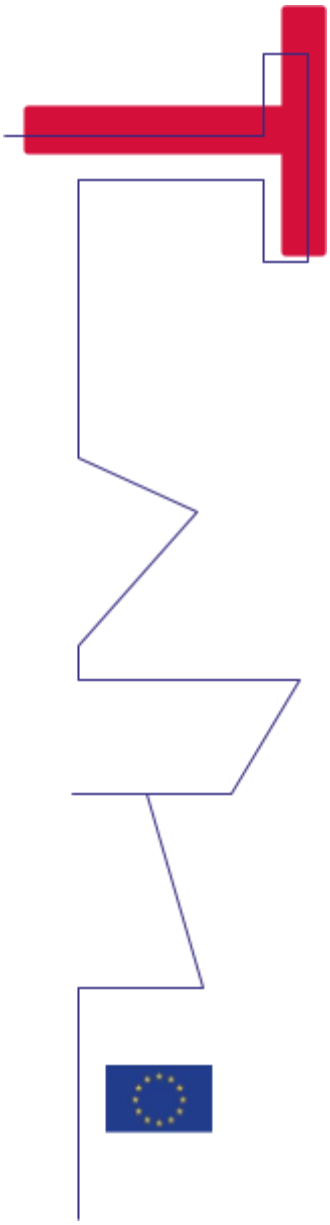

Environmental impact driven by technology on animals in urban areas

Internal report by T-Lab 3 - May 2022

Introduction

The raise of urbanization

It was not until the Anthropocene that urban human societies started to grow significantly across the globe. Western industrialization started in the 1700s and with that urbanization and urban sprawl became a significant part of the landscape. Today, urbanization is a global phenomenon with implications for animals (Isaksson, 2018). According to the UN's (2018) estimates, 55% of the world's population currently live in urban areas, and this number is expected to rise to 68% by 2050. The more humans present in an area, the greater need for buildings and infrastructure, increasing traffic-related air pollution, noise pollution, and artificial light at night.

Urbanization as a threat on wildlife

Together with climate change, urbanization is considered one of the largest threats to wildlife. There are at least four drivers (or environmental stress factors) that are directly related to urbanization and that are general across all geographical zones:

Chemical pollution - Wildlife is burdened by toxic pollutants coming from the air, soil, or the water ecosystem and, in this way, animals can develop health problems when exposed to high levels of pollutants. Reproductive failure and birth effects have been reported (Manisalidis et al., 2020).

Noise - Environmental noise can affect wildlife in various ways. Among them: masking and destructing natural signals, psychological stress and hearing loss which can all lead to behavioral changes (Slabbekoorn et al., 2018).

Artificial light at night (ALAN) - 'Light pollution', e.g. unwanted or excessive artificial light is now considered a major concern for biodiversity and human health. Nighttime lighting is responsible for changes in natural rhythms, and has negative consequences for animals and plants at all biological organization levels (Desouhant et al., 2019).

Human presence - Chemical pollution, noise and artificial light at night are all generated by human activity. On top of their negative impact, wildlife are also directly affected by human presence which is perceived as a threat by most animals.

All four factors can directly lead to habitat loss and fragmentation, which forces rapid decisions about emigrating (if possible) to more suitable habitats or stay and cope with the new conditions (ibid). On top of this the process of urbanization is also changing the remaining 'green' areas by 'managing them' in a way that changes the type of plants growing in them (Cammaerts & Cammaerts, 2018). This also has a strong influence on animal organisms' physiology, behavior and general health.

The purpose of this report is to provide some empirical knowledge to enable the development of 'animal aided design' devices by T-Lab 4 (Urban design for socially and wellbeing), as part of the work of the T-Factor project at Amsterdam Science Park. The rapport, composed by T-Lab 3 (Citizen-led smartness), will present findings related to the impact of technology driven by urbanization on animals, focusing on artificial light at night and man-made sound[1].

1. Sound

Sound is one of the factors that can influence the physiology and/or the behavior of organisms, including humans. The world is full of sounds of abiotic and biotic origin, and animals may use those sounds to gain information about their surrounding environment. Sounds naturally occurring in the environment include abiotic sounds, generated by wind or rain and by rivers or oceans, and biotic sounds, generated by all members of more or less noisy local animal communities. However, it is becoming increasingly clear that the presence of man-made sounds has the potential to undermine the ability of animals to exploit useful environmental sounds (Slabbekoorn et al., 2018).

1.1 Sources of man-made sound

Many of the issues associated with the potential effects of man-made sound on humans, that had been subjected to much research and regulation over the past years (*Environmental Noise Guidelines for the European Region (2018)*, n.d.) apply equally to animals. This type of sound includes environmental noise produced by everything from roadway traffic to airplane overflights and from vessel noise to offshore exploration for oil and gas. The nature of these sounds varies dramatically, from the brief or intermittent high-impact signals produced by destruction or construction activities to the continuously increased background sound levels due to gradually fluctuating amounts of car and vessel traffic.

1.2 The environmental impact on sound

[1] The report does not cover the topic of electric fields. Although this topic can be relevant in the context of the data center in Amsterdam Science Park, evidences shows that humans and animals are able to perceive the presence of static electric fields caused by high-voltage direct current lines (the technology of choice for the transport of large amounts of energy over long distances) at sufficiently high levels . A large number of studies reported responses of animals (e.g., altered metabolic, immunologic or developmental parameters) to a broad range of static electric field strengths as well, but these responses are likely secondary physiological responses to sensory stimulation. Physical considerations also preclude any direct effect of static electric fields on internal physiology, and reports that some physiological processes are affected in minor ways may be explained by other factors (Petri et al., 2017).

Various environmental features affect the way sound spreads: habitat features above and below the water surface determine whether and how sounds originating at one point arrive at receivers and whether and how they may play a role in affecting their behavior. Vegetation may attenuate and filter out or resonate and amplify particular frequencies. Sounds may be reflected by the ground below or the surface above, and reverberations may accumulate over distance and with habitat complexity. Not only that Industrialization and urbanization added new, diverse sound sources to the modern world but also dramatic changes in propagation as a result of altered vegetation or novel obstacles and a multitude of reflective surfaces.

Sound is obviously not the only medium by which animals and humans gather information about the world around them. The visual, chemical, and tactile senses often serve in parallel in affecting auditory perception. Many signals or cues are explicitly multimodal, having, for example, an acoustic and a visual component, which may result in redundancy. This means that relevant information can still be extracted through one channel despite masking problems in the other, and animals have been shown to perceptually shift attention to the sensory information from the channel with the least interference.

1.3 Potential effect of man-made sound on animals

The potential effects on animals (as on humans) also vary rather substantially, from immediate death due to overexposure from extremely intense sounds to changes in physiological stress levels that may or may not have long-term consequences. The potential effects may also range from temporary or permanent hearing loss to behavioral changes that result in animals interrupting activities or leaving their normal home range. Additionally, more subtle man-made sounds may make biologically important signals or cues inaudible due to masking or may undermine optimal reception by distraction, which are effects that may have indirect but severe, detrimental consequences. Not being able to hear or pay sufficient attention to conspecific communication signals may mean missing important social aggregations or mating opportunities. Failing to recognize acoustic cues from the surrounding habitat may also result in the inability to find shelter or the right migratory route. Not hearing prey may prevent animals from finding food. Not detecting a predator may even lead to sudden death.

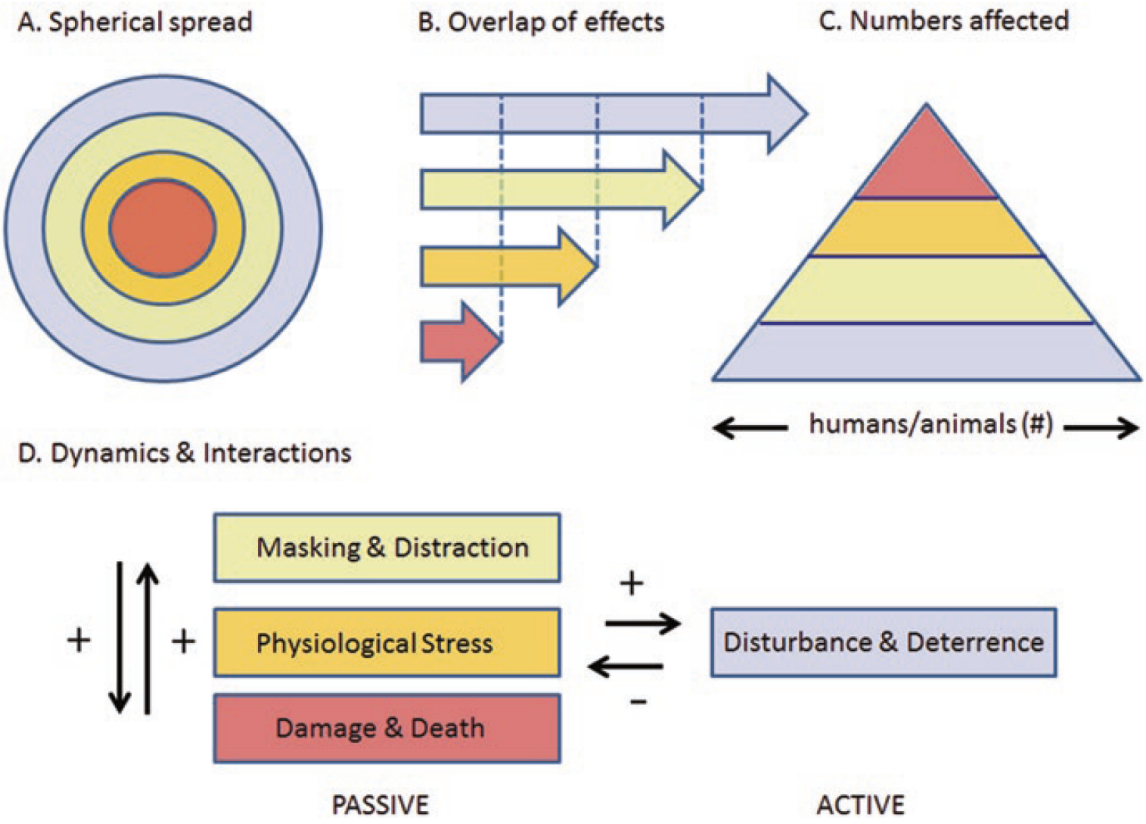

Figure 1: Schematic illustrations providing insight into the nature of potential impact of man-made sounds on animals and emphasizing different aspects.
A: noise impact severity is likely to decrease with distance away from the sound source in all directions due to propagation loss of sound energy
via spherical spread.
B: the variety of potential effects accumulates with proximity to the sound source because the effects typically do not exclude each other but
exhibit zones of overlap.
C: a pyramid of noise-induced health effects, with the growing severity of the effect toward the top segment and the growing number of individuals that are likely to be affected toward the bottom segment).
D: some potential effects are an inherent and passive consequence of sound exposure, whereas others depend on an active response of the animal itself. Many potential effects are likely to be positively correlated (up and down arrows and arrow to the right). If exposure
causes severe impact in one direction, it will likely do so in the other. However, a negative correlation may arise by negative feedback (arrow to the left) when an active behavioral response makes animals less vulnerable in other ways.
Source: (Slabbekoorn et al., 2018).

1.4 Does a man-made sound drive animals' movement to another place?

The sound-induced effects on decisions about movement probably involve a trade-off between reasons to stay and reasons to leave. An animal may stay as it exploits local resources related to feeding or breeding when it is familiar with local risks. However, the sense of fear for predation may be elevated by an unfamiliar

sound. The decision about exchanging familiar conditions and certain resources for an unfamiliar and uncertain destiny may be detrimental but will vary with species and context. The decision whether to stay or leave is also dependent on other aspects such as habituation to the sound, sensitization or resistance to noise pollution. While man-made sound could deter animals from staying in a particular place, it can also be an effective tool to move pest animals from places they are not wanted.
We

2. Light

Unlike natural ecosystems, where daily activities are regulated by natural light–dark cycles, cities are heavily lit to enable performance of a wide array of activities after dark (Svechkina et al., 2020). Artificial light at night (ALAN) results mainly from street lights and road networks and is amplified by skyglow, i.e., reflection of light in the atmosphere, particularly from clouds. Skyglow increases light level over dozens of kilometers, exposing areas beyond urbanized ones. As Artificial light at night becomes more reliable, efficient and affordable, humans and other living organisms become increasingly exposed to negative and pervasive effects of ‘‘light pollution”, e.g. unwanted or excessive artificial light (ibid). Thus, it is now considered a major concern for biodiversity and human health.

2.1 The general effect of artificial light at night

While indoor ALAN primarily affects humans, outdoor ALAN might affect flora and fauna, as well as humans who are involved in outdoor activities that ALAN enables, such as walking, shopping, recreation and sport. Nighttime lighting is responsible for changes in natural rhythms, such as diel, lunar, and seasonal rhythms, and has negative consequences for animals and plants at all biological organization levels, from from the organism (hormones, genes, and traits) to community and ecosystem functioning and thus has consequences for human well-being (Desouhant et al., 2019).

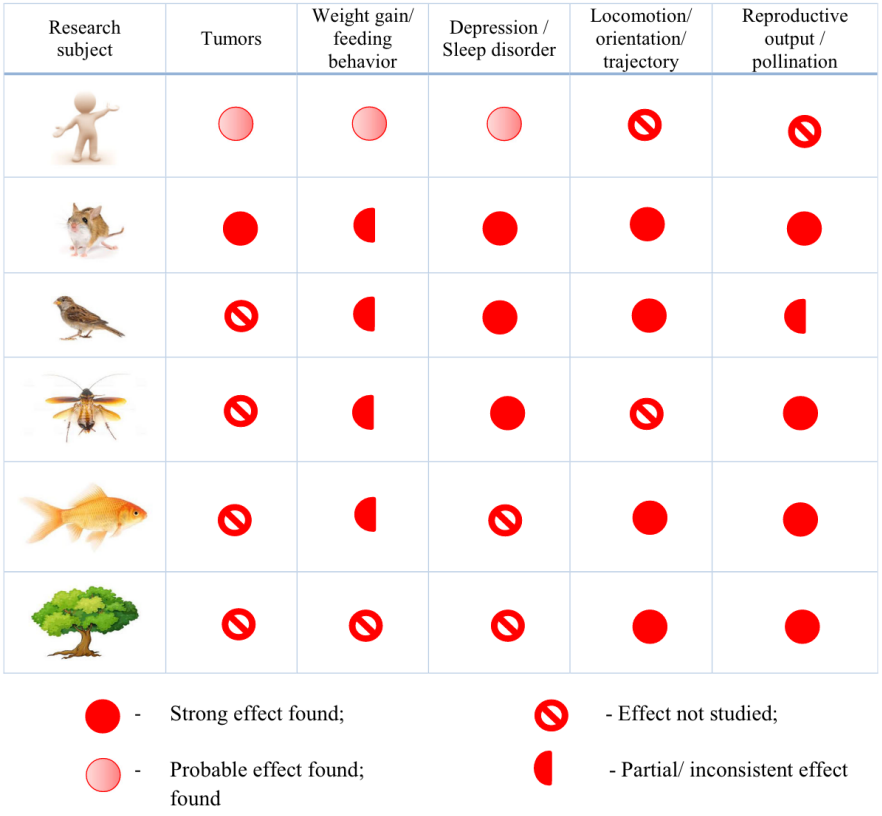

Fig. 5 Studied ecological and health impacts of ALAN

Figure 2: Studies ecological and health impacts on ALAN. Source: (Svechkina et al., 2020)

In general, literature suggests three main pathways through which ALAN exposure might affect living organisms. One pathway relates to melatonin suppression attributed primarily to indoor lighting. The other two pathways include circadian disruption, attributed to night time activities enabled by ALAN, and general stress, caused by rapidly changing illumination levels, which are both associated with indoor, as well as outdoor, lighting. Similar health impacts of ALAN exposure are found indifferent species (Svechkina et al., 2020).

3. Impact of urbanization on insects

Insects are among the organisms with the largest diversity in urbanized environments. Although the diversity of herbivorous insects in urban areas mostly depends on the availability of flowering plants and nesting sites, predators and parasitoids generally require a larger number of resources during their life cycle, and are expected to be particularly influenced by urbanization (Corcos et al., 2019). In general, the increase in urbanization is expected to negatively influence insect

movements, and exacerbate spatial mismatch between them and their resources. At the local scale, the movement of flower-visiting insects is hindered by the presence of buildings and streets. These elements can act as dispersal barriers, and are perceived in different ways by flying insects (e.g. some species are able to fly over streets, but are not able to outmatch buildings). However, flying insects can easily move between habitat patches, and it has been hypothesized that they should be more influenced by resources at the landscape scale rather than by local scale processes. Having said that, research shows that gardens can provide forage for a large number of bumble bee species, but it is the surrounding urban landscape that determines which and how many species that will occur (Ahrné et al., 2009).

3.1 Potential effect of man-made sound on insects

Noise is one of the environmental factors which can impact insects' physiology and ethology (Cammaerts & Cammaerts, 2018). Particularly, it affects species relying on acoustic communication. Signals used in acoustic communication are important for reproduction as females are often attracted by signaling males and base their mate choice on male song (Schmidt et al., 2014). Research about the impact of road noise on tree crickets shows that males were less likely to begin calling in the presence of road noise (Gerhardt & Huber, 2003). Man made noise can also affect females by limiting their ability to locate potential mates (Schmidt et al., 2014).

Another type of impact of road noise in the environment is to mask cues of an approaching predator, and by doing so, increasing the risk of predation. Alternatively, man made noise may distract male crickets by overstimulating their senses and prevent them from responding to predatory threats.

Research shows that man made sound can also affect insects' general behavior. A sound of 42 and 200 beats per minute increased ants' sinuosity of movement, decreased their orientation capability, audacity, tactile perception, brood caring behavior, escaping ability, cognition and short-term memory, and induced slight aggressiveness against nestmates, whereas flowing water noise (a natural environmental sound) did not affect the above cited physiological and ethological traits, and even somewhat enhanced some ones. Based on that researchers concluded that brutal, choppy noise adversely affects ants' (and probably other organisms') health (at least their physiology and ethology), and should thus be avoided in their vicinity, and that smooth calming noise has a beneficial impact on them, reducing stress and improving social relationship as well as cognition and memory for instance (Cammaerts & Cammaerts, 2018).

3.2 The effect of artificial light at night on insects

Artificial light at night affects insects (mostly nocturnal) in different ways. According to Desouhant et al. (2019) these ways include:

4. Spots of artificial light represent traps for numerous species and modify spatial dispersal and distribution of individuals.
5. Artificial light at night could interfere with other activities, such as feeding or mating. It can also increase the metabolism of insects.
6. Finding and choosing a mate requires the utilization of (a combination of) signals or cues that can be affected by artificial light at night at each step of the communication process. Visual signals are particularly affected by light pollution. Indeed, some insect species communicate through bioluminescent flashes used in courtship displays to find and attract mates. With flashing occurring late in the day when ambient light declines, artificial light at night can impede reproduction by reducing the efficiency of the bioluminescent signals.
7. Artificial light at night affects many physiological pathways via a disruption of melatonin synthesis, a key hormone involved in the overall circadian regulation. In a large range of species, the synthesis and release of melatonin occurs in darkness and is suppressed during daylight hours.
8. Artificial light at night may impact population dynamics, as well as community composition and functioning (this is very much Depending on the intensity and spectral composition of lighting and the spectral sensitivity and radius of attraction of the insects).

4. Impact of urbanization on birds

Among the over 10,000 recognized bird species in the world, around 2000 (nearly 20%) occur in cities.

4.1 The dependence of birds on human resources

Depending on their reliance on human resources, birds can be divided into three groups:

Urban avoiders: The urban avoiders are the species that immediately vanish when an area is urbanized. These species are generally characterized by ecological features such as having low natal dispersal, migratory behavior, fear toward humans (long flight-initiation distance), insectivory, and/or low yearly fecundity. However, cities that maintain native vegetation composition and structures (such as Singapore) will retain more native bird species than those that do not.

Urban exploiters: The urban environment can act as an ecological trap by luring and attracting birds to a specific area with its higher abundance of resources (i.e., food and nesting opportunities for cavity-nesting birds) and, in temperate regions, also with its milder winter climate compared to the surrounding nonurban habitats. These factors make birds to evaluate the city habitat as a "high-quality" habitat, thus a preferred habitat compared to more natural habitats. Due to these different species-level responses to urbanization, once an area is urbanized, the species composition will change, with some species vanishing and others flourishing. The risk is that the urban habitat will continue to attract rural birds to the city where they will suffer the negative consequences, ultimately reducing the species future chances of survival. Many of the avian urban exploiters are invasive species. In fact, urban areas have greater abundance of birds per sampling unit than nonurban habitats. This is something that many raptor species have gained from, and some are now becoming increasingly common in urban areas.
Urban adapters: The urban adapter species are not dependent on human resources, but are happy to utilize them from time to time.

4.2 Aiding birds in an urban area

Although the total number of bird species declines once an area is urbanized, many bird species do seem to flourish. In fact, birds are probably the loudest and most visible animal group in the urban habitat. The urban species often exploit anthropogenic resources such as the high abundance of novel food sources and artificial nesting holes, e.g., nest boxes and under roof tiles. In temperate regions, birds can also benefit from the warmer climate caused by the so-called "urban heat island" effect, which is caused by the heat-absorbing properties of the impervious surfaces and buildings together with the scattering effects of air pollution, trapping heat irradiation within the atmosphere of the city. However, in warmer or tropical regions, the urban heating effect can be devastating for birds, leading to heat stress and dehydration (Isaksson, 2018).

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