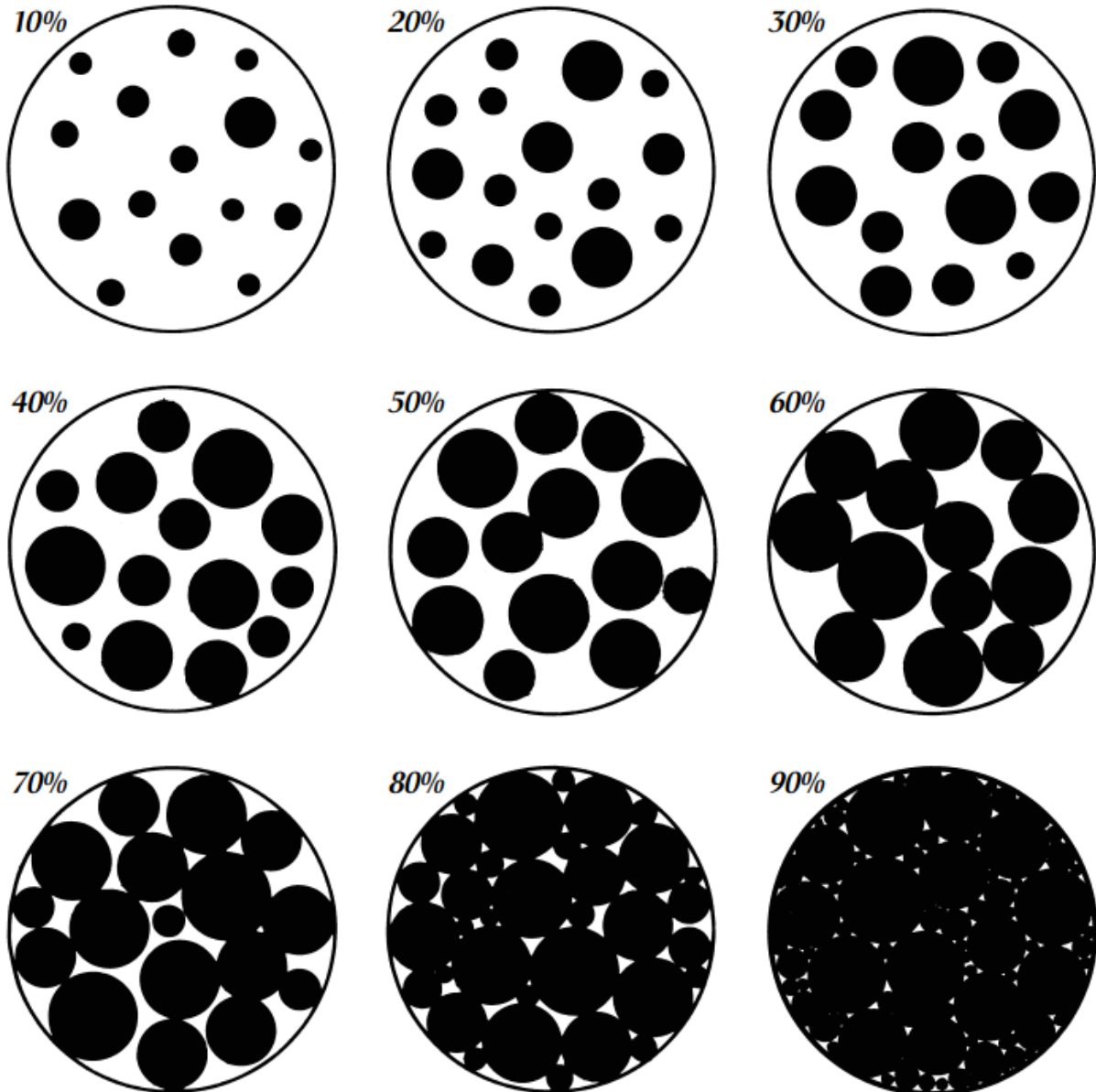
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APPENDICES

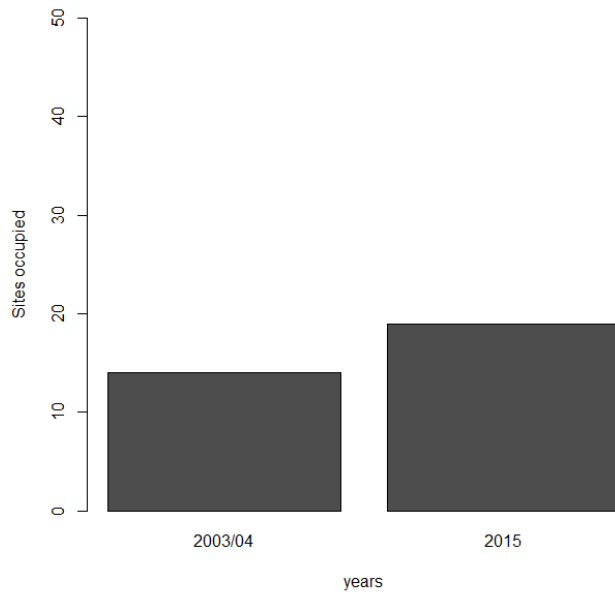
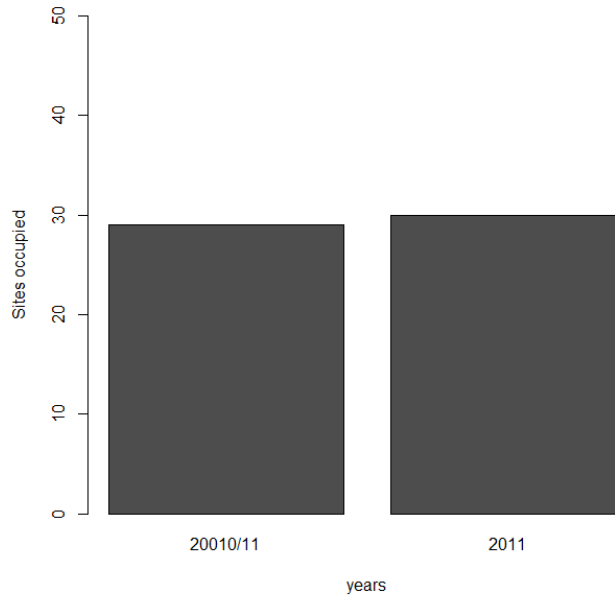
Appendix Ca

Help to determine the degree of coverage of the canopy (Ca). Starting from the minimum coverage of the canopy (10%) up to the maximum (90%) (KARCH, Formular Amphibien in Biberteichen).



Appendix2

Number of breeding sites with the presence of common toad, for the observations of the two studies conducted in 2003-2004 and 2010-11, and the observations made in 2014 and 2105.



Appendix3

Table with the first five top ranked model for the analysis performed in 2014 and 2015.

nPars is the number of parameters , AIC is the Akaike's information Criterion, delta is the different between the AIC of the best model and the AIC of the model, AICwt is the Akaike weight of the model in percent, cumlvtWt is the cumulative AICwt.

pm14 = Permanency 2014, ur14 = Urbanization cover 2014, fo14 = Forest cover 2014, fi14 = Fish presence 2014, ca14 = Canopy cover 2014, pm15 = Permanency 2015, Fav15 = Favorability 2015, fo15 = Forest cover 2015, ur15 = Urbanization cover 2015.

2014 The occupancy from detection / non-detection data model

	nPars	AIC	delta	AICwt	cumlvtwt	Nr. Model
psi(pm14+ur14+fo14)p(.)	5	148.33	0.00	4.6e-01	0.46	29
psi(pm14+fi14+ur14+fo14)p(.)	6	149.59	1.26	2.4e-01	0.70	28
psi(pm14+fi14+ur14+fo14+ca14)p(.)	7	150.00	1.67	2.0e-01	0.90	27
psi(pm14+ur14)p(.)	4	155.71	7.38	1.2e-02	0.92	11
psi(pm14)p(.)	3	155.85	7.52	1.1e-02	0.93	2

2015 The multi-season occupancy model

cumlvtwt	nPars	AIC	delta	AICwt		Nr. Model
psi(pm15+ur15)gam(fav15+fo15)eps(.)p(.)	8	228.72	0.00	3.3e-01	0.33	30
psi(pm15+ur15)gam(fav15)eps(.)p(.)	7	229.45	0.73	2.3e-01	0.57	31
psi(fo15+pm15+ur15)gam(fav15)eps(.)p(.)	8	231.08	2.36	1.0e-01	0.67	28
psi(pm15)gam(fav15+fo15)eps(.)p(.)	7	231.14	2.42	1.0e-01	0.77	17
psi(pm15)gam(fav15)eps(.)p(.)	6	231.22	2.50	9.6e-02	0.86	14

STATEMENT OF AUTHORSHIP

NAME JONATHAN LUPI

TITLE Quantification and explanation of the decline in the number of populations of common toad (*Bufo bufo*), in southern Switzerland.

THESIS SUPERVISOR DR. BENEDIKT R. SCHMIDT
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Neuchâtel.
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University of Zurich.

I declare to have not used other sources or aids other than those specified.

This Master's work was not used for other degree / diploma, in any other institution.

Neuchâtel, September 2015

Jonathan Lupi