UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Urban Vertebrate Ecology of the Pacific Northwest, with Recommendations for Wildlife Stewardship at UBC Vancouver

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Abstract

Over the last century, urban areas in western North America have seen tremendous growth. Major human settlements are often strategically located at the mouth of rivers, along inlets or in valley bottoms, such as Vancouver, Seattle, or Portland. These areas are also of high value to wildlife. As cities expand, habitat is reduced, altered, and fragmented. While many vertebrates have been displaced from some of their original range, some species are able to take advantage of novel foraging opportunities and reduced predation, while adapting to challenges in communication and movement. Not only is UBC's Vancouver campus surrounded by Pacific Spirit Regional Park – its location along the Pacific Flyway gives UBC responsibility in terms of global biodiversity. UBC can improve its wildlife stewardship by facilitating movement and providing opportunities to forage, rest, and breed, as well as by encouraging students, staff, faculty, and visitors to collaborate on future initiatives.

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Introduction

Urban environments differ greatly from natural areas with regard to vegetation cover, stream quality, foraging opportunities, and ambient light and noise levels. Urban areas and human influence in rural, less developed areas have been on the rise for centuries and are predicted to grow at an ever accelerating pace (UN DESA 2005). Greater Vancouver's population has more than quadrupled since 1950, while more than 80% of Canadians live in cities (UN DESA 2005, CIA World Factbook 2012). At the same time, urbanites are changing their understanding and appreciation for wildlife near their homes. Cities around the world are setting ambitious goals to reduce their ecological footprint and 'green' themselves, among them Vancouver its goal to become the world's 'greenest city'. Vancouver and New York City intends to plant 150,000 (City of Vancouver 2011) and 1,000,000 trees (Million Trees NYC 2012), respectively, while Seattle plans to increase their canopy cover by from 23 to 30 % (Seattle reLeaf 2012). Developers in the Capital Regional District (Victoria) are encouraged to set aside a part of their lot for conservation, as this greatly increases the value of new and existing homes (GOERT 2007). Toronto, Chicago and New York implemented "Lights Out" programs to limit the effect of light pollution on migrating birds (Deda *et al*. 2007).

Human development strongly affects the characteristics of the space used by urban vertebrates. Roads, buildings, industrial complexes, rush-hour traffic, nocturnal illumination, and anthropogenic food sources dominate the urban environment (Schlesinger *et al.* 2008). Wildlife has been displaced or seen changes in dispersal and migration, territory characteristics, foraging strategies, communication pathways, mortality factors, reproduction, and hormone production. For example, roadside mortality often ranges between 20 and 80 % for urban vertebrates (Glista *et al.* 2008, Kociolek *et al.* 2011). Many urban areas are known to harbour non-native species that are able to exploit urban environments, while endemic or native species are frequently extirpated (Melles 2006).

Movement: Migration and Dispersal

Linear Elements: Roads, railways, trails

Migration and dispersal of species can be affected to a varying extent by the presence of urban environments. Urban song sparrow (*Melospiza melodia*) populations on Vancouver Island showed lower genetic diversity and were more inbred than their conspecifics in the natural habitat (MacDougall-Shakleton *et al.* 2011). A genetic analysis of kit fox (*Vulpes macrotis*) urban and suburban populations in California demonstrated high gene flow and dispersal between the metapopulations. Despite large urban centres lying between subpopulations, the genetic distance correlated with geographic distance, suggesting that roads do not pose a barrier to dispersal (Schwartz *et al.* 2005). A similar study on red foxes (*V. vulpes*) in Zurich, Switzerland found that human traffic corridors had no measurable impact on fox dispersal or survival. Wandeler *et al.* (2003) identified high levels of gene flow between recently established urban populations and their parental populations along the city perimeter.

Coyotes (*Canis latrans*) in Tucson, AZ, have been observed to use roads, railways, and dry creek beds for dispersal. Especially the latter two serve as corridors for their daily movements from their resting sites in parks and on the urban perimeter to their hunting grounds in residential areas (Grinder and Krausman 2001). During juvenile dispersal, cougars (*Puma concolor*) in urban San Diego County showed preference for wildlife corridors with linear references such as forestry roads or train tracks in or near them (Beier 1995). In some cases, cougars reached busy motorways at night and bedded down until dawn to assess the landscape on the other side and decide whether or not to cross (Beier 1995).

Artificial nocturnal illumination

Street lamps, buildings, and vehicles contribute to artificial nocturnal illumination. Cloud coverage can further amplify sky luminance by a factor of 10, thus making a cloudy night in the suburbs four times as bright as a full moon night in rural areas (Kyba *et al.* 2011). Today, 41 % of North America's land cover is exposed to double or more nocturnal illumination than in historic times. Nocturnal lighting strongly affects foraging, mortality, circadian rhythms, and dispersal of nocturnal organisms including bats (Fam. *Chiroptera*), badgers (*Meles spp.*), many small carnivores, and most rodents of North America (Beier 2006).

Nocturnal vertebrates travel shorter distances in illuminated areas (Beier 2006). A study in the Netherlands found that some predators preferred to walk on illuminated dams, while prey such as hare (*Lepus spp.*) and roe deer (*Capreolus capreolus*) showed a tendency towards darker dams (De Molenaar *et al.* 2003). Perry *et al*. (2008) discovered that the yellow part of the visible light spectrum emitted by outdoor lights can lead to disorientation in red-spotted newts (*Notophthalmus viridescens*) and a raised mortality rate at the population level.

Some migratory birds along the Pacific Flyway travel at night to avoid predation and take advantage of lower temperatures. Weather events may push flocks closer to urban areas, where birds can become disoriented, spend more energy, and experience higher window strike mortality (Rich and Longcore 2004). At night, light sources from structures like lighthouses can attract migratory birds, leading to higher window strike mortality along the flyway (Munro 1924). A steady white light attracts more birds and causes more deaths than coloured or flashing white light (Jones and Francis 2003).

General trends appear present across the taxa, depending on trophic level, foraging behaviour, and visible spectra. Linear structures, such as roads, and nocturnal illumination act as a deterrent to movement among many birds (MacDougall-Shakleton *et al.* 2011), small mammals (De Molenaar *et al.* 2003) and amphibians (Perry *et al*. 2008). Coyotes and other carnivores can use these elements as corridors for dispersal and tend to prefer illuminated areas at night (De Molenaar *et al.* 2003, Schwartz *et al.* 2005). Movement corridors should be designed to reduce the number of large roads crossed while providing enough refuge for light-sensitive species.

Territories

Expanding urban areas comes largely at the expense of habitat conversion and fragmentation (Beier 1996). Urban areas do provide novel habitat that some species may successfully exploit. Territorial behaviour is strongly altered the urban matrix. Most taxa are more bold and aggressive, which can lead to higher frequency, intensity, and cost related to territorial contests (Evans *et al.* 2010). In contrast, squirrels, and possibly other taxonomic groups reduce costs of territoriality by integrating non-natural elements, such as buildings and roads (McCleery and Parker 2011). Further, corvids, canids and many other successful urbanites demonstrate the ability to exploit novel anthropogenic food types, which shrinks the size of their territories and home ranges (Marzluff and Neatherlin 2006). In some cases, the limiting factor appears to be the abundance of shelter or cover, not foraging opportunities (Marzluff *et al.* 2007). The cold and rainy climate on the Pacific coast will further amplify the need for shelter, while the relatively mild winter, lack of snow, and the dense vegetation will provide more cover and foraging opportunities (Marzluff *et al.* 2007).

American crows (*Corvus brachyrhynchos*) have smaller territories and an increased home range overlap of neighbouring pairs closer to campgrounds or residential areas but Steller's jays (*Cyanocitta stelleri*) showed no correlation (Marzluff and Neatherlin 2006). Another study found that urban house finch (*Carpodacus mexicanus*) territories in California city parks grew larger with sparser vegetation, likely due to higher visibility of competitors and the lack of cover in a more open environment (Fernandez-Juricic *et al.* 2005).

Just as crows have smaller territories in or near urban areas, carnivores may also make use of human food sources allowing them to increase their population density. Ralls *et al.* (2007) found higher densities of kit foxes in urban areas. Fedriani *et al.* (2001) conducted mark-recapture and scat surveys of coyote populations in residential areas of California and found that population density was eight times higher in urban areas than in natural wildlands. Coyotes in Tucson, Arizona show a large variability in home range size (1.7 to 59.7 km^2), which shows how easily these canids adapt their behaviour and exploit available food and shelter resources (Grinder and Krausman 2001).

Definition of territory boundaries, territory stability, and territorial behaviour also change in urban habitats. In many species, male individuals establish their territory through calls or marking and may defend it through physical contests with conspecifics. Elevated noise levels in urban areas can reduce the active calling of frogs which results in smaller home ranges, while increased illumination leads to more visual displays for territorial defense (Parris *et al.* 2009).

Conversely, more light means others can better interpret the behaviour and reduces contests escalating to aggression and injury (Jaeger 1981)

Local populations of fox squirrels (*Sciurus niger*) use elements of the urban matrix, such as buildings and roads as territory borders, an energetically advantageous behaviour, as it reduces the cost of marking and repeatedly disputing the borders (McCleery and Parker 2011). Urban squirrels fight over limited numbers of tree cavities and anthropogenic shelters in a much fiercer matter than rural conspecifics suggesting that thermal shelter and concealment cover provided by nest sites are worth the cost of defense (McCleery and Parker 2011).

Territory sizes and population density of many species, especially of cavity nesters, are often limited by nesting opportunities. Further, structures, light, and noise can alter territoriality.

Foraging

Anthropogenic food sources

Human activities in urban areas offer novel food sources, alter seasonal food availability, and induce changes in foraging activity patterns. The establishment of populations in novel urban habitat highly depends on the species-specific foraging strategy. Taxa - especially predators - that show low dietary specialization, a large capacity to exploit novel food sources, and the capability to make use of nocturnal illumination are more likely to dominate urban communities. Some of the main anthropogenic food sources are garbage, domestic cats (*Felis catus*), and seeds at bird feeder stations (Brousseau *et al.* 1996, Quinn 1997, Chase and Walsh 2006).

Among birds, granivores and nectivores tend to thrive better, while canopy dwellers, insectivores, and foliage foragers are often displaced (Chace and Walsh 2006). In urban areas, overall avian biomass is generally higher than in rural and forested areas, possibly due to supplemental and alternate foraging opportunities (Chace and Walsh 2006).

Generalistic foragers such as the ring-billed gulls (*Larus delawarensis*) can alter their dietary mix depending on the proximity of urban foraging sites like landfills, or the seasonal availability of fish (Brousseau *et al.* 1996). In contrast, foraging specialists including bald eagles (*Haliaeetus leucocephalus*) rely on their traditional food sources and only receive small amounts of their daily energy needs from landfills (Elliot *et al.* 2006). Bird feeders provide ample foraging opportunity as 80 million US Americans spend over $1bn every year on setting up and filling feeder stations (Geis and Pomoroy 1993). Brittingham and Temple (1986) determined that feeders boost survival of passerine birds during harsh winters in Wisconsin, but feeders may be less crucial to survival during the very mild winters in the Pacific Northwest and coastal British Columbia. In fact, a follow up study in Pennsylvania which has milder winters than Wisconsin, yet harsher winters than the west coast, found no impact on over winter survival which may also be due to other confounding factors (Egan and Brittingham 1994). Feeders can be classified as a non-native food source and have been found to support non-native birds in areas where they may not normally persist because large amounts of native vegetation remain (Brittingham 1990). Song sparrows whose parents foraged at bird feeders, experienced lower mating and reproductive success, possibly because they had to share their parental attention with more siblings and didn't learn as many different songs (Zanette *et al*. 2009). Predators, such as falcons and domestic cats, are attracted to feeder stations through higher prey densities, so that some stations may act as a trap (Brittingham and Temple 1986).

Similar to passerine birds, Chace and Walsh (2006) found that foraging strategy is a major factor in predicting success of raptors in urban habitats. Usually, raptors do well either when their preferential prey thrives in cities, or if they can conduct prey switching. Falcons and hawks, such as the peregrine falcon (*Falco peregrinus*), the american kestrel (*F. sparverius*), or the red-tailed hawk (*Buteo jamaicensis*), that feed on small mice and songbirds show strong population numbers (Berry *et al*. 1998). Occasionally, their urban densities exceed historical and present values in natural habitats (Chace and Walsh 2006), while rough-legged hawks (*B. lagopus*) and other raptors that favour larger prey don't fare well in cities (Berry *et al.* 1998).

Opportunistic omnivores, such as raccoons (*Procyon lotor*), can switch freely amoung available food resources and dominate among mammals in the city. Fedriani *et al.* (2001) found that especially coyotes, foxes, skunks (*Mephitis spp.*), raccoons and badgers consumed large amounts of trash (3 - 64% of diet). Kit foxes make use of refuse and fruit in urban California (Ralls *et al.* 2007). Coyotes with their home ranges in residential areas were found to rely very little on garbage (only 1.3% of diet), instead replacing voles (*Mictotus spp.*) as their primary source of protein with cats (13%) and squirrels (*S. / Tamiasciurus spp.*; 8%) (Quinn 1997). Raccoons also rapidly learn to exploit novel food sources and are therefore more successful at colonizing urban areas than skunks and Virginia opossums (*Didelphis virginiana*) (Prange and Gehrt 2004).

Artificial nocturnal illumination

Many of the successful mammals, bird, reptiles, and amphibians in cities are usually diurnal and make use of the `night light niche` by foraging under artificial lights (Garber 1978, Longcore and Rich 2004, Beier 2006). Bats make use of the food density provided by street lamps attracting large numbers of insects. (Rydell 1991). Insect attraction to street lamps may vary according to colour and wavelength, with three times more insects attracted to white lights compared to orange ones (Blake *et al.* 1994). Rydell (1991) found that insects around street lights are used as a supplemental foraging opportunity during spring and fall, when other food sources are scarce (Rydell 1991). Elevated noise levels can have deleterious effects on bat feeding, as individuals may not be able to hear the acoustic echo (Schaub *et al.* 2008). Similar to bats, frogs may also feed on insects that are attracted to artificial light sources. Some nocturnal species of frogs that feed more during the full moon occur in higher densities in parks with lit trails (Perry *et al.* 2008).

Coyotes and other large predators can benefit from enhanced nocturnal lighting, as well (Beier 2006). In natural settings, coyotes howl more during new moon and cloudy nights when they moan their unsuccessful hunting (Bender *et al.* 1996). Red foxes and three species of weasels (*Mustela spp.*) showed preference for illuminated dams, likely because they can detect their prey more easily (De Molenaar *et al.* 2003).

Prevalent cloud cover intensifies urban lighting along the west coast which amplifies the negative effect on native prey species and may make this issue perhaps more important than in other areas of North America (Kyba *et al.* 2011). When exposed to elevated lighting, nocturnal prey species may reduce their foraging activity, move their food into darker areas, or shed their light phobic behaviour (Vasquez 1994, Bird *et al.* 2004). These altered foraging strategies can result in reduced body mass, lower survivorship due to predation and starvation, and ultimately declining population size or complete displacement from illuminated areas (Vasquez 1994, Bird *et al.* 2004).

Retaining large amounts of natural vegetation, while limiting the introduction of non-native plants, the availability of anthropogenic food, and reducing artificial illumination would support native vertebrates by giving them a foraging advantage over introduced urban exploiters.

Communication

The overall increase in ambient noise in urban settings affects the vocal communication of urban vertebrates and makes it difficult to overcome the distance between patches induced by habitat fragmentation (Fernandez-Juricic *et al.* 2005, Parris *et al.* 2009, Luther and Derryberry 2012). For birds and frogs, vocal communication is essential for establishing territories, finding mates, and warning conspecifics about predators in the area (Laiolo 2010).

Spanish populations of the threatened Dupont's lark (*Chersophilus duponti*) and house finches (*Carpodacus mexicanus*) in California city parks are two of many examples where urban birds responded to elevated ambient noise levels by reducing song diversity and length (Fernandez-Juricic *et al.* 2005, Laiolo 2008). Similarly, Luther and Derryberry (2012) found a direct positive correlation between traffic levels and minimum acoustic frequency employed by white-crowned sparrows (*Zonotrichia leucophrys*). Other birds and frogs pursue the same strategy, because high frequency songs are less likely to be masked by vehicular noise which is usually in the low frequency range. (Fernandez-Juricic *et al.* 2005, Laiolo 2010, Luther and Derryberry 2012). Urban song birds can afford to risk higher visual exposure when singing at exposed and elevated perches due to lower levels of avian predation (Fernandez-Juricic *et al.* 2005, Moller 2011). There is evidence for evolutionary divergence between urban and rural populations because in natural settings, sparrows favour low pitched calls, but urban individuals responded stronger to recent, high frequency recordings than to historic, low frequency ones

(Luther and Derryberry 2012). Similarly, males in urban frog populations use higher pitched calls to overcome traffic noise even though females are usually more attracted to low pitched calls (Parris *et al.* 2009). Songbirds may also take advantage of nocturnal illumination and start their dawn chorus earlier, effectively beating rush-hour traffic and improving their active calling distance (Bergen and Abs 1997, Fuller *et al.* 2007).

Mammalian communication in urban environments has not been investigated to the same extent as seen in birds. Canids, felids, mustelids, and other families communicate their territorial borders to conspecifics more through scent-marking and direct encounters than vocal communication (Laiolo 2010, Potts *et al*. 2012). One may speculate that smells from pollution, food wastes, and territorial urination by domestic dogs (*C. lupus familiaris*) and cats could have altered traditional communication patterns of employed by mammals.

Communication in among urban populations could be improved by reducing traffic noise near parks as well as keeping suitable patches within calling distance of each other.

Mortality

Traditional mortality factors have been significantly reduced or replaced by a diverse array of new features. Mesopredators have achieved dominance (Quinn 1997), leading to higher levels of nest predation. Feeders may act as a trap and site for disease transmission (Brittingham 1990); extreme densities of single species can lead to disease outbreaks (Koenig *et al.* 2010); poisoning, aerial and aquatic pollution can lead to bioaccumulation of toxins (Riley *et al*. 2003); artificial illumination extirpated many endemic nocturnal prey species (Beier 2006). However, those that succeed benefit from rates of lower starvation and predation (Chace and Walsh 2006).

Collisions

Window strikes and motor-vehicle collisions are by far the biggest source of mortality for urban wildlife with annual estimates ranging between 10 and 80 million avian deaths from collisions in the US (Kociolek *et al.* 2011). While some birds appear to fly higher with the presence of roadside trees or hedgerows, not all species can reduce their mortality rates this way (Kociolek *et al.* 2011). Birds also collide with structures, such as buildings, power lines, or wind turbines (Boal and Mannan 1999, Longcore *et al.* 2008) One urban populations of Cooper's hawks (*Accipiter cooperii*) saw 70 % of mortalities from window strikes alone, which can have impacts at the population level, if the species has naturally low reproductive rates, as is often the case with raptors (Boal and Mannan 1999).

While collisions are non-selective in birds, male juvenile dispersers are the most likely to be killed among mammals, such as cougars or raccoons (Beier 1995, Chace and Walsh 2006). Collisions with vehicles accounted for over 60 % of deaths in urban fox squirrels (McCleery and Parker 2011) and 50 % in urban kit foxes (Ralls *et al.* 2007). Amphibian populations may suffer from high levels of road mortality, especially during seasonal migration (Lesbarreres *et al.* 2006, Glista *et al.* 2008). One survey of over 10,000 vertebrate roadside mortalities identified 76 % of casualties as amphibians (Glista *et al.* 2008). This value is likely to show high site specific and seasonal variability.

Toxins

While toxins may not be immediately lethal, they can persist in the ecosystem for years or decades, and often bioaccumulate towards the predator level (Riley *et al.* 2003). Poisoning, both incidental and on purpose, is a minor mortality factor in urban coyotes (3 - 8 %) (Riley *et al.* 2003). However, some rural coyotes and bobcats (*Lynx rufus*) the same study showed signs of agricultural pesticides, likely through bioaccumulation (Riley *et al.* 2003). Population declines of amphibian species correlate strongly with location downwind of agricultural pesticide spraying (Davidson *et al.* 2002).

Bollinger *et al.* (2005) produced evidence ingestion of only a few grains of road salt can can lead to depression, paralysation and death of small song birds (Bollinger *et al.* 2005). Further, Mineau and Brownlee (2005) suggest that loss of orientation due to extreme salt ingestion along roads greatly elevates the risk of a collision to birds and small mammals alike but they also point out the difficulties in recording road salt related mortality, as they often result in regular motor-vehicle collisions.

Artificial nocturnal illumination

Earlier sections have already pointed out reasons for elevated mortality among nocturnal prey species, such as crested porcupines (*Hystrix indica*) which abandon their light avoidance behaviour during food shortages (Alkon and Saltz 1988, Beier 2006). Beier (2006) suggests that squirrels could be lured out of their nests by lighting at night and become easy prey for nocturnal predators, such as coyotes. Frogs tend to adjust their night vision to the brightest available light source and can be blinded for hours, making their movement through darker areas more dangerous (Perry *et al.* 2008).

Predation

Through the absence of large mammalian predators, namely bears, wolves, and cougars, prey species experience major predator release which compensates for roadside mortality, pollution, and diseases (Chace and Walsh 2006). Even though motor-vehicles killed a 30 % of kit foxes, survival is 45 % higher in urban populations due to the absence of large predators (Ralls *et al.* 2007). While collisions with vehicles accounts for over 60 % of deaths in an urban fox squirrel population, predation mortality is less than 5 % compared to rural predation around 60 % (McCleery *et al.* 2008). Predation through house cats and lower avian predation causes males songbirds to perch higher off the ground (Moller 2011). Falcons and other small or medium sized raptors that enjoy safety from large raptors and hunting pressures can reach higher densities in cities than historically in wildlands (Chace and Walsh 2006).

Abundant anthropogenic foraging opportunities and the absence of large predators have allowed a new guild of mesopredators to establish themselves in urban areas. Some of these, such as American crows, Stellar's jays and raccoons are nest predators that could threaten sensitive song birds in the Pacific Northwest (Marzluff and Neatherlin 2006, Stout *et al.* 2007).

Philanthropic feeding, habituation, and disease

Supplemental feeding has the potential to boost avian overwinter survival, strengthen resistivity to disease, and raise the carrying capacity of urban environments. (Brittigham and Temple 1986, Brittingham 1990). As discussed in the foraging chapter however, overwinter survival may not be elevated along the Pacific coast because of mild temperatures (Egan and Brittingham 1994). Disease transmission and predator attraction to feeder stations are novel mortality factors, but small enough that overall survivorship is increased through feeders (Brittingham 1990, Egan and Brittingham 1994). With more intensive feeding in public spaces, rock doves (*Columba livia*) experience fiercer intraspecific competition and higher juvenile mortality through starvation and disease (Sol *et al.* 1998).

Landscape planners and resource managers can greatly reduce avian mortality by focussing on window strike prevention. Further, reduction of toxins used or produced in routine operations will have a positive long-term effect on the ecosystem.

Reproduction

In some frogs sexual selection is reduced near lights, while some birds show significant changes in spatial age structures with regard to urban elements, and yet other frogs experience altered larval growth rates (Eichler and Gray 1976, Gutierrez *et al.* 1984, Rand *et al.* 1997, Habib *et al.* 2007, Slabbekoorn and Ripmeester 2008). Different levels of ambient light, noise, temperature, food supply, predation, and nesting opportunities can occur individually or in any combination and affect the timing of reproduction, recruitment rates, growth rates, sperm production, and corticosteroid levels (Meyburg *et al.* 1996, Rand *et al.* 1997, Schoech *et al.* 2004, Bonier *et al.* 2007, Marzluff *et al.* 2007, Perry *et al.* 2008, Shustack 2008).

Artificial nocturnal illumination

Black-tailed godwits (*Limosa limosa*) preferred nesting sites away from permanent light sources, such as street lights, possibly because their nests would be more visible near the lamp posts (De Molenaar *et al.* 2000). With increasing ambient light, some female frogs prefer to mate with males that are closer than distant males with more elaborate calls in order to mitigate elevated predation risk (Rand *et al.* 1997). In contrast, male frogs call more and longer with higher levels of illumination, because these individuals can better identify predators (Rand *et al.* 1997, Longcore and Rich 2004).

Laboratory experiments discovered that painted frogs (*Discoglossus pictus*) have lower larval growth rates when exposed to more light and shorter dark periods (Gutierrez *et al.* 1984), while northern leopard frogs (*Rana pipiens*), experience faster larval development under constant lighting (Eichler and Gray 1976), and common Asian toads (*Bufo melanostictus*) produce less sperm with elevated levels of illumination (Biswas *et al.* 1978). These examples illustrate how urban stressors can affect species differently already at the developmental.

Noise

Singling out the effect of urban noise on reproduction proves to be fairly difficult and is not commonly studied because of the many confounding urban stressors. In boreal areas of northern Alberta, ovenbirds (*Seiurus aurocapilla*) experience lower mate finding success, lower fledgling success, and a higher proportion of inexperienced first-time breeders in noisy areeas (Habib *et al.* 2007). Further, traffic noise hampers avian communication and mating songs (Fernandez-Juricic *et al.* 2005)

Temperature and food supply

Large metropolitan areas are known to be warmer than their surrounding areas, which leads plants to green-up earlier. The northern cardinal (*Cardinalis cardinalis*), which is common to eastern North America, nested earlier in cities but showed no significant changes in recruitment (Shustack 2008). For the migratory Acadian flycatcher (*Empidonax virescens*) arrival to urban forests and clutch initiation was later, while breeding time was shorter (Shustack 2008). This study demonstrates that generalizations cannot be made across all taxa. Schoech *et al.* (2004) found that not the amount a food but the predictability of food triggers urban populations to initiate mating and lay their eggs earlier than their rural counterparts. Elevated recruitment rates of American crows in Greater Seattle are tied to high food availability for these opportunistic scavengers (Withey and Marzluff 2009).

Nest predation

The availability of anthropogenic food has led to an influx of American crows into Greater Seattle (Withey and Marzluff 2005, Marzluff *et al.* 2007). While these corvids are opportunistic nest predators and can pose a threat to passerine populations, Marzluff *et al.* (2007) reported higher rates of fledgling success in most species and explained these through the higher food availability. Other nest predators are domestic cats which don't spend much time outside in the cold, wet climate of the Pacific Northwest and are regularly eaten by coyotes, while Stellar's jays are sensitive to human activities (Quinn 1997, Marzluff *et al.* 2007).

Nesting sites

In urban settings, frogs may deposit their eggs in roadside ditches where their larva will be prone to desiccation, elevated lighting, noise, and chemical pollutants, as well as high motor-vehicle mortality as juveniles (Perry *et al.* 2008). Throughout western Washington, snags are not as thick and occur at much lower densities in urban and suburban forests than in natural settings, thereby limiting the amount of suitable breeding sites for cavity-nesters (Blewett and Marzluff 2005). Some ground- nesting birds, such as dark-eyed juncos (*Junco hyemalis*) respond to decreased aerial predation by nesting in the trees which results in elevated recruitment rates (Yeh *et al.* 2007). In Puget Sound, WA, individuals of a thoroughly studied population of bald eagles have constructed nests with unchanged clutch sizes and recruitment rates in immediate proximity to homes (Shirato and Parson 2006).

The lack of nesting sites, especially for cavity nesters appears to be the strongest limiting factor in urban vertebrates, while the reliable food supply boosts reproductive success.

Hormone Production

A handful of studies have looked at the effects urban stressors have on hormone production, particularly of corticosteroids and melatonin.

Corticosteroids

Corticosteroid (cort) levels generally correlate to physiological difficulties an individual is experiencing when maintaining homeostatis (Schoech *et al.* 2004, Atwell *et al.* 2012, Bonier

2012). Bonier *et al*. (2007) detected higher average cort levels in white-crowned sparrow (*Zonotrichia leucophrys*) males, but could not determine a fitness effect. Conversely, females have unchanged average cort levels, but individuals with elevated levels have lower clutch sizes and lower fitness (Bonier *et al.* 2007). In Florida scrub-jays, cort levels correlate negatively with food predictability (Schoech *et al.* 2004), while urban dark-eyed juncos have lower baseline cort levels (Atwell *et al.* 2012). A common garden experiment with urban and wildland juncos showed a rapid rate of genetic change as urban birds were bolder and had lower cort level increases when exposed to anthropogenic stressors, indicating calmer reactions among urban birds (Atwell *et al.* 2012).

<u>Melatonin</u>

Melatonin is a hormone that is produced in response to ambient light and regulates the circadian clock (Bartness and Goldman 1989). During the darker hours, melatonin levels are elevated which leads to a lower basal metabolic rate and reduced energy requirements (Bartness and Goldman 1989, Beier 2006). Further, melatonin levels regulate growth and diurnal migration in many vertebrates (Beiswenger 1977, Bartness and Goldman 1989). Laboratory experiments on amphibians demonstrated exposure to short pulses of artificial light are enough to disrupt melatonin production, with negative effects on physiological performance (Beiswenger 1977, Binkley *et al.* 1988). Wise and Buchanan (2006) suggest that lower overnight melatonin levels will lead to higher basal metabolic rates and elevated energy requirements for amphibians which can pose problem during stressful periods, such as drought or egg production.

These findings suggest that artificial illumination has the potential to significantly lower melatonin production, with substantial population level impacts on resting, foraging, reproduction, movement, health, and ultimately fitness (Chace and Walsh 2006). Further, response to urbanization can be sex-specific and lead to rapid rates of evolution and, ultimately, speciation.

Management recommendations for UBC Vancouver

"*Given that urban areas are situated in productive habitats with inherently high species richness, it is important that local land-use plans incorporate the conservation of habitat fragments from the onset and place particular emphasis on the regionally restricted forest-dependent species*."

– Er *et al.* (2005): Forest loss with urbanization predicts bird extirpations in Vancouver

Adding a section on wildlife stewardship in the Vancouver Campus Plan and developing technical guidelines around this topic is part of the next step towards co-existence of UBC and the environment we were blessed with. UBC's Vancouver campus is rival to none with regard to its natural setting. With this gift comes great responsibility, especially considering UBC's commitment to "exploring and exemplifying […] environmental […] sustainability" (UBC Plan 2012).

Over the last years, canopy cover in some areas on campus has declined rapidly, while existing patches (Rhododendron and Totem Woods) are not large enough to sustain the moist microclimate natural to coastal forests and dry out (Sutherland 2012). With the construction of pedestrian pathways along Main Mall and University Boulevard we must not forget that lawn has barely any value to wildlife. These 'greenways' are essentially sterile landscapes.

The negative effects of traffic are extensively discussed in previous chapters. Because the campus core is pedestrian only and designed to cater to UBC's public realm, this is the areas with the largest potential to improve connectivity (UBC Public Realm 2012). In order for any wildlife stewardship initiative to be successful, it should satisfy most of the following requirements:

- Cater to native, endemic species (local, not from e.g. the Okanagan)
- Habitat improvement (connectivity, foraging, shelter, breeding)
- Located in proper relationship to target species' habitat needs
- Low initial cost, preferably combine with other construction project
- No or low maintenance
- Plants will persist without irrigation after a few years
- Improve stormwater management
- Improve public realm

Areas important for conservation

UBC is fortunate to be located along the Pacific Flyway, a route that millions of migratory birds use every year (Pacific Flyway Council 2012). The Vancouver Natural History Society conducts regular bird counts at the Farm and had identified Cecil Green as another birding hotspot with over 165 observed species (Nature Vancouver 2012). Eagles, hawks and owl can be seen in the Botanical and Nitobe Gardens (Varner, pers. comm.). The many little community gardens, clusters of shrubs, or stands of trees throughout campus act as stepping stones by providing food and refuge.

Rhododendron Wood is a small patch of forest along southern Main Mall and is surrounded entirely by development. Through elevated levels of convection and solar radiation, sharp edges compromise habitat quality at the ground level. The removal of snags to reduce hazards to visitors compromises breeding potential for cavity nesters. However, the patch may serve as a vital stepping stone for canopy dwelling birds, such as ruby-crowned kinglets (*Regulus calendula*) or pine siskins (*Carduelis pinus*) (Melles *et al.* 2003). Rhododendron Wood could be even more valuable as a stepping stone, if northern sections of Main Mall are upgraded.

Corridors

As a result of UBC being completely surrounded by the Pacific Spirit Regional Park, facilitating movement of birds and mammals throughout campus is of great importance. Wildlife can benefit from pedestrian greenways by installing single features such as shrubs, hedgerows, or raingardens. Shrubs should be planted in clusters, not following a grid layout. Berry shrubs and flowering plants could provide valuable foraging opportunities to frugivores and nectivores, such as hummingbirds. An earlier SEEDS study gave recommendations on hedgerow planting at the UBC Farm. (Keery et al. 2009) A detailed guide on raingarden construction including lists of plant species has been published by Oregon State University (Emanuel *et al.* 2010).

Hedgerows and swales can be constructed along busy roads, such as Wesbrook Mall, Marine Drive, or West 16th Avenue. For example, the area along the north side of West 16th Avenue stretching from Wesbrook Mall to East Mall is chronically wet due to irrigation runoff from the sports fields. Rehabilitating this section into a swale could provide valuable wetland habitat, while improving filtration and storage of surface runoff from fields and roads.

It is important to remember the negative effects of street lights on nocturnal species (Beier 2006). Thus, shrubs or hedgerows should provide refuge for light sensitive wildlife without compromising human safety. Further, use of local expertise can assure high quality, potentially lower costs, and provide for applied teaching opportunities. Staff at the Botanical Gardens, landscape architects, and wildlife and horticulture faculty could jointly supervise students designing corridors as part of group projects or a directed study.

Culverts

Marine Drive and West 16th Avenue separate the valuable wetlands and ponds of the Botanical Garden from main area of the Garden, UBC Farm, and Pacific Spirit Regional Park. Culverts could help mammals and amphibians overcome these barriers, while improving stormwater management. These culverts would be between 30 cm and 100 cm wide, contain rocks, logs, and other substrate for cover, while keeping one section elevated and dry. The area around the openings should consist of low stature vegetation consistent with adjacent areas and mesh fences that guide individuals towards the corridor (Patrick *et al.* 2010).

Major road construction appears to be limited in the near future, so that UBC should use this time effectively (Poettcker, pers. comm.). Population, mortality, and movement surveys – as a directed studies project, field course, or lab component – could identify sections in need of culverts. Focal areas could include, but not are not limited to, Marine Drive, West 16th Avenue, and Wesbrook Mall near East Campus Park.

Streams

Over several years, SEEDS has explored the idea of restoring streams around campus (Sawada, pers. comm.). A potential wastewater treatment plant at UBC could produce high quality effluent and feed these streams year-round (Bailey, pers. comm.). Restored streams could provide valuable riparian habitat and corridors which are extremely scarce at this time. Historically, however, none of the streams dealt with the amounts of nutrients a wastewater treatment facility would produce. More importantly, these streams pose logistical difficulties, if salmon (*Onchorynchus spp.*) start to spawn in them. This idea shows how valuable it would be to bring experts (i.e. faculty) from all related fields together and avoid unintended consequences through joint planning. I strongly encourage planners to make use of the wealth of expertise on campus and consult with UBC's world-class faculty.

Engaging the public

Knowledge of wildlife occurrences on campus can be improved by involving students, staff, and visitors. Similar to National Parks, visitors to the Botanical Garden could report recent sightings in the visitor centre or online (Mosquin, pers. comm.). Another idea would see students develop a smartphone app to collect recent sightings of wildlife at UBC, similar to an app used by the international birding platform eBird.org which provides data for scientists (EBird 2012). This app could provide better knowledge about wildlife on campus and help tailor habitat to resident, native species.

Other considerations

Recent research found that house sparrows can potentially mistake road salt for gravel that granivores use to grind up seeds. Only a few salt grains can lead to depression, paralysation and death of songbirds within 30 minutes of ingestion (Bollinger *et al.* 2005). Considering the mild winters Vancouver experiences, operations managers at UBC should consider spreading sand or liquid salt instead of granular salt as the primary de-icer.

Further, research shows that window strikes are significant mortality factor in bird populations (Klem 2006). Decals, strips of tape, strings, attractants close to windows, or screens have proven effective in breaking up window reflection and reducing bird mortalities (Klem *et al.* 2004). Another SEEDS project could develop a cost-effective design for windows that could be implemented in lieu with construction and refitting projects across campus.

In general, reducing vehicular traffic, noise, nocturnal illumination, aerial pollution, and especially window strike mortality and the amount of sterile landscape, while providing linked, diverse nesting, foraging and refuge opportunities will enhance UBC's co-existence with its natural neighbours. All stakeholders have to continuously ensure that stewardship initiatives are indeed supporting endemic species and not the urban exploiters common throughout North America (see note on bird feeders in foraging chapter). Further, staff from different departments must recognize the potential for cooperation and make use of expert faculty and curious students willing to contribute to UBC as a living laboratory.

Conclusion

Urban development in coastal British Columbia and the Pacific Northwest has occurred in areas with high historical levels of biodiversity along the Pacific shoreline and the Fraser River delta. Many endemic species have been displaced or suffered population declines, while native and introduced urban exploiters are well established in the urban matrix. Roads, railway tracks, and buildings appear to pose a barrier to movement and gene flow in most taxa, except for carnivorous mammals. Many taxa show bolder and more aggressive territorial behaviour, while territory sizes for urban residents usually decline due to improved foraging opportunities or shorter active call ranges. Opportunistic generalists and seed eating birds are best at taking advantage of anthropogenic foraging opportunities, while some insectivorous bats and amphibians benefit from street lamps. Birds and frogs had to adapt to higher ambient traffic noise levels by lowering their song or call diversity and length, while communicating at a higher minimum acoustic frequency and avoiding rush-hour traffic. Collisions with windows and vehicles replaced predation and starvation as the leading mortality factor. Further, poisoning, aerial and aquatic pollution have shown to cause bioaccumulation of toxins and growth of tumors. Reproductive success and development is most affected by limited availability of nesting sites, such as arboreal cavities in snags and nest predation. On the west coast, the effects of artificial nocturnal illumination are further amplified by high levels of cloud cover.

Retention of wetlands and natural vegetation, or integrating local plant species and ponds into landscape planning and residential backyards will likely give endemic species an advantage over introduced wildlife. Appropriately designed pedestrian pathways show the highest potential in successfully connecting remaining patches of forest (e.g. Pacific Spirit Regional Park, Rhododendron Wood). Further efforts should focus on attracting dispersers with foraging and shelter opportunities, while simultaneously eliminating window strike mortality along these corridors to take advantage of the absence of motor-vehicle collisions as a mortality factor.

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