Chapter 1

Introduction

1.0 Abstract

As humans expand into formally wild areas interactions between humans and wildlife are on a rapid incline, making it ever more pressing to understand the impacts this exposure has on wildlife. This chapter outlines the ways in which wildlife and humans interact, and the main behavioural hypotheses used to describe these interactions. With a focus on ecotourism and researcher presence and the effects this repeated exposure has been found to have on a variety of animals. I outline the current research gaps on human-wildlife interactions and the need to use new automated methodologies to explore these knowledge gaps.

1.1 Background and literature review

The human population is continuing to expand across the globe and as their settlements grow they transform the environments around them. As this expansion continues it becomes ever more pressing to understand the links and impacts between human and animal behaviour (Rutz *et al.*, 2020).

Geffroy *et al*. (2015) outlined the three mechanisms through which animals can be exposed to humans: (1) they could be forced to interact with humans in a taming process which ultimately leads to domestication; (2) an animal or groups of animals could find themselves in a location where humans have settled, the animals either moving there or remaining in a site, this is an interaction by urbanization; (3) they can interact with humans through ecotourism.

The introduction will be structured as follows.

- A background on the history of ecotourism and the impacts it has on wildlife.
- An overview of the impacts of an increase in anthropogenic noise, and its impact on wildlife and soundscapes.
- Background on habituation and how it factors into ecotourism and research practices as well as anti-predator behaviour and its role in measuring behavioural change due to human presence.

- The main behavioural hypotheses used to describe the way wildlife and humans interact, especially in the context of ecotourism.
- The overall aims and structure of the thesis.
- The impacts of COVID-19 on this PhD.

1.1.1 Ecotourism

This thesis will be looking at the third type of human wildlife interaction, ecotourism. The ecotourism sector is growing rapidly and is already a significant portion of the global tourism market (Moorhouse *et al*., 2015). People have been engaging in wildlife tourism since the 1800s, with it being retailed as an impact-free activity in which visitors can learn to value nature and wildlife leading them to take part in its protection monetarily (Honey, 2008). While this practice has long been done, in the last few decades it has expanded rapidly in popularity with countries across the globe investing in wildlife tourism geared toward attracting more visitors and boosting their local economy (Dowling, 2013; Tablado and D'Amico, 2017).

Ecotourism is defined as a form of tourism which has the intention of minimising impacts on nature, while trying to support conservation and local communities (Blumstein *et al*., 2017). It differs to more commercial forms of tourism with its attempt to reduce impacts. Animal viewing tourism on the whole is based on positive intentions and principles, creating an incentive for conservation and environmental protection and serves as a sustainable alternative to resource exploitation (Tablado and D'Amico, 2017). Nevertheless, even though it is based in these virtuous commitments it still has far reaching negative impacts if not conducted appropriately. Terrestrial animal tourism can lead to serious injury or even direct mortality of the animals (Clevenger *et al*., 2003), habitat degradation (Green and Higginbottom, 2000) and behavioural disruption and physiological stress (Green and Giese, 2004). All of which can lead to decreases in population numbers and on an even larger scale the stability of local ecosystems (Tablado and D'Amico, 2017).

As ecotourism has increased in popularity so has the frequency of scientific studies looking at the implications of these activities on wildlife (Blumstein *et al*., 2017). In most cases, with human presence comes a disturbance in the ecosystem. Being able to understand this effect is pertinent to ensuring future effective conservation management in the face of increasing ecotourism (Wallis and Lee, 1999; Russon and Wallis, 2014).

1.1.2 The impact of anthropogenic noise on wildlife

There has been an increase in global environmental noise levels due to human expansion, urbanisation and the globalisation of transport networks. The acoustic environment changes with an increase in anthropogenic noise as it causes an uptick in the number of high-intensity noise events in the soundscape as well as a constant elevated background sound level (Shannon *et al*., 2016). Shannon *et al*. (2016) conducted a comprehensive systematic review of the current published literature (from 1990-2013) on the impacts of anthropogenic noise on wildlife (both aquatic and terrestrial). They found that across a variety of habitats types and taxa there are common effects of anthropogenic noise including a decrease in population abundance, changes in vocal behaviour due to masking, changes in foraging and vigilance behaviour, changes to fitness and the broader ecological structure of communities. One of the main research gaps they identify is the lack of studies measuring behavioural responses on a gradient of noise levels, as most studies focus on quiet versus loud treatments.

High levels of man-made noise are thought to be mainly concentrated in urban settings (Mennitt *et al*., 2013), however, this is no longer the case as anthropogenic noise becomes prevalent in rural and remote areas as well (Merchan *et al*., 2014). With an increase in tourism in an area comes an increase in the amount and variety of anthropogenic noise (Zaeimdar *et al*., 2014). This increase in anthropogenic noise impacts wildlife in three major ways. The first is it can cause negative physiological effects such as a decrease in immune system function (Du *et al*., 2010). The second is an impact on an animal's fitness through a decrease in reproductive success (Halfwerk *et al*., 2011) or through a higher risk of predation (Chan *et al.,* 2010). The final and third is major behavioural change like changes in communication (Santos *et al*., 2017), in their temporal patterns (Baker *et al*., 2007) and decreases in foraging behaviours in favour for increased vigilance and anti-predator behaviour (Purser and Radford, 2011).

1.1.3 Habituation

Tourist presence has both indirect and direct effects. One of the direct effects is habituation, which produces a decrease in fearfulness and therefore creates a bolder individual. Habituation is the decrease in a behavioural response after the repeated exposure to a stimulus (Mazur, 2006). Indirectly, tourists have been hypothesised to create a 'human shield effect' where prey species use humans as a shield from unhabituated predators, which allows prey species to relax and decrease the frequency and use of their anti-predator behaviours (Geffroy *et al*., 2015). Geffroy *et al*. (2015) postulate that due to this shield habituation occurs and with the habituation a change in behaviour, however these changes in behaviour then become maladaptive once the humans leave that area.

Habituation plays a large and important role in both ecotourism (Higham and Shelton, 2010) and in scientific research (Jack *et al*., 2008). It is the first vital step in many behavioural focused field research studies (Jack *et al*., 2008). Understanding habituation and its potential negative effects is of critical importance. Habituation has the potential to cause behavioural changes for some individuals or groups compared to typical species reactions to humans. The first potential behavioural shift occurs in cases where continued human presence is distracting the animal from its environment including their predators (Chan *et al.,* 2010; Geffroy *et al*., 2015). The second, that in a researcher's presence an animal may feel bolder and at a lesser risk of predation causing them to display behaviours they normally would not (Nowak *et al*., 2014; Geffroy *et al*., 2015). Even highly habituated study groups of primates have shown observer-directed behaviours, establishing that researchers can influence their study organisms' behaviours (Jack *et al*., 2008). Metcalfe *et al*. (2022) found that large-headed capuchins (*Sapajus macrocephalus*) spent less time feeding when researchers were closer demonstrating that human pressure gradients have an influence on an animal's behaviour. Not all habituated primate populations have shown changes in behaviour in the presence of researchers, as seen in a habituated group of white-faced capuchins (*Cebus capucinus*), as researchers found no difference in their activity pattern and ranging behaviour while not in the presence of human observers (Crofoot *et al*., 2010). However, the authors admit that there could still be potential observer effects that are too subtle to detect using the technology used. Meaning it could have impacted their anti-predator or feeding behaviour but this would not be picked up by radio telemetry systems. It does however provide evidence that human presence does not seem to strongly impact habituated primates' movement and activity patterns.

1.1.4 Anti-predator behaviour

Anti-predator behaviours are those that animals use to reduce their probability of being detected, attacked or killed by a predator (Caro, 2005). These include behaviours which help them detect a predator (vigilance), communicate about spotting a predator and fleeing in order to escape a predator (Lima and Dill, 1990). Studying anti-predator behaviour has become the main way to investigate the impacts of human presence as predation is a strong selective force and quantifiable (Blumstein and Fernández-Juricic, 2010; Blumstein, 2014).

Anti-predator behaviours can undergo relaxed selection pressure as generations are exposed to ever changing environments. Over time, anti-predator behaviours can be completely lost in environments that are considered "predator-free" this can even happen on a more rapid timescale through a relaxed selection pressure. Tammer wallabies (*Macropus eugenii*) in New Zealand who have been isolated from predators for 130 years have lost their anti-predator behaviours entirely (Blumstein *et al*., 2004). These longer lasting effects come from both the urbanisation and domestication process however; ecotourism can still have long lasting effects even though the tourist's presence is only temporary (Geffroy *et al*., 2015). The potential longer lasting effects of the temporal aspect of tourism is largely understudied, especially in regards to anti-predator behaviours. We do not know what happens when this exposure is repeated and if this can cause prey species to become habituated leaving them more vulnerable to predation events. A study with harbour seals (*Phoca vitulina*) found that they decreased their anti-predator response to bald eagles (*Haliaeetus leucocephalus*) as human exposure increased (Olson, 2013). This study shows support for the potential threat of animals becoming too relaxed in the presence of humans and increasing their risk of being predated upon.

1.2 The main behavioural hypotheses for how humans and wildlife interact

To understand the effect that human presence has on an animal's behaviour, one must first know the ways in which animals interact with humans. The interactions between wildlife and humans leads to a multitude of changes in an animal's behaviour, affecting anti-predator responses, mating, and feeding behaviours (Geffroy *et al*., 2015). It is important to note that in their three main mechanisms for how humans and wildlife interact Geffroy *et al*. (2015) does not address the way in which humans can interact with animals in a more destructive manner, i.e. through hunting or habitat disturbance. These interactions will of course lead to very different behavioural outcomes, such as avoidance and relocation. The following section details the three main behavioural hypotheses used to describe how wildlife is interacting with humans, with a focus on how it relates to ecotourism and anthropogenic noise (Figure 1.1; Table 1.1).

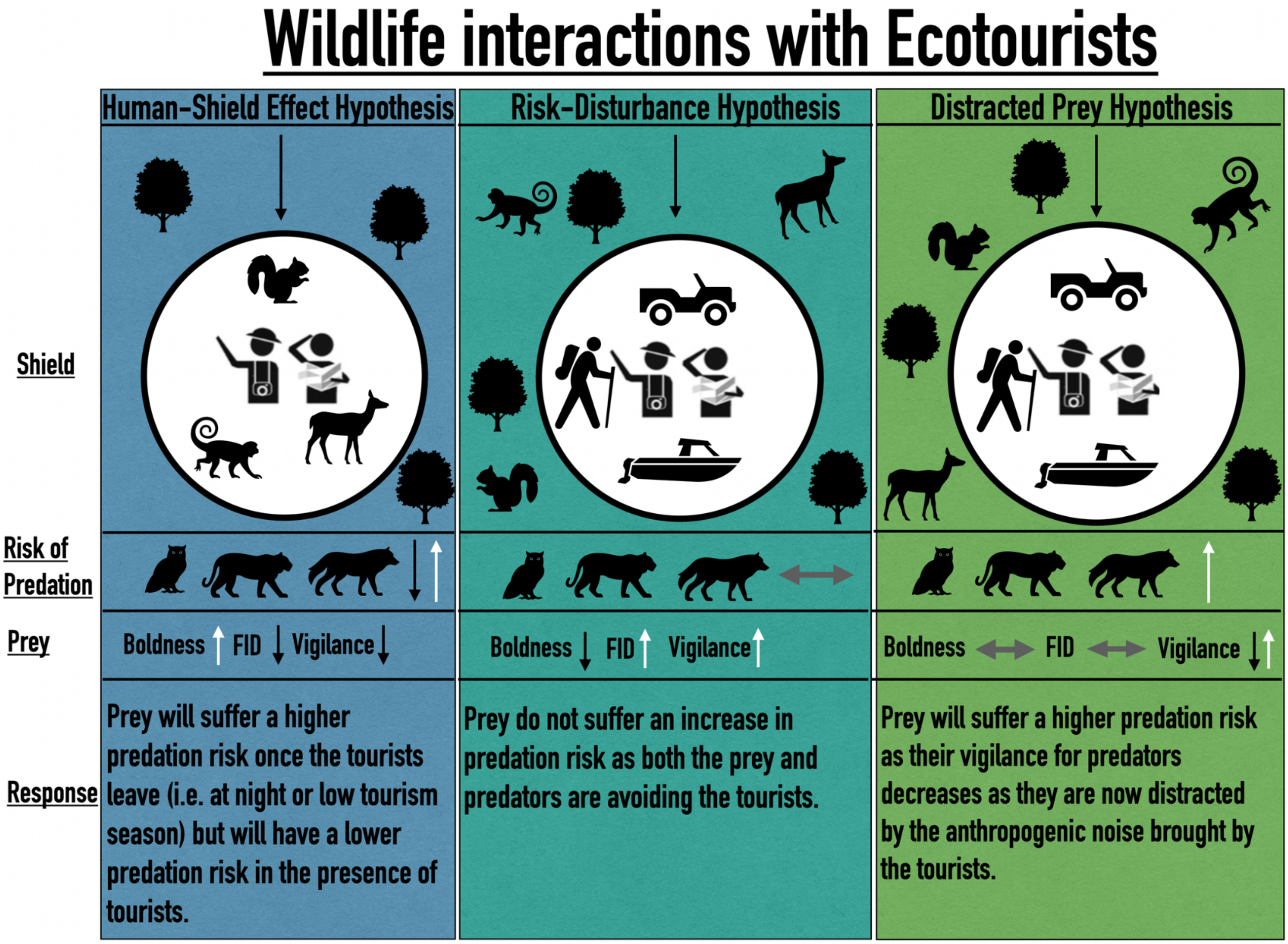

Figure 1.1 Hypotheses describing wildlife interactions with tourists (adapted from a diagram which presented the human-shield effect in Geffroy *et al.*, 2015). A white arrow indicates an increase in presence or occurrence of behaviours (boldness, flight initiation distance (FID) and vigilance), black arrows indicate a decrease and grey arrows indicates no change.

1.2.1 Human shield effect

Human presence has been shown to decrease the chance of an encounter with predators in many prey species (Isbell and Young, 1993; Geffroy *et al*., 2015). Muhly *et al*. (2011) showed that in high human activity areas (>32 humans/day) ungulate prey species were three times as abundant as predator species and predators were less abundant on roads and trails that exceeded 18 humans/day, providing evidence that human presence can attract prey species seeking refuge from predators. Another piece of evidence for this hypothesis was found in Grand Teton National Park, Wyoming, USA where moose (*Alces alces*) shift their birth sites toward paved roads to avoid predators like brown bears (*Ursus arctos*) who are traffic-averse (Berger, 2007). This phenomenon is not limited to large ungulates; vervet monkeys (*Chlorocebus pygerythrus*) who become associated with humans had a decreased encounter rate with leopards (*Panthera pardus*) and experienced a decrease in predation events (Isbell and Young, 1993). Studies show that some prey species move towards urbanised areas, potentially due to this theoretical protective shield where they experience less predation. This then leads to a disturbance in the predator-prey relationship and can potentially have a negative impact on predators in an ecosystem that is tipped in favour of prey species.

Animals not only shift closer to humans, they also change their behaviour while being watched by humans (Hobaiter *et al*., 2017). Nowak *et al*. (2014) was one of the first papers to look at the 'observer effect' under scientific scrutiny. They tested how the presence of human observers shifted feeding behaviours in two groups of habituated samango monkeys (*Cercopithecus mitis erythrarcus*). They found that when human observers were present at feeding platforms, the giving up density (GUD, the amount of food left by a forager in an experimental food patch) was reduced at all feeding patch heights. They suggest that human observers lower the monkeys perceived risk of their terrestrial predators, therefore, affecting their foraging decisions on the ground.

When tourists interact with wild animals, the tourists can act as a predator deterrent by creating a protective theoretical "shield" and with this shield comes increased boldness (Geffroy *et al*., 2015). This increase in boldness is a result of habituation and leads to these individuals having a higher predation risk, from both predators and hunters, once the tourists leave. Conversely tourists which hunt or fish (consumptive tourism) have the opposite effect, causing animals to become timid rather than bold (Arlinghaus *et al*., 2016). However, even non-consumptive passive wildlife viewing tourism has negative effects on wildlife. Asian rhinoceroses (*Rhinoceros unicornis*) (Lott and McCoy, 1995), woodland caribou (*Rangifer tarandus caribou*) (Duchesne *et al*., 2000) and bighorn sheep (*Ovis canadensis*) (Stockwell *et al*., 1991) have all been shown to be negatively impacted by tourism; in the presence of tourists all three species spent less time feeding and more time being vigilant. Behavioural changes in foraging, vigilance and resting behaviours are used as indicators of wildlife disturbance by ecotourists as with woodland caribou in Duchesne *et al*. (2000).

1.2.2 Risk disturbance hypothesis

An alternate theory to the one presented by Geffroy *et al*., (2015) is the risk disturbance hypothesis. The risk disturbance hypothesis predicts that humans and the anthropogenic noise associated with them will elicit anti-predator behaviour. These behaviours take away time and energy from fitness enhancing behaviours such as resting, foraging, mating displays and parental care (Frid and Dill, 2002; Shannon *et al*., 2014). This theory was first presented 50 years ago by Walter (1969), he presented his hypothesis that animals respond to human disturbance the same way they would to predators. He conducted an experiment where he approached Thomson's gazelles (*Gazella thomsoni*) in a vehicle and tested whether their Flight Initiation Distance (FID, the distance in which prey will flee from an object) depended on sex, social status or age. He went on to gauge the FID response of the gazelles when fleeing from African wild dogs (*Lycaon pictus*) and found similar variables affecting the responses to a car and predator species. Tadesse and Kotler (2012) used GUD to see how tourism affected the Nubian ibex (*Capra nubiana*). They found that the GUD was the highest when tourist activity was at its peak and in the habitat type most frequently visited by tourists. They were able to demonstrate that even a habituated population of Nubian ibex was affected by tourist presence and that these tourists caused a significant increase in the ibex's foraging costs. The ibex showed similar behaviours in response to the humans as they would to natural predators. Pygmy marmosets have been found to decrease play behaviours and decrease use of the lower level of the forest where there were higher levels of tourism, suggest higher levels of vigilance due to ecotourists (de la Torre *et al*., 2000).

Disturbance by humans can not only change fitness enhancing behaviour but it can also shift an animal's temporal and spatial behavioural patterns. A meta-analysis by Gaynor *et al*. (2018) examined the human-induced spatial shifts in wildlife and found an increase in nocturnal activity in animals due to human disturbance. This spatial shifting has been seen in cheetahs (*Acinonyx jubatus*), who have been found to alter their feeding to coincide with times of lower tourist densities (Gakahu,1992; Hodgkinson *et al*., 2014). This shift could have large ramifications for the ecosystem. As animals are shifting their temporal activities it alters not only predator and prey behaviours but it also causes disruptions and changes on a trophic level (Gaynor *et al*., 2018).

1.2.3 Distracted prey hypothesis

Anthropogenic noise brought on by human presence has also been found to impact anti-predator behaviour. Karp and Root (2009) found that ecotourists having loud conversations increased the FID and general alertness of hoatzin birds (*Opisthocomus hoazin*) in Peru. Building on the risk disturbance hypothesis, Chan *et al*. (2010) proposed the 'distracted prey hypothesis'. This hypothesis states that an animal can be distracted by any stimulus it is able to perceive, and this distraction takes time from the animal's finite attention, potentially causing it to become more vulnerable to threats (Chan *et al*., 2010). Chan *et al*. (2010) found that hermit crabs (*Coenobita clypeatus*) were distracted when played the sound of a motor boat and allowed a simulated predator to get closer before seeking shelter. This study supports the distracted prey hypothesis and suggests that anthropogenic sounds can distract prey species and allow them to become more vulnerable to predation.

Purser and Radford (2011) found that three-spined sticklebacks (*Gasterostesus aculeatus*) decreased their foraging efficiency after exposure to a brief prolonged noise. Their results also established that even brief acoustic noise can influence many behaviours because of the attention loss. Many different mammal species have been found to increase vigilance behaviours when in the presence of tourist transport: polar bears (*Ursus maritimes*) with tourist vehicles (Dyck and Baydack, 2004) and bottlenose dolphins (*Tursiops trunscatus*) with tourist boats (Constantine *et al*., 2004). These examples demonstrate that animals are having to use a portion of their attention on the tourists or their vehicles, which is a cost to their fitness, and is also potentially distracting them from their surroundings and therefore the predators in the landscape.

Table 1.1 Displays the three behavioural human wildlife interaction hypotheses and the behavioural changes that the postulate occurs when humans and wildlife interact. The arrows indicate if the behaviour listed will stay the same (a yellow arrow), decrease (an orange arrow) or increase (a purple arrow) and in the same table cell the study which found evidence of support of the behavioural changes is referenced.

Behaviour	Human-Shield Effect Hypothesis	Risk-Disturbance Hypothesis	Distracted Prey Hypothesis
Non-human vigilance	↓ Olson, 2013	→ stays the same	↓ Chan *et al.*, 2010
Human Related Vigilance (anthropogenic noise)	↓ Olson, 2013	↑ Lott & McCoy, 1995	↑ Dyck & Baydack, 2004
Eating	↑ Nowack *et al.*, 2014	↓ Tadesse & Kotler, 2012	↓ Purser & Radford, 2011
Social (i.e play, grooming)	→ stays the same	↓ de la Torre *et al., 2000*	↓ de la Torre *et al., 2000*
Fight Initiation Distance	↓ Isbell & Young, 1993	↑ Walther, 1969	↓ Chan *et al.*, 2010
Alarm Calls (related to humans)	↓ Jack *et al.*, 2008	↑ de la Torre *et al., 2000*	↑ de la Torre *et al., 2000*
Use of lower strata of the tree	↑	↓ de la Torre *et al., 2000*	↓
Fleeing probability	↓ Muhly *et al.*, 2011	↑ Walther, 1969	↑ Karp & Root, 2009

1.3 Research Gaps

Ecotourists are potentially leaving residual effects from their theoretical protective shield that are causing a change in prey species behaviour and having both a positive and negative effect on the animal (Geffroy *et al.*, 2015; Olson, 2013). The habituation of these animals to humans can result in the total loss or decrease in fear responses that could potentially result in an increase in mortality risk due to poaching or capture for the pet trade (Møller, 2017). It could lead to a positive skew for prey species survival rates with a negative repercussion for predator species, which can impact ecosystem function and biodiversity (Shannon *et al.*, 2014). Or it could be having negative consequences on their fitness through distraction or fleeing behaviours. Having a clearer understanding as to how ecotourists are affecting an animal's perception of their environment is important as it will also allow us to better understand the potential skew towards prey species that tourists can create and how their presence changes an environment and how quickly the behavioural change occurs. Metcalfe *et al.*'s (2022) study demonstrated that behavioural changes were also present on a human pressure gradient. Implying that not only are human observers having an impact but that this impact can even be seen on a more nuanced gradient of exposure. Gradients of exposure have been identified as key knowledge gaps in our current understanding of the impacts of anthropogenic noise on wildlife, especially those that come from human presence (Shannon *et al.*, 2016). Being able to quantify on gradient of exposure when these behavioural changes are occurring is incredibly important information for researchers and ecotourist operators alike.

To investigate these behavioural changes most traditional monitoring methods rely on research presence, however, we do not know if the presence of researchers could be causing observer effects. Observer effects result when a study organism shifts their behaviour in response to the research present (McDougall, 2012). Even when researchers try to mitigate the impacts of their presence through habituation, as discussed above habitation too can cause behavioural changes (Jack *et al.*, 2008). As further studies provide more evidence that human observational studies have an inherit bias (McDougall, 2012) it becomes ever more pressing to investigate new avenues for passive methodological techniques which do not require human presence.

Technological advances have been used to overcome this bias in the forms of non-invasive recording devices like Audiomoths and camera traps. For example, the Automated Behavioural Response system (ABR), combines a speaker which provides audio playback with a camera trap (Suraci *et al.*, 2017). The ABR allows one to capture a focal individual's response to an audio stimulus and conduct playback experiments without the need for a human observer. The ABR has yet to be used to test behavioural studies, however it has the potential to revolutionise future behavioural ecology studies (Palmer *et al*., 2022).

1.4 Overall aims and structure

This thesis aims to explore the effects of anthropogenic noise disturbance on the eastern pygmy marmoset, *Cebuella niveiventris*, in the Área de Conservación Regional Comunal Tamshiyacu Tahuayo in north-eastern Peru. This thesis is structured as follows:

Chapter 2 Provides a background on the study species and site.

Chapter 3 Aims to investigate the best methodology to quantify anthropogenic noise exposure levels. I compare a manual analysis to a bioacoustic index, the NDSI score.

Chapter 4 Aims to investigate the impact of anthropogenic disturbance on the structure and duration of pygmy marmoset calls, over an exposure gradient. I use the anthropogenic noise data that was catalogued in Chapter 3 to establish a gradient of exposure. I analysed the calls of 23 groups along this gradient to investigate where there were significant changes in the structure and duration of four different call types, and if there was a correlation between these changes and exposure to anthropogenic noise.

Chapter 5 Provides a diurnal riverine raptor species inventory for the Área de Conservación Regional Comunal Tamshiyacu Tahuayo. The inventory serves to establish the diurnal riverine raptors present in area that could be potential predators to the pygmy marmoset. This information helped inform which predator calls would be used in the playback experiment conducted in Chapter 6.

Chapter 6 Aims to test the validity of Automated Behavioural Response (ABR) systems as a methodology to investigate behavioural hypotheses. I use an ABR system, a camera trapping play-back approach created by Suraci *et al*. (2017), to investigate its potential use in behavioural ecological studies focusing on the impacts of human presence and anthropogenic noise on animal behaviour. This chapter is a pilot study using pygmy marmosets and the distracted prey hypothesis as a model system.

Chapter 7 Provides a discussion of the findings of the thesis. I discuss the knowledges gaps filled by the results found. I also provide the next steps in furthering this research in the future.

1.5 Impact of COVID-19 on PhD work

This thesis was originally designed to explore the effects of tourism with a focus on anthropogenic noise on pygmy marmoset behaviour, *Cebuella niveiventris*, in the Área de Conservación Regional Comunal Tamshiyacu Tahuayo in north-eastern Peru. However, due to COVID-19, some chapters were removed and others restructured. Originally the thesis was meant to contain the following five data chapters:

1) Investigating the impact of anthropogenic noise on pygmy marmoset calls on a gradient of exposure and across the peak and low tourist season.
2) A diurnal riverine raptor species inventory, to establish that the pygmy marmoset groups are exposed to same raptor species whose calls would be used in a following chapter.
3) Investigating how varying levels of human exposure impact anti-predator behaviours in pygmy marmosets. Conducting a playback with predator calls using ABR technology.
4) Investigating if tourism creates a habituation to anthropogenic noise disturbance and resulting in a decrease in vigilance in pygmy marmosets. Conducting a playback with anthropogenic noise and predator calls using ABR technology.
5) Comparing traditional playback experiment methodologies with an ABR system to see if this is an appropriate new methodology that can be more widely used in primatology research.

However, due to Covid-19 I was not able to complete the two data collection trips to Peru I had planned for 2020. The first was planned for March-May to complete the second data collection trip for the first and second data chapter and the first data collection period for the third and fourth chapter. The second and final data collection trip was meant to be in July-August 2020, to complete the second data collection trip for the third and fourth chapter and the data collection for the fifth chapter.

I was able to utilise local guides at the field site to collect the second half of the raptor species survey, allowing me to complete that chapter as planned. This was the only chapter that followed its original design. The first chapter discussed above was split into two; the first keeping to its original investigation but only looking at one season worth of data as I was unable to collect the call and exposure data for the peak tourist season, the second now using the acoustic data on the anthropogenic noise catalogued for the previous chapter to see if acoustic ecology indices are applicable replacements for human manual acoustic analysis. In September-October of 2021 I was finally able to return to the field, however, only for a limited six weeks due to time constraints with PhD hand in deadlines. Therefore, the third and fourth planned data chapters of the thesis had to be condensed into one pilot study chapter due to time constraints. I therefore wasn't able to do the full behavioural testing I had originally planned. The final planned data chapter had to be scrapped again due to time constraints in the final field data collection period.

1.6 References

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