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Essay

Novel predation opportunities in anthropogenic landscapes

Patricia A. Fleming [a, *], Philip W. Bateman [b, *]

[a] School of Veterinary and Life Sciences, Murdoch University, Murdoch, WA, Australia
[b] School of Molecular and Life Sciences, Curtin University, Bentley, WA, Australia

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Novel ecosystems ('emerging ecosystems') result when species occur in combinations and relative abundances that have not occurred previously within a given biome, due to deliberate or inadvertent human agency. Humans have changed the environment through disturbance, physical structures or additional resources. Many vertebrate predators inhabit cities, towns and other places that humans have built or altered, and make use of these anthropogenic niches. These predators range in size from bats swarming around lamp posts, to leopards stalking domestic animals in the heart of cities. In this essay, we describe four scenarios where predators opportunistically make use of anthropogenic niches. First, humans are surrounded by animals, including synanthropic rodents and birds, livestock and pets, that can be novel prey for opportunistic predators. Second, feeding on prey concentrations created through anthropogenic niches increases their hunting efficiency, by reducing both search and commute times. Third, anthropogenic environments create novel situations such as thermals and artificial lighting that advantage some predators, increasing their capture success. Finally, many predators have developed novel hunting strategies to make the most of opportunities in anthropogenic environments that can lead to greater hunting success. We give examples of these four scenarios and have developed a conceptual model that captures the common mechanisms relevant to each, with predictions for how these can be explored further in future studies. Predators exploiting anthropogenic niches can experience greater ease of hunting, decreased search effort and/or increased capture success. Consequently, these animals experience many physiological and reproductive benefits over conspecifics that do not make similar use of anthropogenic niches, ultimately benefitting from living alongside humans.

Humans have altered the Earth markedly. Anthropogenic biomes dominate the Earth's terrestrial biosphere, covering more than three-quarters of its ice-free land (Ellis & Ramankutty, 2008). We are surrounded by buildings, roads, agriculture, cleared open spaces, artificial lighting, introduced plants and animals. While more than half of the world's human population now lives in cities (which cover 1.5 million km^2), anthropogenic changes across agricultural landscapes (7.7 million km^2) also continue, with about half of the world's nonurban population living in agricultural villages (Ellis & Ramankutty, 2008; Grimm et al., 2008). All these changes markedly alter the environment for the animals that live near humans or their activities, and can provide novel opportunities (anthropogenic niches) that such species would not otherwise have. Anthropogenic environments can be either surrogates of natural environments or novel environments (Van Dyck, 2012). Herein we consider an anthropogenic niche to be an ecological niche created through human activities that may have the capacity to influence behavioural or phenotypic traits of an organism, regardless of whether it is entirely novel or has surrogate elements.

Bats probably form the most diverse group of mammals in urban areas (Jung & Threlfall, 2016), where they are both predator and prey, but all major terrestrial mammalian carnivore families have representatives that show some degree of association with human settlement (Bateman & Fleming, 2012). Many predatory bird species do well around human activities, especially corvids (Marzluff, McGowan, Donnelly, & Knight, 2001) and raptors (Bird, Varland, & Negro, 1996). A number of reptiles also exploit anthropogenic landscapes; for example, many snake species make use of synanthropic prey (e.g. Wolfe, Bateman, & Fleming, 2018), while geckos excel in feeding around artificial lighting (Perry & Fisher, 2006). In the aquatic realm, many pinniped species have demonstrated their

* Correspondence: P. A. Fleming, School of Veterinary and Life Sciences, Murdoch University, South Street, Murdoch, WA, 6152, Australia; P. W. Bateman, School of Molecular and Life Sciences, Curtin University, Kent Street, Bentley, WA, 6120, Australia.
E-mail addresses: t.fleming@murdoch.edu.au (P. A. Fleming), bill.bateman@curtin.edu.au (P. W. Bateman).

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ready willingness to exploit anthropogenic niches to their benefit (Keefer et al., 2012).

In this essay, we discuss evidence for how predators adjust their hunting and feeding strategies to exploit opportunities created through human activities. We have identified four scenarios where predators demonstrate exploitation of anthropogenic niches to their advantage (Fig. 1). We discuss these four scenarios, with examples below. Finally, we have developed a conceptual model that captures the common mechanisms that benefit predators under these scenarios, with specific examples of how researchers could quantify the impacts of these opportunities on predator populations. We conclude with a brief discussion for further exploration.

NOVEL PREY MEANS NEW OPPORTUNITIES

First, predators may benefit from human disturbance through availability of novel prey that they would not normally have in their natural diet. Human disturbance can substantially alter invertebrate and vertebrate community composition, and predators can therefore benefit through the availability of novel prey. Many predator species have come to exploit our cities and towns because of the abundance of synanthropic prey species, animals that are not domesticated but live near and benefit from humans and their dwellings, such as rodents (rats and mice) and birds (sparrows and pigeons; Table 1). For example, cats, *Felis catus*, may have started to feed upon rodents dwelling around human food stores around 9500 years ago (Driscoll et al., 2007), and thus became habituated to people, leading to their domestication. Pets and livestock (e.g. chickens, cats, dogs, rabbits, pigs and cattle) can also make easy pickings for predators and are regularly detected in the diets of a range of carnivores. Human activities can also attract prey species that can utilize refuse, or benefit from clearing or other habitat modification, leading to a shift in prey availability. For example, the myrmecophagous behaviour of urban agamid lizards, *Psammophilus dorsalis*, is magnified in the urban habitat, where Hymenoptera is the most abundant insect order found (Balakrishna, Batabyal, & Thaker, 2016).

STRUCTURES THAT ATTRACT AND CONCENTRATE PREY

Second, anthropogenic niches can have the effect of increasing prey density and therefore decreasing prey search time for predators (Table 1). Many prey species using anthropogenic niches reach elevated population densities. Animals may congregate by choice for resources (e.g. food, water, shelter/refuge), or are forced to use specific sites while travelling (e.g. road underpasses, weirs, dam ladders). To some degree, if their congregation increases predation risk, then these structures are acting as an ecological trap (sensu Robertson, Rehage, & Sih, 2013) for prey.

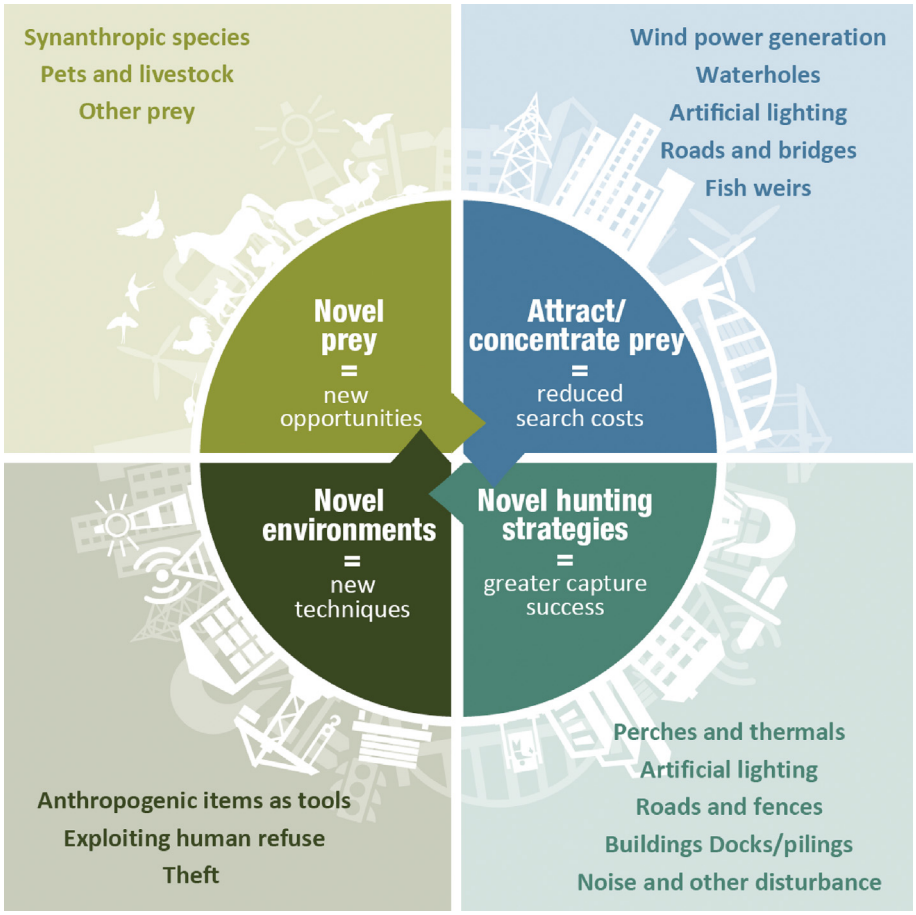

Figure 1. Four scenarios where predators benefit from anthropogenic niches. As urbanization and human disturbance of landscapes increases, a diversity of novel opportunities arises. Variation and specialization in predatory strategies occur naturally, but innovative strategies to find and capture prey are increasingly likely to develop. First, predators may benefit through availability of novel prey, which they would not normally have in their natural diet. Second, anthropogenic niches can increase prey density, reducing search costs. Third, anthropogenic disturbance and activities can aid their hunting strategies, making it easier to capture prey. Finally, new environments can provide novel opportunities that lead to novel predation techniques.