Landscape composition predicts the local abundance of painted turtles (*Chrysemys picta*)

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Abstract

Urbanisation is a severe form of habitat loss, degradation, and fragmentation that imperils wildlife. Landscape modifications via urbanisation can indeed harm species such as freshwater turtles that rely on both aquatic and surrounding terrestrial habitats to survive and reproduce. In this study, I tested the hypothesis that the local abundance of painted turtles depends on landscape composition. I predicted that there would be fewer turtles in more urban areas with higher road densities and more turtles in wetlands near other wetlands. From visual surveys of 34 wetlands around Ottawa, I found that there were more painted turtles in sites surrounded by a lot of forest and in larger wetlands. The proportion of wetland in the surrounding area and road density, however, did not have a significant effect on local abundance. The absence of effect must be interpreted with caution because of my modest sample size and the potential delay in turtles' response to changes in the habitat. Nevertheless, forest cover appears to be the best predictor of local painted turtle abundance. The conclusions of this study reiterate the need for proper management of forested land and green areas in urban landscapes to protect turtles cohabiting with humans.

Keywords: Urbanisation, Habitat, Turtle, Wetland, Forest, Road

Résumé

L’urbanisation est une forme aiguë de perte, de dégradation et de fragmentation d’habitat qui met en péril la faune. Les modifications de l’habitat à l’échelle du paysage via l'urbanisation peuvent en effet nuire à de nombreuses espèces telles que les tortues d’eau douce qui dépendent à la fois des habitats aquatiques et terrestres pour survivre et se reproduire. Dans cette étude, j'ai testé l'hypothèse selon laquelle l'abondance locale de tortues peintes dépend de la composition du paysage. J'ai prédit qu'il y aurait moins de tortues dans les zones plus urbaines avec une densité de routes plus élevée et plus de tortues dans les zones humides qui sont à proximité d'autres zones humides. À partir d’observations visuelles de 34 zones humides dans la région d'Ottawa, j'ai constaté qu'il y avait plus de tortues peintes dans les sites où il y avait plus de forêt aux alentours et dans les zones humides de plus grande superficie. Toutefois, la proportion de zones humides et la densité de routes dans les environs n'avaient pas d'effet significatif sur l'abondance locale de tortues peintes. Cette absence d’effet doit être interprétée avec prudence en raison de ma taille d’échantillon modeste et du délai potentiel dans la réponse des tortues à la modification de l’habitat. Néanmoins, le couvert forestier semble être le meilleur indicateur de l'abondance locale de tortues peintes. Les conclusions de cette étude réitèrent la nécessité d'une gestion adéquate des terres boisées et des espaces verts dans les paysages urbains afin de protéger les tortues peintes qui y cohabitent avec les humains.

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Introduction

Many scientists define our epoch as the Anthropocene, an era dominated by *Homo sapiens* (Lewis and Maslin 2015), where only 5 % of Earth’s terrestrial area remains unmodified by human activities (Kennedy et al. 2019). Humans are driving a major biodiversity crisis, with one million species threatened with extinction (IPBES 2019) and an expected species loss of up to 50 % around 2050 (Koh et al. 2004); we are in the midst of the sixth mass extinction (Thomas et al. 2004, Ceballos et al. 2015). Globally, reptiles are one of the most endangered groups, and freshwater turtles are highly threatened (Böhm et al. 2013).

Many factors may cause the plight of reptiles, and particularly turtles, including habitat loss and degradation (Gibbons et al. 2000). Habitat loss and degradation have many implications for wildlife, including an increase in habitat fragmentation, which in turn increases isolation (Meffe and Carroll 1997) and predation pressure (Oehler and Litvaitis 1996). Indeed, fragmentation may elevate predation rates via an increase in predator abundance (Oehler and Litvaitis 1996) due to a human-induced increase in food supply (Baxter-Gilbert et al. 2015). Fragmentation therefore results in an increase in the mortality rate and the probability of extinction of many species (Shepard et al. 2008). Worldwide, the rate of wetland loss, a critical habitat for freshwater turtles and other wildlife, is three times the rate of forest loss (Ramsar Convention on Wetlands 2018). Southern Ontario is no exception, where large numbers of wetlands have been drained or filled to accommodate urbanisation and agricultural activities (Ontario Ministry of Natural Resources and Forestry (OMNRF) 2017), which results in a loss of 72 % of the originally present wetlands (Ontario Biodiversity Council 2010, 2015). Over the years, therefore, freshwater turtles have lost an important part of their habitat.

One human-made habitat modification particularly impedes wildlife movement and fragments the habitat: roads. Roads can have indirect effects on turtles, such as isolating populations, but they can also affect turtles directly through roadkill (Shepard et al. 2008). Indeed, Gibbs and Shriver (2002) estimated that large-bodied pond turtle mortality increases when road density exceeds 2 km/km^2. Turtles are thought to be especially affected by roads because they are long-lived and late-maturing species that depend on high adult survivorship to counterbalance naturally high egg, hatchling, and juvenile mortality (Howell and Seigel 2019). Therefore, population viability is highly sensitive to additive adult mortality caused by roadkill (Selina 1998, Litzgus 2006). Moreover, it has been showed that wildlife can have a lagged response to road construction. For amphibians and reptiles, species loss is perceptible within 8 years, but the full effects take decades to be detectable (Findlay and Bourdages 2000). Some suggest that the effects might not even be observable during a human lifetime, which might skew research conclusions (Shepard et al. 2008). Roads are certainly of major concern for turtle welfare, but their impact needs to be assessed at the appropriate temporal scale (Findlay and Bourdages 2000).

Urbanisation is a paradigmatic case of habitat loss, degradation, and fragmentation, undeniably modifying ecological processes at multiple scales, intensively and irreversibly (Stokeld et al. 2014). Landscape-level factors are important for freshwater turtles because they use both aquatic and surrounding terrestrial habitats to survive and reproduce. Indeed, terrestrial habitats are needed for dispersal, nesting, and, in some species, aestivation (Buchanan et al. 2019). Terrestrial habitats can be important refuges (Roe and Georges 2007) and can be essential for dispersion in case of drought (Winchell and Gibbs 2016). Landscape modifications via urbanisation can therefore have a profound impact on turtle populations.

The painted turtle (*Chrysemys picta*) is found across North America (Ernst and Lovich 2009) and is an ideal species for research because it is easily sampled and recognized (Marchand and Litvaitis 2004). Even though painted turtle populations are considered globally stable by the IUCN (van Dijk 2011), they are considered Special Concern by the Committee on the Status of Endangered Wildlife in Canada because of habitat loss (COSEWIC, 2018). It is therefore an appropriate model for studying urbanisation effects on turtles (Figure 1).

I wish to test the hypothesis that the local abundance of painted turtles depends on landscape composition. I predict that there should be more painted turtles in more natural landscapes. Indeed, more natural landscapes should be less isolated, less fragmented, and less conducive to roadkill than more urban landscapes, resulting in higher habitat quality. I also predict that there should be more painted turtles in areas with more wetlands, as the species prefers shallow-water habitats with abundant basking sites (Ernst and Lovich 2009). Finally, I predict fewer turtles in areas with high road densities, as roads can severely impact adult survival and cause population declines (Szerlag and McRobert 2006, Fahrig and Rytwinski 2009, Crawford et al. 2014).

Although several studies have already investigated the link between painted turtles and urbanisation (Marchand and Litvaitis 2004, DeCatanzaro and Chow-Fraser 2010, Eskew et al. 2010, Buchanan et al. 2019), none have, to my knowledge, (1) exploited a gradient of buffer widths for landscape composition to determine the buffer size at which the relationship with landscape variables is maximised, and (2) study the link between turtle abundance and landscape factors in the rapidly developing region of Ottawa.

Methods

Study area.— I assessed painted turtle abundance in 34 wetlands in the Ottawa region. The region is spatially heterogeneous in term of landscapes, which allowed me to obtain variability among sites. Potential sites were identified using ArcMap version 10.6 (ESRI, 2018; http://www.esri.com) and selected to span a gradient of urbanisation. To minimize potential dispersion between sites and spatial auto-correlation (Stokeld et al. 2014), I only selected wetlands that were at least 1.5 km apart. This distance was chosen because it is beyond most painted turtle dispersion (Steen and Gibbs 2004). Indeed, painted turtles generally travel less than 500 m in one season (Marchand and Litvaitis 2004) and nest generally less than 200 m away from their wetland (Steen et al. 2012). The maximum reported distance covered overland by a painted turtle is 625 m (Christens and Bider 1987, according to Patrick and Gibbs 2010). After a first visit to 40 sites, I selected 34 for the study based on ease of access and ability to fully scan the wetland from its edge. Importantly, I did not select sites on the basis of their expected suitability for turtles, as this is part of my research question.

Selected sites included a variety of types of wetlands from natural to artificial ones, such as stormwater management ponds and ponds in golf courses and parks. Wetlands varied in size, ranging from 0.12 ha to 19.57 ha, with a mean area of 4.12 ha. Landscapes around wetlands differed among sites. For instance, some sites were mainly surrounded by forest or agricultural lands, some sites were surrounded by roads and residential or commercial areas, and others were surrounded by a combination of many landscape types (Figure 2).

Visual surveys.— I counted the number of painted turtles present at a site by scanning the wetland with binoculars and a spotting scope from different locations until most of the wetland perimeter and potential basking sites were scrutinized. Painted turtles are easily recognized and distinguishable from the other species inhabiting wetlands in Ottawa because of the conspicuous red and yellow colours on their throat and limbs, and the size and flattened shape of their carapace (Ernst and Lovich 2009). I noted the number of turtles observed.

The probability of turtle detection is highly related to basking behaviour. As this behaviour is very sensitive to environmental conditions, I estimated the ambient temperature, wind, and cloud cover to control for their effect on my observations. I retrieved the ambient temperature from hourly data report of the Ottawa CDA RCS weather station of Environment Canada (https://climat.meteo.gc.ca/). I estimated wind speed based on the Beaufort wind force scale. I approximated the cloud cover based on the proportion of cloud cover in the sky over the wetland during my observations. Surveys were conducted from

30 May to 27 August 2019 on days with no rain. I visited each site nine times. In general, I sampled all 34 sites consecutively before revisiting a site, and I changed the order of visits so that sites were not surveyed at the same time of day for the nine visits. This allowed me to reduce among-site variation in the detection probability, which changes with the time of day and the date.

Landscape composition.— I conducted landscape analyses in ArcMap version 10.6 (ESRI, 2018; http://www.esri.com), using the Ontario Land Cover Compilation (OLCC) v.2.0 layer. Although the original file contained 29 land cover classes, I condensed them to five cover types (open water, wetland, forest, anthropogenic, agriculture), which increases the map accuracy (Marchand and Litvaitis 2004). I delineated wetland edges manually at a 1:3000 scale with orthophotos to obtain wetland area and control for its effect on local abundance. Buffers were created from the sites' perimeter, excluding the wetland itself, from 50 m to 2000 m distances at 50-m increments (Figure 3). Land cover was measured as a percentage of the total buffer area for each cover type. I calculated correlations between the number of turtles observed at each site and the percentage of each land cover type for each buffer distance, and I retained only the buffer distance at which the correlation was maximal for further statistical analyses. Although land cover types are correlated to each other because the sum of their proportions equals one, their highest correlation with turtle abundance were all at different buffer distances. I also measured road densities as road length per unit of area in ArcMap, and I selected the buffer distance at which the correlation with painted turtle abundance was the highest (50 m – 2000 m) for my statistical models.

Statistical analyses.— To investigate the effect of survey conditions on turtle counts (i.e., survey duration, wind intensity, cloud cover, mean temperature during survey, and wetland area), I used a mixed model and incorporated site ID as a random factor, which takes into account the non-independence of the nine visits to each site. I used a Poisson distribution because it is well-suited for counts of individuals, which are always positive integers (Faraway 2006). To control for overdispersion of the data, I added a random variable to the model which allocates a unique number to each observation (Elston et al. 2001). To estimate the effect of land cover variables on local abundances, I used a generalized linear model. For this second model, I considered the highest count for a site as the best approximation of local abundance and used that value. Selecting the highest counts confers several advantages: (1) it removes some noise in the data, (2) it is appropriate for a seasonal time frame, and (3) it reduces the variation in ambient temperature during surveys among sites because all maximum number of observations happened in a narrower range of temperature that are more suitable for basking. A follow-up analysis revealed that using the mean or the sum of painted turtle counts for each wetland did not change the statistical conclusions. I used a quasi-Poisson distribution to control for overdispersion in the data because the variance was much greater than the mean. Due to low power caused by my modest sample size (n = 34), I had to reduce the number of variables included in this model. Therefore, I selected only the two land cover types for which the correlation with turtle abundance was over 0.3 and I combined all road types into one variable (road density at 300-m buffer distance). I also added wetland area to the model. As explained above, using the highest count for each site removed the necessity to include temperature as a control variable. I completed all statistical analyses in R version 3.5.3 (R Core Team 2019) using the lmerTest package (Kuznetsova et al. 2017).

Results

I found painted turtles in 88 % of wetlands (30/34), ranging from one observed individual to 415, all visits combined (n = 1895 observations, mean maximum abundance of 16.2 ± 4.8 turtles per wetland) (Figure 2; Appendix 1).

Sampling conditions influenced the number of turtles observed. Indeed, more turtles were observed during longer sessions on cold days with few clouds (all p values < 0.01; Table 1), but the turtle count was unaffected by wind speed (p = 0.93) or wetland area (p = 0.17). However, wetland area is highly correlated with sampling duration (r = 0.53; Figure 4). Larger wetlands take generally more time to sample, which results in a higher number of turtles observed.

I obtained the scale of maximum effect for each land cover type through correlations between the number of turtles and the land cover proportions (Figure 5). The highest correlation is at a buffer distance of 900 m for water cover (r = 0.24), 200 m for wetland cover (r = 0.27), 600 m for forest cover (r = 0.35), 100 m for anthropogenic cover (r = −0.21), and 700 m for agricultural cover (r = −0.30). I included the values for each variable at these buffer distances in the second model.

All variables considered for the second model evaluating land cover effect on turtle abundance showed moderate to high correlations between each other (Figure 6), the highest correlation being between forest cover and road density ($r = -0.58$). The proportion of forest and wetland were variable among sites, but road density was low for all sites (Figure 7). More turtles were detected in wetlands surrounded by a lot of forest and in larger wetlands (p values < 0.01; Table 2). For instance, a 10 % increase from the mean in forest cover results in six more turtles inhabiting the wetland, when all other variables are set at the mean (Figure 8). Wetland proportion ($p = 0.18$) and road density ($p = 0.46$), however, were not significant predictors of local turtle abundance.

Discussion

Painted turtle presence

Painted turtles were found in a surprisingly large variety of wetlands, from the most secluded ones to ponds located in crowded parks or golf courses in the center of the city. This observation is consistent with the literature which proposes that painted turtles can live in highly human-altered wetlands and seem to be the most tolerant turtle species to anthropogenic changes (DeCatanzaro and Chow-Fraser 2010). Tolerance to habitat alteration corroborates the understanding of painted turtles as a generalist species with a wide niche breadth (Swihart et al. 2006, Stokeld et al. 2014, Buchanan et al. 2019).

Although human-modifications of a habitat are often detrimental to wildlife, in part because it fragments the area, isolates the populations, and increases mortality through roadkill (Shepard et al. 2008, Stokeld et al. 2014), more urban areas could benefit turtles for two main reasons (DeCatanzaro and Chow-Fraser 2010): developed areas may provide (1) new nesting sites through the creation of canopy gaps (e.g., residential lawns, roadside banks; Baldwin et al. 2004, Marchand and Litvaitis 2004) and (2) more abundant food sources as water bodies may have become more eutrophic and thus have an increased productivity (Knight and Gibbons 1968, Buchanan et al. 2019). High turtle abundances observed in urban areas could also be due to low emigration rates, as expected in large isolated patches. Indeed, urban turtle populations have been isolated from others by wetland loss and human disturbance, which could result in a reduced dispersion outside of the wetland and a high population size (Gosling and Sutherland 2000, Rizkalla and Swihart 2006, DeCatanzaro and Chow-Fraser 2010).

The four unoccupied wetlands in my study are young (were formed between 2007-2017) or dried up in the past few years, which indicates that painted turtles just may not yet have had time to colonize the new habitat. Buchanan et al. (2019) suggested that painted turtles have a great ability to disperse and colonize created wetlands, but the probability of colonization depends on many factors such as isolation, habitat quality, wetland area, and wetland inundation levels (Cosentino et al. 2010). Unfortunately, I do not have sufficient data to estimate these probabilities, but it would have been an interesting exercise to determine how likely they were to be occupied.

Painted turtle detection

Sampling conditions had a significant effect on turtle detection. More turtles were observed during longer sessions and when it was cooler with few clouds. The increase in the number of turtles detected with increased sample duration is trivial for two main reasons. (1) In general, as sampling effort increases, the number of individuals sampled increases. (2) Wetlands take longer to sample usually because they are larger, and, all else being equal, larger suitable patches of habitat have the potential to sustain larger population sizes (Connor et al. 2000; although all else is never equal, and in almost half the studies density can be negatively associated with patch size, see Bender et al. 1998). Moreover, the effect of environmental conditions on turtle counts was also expected because turtles were mainly observed while they were basking. Basking is highly related to environmental conditions such as temperature and cloud cover. Indeed, the need for basking at 30 °C should be much less than at 15 °C, as the preferred body temperature ranges between 21.3 and 25.0 °C in painted turtles (Edwards and Blouin-Demers 2007).

Turtle detection might be biased towards less developed areas because there is less human activity taking place in proximity of the wetland. Even though I tried to minimize my impact on turtle detection at each visit – through attenuation of the noise I made when approaching wetlands and limited proximity with wetland edges, some factors were outside and beyond my control. For instance, in more developed areas, some sites were visited before me by hikers, bikers, swimmers, or dog owners. Turtles may have been scared away before I could see them. Some other wetlands were in close proximity to construction sites making enormous sound pollution, which could also scare away turtles. However, as developed areas are generally more visited than others, disturbed more frequently and over a longer period of time, turtles might be habituated to human presence and no longer disturbed by their activities in those areas. Benign encounters with humans are indeed thought to result in habituation to human presence in turtles (Bateman et al. 2014). This mechanism could therefore compensate for the effects of increased disturbance in developed areas.

Accurate estimates of abundance are hard to acquire and require a lot of resources invested in a long-term mark-recapture study (Buchanan et al. 2019) because there is considerable variance in observability of turtles (Dorland et al. 2014). In the context of my study, I decided to use the maximum number of painted turtles observed in one visit as a proxy for population size at a site. The number of visits at each site was high and equal across sites, which should reduce the variability in detection overall. As I visited each site nine times, it would have been possible to calculate estimates of population size based on the detection probability with point count N-mixture models and the unmarked package in R (Royle 2004, Fiske and Chandler 2011, Ficetola et al. 2018, Fiske et al. 2020). However, this type of model requires a lot of assumptions, which prevents me from obtaining accurate estimates. Indeed, it does not take into account detection errors and suppose that the detection probability is constant. I am confident that the detection probability is not the same for each visit and each site, as conditions in the field varied greatly. Although I understand the value of such models, I do not think it would have been a useful addition to my study.

Landscape predictors of turtle abundance

The main goal of this study was to test the hypothesis that local abundance of painted turtles depends on landscape composition. My hypothesis is partly supported, with some landscape cover types (e.g., forest cover) being better predictors of local turtle abundance than others (e.g., wetland cover).

I predicted that there would be fewer painted turtles in more urban landscapes. I found that there were more painted turtles when there was more forest surrounding the wetland. In fact, when every other parameter is set to the mean, the number of turtles predicted in a wetland increases by 90 individuals for an associated increase from 0 to 65 % of forest cover. This result was also found in similar studies (Patrick and Gibbs 2010, Quesnelle et al. 2013, Buchanan et al. 2019), which confirms the importance of forest cover in the surrounding terrestrial habitat of turtles. However, it is difficult to assess directly the effect of urbanisation, because agricultural and anthropogenic covers were excluded from my model. In my study, forest cover was highly negatively correlated with anthropogenic and agricultural cover. Urbanisation and agriculture have certainly led to important forest losses over time and still do. Bearing in mind that forest did have a positive significant effect on turtle populations, I can assume that, in turn, urbanisation may have a negative effect. Conversion of forested land into agriculture may indeed cause fragmentation, degradation, and affect wetland hydrology (Findlay and Houlahan 1997). Therefore, my study suggests that lower turtle abundances should be observed in more urbanized areas. My prediction is supported, although the strength of my inference is low. In the literature, both results have been found, with human-modified areas having negative effects on amphibians (Griffin et al. 2017) and turtles (Karunarathna et al. 2017, Stratmann et al. 2020), or having no effects (Bowen and Janzen 2008, Eskew et al. 2010, Stokeld et al. 2014). It is possible that the potential gain in nesting sites and food availability associated with urbanized areas (DeCatanzaro and Chow-Fraser 2010) compensates for the loss of refuges and connectivity (Meffe and Carroll 1997, Roe and Georges 2007). Unfortunately, the results of my study do not allow me to shed light on this uncertainty in the scientific literature, in part because the effect is most certainly species-specific and context-specific.

I also predicted that there would be more painted turtles in areas surrounded by other wetlands. However, I did not find support for this prediction. Wetland cover was not significantly correlated with turtle abundance, which is consistent with a study that has found that turtle occurrence is not related to wetland amount in southeastern Ontario (Quesnelle et al. 2013). The loss of connectivity between wetlands, through deforestation and other human-induced habitat modifications, could explain the absence of correlation between wetland cover and turtle densities. However, I found that there were more painted turtles in larger wetlands, which means that the size of a wetland is a significant predictor of local painted turtle abundance. This is consistent with the literature (Failey et al. 2007, Price et al. 2013, Winchell and Gibbs 2016) and could be explained by an increased productivity in larger wetlands (Winchell and Gibbs 2016), or simply by the fact that larger habitats can support larger populations, all else being equal.

Roads

I found no effect of road density on painted turtle abundance. I predicted that there would be fewer turtles in wetlands surrounded by high road densities because such infrastructures fragment the area (Shepard et al. 2008) and can cause high adult mortality (Crawford et al. 2014). My prediction was not supported by my data. This result is unexpected given that forest cover affected positively turtle density and that there is a high negative correlation between road density and forest cover. The correlation between those variables was in fact the highest between all variables in my model ($r = -0.58$) and, thus, the effect of road density could have been masked by its high correlation with forest cover. Masking seems improbable, however, because all my variables had variance inflation factors (VIF) bellow 3 (Zuur et al. 2010).

The absence of correlation between road density and painted turtle abundance could be explained by at least three factors. (1) Wildlife often exhibits a lagged response to habitat modification (Reese and Welsh 1998). It could take several decades before we observe the effects of roads on reptiles (Findlay and Bourdages 2000), especially on long-lived species such as turtles. If indeed roads have an effect on turtle populations, my results suggest that it simply cannot be detected yet. Over the past 50 years, the Ottawa road landscape has dramatically changed, with more and bigger roads being built. Since turtles have long generation times (Vanek and Glowacki 2019), it is possible that those changes are too recent for their effects to be observed. (2) My study may not have enough power to detect the effect of roads on turtle populations because of my modest sample size and the small variation in road density among my sites. In my methodology, I decided to combine all road types into one variable and to test its effect at only one buffer size (at which the correlation was maximized; 300 m). I had to reduce the number of variables tested because my sample size was too small to build more complex models. However, some studies have found that road mortality varies with road types and traffic volumes (Findlay and Houlahan 1997, Gibbs and Shriver 2002, Szerlag and McRobert 2006, Winchell and Gibbs 2016), with high road density and low traffic volumes causing low mortality levels. In residential areas, where most of the urban sites of my study were located, low traffic levels combined with low speed limits could explain a low mortality rate and the absence of correlation between road density and turtle abundance (Eskew et al. 2010, Winchell and Gibbs 2016). Yet, not all studies have used different road categories in their analyses, but they still found significant effects or road density on turtle populations (e.g. DeCatanzaro and Chow-Fraser 2010). In any case, the amalgamation of road types and traffic volumes into one broad variable could explain, at least partially, the non-significant result I found. (3) The road densities in the Ottawa region may not be high enough to alter population sizes. On average, my sites had a 0.005 km/km^2 road density within a radius of 300 m from the wetland's edge. Gibbs and Shriver (2002) predicted that roads are significantly contributing to adult morality in large-bodied pond turtles at a regional scale when road density is over 2 km/km^2. However, based on their predictive model, roads do not threaten small-bodied pond turtles such as *Chrysemys picta*. It is therefore unclear if road density is simply not high enough to have a significant effect on painted turtle population or if there is just no effect. Thus, my results do not allow me to conclude whether roads negatively affect turtle populations or not. In fact, the literature is quite divided on that matter, with studies that have found effects of roads on reptiles (Findlay and Houlahan 1997, DeCatanzaro and Chow-Fraser 2010) and others that have not (Quesnelle et al. 2013, Dorland et al. 2014). Once again, the conflicting results found in the literature might be symptomatic of a context specificity.

Conclusion

My study, in addition to others, emphasizes the fact that biodiversity critically depends on terrestrial habitat surrounding wetlands (Semlitsch and Bodie 2003). Protecting larger areas around wetlands, especially forested ones, could be crucial to turtle population persistence.

Potential synergistic effects of urbanisation are worrisome. For example, the effect of forest loss could be aggravated by roadkill (Patrick and Gibbs 2010). This might seem improbable in my study system because I have not found negative effects of roads on turtle populations. However, the absence of immediate response in population abundance to habitat modification at the landscape level can be misleading. Indeed, the results of this study should be interpreted with caution because of the potential delay in turtles' response to changes in the habitat (Reese and Welsh 1998, Marchand and Litvaitis 2004). Even if we stopped road construction immediately, diversity would still decline (Findlay and Bourdages 2000). We should also bear in mind that a high abundance does not imply that the population is stable (Winchell and Gibbs 2016). Only a long-term monitoring study could assess the state of the population.

The conservation-minded management of urban green-spaces could offer important amounts of suitable habitat for turtles that would be inexistent otherwise (Colding et al. 2006) and could even complement nature reserves (Winchell and Gibbs 2016). Anecdotally, I noticed that my sites located in golf courses and parks were able to sustain relatively large populations compared to sites in more industrialized areas, surrounded by small amounts of vegetation. This reiterates the need for protection and proper management of wetlands in urban areas through effective incentive programs for private landowners and collective efforts.

References

Baldwin, E. A., M. N. Marchand, and J. Litvaitis. 2004. Terrestrial habitat use by nesting painted turtles in landscapes with different levels of fragmentation. Northeastern Naturalist 11:41–48.

Bateman, P. W., P. A. Fleming, B. C. Jones, and B. B. Rothermel. 2014. Defensive responses of gopher tortoises (Gopherus polyphemus) are influenced by risk assessment and level of habituation to humans. Behaviour 151:1267–1280.

Baxter-Gilbert, J. H., J. L. Riley, D. Lesbarrères, and J. D. Litzgus. 2015. Mitigating reptile road mortality: Fence failures compromise ecopassage effectiveness. PLoS ONE 10:1–15.

Bender, D. J., T. A. Contreras, and L. Fahrig. 1998. Habitat Loss and Population Decline: A Meta-Analysis of the Patch Size Effect. Ecology 79:517.

Böhm, M., B. Collen, J. E. M. Baillie, P. Bowles, J. Chanson, N. Cox, G. Hammerson, M. Hoffmann, S. R. Livingstone, M. Ram, A. G. J. Rhodin, S. N. Stuart, P. P. van Dijk, B. E. Young, L. E. Afuang, A. Aghasyan, A. García, C. Aguilar, R. Ajtic, F. Akarsu, L. R. V. Alencar, A. Allison, N. Ananjeva, S. Anderson, C. Andrén, D. Ariano-Sánchez, J. C. Arredondo, M. Auliya, C. C. Austin, A. Avci, P. J. Baker, A. F. Barreto-Lima, C. L. Barrio-Amorós, D. Basu, M. F. Bates, A. Batistella, A. Bauer, D. Bennett, W. Böhme, D. Broadley, R. Brown, J. Burgess, A. Captain, S. Carreira, M. del R. Castañeda, F. Castro, A. Catenazzi, J. R. Cedeño-Vázquez, D. G. Chapple, M. Cheylan, D. F. Cisneros-Heredia, D. Cogalniceanu, H. Cogger, C. Corti, G. C. Costa, P. J. Couper, T. Courtney, J. Crnobrnja-Isailovic, P. A. Crochet, B. Crother, F. Cruz, J. C. Daltry, R. J. R. Daniels, I. Das, A. de Silva, A. C. Diesmos, L. Dirksen, T. M. Doan, C. K. Dodd, J. S. Doody, M. E. Dorcas, J. Duarte de Barros Filho, V. T. Egan, E. H. El Mouden, D. Embert, R. E. Espinoza, A. Fallabrino, X. Feng, Z. J. Feng, L. Fitzgerald, O. Flores-Villela, F. G. R. França, D. Frost, H. Gadsden, T. Gamble, S. R. Ganesh, M. A. Garcia, J. E. García-Pérez, J. Gatus, M. Gaulke, P. Geniez, A. Georges, J. Gerlach, S. Goldberg, J. C. T. Gonzalez, D. J. Gower, T. Grant, E. Greenbaum, C. Grieco, P. Guo, A. M. Hamilton, K. Hare, S. B. Hedges, N. Heideman, C. Hilton-Taylor, R. Hitchmough, B. Hollingsworth, M. Hutchinson, I. Ineich, J. Iverson, F. M. Jaksic, R. Jenkins, U. Joger, R. Jose, Y. Kaska, U. Kaya, J. S. Keogh, G. Köhler, G. Kuchling, Y. Kumlutaş, A. Kwet, E. La Marca, W. Lamar, A. Lane, B. Lardner, C. Latta, G. Latta, M. Lau, P. Lavin, D. Lawson, M. LeBreton, E. Lehr, D. Limpus, N. Lipczynski, A. S. Lobo, M. A. López-Luna, L. Luiselli, V. Lukoschek, M. Lundberg, P. Lymberakis, R. Macey, W. E. Magnusson, D. L. Mahler, A. Malhotra, J. Mariaux, B. Maritz, O. A. V. Marques, R. Márquez, M. Martins, G. Masterson, J. A. Mateo, R. Mathew, N. Mathews, G. Mayer, J. R. McCranie, G. J. Measey, F. Mendoza-Quijano, M. Menegon, S. Métrailler, D. A. Milton, C. Montgomery, S. A. A. Morato, T. Mott, A. Muñoz-Alonso, J. Murphy, T. Q. Nguyen, G. Nilson, C. Nogueira, H. Núñez, N. Orlov, H. Ota, J. Ottenwalder, T. Papenfuss, S. Pasachnik, P. Passos, O. S. G. Pauwels, N. Pérez-Buitrago, V. Pérez-Mellado, E. R. Pianka, J. Pleguezuelos, C.

Pollock, P. Ponce-Campos, R. Powell, F. Pupin, G. E. Quintero Díaz, R. Radder, J. Ramer, A. R. Rasmussen, C. Raxworthy, R. Reynolds, N. Richman, E. L. Rico, E. Riservato, G. Rivas, P. L. B. da Rocha, M. O. Rödel, L. Rodríguez Schettino, W. M. Roosenburg, J. P. Ross, R. Sadek, K. Sanders, G. Santos-Barrera, H. H. Schleich, B. R. Schmidt, A. Schmitz, M. Sharifi, G. Shea, H. T. Shi, R. Shine, R. Sindaco, T. Slimani, R. Somaweera, S. Spawls, P. Stafford, R. Stuebing, S. Sweet, E. Sy, H. J. Temple, M. F. Tognelli, K. Tolley, P. J. Tolson, B. Tuniyev, S. Tuniyev, N. üzüm, G. van Buurt, M. Van Sluys, A. Velasco, M. Vences, M. Veselý, S. Vinke, T. Vinke, G. Vogel, M. Vogrin, R. C. Vogt, O. R. Wearn, Y. L. Werner, M. J. Whiting, T. Wiewandt, J. Wilkinson, B. Wilson, S. Wren, T. Zamin, K. Zhou, and G. Zug. 2013. The conservation status of the world's reptiles. Biological Conservation 157:372–385.

Bowen, K. D., and F. J. Janzen. 2008. Human Recreation and the Nesting Ecology of a Freshwater Turtle (Chrysemys picta). Chelonian Conservation and Biology 7:95–100.

Buchanan, S. W., B. Buffum, G. Puggioni, and N. E. Karraker. 2019. Occupancy of freshwater turtles across a gradient of altered landscapes. Journal of Wildlife Management 83:435–445.

Ceballos, G., P. R. Ehrlich, A. D. Barnosky, A. García, R. M. Pringle, and T. M. Palmer. 2015. Accelerated modern human-induced species losses: Entering the sixth mass extinction. Science Advances 1:9–13.

Christens, E., and J. R. Bider. 1987. Nesting Activity and Hatching Success of the Painted Turtle (*Chrysemys picta marginata*) in Southwestern Quebec. Herpetologica 43:55–65.

Colding, J., J. Lundberg, and C. Folke. 2006. Incorporating Green-area User Groups in Urban Ecosystem Management. AMBIO: A Journal of the Human Environment 35:237–244.

Connor, E. F., A. C. Courtney, and J. M. Yoder. 2000. Individuals-area relationships: The relationship between animal population density and area. Ecology 81:734–748.

Cosentino, B. J., R. L. Schooley, and C. A. Phillips. 2010. Wetland hydrology, area, and isolation influence occupancy and spatial turnover of the painted turtle, Chrysemys picta. Landscape Ecology 25:1589–1600.

Crawford, B. A., J. C. Maerz, N. P. Nibbelink, K. A. Buhlmann, and T. M. Norton. 2014. Estimating the consequences of multiple threats and management strategies for semi-aquatic turtles. Journal of Applied Ecology 51:359–366.

DeCatanzaro, R., and P. Chow-Fraser. 2010. Relationship of road density and marsh condition to turtle assemblage characteristics in the Laurentian Great Lakes. Journal of Great Lakes Research 36:357–365.

Díaz, S., J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.

van Dijk, P. P. 2011. Chrysemys picta (errata version published in 2016). The IUCN Red List of Threatened Species 2011.

Dorland, A., T. Rytwinski, and L. Fahrig. 2014. Do roads reduce painted turtle (Chrysemys picta) populations? PLoS ONE 9.

Edwards, A. L., and G. Blouin-Demers. 2007. Thermoregulation as a function of thermal quality in a northern population of painted turtles, *Chrysemys picta*. Canadian Journal of Zoology 85:526–535.

Elston, D. A., R. Moss, T. Boulinier, C. Arrowsmith, and X. Lambin. 2001. Analysis of aggregation, a worked example: Numbers of ticks on red grouse chicks. Parasitology 122:563–569.

Ernst, C. H., and J. E. Lovich. 2009. Turtles of the United States and Canada. John Hopkins University Press, Baltimore.

Eskew, E. A., S. J. Price, and M. E. Dorcas. 2010. Survivorship and Population Densities of Painted Turtles (Chrysemys picta) in Recently Modified Suburban Landscapes. Chelonian Conservation and Biology 9:244–249.

Fahrig, L., and T. Rytwinski. 2009. Effects of roads on animal abundance: An empirical review and synthesis. Ecology and Society 14: 21.

Failey, E. L., J. C. McCoy, S. J. Price, and M. E. Dorcas. 2007. Ecology of Turtles Inhabiting Golf Course and Farm Ponds in the Western Piedmont of North Carolina. Journal of the Noth Carolina Academy of Science 123:221–232.

Faraway, J. J. 2006. Count Regression. Pages 61–74. Extending the Linear Model with R: Generalized Linear, Mixed Effects and Nonparametric Regression Models. Chapman & Hall/CRC Taylor & Francis Group, London, New York.

Ficetola, G. F., B. Barzaghi, A. Melotto, M. Muraro, E. Lunghi, C. Canedoli, E. Lo Parrino, V. Nanni, I. Silva-Rocha, A. Urso, M. A. Carretero, D. Salvi, S. Scali, G. Scarì, R. Pennati, F. Andreone, and R. Manenti. 2018. N-mixture models reliably estimate the abundance of small vertebrates. Scientific Reports 8:1–8.

Findlay, C. S., and J. Bourdages. 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology 14:86–94.

Findlay, C. S., and J. Houlahan. 1997. Anthropogenic Correlates of Species Richness in Southeastern Ontario Wetlands. Correlativos Antropogenicos de la Riqueza de Especies en Humedales del Sureste de Ontario. Conservation Biology 11:1000–1009.

Fiske, I., and R. Chandler. 2011. unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. Journal of Statistical Software 43:1–23.

Fiske, I., R. Chandler, D. Miller, A. Royle, M. Kery, J. Hostetler, A. Smith, and K. Kellner. 2020. Package ‘ unmarked .’ R topics documented.

Gibbons, J. W., D. E. Scott, T. J. Ryan, K. A. Buhlmann, T. D. Tuberville, B. S. Metts, J. L. Greene, T. Mills, Y. Leiden, S. Poppy, and C. T. Winne. 2000. The Global Decline of Reptiles, Déjà Vu Amphibians. BioScience 50:653–666.

Gibbs, J. P., and W. G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16:1647–1652.

Gosling, L. M., and W. J. Sutherland. 2000. Butterfly movement and conservation in patchy land. Pages 85–104. Behaviour and conservation. Cambridge University Press.

Griffin, L. P., J. W. Brownscombe, T. O. Gagné, A. D. M. Wilson, S. J. Cooke, and A. J. Danylchuk. 2017. Individual-level behavioral responses of immature green turtles to snorkeler disturbance. Oecologia 183:909–917.

Howell, H. J., and R. A. Seigel. 2019. The Effects of Road Mortality on Small, Isolated Turtle Populations. Journal of Herpetology 53:39–46.

Karunarathna, S., A. A. T. Amarasinghe, S. Henkanaththegedara, T. Surasinghe, M. Madawala, D. Gabadage, and M. Botejue. 2017. Distribution, habitat associations and conservation implications of Sri Lankan freshwater terrapins outside the protected area network. Aquatic Conservation: Marine and Freshwater Ecosystems 27:1301–1312.

Kennedy, C. M., J. R. Oakleaf, D. M. Theobald, S. Baruch-Mordo, and J. Kiesecker. 2019. Managing the middle: A shift in conservation priorities based on the global human modification gradient. Global Change Biology 25:811–826.

Knight, A. W., and J. W. Gibbons. 1968. Food of the Painted Turtle , Chrysemys picta , in a Polluted River. The American Midland Naturalist 80:558–562.

Koh, L. P., R. R. Dunn, N. S. Sodhi, R. K. Colwell, H. C. Proctor, and V. S. Smith. 2004. Species coextinctions and the biodiversity crisis. Science 305:1632–1634.

Kuznetsova, A., P. Brockhoff, and R. Christensen. 2017. lmerTest Package: Tests in Linear Mixed Effects Models. Journal of Statistical Software 82:1–26.

Lewis, S. L., and M. A. Maslin. 2015. Defining the Anthropocene. Nature 519:171–180.

Litzgus, J. D. 2006. Sex Differences in Longevity in the Spotted Turtle (Clemmys guttata). Copeia 2006:281–288.

Marchand, M. N., and J. A. Litvaitis. 2004. Effects of Habitat Features and Landscape Composition on the Population Structure of a Common Aquatic Turtle in a Region Undergoing Rapid Development. Conservation Biology 18:758–767.

Meffe, G. K., and C. R. Carroll. 1997. Principles of Conservation Biology. Second edition. Sunderland, Massachusetts: Sinauer Associates Inc.

Oehler, J. D., and J. A. Litvaitis. 1996. The role of spatial scale in understanding responses of medium-sized carnivores to forest fragmentation. Canadian Journal of Zoology 74:2070–2079.

Ontario Biodiversity Council (OBC). 2010. State of Ontario's Biodiversity 2010: A report of the Ontario Biodiversity Council. Peterborough, ON.

Ontario Biodiversity Council (OBC). 2015. State of Ontario's Biodiversity 2015: A report of the Ontario Biodiversity Council. Peterborough, ON.

Ontario Ministry of Natural Resources and Forestry (OMNRF). 2017. A Wetland Conservation Strategy for Ontario 2017–2030. Queen's Printer for Ontario, Toronto, ON.

Patrick, D. A., and J. P. Gibbs. 2010. Population structure and movements of freshwater turtles across a road-density gradient. Landscape Ecology 25:791–801.

Price, S. J., J. Guzy, L. Witczak, and M. E. Dorcas. 2013. Do Ponds on Golf Courses Provide Suitable Habitat for Wetland-Dependent Animals in Suburban Areas? An Assessment of Turtle Abundances. Journal of Herpetology 47:243–250.

Quesnelle, P. E., L. Fahrig, and K. E. Lindsay. 2013. Effects of habitat loss, habitat configuration and matrix composition on declining wetland species. Biological Conservation 160:200–208.

R Core Team. 2019. R: A Language and Environment for Statistical Computing. Vienna, Austria.

Ramsar Convention on Wetlands. 2018. Global Wetland Outlook: State of the World's Wetlands and their Services to People. Gland, Switzerland: Ramsar Convention Secretariat.

Reese, D. A., and H. H. Welsh. 1998. Comparative Demography of Clemmys marmorata Populations in the Trinity River of California in the Context of Dam-induced Alterations. Journal of Herpetology 32:505–515.

Rizkalla, C. E., and R. K. Swihart. 2006. Community structure and differential responses of aquatic turtles to agriculturally induced habitat fragmentation. Landscape Ecology 21:1361–1375.

Roe, J. H., and A. Georges. 2007. Heterogeneous wetland complexes, buffer zones, and travel corridors: Landscape management for freshwater reptiles. Biological Conservation 135:67–76.

Royle, J. A. 2004. N-Mixture Models for Estimating Population Size from Spatially Replicated Counts. Biometrics 60:108–115.

Selina S., H. 1998. Application of Life-History Theory and Population Model Analysis to Turtle Conservation. Copeia 1998:367–375.

Semlitsch, R. D., and J. R. Bodie. 2003. Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. Conservation Biology 17:1219–1228.

Shepard, D. B., A. R. Kuhns, M. J. Dreslik, and C. A. Phillips. 2008. Roads as barriers to animal movement in fragmented landscapes. Animal Conservation 11:288–296.

Steen, D. A., J. P. Gibbs, K. A. Buhlmann, J. L. Carr, B. W. Compton, J. D. Congdon, J. S. Doody, J. C. Godwin, K. L. Holcomb, D. R. Jackson, F. J. Janzen, G. Johnson, M. T. Jones, J. T. Lamer, T. A. Langen, M. V. Plummer, J. W. Rowe, R. A. Saumure, J. K. Tucker, and D. S. Wilson. 2012. Terrestrial habitat requirements of nesting freshwater turtles. Biological Conservation 150:121–128.

Steen, D. a, and J. P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143–1148.

Stokeld, D., A. J. Hamer, R. Van Der Ree, V. Pettigrove, and G. Gillespie. 2014. Factors influencing occurrence of a freshwater turtle in an urban landscape: A resilient species? Wildlife Research 41:163–171.

Stratmann, T. S. M., T. M. Floyd, and K. Barrett. 2020. Habitat and History Influence Abundance of Bog Turtles. Journal of Wildlife Management 84:331–343.

Swihart, R. K., J. J. Lusk, J. E. Duchamp, C. E. Rizkalla, and J. E. Moore. 2006. The roles of landscape context, niche breadth, and range boundaries in predicting species responses to habitat alteration. Diversity and Distributions 12:277–287.

Szerlag, S., and S. P. McRobert. 2006. Road occurrence and mortality of the northern diamondback terrapin. Applied Herpetology 3:27–37.

Thomas, J. A., M. G. Telfer, D. B. Roy, C. D. Preston, J. J. D. Greenwood, J. Asher, R. Fox, R. T. Clarke, and J. H. Lawton. 2004. Comparative Losses of British Butterflies, Birds, and Plants and the Global Extinction Crisis. Science 303:1879–1881.

Vanek, J. P., and G. A. Glowacki. 2019. Assessing the impacts of urbanization on sex ratios of painted turtles (Chrysemys picta). Diversity 11:1–13.

Winchell, K. M., and J. P. Gibbs. 2016. Golf courses as habitat for aquatic turtles in urbanized landscapes. Landscape and Urban Planning 147:59–70.

Zuur, A. F., E. N. Ieno, and C. S. Elphick. 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution 1:3–14.

Table 1. Mixed model investigating the effects of sampling conditions on the number of painted turtles observed (N = 306) around Ottawa, Ontario, Canada. All variables except wind intensity (which is a categorical variable) were standardized. Significant p values for $\alpha = 0.05$ are in bold.

Variables	**Estimate**	**Degrees of freedom**	**p value**
Intercept	0.4636	1	0.496
Sampling duration	7.4351	1	**0.006**
Wind	1.2673	5	0.938
Cloud cover	9.0100	1	**0.003**
Mean temperature	9.1270	1	**0.003**
Wetland area	1.8986	1	0.168

Table 2. Generalized linear model investigating the effects of land cover and road density on the number of painted turtles observed (N = 34) around Ottawa, Ontario, Canada. All variables were standardized. Significant p values for $\alpha = 0.05$ are in bold. The buffer distance used to measure land type proportion and road density was variable for each predictor (forest: 600 m; wetland: 200 m; road density: 300 m).

Variables	**Estimate**	**Standard error**	**t value**	**p value**
Intercept	2.3627	0.2611	9.049	**> 0.001**
Forest cover	0.7391	0.2464	3.000	**0.006**
Wetland cover	0.2352	0.1707	1.378	0.179
Road density	0.2651	0.3564	0.744	0.463
Wetland area	0.5918	0.1659	3.566	**0.001**

Figure 1. Painted turtle (*Chrysemys picta*) observed basking during one of my surveys. I used painted turtles as a model species for studying urbanisation effects on turtles at the landscape level.

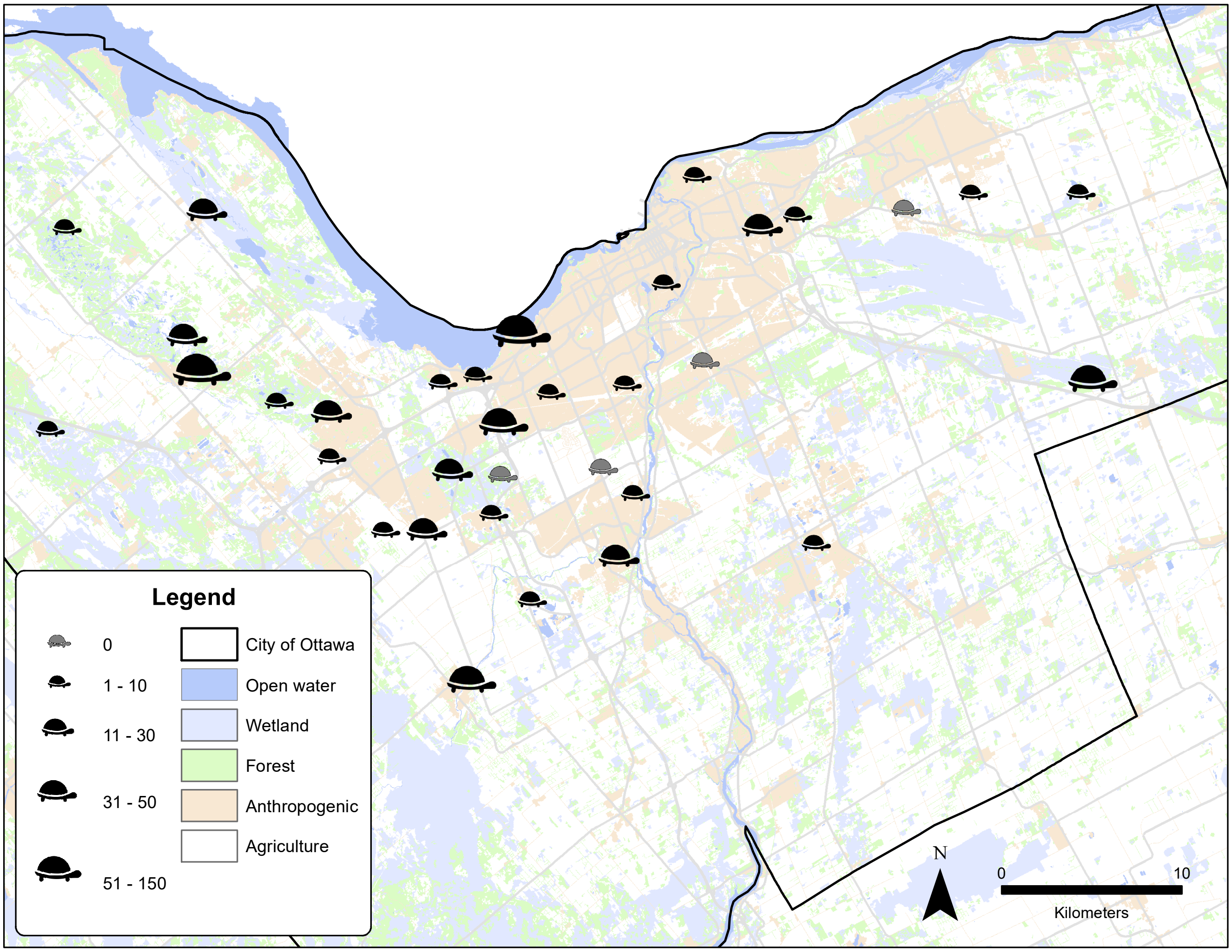

Figure 2. Maximum number of painted turtles observed during one visit at each site (N = 34) around Ottawa, Ontario, Canada.

Figure 3. Buffers were created from 50 m to 2000 m (at 50-m increments) from the wetlands' perimeter to measure land cover. The wetland perimeter is delineated in black, and the first two buffer distances (50 m and 100 m from the wetland's perimeter) are shown in yellow.

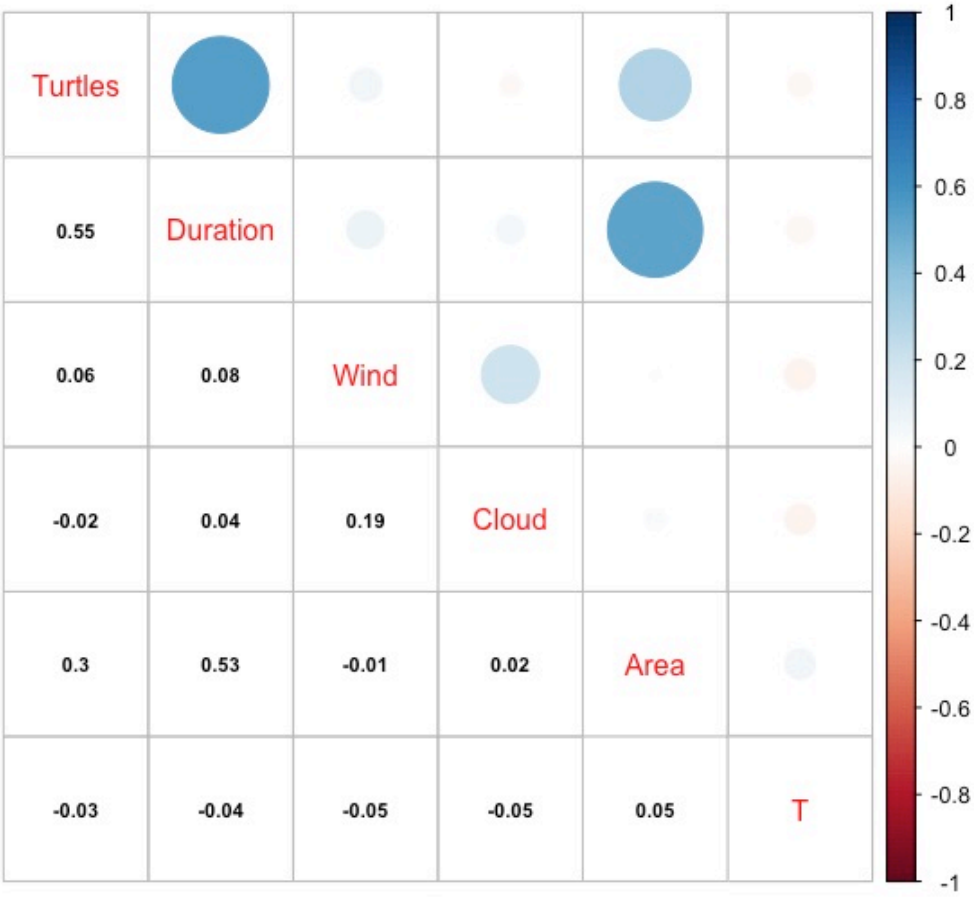

Figure 4. Correlation matrix of all measured variables for the analysis of survey conditions. This correlogram displays larger circles when the correlation coefficient is higher. Legend: Turtles = Number of turtles observed during a visit to a wetland; Duration = Visual survey duration; Wind = Wind speed; Cloud = Cloud cover; Area = Wetland area; T = Ambient temperature during the visit.

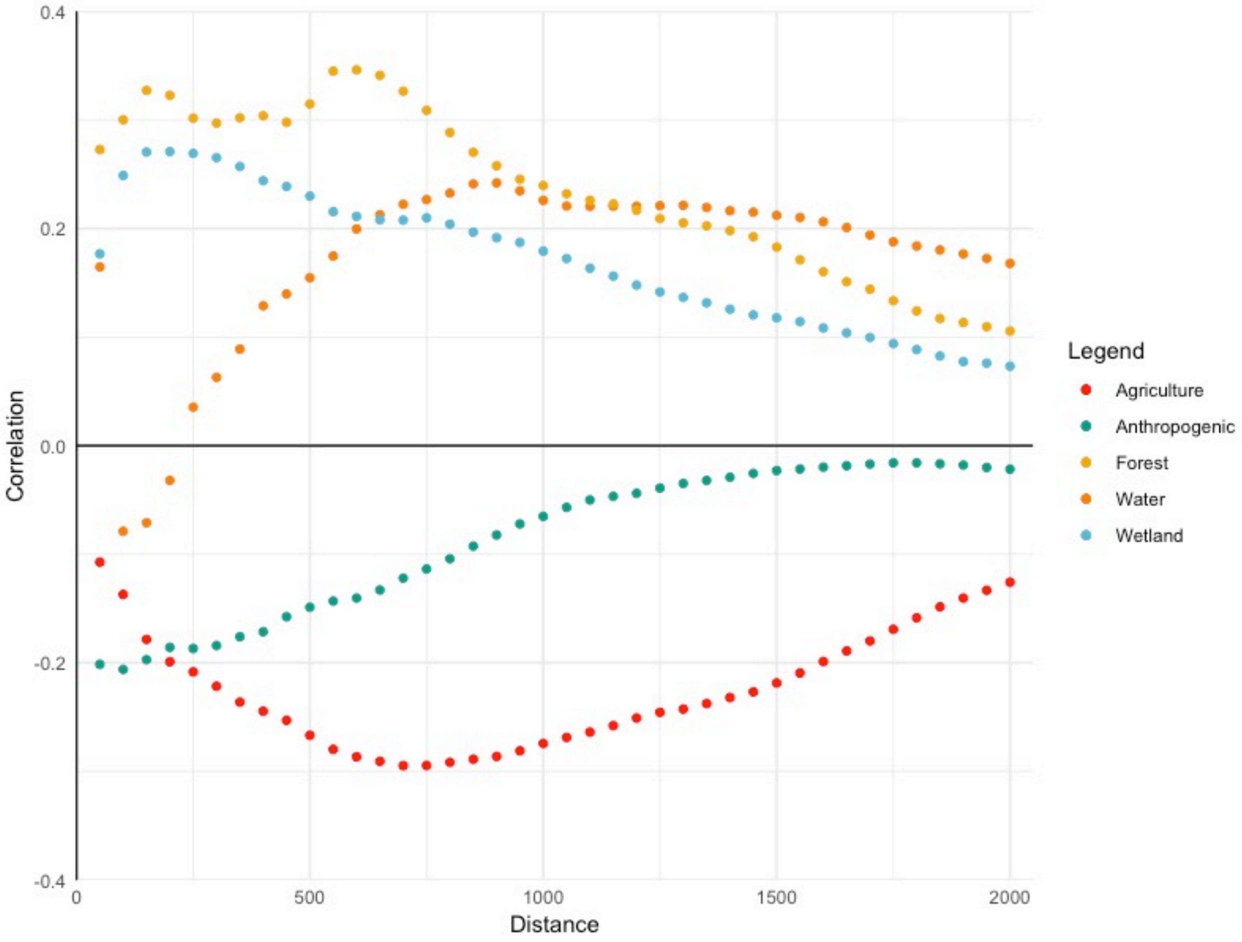

Figure 5. Correlation between the maximum number of turtles observed and the proportion of the 5 landscape cover types at various buffer distances (from 50 m to 2000 m at 50-m intervals). The highest absolute value is at 900 m for water cover, 200 m for wetland cover, 600 m for forest cover, 100 m for anthropogenic cover, and 700 m for agricultural cover.

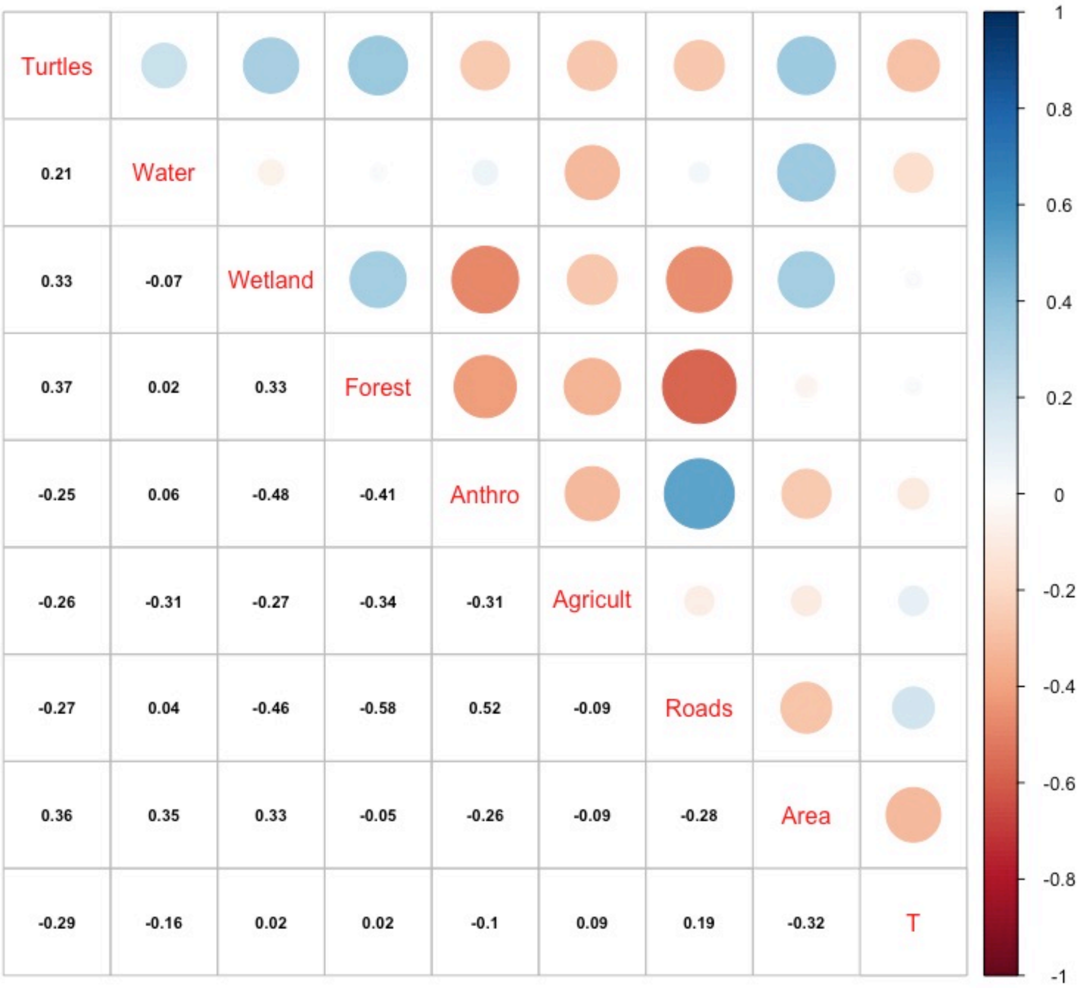

Figure 6. Correlation matrix of all measured variables for the land cover analysis. This correlogram displays larger circles when the correlation coefficient is higher. Legend: Turtles = Maximum number of turtles observed; Water = Water cover; Wetland = Wetland cover; Forest = Forest cover; Anthro = Anthropogenic cover; Agricult = Agricultural cover; Roads = Road density; Area = Wetland area; T = Ambient temperature when the maximum number of turtles was observed.

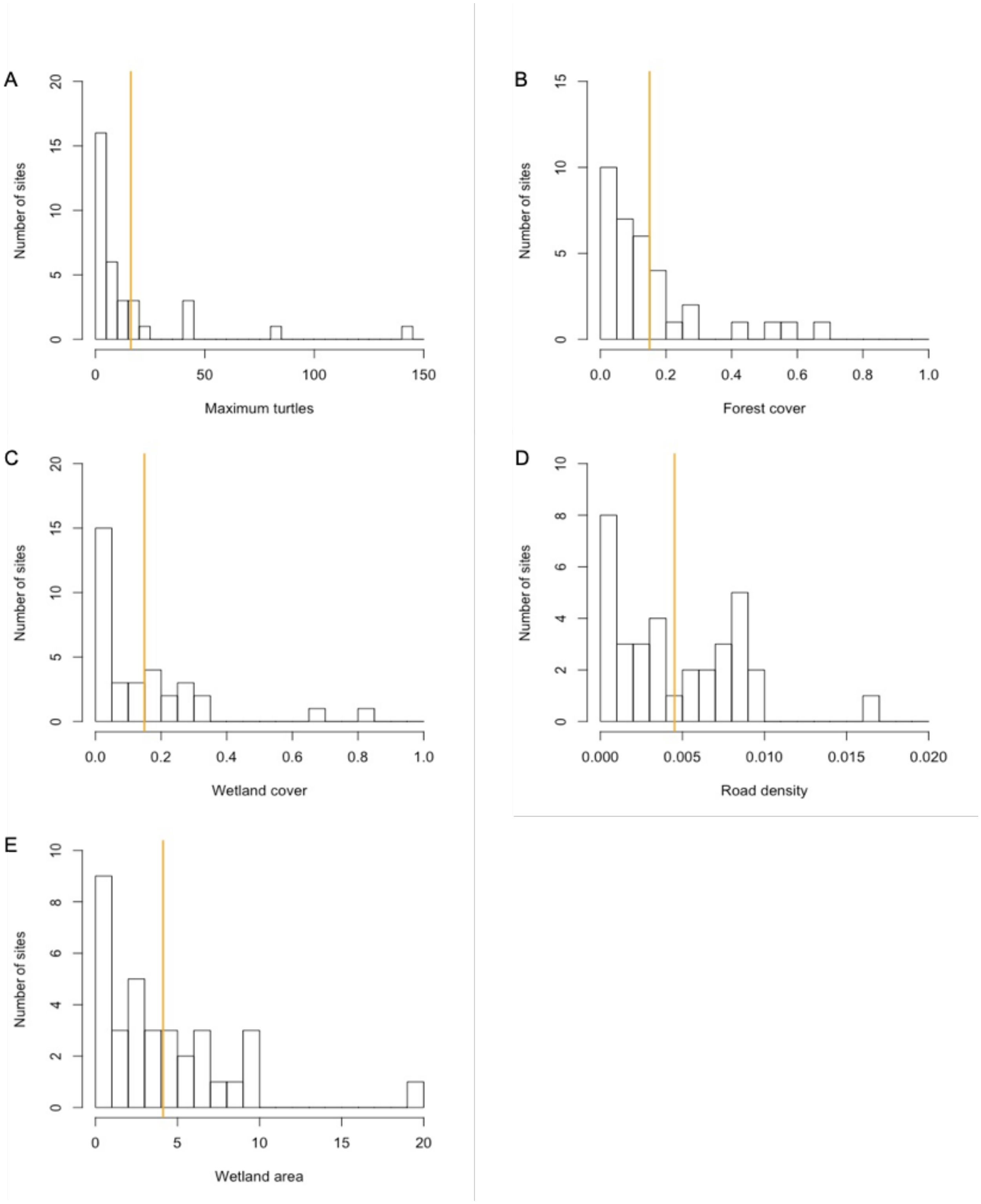

Figure 7. Variability of the variables used in the modelling of the effects of land cover on painted turtle abundance (N = 34). The yellow line represents the mean. The buffer distance used to measure land type proportion and road density was variable for each predictor (forest: 600 m; wetland: 200 m; road density: 300 m). Maximum turtles (A) is the maximum number of turtles observed at one site, forest (B) and wetland (C) covers represent a proportion of the buffer area that is covered by this land type, road density (D) is calculated in km/km^2, and wetland area (E) is in hectares.

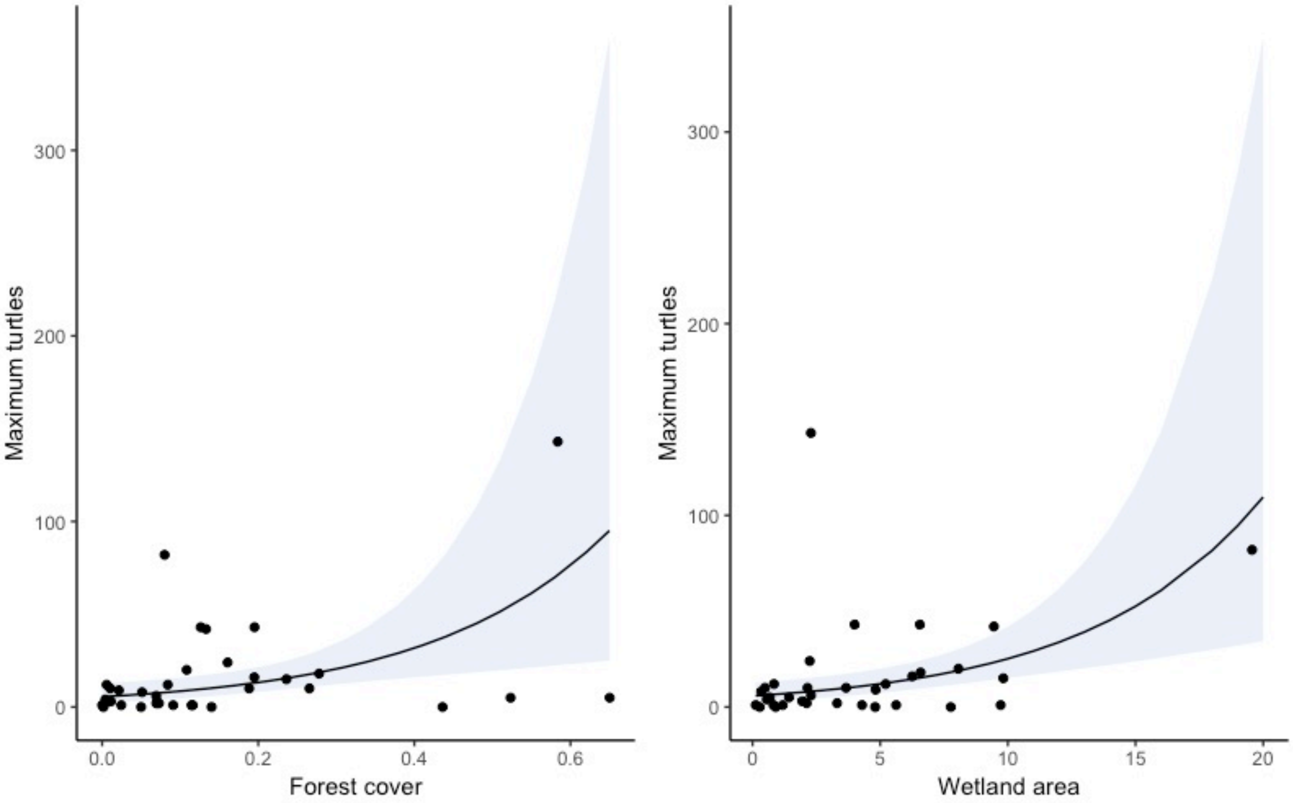

Figure 8. Maximum number of painted turtles predicted in a wetland based on the forest proportion (%) and the wetland area (ha) when all other predictors are set to the mean. The points displayed represent the actual data points. The light blue cloud represents the 95 % confidence interval.

Appendix 1

Summarized information on the 34 surveyed sites. The maximum number of painted turtles observed (Max painted) is given as the highest number observed during one of the 9 visits, while the total number of turtles observed at one site (Total Painted) is the sum of those 9 visits.

Site	Max Painted	Total Painted	Wetland area (m^2)	Latitude	Longitude
1	1	1	56231	45°16'53.13"N	75°48'30.38"W
2	0	0	48004	45°18'02.05"N	75°48'06.42"W
3	18	75	65808	45°18'08.92"N	75°50'14.99"W
4	43	189	65520	45°19'36.29"N	75°48'08.22"W
5	0	0	2821	45°18'17.24"N	75°43'52.66"W
6	1	2	11797	45°27'03.75"N	75°39'59.82"W
7	12	29	8397	45°25'34.41"N	75°37'12.27"W
8	82	299	195652	45°22'18.05"N	75°47'41.22"W
9	10	35	21526	45°20'48.60"N	75°42'52.31"W
10	0	0	77636	45°21'26.36"N	75°39'34.22"W
11	12	24	52127	45°16'21.16"N	75°51'18.15"W
12	143	415	22853	45°21'04.26"N	76°00'55.83"W
13	6	17	22869	45°21'02.96"N	75°49'10.78"W
14	43	140	39950	45°11'53.09"N	75°49'21.88"W
15	3	5	19452	45°16'20.23"N	75°53'03.93"W
16	1	1	1231	45°18'31.11"N	75°55'24.08"W
17	1	1	97172	45°26'36.94"N	75°23'39.75"W
18	8	47	3368	45°20'47.77"N	75°50'42.80"W
19	1	1	42874	45°26'36.68"N	75°28'16.22"W
20	5	18	14273	45°20'09.71"N	75°57'40.05"W
21	16	50	62553	45°22'06.13"N	76°01'28.03"W
22	5	13	6760	45°25'17.33"N	76°06'45.53"W
23	42	78	94519	45°20'59.86"N	75°23'07.77"W
24	1	1	8199	45°23'49.06"N	75°41'14.04"W
25	0	0	9039	45°26'05.65"N	75°31'01.91"W
26	10	53	4868	45°25'53.83"N	75°35'40.83"W
27	9	27	48213	45°16'05.22"N	75°34'53.86"W
28	24	132	22392	45°15'38.26"N	75°43'13.23"W
29	2	5	21212	45°17'31.37"N	75°42'29.97"W
30	4	15	5595	45°20'31.35"N	75°46'06.74"W
31	20	101	80637	45°25'51.59"N	76°00'49.72"W
32	10	47	36587	45°19'14.23"N	76°07'20.84"W
33	15	65	98211	45°19'55.84"N	75°55'12,53"W
34	2	9	33085	45°14'18.70"N	75°46'49.96"W