CHAPTER 11

Conservation behaviour

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Overview

In a rapidly changing world, an individual's behaviour is a key response to the changing environment, and it may permit individuals, populations, and species to survive, and sometimes even thrive, in human-dominated landscapes. Conservation behaviour is an emerging field focused on applying insights from animal behaviour research to conservation and management. In this chapter we provide an overview of how an understanding of animal behaviour can be used to predict the impacts of human activities on wildlife, and how it can be harnessed as a powerful tool in conservation and management interventions. We illustrate our points by describing a cognitive framework for conservation. We also include practical advice for behavioural ecologists seeking to have a greater impact on the conservation of species and habitats.

11.1 Introduction

For a newly hatched turtle, deciding where to go is straightforward. As it emerges from the beach burrow in which it hatched with its many siblings, it will start to crawl towards the light, because for millions of years, the reflections of the Moon and stars on the water reliably represented the hatchling's destination—the sea (Salmon 2005). Unfortunately for the turtles, human development along seashores, as well as inland, results in elevated artificial light levels that 'drown' the natural light on the shore (see Chapter 4 to read more about light pollution), causing the turtles to crawl away from the sea and towards the land (Tuxbury and Salmon 2005). These hatchlings then either get captured by predators, get run over by vehicles, or just die of exhaustion and dehydration away from the shore (Witherington 1997). Light, a previously reliable cue signalling where the ocean is, now leads countless turtle hatchlings to their doom in a process that has become known as an evolutionary trap (Schlaepfer et al. 2002; Schlaepfer et al. 2005; see also Chapter 19). By understanding the mechanisms leading to the hatchlings' detrimental behaviour, researchers could devise effective mitigation strategies (Robertson and Blumstein 2019). These include turning off unnecessary lights, redirecting light sources away from the sea, altering the spectral properties of the lights to reduce the turtles' attraction to them (for example, by creating pulsing lights at frequencies in which the pulses are not visible to the human eye), and producing additional orientation cues for the turtles, such as restoring and vegetating dunes between the beaches and the land (Witherington 1997; Salmon 2005; see also Chapter 8).

Turtles are not the only species using light as a cue to guide their behaviour. Thousands of species of birds, insects, mammals, and amphibians rely on natural illumination (such as the lights of the Moon or the stars) for navigation, making them extremely sensitive to light pollution (Longcore and Rich 2004; see also Chapter 4). In the USA alone, between 100 million to 1 billion birds are killed every year by colliding with windows, and many of these birds are migrating birds attracted to artificial lights (Loss et al. 2014). Recent evidence suggests that social behaviour might increase the vulnerability of birds to collisions, with species that produce

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flight calls during nocturnal migration tending to be especially prone to collisions (Winger et al. 2019). These calls have probably evolved to facilitate collective decision-making during migration at night, but nowadays such collective decision-making may lead to mass collisions instead.

In an attempt to alleviate this huge problem, in many US cities, like New York, Philadelphia, and San Francisco, some skyscrapers and other landmarks have started a 'lights out' programme during bird migration seasons (Beatley 2020). Similar programmes are becoming more common around the world. For example, in Phillip Island, located just off mainland Australia, businesses turn off their lights at night to prevent shearwater *Ardenna tenuirostris* fledglings from becoming disoriented as they embark on their annual migration to Alaska (Rodriguez et al. 2014; see also Box 4.1 in Chapter 4), and Canada's Fatal Light Awareness Program (FLAP) has been operating for over 30 years to keep birds safe from deadly collisions with buildings. While all of these campaigns are crucial in reducing the number of bird collisions, understanding the way animals perceive light can help us do an even better job at creating sensory-attuned solutions (Adams et al. 2021).

These examples illustrate the power of understanding the cues animals use to make decisions and the promise of creating behaviourally informed mitigations. Such mitigations, in the case of turning off skyscraper lights, have the potential to save the lives of millions of individual animals globally at a relatively limited cost.

By the time this book is published, the global human population will have crossed the 8 billion mark. This growth comes with a heavy price tag for the planet's natural systems—there is virtually no ecosystem on our planet that has not been modified, at least to some extent, by anthropogenic disturbances (Bradshaw et al. 2021). Natural areas are converted to residential areas and agricultural fields (Chapter 8), invasive species wreak havoc on native communities (Chapter 6), noise pollution seeps into every corner of the Earth, including protected areas (Buxton et al. 2017; Chapter 2), light pollution completely transforms the nocturnal environment (Chapter 4), and climate change is fundamentally changing the conditions in both terrestrial and aquatic systems (Chapter 1; Chapter 5). Individuals may survive these environmental changes (sometimes referred to as human-induced rapid environmental changes or HIREC; Sih 2013) if they are sufficiently plastic, but ultimately, a population will persist by adaptation (see also Chapter 14). However, adaptation is a relatively slow process, creating a mismatch between the rate of environmental change and the rate of the evolutionary response to it (Ehrlich and Blumstein 2018). In other words, we alter habitats at such a fast rate that wild populations may die off before selection has a chance to save them. This is where animal behavioural responses come into play, enabling animals to better confront a rapidly changing environment, and allowing populations and species to survive, and sometimes even thrive, in anthropogenically modified habitats (Berger-Tal and Saltz 2016a). In this chapter we provide an overview of conservation behaviour, a research field aimed at applying animal behaviour research to improve conservation and management. We will provide a cognitive-based framework for conservation, and demonstrate how understanding the mechanisms, consequences, challenges, and applications of how animals behaviourally respond to a rapidly changing environment is a powerful tool in the hands of people who want to ensure the continued survival of wildlife in the Anthropocene.

11.2 Using animal behaviour to improve conservation success

11.2.1 The links between conservation and animal behaviour

The field of conservation behaviour focuses on using insights from the field of animal behaviour (including studies into the mechanisms, development, function, and phylogeny of behavioural variation; sensu Tinbergen 1963) to aid the conservation and management of species and habitats. This can be achieved in three main ways (Berger-Tal et al. 2011; Figure 11.1). First of all, by understanding how animals behaviourally react to changing environments, we can better predict the outcomes of anthropogenic disturbances and the way wild populations are expected to be impacted by them. This

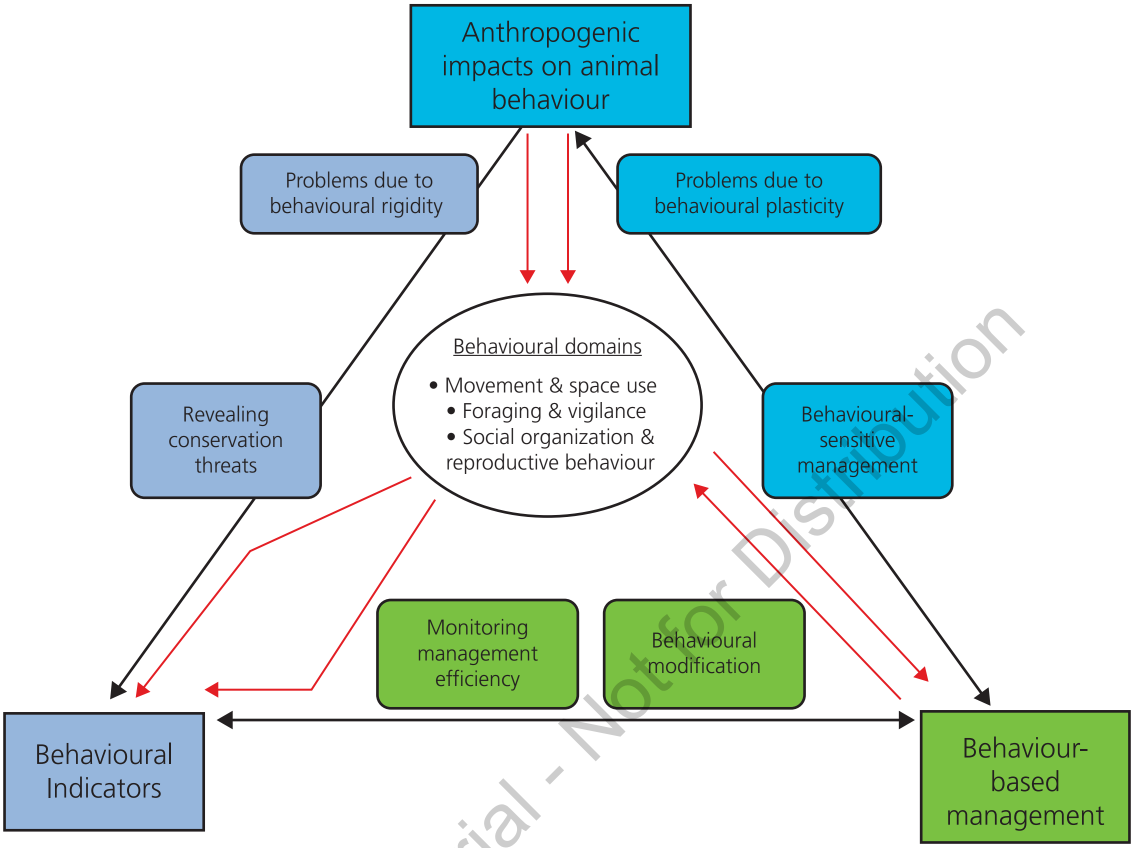

Figure 11.1 The conservation behaviour framework is composed of three basic interrelated conservation themes: (1) anthropogenic impacts on animal behaviour; (2) behaviour-based management; (3) behavioural indicators. The black arrows represent interactions between the conservation themes. Red arrows represent the pathways that connect each theme to the behavioural domains.

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information can be instrumental in designing ways to reduce the impacts of these disturbances, either by targeting and modifying the disturbance itself (if eliminating it is not a feasible option), or by manipulating the behaviour of individuals of the species in question (Berger-Tal and Saltz 2016b). Second, knowledge of animal behaviour may be directly used in planning and executing conservation interventions. Understanding why animals behave the way they do (e.g. what attracts them to certain places and repels them from others) can be the difference between success and failure in conservation interventions (Greggor et al. 2020). Since resources in conservation and management are almost always scarce (Bottrill et al. 2008), and any resources invested in a failed intervention are resources that are denied from other pressing conservation issues that may be just as important, it is crucial that we maximize the chances of such interventions to succeed. Lastly, we can use the behaviour of animals to gain insights into the state and the welfare of animal populations. In some cases, behavioural indicators can reveal wildlife population changes long before demographic trends are evident, thus buying us precious time that can be used to try to reverse negative trends while this is still feasible (Kotler et al. 2016). Behavioural indicators also have an important role in the field of animal welfare, where behavioural knowledge can be harnessed for effective welfare interventions and to improve welfare outcomes of conservation interventions (see Chapter 15 for detailed examples).

11.2.2 Attracting and repelling animals for conservation purposes

At a very fundamental level, behaviour is all about making decisions. We learn that the world can be viewed as patches—should an individual eat in a patch with no predators but lots of competitors, or should it take the risk and eat in a patch with more resources but also more predators? The food in the patch may be very attractive, but the predators that accompany the food may be less so (Brown and Kotler 2004). Indeed, we can envision an animal moving through a natural landscape as making a series of attract-repel decisions. This attract-repel framework (Greggor et al. 2020; Figure 11.2) is a productive one in which to view many conservation problems. It provides insights into preferences that, among other things, can be formalized in resource selection function models (Boyce et al. 2002), or

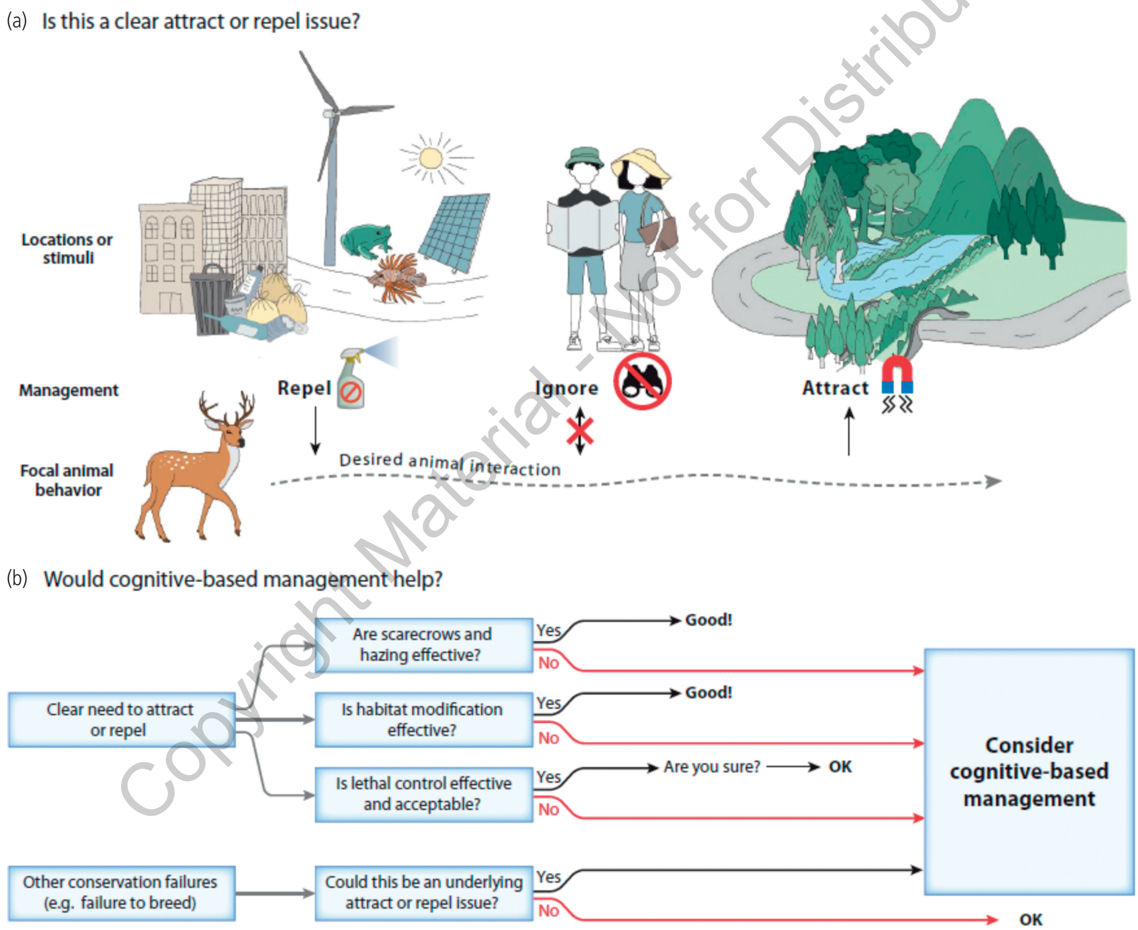

Figure 11.2 Attract-repel issues and the role of cognitive-based management. (a) Many conservation challenges can be defined along an attract-repel continuum in which we want to repel animals from certain locations or stimuli (left, e.g. human settlements, garbage, roads, wind turbines, invasive predators and prey, and ecological traps such as solar panels). At the same time, we want animals to ignore other stimuli (middle, e.g. ecotourists) and be attracted to specific locations and stimuli (right, e.g. overpasses and high-quality habitats). (b) With these cases in mind, we can then decide if cognitive-based management is appropriate for managing the issue.

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used to understand wildlife responses to humans (Hebblewhite and Merrill 2008), and thus provides insights that can be mined to create attractants or deterrents.

We may wish to repel animals from sustainable power facilities (e.g. concentrated solar facilities incinerate many birds annually; Chock et al. 2021) and from roads (one review noted that in the USA alone, 1 million vertebrates are killed each day by cars; Forman and Alexander 1998). Or, we may wish to attract animals to road crossings that are installed to reduce vehicular collisions (Glista et al. 2009). Novel predators (i.e. predators introduced to the system by humans) are often something that prey animals must also avoid in order to survive; Stobo-Wilson et al. (2022: 984) noted that an estimated '697 million reptiles, 510 million birds and 1,435 million mammals are killed by foxes and cats across Australia each year'. This toll occurs despite substantial lethal predator control in Australia and further advances may require coming up with new ways to have individuals avoid predators, such as by anti-predator training (Griffin et al. 2000; Moseby et al. 2016; Blumstein et al. 2019). We may hope that animals ignore ecotourists, a process that can happen via habituation-like processes (Blumstein 2016), but sometimes they sensitize or otherwise learn to avoid humans (Blumstein 2014).

Understanding what attracts and repels animals becomes especially critical when attempting to estimate the consequences of habitat loss for wild populations. Habitat loss and habitat fragmentation are a major threat to biodiversity (Haddad et al. 2015; Chapter 8) as they limit dispersal (Crooks and Sanjayan 2006), reduce access to resources such as food, mates, and shelter (e.g. Bain et al. 2014; Lumsden et al. 2021), and create small populations that are more susceptible to Allee effects and loss of genetic variability (Crooks et al. 2017), and hence more likely to go extinct. The severity of the impact that habitat fragmentation will have on a given species or population will be determined by how a species moves around (i.e. does it fly? Can it walk?), its navigation capacity (i.e. how can it find its way across natural and altered habitat?), and its motivation to move (Nathan et al. 2008). An animal's motivation to move across an altered anthropogenic landscape will be directly determined by how repelled it is by this environment (or more precisely, by the interactions between the various repelling and attracting forces within this matrix). Understanding these forces might allow us to discover that we can facilitate movement across such anthropogenically disturbed habitats, thus alleviating the detrimental impact of habitat loss and fragmentation (Chapter 8). However, it is also very important to remember that barriers to animal movement are not always visible to the human eye, and that fragmentation can occur even when no physical barrier is found (Berger-Tal and Saltz 2019; Chapter 8). Such invisible barriers may include (among other things) areas with altered acoustic conditions (Francis and Barber 2013), altered visual conditions (Jones and Hale 2020), or increased perceived risk of predation (Shamoon et al. 2018). Moreover, increased risk of predation may also be facilitated by altered acoustic, visual, or other sensory conditions, as well as by the presence of human hunters (Chapter 7). Many species, in particular species that rely on acoustic information for communication or for evaluating their environment (e.g. songbirds), are repelled by the noise emitted by human-made infrastructures such as roads (McClure et al. 2013). Thus, noise may create habitat loss on a vast scale, but this will be closely tied to the spectral properties of the noise, and the hearing thresholds of the species in question (Chapter 2).

Another important but non-intuitive driver of fragmentation is behavioural change in animals within human-dominated landscapes (see also Chapters 9 and 14). The mechanisms leading to such behavioural changes may vary from behavioural flexibility to anthropogenic selection on behaviour (Swaddle 2016), but regardless of the mechanism, the utilization of anthropogenic resources and the ensuing higher exposure of wildlife to humans may lead to various behavioural modifications, such as reduced anti-predatory behaviours (Saltz et al. 2018; Geffroy et al. 2020), increased dependence on anthropogenic resources (Oro et al. 2013; Hulme-Beaman et al. 2016), and reduced dispersal (Evans et al. 2012; Berger-Tal and Saltz 2019). Such local adaptations may create behavioural barriers between urban-adapted populations and rural populations of the same species, even when these populations are geographically adjacent. It is important to note, though, that the urban environment is not uniform, and different urban habitats (sometimes within the same city) may select for different behavioural adaptations (Uchida et al. 2021; Vardi and Berger-Tal 2022).

Just as it is imperative to have a good understanding of the drivers of animals' movement to be able to estimate the impacts of habitat fragmentation, we have to understand what attracts animals to certain areas and not to others when attempting to enhance connectivity among populations by means of habitat restoration and the creation of movement corridors (Chetkiewicz et al. 2006). Too many times humans have built structures for animals to use, only to discover that the animals, in their stubborn insistence on perceiving and experiencing the world in their own unique, non-human ways (defined as their *umwelt*; von Uexküll 1909), chose not to use these structures (van Dyck 2012; Hale and Swearer 2017; Chapter 8). Successful restoration (of habitats and of connectivity) requires an innovative approach that considers the way animals perceive their world, enhancing cues and habitats that the focal animals are attracted to, and removing cues and habitats that the focal animals are repelled from (Jones et al. 2021). In the same way, habitat restoration may include attempts to reduce the impacts of invasive species by tuning into the cues they respond to the most (Robertson et al. 2017; Jones et al. 2021).

As discussed in Chapter 13, a considerable amount of effort goes into managing wildlife-human interactions. For instance, the city of Toronto spent millions of dollars designing and deploying racoon *Procyon lotor*-proof trash cans that racoons quickly figured out how to open (Doubek 2018). Crop foraging by non-human primates and elephants is widely perceived as an expensive behavioural problem (Hill 2018). Predation by the recovered California sea lions *Zalophus californianus* and the endangered Steller sea lion *Eumetopias jubatus* on 13 species of endangered salmonids concentrated at the Bonneville dam tailrace creates a serious conservation challenge (Schakner and Blumstein 2021; Tidwell et al. 2021). While lethal control is often politically acceptable to prevent birds from eating crops (even if it may be only marginally cost-effective; Blackwell et al. 2003), killing elephants, non-human primates, and marine mammals is not typically considered an acceptable intervention. Thus, managers must come up with non-lethal ways to repel animals from key resources.

Non-lethal control can be based on fear conditioning, a type of rapid associative learning where animals quickly learn to avoid an alarming stimulus. For instance, Götz and Janik (2013) and Schakner et al. (2016) fear conditioned harbour seals *Phoca vitulina* and sea lions (respectfully) using an acoustic startle device. Harbour seals were deterred from fish pens (Götz and Janik 2013), while sea lions rapidly learned to expect an aversive sound and modified their behaviour to avoid it, but it did not successfully prevent them from eating fish from bait barges or from the lines of commercial sport fishing boats (Schakner et al. 2017). Understanding the evolutionary basis of fear responses can lead to innovative management interventions. For example, painting artificial eyespots on cattle significantly reduced predation by large predators (Radford et al. 2020).

Conservation translocations are another important management strategy that may benefit from adopting an explicit attract-repel framework. Conservation translocations, as discussed in Chapter 12, are used to recover populations or to supplement extant populations' size. Many translocations fail in the sense that animals are not anchored to the release site, which may have been specifically selected because it had sufficient resources. This may lead to dispersal away from the release site followed by increased mortality and, consequently, failure of the translocation project (Berger-Tal et al. 2020). Anchoring can be framed as the need to make a location attractive to released individuals. While ecologists may initially view conspecifics as potential competitors, behavioural ecologists recognize that living with conspecifics may be beneficial. For an individual that must make a decision about a suitable habitat, the presence of conspecifics may provide information that others have found a given location to be suitable (Stamps 1988; Muller et al. 1997).

Conspecific attraction explicitly falls within the attract-repel framework. By providing cues of others, habitat may be viewed as an appropriate location to settle. While living animals may be the best evidence of suitable habitat, cues associated with animals may be sufficient and these cues may come from any modality; olfactory, visual, or acoustic (e.g. Kress 1977; Linklater et al. 2006). A recent example illustrates anchoring using conspecific cues nicely (Hennessy et al. 2022). Burrowing owls *Athene cunicularia hypugaea* were 20 times less likely to leave a release site when living owls were present at the release site or when artificial visual cues (simulated 'whitewash' placed outside release burrows) or artificial acoustic cues (broadcasting the sound of burrowing owls) were deployed. Conservation Evidence (https://www.conservationevidence.com) suggests that for birds, visual or acoustic cues are likely to be beneficial in keeping animals from leaving their release site, but conspecific attraction does not always work and more work is needed to understand when and why the application of such cues works (Putman and Blumstein 2019).

11.3 A cognitive framework for species conservation and management

To better understand the rules of attraction, we must understand cognition. Cognition, as Sara Shettleworth (2010: 278) defined it, 'includes perception, learning, memory and decision making, in short all ways in which animals take in information about the world through the senses, process, retain and decide to act on it'. Cognitive-based management focuses on decisions that animals make about approaching or avoiding specific features or resources. It provides a mechanistic understanding of conservation failures. For instance, culling badgers *Meles meles* in the UK (Woodroffe et al. 2006) failed to eliminate bovine tuberculosis because culling individuals attracted badgers from neighbouring territories, and facilitated the continued spread of the disease (see also Box 17.1 in Chapter 17). Cognitive-based management may explain why certain habitat manipulations create ecological and evolutionary traps (Robertson and Hutto 2006; Hale and Swearer 2016). For instance, planting trees in the Negev Desert created perches for predatory birds that then targeted the critically endangered Be'er Sheva fringe-fingered lizard *Acanthodactylus beershebensis*, which were unaware that the planted area was more dangerous for them (Hawlena et al. 2010). In another example, roadside signs with hollow poles created an ecological trap for mourning wheatears *Oenanthe lugens* looking for nesting cavities in what they perceived to be high-quality territories (Ben-Aharon et al. 2020). Greggor et al. (2020) proposed a set of rules that incorporates a cognitive view of why species are attracted by or repelled from various stimuli. Understanding these rules can help us decipher why animals behave the way they do, and consequently to design more successful conservation interventions.

The first two rules focus on perception and attention. The umwelt, a species' perceptual world, matters. To attract or repel an animal, we must understand what it can perceive, and realize that the sensory world of species may be vastly different from our own (Lim et al. 2008). This includes both the range of perception (e.g. bats using ultrasounds, elephants using infrasounds, snakes using infrared vision, and countless more examples), as well as the sensory modality such as magnetoreception (i.e. the detection of magnetic fields) and electroreception (i.e. sensitivity to electric fields). Dominoni et al. (2020) proposed three different mechanisms that underlie the ecological effects of sensory pollutants on wildlife: masking, misleading, and distracting. Sensory pollutants may mask stimuli. For example, the advertisement calls of many animal species—including frogs, birds, and insects—are often used by the females to assess male quality and choose the best male. Noise pollution (Chapter 2) may mask the males' calls and lead to females choosing lower-quality males, leading to reduced reproductive success (Halfwerk et al. 2011; Candolin and Wong 2019). Sensory pollutants may also mislead animals, leading them to lesser-quality areas and even into ecological traps. Misleading cues may also expedite unnecessary behaviours. For example, chemical compounds (Chapter 3) may be misidentified as predator cues, leading to costly behavioural reactions and sometimes even inhibiting growth (Lürling 2006). Lastly, for many species, including humans, the environment is filled with multiple sensory distractors. Attention, the ability to focus on a task, or acquire information through a sense organ, is always limited and animals are distractible (Chan and Blumstein 2011). Distractions may interfere with natural risk assessment or with the localization of preferred food sources (Riffell et al. 2014), inadvertently making a location undesirable, even when it's a high-quality site (a perceptual trap; Patten and Kelly 2010).

Once we have a deeper understanding of organisms' umwelt, we can use that knowledge to strategically make some locations attractive, and other locations undesirable. For example, by illuminating gillnets along Mexico's Baja California peninsula with green LED lights, researchers have reduced fisheries' bycatch by 63%, including a 95% reduction in shark, skates, and rays bycatch, while target fish catch and value were not affected. Moreover, illuminated nets significantly reduced the mean time required to retrieve and disentangle nets (Senko et al. 2022).

The next two rules of attraction (Greggor et al. 2020) focus on decision-making. All decisions are economic and thus involve trade-offs. Repelling an animal from a patch must be viewed explicitly in the context of other options it has. If there are no other desirable patches, then it will be much more difficult to successfully repel them. And, importantly, not all cues are equally valuable for decisions. This means that the cues we use as attractants or repellents must not only be perceivable, they must be valuable.

Much of cognitive-based management requires a foundational understanding of learning. Learning is Bayesian, which means that prior experience is important. Learning may be biased to focus on certain information that, over evolutionary time, has proved beneficial. Some associations, in particular those without any evolutionary context, are impossible to teach, as seen with tammar wallabies *Notamacropus eugenii* that can be easily conditioned to avoid foxes *Vulpes vulpes* (Griffin et al. 2001) but not goats *Capra hircus* (Griffin et al. 2002). The order of cues and experiences matter, and therefore we must understand how animals naturally learn if we are to modify their behaviour (for pre-release training examples, see Chapter 12). Many species have sensitive periods—a time interval that is particularly important in learning, after which it may be difficult to change specific preferences or learn a particular skill (e.g. bird song; Marler and Peters 1987). We must be explicit about what we are teaching animals; animals may learn other things associated with our desired target and this may lead to ineffective interventions. And finally, social learning can be an accelerant, as seen in California sea lions where information about the location of endangered salmonids travels across social networks at sea lion haul-out sites and spreads like a pathogen through these networks (Schakner et al. 2016).

But it's not just how things are learned; it's how they are maintained. Thus, memory is important as well. Animals are more likely to remember survival-related information than 'random' information, and certain evolved contingencies than other non-evolved contingencies. Once memorized, memory may replace perception, to some extent, in directing the movement of animals (Fagan et al. 2013). This may be beneficial in some cases, since animals may be able to find memorized patches even when the signals leading to these patches are masked by sensory pollution. However, in other cases, animals relying solely on their memory may find themselves in trouble if this habitat has been modified since the animal last visited it.

11.4 Leveraging behavioural knowledge to make an impact

Behavioural ecologists, by their very nature, recognize that behaviour is an adaptation to the environment and thus, because environmental change is rapid in the Anthropocene, they are uniquely positioned to provide mechanistic insights that may improve wildlife conservation (as is detailed above). Additionally, many field behavioural ecologists recognize and mourn the loss of species—the species they study, the species that inspire them, the species that provide vital ecosystem services. In the Anthropocene, all field behavioural ecologists, whether they self-identify or not, are conservation scientists with much to share. Indeed, many behavioural ecologists have a visceral desire to do impactful work. But how to contribute?

One vital way that behavioural ecologists have contributed is by creating frameworks to identify the mechanistic basis of response to environmental changes (e.g. Francis and Barber 2013; Todgham and Stillman 2013; Swaddle et al. 2015; Sih et al. 2016; Razgour et al. 2018). Animals may respond to changes behaviourally, genetically, or physiologically. Gene-environment interactions are expected. Causal pathways are not always direct. Feedbacks may be important. Unpacking these causal models of phenotypic change are important advances that give us the tools to understand the response to rapid environmental change. This permits us to both identify the limits of plasticity, and to identify the precise way that animals do respond to changes, because these may offer concrete ways to manage behaviour in a rapidly changing world. Indeed, the attract-repel framework that guides much of this chapter illustrates the importance of considering behavioural mechanisms.

Because mechanisms are levers of change, mechanistic insights complement the already established genetic and ecological toolkits. But creating tools is not the same as applying tools, and there is a recognized evidence-knowledge gap whereby good ideas do not get applied because of a lack of appropriate knowledge in the hands of those who wish to use it (Dubois et al. 2020). This is not through the lack of outreach or the lack of communication. With a number of books (including this one!), and many review articles already written, behavioural ecologists have been doing an excellent job of making knowledge accessible to those who may need it. But making knowledge accessible is not the same as making knowledge useful.

While we may learn Hamilton's Rule and the Optimal Foraging theory in class, we're not often taught to apply knowledge. Applying knowledge has its own textbook, its own tricks, its own art. The application of knowledge is no less exciting and intellectually interesting than the creation of knowledge. For example, behavioural ecologists study communication, cooperation, and social networks of animals and know that information travels through social networks and that social bonds have many benefits. It's time to apply these same principles to ourselves in order to improve the usefulness of scientific knowledge (as conservation psychologists and other conservation social scientists have been doing for years; Clayton and Myers 2015).

To have an applied impact, behavioural ecologists must embed themselves into conservation networks and create opportunities to co-create projects with wildlife managers. Co-creation is the secret sauce of effective cooperation (Jones 2018). Co-creation requires behavioural ecologists to seek out managers with a well-defined conservation problem and work with them to come up with hypotheses to solve it (sensu Caro and Sherman 2013). This contrasts an alternative model of advertising one's favourite tool. It's not the tool, it's the problem that matters.

Many solutions are likely to not be behavioural in any meaningful sense. If a species is being poached to extinction (e.g. there were fewer than ten remaining vaquita *Phocoena sinus* when we wrote the chapter), immediate cessation of illegal killing is essential. Yet many problems intersect in some meaningful way with behaviour. And this is where the value of creating a rich behavioural toolkit becomes important. Behavioural ecologists are in an excellent position to suggest possible tools for a variety of problems but they must do so in a collaborative way.

Developing mechanistic frameworks can be important, but empowering managers with decision support tools is *extremely* useful (Box 11.1). Decision support tools are algorithms that improve decision-making. Many can be structured as decision trees whereby if a specific situation is encountered, then there are options. Once those options are explored and a problem solved, there may be another question or challenge to be addressed. Greggor et al. (2020) structured the attract-repel framework as two decision trees; the first to ask whether cognition-based management should be considered (Figure 11.2) and the second to walk users through a series of steps to develop effective attractants or repellents. To make an impact, we encourage others to develop behaviourally informed decision support tools that can be used to address specific management problems.

We view the selection and application of a behavioural tool to address a conservation problem as a hypothesis that must be evaluated. Contemporary conservation science understands the value of adaptive management. Adaptive management either actively designs experiments to evaluate the efficacy of a management intervention or designs analyses to passively infer its efficacy. We assert that all behavioural interventions should be evaluated in the context of adaptive

Box 11.1 Using conservation behaviour to improve conservation decision-making

Many readers of this book are likely academics. As academics, we measure our impact by publications and citations, invited talks and awards. Conservation scientists and practitioners measure their impact by achieving their management objectives (e.g. keeping bears and racoons out of dumpsters and recovering a population or species from the verge of extinction). While academic behavioural biologists have much to contribute to conservation science, we can increase the impact of our research by understanding more about the context under which conservation and management interventions are implemented by conservation practitioners, and by developing tools to assist them.

Decisions regarding conservation behaviour interventions are just part of a larger series of decisions involved in planning and implementing any conservation project. To be effective, integrative conservation cannot focus strictly on the biological aspects of the intervention, and must consider the needs, wants, and desires of all human stakeholders. There is a suite of social science tools that can be used to engage stakeholders and genuinely understand their perspectives. Since most conservation actions are in some way related to humans, and since most problems can be framed in the context of a socioecological system (e.g. Berkes et al. 2001), this understanding is essential.

Most decisions also involve trade-offs, and options that may have different probabilities of success as well as associated risks. All decisions are made with some degree of uncertainty. Decision science (Hemming et al. 2022) provides a series of theories, frameworks, and tools to help make informed decisions (e.g. Kleindorfer et al. 1993; Burgman 2005). Structured decision-making breaks down a decision problem into a series of steps. The problem must be specified, and its objectives and performance measures defined. Alternatives must be developed and the consequences of these alternative actions must be evaluated. This permits trade-offs to be clearly understood. Based on this, an action is selected, but this action must be implemented in such a way that it can be monitored. Adaptive management (Williams 2011) is therefore a key attribute of application, and informed conservation behaviourists who wish to have impactful work will work with managers to ensure proper monitoring and evaluation.

There are several decision-support frameworks that are used in natural resource management that facilitate employing these steps. For instance, the Open Standards for Conservation (CMP 2020), priority threat management (Carwardine et al. 2019), and structured decision-making (Gregory et al. 2012) all provide processes to break down complex problems into a series of discrete and assessable objectives.

What, then, is the role of an academic-based conservation behaviourist? One thing that academics can do is to make it easier for managers to make decisions. And this is where decision support tools come into play. Decision support tools can be quantitative or qualitative but their goal is to help a decision-maker address a specific problem. In this chapter we highlighted the Greggor et al. (2020) paper, which contained explicit decision support tools. Referring back to Figure 11.2, we note that this series of questions was structured in such a way as to help a manager determine whether cognitive-based management was potentially useful. Greggor et al. (2020) also contains a detailed figure, developed as a bifurcating tree, where a manager seeking to attract or repel animals in a particular situation has a series of questions to address. Only when a question is answered positively does one move to the next question. By troubleshooting management actions using this tool, Greggor et al. (2020) provides a process to achieve effective attract-repel outcomes.

We suggest that a valuable role of academic-based conservation behaviourists is to develop similar decision support tools for a variety of problems for which behavioural insights might offer solutions. Developing these is not easy and requires thought. Indeed, the successful translation of ideas to successful actions is in itself an intellectual challenge and can be highly rewarding. In the future we hope that managers will have access to a variety of decision support tools that explicitly involve conservation behaviour management actions, so that the right tools will be used to improve conservation and management outcomes.

management. But more importantly, because conservation funds are limited, it's also essential to conduct comparative effectiveness evaluation, whereby alternative interventions are evaluated not only with respect to their success, but with respect to their cost (Blumstein and Berger-Tal 2015, White et al. 2022). In some cases, it may be relatively simple to use a behaviourally informed intervention, such as turning off lights to reduce bird strikes, and to have a huge impact. By critically evaluating behavioural interventions and selecting those that are cost-effective, we will develop a culture of evidence-based decision-making and, over time, will create improved conservation outcomes (Sutherland et al. 2004; Walsh et al. 2015).

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