PREDATOR AND PREY INTERACTIONS AND RESPONSES TO URBANIZATION

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Index

Abstract

Urbanization has been proven to change many organisms through landscape changes and increased human interaction. Predation is a shaping force in interaction with prey. The continuous increase in urbanization has raised the question of what the effects on animals are. Significant changes in predator abundance and composition due to urbanization have been found, and these predatory changes can affect animals in lower trophic levels. This thesis explores the effects of urbanization on predators and its prey. It reports the general loss of apex predators, and changes in species composition in mesopredators. It shows that loss of apex predators can cause mesopredator release. It also shows that mesopredator outbreak often does not occur in urban environments. Predation pressure seems to be lower in urban environments, even though predator abundance does not necessarily decrease. This can be caused by many factors, the most important one being anthropogenic resource subsidies. Through this relieve from predation pressure, most urban prey species show adapted predator responses.

Introduction

The human population on Earth is increasing, and has been increasing for many years already. In 1950 there were around 1 billion people on Earth. This has increased to over 7.3 billion in 2015, and is expected to increase to 11 billion by the year 2100 (United Nations, 2017). This increase in people leads to an increase in their preferred environment, namely cities. The amount and size of cities has increased dramatically over the last decade, and the amount of people living in these cities increased as well (Grimm *et al.*, 2008). Because of this, more and more natural landscapes are changed into urban environments. The urban environment is more homogenous than most natural environments (McKinney & Lockwood, 1999; Olden & Poff, 2003). In addition to that, since cities are similar everywhere, global homogenization takes place (McKinney, 2006). Urbanization, in general, seems to lead to a change in species composition and a decrease of local diversity (DeCandido, Muir, & Gargiullo, 2004; Fattorini, 2011; McKinney, 2006). One example is a study by Tait, Daniels & Hill (2005). They report an overall increase in amount of species, both plants and vertebrate animals, but a loss of local species, in the city of Adelaide, Australia. The study looked at the presence or absence of species from 1836 to 2002. The increase in species is caused by an increase of imported species. The amount of local plant species declined by only 1 percent, with an increase of 46 percent in total plant species. Mammals showed a loss of 50 percent of the local species. This was partially mediated by a 25 percent increase of introduced species (Tait, Daniels, & Hill, 2005). Grimm *et al.* (2008) report that in general, species richness declines in urban environments, while plant species richness often increases through human introduction and direct control.

Predators and their interactions with prey are an important part of ecosystems. Predators are a strong force in shaping communities through interactions with prey (Fischer *et al.*, 2012; Ripple *et al.*, 2014). They are the top layer of the food web (Prugh *et al.*, 2009; Ritchie & Johnson, 2009). Through that, they control not only the food web, but also affect ecosystem functions (Ripple *et al.*, 2014). One example is the increase in carbon storage sea otters provide by maintaining kelp forests (Wilmers *et al.*, 2012). They do not only affect prey directly through predation (Crooks & Soulé, 1999), but also indirectly through 'perceived predation', caused by the knowledge that predators are present in the area (Suraci *et al.*, 2016; Zanette *et al.*, 2011). Predators are strongly affected by urbanization however. Prey uses urban environments as a refuge, moving away from their natural habitats to avoid apex predators (Jones *et al.*, 2016). Predators are often hunted down by humans, which prevents them from following their prey (Brook, Johnson, & Ritchie, 2012; Packer *et al.*, 2005). Therefore, this thesis will explore the effects of urbanization on predators, and its subsequent effects on prey in urban environments.

Predator types

Predators can be divided into two categories. The first category are the top predators, or apex predators. These are the biggest predators, the species that are at the top of the food web (Ritchie & Johnson, 2009). In general, these predators are only hunted upon by humans. The second category are the mesopredators. These predators take in lower trophic positions than apex predators, and are generally smaller than the apex predators (Nishijima, Takimoto, & Miyashita, 2014; Ritchie & Johnson, 2009). They prey on animals lower in the food web, but they can also be predated by predators higher in the food web (Prugh *et al.*, 2009). Apex predators and mesopredators are relative terms, an apex predator in one area can be a mesopredator in another area. Even though both are not clearly defined categories, human interaction, and specifically urbanization affects these two categories differently. This will be discussed in the section below.

Urbanization and apex predators

Apex predators are the top predators in an area (Ritchie & Johnson, 2009). These animals, in general, are large, and need large prey and large home ranges, because they have a high energy expenditure (Ripple *et al.*, 2014). Estes *et al.* (2011) write that apex predators are key species, and loss of these species can cause changes from increased fire frequencies to an increase of carbon influx into the atmosphere. Also, the important role of predators in foodweb functioning is emphasized. Loss of apex predators might cause changes in mesopredator populations, which in turn might cause effects on organisms lower in the food web. Many apex predators lived in abundance over the World (Estes *et al.*, 2011). Some areas in North America for example had up to 5 apex predators. However, these numbers have now declined, and there are many areas that do not have apex predators anymore (Figure 1, Prugh *et al.*, 2009). The declines are mainly caused by human activities (Laliberte & Ripple,

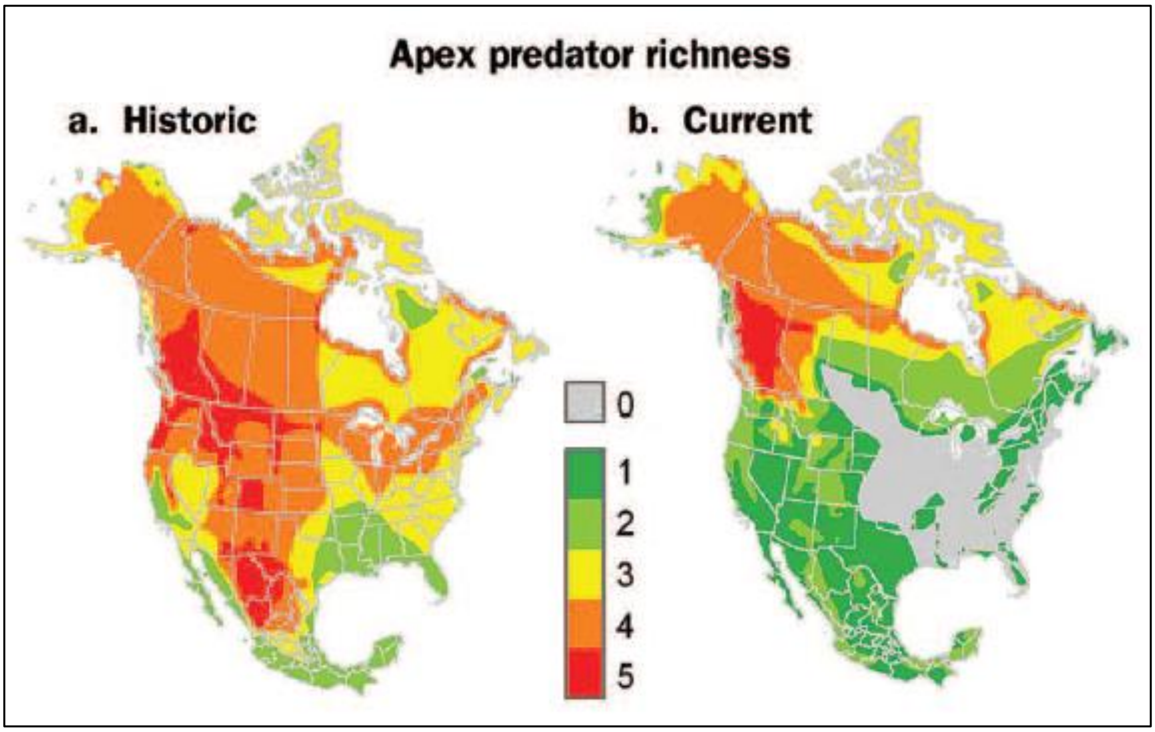

Figure 1. Changes in apex predator abundance in North America. a shows the amount of predators historically. b shows the current amount of predators. Adapted from Prugh et al.*, 2009.*

2004). Urban areas have dense human populations, and through that cause increases in human activity in an area (Grimm *et al.*, 2008). Because of the prey and territory requirements mentioned before, these predators often clash with humans. Some predators can attack human lifestock, or even humans themselves, which causes humans to hunt them (Packer *et al.*, 2005). In addition, humans destroy habitats by clearing forrests to turn them into farmland, or by building and expanding cities (Prugh *et al.*, 2009; Ripple *et al.*, 2014; Ritchie & Johnson, 2009). A study by Isaac, White, Ierodiaconou, & Cooke (2014) for example shows the reduction of the powerful owl (*Ninox strenua*) due to reduction of suitably sized tree hollows. Hollow trees in urban areas get removed because of the risk of them falling over and causing damage to humans or human property. Smaller animals, mainly marsupials, also use hollows, but since they are smaller, they can live in trees that are not as much of a danger yet. Therefore, they are able to populate urban areas. Additionally, urbanization causes fragmentation (Alberti, 2005). This also causes predator loss of apex predators because of their need for larger territories, and the increase in human interaction that is likely to be caused by fragmentation (Prugh *et al.*, 2009). This loss of apex predators causes problems. So, apex predators are suppressed by human interaction. Because of the high amount of human activity, they have difficulty populating urban environments.

Urbanization and mesopredators

Mesopredators are the lower level predators. This is a relative term. The coyote (*Canis latrans*) is an example of this. In environments where the wolf (*Canis lupus*) is around, the coyote remains a mesopredator, being suppressed by the wolf. When the wolf disappears however, the coyote takes its place as the apex predator, and suppresses other, lower level carnivores (Levi & Wilmers, 2012). The effect of human influence, and urbanization in particular, on mesopredators is not conclusive. Some species are affected differently than others. Mesopredators sometimes have to cope with some of the same problems that apex predators have. They are also sometimes hunted upon by humans, or their pets, and they too can suffer from fragmentation (Faeth *et al.*, 2005). Next to that, they have to compete with other exotic mesopredators, that were introduced by humans, for example domestic cats (*Felis catus*) (Chamberlain *et al.*, 2009;Crooks & Soulé, 1999). Also, specifically for avian predators, the risks of collisions and electrocution are detrimental to the survival of populations (Chace & Walsh, 2006; Isaac *et al.*, 2014). Noise is another effect that can disrupt predators. Noise can prevent predators from using sound queues to find prey (Francis, Ortega, & Cruz, 2009). However, mesopredators also have some advantages in the city. First, they get relieved from the pressure of the natural apex predator, since these cannot live in the city anymore (Chace & Walsh, 2006; Crooks & Soulé, 1999). Second, human waste, but also food from for example bird feeders or pet food, can be consumed by most omnivorous mesopredators, which means there is enough food to maintain multiple mesopredator populations (Chace & Walsh, 2006; Rodewald, Kearns, & Shustack, 2011). This leads to the flourishing of some mesopredators, while others disappear. Species that are seen as a direct threat to humans, like snakes for example, are actively hunted by humans, or killed by their pets, and have difficulty populating an area (Faeth *et al.*, 2005). Other mammalian predators, like the raccoon or the opossum, or avian predators, like certain corvids, can utilize anthropogenic food sources very well (Crooks, 2002; Rodewald *et al.*, 2011). Therefore, they might more easily breed and maintain a population in these urban environments. A literature study by Fischer *et al.* (2012) suggests that in general, mesopredator abundance increases. However, they also indicate that more research is needed towards complete predator community composition, to see if losses in some species is compensated by increases in other species.

Trophic cascades and urbanization

In natural environments apex predators take in a top position in the food web. They can suppress or release specific animals, either mesopredator species or prey species (Crooks & Soulé, 1999; Levi & Wilmers, 2012). These species can have effects on even lower levels. Trophic cascades are the effects that predators of higher trophic level have on lower trophic level abundance or biomass (Paine, 1980). For example, predation by wolves might cause a decrease in abundance of ungulates. This also decreases the nitrogen mineralization caused by these ungulates. This can change the vegetation composition (Estes *et al.*, 2011). Another good example is the effect of sea otters (*Enhydra lutris*) on its environment. The sea otter predates on sea urchins. This relieves herbivore pressure on the kelp forests (Ripple *et al.*, 2014). Another example is the relationship between wolves, coyotes and pronghorn (*Antilocapra americana*). Wolf presence caused a four times increased in pronghorn neonatal survival by suppressing coyotes. This can increase pronghorn population sizes (Berger, Gese, & Berger, 2008).

Although apex predator-mesopredator-prey is a common relationship, sometimes it gets more complex than that. Levi & Wilmers (2012) for example talk about an interaction chain with four layers. The cascade consists of three predators, the wolf, the coyote and the fox, with the fourth level being prey. The interactions between the three predators were modelled. The models showed that coyote abundance was negatively correlated with fox abundance. They also showed that, dependent on environment, wolves had either no or positive effects on fox population growth. This could mean that the disappearance of wolves in certain areas leads to the release of coyotes. This in turn leads to suppression of small mesopredators, which leads to a release of smaller prey populations.

Apex predator loss and trophic cascades

The article by Ripple *et al.* (2014) summarizes many trophic cascades. However, since urbanization leads to the loss of apex predators, this means that these cascading effects change. This change was investigated by Soulé *et al.* (1988). They discussed that the disappearance of the coyote from several smaller habitat fragments caused a release of mesopredator abundance. This release, called mesopredator release, can cause collapse of prey species. This process has been studied several times. In an article by Crooks and Soulé (1999) the effect of the decline of the coyote as an apex predator are investigated. They theorized that decline of the coyote would lead to the release of both native and non-native mesopredators. These mesopredators, in turn, would suppress the local scrub-breeding birds, and

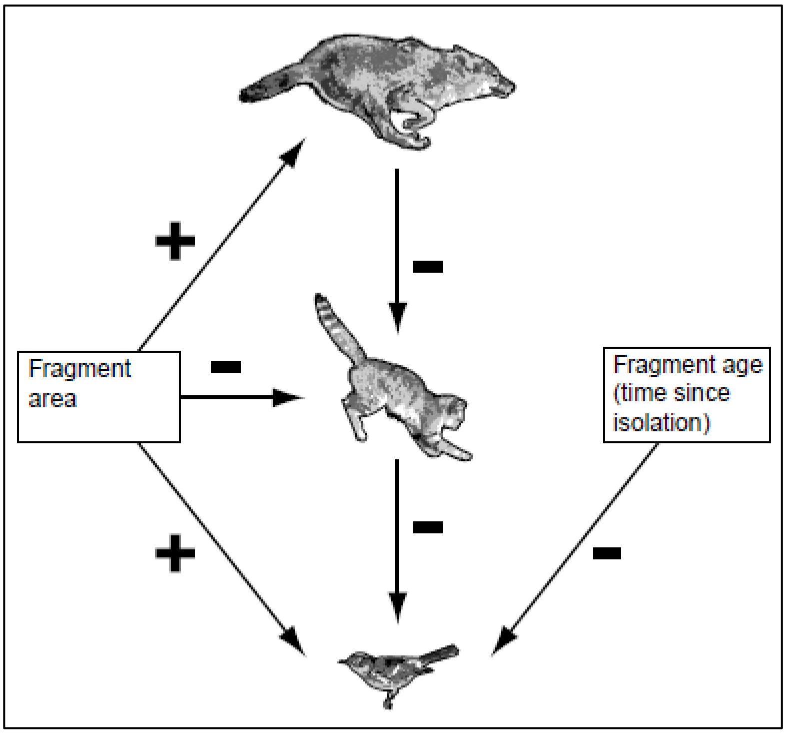

Figure 2. A model of apex predator, mesopredator and prey interactions, in combination with fragment area size and age. From Crooks & Soulé (1999)

drive them into extinction. They surveyed several urban habitat fragments. This survey revealed habitat fragmentation as lead predictor of coyote abundance. It also proved that coyote loss leads to an increase in mesopredator abundance. This in turn leads to increased predation pressure, and eventually the extinction of native prey species (Figure 2). An interesting outcome of the study is that domestic cats probably have the biggest impact on bird extinction in this area. These cats get fed by their owners, and therefore are not dependent on the carrying capacity of the fragment they hunt in. They do not kill to feed and survive, but just for entertainment. That leads to an exploitation of the prey species that is far higher than carrying capacity.

The examples mentioned above show clear effects of the loss of an apex predator. However, this effect of predator release is not the same in all cases. Sometimes, the disappearance of an apex predator does not change prey abundance, and sometimes it only has a positive effect. In a study where the effect of removal of feral cats was investigated, Bonnaud *et al.* (2010) show that the removal of this apex predator does not cause a change in mesopredator predation pressure, in this case predation by rats. Instead of a decrease in yelkouan shearwater (*Puffinus yelkouan*), the local prey species, an increase was recorded. Nishijima, Takimoto and Miyashita (2014) pointed to shared and alternative prey as an explanation for these differences. In general, mesopredators have an omnivorous nature. This means they can use a different food source than the apex predator uses. For example, sometimes mesopredators eat plant materials, which is not utilized by apex predators. This would mean that mesopredators which are worse in utilizing shared prey, can still persist. Therefore, it is predicted that the effect of mesopredator release is stronger when alternative prey is more abundant, since this increases the mesopredator abundance. They made a model (Figure 3) with the factors apex predator, mesopredator, shared prey and alternative prey. This model showed that alternative prey can cause the coexistence of apex predators and mesopredators. It also shows that higher amounts of alternative prey increase the risk of shared prey collapse after the loss of apex predators. The model also shows that controlling alternative prey, mesopredators and apex predators can lead to a successful management strategy for shared prey.

Urbanization and trophic cascades

This is important for urban environments, because they contain strong alternative food sources in the shape of anthropogenic food sources. Rodewald, Kearns and Shustack (2011) call these resources resource subsidies. They state that humans can influence predator-prey relationships both directly, by removing or adding either of them, or indirectly, by providing these subsidies. These effects can influence the effects of predators on prey and mesopredator release specifically. These resource subsidies can consist of bird feeders, human waste, or food that is placed to attract mammalian species. The outcome of the research is that increased urbanization reduces the strength of the predator-prey

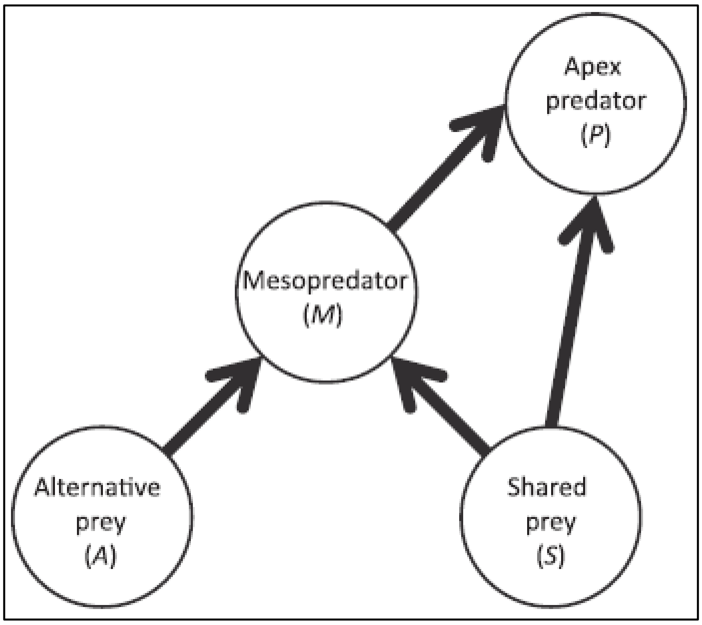

Figure 3. Model of apex predator, mesopredator and both shared and alternative prey interactions. From Nishijima, Takimoto and Miyashita (2014).

relationship. Increase in predator abundance in urban environments barely increases bird nesting failure, if it increases it at all. In rural environments however, increase in predator abundance does increase nest failure significantly (Rodewald *et al.*, 2011). The study suggests that this is caused by the resource subsidies provided by humans. This is supported by their findings that predator activity increases over a rural-to-urban gradient, and the fact that most of the predators they found are also known to eat anthropogenic resources regularly. This theory is further supported by Fischer *et al.* (2012). In their article, they review the predation paradox. This predation paradox is based on the findings that predator abundance increases in urban environments, but predation rates do not. Predation rates actually show a decline in urban environments, despite of the predator increase. Multiple possible explanations for this paradox are given. The first is the human resource supplementation mentioned before. This is extended by the effect human fertilizer and water subsidies have on plant growth. Through these anthropogenic additions, plants can grow for a longer period of the year. This means there is more plant material to be consumed. The second explanation for the predation paradox is that this effect could be caused by the increase of prey species. This prey abundance can increase to such extents, that the predation rates seem to decrease. In this way, they might evade the control of predation. A third factor that might influence this predator-prey interaction is the specialization of certain predators. Evidence suggests that certain avian predators focus on the most abundant prey species. This can remove predation pressure from other species. This might be caused by an increase in prey species through resource complementation, which causes certain prey species to proliferate. An example of this is given in the article by Estes & Mannan (2003). They show that urban cooper's hawks change the prey they bring to their nests. In rural environments, they catch a wide variety of prey. In urban areas however, the most abundant prey is the dove, consisting of 57% of the hawk diet in this study. This is only 4% of rural hawk diet. Next to this change in predator diet, a fourth factor might be the changes in

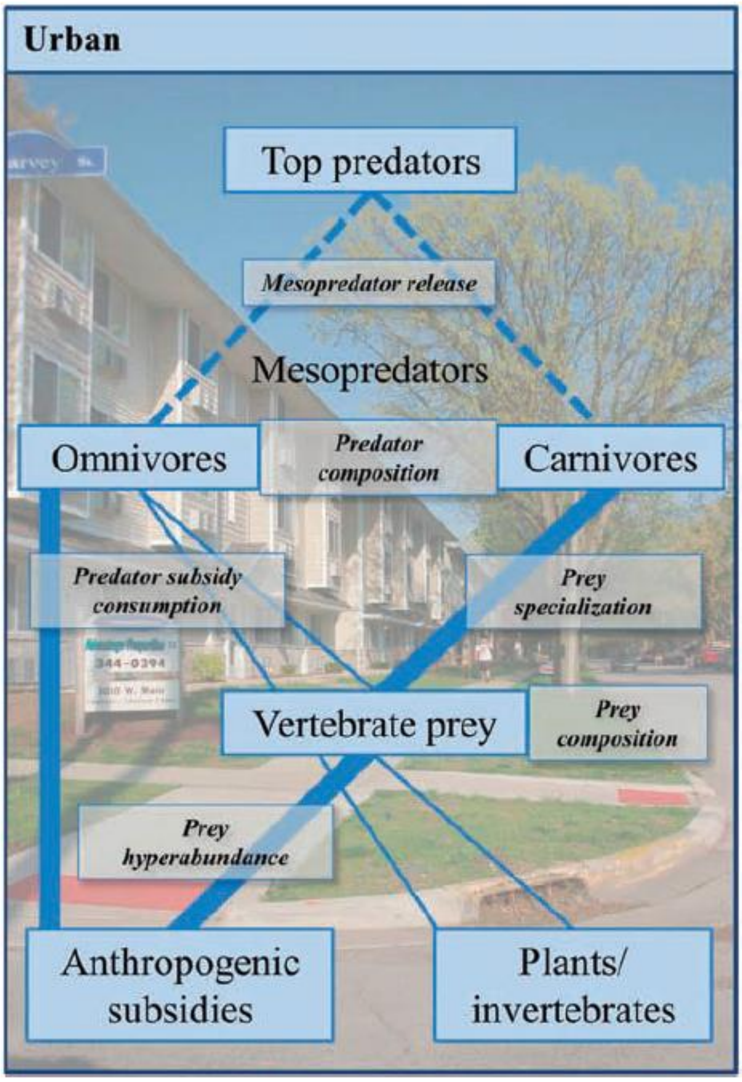

Figure 4. Model indicating several interactions in urban environments. Thick lines indicate an increase of strength of the interaction, thin lines indicate a weakening of strength of the interaction compared to non-urban environments. Dashed lines indicate an interaction that has disappeared. The boxes with italics indicate theories that might explain these changes. From Fischer et al. *(2012).*

species composition in urban environments. Snakes for example decrease over a rural-to-urban gradient (Patten & Bolger, 2003). Since snakes are a strong nest predator, this decrease might reduce predation pressure, which might not be replaced by other predators. A fifth factor is on the prey side. It might be that urbanization and its consequent predator pressure has selected for prey species that are better adapted to urban predation. Through that, predation pressure might be alleviated (Fischer *et al.*, 2012). These interactions have been made into a model (Figure 4).

Behavioral prey responses to urbanization

Because of the decrease in predation pressure, urban prey behavior can differ from rural prey behavior. It could also mean that animals that are particularly weak to predation pressure could populate urban areas (Møller & Ibáñez-Álamo, 2012), which might change species composition in urban environments. Anti-predator behavior is dependent on weighing the costs against the benefits of the behavior (Díaz *et al.*, 2013). Lima (2009) writes that predation risk can cause significant changes in behaviour of breeding birds. In his article, he states that nest predation can change nesting location of a new nest, but some birds can also assess predation risk in certain areas and select sites that have lower predation risk, without having experienced actual predation.

There are several stages in a predation sequence that can be looked at when investigating the effects of the change in predation pressure in urban environments on prey behavior (Caro, 2005). Each stage requires its own changes to optimize behavior in urban environments. The behavioral changes will be discussed in the order that they occur when prey faces its predator. The order of contents of these phases will be based on the order T. Caro uses in his book “antipredatory defences in birds and mammals” (2005). The first phase is what prey does to prevent being reached by predators. After that, the behavioral responses of prey on vigilance, grouping behavior or flocking, flight and escape behavior will be explored.

Urban-induced changes to avoid being reached

One way to prevent being predated is to avoid being reached by predators. Kövér *et al.* (2015) suggest that crows increase nesting height to avoid being reached by predators. They found a significant increase in nest height of urban crows compared to rural crows. However, this difference was rather small (all around 16 meters), suggesting that the height of nests might be important independent of habitat. This is supported by Gering & Blair (1999). They write that height does not affect predation chance differently in urban than in rural environments. They tested several sites among a rural-to-urban gradient, with multiple nests on each site. One half of these nests were on ground level, the other half were on a height of around two meters. There was a decrease of predation in more urban areas, but this was not connected to nesting height. They also write that their results were different in a pilot study in a different location. There, the effect of nest height on predation was stronger than the effect of urbanization intensity. This means that there might be other factors playing a role, for example geographical location (Gering & Blair, 1999). This means it remains unclear if, and in what way, birds should change their nesting height in urban environments compared to rural environments.

Another factor that affects how easy prey can be reached, is song post height. Male birds sing to attract females or to deter competing males (Møller, Nielsen, & Garamzegi, 2008). However, this singing could also attract unwanted attention. Singing loudly can direct predators to the presence of the singing bird (Lima, 2009). One factor influencing accesibility by predators is song post height and exposure. It is likely that this song post height differs from urban to rural environment, because urban bird density is generally higher than density of the same bird in rural environments (Chace & Walsh, 2006; AP Møller, 2005). Therefore, competition between birds will be higher in urban environments, which might make birds increase their song height and exposure (Møller, 2011). On the other hand, this increases visibility for predators (Møller, 2005). However, predator composition changes in urban environments compared to rural environments. Generally, specialist avian predators that hunt for mature birds decrease in abundance (Isaac *et al.*, 2014; Sorace & Gustin, 2009; Valcarcel & Fernández-Juricic, 2009). This is countered by an increase in mammalian predators, mainly domestic cats (Crooks, 2002; Smith *et al.*, 2016). These cats can hunt birds more easily when bird song post height is lower. Møller (2011) investigated changes in song post height between urban and rural environments. He found that the majority of birds indeed increases song post height in urban environments. However, surprisingly, a small part of the bird species actually lowered their singing height. This might have been caused by sampling effects (Møller, 2011). However, the increase in song post height was indeed connected to an increase in cat predators, strengthening the theory that a change in predator composition changes song post height.

Urban-induced changes in vigilance behavior

When animals are in an environment where predation pressure is strong, they have to expend more energy on vigilance behavior. When predation pressure decreases however, it can harm an animal to spend too much time on vigilance behavior, because in the time it is vigilant, it cannot gather food (Díaz *et al.*, 2013; Eason *et al.*, 2006). Since the predation pressure in cities is lower than in rural areas (Fischer *et al.*, 2012), it is expected that animals spend less time on vigilance behavior in cities. This was investigated on fox squirrels (*Sciurus niger*) by Mccleery (2009). He shows that squirrels express less vigilance behavior in urban environments when confronted with both coyote and hawk vocalizations. This suggests there is indeed a correlation between urbanization and vigilance behavior. However, more replications should be done, since this is only found in one article, and only one urban-to-rural gradient is used.

Batabyal, Balakrishna & Thaker (2017) looked at anti-predatory behavior in peninsular rock agamas over an urban-to-rural gradient. One of the things they investigated was the perch height. They found that urban agamas have lower perch height than rural ones, even though there were plenty high places to sit. Higher perch spots give better view of potential predator approach, and therefore are a way to increase vigilance. Since predation pressure is lower in urban areas (Fischer *et al.*, 2012), urban agamas probably do not need the increase in vigilance. Also, since urban environments have more hiding spots, it might be that higher perch spots are used to compensate for longer flight distance.

Urban-induced changes in flocking behavior

Another behavior associated with predation risk is flocking. Valcarcel & Fernández-Juricic (2009) investigated this in house finches. They expected flock sizes to be larger in rural environments because larger flock sizes cause higher chance of predators being spotted, and it reduces the chance for each individual to be caught. However, they found a decrease in flock size over an urban-to-rural gradient. This could have been caused by the general increase in food abundance mentioned earlier. This can cause higher finch density per patch (Walther & Gosler, 2001). Also, it could be that the presence of humans could cause more flocking, because they are seen as a threat to these finches, even though humans generally do not actively persecute the birds (Frid & Dill, 2002).

Urban-induced changes in flight behavior

Once prey is spotted by predators, there are several factors that influence predation success. One general response that is well described, is Flight Initiation Distance (FID). FID is the straight line distance between predator and prey on which prey initiates flight (Grolle, Lopez, & Gerson, 2014). It is expected that a lower predation pressure leads to lower FID, since flight costs energy and it prevents foraging, and therefore it is profitable to only flee when risk is high (Diego-Rasilla, 2003). Also, because of regular human disturbance associated with cities (Batabyal, Balakrishna, & Thaker, 2017; Valcarcel & Fernández-Juricic, 2009), animals might respond less due to habituation (Valcarcel & Fernández-Juricic, 2009). In the research of peninsular rock agamas by Batabyal, Balakrishna, & Thaker (2017), it was shown that FID in response to human attacking behavior was lower in urban males than in rural males. This effect was only seen in males, because the preferred female response to predation risk is sitting still. This is likely to be caused by their camouflaged appearance, and their smaller size, which causes lower sprinting speed (Batabyal *et al.*, 2017). Grolle, Lopez and Gerson (2014) support this effect of increased FID in rural areas in western fence lizards (*Sceloporus occidentalis*). They did not test for differences between males and females, but instead showed a general increase in FID in rural compared to urban environments. Lin *et al.* (2012) show that urbanization also decreases FID in certain coastal bird species. Møller (2015) supports this effect. He showed that urbanization was the strongest predictor of FID out of a group of 13 different predictors that were tested, including body mass and predation.

All taken together, current evidence suggests most animals show a decrease in FID within urban areas.

Urban-induced changes in escape behavior

When an animal is caught, it is not always over. Sometimes they can escape from their predator through display of behavior. Cats are responsible for the biggest part of predation pressure in urban environments (Crooks & Soulé, 1999). On the other hand, avian predators have a bigger contribution to predation pressure in rural environments (Møller, 2011). Therefore, it is likely that birds in urban environments show escape behavior that is better fitted to cat capture, while rural birds show behavior that is better fitted to escape from avian predators. This was researched by Møller and Ibáñez-Álamo (2012). They also predicted general escape behavior to be lower in urban birds compared to rural birds, because of the lower general predation pressure in urban environments. They showed that this was indeed the case for wriggling behavior. However, tonic immobility, the time that a bird sits still after being free, was higher in an urban area. This measurement is an indication of fear level (Møller, Christiansen, & Mousseau, 2011). It is also related to predation susceptibility by sparrowhawks. Finally, it was found that feather loss occurred more in urban environments. This too is associated with susceptibility to sparrowhawk predation. The strength of these connections increased when an area was urbanized for a longer time. This suggests that it takes time for species to differentiate from the rural to urban environment. Another interesting finding in this research was that urban birds made more alarm calls than rural birds. This could be explained by the fact that urban environments lead to lower dispersal and smaller genetic variation, which would mean more relatives living in close proximity (Møller & Ibáñez-Álamo, 2012). However, this study was the only one on the subject of urbanization in connection with escape behavior. Therefore, more research should be done to increase the evidence for the effects found in this study.

Conclusion

This thesis has shown that urbanization has created significant changes in predator composition and behavior. It has shown that urbanization has caused a decline in apex predators, and changed the composition of mesopredators, declining some, but increasing others. A significant change is the introduction of domestic cats, who are abundant in urban areas and are fed by their owners. This causes them to kill prey independent of carrying capacity. Sometimes, the loss of apex predators caused a cascading effect, increasing one mesopredator, and through that decreasing its prey significantly. However, this cascading effect in general does not occur in urban environments. In urban environments, prey abundance generally is not affected by this mesopredator release at all. Several factors mitigate this mesopredator release. These factors are prey change by predators, changes in predator composition or an increase in prey abundance in urban areas. However, probably the biggest factor that reduces mesopredator release is the anthropogenic food subsidies in urban environments. These anthropogenic resources take away a large part of nest predation in birds. Through that it can significantly change behavior in prey species living in urban environments. Animals seem to show differences in perch height and less vigilance related behavior. Birds increase their song post height to adapt to predator composition changes. Also, the flight initiation distance became significantly lower in urban animals. There is also evidence for change in behavior while being caught, showing an increase in alarm calls in urban birds, but a decrease in wriggling behavior. These changes show how urban environments can change prey behavior through changes in predation pressure. Species that are adapted to this decrease in predation pressure can populate urban areas more easily. Because of these changes, if there were to be an introduction of predators, these would have strong effects on prey abundance. This possible change in predator impact might be an interesting area for research to come. Anthropogenic resources might be interesting for policymakers who try to control the abundance of certain urban species, since they seem to have big effects on mesopredators and their prey.

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