Habitat suitability, space use, and human-wildlife coexistence for wild river otters (*Lontra canadensis*)

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A Thesis
In the Department of
Geography, Planning, and Environment

Presented in Partial Fulfillment of the Requirements
For the Degree of
Master of Science

at Concordia University
Montréal, Québec, Canada

July 2023

CONCORDIA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

This is to certify that the thesis prepared

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Entitled: Habitat suitability, space use and human-wildlife coexistence for wild river otters (*Lontra canadensis*)

and submitted in partial fulfillment of the requirements for the degree of

Master of Science (Geography, Urban and Environmental Studies)

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ABSTRACT

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Land use change and urban sprawl increase the likelihood of encounters between humans and wildlife. River otters (*Lontra canadensis*) are a species that coexists, but also conflicts, with humans over the use of space on Protection Island, British Columbia. River otters are sensitive to human-induced disturbances yet also inhabit environments with relatively high densities of humans and anthropogenic structures. I investigated the effect of human activity and disturbance on river otter use of space and behaviour to elucidate implications for habitat suitability and wildlife management in anthropogenic landscapes. I drew on 23 semi-structured core interviews and 18 surveys to discuss the human-otter dynamics on the island and perceptions of river otter behavior among residents. I then investigated the relative importance of anthropogenic (e.g., distance to buildings and roads, level of human use of docks), environmental (e.g., land cover type), biological (distance to dens), and topographic (elevation) variables for habitat suitability in wild river otters sharing their environment with humans. I used maximum entropy (MaxEnt) species distribution models to identify the most important factors for river otter habitat suitability and space use in anthropogenic landscapes. Two scenarios were modeled with MaxEnt using 660 and 207 occurrence points respectively. I found that the most suitable habitats for North American river otters in this study were areas of low elevation, with exposed land as the dominant land cover type, near water or wetlands, and that river otters and humans are able to coexist quite well, at least in some urban contexts. Finally, I performed Pearson's Chi-squared tests on 594 observations from 178 behavioural samples to evaluate three hypotheses focusing on behavioural differences among river otters associated with the use of an anthropogenic habitat feature (i.e docks), and land. The results indicated that river otters used docks more than would be expected by chance and, disproportionately for individual and social activities and they used docks more than expected during the overnight period. Overall, this suggests docks may act as an anthropogenic habitat attractant for river otters. This study helps clarify relationships between river otter behaviour and space use in landscapes they share with humans and in environments where anthropogenic structures are present, which can inform the development of targeted conservation initiatives and enhance human-wildlife coexistence.

ACKNOWLEDGMENTS

An incredible number of people have played an instrumental role in this project, as evidenced by the length of this section. I would like to express the utmost gratitude and appreciation to those named below and all those that are not. Thank you all for your interest and for letting me ramble about otters and for thinking of me when you came across cute otter videos, they always put a smile on my face.

To Sarah, thank you for everything. Thank you for being gentle and kind when I needed it most and for your support throughout this process. It was so lovely to have a supervisor that cared about us as people and our personal successes beyond our triumphs in school. Thank you so much for all of your help and support!

To Angela, thank you for your patience when I had millions of questions for you and for greeting me with a smile the many times I showed up at your door unannounced. You were instrumental in this process.

To the PIES Lab (Mikaela, Brogan, Stephanie, Ariana, Jack, Megan, Jennifer, Yisa), thank you for your support and willingness to help. A special thank you to Yisa and Jennifer for sharing your knowledge of MaxEnt with me and taking the time to help me problem solve when things weren't working as planned, I so appreciated your help.

To the residents of Protection Island, I am incredibly grateful for the support and kindness you showed the Otter Girl during the Summer and Fall of 2022. This project could not have come to be without your interest, support, and willingness to be involved. I will always be thankful towards those of you who let me sit on your dock or texted me your otter sightings in support of my pursuit to locate them, chatted with me on the ferry or island about how things were going, participated in the project, and invited me into your homes. Thank you for a memorable time in your beautiful community. I will always carry with me the memories of my time on the Island and with all of you. A special shoutout to Joanne and Heidi for being such lovely, friendly faces and for your friendships.

To Nancy, Bob (and the rest of the Turner family), I am incredibly thankful for you and the role you played in this journey. I cannot express how grateful I am for the generosity and support you showed towards someone you had never met. Your interest in this project and eagerness to help it come to fruition in any way you could were instrumental to its success. You provided me with a familial environment, a home away from home, while I was in a new place, which was something I didn't expect, and was incredibly grateful to have.

To my parents and my sister Em (my best friend and inspiration in life), thank you for being strong and supportive voices of reason when I was overwhelmed and for giving me a kick in the butt when I needed it, you always seemed to know what I needed to hear. And to Parker, thank you for inviting me to come visit even when your lives were crazy, and for your words of encouragement and support throughout this process.

To Kaela, thank you for everything, for listening to my woes and celebrating my wins despite the distance. I will forever be grateful to you for sharing your wisdom, experiences and resources throughout this process. Even more so, I am thankful for the moments in between, where we put school aside and had fun. I so look forward to seeing what awesome things you continue to do and to share in some of these adventures.

To Emily, Mikaela and Ariana, I'm so glad we got to do this together. I so appreciated having people to commiserate with when things went unexpectedly, to problem solve with, and to share this wild journey with. I'm incredibly grateful for your friendships and support throughout this process.

To Emilie and Hannah, thanks for being such supportive roommates. It has been so lovely to come home at the end of the day to both of you. Thank you for listening to me, helping me take the time to relax and for hugs when I needed them.

CONTRIBUTION OF AUTHORS TO THE MANUSCRIPT CHAPTER OF THIS THESIS

Sarah Turner and I conceptualized this project. I conducted the data collection, preparation, and analysis, and wrote the manuscript. Sarah Turner supervised the entire project, provided feedback and ideas for analyses and text, edited this thesis, and provided funding support. Angela Kross provided technical support and knowledge for the conceptualization and application of the data preparation process in Geographic Information Systems (GIS).

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List of Abbreviations

ASCII	American Standard Code for Information Interchange
AUC	Area under the curve
CL	Caroline Lesage
DFW	Driftwood
GPS	Global positioning system
HWC	Human-wildlife conflict
LHU	Level of human use
m	Meter
MaxEnt	Maximum entropy
MeHg	Methylmercury
NAD	North American Datum
PA	Protected area
PI	Protection Island
ROC	Receiver operating curve
SDM	Species distribution modelling
SIMPP	Saysutshun Island Marine Provincial Park

CHAPTER 1

INTRODUCTION

Human activities are altering ecosystems globally at extraordinarily fast rates, causing critical declines in biodiversity and exposing animal species to novel conditions for which they are not adapted evolutionarily (Sih, et al. 2011; Sih 2013; Ceballos et al. 2015; Wong and Candolin 2015). Interactions between humans and wildlife have the potential to be negative, positive, or neutral; however, when encounters between humans and wildlife negatively affect one group, or both, they are described as human-wildlife conflicts (HWCs) (Madden 2004; Nyhus 2016). While HWCs occur in numerous environments and contexts, they frequently occur in close proximity to protected areas, to agricultural areas, and in urban environments (König et al. 2020). Global changes, such as land transformation and development, increase the likelihood of interactions between humans and wildlife, and these conflicts are becoming increasingly severe (Madden 2004; Basak et al. 2022). The majority of the global human population inhabits urban areas, and this is apparent in North America where less than 30% of the population lives in rural areas (Nyhus, 2016; Basak et al. 2022). As land worldwide is increasingly converted to urban environments, the quantity and quality of natural habitat available for wildlife is decreasing, and as such, many species are likely to utilize urban areas for habitat and resources (Madden 2004; Basak et al. 2022).

The history of conflict between humans and animals is enduring and complex, occurring across a spectrum of temporal and spatial scales and social and cultural contexts (Jochum et al. 2014). These conflicts surround both wild and domestic animals and may stem from differing cultural, political and economic circumstances (Emel and Wolch 1998). For example, wildlife can have detrimental consequences for people who rely on subsistence agriculture, both in terms of the health of farmers who may have closer contact with wildlife and financially through the direct loss of crops (Hill 2004). For example, a study of farmers in Entebbe, Uganda indicated that vervet monkeys (*Cercopithecus aethiops pygerthrus*) are seen as a nuisance by the majority of farmers, in large part because of the financial implications from the loss of crops due to crop-raiding (Saj et al. 2001). Such losses can amount up to $400 USD per season (Saj et al. 2001). In response to this conflict and the crop-raiding by vervets, at least one human individual undertook actions that were fatal for a vervet monkey (Saj et al. 2001). Crop raiding is a common concern for farmers surrounding and in close proximity to protected areas (PA) (Mackenzie and Ahabyona, 2012). Elephants (*Loxodonta cyclotis*) are another species that experience conflicts with humans over damage to crops, primarily in close proximity to PAs (Chiyo et al. 2005; Mackenzie and Ahabyona, 2012). The largest source of crop damage to households and the broader farming community surrounding Kibale National Park, Uganda, in terms of the size of damaged crop areas, was crop-raiding elephants (Mackenzie and Ahabyona, 2012).

Anthropogenic activities and development often lead to habitat degradation and fragmentation, which can have critical implications for biodiversity due to the reduced quality and quantity of available habitat for wildlife (Markovchick-Nicholls et al. 2008). In certain cases, humans deliberately negatively alter or remove habitat through the transformation of existing habitat to new land uses and land cover types, and these conversions are increasingly to urban land cover (Hanski 2011). For example, some European countries have increased the number of "managed forests" by transforming naturalized forests to this new highly controlled land use (Hanksi 2011). The fragmentation and decline in available habitat have important implications for wildlife population persistence and these effects may be evolutionary, reproductive, and/or genetic in nature (Fahrig 2002; Hanski 2011). As Hanksi (2011) summarized, "habitat loss and fragmentation are likely to alter many components of natural selection and hence lead to evolutionary change" (p. 248). For example, the loss and fragmentation of the Australian Macquarie perch's (*Macquaria australasica*) habitat, primarily as a result of human-induced pressures and activities, has had important genetic implications for this species (Pavlova et al. 2017). Specifically, fragmentation leads to increasingly small and isolated populations, which can lead to declines in the genetic diversity of populations and inbreeding, as was the case for the Macquarie perch which experienced decreasing population sizes in part due to the fragmentation-induced reduction in genetic connectivity (Hanski 2011; Pavlova et al. 2017). Lastly, the fragmentation and loss of habitat can have important reproductive implications for species, which was the case for the cactus bug (*Chelinidea vittiger*) that experienced negative reproductive consequences due to the reduction in movement by individuals of the species (Fletcher Jr. et al. 2018). Local species abundance, that is the number of individuals in a particular population, and their distribution across the landscape can also be negatively affected by the loss of habitat (Fahrig 2003). As such, the development and implementation of conservation initiatives can benefit from increased understanding of species abundance and distribution (Villero et al. 2017), as well as changes in distribution that may occur in response to anthropogenic pressures and reduced habitat quality.

Species distribution models (SDM) spatially approximate and project the distribution of a particular species or many species based on environmental and ecological information as well as observations of species habitat use in the study area (Veloz 2009; Franklin 2010; Sinclair et al. 2010; Elith et al. 2011). SDMs are used in numerous fields including, but not limited to, wildlife management, conservation biology, and biogeography (Araújo and Guisan 2006). In order to address concerns about the effect of urbanization on wildlife species, and to develop any subsequent conservation initiatives, it is critical to ascertain the species distribution and understand their behaviour, specifically their use of space across the landscape (Tarabon et al. 2019). SDMs are a valuable tool for identifying environmental and landscape characteristics that may limit species distributions or may be critical for suitability (Tarabon et al. 2019).

North American river otters (*Lontra canadensis*) (hereafter referred to in this thesis as river otters) are found throughout much of North America, however their current range is smaller than their historical range in Canada and the United States (Larivière and Walton 1998; Gallant et al. 2009). Anthropogenic processes such as habitat loss due to urbanization and pollution are important contributors to this decline, and the contraction of the river otter's range is not easily explained by other factors that can influence population declines in wildlife populations (i.e., illnesses or predators) (Larivière and Walton 1998; Doherty 2010; Lawrence 2016). Declines in river otter populations and the contraction of their historical range has led to the introduction of programs aimed at mitigating this decline and at reintroducing river otters to various parts of their historical range (Gallant et al. 2009). Beginning in 1976, these programs have allowed more than 4,100 individuals to be reintroduced in Alberta (Canada) and 21 states in the U.S. (Hubbard and Serfass 2004). River otters are sensitive to human-induced disturbances, a characteristic that makes them an ideal focal species for a study on habitat selection in an anthropogenic context.

Protection Island (PI), British Columbia, is a suburb of the City of Nanaimo located on Vancouver Island. PI has a relatively high population density and is adjacent to the Saysutshun (Newcastle) Island Marine Provincial Park (SIMPP), where in contrast, humans are typically only day-visitors. Human and river otter habitat use overlaps and often conflicts in this landscape, providing an interesting and ecologically relevant site to examine habitat-suitability and human-wildlife coexistence in a relatively urban environment.

In Chapter 2 of this thesis, I will discuss human-wildlife conflicts and coexistence, the terminology surrounding them, and factors that influence them. I will draw on interviews and surveys conducted with residents to discuss the human-river otter dynamics on Protection Island, British Columbia, and contextualize participant perceptions of river otter behaviour within the broader literature on river otter ecology. I will also share some autoethnographic reflections of my time on Protection Island and engaging with the residents, on their generosity and participation in this project, and on the insights drawn from this experience.

In Chapter 3 of this thesis, I will present the manuscript on habitat suitability for wild river otters in anthropogenic landscapes, using a case study of Protection Island. In this manuscript, I examine the relative importance of anthropogenic and environmental characteristics of the landscape to habitat suitability in wild river otters. Further, I identify the features of the landscape that are most influential for habitat suitability in this species when inhabiting anthropogenic landscapes. Additionally, I propose new thresholds for habitat suitability categorizations in river otters based on observations of human and river otter behaviour in the landscape, as well as the results of the maximum entropy (MaxEnt) species distribution models I employed. Finally, I examine river otter behaviour in the context of habitat use, specifically examining behaviour in relation to the use of docks which are an anthropogenic structure

Lastly, I discuss the general conclusions of this work and provide future directions for study on this group, species, and in this field.

CHAPTER 2

HUMAN-WILDLIFE COEXISTENCE

2.1 Terminology: Conflict or coexistence

The terminology used in discourse on interactions between humans and wildlife is important, as researchers have shifted away from the prevailing negative connotation associated with HWCs, the use of the term *coexistence* as opposed to *conflict* has become increasingly common (Frank 2016). Peterson et al. (2010) suggest that human-wildlife conflict acts as a "terministic screen", which is described as "a concept that attempts to describe the ways in which knowledge, understanding, and perception are necessarily mediated through a selective rhetorical lens" (Muckelbauer 2003; p. 904). When terministic screens are used, certain parts of a real situation receive less focus and prominence while others receive greater attention and importance (Peterson et al. 2013). While terministic screens are not inherently an issue, they can rapidly become one and negatively affect progress in a particular field or context (Peterson et al. 2010). For example, this occurs when the user suggests that the actions of wildlife and humans involved in these conflicts are intentional acts of hostility towards the other party, and that 'conscious antagonism' is at the root (Peterson et al. 2010; Peterson et al. 2013). Arguably, this is the case for the phrase *human-wildlife conflict*, and this idea that the human-wildlife conflict terministic screen may be an issue, is further reinforced when the speaker unintentionally suggests that the perceived negative consequences of HWCs on humans and our interests are a result of deliberate actions by wildlife (Peterson et al. 2013). As Hahn (2019) suggests "human–wildlife conflict is used as a terministic screen in which wildlife becomes the villain that can be abused so long as the harm is offset" (p. 348). Despite the ongoing shift towards preferential use of human-wildlife coexistence, I consciously elect to continue using human-wildlife conflict, in some contexts, when characterizing these interactions and the factors that influence them, given that it is still prominently used in the body of literature I am engaging with (e.g. Madden 2004; Nyhus 2016).

Humans often deem animals that utilize resources on their land or in their homes, or that create dens in human-made structures, as "nuisance species" (Barrett et al. 2019). Animals in HWCs are often considered nuisance species. However, there is no specific ecological attribute of an animal that designates it as such. Rather, it is how humans perceive animals and their actions that is likely to get a species labelled a "nuisance" (Colautti and MacIsaac 2004). People sharing living space with wildlife whose presence they deem undesirable, may use various methods to try to bar wildlife from access to specific locations, may attempt to deter their presence overall, or may try to apprehend them (Nyhus 2016). For example, to deter animals from entering urban and/or developing areas, non-lethal mitigation measures including physical barriers such as fences may be employed (Schell et al. 2021). One reason river otters are often viewed as a nuisance species is because they may defecate and urinate (known as sprainting) repeatedly in the same location, creating a latrine that serves in olfactory communication among individual and groups of river otters (Melquist and Hornocker 1983; Gorman and Trowbridge 1989; Ben-David et al. 1998). The latrine may be visited by numerous individuals that likewise "contribute" to the latrine. The resulting odour and accumulation of faeces can be unpleasant. On Protection Island, residents use numerous methods to block river otters from access to residents' homes and boats (Figure 2-1a, 2-1b). These measures include, but are not limited to, chicken wire (A. Cameron, PI Resident, personal communication), sonic emitters (devices that release high pitched noise in response to motion, Figure 2-1a) (M. Compton, PI Resident, personal communication), and scent-based products such as tea tree oil (PI resident, personal communication). However, animals may learn to evade or overcome deterrence methods when subjected to them regularly (Barrett et al. 2019).

Figure 2-1- Examples of barriers and deterrence measures used on Protection Island, a) sonic emitter, b) spikes to deter entrance to a boat.

2.2 Factors influencing HWCs

HWCs are often conceptualized as situations where wildlife are the perpetrators or instigators of conflict, however, conflicts may arise due to differences or confrontations between human individuals or various social groups, or due to actions taken by humans that have important implications for wildlife (Madden and McQuinn 2014; Frank 2016). Conflicts between and among humans, stemming from differences or conflict between individuals or groups, are frequently at the root of HWCs (Madden and McQuinn 2014). For example, lions (*Panthera leo*) that people come across by chance can be susceptible to targeted killings in Mozambique due to a belief that people-lions, created from the twig from a *dimika* tree through acts of sorcery, may be used for acts of violence towards other humans (West 2001; Dickman 2010). Humans display a diversity of behavioural responses to HWCs and the specific context and conditions under which conflicts have arisen will also influence the outcome of conflicts and whether humans are tolerant and willing to coexist (Dickman 2010; Frank 2016). The factors that influence the presence and severity of conflicts fall within several broader categories including, but not limited to, behaviour (human and animal), ecology, economics, culture, and biology (Madden 2004; Nyhus 2016). Further, demographic characteristics of humans including sex, gender, age and ethnicity can influence an individuals' susceptibility to the consequences of human-wildlife conflicts (Hill 2004). For example, the nature and severity of conflict experienced by individuals can be gendered (shaped by gender identity and social context) as the ways we approach their environment, the activities we engage in, and responses to conflict likely also differ based on gender and/or sex (Nyhus 2016). For instance, women in Uttarakhand, India experience more consequences from crop-raiding by elephants (*Elephas maximus indicus*) than their male counterparts, as a result of "the gendered division of labor and its relationship to women's status and identity in the study site" (Ogra 2008; p. 21). Their vulnerabilities can be financial, physical, and psychological and relate to access to food (Ogra 2008).

The actual risk of encounters and conflicts between humans and wildlife do not necessarily align with the perceived risk of the individuals involved (Dickman 2010). Individual people or groups involved in encounters and HWCs may perceive the risks to be greater than the actual risk, if they feel powerless over the situation, and some individuals involved in HWCs may display "hyper-awareness" (Hill 2004; Dickman 2010).

2.2.1 Social and cultural factors

The perceived severity of a conflict is heavily influenced by the interplay of a person's social, personal, and cultural experiences and values (Dickman 2010). These experiences and factors are critical to human decision-making between responses of tolerance and antagonism as they are influential in forming our perceptions of the species, the risks they pose, and the extent of the damage they are causing (Dickman 2010). For example, residents in Tanzania described negative perceptions and showed greater antagonism towards species they perceived as unattractive, like the spotted hyaena (*Crocuta crocuta*), in comparison to species deemed more attractive, like leopards (*Panthera pardus*) (Dickman 2008). Further, despite both pigeons (*Columbia livia domestica*) and foxes (*Vulpes vulpes*) living in the same European cities, there is a negative perception of pigeons and a positive perception of foxes (Souza et al. 2012), likely because pigeons are perceived as dirty and foxes as "cute" creatures. Additionally, humans have a propensity to prioritize the protection of animals that we deem desirable, cute, or charismatic (Turner 2022). For example, creatures such as rodents tend to receive fewer protective measures than animals such as pandas (*Ailuropoda melanoleuca*) (Turner 2022).

While individual experiences and factors influence HWCs, there are also broader social and cultural processes, norms, and traditions that underly differences in responses and attitudes by individuals and groups and these can heavily influence conflicts (Manfredo and Dayer 2004; Dickman 2013). Our choices regarding conflict and coexistence are influenced by these individual and cultural level factors that inform our behaviours and perceptions towards a species (Manfredo and Dayer 2004; Frank 2016). Humans tend to be inflexible regarding the values that are instilled from an early age and these values heavily influence their perceptions of and actions towards wildlife (Manfredo and Dayer 2004). For example, Manfredo and Dayer (2004) describe a scenario where some individuals may have the belief that killing wildlife is inexcusable regardless of the context, while others may believe human interests are a justifiable reason, despite these individuals sharing the value of "respect for life." Further, attitudes and actions towards wildlife species can be affected by animosity that is present between social groups, the result of this animosity may be manifested as acts of aggression towards wildlife (Dickman 2013). The above example of people-lions in Mozambique (Section 2.2) is an example of how animosity may result from such differences between social groups, where lions are killed by one group due to the belief another social group may use the people-lions for acts of violence against humans (West 2001; Dickman 2010).

The visibility of the species involved in a conflict has important implications for human perceptions of the damage they cause and therefore, the antagonism or blame directed towards them (Dickman 2013). River otters, the conflict species in this study, are highly visible in the study landscape as they use aquatic and terrestrial habitats, are relatively large (5-14kg) , often live in large family groups made up of offspring and their mother, and frequently use anthropogenic structures such as docks and boats when foraging and socializing (Melquist and Hornocker 1983; Larivière and Walton 1998; Dickman 2013). Humans may display a certain level of tolerance as a result of regular exposure and habituation to interactions with animals, to messes or damages by the animals (Frank 2016). However such tolerance may have limits (Frank 2016). In this study, for instance, some residents indicated tolerance towards river otters that were utilizing their boats or docks to defecate or for other activities, but having river otters denning under their homes (which creates a strong odour) was beyond their threshold of tolerance (Frank 2016).

HWCs may also be rooted in economic and financial considerations (Dickman 2013; Nyhus 2016). Financially vulnerable individuals are likely more susceptible to detrimental consequences of conflicts (Dickman 2013). For example, in the context of agriculture, loss due to crop-raiding species may be substantially larger for individuals, but considerably lower at the larger scales such as the village or community-level (Hill 2004). Therefore, the perceived consequences of less extensive damages resulting from HWCs is likely to be considerably greater for individuals that are financially dependent on this activity or have limited other resources (Dickman 2010; Dickman 2013).

2.3 Conflict and ecology

Human-wildlife conflicts have important effects on numerous aspects of species ecology including but not limited to, decreases in species abundance and declines in species distributions (Woodroffe et al. 2005). There may also be ecosystem-level implications when the species' encountering conflict are keystones species (Woodroffe et al. 2005). For example, the perceived negative effects of sea otters (*Enhydra lutris*) on shellfish fisheries in California have long been contentious and this conflict resulted in proposed management practices with the potential to be detrimental to sea otter populations, which would in turn have important implications for associated marine communities, that could lead to declines in kelp abundance as a direct result of increasing herbivorous sea urchin populations (Woodroffe et al. 2005). Marine ecosystem structure is heavily influenced by sea otter presence and activity, and marine plant communities benefit from the population control of sea urchins provided by sea otters (Estes and Palmisano 1974). Thus, the removing sea otters can cause a trophic cascade and strongly influence the kelp, urchin, and sea otter dynamics in these landscapes (Estes and Palmisano 1974; Coleman and Williams 2002).

2.4 Methods

2.4.1 Context and Background

The geographically small size of Protection Island, ~1.4 km^2 (~ 1 km by 1.4 km) (McMillan 2016), and its naturalized feeling in comparison to other suburban landscapes, fosters a strong sense of community among residents. These characteristics, the proximity to necessities ~1.6 kilometers across the Nanaimo Harbour (McMillan 2016), and the primary modes of transportation on Protection Island being golf carts, bicycles, and foot, attract retirees, young families, and nature lovers. Protection Island resident Robert Turner highlighted that "if you wanted to be in a subdivision without a forest or natural areas, you wouldn't probably put up with the inconvenience of being on a little island, you'd be in a suburb of Nanaimo up on Mount Benson or something like that" (personal communication). Fellow islander Jennifer Cluff emphasized the presence of wildlife on the island and in the coastal waters as an attractant for arriving residents, suggesting "at least 50% or more of the people who move here are animal lovers when they move here and they're moving here in order to be closer to the animals" (personal communication).

Protection Island provides an interesting and ecologically relevant site to examine habitat-suitability and human-wildlife coexistence in a relatively urban environment as there is a relatively high density of people and it is close to SIMPP, where there is camping but are no residences and is within walking distance from PI at low tide (McMillan 2016).

The residents of Protection Island were engaged, supportive, and generous with their time during my stay on the island from May 29th to August 31st, 2022, and October 22nd to November 13th, 2022. Beyond formal interactions such as interviews, residents welcomed me into their homes, spoke to me on ferry rides to and from Nanaimo, and offered me cold drinks or a reprieve in an air-conditioned home when they saw me conducting field work on the beach on hot days. Numerous residents were engaged and helpful in my pursuit to locate river otters on the island. Various residents would send me emails or text messages or would stop me on the island to report their sightings, providing me valuable information about space-use by river otters on the island. Further, several residents gave me permission to sit on their docks and conduct behavioural observations and global positioning systems (GPS) surveys on their property to identify signs of river otter presence. A large part of the shoreline on PI is located on privately owned property and therefore, the residents that offered to let me position a trail camera on their properties were also instrumental to the procurement of behavioural and presence information on river otters in this landscape.

2.4.2 Interviews and Surveys

While on PI, I conducted 23 semi-structured core interviews, of which six included follow-up interviews. I also conducted 18 surveys focusing on the participants life-history, attitudes and perceptions towards river otters, and past encounters and experiences with river otters (see Appendix A for survey and interview questions). These interviews were conducted with Protection Island residents and community members. Potential participants were invited to participate in one of three ways. Firstly, I used the snowball method, where a known contact provided the invitation to the community through the Protection Island residents Listserv and interested participants initiated communication with me. Secondly, participants would introduce me to other Protection Island residents who may have been interested in participating in this study or participants would provide my contact information to these potential participants, who would reach out to me. Lastly, in the course of conversations with community members and visitors encountered on Protection Island or the Protection Island Ferry, potential participants would express interest in participating in the study and I would then invite them to participate. This research project received research ethics approval from The Concordia University Animal Research Ethics Committee (AREC) (Protocol Number: 30016344) and from the Concordia University Human Research Ethics Committee (Certificate Number: 30016581) (see Appendix A for ethics certificates).

Residents were given the option of having their identity kept anonymous or to be named in this thesis and any resulting publications. For residents who did not wish to be named, a letter identifier was assigned alphabetically in order of appearance in the following section. I elected to do so to respect the desired anonymity of participants while also allowing readers to identify when statements were made by the same individual.

I draw on these connections to provide context for this study and to describe the nature of human-otter interactions, coexistence, and conflict on Protection Island. In the following two sections, I synthesize and describe human-otter interactions (passive and direct) shared by residents of the island, as well their attitudes towards and perceptions of river otters in this landscape.

2.5 Results

2.5.1 Human-otter encounters on Protection Island

The attitudes and perceptions towards river otters differ among residents. For example, several residents consider river otters to be a nuisance and others strongly disliked river otters (M.Harris, PI Resident, personal communication; H. Sinclair, PI Resident, personal communication; G. Bigl, PI Resident, personal communication; PI Resident A, personal communication). At least one resident expressed feelings of hostility towards river otters (M.Harris, personal communication). In contrast, other residents feel strongly positive towards river otters. For example, resident Jennifer Cluff suggested, “we see them as a happy creature and I think that if you’re going to not be angry it’s because you’re laughing” (personal communication). These positive sentiments are supported by fellow islander Robert Turner who highlighted his fascination with river otters, saying “you just get a hint of how smart, and I think fun-loving from what I see, they really do seem to play and they’re very clever and so that makes them much more interesting” (personal communication).

The experience of having river otters den under homes or regularly defecate on docks and boats appears to strongly influence peoples’ responses to river otter, in many cases. For example, Margaret Harris suggested a feeling of hostility towards river otters, highlighting frustration at “continually hav[ing] to clean up their smelly and messy excrement on and in our boat and on our dock” (personal communication). While most negative sentiments towards river otters are expressed in the context of boats and homes, one islander emphasized concern about the river otters’ effect on the local environment and described it as problematic, saying “this area is overrun with otters, the sealife has suffered because of them and the natural sea flora has been seriously depleted” (PI Resident B, personal communication).

Numerous residents have experienced passive encounters with river otters, which are generally direct visual observations of river otters from a distance that do not elicit negative emotions. However in contrast, some residents have had close encounters with river otters, which involves being in immediate proximity to river otters as opposed to viewing them from a distance. A second important aspect of these encounters is that some have elicited negative emotions, primarily fear responses. For example, island resident Marilyn Compton describes how:

> Going to town in our boat there was a mom and a baby [otters] that were on the boat when we were halfway across. They went to town with us and when we got out the mom abandoned the baby, we got home at the end of the day from working and the baby was still on the bow of our boat crying and then as soon as we got there the baby jumped off onto the dock (personal communication, 2022).

When asked to describe how she felt during this interaction, Marilyn indicated:

> It scared me because the mom actually ran right across my feet and then into the back of the boat and I thought she was going to jump off, but she didn't, she actually stayed in the back of the boat for the whole trip, but I sat with my feet up on the seat (M. Compton, personal communication).

In another case, Robert and Marcia Nassey "had an otter on the dock that [got] caught in the net" (R. Nassey, PI Resident, personal communication). Marcia described their response, sharing "the mom was going around me and I had to talk to her, calm her down. But I had a post with me because I thought if I was her, I would think about attacking me" (M. Nassey, PI Resident, personal communication).

Further, Kimberly Kelly described nervousness, yet understanding at a mother river otters' maternal actions, "because you never want to get too close to a wild animal particularly one that's in a defensive mode but also being a mom of little ones I kind of feel like I got it; I understood you know?" (PI Resident, personal communication). This nervous feeling was elicited in the following encounter:

> Last summer, I was heading out to the dock and there was, at the end of our dock there's kind of a "T," a finger that goes in a "T" and her pups were on the dock and our finger is right that the end there and she was huge and she kind of like stood across the dock and was really not going to move. […] because she was really standing her ground and she just scurried down the dock and the pups went in the water and she went in the water with them. But then her head came up and she was kind of hissing, kind of head bobbing and you know, yeah, acting like a mama would (K. Kelly, personal communication).

> Lastly, Curtis Hobson described an incident where he was scared while capturing crabs at the community dock (PI Resident, personal communication). Curtis described how:
> We were crabbing and we threw the crab sling out and were waiting and I think we caught a few undersized ones and then threw it back and all of a sudden it was moving quickly like something had grabbed it and I'm like "oh no, it's an otter" and so I didn't want to pull on it in case I slinged the otter (C. Hobson, personal communication).

However, that's not to say that all interactions had negative associations. Joanne Leslie described a "revealing and heart-warming incident" where she observed river otters engaging in playful behaviours (PI Resident, personal communication). Joanne shared that one winter on the island:

> When the snow came, of course the hillside was heavily snowed and I realised as I was looking out one morning that the otters had created a snow slide and it was a perfectly formed narrow slide that went from the top of the hill all the way down to the bottom of the hill and as I watched the otters, there were two or three of them in the group, maybe four, you know cause they all look alike from a distance. They kept going up and down sliding up and down, obviously playing (Figure 2-2) (J. Leslie, personal communication).

Figure 2-2- Photograph of a snow slide created by river otters on Protection Island (Photo credit: Joanne Leslie, used with permission)

2.5.2 Cohabitants of the island: Resident perceptions and attitudes towards river otters

The dynamic between river otters and humans on Protection Island is well-described by Andrew Cameron, who referred to them "as co-residents of the island" (personal communication). There is a general trend among residents regarding a willingness to coexist, as most residents appear to have reconciled with the idea that river otters were present on the island before humans and therefore, that it is important to coexist. For example, Jim Irvine highlighted, "they're just trying to survive in an increasingly human-based environment and we're encroaching on their territory, so I think we need to try to learn to live with them" (PI Resident, personal communication). This sentiment was further reinforced by Melissa Hadley, who put forth the idea that, "I think we have a tendency to want our place to be our place and I just think we're in their place and as much as possible, I'd like us to learn to cohabit" (PI Resident, personal communication). However, despite a willingness to coexist, there was also a degree of intolerance or frustration on the part of some residents, primarily due to defecation and scent. For example, "I didn't realize the extent of their marking or their defecation habits so I guess I'm less tolerant of having them in my living space perhaps than I might have been previously" (J. Irvine, personal communication).

Further, some residents attributed this willingness to coexist to the nature and characteristics of the environment and of life on Protection Island. For example, Joanne Leslie described that residents:

> Have come to a place where their neighbours in particular, appreciate and protect the wildlife that exists here. Because we're so close to the ocean, because we're surrounded by the sea, well in this case the Salish sea, we've come to realize how it is worth protecting and I think that is why there is more coexistence among islanders than conflict, when it comes to otters (personal communication).

Further, Kimberly Kelly suggested that:

> Because we're so integrated with the foreshore and with the waterfront most of us have boats on docks and so you're right it's almost a daily run in and I have to say a lot of the times we really love it, to see them. Until our boats get defecated on and then you're a little bit grumpy about it but they seem to be pretty strategic and almost in an amusing way. But I think the people who live on the island choose to live here because they like the lifestyle and I think that people here yeah just find it's part of the island life, it's one of the things we deal with living here because this is the otter's home and it's our home as well (personal communication).
>
> While numerous residents were willing to coexist, it is clear that others were not, as river otters have been found poisoned several times on the island. As one resident described: We've mentioned before that some people are poisoning them and we had an encounter where we found an otter that was poisoned and was at the end of its life and it was really suffering and that was really sad and that experience stands out to me because I just think that's not right. And so, I think we were all really affected by that and to see how sad an end that was (PI Resident C, personal communication).

2.5.3 Residents' behavioural observations of river otters

River otters are a regular part of the landscape on Protection Island and residents have garnered perceptions of river otter behavior through personal observations and experiences in this landscape. Throughout the interview process residents shared behavioural observations of river otters including but not limited to sociality, space-use, denning, and learned behaviours.

A common source of human-otter conflict on PI stems from the scent-marking performed by river otters on boats, docks, and when denning under people's homes. River otters are perceived as territorial animals by residents of PI and scent-marking is well documented behaviour in river otters when referencing territoriality. River otters use scent-marking as a tool for avoiding direct intra-specific conflict and preserving their sizeable home ranges when there is overlap with other river otters ranges (Almonte 2011). Latrine sites can allow female river otters to display territoriality towards others, and "while solitary male otters use latrines to facilitate mutual avoidance, this behavior also serves as intra-group communication for social animals" (Ben-David et al. 2005; p.1342). Further, male river otters may convey social status through scent-marking at latrine sites (Rostain et al. 2004). Numerous residents have experienced what may be perceived as territoriality between different river otter groups in the Nanaimo Harbour and Protection Island area. For example, Marilyn Compton described a situation where "one otter is trying to mark a territory and then it goes to the downtown side and then another otter tries to mark it as their territory" (personal communication). This is further supported by resident Kimberly Kelly, who had:

> An experience this summer where the otters had targeted our boat so they were trying to get in it and they were defecating on the front and then our boat went to town and the otters in town got the scent and then we had this otter war and then our boat went down the channel and there were 3 hits on our boat while they each took a turn trying to take over its territory while it was there (personal communication, 2022).

Residents of the island who experienced scent-marking on their boats described that they believe river otters preferential select absorbent materials. For example, Dave Webber described a preference for "anything that will absorb or hold the odour" and supports this with the observation that the river otters preferred his wooden float for marking over the:

> New float that we have that's only two or three years old, [which] generally speaking the otters have not liked that deck, it doesn't retain any odours or anything so it's not an effective way for them to communicate (PI Resident, personal communication).

Further, river otters on Protection Island are perceived as being deliberate in their selection of location for scent-marking. For example, Marcia Nassey described how "they poop on the ropes for a reason, when they see you coming. I think they do it on purpose" (personal communication, 2022). Kimberly Kelly further described this behaviour as "calculated" (personal communication).

If scent-marking is being used as a tool for intra-specific communication, then we would expect river otters inhabiting tidal environments to scent-mark above the high tide line as any odour would likely be diminished or rendered absent by several hours of high tide. However, resident Andrew Cameron observed behaviour that would contradict this expectation, and described this observation, stating:

> I didn't know otters did that, but I watched them down on the point, where I so often see groups of them hanging out, particularly in the sort of late winter early spring, as five of them each took a turn defecating in the same spot. And that was interesting because a) that was the first time of me realizing that they would use a latrine and all go defecate in the same place, but b) what I thought was particularly surprising was that it was below the tide line, so it wasn't very far from the tide and so, it was washed away within a matter of hours. Like it wasn't done to mark territories per se or anything. […] I don't know why they did it below the high tide line, well below the high tide line (personal communication).

This suggests that further research on the use of latrine sites and their localization may be beneficial to increasing understanding of the role of scent-marking and latrine sites in river otter ecology in coastal environments. Further, it may be interesting to examine whether this may be a learned behaviour, as hypothesized by Andrew Cameron (personal communication).

River otters have been posited to use different types of environments for specific classes of behaviour and necessities (Reid et al. 1994*b*; Almonte 2011). Their terrestrial environments are used for the majority of their behaviours and activities, while play and foraging behaviours are typically conducted in aquatic environments (Almonte 2011). River otters in the PI landscape were characterized as playful creatures by numerous residents of the island (PI Resident D, personal communication; C. Ashley, PI Resident, personal communication; J. Leslie, personal communication; S. Diewert, PI Resident, personal communication). For example, Joanne Leslie describes that "I've heard that they're playful but [that they] actually could play a game and invent a method in which to play, they invented a slide" (personal communication). Residents have also observed parental or adult river otters modeling juveniles species-appropriate, aquatic behaviours. For example, Rudi Bigl described that "they grab them and take them to the water because then they've got to, from my understanding, they've got to teach them how to swim" (PI Resident, personal communication). Further, Heidi Rickson recalled "watching the mum teaching them to fish and teaching them, I guess to eat, or tempting them to fish because she would bring up a crab or a sole or a blenny" (PI Resident, personal communication). Despite the adaptation to both aquatic and terrestrial environments, some residents have noticed more awkward-looking mobility on land. For example, Wendy Chandler described how "they seem like such a different animal when they're in the water compared to when they're on land. Just the way they walk and run" (PI Resident, personal communication). This was further supported by Andrew Cameron, who indicated he:

> Like[s] seeing how well they move in the water and then I'm always amazed to watch them move on land and see how awkward they look, where they're clear trade-off or their biology is to be more water optimized and less land (personal communication).

River otters require two connected types of habitat, one terrestrial and one aquatic in order to meet their various needs (Reid et al. 1994*b*). River otter dens are terrestrial and are frequently located along the shoreline in this landscape. River otters preferentially utilize pre-existing dens that other species have formed or parts of the natural landscape that are well suited to be dens (Melquist and Hornocker 1983). Resident Jennifer Cluff noticed these burrows in a vegetated area behind her home and described that:

> They have a safety burrow. Cause they're unlike raccoons, like right now were dealing a similar problem with raccoons, raccoons don't have a safety burrow, so they're right freaked out about defending their babies. But the otter has a safety burrow so she right away moves them (personal communication).

River otters on Protection Island are known to den under homes and appear to preferentially select seasonal homes that are vacant for a longer period of time. This idea was supported by a resident who has experienced river otters denning under their seasonal home, and they described that "there's a creek right there and it's dry and comfortable and there's nobody around so I totally get why they would move in" (PI Resident E, personal communication). This was also supported by Heather Sinclair who indicated that prolonged absences seem appealing to river otters, describing about their own experience of river otters denning under their home, that she "think[s] that's what happened here. No one was here for 5 weeks" (personal communication). River otters are also known to travel away from the shoreline and towards the center of the island. Kevin Pistor shared that "they do travel a fair distance from the shoreline" (PI Resident, personal communication). This was surprising to resident Andrew Cameron, who described that:

> I would come across the yard which always surprised me because I was high in the center island. I never expected to see them that far from water really but now that I've gotten to know the island more and know that will hoof it across it and sometimes potentially have dens in the center of the island (personal communication).

River otters have been observed utilizing anthropogenic structures on the island as a means of protected travel. There a several culverts with numerous entrance and exit points that create a network for river otters to traverse the island relatively undetected by humans. Resident Kimberly Kelly described that "they use a culvert to access you know, sort of more the front of our property so they used it underground. And it's quite [a] long ways, I mean it's maybe 150 feet" [~50 m] (personal communication).

A family group made up of offspring and their mother, but not an adult male/father, is the typical social organization for river otters (Melquist and Hornocker 1983). River otters on Protection Island appear to follow this social organization, as numerous residents have observed what they perceive as "family groups." For example, Wendy Chandler and Kathi Diewert described river otters on the island as being "family-oriented" (PI Residents, personal communications). Further, river otters are regularly observed swimming in family groups (J. Irvine, personal communication; K. Diewert, personal communication; V. McFarlane, PI Resident, personal communication). Families of river otters are also observed on the community dock at Mud Bay, Sandee Tranfield describes "walking down the dock you'll see a whole family of them and as soon as they see humans, they scatter" (PI Resident, personal communication). The crepuscular period, prior to the sun rising and after the sun sets, as well as the night hours are the typical active periods for river otters (Larivière and Walton 1998). This finding was supported by resident Joanne Leslie who described that "they're most active at dawn and again at dusk" (personal communication). However, river otters on Protection are active and observed at all times of the day. For example, resident Melissa Hadley shares that "I think we actually see them more, not so much in the early morning as we do later in the afternoon" (personal communication). Further, river otters are certainly active during the day on the island, as they are known to sunbathe (PI Resident F, personal communication; PI Resident G, personal communication; S. Diewert, personal communication), including on personal and public docks (Figure 2-3). The lack of a perceived clear night and crepuscular schedule that is typical of river otters may stem from the tidal nature of this coastal island. River otters are likely feeding opportunistically during the different tides and their active periods likely are influenced by and reflect the tide schedules to a certain extent.

Figure 2-3- River otters using docks on Protection Island (Photo credit: Jim MacQuarrie, used with permission).

Through my interviews, I found contradicting perceptions of the behavioural response of river otters to the presence of humans and human structures in this landscape. Some residents described their behaviour as "brazen" (J. Irvine, personal communication), or described "how tenacious they are, you know once they have picked a boat or a space to target, they just keep going and going and going back to that space and it seems again almost in a matter that's teasing" (K. Kelly, personal communication). However, in contrast, another resident shared that "they're more cautious than I would have thought. You think, especially in a place like this, they're interacting with people on a very regular basis" (PI Resident G, personal communication). Despite the prolonged and regular exposure to humans and human structures, the same resident expressed surprise at:

> …the fact that they are so skittish. There's lots of people around, they like boats, they like being next to the docks, there's good food sources and they can come out and sun themselves and stuff, but they are so spooked by us. I do find it a bit surprising that there hasn't been some adjustment to that (personal communication).

The mechanisms underlying these different behavioural responses warrants further investigation. Possible explanations include variation in animal personality (an interesting lens through which to examine individual variation in behaviour and the potential fitness implications of those variations) (Réale et al. 2007). As well as age, sex and other life history or ecological variables.

2.6 Autoethnographic Reflections of my time engaging with residents

In keeping with the tradition of autoethnography, I wanted to reflect on my experience conducting field work on Protection Island and engaging with the residents and broader community of the island. Autoethnography incorporates "personal experience ("auto") to describe and interpret ("graphy") cultural texts, experiences, beliefs, and practices ("ethno")" (Adams et al. 2017; p.1). Using this method, I drawn on my personal experiences on Protection Island during the summer and fall of 2022, to reflect on changes in my perceptions of and discourse surrounding human-wildlife conflicts that have arisen from these conversations, my personal experiences, and the lived experiences of residents that have been shared with me (Neville-Jan 2003; Adams et al. 2017).

As described in the sections above, humans and river otters on Protection Island compete for resources, specifically space, which leads to passive and direct interactions. Despite these interactions, a common perception of river otters as a 'nuisance' species, and in some cases a general dislike of river otters (M. Harris, personal communication; H. Sinclair, personal communication; G. Bigl, personal communication; PI resident, personal communication), there is a strong willingness among many residents to coexist with river otters.

I entered into this research with a vision of human-wildlife conflicts as contentious interactions between people and animals. However, throughout my field research experience, my perceptions' and thoughts surrounding human-wildlife conflicts have shifted. My perception of human-wildlife conflicts prior to this experience was informed by my educational experiences and the media with which I engaged. This perception would best be described, perhaps naively, as a dualism, where conflict and coexistence were mutually exclusive. While my views of human-wildlife conflicts did not align with the idea of the human-wildlife conflict terministic screen, where animals are perceived as engaging in intentional acts of hostility in ways that are contrary to the interests of humans involved (Peterson et al. 2010; Peterson et al. 2013), my thoughts and ideas surrounding human-wildlife conflicts were predominantly human-focused. Specifically, my ideas focused on the consequences experienced by humans and very little on the role humans play in exacerbating conflicts, regardless of the root cause of their actions. Further, my knowledge of factors influencing the ways in which humans and animals interact, and more specifically influence conflicts, was basic. This is evidenced by my initial planned interview questions for participants, which lacked inquiries that would encourage participants to discuss past experiences, particularly those surrounding interactions with animals and wildlife that could influence how they engage and interact with, as well as perceive wildlife. Dr. Katja Neves, a member of my thesis proposal committee, made a critical suggestion during a meeting to include questions about the life history of the people I engaged with, including the previous experiences and knowledge they have of animals and wildlife in general (Concordia University, personal communication). Dr. Neves suggested that this could provide pivotal information and context that could underly the experiences residents have had with river otters (personal communication).

These life history characteristics were instrumental in understanding how past experiences with animals and wildlife can inform behaviour and decision-making in future interactions, both passive and direct. Further, conversations surrounding this topic drew my awareness to the role that these experiences can have in informing perceptions of risk and reinforcing or contradicting the human-wildlife conflict terministic screen, where the speaker suggests that wildlife are acting deliberately against humans and their interests (Peterson et al. 2013). This experience has made me much more aware of the external and internal drivers that influence how humans and animals behave in landscapes where use of space and resources by both groups overlap.

The dualistic perception I had of human-wildlife conflicts prior to my time on Protection Island was challenged and contradicted by the general trend among residents of being willing to coexist despite sentiments of annoyance or frustration at the actions of river otters. This view of the human-otter dynamics on Protection Island thus highlighted for me a common view of human-wildlife conflicts as existing along a conflict-coexistence continuum where the extremes are intolerance/conflict and respect and complete coexistence (Frank 2016; Nyhus 2016). The residents of Protection Island highlighted to me that it is possible to exist intermediately along the spectrum, where a conflict exists but there is a certain tolerance or willingness to coexist that generally prevents the residents from imposing strong mitigation measures and actions (Frank 2016).

I came out of this experience with a feeling that it is important to confront, or at least be aware, of our internal biases and experiences that we carry into spaces we share with wildlife that may heighten our perceptions of the damages and challenges associated with sharing our environment with animals.

Chapter 3

Habitat suitability, space use, and human-wildlife coexistence for river otters (*Lontra canadensis*) on Protection Island, British Columbia

Written as a manuscript to be submitted to the *Journal of Wildlife Management*

3.1.1 Introduction

Globally, ecosystems are being modified at incredibly fast rates, exposing animal species to novel contexts or conditions for which they have not adapted evolutionarily, causing critical biodiversity declines (Sih, et al. 2011, Sih 2013, Ceballos et al. 2015, Wong and Candolin 2015). Interactions between humans and wildlife are increasing as a result of land transformation and development, and these conflicts are becoming increasingly severe (Madden 2004; Basak et al. 2022). Numerous anthropogenic activities lead to habitat degradation and fragmentation, which can in turn have critical implications for biodiversity (Markovchick-Nicholls et al. 2008). It is crucial to identify the distribution and understand the behaviour of a species, particularly regarding their use of space across the landscape, in order to address concerns about the effect of urbanization on wildlife species and to develop conservation initiatives or future projects (Tarabon et al. 2019).

North American river otters (*Lontra canadensis*) (hereafter referred to as river otters) are a member of the family Mustelidae whose range in Canada and the United-States has been affected by human land use. River otters occupy less than 25% of their historical range (circa 1977) and have undergone population declines (Larivière and Walton 1998; Gallant et al. 2009; Reed-Smith 2012). Anthropogenically driven habitat loss caused by urbanization and pollution are likely important contributors to this decline, because river otters lack diseases or predators that adequately explain this level of population decline (Larivière and Walton 1998; Doherty 2010; Lawrence 2016). This situation has led to the introduction of programs aimed at reintroducing river otters to some parts of their historical range (Gallant et al. 2009). Since 1976 these programs have reintroduced more than 4,100 individuals to Alberta (Canada) and 21 states (USA) (Hubbard and Serfass 2004). This characteristic of river otters – their sensitivity to human-induced disturbance – makes them an ideal focal species for a study on habitat selection in an anthropogenic context.

Urbanization has important implications for river otter populations, as availability of suitable habitat declines, for example, due to the increase in the development of housing and other structures, which can lead to subsequent population declines (Tüzün and Albayrak 2005; Holland et al. 2019). In some contexts, river otters appear to be sensitive to disturbances and loss of habitat, but they are also able to behave flexibly depending on the conditions of their environment (DeNeve Weeks 2020). As such, wildlife management and conservation practices can benefit from increased understanding of the sensitivity and responses of species like river otters, to human contact, and to changes in land cover (Holland et al. 2019).

This species requires two connected types of habitat, terrestrial and aquatic - to meet their ecological needs (Reid et al. 1994*b*). River otters lack the physiological characteristics required for a fully aquatic lifestyle and as such are semi-aquatic organisms that shelter and give birth on land (Melquist and Dronkert 1987, cited in Gallant et al. 2009). Further, the presence of appropriate shelter and prey availability are limiting factors (Melquist and Hornocker 1983; Melquist and Dronkert 1987, cited in Gallant et al. 2009). Home range size in river otters is variable, ranging from approximately 16 to 280 square kilometers depending on age, sex, and whether the individual is accompanied by young (Reid et al. 1994*b*). Ecologically, river otters are important predators and while they may feed on amphibians or terrestrial invertebrates if the main component of their diet is fish and other aquatic organisms (Reid et al. 1994*a*, 1994*b*; Ben-David et al. 2001; Crowley et al. 2018). Further, otters are social mustelids (Gorman et al. 2006), with varying social organization, and seasonality plays an important role in the type of group they associate with and in their use of habitat (Reid et al. 1994*b*).

River otters create and use specific latrine sites that serve in olfactory communication for individual and groups of river otters (Melquist and Hornocker 1983). These sites are an important factor underlying various aspects of river otter ecology including their choice of habitats (Green et al. 2015), and are influenced by sex and sociality (Ben-David et al. 2005). The sensitivity of this species to change and disturbance is highlighted by their use as an indicator species in studies on toxicology (Ben-David et al. 2001; Crowley et al. 2018). River otters are susceptible to increased methylmercury (MeHg) levels because of their primarily aquatic and fish-based diets (Chan et al. 2003). As such, they have been studied as indicators of bioaccumulation of toxins and pollutants, such as MeHg and organohalogenated compounds, in the environments they inhabit (Ben-David et al. 2001; Carpenter et al. 2014). Therefore, as an indicator species and apex predator, river otters reflect the overall health of the ecosystem (Allen 2020; Crowley and Hodder 2019).

The relative importance of anthropogenic effects versus environmental and biological factors on river otter habitat suitability remains unclear. Some studies suggest anthropogenic variables are not as important to habitat suitability for river otters as vegetation or other environmental variables (Gallant et al. 2009), whereas other studies show that biological/environmental variables are more important than anthropogenic variables and that river otters display high levels of avoidance to human disturbance (Allen 2020; Lawrence 2016). For example, Barbosa et al. (2001) found that anthropogenic variables were less influential to Eurasian river otter (*Lutra lutra*) habitat occupancy than environmental factors. In contrast, Melquist and Hornocker (1983) observed preferential habitat selection for areas with lower human presence. Overall, it appears that while most river otters prefer undisturbed areas, access to high-quality, ecologically important necessities such as foraging and den sites, may make river otters more tolerant of human disturbance (Melquist and Hornocker 1983; Cotey 2021). This is further supported by Prenda et al. (2001), who suggested that the availability of adequate shelter mediates the relative effect of human disturbance on Eurasian river otters (*Lutra lutra*).

3.1.2 Species distribution modelling

Species distribution modeling (SDM) refers to the process of spatially approximating species distributions based on biological and environmental information as well as observations or other evidence of species use of the study area (Veloz 2009; Franklin 2010; Elith et al. 2011). SDMs are applicable in numerous fields including wildlife management, conservation biology, and biogeography (Araújo and Guisan 2006). Among the available methods that can be used for SDM, is the maximum entropy (MaxEnt) model which allows researchers to use data that is deficient and or missing information that is required in other statistical modeling methods, to draw conclusions or make predictions (Phillips et al. 2006). The MaxEnt model is utilized across a wide range of fields, including biosecurity, evolutionary, and ecological contexts, and is particularly strong for species distribution modeling (Phillips et al. 2006; Elith et al. 2011). The ability to use MaxEnt with presence-only data, as opposed to presence-absence data, is amongst its greatest advantages as challenges in many locations and large-scale field-based studies can make it difficult to obtain both presence and absence data on the focal species (Phillips et al. 2006; Phillips et al. 2009; Elith et al. 2011).

There are three broad categories of environmental variables used in MaxEnt models: disturbance (which may be anthropogenic or environmental), resource (e.g., food), and ecophysiological (e.g., precipitation and temperature) (Guisan and Thuiller 2005). It is critical that researchers consider the ecological context and characteristics of the species of interest in the variable selection process to ensure that SDMs are representative, and that meaningful inferences and conclusions can be drawn (Austin 2002). Further, to evaluate the effectiveness of conservation initiatives, understanding the factors that limit the focal species distribution is critical (Fourcade et al. 2014).

3.1.3 This study

The role that human activity has on habitat suitability and selection cannot be overstated. However, there is also a need to investigate how the adaptive capacity of river otters and the presence of interactions between humans and river otters influence these processes in anthropogenic landscapes (Allen 2020). River otters are an ecologically important, generalist predator (Habib et al. 2003; Holland et al. 2019), that encounters conflicts with humans over the use of space. For example, the recovery of sea otters (*Enhydra lutris*) in British-Columbia has been contentious given the desire of local First Nations to utilize sea otters for traditional activities and the financial and cultural losses experienced as sea otters reduce the availability of invertebrate populations that serve as traditional food and support commercial fisheries (Echeverri et al. 2017). While the re-population of portions of the sea otters' historical range and their growing population sizes are positive reflections of conservation initiatives targeting this species, their increasing distribution and numbers have led to rising hunting levels of sea otters due to these human-otter conflicts (Martone et al. 2020). River otters are sensitive animals and are vulnerable to the loss and division of habitat (particularly riparian habitat), to pollutants in the aquatic portions of their environments, and to urban development near shorelines, among other human-induced pressures (Boyle 2006). For instance, river otters primarily feed on aquatic organisms and are susceptible to bioaccumulation of pollutants (Boyle 2006). Therefore, the effect of human activity and disturbance on river otters warrants further examination to elucidate its importance to habitat suitability, selection, and wildlife management in anthropogenic landscapes. In this study I used species distribution modeling, specifically maximum entropy modeling, to address the question: what factors define suitable habitat and drive river otter use of space in anthropogenic landscapes?

I predicted that anthropogenic variables would overall be more important to habitat suitability in wild river otters than environmental and topographic variables. I predicted this as numerous threats and vulnerabilities of river otters are anthropogenic in nature and therefore, I predicted that they are likely to be important mediators of habitat suitability for river otters in urban environments (Boyle 2006). Lastly, I predicted that areas with high levels of human use and close to roads and buildings would be less suitable for river otters.

Further, I was interested in how river otter behaviour may vary with their use of anthropogenic spaces compared to other spaces. In particular, residents of the island shared that river otters were frequently using docks. Despite the availability and presence of what would appear to be higher quality and more natural habitat, there may be characteristics of docks that act as attractants for river otters and may lead them to view docks as high-quality habitat. As such, I explored four hypotheses about river otter behaviour and use of their environment. I hypothesized that patterns of river otter behaviour on docks would differ significantly from patterns of river behaviour on land and that river otters would use docks more frequently than expected by chance compared to their use of land. Secondly, I hypothesize that river otters would display foraging behaviours more frequently on docks than on land as this would indicate docks are high quality habitat due to proximity to foraging. Thirdly, I hypothesize that river otters would display social, movement, and feeding behaviours, more frequently during the crepuscular and overnight hours, as the crepuscular period and the night hours are the typical active periods for river otters and individual behaviours often constitute rest behaviours (Larivière and Walton 1998). Finally, I hypothesized that river otters would be more likely to use docks overnight as they are active during these hours, do not have nocturnal predators on Protection Island, and because there are fewer humans around at night on Protection Island compared to during the day.

3.2 Methods

3.2.1 Study site and group

I conducted fieldwork for this study on Protection Island, a small island located off the eastern coast of Vancouver Island across from the City of Nanaimo, in British Columbia (Figure 3-1). Protection Island is primarily residential, with approximately 350 residents and a single commercial business (The Dinghy Dock Pub) (Tourism Nanaimo 2022). I estimate the study population of river otters consists of approximately 25 to 30 individuals of both sexes and mixed-ages. The elevation on Protection Island ranges from sea level to 30.48 meters (Ruddiman 1980).

Figure 3-1 - Map of Protection Island, British Columbia with landscape features including trails, roads, the wetland, parks, docks, and building footprints.

This study incorporates several types of data, collection methods, and analyses. For the spatial analysis, presence data and detailed substrate information were collected through field-based surveying while data for other predictor variables were obtained from various municipal and provincial databases. Further, behavioural data were derived from behavioural focal samples collected opportunistically throughout the study period and footage from motion activated UltraFire XP9 trail cameras (Reconyx, Holmen, WI, USA) placed at four locations on the island.

3.2.2 Preliminary data collection

I placed trail cameras in four locations to record behavior, space use, and to obtain population estimates. I selected the trail camera locations based on the following criteria: 1) strong potential for river otter activity, 2) permission from private property owners or City of Nanaimo to install and record river otter behaviour, 3) minimal likelihood of camera theft. I identified suitable and ideal areas for trail cameras based on local knowledge from conversations with local community members who reside on PI and personal observations from scheduled walks around the island.

Three trail cameras were operational beginning mid-June 2022 on the northern, western, and southern sides of the island, while a fourth camera was installed mid-July on the eastern side of the island. All four cameras were removed at the end of August. However, the camera on the northern side of the island was operational for a second period from October 23rd to November 10th during a fall field season.

Upon arrival on the island, I selected the locations to place the trail cameras based on the appearance of river otter activity, or the potential for river otter activity given the type of environment present. These locations were regularly re-evaluated based on observable patterns of river otter activity and/or sightings identified from locational information derived during the interview process and scheduled walks. My protocol was such that if this information indicated greater river otter activity in a different location and a trail camera was recording little activity, then the location of this camera would be adjusted or re-positioned to a location of greater activity. All specific permissions required to position trail cameras in the desired locations were obtained by homeowners for private land and the City of Nanaimo for public land.

3.2.3 Species presence data

I collected species presence data through perimeter walks around the island shoreline, point location surveys and random visits to specific sites. If river otters were observed during these surveys, I initiated an *ad libitum* behaviour sample and continued until the river otter was out of sight or could not be followed. The survey activity was resumed when the behavioural sample ended.

3.2.3.1 Perimeter walks

I conducted island perimeter walks daily at 7:30 AM and 1:30 PM, from June 1st to 26th. The perimeter walks were performed along the shoreline as much as possible. However, when the tide was too high to walk along the shoreline, I would move to the road and return to shoreline at the next possible access point where the tide was at an appropriate level. When signs of river otters were encountered during the perimeter walk, a GPS point was recorded with the date and type of sign. The types of signs of river otters searched for included feces or latrine sites, crabs eaten, mussels eaten, and footprints. Further, the trail camera batteries and SD cards were often exchanged during these perimeter walks.

Beginning on July 2nd, the perimeter walks were performed once a day during low tide and therefore, the time of day differed substantially throughout. When river otters were sighted, I initiated a behavioural observation using a Sony FDR-AX43 4K video camera. An additional step was added beginning on July 2nd. The locations of first and last sighting of the river otters in the behavioural sample were recorded on the GPS with the location, time, and number of river otters and the path of the river otters were drawn on a plasticized map of the island in order to visualize their use of space.

3.2.3.2 Point location surveys

Once I had identified locations of river otter activity, I surveyed the island following a shortened route between the various locations of known activity. I alternated between two morning blocks (5:30 AM and 8:00 AM) and two afternoon/evening blocks (1:30 PM and 7:00 PM). During these scheduled surveys, GPS points for sightings and other signs of river otter presence (e.g., feces, eaten crabs) were collected. The set of blocks selected for a particular day were dependent on tide height (the time of low tide). However, where possible, the surveys were performed during each set at least twice a week.

3.2.3.3 Random visits to specific sites

In addition to the perimeter walks, local knowledge of locations with reported river otter activity and personal observations were used to identify locations to investigate for signs of river otters. These locations included private docks, the Dinghy Dock Pub, and parks. From June 6 to June 29, 2022, I visited these locations four times a week in the mornings at approximately 5:15 AM and 7:30 PM and signs of river otters were recorded, and behavioural observations were performed when river otters were present.

3.2.4 Geospatial data collection and preparation

A handheld GPS unit (Garmin 64 & 64st) and three open-source databases (the City of Nanaimo Data Catalogue, Government of British Columbia Data Catalogue, and LidarBC), were used to obtain the spatial data. I used 11 explanatory environmental variables in the MaxEnt model: distance to buildings, distance to known den sites, level of human use of docks, density of driftwood, elevation, level of human use of parks, distance to roads, substrate type, level of human use of trails, vegetation type, and distance to water and/or wetland (Table 3-1). I was unable to incorporate detailed fresh-water hydrological data in the models (Bradie and Leung 2017), and there are no major rivers or lakes present on Protection Island. I derived spatial information on the substrate types in ArcGIS Pro (version 2.8.8) from GPS points taken in the field throughout the data collection period, following the methodology described in Sections 3.2.4.1 (Esri Inc. 2021, Redlands, CA, USA). The preparation of the remaining predictor variables is described in Section 3.2.4.2.

3.2.4.1 Spatial data preparation: Substrate type

The raw habitat data were collected using a handheld GPS in point format. Each substrate type was assigned a unique identifier which was used to select and separate each substrate type into a separate feature class file. The *Find Point Clusters* tool from the GeoAnalytics (minimum features per cluster: 3, time: 5 minutes, search distance: 20 meters) toolbox was used to facilitate the identification of polygons. A polygon feature class was created for each substrate type, where the substrate polygons were manually identified and saved into. To eliminate the gaps and overlap between polygons of different substrate types created by the manual drawing of polygons and ensure substrate was continuous, I merged the seven feature classes and imported the full substrate feature class into a Feature Dataset and created a new topology. I used two rules when creating the topology: 1) categories must not have gaps and 2) categories must not have overlap. The topology was validated using the error inspector and 1440 errors were detected and resolved accordingly.

Table 3-1 Descriptions of environmental predictor variables used in MaxEnt analyses

Category	Variable	Definition	Abbreviations	Categories of Variable	Source
Anthropogenic	Distance to buildings	Distance from the nearest building	buildroads_proj DB	Continuous (meters)	City of Nanaimo Data Catalogue (2011*a*, 2011*c*)
	Distance to roads	Distance from the nearest segment of road	buildroads_proj RO	Continuous (meters)	
	Docks: Level of human use	Level of human use of the dock based on number of boats and likely foot and boat traffic	docks_proj_other DO	1: Personal docks with few boats 2: Personal dock with numerous boats 3: Large community dock and ferry dock	Handheld GPS points
	Trails: Level of human use	Level of human use of the trail based on type of area it connects to	trails_proj_other TR	1: Connector between inner parks 2: Connector to beach 3: Connector to or between busy areas	City of Nanaimo Data Catalogue (2020) Handheld GPS points
	Parks: Level of human use	Level of human use of parks based on the presence of features such as boardwalks, picnic tables, jungle gyms, and dog parks	parks_prof_other PA	1: Parks not in one of below categories (low) 2: Presence of boardwalk (moderate) 3: Contain picnic tables/jungle gym (high) 4: Dog park (very high)	City of Nanaimo Data Catalogue (2011*b*)
Biological	Distance to den sites	Distance to dens identified through personal observations or knowledge shared by islanders	densites_proj DD	Continuous (meters)	Handheld GPS points
Environmental	Density of driftwood	Estimate of the value, depth and overall amount of driftwood on the coastline in a particular area	dfw_proj DW	Categorical	Handheld GPS points
	Substrate type	Type of substrate present along shoreline	subswithother SU	1: Sand 2: Sandstone 3: Seaweed 4: Boulder 6: Mussels 8: Rock and pebbles 9: Seagrass	
	Land cover type	Land cover type	lc_proj LC	1: Water 2: Exposed land 3: Developed land 4: Coniferous forest 5: Wetland	GeoBC Branch (2000*a*, 2000b, 2000*c*, 2000*d*, 2000*e*)
	Distance to water/wetland	Distance to ocean along the coastline and to the wetland in Smugglers Park	waterwet_proj WW	Continuous (meters)	

Topographic	Elevation	Elevation above sea level	dem_proj DEM	Continuous (meters)	LidarBC (2019)

3.2.4.2 Spatial data preparation: Other predictor variables

For the continuous predictor variables: distance to buildings, to roads, to water/wetlands, and to dens, the Euclidean Distance tool in the Spatial Analyst geoprocessing toolbox was used to create the raster files necessary for the MaxEnt models. For the density of driftwood, the Kernel Density tool in the Spatial Analyst toolbox with a radius of 50 meters was used to calculate the density of the driftwood points. The driftwood polygons were converted to raster and the file was reclassified, using the Reclassify tool in the Spatial Analyst geoprocessing toolbox, where cells with driftwood were assigned a value 10 for being highly dense and those without were assigned a value of 0. The Raster Calculator was then used to sum the density values for each cell and any value over 9 was reclassified to this value as it meant the cell had the highest possible density. For the categorical anthropogenic predictor variables: level of human use of parks, trails, and docks, the Reclassify tool was used to classify the locations based on human use where lower values indicate a low level of human use and higher values indicated high levels of human use. The elevation and land cover class variables were obtained in meters and with the correct classifications and did not require further preparation.

3.2.5 Species distribution modeling: MaxEnt

In order to perform MaxEnt species distribution modeling, all environmental and anthropogenic predictor variables must have the same extent, projection, and resolution (Figure 3-2, 3-3). As such, all data were projected to North American Datum (NAD) 1983 UTM Zone 10N. All rasters were converted to ASCII format.

Pearson’s correlation coefficient was calculated for the environmental predictor variables in R version (4.3.0) (R Core Team 2023) to establish spatial independence between these factors (Ginath Yuh et al. 2020). A set of 10,000 random background points was generated using the "randomPoints" function in the “dismo” Species Distribution Modeling package (Hijmans et al. 2023), based on a raster stack of the environmental predictor variables used in this study. Values were then extracted from the random background points to test for correlations between predictor variables. One pair of variables, distance to buildings and distance to roads were highly correlated with a coefficient of 0.8598, which was beyond the selected threshold of +/- 0.75 (Table 3-2). This threshold was consistent with other studies in the field, specifically a study of habitat suitability and anthropogenic factors in Neotropical river otters (*Lontra longicaudis*) (Gomez et al. 2014). Studies have suggested thresholds ranging from 0.7 to 0.85 to account for the presence of multicollinearity (Gomez et al. 2014, e.g. Dormann et al. 2013; Kramer-Schadt et al. 2013; Syfert et al. 2013). Therefore, the two predictor variables were combined into a single layer using the Merge tool in the Data Management toolbox in ArcGIS Pro (Esri Inc. 2021). The resulting variable, the distance to roads and buildings, was used for all subsequent analysis.

Table 3-2. Correlation between predictor variables

	DB	DEM	DD	DW	DO	LC	PA	RO	SU	TR	WW
DB	1										
DEM	NA	1									
DD	-0.13	NA	1								
DW	-0.13	NA	-0.10	1							
DO	-0.02	NA	0.06	0.00	1						
LC	-0.67	NA	0.06	-0.05	0.04	1					
PA	0.12	NA	-0.01	0.03	-0.05	-0.33	1				
RO	0.86	NA	-0.06	-0.05	-0.05	-0.72	0.11	1			
SU	0.02	NA	0.04	-0.25	-0.25	0.15	-0.12	-0.10	1		
TR	0.01	NA	0.00	0.01	0.01	-0.04	0.10	0.01	-0.01	1	
WW	-0.58	NA	0.03	-0.06	-0.06	0.71	-0.27	-0.69	0.21	-0.03	1

*DB=distance to buildings, DEM= elevation, DD=distance to dens, DW=density of driftwood, DO=docks (level of human use), LC=land cover, PA=parks (level of human use), RO=distance to roads, SU=substrate, TR=trails (level of human use), WW=distance to water/wetland

** Highly correlated variables in red (+/- 0.75)

*** Elevation (DEM) received NA as the random points were likely selected in areas where raster pixels may not have values

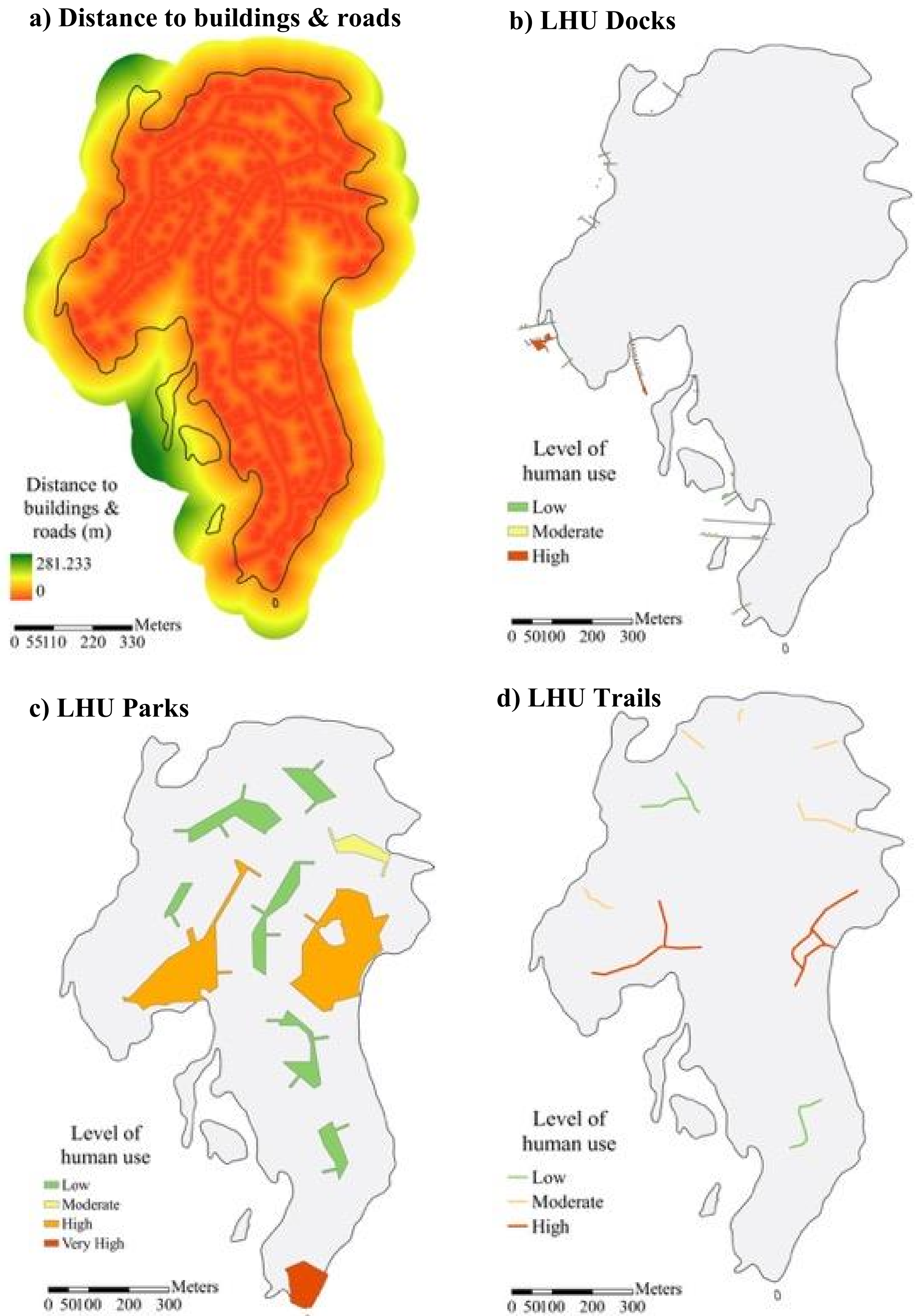

Figure 3-2 - Maps of the anthropogenic predictor variables used in the maximum entropy (MaxEnt) models, where a) is the distance to buildings and roads, b) is the level of human use of docks, c) is the level of human use of parks, and d) is the level of human use of trails

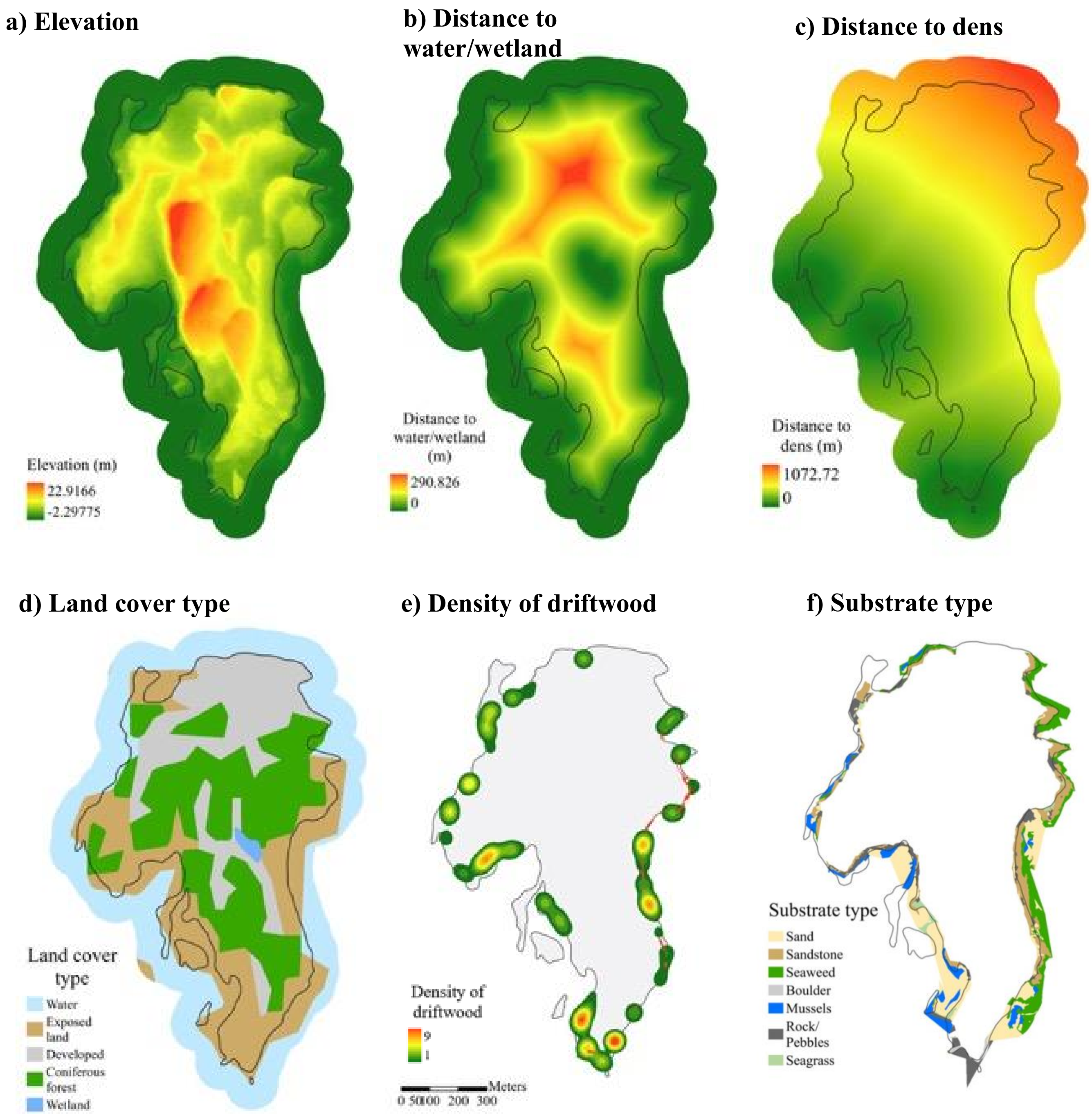

Figure 3-3 - Maps of the environmental predictor variables used in the maximum entropy (MaxEnt) models, where a) is elevation, b) is the distance to water/wetland, c) is the distance to dens, d) is land cover type, e) is the density of driftwood, and f) substrate

I elected to run two sets of models, one using the full set of occurrence points and a second, where only the occurrences that were more accurate were used and therefore, sightings shared by residents and crabs eaten were removed from the model. I chose to do this to identify whether models performed worse when occurrences that were less accurate were included because sightings shared by residents were less specific in location and there was the possibility crabs may have been eaten by other animals.

Two separate scenarios were evaluated for each set of models in this project. Occurrence data are often spatially autocorrelated given that regions in a study area that are most accessible tend to be surveyed more frequently, whether intentionally or not, which can cause the overfitting of the model (Boria et al. 2014). Spatial autocorrelation of occurrence points is an issue that the common parameter used to evaluate the models is highly sensitive to (Veloz 2009). The area under the curve (AUC) may be inaccurate and exaggerated, and the resulting predictions of the model may be biased and/or limited when spatial autocorrelation is present (Boria et al. 2014; Veloz 2009). Boria et al. (2014) showed that overall models performed better and the model was less likely to overfit if the presence-only data were spatial filtered prior to modeling. As such, Scenario 2 used one of the available methods to address the spatial sampling bias in the presence points, reduce the presence of groupings, and increase independence between points (Brown et al. 2017): spatial filtering of the points (Scenario 2). All iterations of the MaxEnt (Version 3.4.4) model used the following settings: random test percentage = 0, regularization multiplier = 1, maximum number of background points = 10 000, replicates = 10 (Phillips 2017).

3.2.5.1 Scenario 1: Full occurrence points

I used the full set of occurrence points in this model; that is, I used all types of observation employed in this study: sightings in-person (CL), sightings by trail cameras, sightings reported by residents, as well as field observation of river otter feces, latrine sites, and crabs that had been eaten (CL) (Figure 3-4a). This resulted in 660 occurrence points.

3.2.5.2 Scenario 2: Spatial filtering at 5m resolution

The occurrence points were filtered and rarefied using the Single Distance Spatially Rarefy Occurrence Data for SDMs geoprocessing tool in the SDMtoolbox in ArcMap 10.7 (Brown 2014; Esri Inc. 2019). The resolution chosen to rarefy the occurrence points was 5 meters, which results in one occurrence point per five-meter radius (Brown 2014). This resulted in the use of 207 unique occurrence points in this iteration of model (Figure 3-4b). The 5-meter resolution was selected intentionally for three reasons: 1) because of the small spatial nature of Protection Island, 2) due to the error margin of GPS being 3 meters, and 3) because 5 meters could be the difference between an occurrence point being positioned on an aquatic and terrestrial section of the island, which is an important distinction for semi-aquatic species such as river otters.

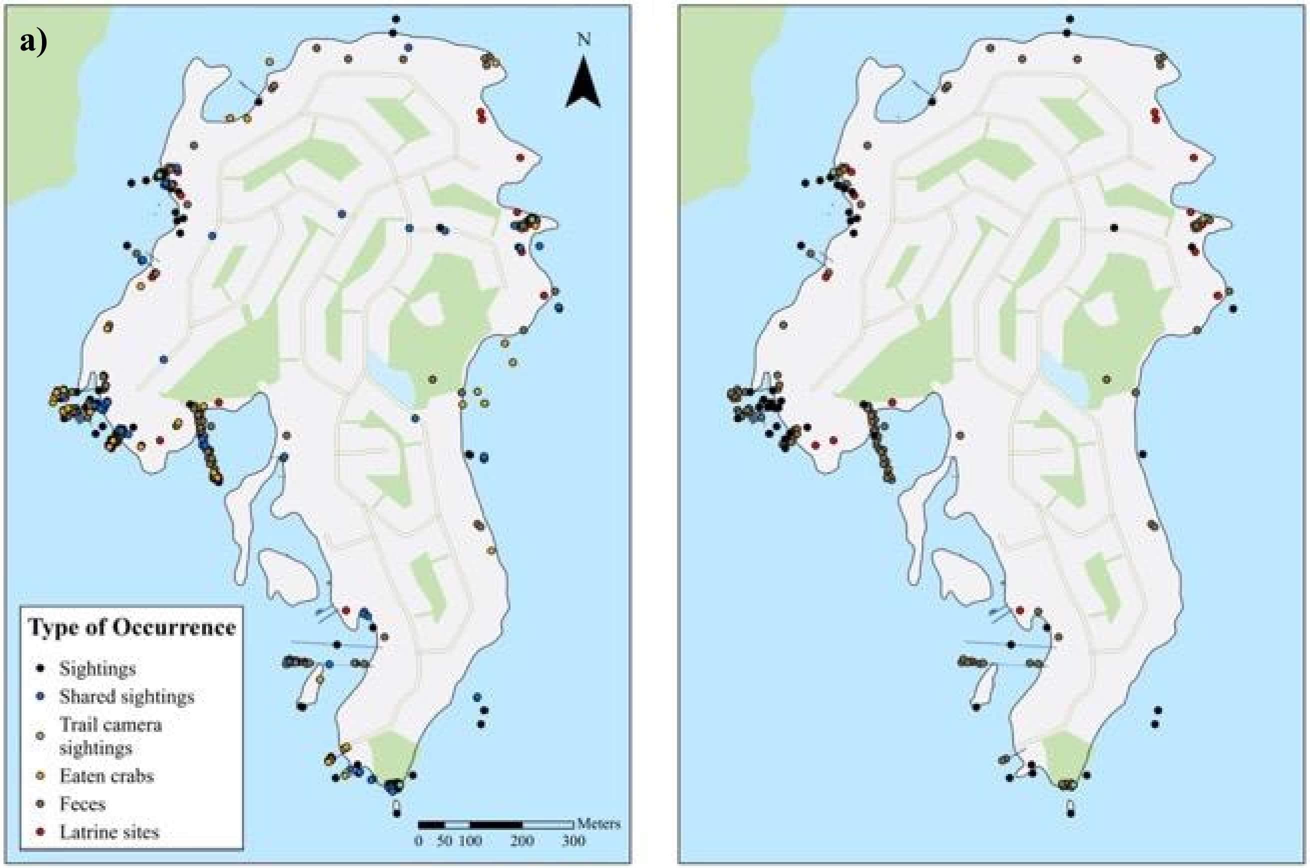

Figure 3-4 - Maps of occurrence points used in MaxEnt analysis for a) Scenario 1 using all occurrence points (N = 660), and b) Scenario 2 using the spatially rarefied occurrence points (N = 207). The GPS points taken along the shoreline that are reported in these maps were taken at low tide.

3.2.6 Habitat suitability

3.2.6.1 Using equal interval classifications

As far as I am aware, there are no published habitat suitability thresholds biologically relevant and specific to North American river otters. I therefore utilized Weinberger's (2016) suitability scale, with four categories for suitability in Eurasian river otters: 0-0.25, 0.25-0.5, 0.5-0.75 and 0.75-1. I have labeled these categories: unsuitable (0-0.25), low suitability (0.25-0.5), moderate suitability (0.5-0.75), and high suitability (0.75-1).

3.2.6.2 Proposing new thresholds based on Jenks natural breaks

Following the initial classification of habitat suitability using the above categories, I observed that suitable areas were more restrictive on Protection Island than I felt was likely based on visual observations of river otters during the field season, that more of the island habitat should be at least considered to have a higher level of suitability than was reflected in the initial habitat suitability results which employed equal interval classifications (Section 3.3.4). As such, I elected to explore new thresholds for habitat suitability for river otters in urban landscapes. Therefore, I propose the use of the Jenks Natural Breaks with four classes: unsuitable (0 – 0.135), low suitability (0.135 – 0.35), moderate suitability (0.35 – 0.6), high suitability (0.6 – 1.0). Jenks Natural Breaks is a method of classification that accounts for the presence of divisions that are naturally present in the data and therefore, groupings that are ideal for the data in use are created (Chen et al. 2013). This classification method simultaneously makes the variance between classes as large as possible and makes the variance within each class as small as possible (Jenks 1967, cited in Jiang 2013). These new proposed thresholds were derived from the average values for each category from the various model iterations. These raw values for the categories for each model iteration were calculated in ArcGIS Pro using the Natural Breaks classification in the Reclassify tool.

3.2.7 Behavioural data collection and analysis

The objective of the behavioural analysis was to examine behavioural differences among river otters with a particular focus on the use of docks and land. Behavioural data were extracted from videos collected using trails cameras (10 minutes maximum) and observations recorded during the procedures described in Sections 3.2.2.1 to 3.2.2.3. When I observed river otters during the data collection period, I initiated *ad libitum* behavioural data collection sample and the river otter was continuously observed and recorded, using a Sony FDR-AX43 4K video camera, until the river otters were out of sight (OOS) for five minutes, at which point the sample was terminated. During these samples, every behavior and social interaction (Appendix C) was recorded, including the portion of the sample for which the individual was out of sight (Altmann 1974).

Scan samples were collected from all videos by CL (trail camera and hand-held videos). This method used systematic instantaneous behavioural samples taken at a specific time interval and recording locations and behaviours of individuals at the pre-determined interval (Altmann 1974) using a behavioural ethogram (Appendix C). The first observable behaviour at the start of the sample was recorded for each individual. However, given the fixed nature of trail cameras, this behaviour could occur a period of time after the camera was triggered if the individuals were not fully in frame. For trail camera samples, a second observation was recorded five minutes after the first if individuals were still present in the frame. For samples collected with the handheld video camera, additional observations were recorded if the individuals were still present five minutes later. Further, additional observations were recorded when the individual(s) moved to or entered into the water and subsequently returned to a dock, boat, or land. For these observations, the entire group of individuals had to depart and return to trigger a new observation before the five-minute mark. If some individuals departed but others remained, observations continued for the remaining individuals. I then aggregated the scan sample behaviours into activity budget categories: individual (e.g. self-grooming, inactive lie, scent marking, stand); social (e.g. grooming, play); move (e.g. walk, run, dig, rub ground); and feed (e.g. forage feeding, drink) (see Ethogram in Appendix C for more details).

Behavioural observations of river otters in water were beyond the scope of this project, as the observable detail from land was substantially compromised relative to observations of their behaviours on land and docks. Clear measures of in-water behaviours would require sophisticated equipment. Therefore, the 27 samples of the total 209 samples where individuals only displayed swimming behaviour were not included in the analysis. Further, observations where either the behaviour or the location could not be identified due to poor visibility, were removed. As such, 594 observations from 178 samples were used in the statistical analysis.

To examine the relationship between time of day, behavioural categories, and land versus dock use, I assigned samples to one of three time of day periods: daytime, crepuscular, and overnight. I calculated the average time from the start of civil twilight to sunrise, and sunset to end of civil twilight for each of the 1st, 15th, and last day of each month, to obtain a monthly average length of morning and evening crepuscular periods (Time and Date n.d.*a,* n.d.*b,* n.d.*c,* n.d.*d,* n.d.*e*). I added and subtracted these values from the time of sunrise and sunset, respectively, on the 15th of the month to obtain a morning and evening crepuscular period. Following the identification of the crepuscular periods, I determined the daytime period would be from the end of the morning crepuscular period to the beginning of the evening crepuscular period, and the overnight period would be from the end of the evening crepuscular period to beginning of morning crepuscular period. I elected to use civil twilight in these calculations based on other studies examining time of day. For instance, Ensing et al. (2014) and Horton et al. (2015) used similar reference points to establish day and night periods, using civil twilight start and end times. Further, animals that display more activity during the time of day where the amount of light transitions from dark to light and light to dark are categorized as crepuscular, and this transition of light occurs at the fastest rate during the civil twilight period (Daan and Aschoff 1975; Schumman et al. 2005).

Three Pearson's Chi-squared tests were conducted in R to evaluate four hypotheses and *post hoc* analysis was performed on statistically significant results using the "chisq.posthoc.test" function in R which applies the Bonferroni adjustment (Ebbert 2023).

3.3 Results

To measure habitat suitability for river otters and assess the relative importance of different variables in shaping river otter habitat use, I used the full data set of observed occurrences of river otters in the final models. The results of the models using only the most reliable subset of occurrence information are available in Appendix D.

3.3.1 Habitat suitability for river otters on PI

The most commonly used parameter for evaluating and comparing MaxEnt models is the area (AUC) under the receiver operating curve (ROC) (Fourcade et al. 2014). A model performs and fits optimally when the AUC is equal to 1, in contrast, models with a value near 0.5 perform weakly, and not different from a random distribution (Baldwin 2009). The mean AUC for Scenario 1, using the full set of occurrence points, was 0.895 after 10 replicates (Figure 3-5). The mean AUC for Scenario 2, using the spatially rarified occurrence data, was 0.858 after 10 replicates (Figure 3-6).

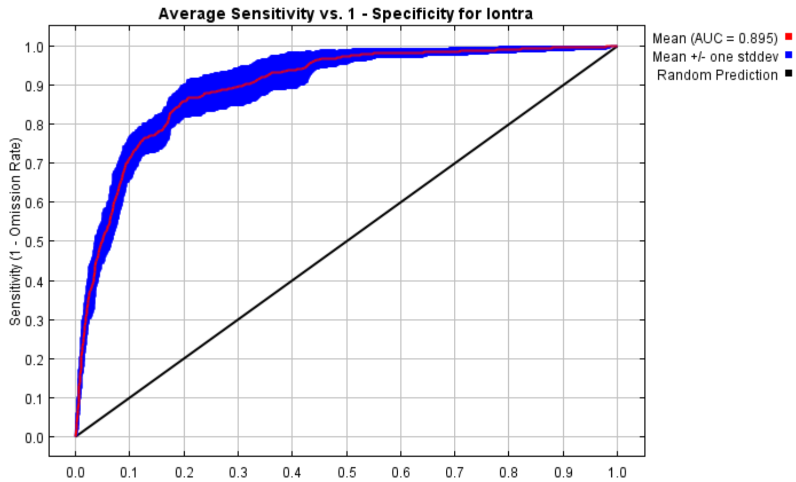

Figure 3-5 - MaxEnt model evaluation for Scenario 1 using the full set of occurrences.

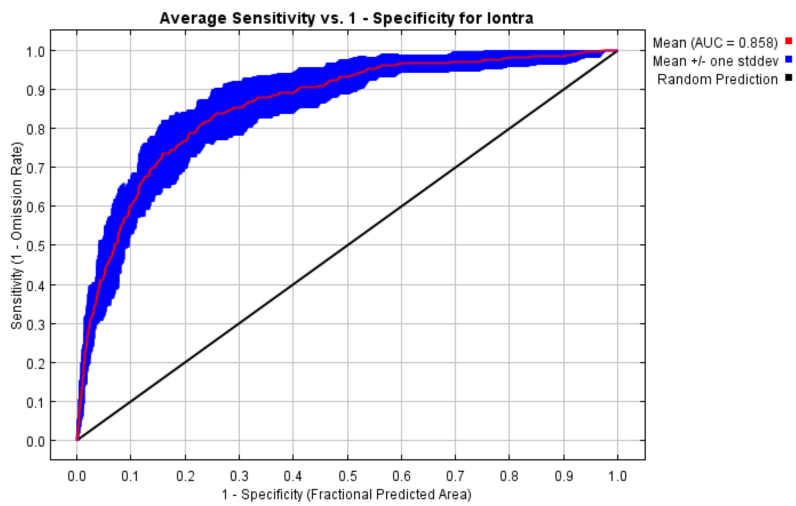

Figure 3-6- MaxEnt model evaluation for Scenario 2 using the spatially filtered occurrences.

3.3.2 Environmental predictor variable contributions

Distance to dens, distance to driftwood, and level of human use of docks were the most important variables for habitat suitability for the full set of occurrences (Scenario 1) and the spatially filtered modes (Scenario 2) (Table 3-3). The percent contributions for distance to dens were 40.5% and 31%, for distance to driftwood were 15.8% and 19.4%, and for level of human use of docks, were 15.4% and 14.5%, respectively, for Scenario 1 and Scenario 2.

Figure 3-7- River otter eating a crab on a dock on Protection Island (Photo credit: Jim MacQuarrie, used with permission).

The remaining predictor variables contributed far less individually to suitability, in total accounting for 28.1 and 34.9%, respectively for both scenarios. The remaining anthropogenic predictors variables (distance to buildings and roads, level of human use of parks, and level of human use of trails) contributed just 4% and 7% respectively to each scenario.

Table 3-3. Percent contributions of predictor variables to MaxEnt models for the two scenarios

Variable	Percent contribution Scenario 1 (Full occurrences)	Percent contribution Scenario 2 (Spatially filtered)
Distance to dens	40.5	31
Density of driftwood	15.8	19.4
Docks (LHU)	15.4	14.5
Distance to water/wetland	13	12
DEM	8.2	11
Distance to buildings & roads	3.5	5.6
Substrate type	2.4	4.1
Land cover class	0.5	0.8
Parks (LHU)	0.5	1.4
Trails (LHU)	0	0

3.3.3 Responses to individual predictor variables

These models found that the probability of river otters finding suitable habitat is highest close to the sites where dens are present and declines further from these locations. Specifically, the likelihood decreases up to a distance of approximately 100 meters for both scenarios (Figure 3-8a). Subsequently, the probability of habitat being suitable for the full set of occurrences (Scenario 1) remains relatively stable until an approximate distance of 700 meters from the dens before increasing as the distance increases to 800 meters, and then declines steadily. Using the spatially rarified occurrences (Scenario 2), the probability plateaus from 100 meters to approximately 1000 meters before continuing to decline at further distances (Figure 3-9a). The probability of finding suitable habitat is highest at intermediate densities of driftwood along the shoreline (Figure 3-8b, 3-9b). This likelihood increased as the density of driftwood increased up to intermediate densities. At intermediate densities the likelihood of river otters finding the habitat suitable begins to decline and continues to decline until the highest density. While the presence of docks is important when considering the probability of river otters utilizing habitat, the level of suitability was consistent across all levels of human use and was considered highly suitable (Figure 3-8c, 3-9c).

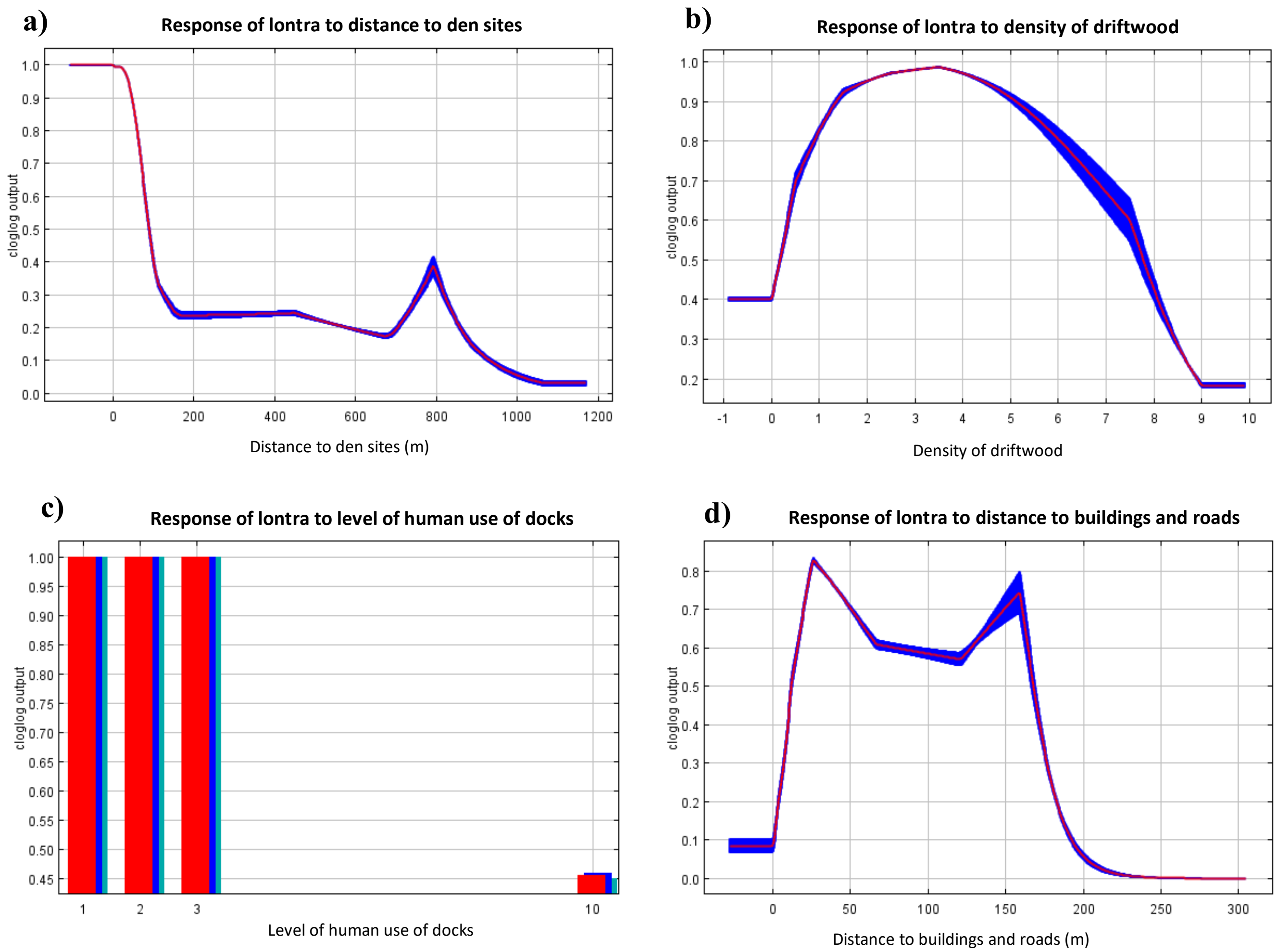

Figure 3-8- River otter responses to the three most important predictors of suitability for Scenario 1, a) distance to dens, b) density of driftwood, c) level of human use of docks, and to d) the distance to buildings and roads. In c), the value 10 represents the category of non-dock areas which are not attributed a level of human use for docks but still allows us to obtain valuable information about habitat suitability on the island. The red lines for the continuous variables and bars for the categorical variables represent the mean response of the individual predictor variable for the 10 replicates performed in this analysis and the blue represents +/- one standard deviation from the mean response for the same replicates (Araújo et al. 2021, supplementary material).

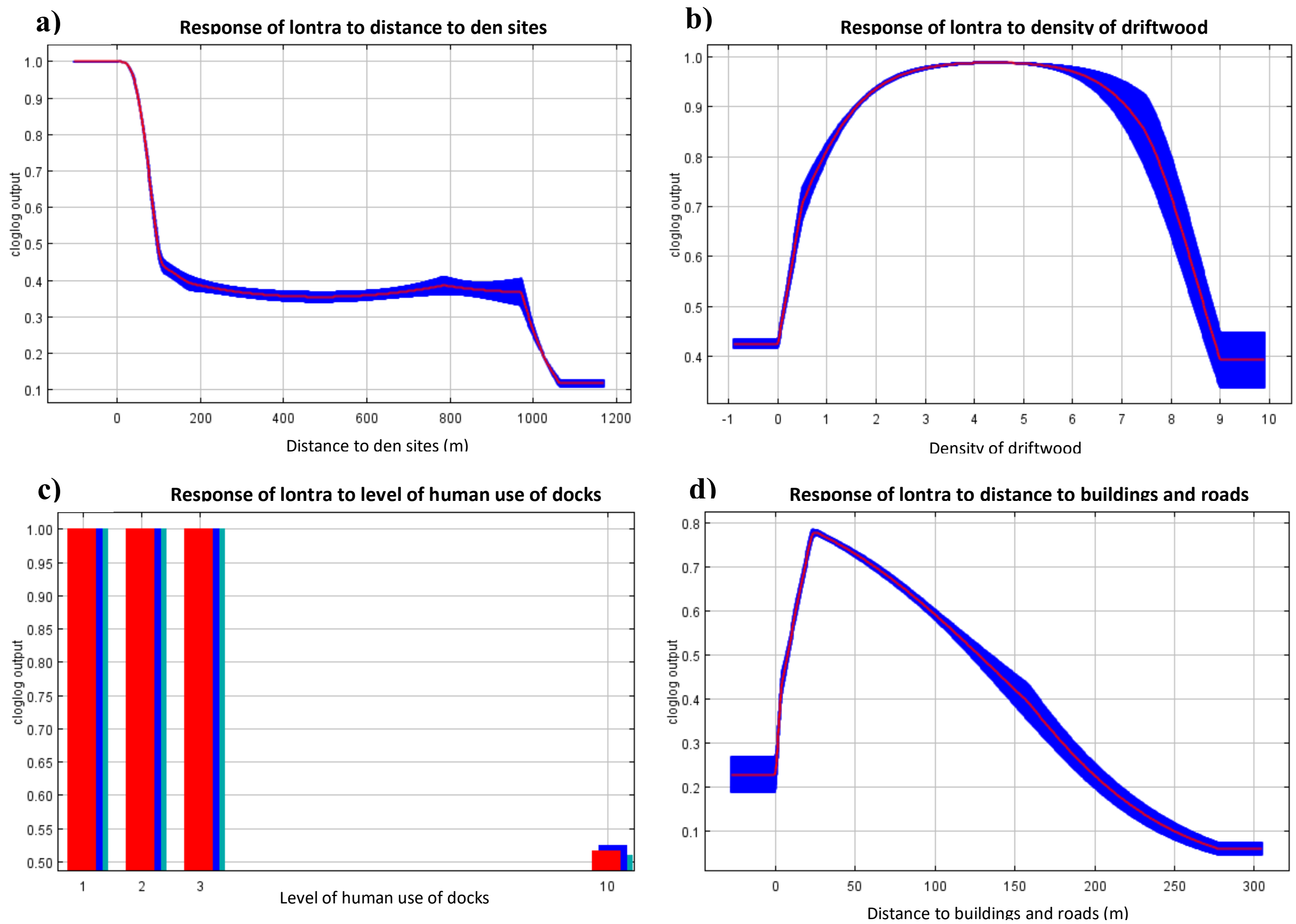

Figure 3-9 - River otter responses to the three most important predictors of suitability for Scenario 2, a) distance to dens, b) density of driftwood, c) level of human use of docks, and d) the distance to buildings and roads. In c), the value 10 represents the category of non-dock areas which are not attributed a level of human use for docks but still allows us to obtain valuable information about habitat suitability on the island. The red lines for the continuous variables and bars for the categorical variables represent the mean response of the individual predictor variable for the 10 replicates performed in this analysis and the blue represents +/- one standard deviation from the mean response for the same replicates (Araújo et al. 2021, supplementary material).

3.3.4 Habitat suitability

3.3.4.1 Using equal interval classifications

Using the full set of occurrence points (Scenario 1) indicated that 82.87% of habitat was unsuitable, 11.16% had low suitability, 4.05% was moderately suitable and 1.93% was highly suitable (Table 3-4, Figure 3-10a). When the occurrence points were filtered at a resolution of 5 meters (Scenario 2), 71.83% of habitat was unsuitable, 16.68% had low suitability, 7.33% was moderately suitable and 4.16% was highly suitable (Table 3-4, Figure 3-10b).

Table 3-4. Habitat suitability using equal interval classifications for river otters, as indicated by area

Suitability	Scenario 1 (Full occurrences)		Scenario 2 (Spatially filtered)	
	Area (%)	Area (m^2)	Area (%)	Area (m^2)
Unsuitable (0.00 - 0.25)	82.87	1,008,789	71.83	874,405
Low (0.25 - 0.50)	11.16	135,794	16.68	203,037
Moderate (0.50 - 0.75)	4.05	49,264	7.33	89,273
High (0.75 - 1.00)	1.93	23,487	4.16	50,619

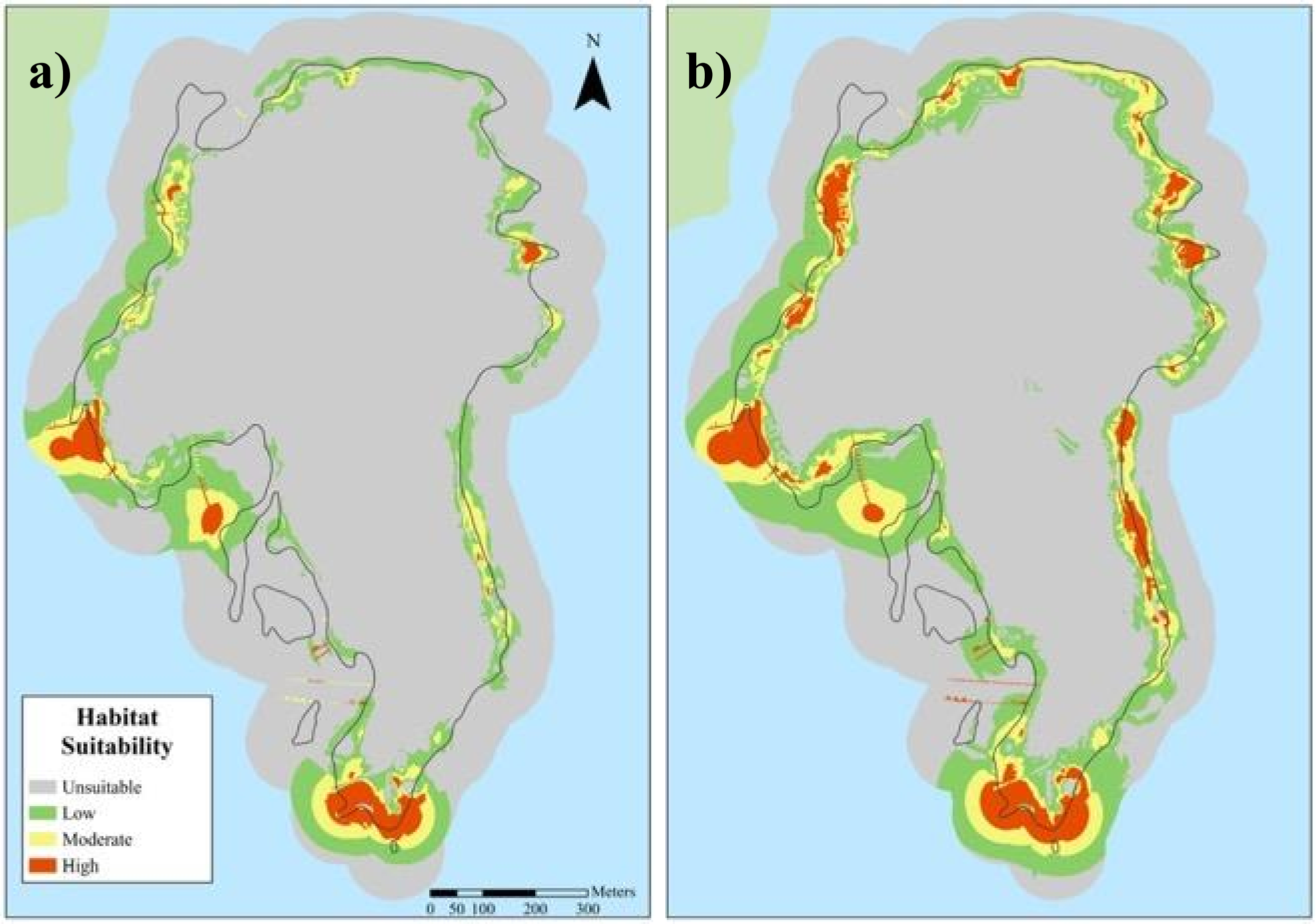

Figure 3-10 - Habitat suitability for river otters in 2022 on Protection Island based on the MaxEnt analysis and using equal interval classifications, for a) Scenario 1 (full occurrences), and b) Scenario 2 (spatially rarefied).

3.4.2 Using proposed thresholds based on Jenks natural breaks

Using the full set of occurrence points (Scenario 1) and the proposed thresholds, the results indicate that 66.83% of habitat was unsuitable, 22.27% had low suitability, 6.91% was moderately suitable and 3.99% was highly suitable (Table 3-5, Figure 3-11a). When the occurrence points were filtered at a resolution of 5 meters (Scenario 2), 56.14% of habitat was unsuitable, 24.56% had low suitability, 11.24% was moderately suitable and 8.06% was highly suitable (Table 3-5, Figure 3-11b).

Table 3-5. Habitat suitability using Jenks Natural Breaks for river otters, as indicated by area

Suitability	Scenario 1 (Full occurrences)		Scenario 2 (Spatially filtered)	
	Area (%)	Area (m^2)	Area (%)	Area (m^2)
Unsuitable (0.00 - 0.135)	66.83	813,591	56.14	683,391
Low (0.135 - 0.35)	22.27	271,043	24.56	298,919
Moderate (0.35 - 0.6)	6.91	84,1342	11.24	136, 852
High (0.6 - 1.00)	3.99	48,566	8.06	98,172

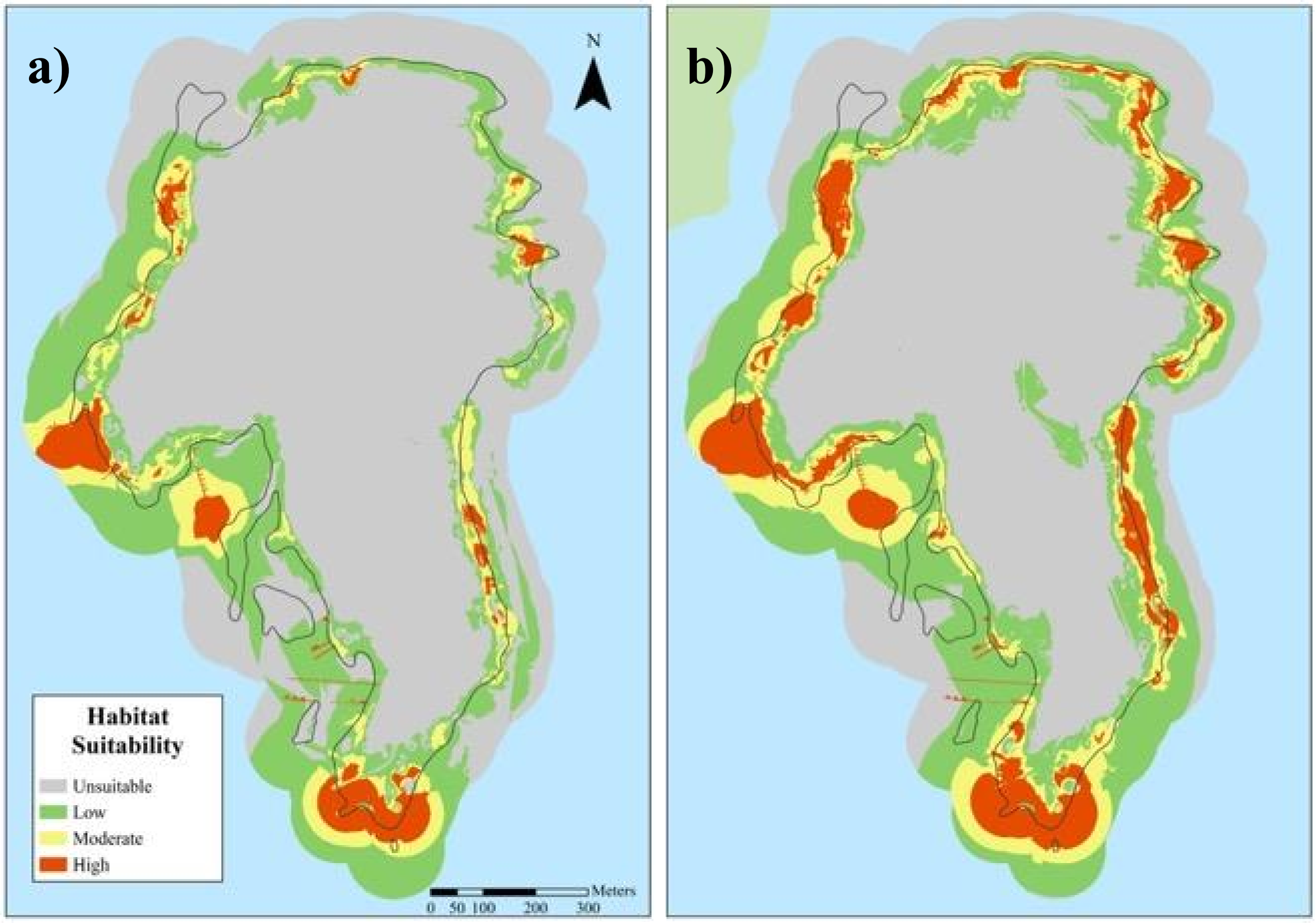

Figure 3-11 - Habitat suitability for river otters in 2022 on Protection Island based on the MaxEnt analysis and using the proposed new classifications, for a) Scenario 1 (full occurrences), and b) Scenario 2 (spatially rarefied).

3.3.5 Behavioural analysis

Overall, the results of the behavioural analysis supported the first hypothesis, indicating that river otter behaviour differed on docks than on land, and river otters used docks more frequently than expected by chance. Pearson's Chi-squared indicated river otter behaviours were significantly different when on land compared to docks, X^2 (3, N = 594) = 63.076, *p*-value < .001. The *post hoc* test with Bonferroni correction indicated that the frequency of behaviours in the individual (*p*-value < 0.001), movement (*p*-value = <0.000) and social categories (*p*-value = <0.000) differed significantly between land and docks, but that the frequency of feeding behaviours did not (*p*-value = 1.000). This result indicates the second hypothesis is not supported, as river otters displayed feeding behaviours (Appendix C) as frequently as expected on both docks and land. River otters displayed more movement behaviours on land and less on docks than expected, whereas they displayed less individual and social behaviour on land and more on docks than expected (Figure 3-12).

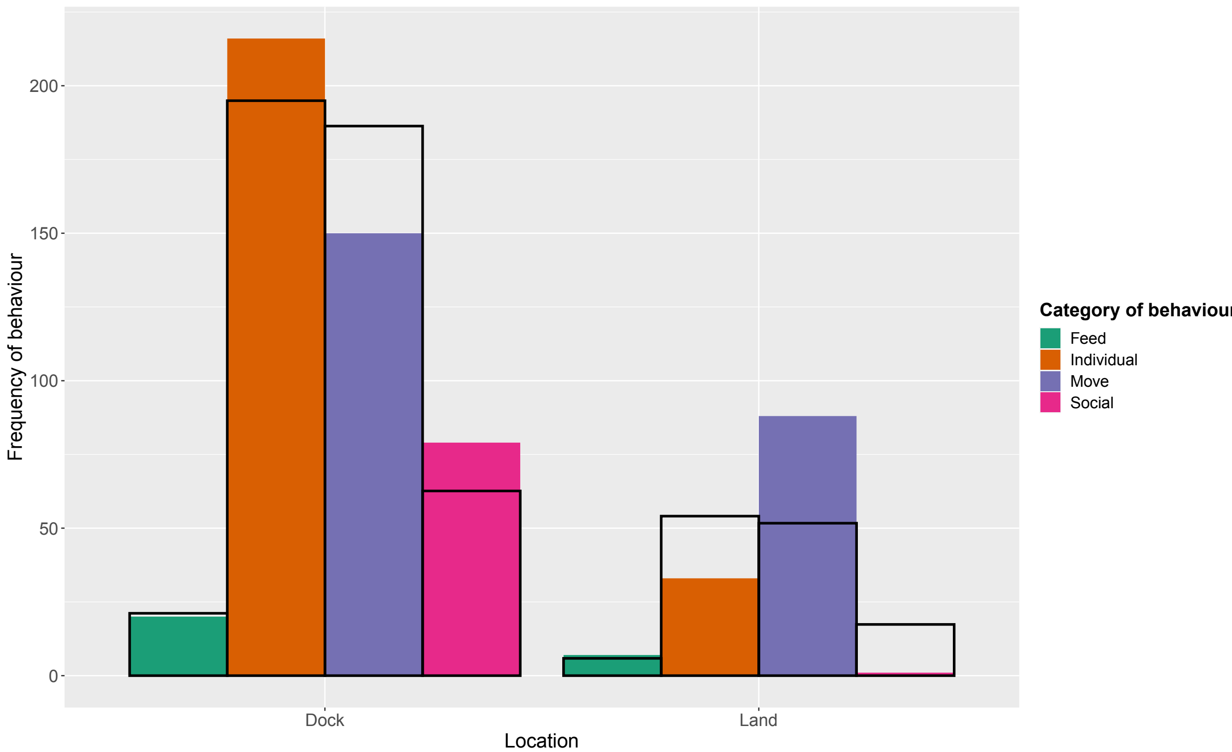

Figure 3-12- Results of Pearson's Chi-squared test, observed and expected frequencies of behaviour by time of day. The bold coloured bars are observed frequencies, while opaque bars are expected frequencies.

The results from the Pearson's Chi-squared indicated that river otter activities differed by time-of-day, X^2 (6, N = 594) = 41.271, *p*-value < .001. The *post hoc* test with Bonferroni correction indicated that the frequency of movement behaviours was significantly more frequent in the crepuscular (*p*-value = .027) and overnight periods (*p*-value < .001) and social behaviours were significantly less frequent in the daytime (*p*-value < .010) and more frequent in overnight periods (*p*-value < .001) (Figure 3-13). River otters were active throughout the day and night and did display movement behaviours more frequently during the crepuscular period than by chance. However overall, these results indicate the second hypothesis was not supported and river otters did not preferentially display feeding, movement, and social behaviours during the crepuscular and overnight periods.

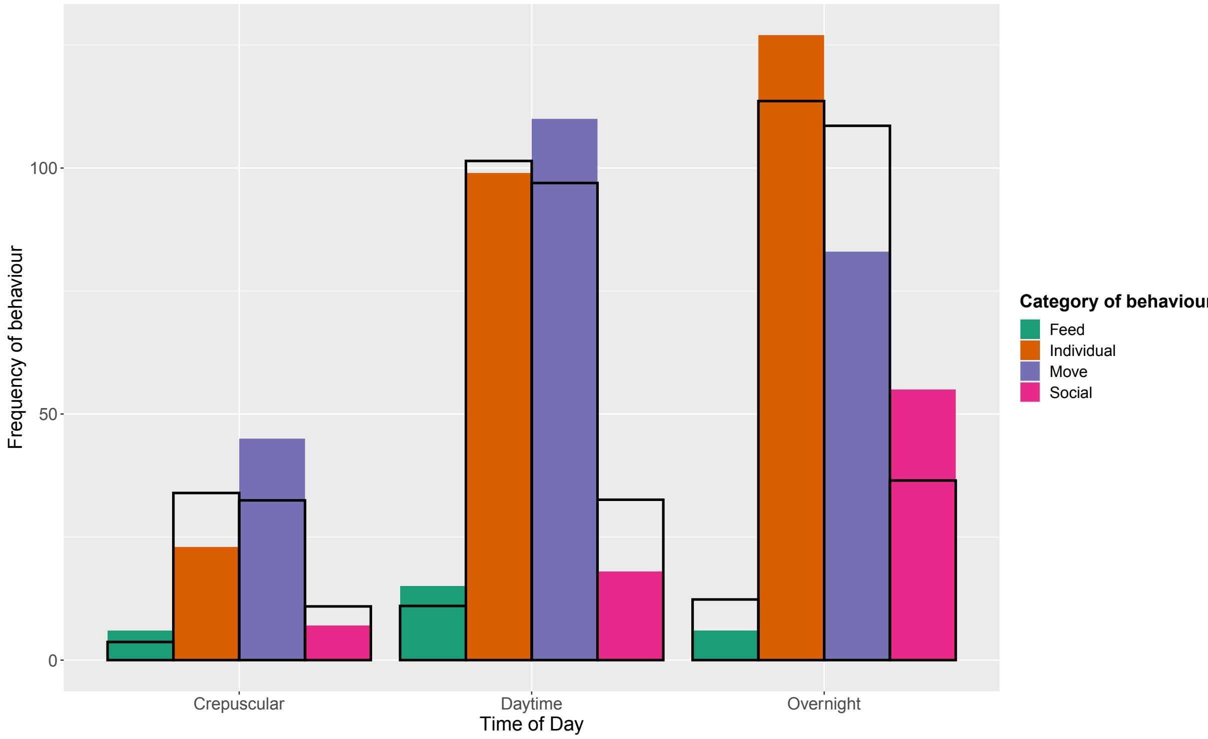

Figure 3-13- Results of Pearson's Chi-squared test, observed and expected frequencies of behaviour by time of day. The bold bars are observed frequencies, while opaque bars are expected frequencies.

The results from the Pearson's Chi-squared indicated that the frequency with which river otters were using land and docks differed according to time-of-day, X^2 (2, N = 594) = 51.603, *p*-value < .001. The post hoc test with Bonferroni correction indicated that the frequency of land and dock use differed significantly between the morning (*p*-value < .001), crepuscular (*p*-value < .001) and overnight periods (*p*-value = < 0.000). River otters spent less time on docks and on land during the crepuscular period than expected. Further, they spent more time on docks and less on land than expected during the overnight period. This partially supports the third hypothesis as river otters did utilize docks more often than expected during the overnight period. However, they also spent less time on docks and more on land during the crepuscular period, which contradicts the hypothesis and suggests river otters may be swimming or using other segments of habitat during the crepuscular hours (Figure 3-14).

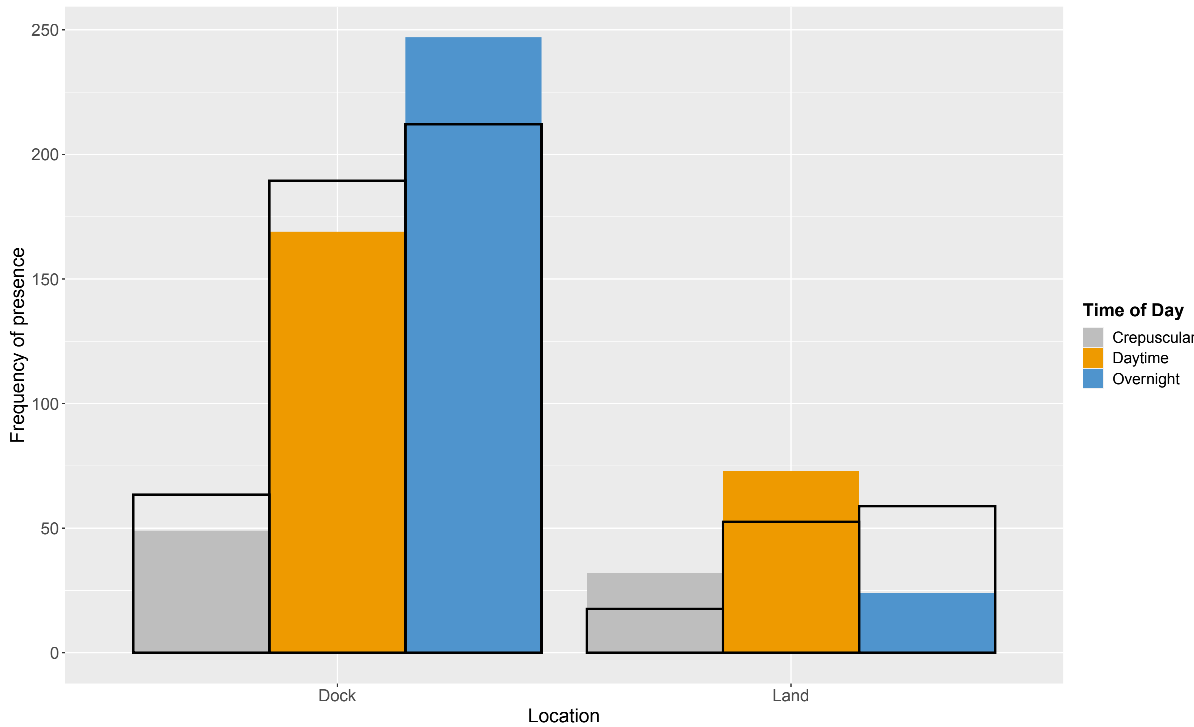

Figure 3-14- Results of Pearson's Chi-squared test, observed and expected frequencies of presence by time of day on docks and on land. The bold bars are observed frequencies, while opaque bars are expected frequencies.

3.4 Discussion

Overall, the non-anthropogenic variables were more important to habitat suitability than the anthropogenic variables in this study. The results of this study indicate that suitable habitat for North American river otters on Protection Island are areas where the land cover type is exposed land, where there is water or wetlands nearby, and where elevations are low. Other studies that examined river otters living in proximity to people have found similar results, particularly in relation to the most suitable elevation levels and substate types (Durbin 1993; Barbosa et al. 2001; Allen 2020; Morton et al. 2022) with notable differences in relation to the importance of roads and dominant land cover type (e.g. Gallant et al. 2009; Lawrence 2016; Weinberger 2016; Weinberger et al. 2016; Hanrahan et al. 2019; Allen 2020; Morton et al. 2022).

Biological, environmental, and topographic predictor variables were more important than anthropogenic factors in explaining river otter habitat suitability in this study. However, I also found that docks use was a key factor in defining suitable habitat in this study. This study indicates that areas near water or wetlands, with the land cover type of exposed land, and with low elevations are the most suitability habitat for North American river otters. Further, these findings indicate that in some urban contexts, humans and river otters coexist well.

The prediction that anthropogenic variables, overall, would be more important to defining habitat suitability in wild river otters than the other predictor variables was not supported by these findings. In particular, high levels of human use, and proximity to roads and buildings explained relatively small percentages of river otter habitat suitability in these results, and counter-intuitively, habitat suitability was greatest at near and intermediate distances from areas of highest human disturbance.

In general, findings have been inconsistent in terms of the relative importance of anthropogenic and environmental/biological variables in determining habitat suitability for river otters (e.g. Allen 2020; Gallant et al. 2009; Lawrence 2016). This study aligns with others that suggest non-anthropogenic variables were more important to habitat suitability than anthropogenic variables (e.g., Taylor et al. 2022). For instance, Gallant et al. (2009) found that overall, anthropogenic features were significantly less important than non-anthropogenic features for habitat suitability in North American river otters, and Barbosa et al. (2001) found that anthropogenic variables were less influential on otter habitat use than environmental factors for Eurasian river otters.

In Scenario 1 (all locations used), suitability increased as the distance from roads and buildings approached approximately 25 meters, then was moderately suitable at intermediate distances before rapidly declining as distances increased beyond 160 meters (Figure 3-8d). In Scenario 2 (filtered locations used), suitability increased too as the distance from roads and buildings approached 25 meters before declining as the distance increased (Figure 3-9d). In many other studies, the density of roads or distance to roads has been found to be a key variable in predicting and defining habitat suitability for otters. For example, latrine activity (a measure of habitat use) was found to be lower closer to roads (Lawrence 2016), and studies have indicated that North American and Eurasian river otters show high levels of avoidance of roads, including preferential selection of areas further from roads for foraging (Weinberger 2016; Weinberger et al. 2016; Hanrahan et al. 2019). Further, roads have been identified as a frequently observed human disturbance in non-protected areas (Gallant et al. 2009). The quality and quantity of habitat in proximity to roads can decline due to factors such as the presence of pollutants (e.g. water, noise, light) and other negative implications of roads for wildlife include direct road mortality (Eurasian river otters: Barbosa et al. 2001; Barbosa et al. 2003; general: Jaeger et al. 2005; Fahrig & Rytwinski 2009). In contrast, Taylor et al. (2022) found that river otter occurrence was not significantly predicted by human-disturbance variables, such as the density of roads. The overall differing results in this study, that suitability is greatest at near and intermediate distances from roads, may be due to the unique nature of gravel roads and of travel on Protection Island. The majority of human movement on the island roads is restricted to speeds of 20 km/hr or less using primarily golfcarts, bikes, or on foot and to a much lesser degree automobiles. Further, the maximum distance from roads that river otters can achieve in their terrestrial environment is approximately 140 meters (Figure 3-2a). The characteristics of automobile traffic associated with roads in most settings, including noise, light and speed, are diminished when speeds are reduced.

In both of the model scenarios, the highest level of human use in parks corresponded with the most suitable habitat: highly suitable for river otters and the remaining three lower levels of human use were equally and weakly suitable. In both scenarios, all three levels of human use for trails were indicated to be moderately suitable for river otters and suitability was equal across the three levels of human use. It may be that the extent to which human activities modify the landscape is a more important influence on habitat suitability, rather than the presence of humans and human activity on its own (Gallant et al. 2009). The model results support this suggestion, and suggest that the addition of parks, trails, and small docks do not apparently degrade habitat suitability for river otters. Furthermore, the results support the suggestion that when river otters have access to ecologically important resources, such as superior foraging and den sites, they are likely to be more tolerant of human activities and disturbances (Cotey 2021).

The results of this study also indicate that substrate may mediate river otter presence and habitat suitability. Sandstone, boulders, and rock/pebbles were the most suitable substrate types in this landscape. This finding is supported by Barbosa et al. (2001) and Durbin (1993) who found that Eurasian river otter presence was more likely where substrate was impermeable and that otters preferred boulders, respectively. In contrast, in this study, softer substrates such as sand and mud were classified as only moderately suitable. This is contrary to the findings from Jeffress et al. (2011) and Williamson and Clark (2011) who found that river otters were most likely to be detected where mud substrate was present and generally where substrate was softer. However, while detectability of Eurasian or North American river otter presence may be highest on the substrate types highlighted above, more research is needed to elucidate whether these are more suitable habitat substrates or whether they are simply the substrate types that allow us to detect river otter presence most easily.

Low elevation has been identified as an important factor in determining suitable habitat for river otters (Allen 2020; Morton et al. 2022). Allen (2020) found that elevation was by far the most important variable in their MaxEnt models compared to other environmental variables, including land cover and riparian habitat. Further, elevation was found to be an important predictor for habitat suitability in river otters in Western Montana with lower elevations showing greater probabilities of river otter presence (Morton et al. 2022). However, elevation was not a largely influential factor in the models. The elevation range was much greater in Allen's (2020) study (91- 427m), compared to this study (~2m below sea level to 22.9 m above sea level), and the smaller elevation range and lack of higher elevations in this dataset likely explains the lack of contribution by elevation in these models. Further, while this study supports the higher suitability at lower elevations indicated by Morton et al. (2022), a large extent of their study area was situated at lower elevations and therefore, they may have experienced the same bias towards lower elevations in their models as I did.

The relative importance of land cover type in defining suitable habitat for otters has varied considerably across studies. In some studies, land cover type, in general, was the strongest predictor for river otter presence and habitat suitability (Jeffress et al. 2011; Allen 2020; Morton et al. 2022). Specific land cover types, such as evergreen forest (Allen 2020; Morton et al. 2022) and mixed forest (Allen 2020) have also been found to be significantly associated with habitat selection and greater probabilities of presence in river otters. As in this study, other studies found that the prominent land cover vegetation type contributed minimally and had weak importance to the fit of the maxEnt model (Bieber 2016; Bieber et al. 2018). While land cover type did not contribute substantially to defining habitat suitability in this study, I noted that developed land was the least or second least suitable type in both models. I also found that coniferous forests were the least and second least suitable cover classes in these models, results that differed from other research that identified evergreen forests as the most suitable land cover type for river otter habitat (Morton et al. 2022), that river otter occurrence was positively related to the presence of evergreen forests (Allen 2020). However, I had relatively few occurrence points for coniferous forests in this study, so sample size may have been a factor in these findings.

There is a wide range of thresholds used to classify degrees of habitat suitability in MaxEnt studies (e.g., classifying suitability measures into categories such as “highly suitable,” “moderately suitable,” and “unsuitable”). Yet, the selection of the habitat suitability classes is critical to the interpretation of results. Wilson and colleagues (2005) suggested that the use of suitability categories selected *a priori* for binary classifications of presence/absence could limit the potential to consider and adapt the results within the specific context of a study. Liu et al. (2005) found that the use of the threshold for habitat suitability of 0.5 as the threshold to create binary presence-absence categories was among the poorest methods for selecting the appropriate threshold. I had similar concerns about the criteria for classifying habitat suitability into non-binary, ordinal categories. The classification values of < 0.2, 0.2 – 0.4, 0.4 – 0.6 and > 0.6 are commonly used in MaxEnt studies as the suitability or potential habitat classes (e.g. Yang et al. 2013; Ginath Yuh et al. 2020; Kamyo and Asanok 2020). However, I argue that using generic and/or equal-interval classifications do not always create biologically accurately representation of habitat suitability. Further, I suggest that many studies of habitat suitability or studies that employ species distribution modeling should also consider visual observations indicative of animal behavioural, at least to some extent, in the threshold selection process. The use of Jenks Natural Breaks may provide more realistic categories, in that this method creates suitability classes based on divisions that are naturally present in the data and as such, these classes are more specific to the study context (Naher et al. 2021). In this study, I aimed to incorporate animal and human behaviour in the general ecology and mapping process. Further, I suggest a more appropriate scale for habitat suitability in river otters based on observations of both groups in this landscape and the results derived from MaxEnt analysis.

Based on visual observations of the Jenks Natural Breaks with four classes, I propose the following scale for categorizing habitat suitability in river otters inhabiting urban landscapes: unsuitable (0 – 0.135), low suitability (0.135 – 0.35), moderate suitability (0.35 – 0.6), high suitability (0.6 – 1.0). I recognize that this study used one specific area (PI), so I generalize results with some caution, nonetheless, anthropogenic variables seemed to be less influential in this context and river otters were able to adjust their behaviour to accommodate anthropogenic structures and modifications in the landscape, and as such I suggest that researchers consider this less restrictive scale of habitat suitability in future. River otters in this study were observed utilizing the entire coastline of the island and therefore, while their section of habitat may not always have been ideal, I suggest that this scale that categorizes fewer and smaller sections of habitat as unsuitable, should be considered for future research on urban otters.

In Scenarios 1 and 2, the three levels of human use of docks were found to be equally and highly suitable as habitat for river otters, suggesting that river otters were likely choosing docks preferentially over other habitat features. The behavioural analysis indicated that otters use docks more than would be expected by chance and, disproportionately for individual and social activities. Further, river otters spent more time on docks and less on land than expected during the overnight period. One interpretation of the preference for docks I observed in this study, is that docks may constitute an attractant for river otters. Features within a landscape, both natural and anthropogenic, may attract animals and prompt them to preferentially utilize a feature within a portion of their habitat; these features are known as attractants (Burton et al. 2015). While attractants may provide access to desirable habitat and resources, there can be negative consequences associated with certain attractants. For example, roads may cause injury or mortality for wildlife species that are attracted to them for the access to important resources they provide (Hill et al. 2021). Specifically, while roads may serve as heat sources for amphibians and reptiles, these taxa are often unable to quickly avoid vehicles that approach and therefore, are vulnerable to injury or mortality when using roads (Fahrig and Rytwinski 2009).

I argue that docks are acting as attractants for river otters on PI. As evidenced by the high "suitability" of docks in these models, and a strong concentration of occurrence points on docks, docks appear to have characteristics that lead river otters to perceive these anthropogenic structures as high-quality habitat, despite the presence and availability of what appears to be higher quality and more natural habitat (i.e. habitat with higher food availability, lower encounter rates with humans, and shelter from predators). I posit that docks may be appealing to river otters due to the proximity of docks to water and to foraging sites and the opportunity to quickly evade perceived threats. Further, river otter diets are mostly comprised of aquatic organisms and therefore, the majority of foraging activities occur in bodies of water (Williams et al. 2002). However, the lack of preferential selection of docks for feeding behaviours and given that river otters did not display foraging behaviours more frequently on land than expected by chance, indicate that likely the foraging behaviours are occurring in water and therefore, it may not be possible to identify differences in land and dock use for foraging behaviour. Therefore, the presence of docks may also act as a prime resting and socializing location during and after foraging bouts and therefore, may be more attractive to river otters than high-quality habitat without docks.

In comparison to their terrestrial counterparts, semi-aquatic animals such as river otters have greater energy expenditures when locomoting on land and the proximity to water that docks provide may allow greater ease of movement and more rapid avoidance of humans and other perceived threats than do the island's land-based habitats Williams et al. 2002). However, while docks appear to act as an attractant for river otters and river otters may quickly take to the water, they may also increase vulnerability to predation, in particular diurnal eagles target juvenile/young river otters on exposed docks (Figure 3-15). The preferential use of docks overnight may indicate flexible behavioural avoidance of predators and humans, as river otters do not have nocturnal predators in this landscape and humans use docks less frequently at this time of day.

Figure 3-15 - Example of a predation threat and ecological interaction on docks, Protection Island, 2022.

Anthropogenic modifications to habitat can create novel environments, conditions, and features for which animals are not adapted, and given that these rapidly occurring land use changes may occur faster than natural selection, animals may not be adapted to accurately discern signals of habitat quality in these new environments, and may select poor quality habitats with more costs than benefits (Schlaepger et al. 2002; Gilroy and Sutherland 2007). Such ecological traps (*sensu* Dwernchuk and Boag 1972) occur when animals mistake low quality habitat for high quality habitat, and preferentially select this lower quality habitat even when high-quality habitat is present and available in the landscape (Schlaepger et al. 2002; Battin 2004; Patten and Kelly 2010). Animals may become attracted to portions of the habitat that have suboptimal suitability in terms of reproduction and survival and perceive high-quality habitat as less attractive than these low-quality sections (Robertson and Hutto 2006). To evaluate whether docks may be acting as ecological traps for river otters in this environment, further examination is required to assess whether there are of the fitness costs (reproductive or survival) disproportionately associated with docks, such as increased interactions with humans or increased predation risk compared to other portions of habitat, and if these costs outweigh potential benefits, such as increased access to food and social interactions.

3.4.1 Limitations and Future Considerations

In future iterations of the models used in this analysis, I think it would be beneficial to incorporate hydrological information, which was beyond the scope of this project but has shown to be important in other habitat selection and suitability studies in otters. This is supported by Bradie and Leung's (2017) study on variable frequency and importance, in which the authors found that in models for aquatic species, bathymetry was both the most common and important variable input to the model, while in terrestrial study species these variables were precipitation and temperature. Further, the study area and extent for this project was highly localized and therefore generalizations and inferences acquired from this study should be interpreted with caution. This small study area also caused limitations in the availability of spatial data as several datasets aggregated the entire Protection Island region into a single class. This lack of spatial variation in the different datasets rendered them unusable for this type of study. Additionally, direct comparisons to results of other studies should be interpreted with caution as variable definitions and classes may differ between studies and underly any identified differences. Further, future iterations of the model may be replicated with the predictor variable distance to dens, to examine whether it influences outcomes of the model importantly and may be acting circularly in that we would expect areas where dens are located to be high quality habitat. Lastly, it may valuable to identify landscaped features such as ponds throughout the island, particularly in the central portion of the island. Residents report river otters using ponds to drink and feed on fish. However, these landscape features are located on private property and therefore, the identification of these locations was often beyond the scope of this project.

3.5 Conclusions

Overall, the non-anthropogenic variables, particularly distance to dens, density of driftwood, and distance to water or wetland, were more important to habitat suitability than the anthropogenic variables in this study and river otters showed high tolerance to areas of high human disturbance and activity. Suitability declines as the distance to dens and to water or wetlands increases, while suitability increases to intermediate densities of driftwood before it declines as the density increases. I suggest that ecologically important resources such as high-quality foraging and den sites may mediate tolerance to human presence and that anthropogenic structures in this landscape have the potential to act as habitat traps (Cotey 2021). The findings of this study suggest that the most suitable habitats for North American river otters are areas of low elevation, with exposed land as the dominant non-aquatic land cover type, and in close proximity to water or wetlands, and that river otters and humans are able to coexist quite well, at least in some urban contexts. Lastly, I suggest that docks may act as an attractant for river otters and allow them to perform species appropriate behaviours despite the presence of humans and the potentially heightened predation risk.

By understanding the habitat characters that are important to river otters across anthropogenically modified landscapes, human-wildlife coexistence can be promoted by ensuring the presence of suitable environments for river otters, particularly where anthropogenic pressure is high. Further, this study helps clarify the relationships between river otter behaviour and space use in landscapes they share with humans and in environments where anthropogenic structures are present, which can inform the development of targeted conservation initiatives and enhance human-wildlife coexistence.

CHAPTER 4

CONCLUSIONS

In future iterations of the models used in this analysis, I think it would be beneficial to incorporate hydrological information which was beyond the scope of this project but has shown to be important in other habitat selection and suitability studies in otters. This is supported by Bradie and Leung's (2017) study on variable frequency and importance, in which the authors found that in models for aquatic species, bathymetry was both the most common and important variable input to the model, while in terrestrial study species these variables were precipitation and temperature. Further, the geographic area and temporal extent of this study suggest that generalizations and inferences acquired from this study should be interpreted with caution. This small study area also meant the availability of spatial data was limited as several datasets aggregated the Protection Island region into a single class. This lack of spatial variation in the different datasets rendered them unusable for this type of study. Lastly, direct comparisons to results of other studies should be interpreted with caution as variable definitions and classes may differ between studies and underly any identified differences.

River otters are often an aspect of daily life for many residents of Protection Island. Despite the presence of conflicts over river otter behaviour such as scent-marking and denning under homes, the residents of Protection Island generally display high levels of tolerance and a strong willingness to coexist with river otters. Further, through observations and interactions with river otters, numerous residents have developed perceptions of river otter behaviour that both align with and build upon existing literature on river otter behaviour, including but not limited to social, scent-marking, and denning behaviour.

The results of this study indicate that non-anthropogenic variables may be more important mediators of habitat suitability than anthropogenic variables and landscape features. I suggest that river otters may be more tolerant of humans presence and structures if they have adequate access to superior quality foraging and den sites, which are important resources for river otters (Cotey 2021). River otters in this study showed high levels of tolerance to portions of habitat with high human disturbance and activity, co-occurring with humans in these areas.

Overall, these findings suggest that suitable habitats for North American river otters may be best characterized by features such as exposed land cover types, low elevations, and proximity to water and wetlands. The results of this study also indicate that despite the potential for increased encounters with humans and predators, docks may serve as an attractant for river otters in this landscape and allow them to perform species appropriate behaviours in close proximity to high-quality habitat. Overall, these results highlight how river otter and humans appear to share overlapping habitat preferences in urban contexts and are able to coexist well.

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APPENDIX A

HUMAN AND ANIMAL ETHICS MATERIALS

Informational interview questions

1. Do you have pets? If so, what kind?

2. Did you grow up with pets? If so, what kind?

3. How would you, or what word would you use to best describe you're general feeling towards animals?

4. Have you had any other previous encounters with wildlife? If so, can you please describe it?

5. Have your previous academic, professional, or life experiences involved working with, around or been about animals or wildlife?

6. Prior to living on the island [or visiting the park] did you have any experiences with otters?

7. Have you ever seen or encountered otters on Saysutshun (Newcastle Island) Marine Park or Protection Island? If so, can you please indicate on this map where this sighting(s) or interaction(s) occurred?

8. Could you describe your encounters(s) with otters… What were they doing? How many were there? What did you think of them?

9. Can you describe your attitude towards otters in general, prior to the encounter if you have had one or your current attitude if you have not?

10. If you had to describe your attitude towards otters in one word, what would it be?

11. Did your encounter with the otter(s) change your perception of them (or your attitude towards otters, or feelings about otters)? If so, how?

12. Can you share any example of measures that you have taken to reduce the likelihood of encounters with otters? Or to stop otters from going on their property?

13. Are there any additional insights or information you would like to add?

14. In starting to look at interviews from when I was here in the summer, I'm starting to see a story more of coexistence than conflict with otters, is there anything about the island, the community, the people, anything that you can think of that you think contributes to that or makes it so? That it's more a story of coexistence than conflict?

15. And having lived on the island and had otters around, is there anything about them that has surprised you? That you didn't expect? Whether it be about their behaviour or just in general.

16. Is there anything that you've learned about yourself? Or that you can reflect on having coexisted with otters?

Participant Survey

UNIVERSITÉ
Concordia
UNIVERSITY

Survey : Human-Otter Coexistence

Name (please print):
Date:

Part 1: Brief Questions

1) Could you describe your encounters(s) with otters… What were they doing? How many were there? What did you think of them?

2) Can you describe your attitude towards otters, prior to the encounter if you have had one or currently if you have not?

3) If you had to describe your attitude towards otters in one word, what would it be?

4) Can you describe how the encounter with the otter(s) changed your perception of, or attitude towards otters?

5) Are there any additional insights or information you would like to add?

(Please see other side for Part 2)

Part 2: Locations of sighting(s) and/or encounter(s)

If you have ever sighted or had an encounter with an otter on Protection Island or Saysutshun (Newcastle Island) Marine Provincial Park, please indicate where this sighting(s) or interaction(s) has occurred.

Please use a dot for sightings and an X for other encounters.

Consent form for interviews
Note: A modified version of this consent form was used for the surveys.

INFORMATION AND CONSENT FORM

Study Title: The impact of personality traits on space use in river otters (*Lontra canadensis*) on Protection Island, British Columbia
Researcher: Caroline Lesage
Researcher's Contact Information: 514-210-3473, caroline.lesage@mail.concordia.ca
Faculty Supervisor: Dr. Sarah Turner
Faculty Supervisor's Contact Information: (514-848-2424 Ext 2022), sarah.turner@concordia.ca
Source of funding for the study: Natural Sciences and Engineering Research Council of Canada (NSERC), Fonds de Recherche du Québec Nature et technologies (FRQNT), NSERC-CREATE, Ministry of Education and Higher Education of Quebec (MEES)

You are being invited to participate in the research study 'The impact of personality traits on space use in river otters (*Lontra canadensis*) on Protection Island, British Columbia'. This form provides information about what participating would mean. Please read it carefully before deciding if you want to participate or not. If there is anything you do not understand, or if you want more information, please ask the researcher.

A. PURPOSE

The purpose of the research is to understand human perceptions of otters and whether encounters with otters influence people's perceptions of and attitude towards these animals. This research intends to inform human-wildlife coexistence and the development of conservation initiatives.

B. PROCEDURES

If you participate, you will be asked to participate in an interview that includes questions on perceptions and attitudes towards otters, encounters with otters, and locating encounters with otters on a map (if applicable).

In total, participating in this study will take 5-10 minutes. This interview will take place in person.

C. RISKS AND BENEFITS

You might face certain risks by participating in this research. There is a risk that your social interactions, professional relationships, and/or reputation may be negatively impacted if you provide answers that may be perceived as criticism towards park managers, your community, or government (municipal and/or federal) practices or policies. If you have any concerns about such risks, you may choose to have your information anonymized to ensure your identity will not be revealed (see Section D).

This research is not intended to benefit you personally but may have important implications for human-wildlife coexistence, environmental management, and the development of conservation initiatives.

D. CONFIDENTIALITY

We will gather the following information as part of this research: name and type of participant (example: Protection Island Resident, Saysutshun (Newcastle Island) Marine Provincial Park user, etc.).

We will not allow anyone to access the information, except people directly involved in conducting the research. We will only use the information for the purposes of the research described in this form.

[ ] Coded: The information gathered will be coded. That means that the information will be identified by a unique code. Only the researchers will have a list that links the code to your name.
OR
[ ] Participant choice: You can decide whether the information gathered will be identifiable or whether you would like your information coded, as described directly above.

If you choose the coded option, we will protect the information by providing your information with a unique code that will appear on interview materials, data, etc. The only people with access to the codes will be the researchers. All data pertaining to your involvement will be saved in a password protected folder on a secure hard drive.

The interview will be recorded if you provide consent (Section F). If you consent to the interview being recorded, the recordings will be deleted within 1 month of completion of the interview transcript. You will have until 1 month after you receive the transcript to withdraw from the study.

We intend to use the results of this research in the primary researcher's thesis, presentations, and potentially in published articles. Please indicate below whether you accept to be identified in the aforementioned publications:

[ ] I accept that my name and the information I provide appear in publications of the results of the research.

[ ] Please do not publish my name as part of the results of the research.

We will destroy the information five years after the end of the study, approximately August 2028.

E. CONDITIONS OF PARTICIPATION

You do not have to participate in this research. It is purely your decision. If you do participate, you can stop at any time. You can also ask that the information you provided not be used, and your choice will be respected. If you decide that you don't want us to use your information, you must tell the researcher within 1 month of receiving the interview transcript.

There are no negative consequences for not participating, stopping in the middle, or asking us not to use your information. You will have until 1 month after you receive the transcript to withdraw from the study.

F. PARTICIPANT'S DECLARATION

Do you consent to this interview being audio-recorded? (please circle one) YES NO

I have read and understood this form. I have had the chance to ask questions and any questions have been answered. I agree to participate in this research under the conditions described.

NAME (please print)

____

SIGNATURE

____

DATE

____

If you have questions about the scientific or scholarly aspects of this research, please contact the researcher. Their contact information is on page 1. You may also contact their faculty supervisor.

If you have concerns about ethical issues in this research, please contact the Manager, Research Ethics, Concordia University, 514.848.2424 ex. 7481 or oor.ethics@concordia.ca.

Human ethics certificate

CERTIFICATION OF ETHICAL ACCEPTABILITY
FOR RESEARCH INVOLVING HUMAN SUBJECTS

Name of Applicant:	Caroline Lesage
Department:	Faculty of Arts and Science\Geography, Planning & Environment
Agency:	N/A
Title of Project:	The impact of personality traits on space use in river otters (Lontra canadensis) on Protection Island, British Columbia
Certification Number:	30016581

Valid From: June 01, 2022 To: May 31, 2023

The members of the University Human Research Ethics Committee have examined the application for a grant to support the above-named project, and consider the experimental procedures, as outlined by the applicant, to be acceptable on ethical grounds for research involving human subjects.

Richard DeMont

Dr. Richard DeMont, Chair, University Human Research Ethics Committee

Animal ethics certificate

Certification of Ethical Acceptability for Research or Teaching Involving the Use of Animals

DATE: April 28, 2022

NAME: Dr. Sarah Turner

DEPARTMENT: Geography, Planning and Environment

PROTOCOL NUMBER: 30016344

APPROVAL PERIOD: May 1, 2022 – April 30, 2023

Funding Source	**Project Title**

The Concordia University Animal Research Ethics Committee (AREC) has reviewed the *Animal Utilization Summary Protocol Form* relating to the above research project(s), and hereby certifies that the proposed procedures are in accordance with the principles established in the Canadian Council on Animal Care's (CCAC) *Guide to the Care and Use of Experimental Animals*.

The AREC's final approval is, however, always contingent upon the funding agency's approval of the grant application, and/or the successful establishment of peer review.

The AREC will continue to review this protocol and monitor adherence to the CCAC Guidelines, on a regular basis, throughout the entire period of the research.

Dr. Grant Brown (Department of Biology), Vice-Chair, Animal Research Ethics Committee

APPENDIX B

BEHAVIOURAL DATA COLLECTION METHODS

I used several methods to collect behavioural data on river otters: *ad libitum* sampling and scan samples. *Ad libitum* sampling involves recording maximum number of observations and behaviours when the focal species is encountered, while scan sampling is more systematic and involves determining a specific time interval and recording locations and/or behaviours of individuals at the pre-determined interval (Altmann 1974). When river otters were observed, an *ad libitum* sample was initiated and the river otter was continuously observed and recorded, using a Sony FDR-AX43 4K video camera, until the river otters were out of sight (OOS) for a period of time at which point the sample was terminated. During these samples, every behavior and social interaction was recorded, including the portion of the sample for which the individual was out of sight (Altmann 1974). These methods vary in the type of behavioural information that can be collected. *Ad libitum* sampling involve both state behaviours such as walking, which are measured as a time, and event behaviours such as scratching, which are considered instantaneous and therefore, the frequency of these behaviours are recorded as opposed to the duration (Altmann 1974). In contrast, scan sampling only involves the recording of state behaviours (Altmann 1974). In this study, state behaviours were recorded during the coding process.

During the video recordings I narrated the behaviour and interactions (if applicable), to simplify the data extraction process later on. If more than one individual was present, I noted the number of individuals present and if possible, record the entire group. An ethogram was used to code river otter behaviour displayed during the behavioural observations. The ethogram used was adapted from existing ethograms for captive otters. The ethogram was largely based on the ethogram described in Packard and Ribic (1982), with adaptations from ethograms used in captive contexts for common otters (*Lutra lutra*) by Azevedo et al. (2015) and in Asian small clawed otters (*Aonyx cinereus*) by Cuculescu-Santana et al. (2017). The ethogram from Packard and Ribic (1982) was applied to *Enhydra lutris,* however, it provided an extensive initial ethogram of general otter (i.e., Lutrid) behaviour in the categories of grooming and resting, locomotion, feeding, and social interactions. This ethogram provided a strong basis to which species-specific behaviours for river otters could be added, if and when they arose.

APPENDIX C

ETHOGRAM OF BEHAVIOURS

Category	Behaviour	Code	Definition	Source
Social	Chase	Ch	"Rapid swimming; one otter behind another"	Packard & Ribic (1982)
	Deviate	De	"The animal swerves from the other, moving the body or even take a few steps back."	Azevedo et al. (2015)
	Escape	Es	"The animal quickly moves far away from the other otter."	Azevedo et al. (2015)
	Fight/aggression	Fi	"Rough fighting or other aggressive displays towards another otter;"	Cuculescu-Santana et al. (2017)
	Social grooming	Gr	"Grooming another otter (using paws or mouth to clean, dry or smooth fur);"	Cuculescu-Santana et al. (2017)
	Mutual porpoise	Mp	"Porpoise as described under locomotion; synchronously or in close sequence with a partner moving in same direction"	Packard & Ribic (1982)
	Mate	Mt	"Male places itself on top of the female, involving her with the anterior limbs and biting her on the neck. Female can also show this behavior."	Azevedo et al. (2015)
	Riding	Ri	"The otter places its body on the belly of another otter, by swimming up slowly or by rolling sideways onto its partner; the other otter may move away or remain stationary Low intensity: front half of body covers head and front half of partner's body High intensity: full body contact"	Packard & Ribic (1982)
	Play	Pl	(1) "Non-aggressive playful interaction with another otter, including play fighting," (2) "Male and female involve with each other physically. They can roll entangled, smell, touch, push, grab, rub in each other or on the ground."	(1) Cuculescu-Santana et al. (2017) (2) Azevedo et al. (2015)
	Play with object	Po	"Non-aggressive playful interaction […] with an object other than food, e.g. pebble, plastic toy"	Cuculescu-Santana et al. (2017)
	Smell	Sm	"The animal directs its snout to the mate with smooth vertical oscillations, at a very close distance, sometimes touching the other animal."	Azevedo et al. (2015)
	Rub	Rb	"The animal leans on the other animal's body and can move smoothly against the other."	Azevedo et al. (2015)
	Wrestling	Wr	"In a vertical position, two otters actively grasp each other with forearms around the head and shoulders, then twist to break the hold"	Packard & Ribic (1982)
	Drink	Dr	Drink water	
	Forage Feed	Ff	(1) "Moving on land with the head down and the nose close to the ground, interpreted as searching	(1) Cuculescu-

Feed			for food;" (2) "The animal is standing on the four limbs or lying with belly down and the head up. Both anterior limbs hold the food on the floor. The otter moves the head to reach the food and eat."	Santana et al. (2017) (2) Azevedo et al. (2015)
	Forage feed while walking	FfWa		
	Periscope	Pe	"Only the shoulders and head are visible above the water, as the otter takes a few seconds to "look around"; usually precedes a high-intensity dive"	Packard & Ribic (1982)
	Provision Feed	Pf	Eat human food	
	Provision feed while walking	PfWa	Eat human food while walking	
	Pounding	Pn	"Rapid pounding movements are made onto the chest with or without an object held between the forepaws; a hard object may be balanced on the chest as the otter floats on its back; observer can often hear pounding"	Packard & Ribic (1982)
	Submerged	TS	"Body is totally submerged; the otter reappears at a short distance not in line with previous direction of movement"	Packard & Ribic (1982)
Move	Climb	Cl	"climbing on higher structures"	Cuculescu-Santana et al. (2017)
	Clapping	Cp	"The animal places itself on top of its posterior limbs, moving its anterior limbs against each other repeatedly. Sometimes the animal jumps slightly."	Azevedo et al. (2015)
	Dive	Di	"From a belly-down position, the otter submerges head then feet Low intensity: arching of the back is minimal High intensity: otter leaps out of water with arched torso clearly visible"	Packard & Ribic (1982)
	Dig	Dg	"The animal uses its anterior limbs, alternatively, from up-down and front-back, to open a hole in the ground. The otter is supporting the weight on the posterior limbs, leaning the body towards the floor, with the tail up or down. Sometimes, the animal may fall down, lying on the floor sideways or with the belly up, but soon returns to the original position."	Azevedo et al. (2015)
	Folding dive	Fd	"From a belly-up position, the rear feet and shoulders move toward the center of the body and the otter sinks backward into the water"	Packard & Ribic (1982)
	Porpoising	Pp	"As the otter swims just below the surface, the arched back repeatedly appears on the surface; general movement is in the forward direction as contrasted with a feeding dive Low intensity: back just breaks the water surface High intensity: repeatedly the otter leaps out of the water with back arched in an inverted U"	Packard & Ribic (1982)
	Rocking	Ro	"From a belly-up position, the otter does a side roll with torso arched such that the feet and paws remain out of the water Low intensity: otter rocks	Packard & Ribic (1982)

Move			180"from side to side High intensity: otter rolls 360"	
	Rub ground	Rg	"The animal leans on the ground moving smoothly the all body against the floor, sometimes coiling, but always moving forward. The body may be with the belly up, down or sideways."	Azevedo et al. (2015)
	Run	Rn	(1) "Faster locomotion on land" (2) "The animal moves quickly, slightly jumping, alternating the anterior with the posterior limbs."	(1) Cuculescu-Santana et al. (2017) (2) Azevedo et al. (2015)
	Rowing	Rw	"Floating belly-up, otter folds ventrally in a V shape then straightens; may be repeated; otter does not submerge"	Packard & Ribic (1982)
	Sidestroke	Se	"The otter moves along the surface on its side; one foot may be waved above surface and head may be oriented toward an object"	Packard & Ribic (1982)
	Sculling	Sg	"Belly-up, the otter moves along the surface propelled by movement of the tail and (or) feet"	Packard & Ribic (1982)
	Walk	Wa	"Slower locomotion on land"	Cuculescu-Santana et al. (2017)
	Swim	Swim	(1) "Locomotion in water, with the head in or out of water, including looking for food in the water;" (2) "Belly-down, the head and back are visible moving along the surface" (3) "The animal moves underwater or at the surface, with the belly up or down. At the surface, the otter slides moving the tail smoothly and sideways. When the belly is up, the animal is floating with the limbs still, the anterior ones resting on the body. With the belly down, one cannot say how the limbs are positioned, as well as the swimming underwater which does not allow to specify how the otter behaves."	(1) Cuculescu-Santana et al. (2017) (2) Packard & Ribic (1982) (3) Azevedo et al. (2015)
	Underwater swim	US	"Body is totally submerged, the otter reappears at a distance at a location in line with previous direction of movement"	Packard & Ribic (1982)
	Other movement	Other	Other movement behaviours that are not one of the specified behaviours	
	Examine other	ExOther	"examine object (stone, bottle, insect, whatever…): manipulates object with hands, looks, sniffs etc."	Brogan Granby Ethogram
	Examine water	ExWater	"examin[e] water: dabbling hands (or feet e.g. Ribbon) in water, making bubbles, swishing water around"	Brogan Granby Ethogram
	Float	Fl	"Otter floats belly-up on the surface, rear feet up, no sculling, feeding or grooming movements Low intensity: body motionless. High intensity: slight movement of paws, head, or feet."	Packard & Ribic (1982)

Individual	Groom self	Gs	"The animal licks, bites and scratches the fur."	Azevedo et al. (2015)
	Hanging	Ha	"Belly-down with both rear and head submerged; the arched back remains visible at the surface motionless for a few seconds as the otter apparently grooms its belly"	Packard & Ribic (1982)
	Inactive lie/sleep	Il	(1) "Lying down with head down, eyes open or closed; occasionally looking around when a noise occurs;" (2) "The animal is lying in a resting moment, with eyes open or closed. The body may be stretched or curled in fetal position. The otter may be lying on the side or with the belly up or down. The head may be laying on the body or on the floor, but if there is a strong noise, the otter may raise the head, resting again immediately after."	(1) Cuculescu-Santana et al. (2017) (2) Azevedo et al. (2015)
	Logroll	Lo	"From a belly-up position, the otter rotates to the side like a rolling log; differs from rocking in that feet and paws are submerged"	Packard & Ribic (1982)
	Rub self	Rs	"Rear feet rub some area of otter's own body Low intensity: both rear feet are rubbed slowly against each other in a "hand-washing" movement High intensity: rapid scratching movement of one foot directed toward back, neck, or side of body"	Packard & Ribic (1982)
	Stand bipedal	Sb	Stand on rear/hind limbs	
	Stand/still	Sd	"The animal is stopped, standing on the four limbs, with the belly touching the floor or not, staring fixedly in one direction or observing to the surrounding environment.”	Azevedo et al. (2015)
	Shake	Ak	"The animal oscillates very quickly its body, horizontally, starting from the neck towards the tail, to remove the water from its fur."	
	Scent marking	Sk	"Rubbing a body part against the ground, a structure or a wall”	Cuculescu-Santana et al. (2017)
	Somersault	So	"Full 360" forward roll with the head tucked close to the belly; often only the curved back is visible until the head reappears at the end of the roll"	Packard & Ribic (1982)
	Stroke	Sr	"Front paws repeatedly stroke some area of the otter's own body; may vary in intensity (rapidity of strokes); commonly directed toward: chest, head, rear feet, belly, tail, flank, back"	Packard & Ribic (1982)
	Sit	St		
	Sniffing	Sn	"The animal directs its snout, with smooth vertical oscillations, to the air, ground or other stimulus."	Azevedo et al. (2015)
Individual	Spraint	Sa	"The animal urinates and/or defecates."	Azevedo et al. (2015)
Mother-Infant	Clasp	Cs	"Female uses front arms to hold pup to her chest; the pup is usually clasped around the chest, neck or head and becomes limp"	Packard & Ribic (1982)
	Suckle	Su	"Pup has mouth in area of female's nipples Low intensity: suckling interrupted High intensity: continuous contact with nipples"	Packard & Ribic (1982)

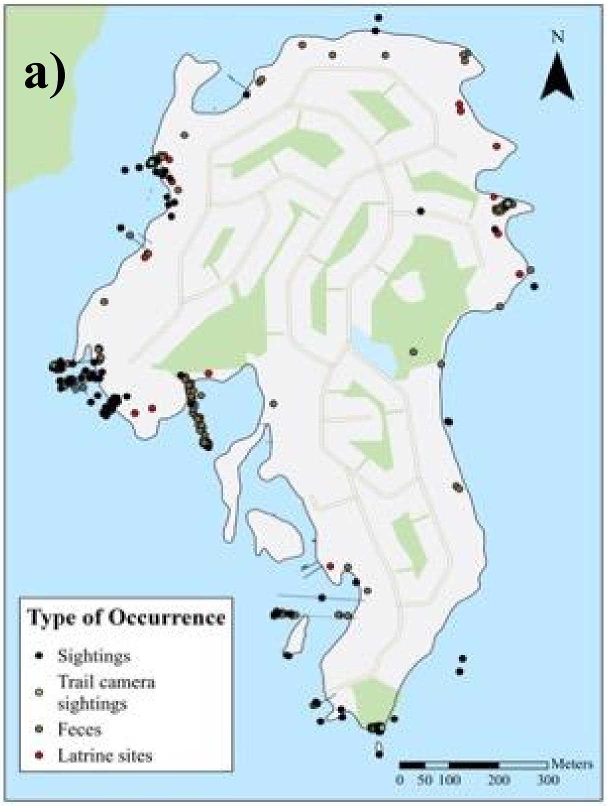
APPENDIX D

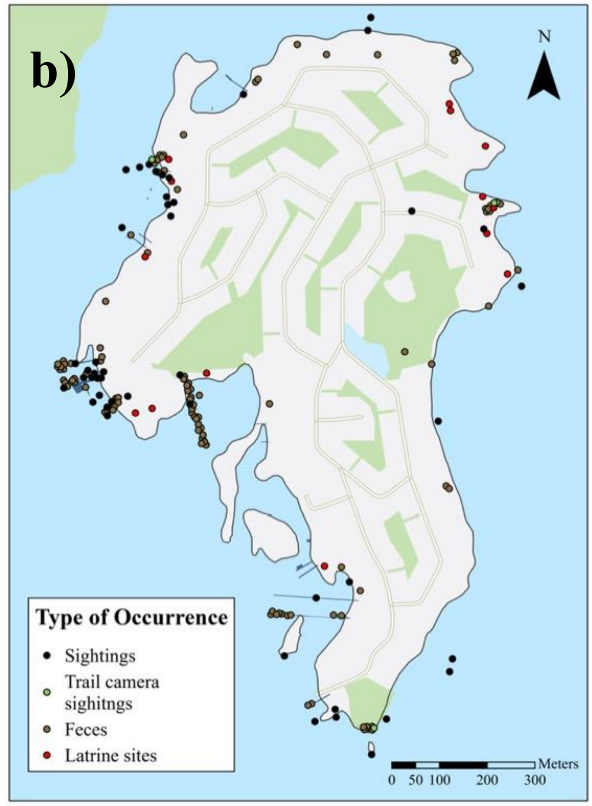
MAXENT RESULTS: SUBSET OF OCCURRENCES AND INCORPORATING A BIAS FILE

In addition to the two scenarios presented for the full set of occurrences in the above manuscript, a third scenario incorporating a bias file was evaluated for the subset of occurrence points described in this appendix. In this analysis, I separated these observations into a subset with the most verifiable occurrence points (i.e., data points obtained through direct researcher observation and trail cameras) and the occurrence points reported from other sources. The same analysis was conducted incorporating a subset of the occurrences that were more accurate, so sightings shared by residents and crabs eaten were removed from the model. I chose to do this to see whether models performed more poorly when occurrences that were less accurate were included, as sightings shared by residents were less specific in location and there was the possibility crabs may have been eaten by other animals. In this appendix, I present the results of the MaxEnt model for the three scenarios for the subset of occurrence points (Figure D-1a, D-1b, D-1c). The results presented in the above manuscript incorporate all occurrence types.

Full occurrence data: Scenario 3 (Bias File)

MaxEnt can apply the same spatial bias in the occurrence points to the selection of background points used in the model by incorporating a bias file that reflects this spatial bias (Kramer-Schadt et al. 2013). This allows "both presences and background samples [to] have the same bias" when executing the MaxEnt models (El-Gabbas and Dormann 2018, p. 1162). The bias files were created to address the spatial sampling bias using the Gaussian Kernel Density of Sampling Localities tool in SDMtoolbox in ArcGIS Pro version 3.0.3 with a sampling bias distance of 50 meters (Brown 2014; Esri Inc. 2022). This allowed MaxEnt to select background points with the same bias as the occurrence data, where occurrence points further from others in space have higher weights than those in close proximity to other points or clusters of points (Brown 2014).





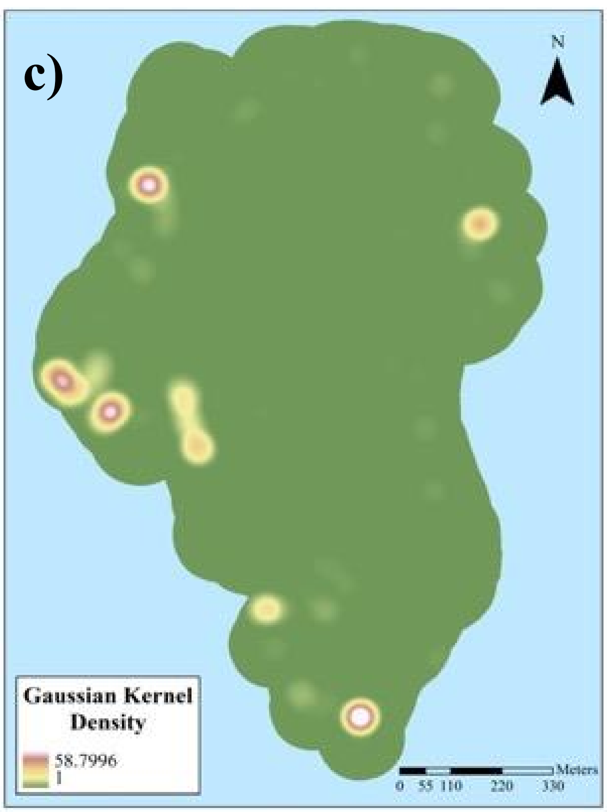


Figure D-1-Maps of occurrence points used in MaxEnt analysis with the accurate subset of occurrence points for a) Scenario 1 using all occurrence points (N = 546), b) Scenario 2 using the spatially rarefied occurrence points (N = 169), and c) using the bias file.

Results

Habitat suitability for river otters on PI

The average AUC for Scenario 1, using the full set of occurrence points, was 0.917 after 10 replicates (Figure D-2). The average AUC for Scenario 2, using the spatially rarified occurrence data, was 0.894 after 10 replicates (Figure D-3). The average AUC for Scenario 3, using the bias file, was 0.878 after 10 replicates (Figure D-4).

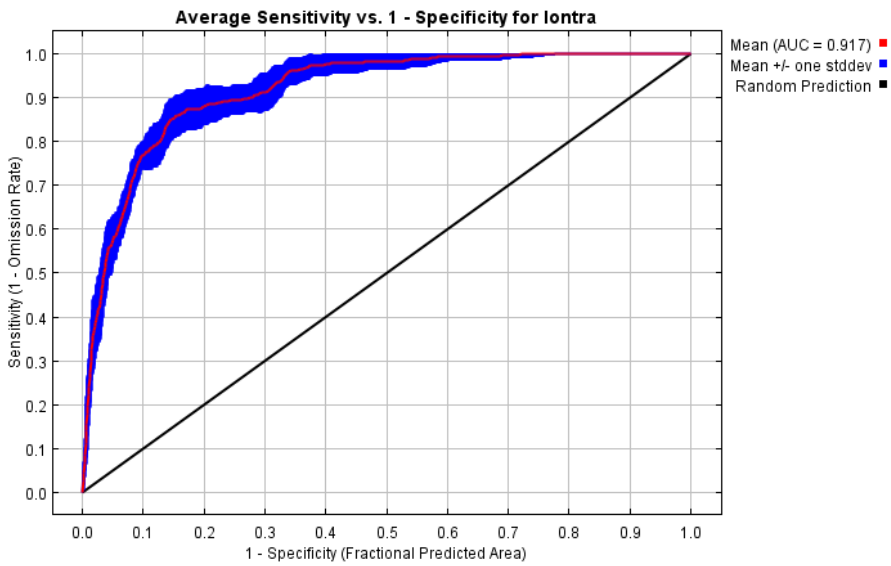


Figure D-2- MaxEnt model evaluation for Scenario 1 using the full subset of more accurate occurrences.

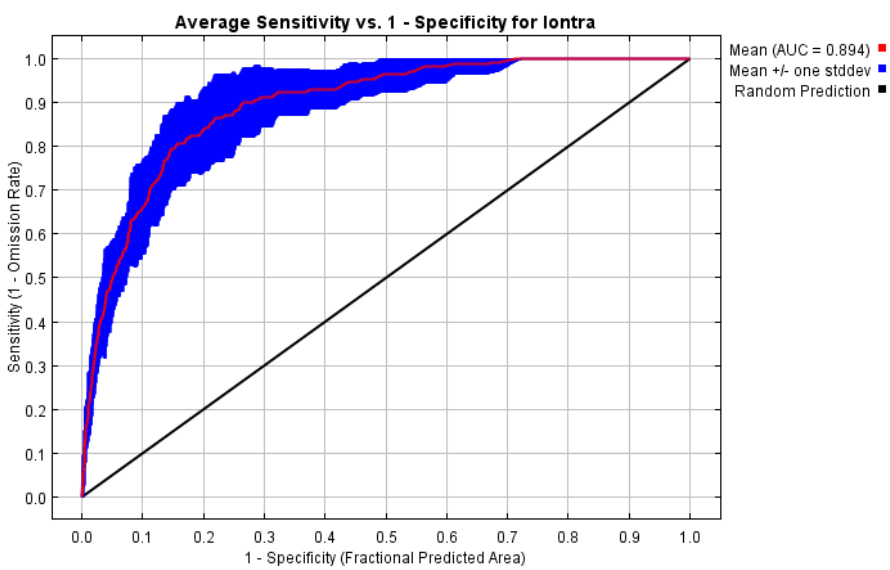


Figure D-3-MaxEnt model evaluation for Scenario 2 using the spatially filtered more accurate occurrences.

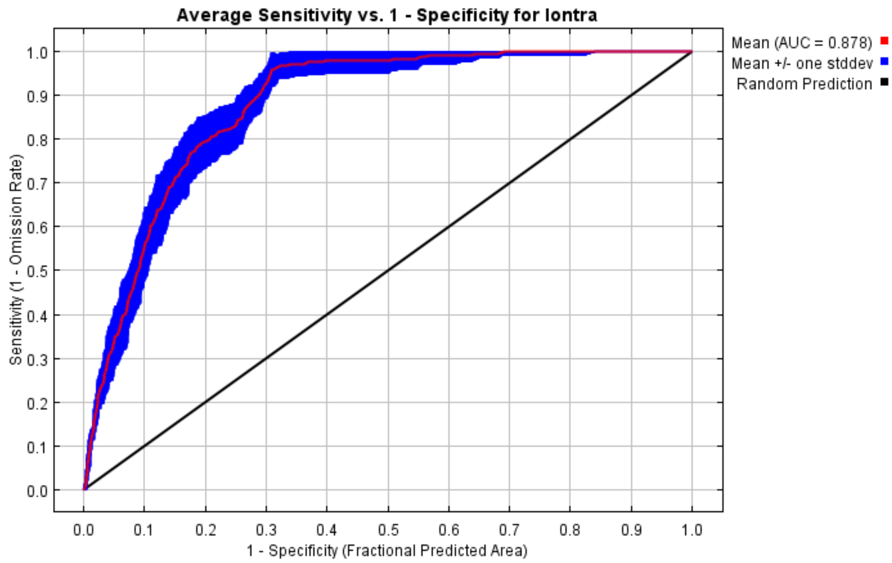


Figure D-4-MaxEnt model evaluation for Scenario 3 using the bias file with the subset of more accurate occurrences.

Environmental Predictor Variable Contributions

The most important variables for habitat suitability, as indicated by the models, were distance to dens, level of human use of docks, and density of driftwood for the full set of occurrences (Scenario 1; Table D-1). These factors contributed 37.1%, 16.3%, and 15.6% respectively to the model. For the spatially filtered model, the most important variables were distance to dens, level of human use of docks, and distance to water and wetlands (Table D-1). The percent contribution of these variables to the model were 26.8%, 19.7% and 16% respectively. The most important variables contributing to habitat suitability using the bias file (Scenario 3) were the elevation, the distance to water or the wetland, and level of human use of docks with contributions of 29.3%, 25.7% and 16.5%, respectively (Table D-1).

The remaining predictor variables contributed far less individually to suitability, in total accounting for 31%, 37.6%, and 28.4% respectively for each scenario. The remaining anthropogenic predictors variables (distance to buildings and roads, level of human use of parks, and level of human use of trails) contributed just 5.4%, 6.4% and 10.9% respectively to each scenario (Table D-1).

Table D-1. Percent contributions of predictor variables to MaxEnt models for the three scenarios

Variable	Percent contribution Scenario 1 (Full occurrences)	Percent contribution Scenario 2 (Spatially filtered)	Percent contribution Scenario 3 (Bias file)
Distance to dens	37.1	26.8	4.1
Docks (LHU)	16.3	19.7	16.5
Density of driftwood	15.6	15.8	3.5
Distance to water/wetland	14.3	16	25.7
DEM	7.3	10.5	29.3
Distance to buildings & roads	4.6	6.3	9.9
Substrate type	3.2	4.5	8.8
Parks (LHU)	0.8	0.1	1
Land cover class	0.8	0.4	1.1
Trails (LHU)	0	0	0

Responses to individual predictor variables

Scenario 1: Full occurrence set

The models indicate that the probability of river otters finding suitable habitat is highest close to the sites where dens are present, then sharply declines up to a distance of 100 meters (Figure D-5a). The probability of finding suitable habitat then remains relatively stable between the distances of approximately 100 meters and 700 meters, before increasing up to a distance of 800 meters and then declining (Figure D-5a). For the level of humans use on docks, the level of suitability was consistent across all levels of human use and was considered highly suitable (Figure D-5b). Lastly, the probability of finding suitable habitat increases to intermediate densities of driftwood before declining steadily at higher densities of driftwood (Figure D-5c).

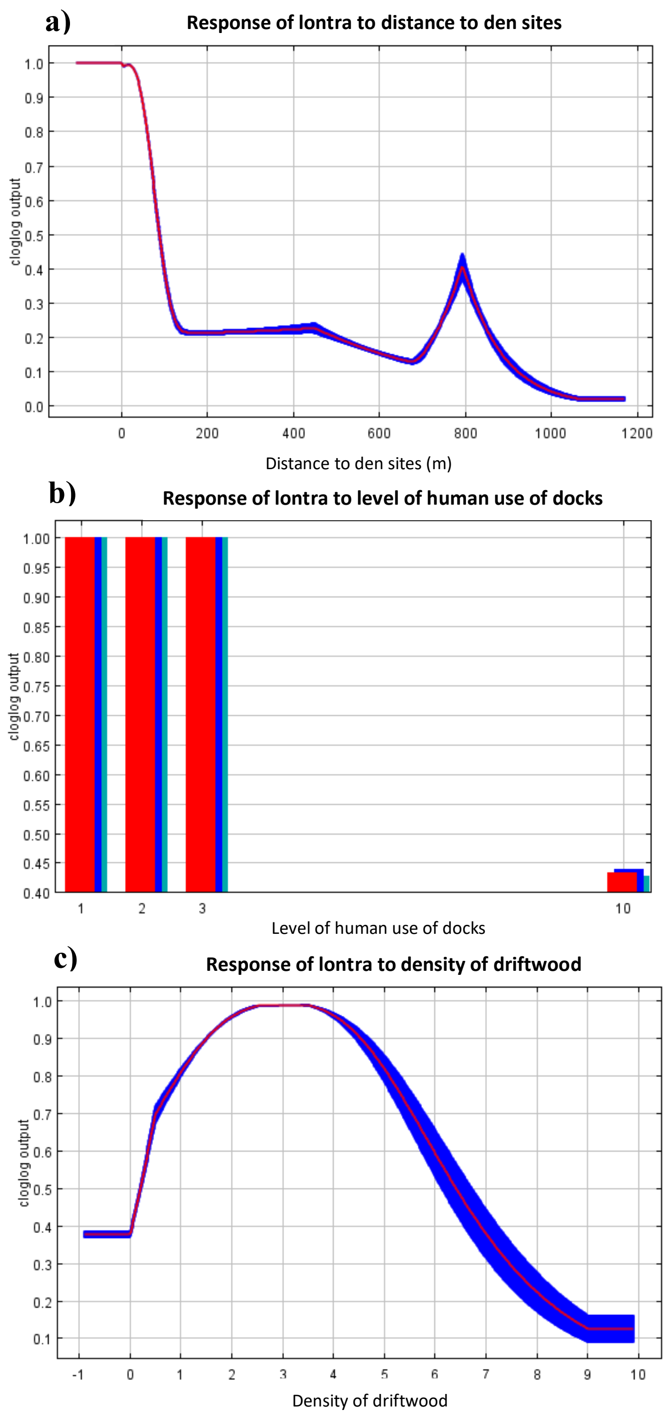


Figure D-5-River otter responses to the three most important predictors of suitability for Scenario 1, a) distance to dens, b) level of human use of docks, and c) density of driftwood. In b), the value 10 represents the category of non-dock areas which are not attributed a level of human use for docks The red lines for the continuous variables and bars for the categorical variables represent the mean response of the individual predictor variable for the 10 replicates performed in this analysis and the blue represents +/- one standard deviation from the mean response for the same replicates (Araújo et al. 2021, supplementary material).

Scenario 2: Spatial filtered at 5m resolution

When occurrence points have been spatially rarefied to 5 meters, the models indicate that the probability of river otters finding suitable habitat is highest close to den sites, then sharply declines up to a distance of 100 meters, and subsequently plateaus up to a distance of 1000 meters (Figure D-6a). Beyond 1000 meters, the probability of finding suitable habitat declines briefly at 1050 meters before remaining stable beyond this distance (Figure D-6a). For the level of humans use on docks, the level of suitability was consistent across all levels of human use and was considered highly suitable (Figure D-6b). Lastly, these models indicate that the probability of finding suitable habitat is highest up to a distance of 25 meters from water or wetlands, at which point suitability declines to a distance of 125 meters and then remains stable at distances beyond 125 meters (Figure D-6c).

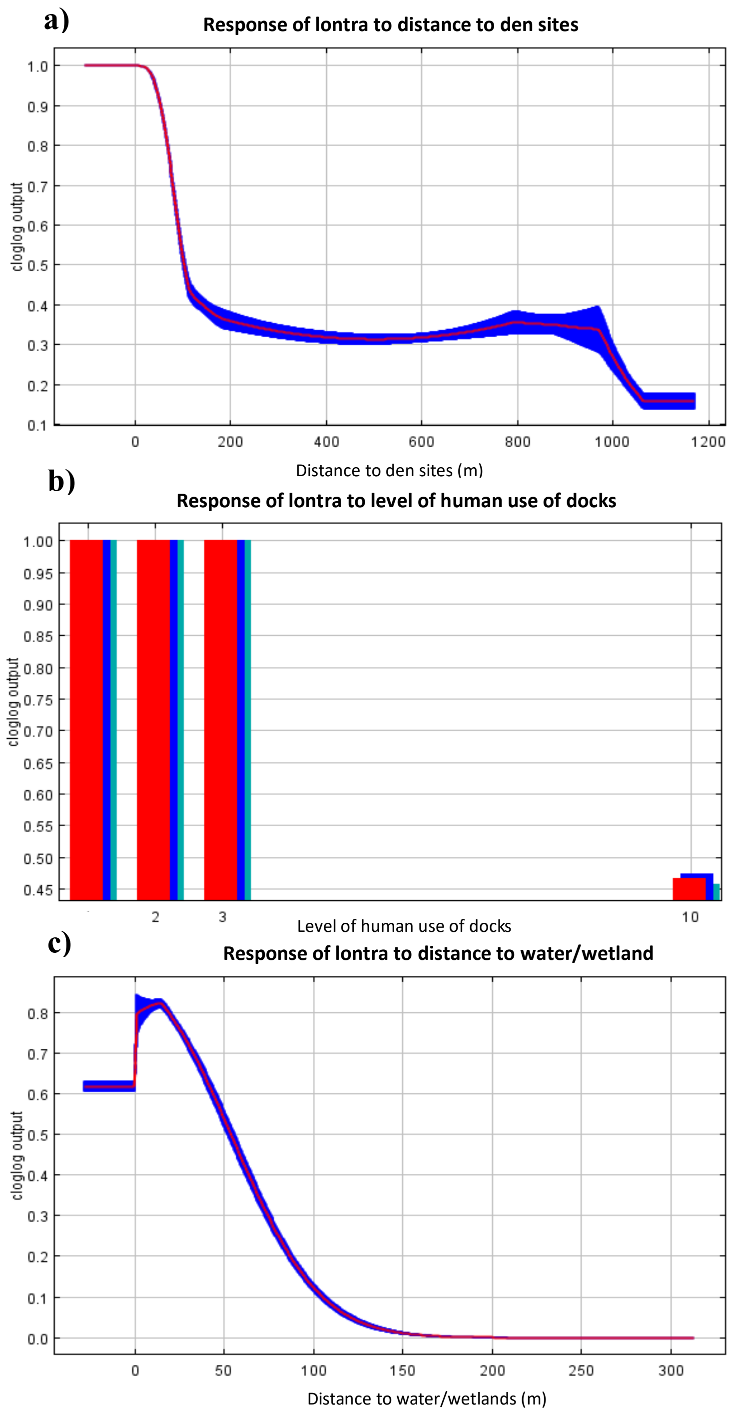


Figure D-6- River otter responses to the three most important predictors of suitability for Scenario 2, a) distance to dens, b) level of human use of docks, and c) distance to water or wetland. In b), the value 10 represents the category of non-dock areas which are not attributed a level of human use for docks. The red lines for the continuous variables and bars for the categorical variables represent the mean response of the individual predictor variable for the 10 replicates performed in this analysis and the blue represents +/- one standard deviation from the mean response for the same replicates (Araújo et al. 2021, supplementary material).

Scenario 3: Bias file
When using the bias file to account for spatial bias, these models indicate that the probability of river otters finding suitable habitat increases from approximately 2 meters below sea level to 3 meters above, then declines up to an elevation of approximately 11 meters, before stabilizing at elevations beyond 11 meters (Figure D-7a). Further, these models indicate that the probability of finding suitable habitat is highest close to water or wetlands, and declines steadily as distance from water or wetlands increases. (Figure D-7b). Lastly, all levels of human use on docks were considered highly suitable, however, the intermediate level of human use was slightly more suitable than the highest and lowest levels of use on docks (Figure D-7c).

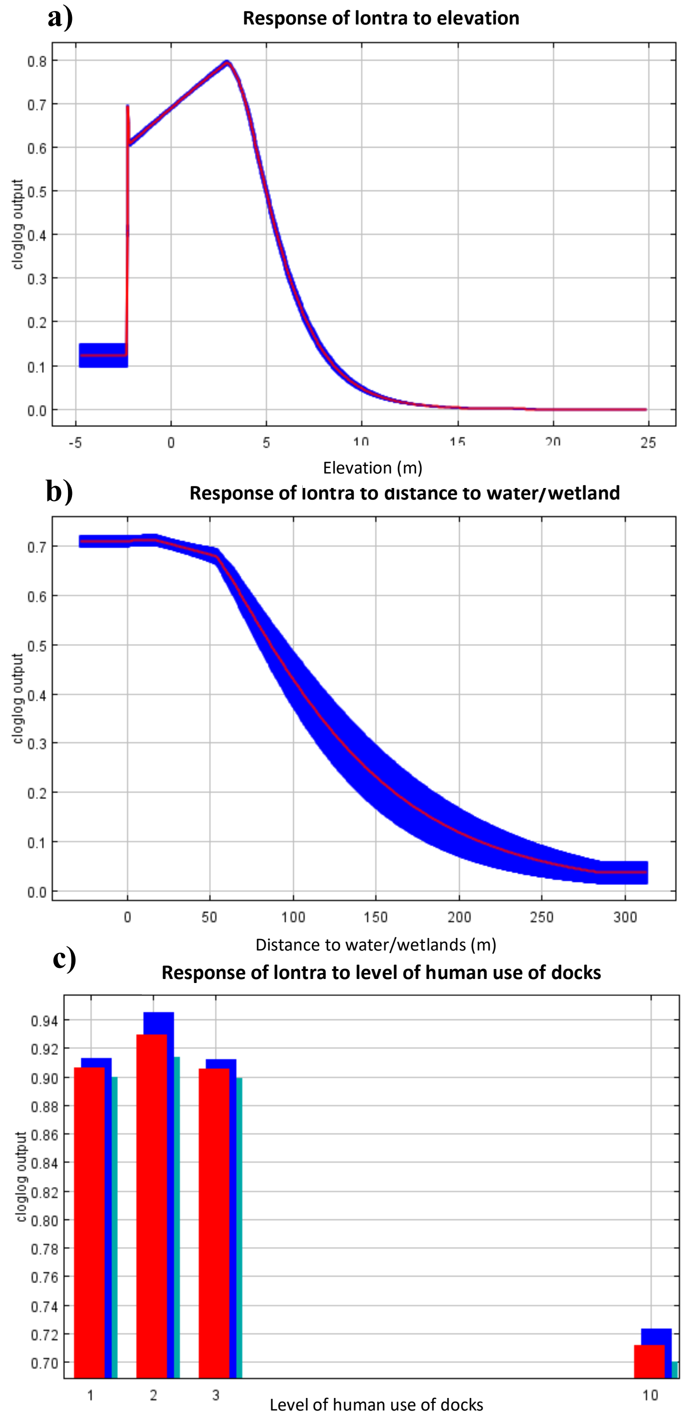


Figure D-7-River otter responses to the three most important predictors of suitability for Scenario 3, a) elevation, b) distance to water or wetland, and c) level of human use of docks. In c), the value 10 represents the category of non-dock areas which are not attributed a level of human use for docks. The red lines for the continuous variables and bars for the categorical variables represent the mean response of the individual predictor variable for the 10 replicates performed in this analysis and the blue represents +/- one standard deviation from the mean response for the same replicates (Araújo et al. 2021, supplementary material).

Habitat suitability

Using equal interval classifications

Using the full set of occurrence points (Scenario 1) indicated that 86.91 % of habitat was unsuitable, 8.53 % had low suitability, 3.23 % was moderately suitable and 1.32 % was highly suitable (Table D-2, Figure D-8a). When the occurrence points were filtered at a resolution of 5 meters (Scenario 2), 78.94 % of habitat was unsuitable, 12.76 % had low suitability, 5.43 % was moderately suitable and 2.87 % was highly suitable (Table D-2, Figure D-8b). Lastly, when using the bias file (Scenario 3), 48.34 % of habitat was unsuitable, 18.0 % had low suitability, 26.90 % was moderately suitable and 6.76 % was highly suitable (Table D-2, Figure D-8c).

Table D-2. Habitat suitability for river otters using equal interval classifications, as indicated by area

Suitability	Scenario 1 (Full occurrences)		Scenario 2 (Spatially filtered)		Scenario 3 (Bias file)	
	Area (%)	Area (m^2)	Area (%)	Area (m^2)	Area (%)	Area (m^2)
Unsuitable (0.00 - 0.25)	86.91	1,058,007	78.94	961,050	48.34	588,513
Low (0.25 - 0.50)	8.53	103,897	12.76	155,326	18.0	219,089
Moderate (0.50 - 0.75)	3.23	39,333	5.43	66,051	26.90	327,413
High (0.75 - 1.00)	1.32	16,097	2.87	34,907	6.76	82,319

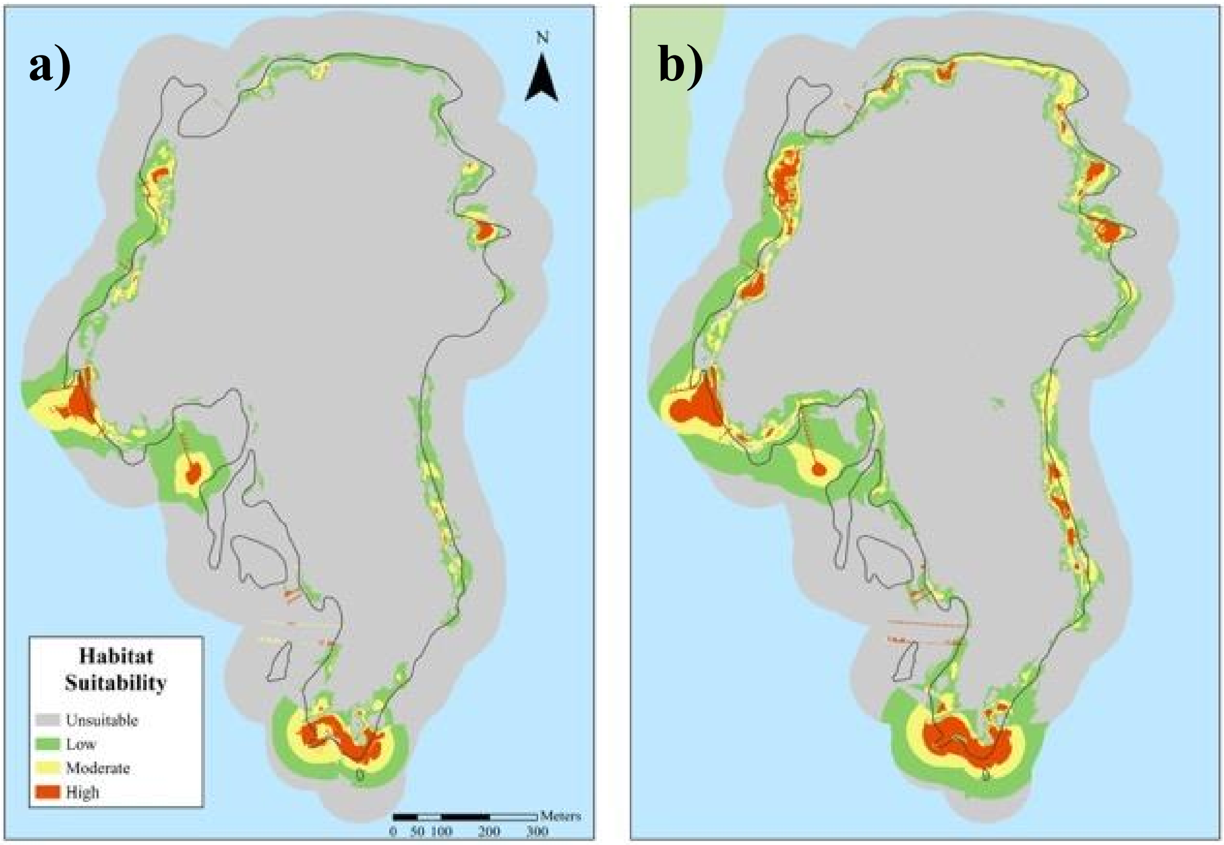


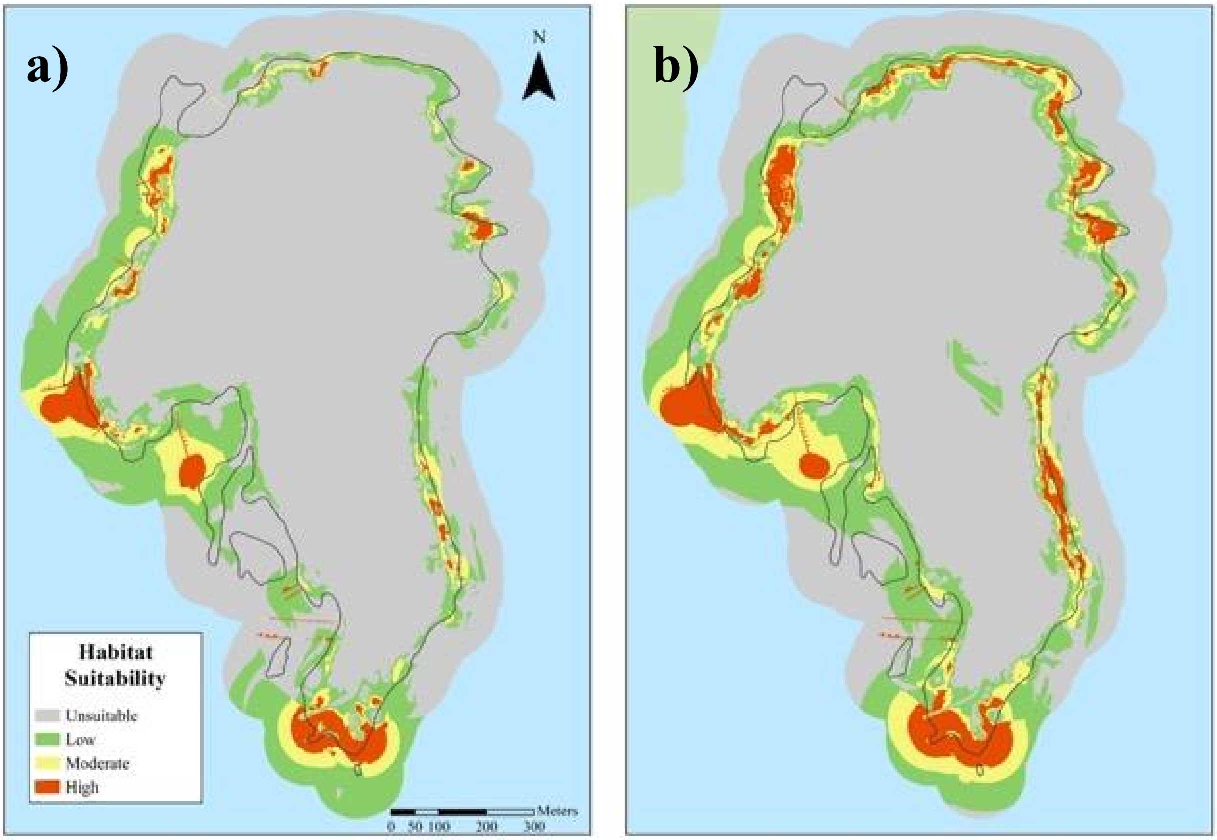
Figure D-8-Habitat suitability for river otters on Protection Island based on the MaxEnt analysis using the subset of more accurate occurrences, and using equal interval classifications for a) Scenario 1 (full occurrences), b) Scenario 2 (spatially rarefied), and c) Scenario 3 (bias file).

Using proposed thresholds based on Jenks natural breaks

When using the proposed classifications based on Jenks Natural breaks and the full set of occurrence points (Scenario 1), these results indicated that 74.47 % of habitat was unsuitable, 17.13 % had low suitability, 5.40 % was moderately suitable and 2.99 % was highly suitable (Table D-3, Figure D-9a). When the occurrence points were filtered at a resolution of 5 meters (Scenario 2), 66.76 % of habitat was unsuitable, 18.81 % had low suitability, 8.98 % was moderately suitable and 5.45% was highly suitable (Table D-3, Figure D-9b). Lastly, when using the bias file (Scenario 3), 37.58 % of habitat was unsuitable, 18.44 % had low suitability, 16.84% was moderately suitable and 27.14 % was highly suitable (Table D-3, Figure D-9c).

Table D-3. Habitat suitability for river otters using proposed classifications, as indicated by area

Suitability	Scenario 1 (Full occurrences)		Scenario 2 (Spatially filtered)		Scenario 3 (Bias file)	
	Area (%)	Area (m^2)	Area (%)	Area (m^2)	Area (%)	Area (m^2)
Unsuitable (0.00 - 0.135)	74.47	906,589	66.76	812,694	37.58	457,531
Low (0.135 - 0.35)	17.13	208,587	18.81	228,965	18.44	224,446
Moderate (0.35 - 0.6)	5.40	65,730	8.98	109,297	16.84	204,949
High (0.6 - 1.00)	2.99	36,428	5.45	66,378	27.14	330,408



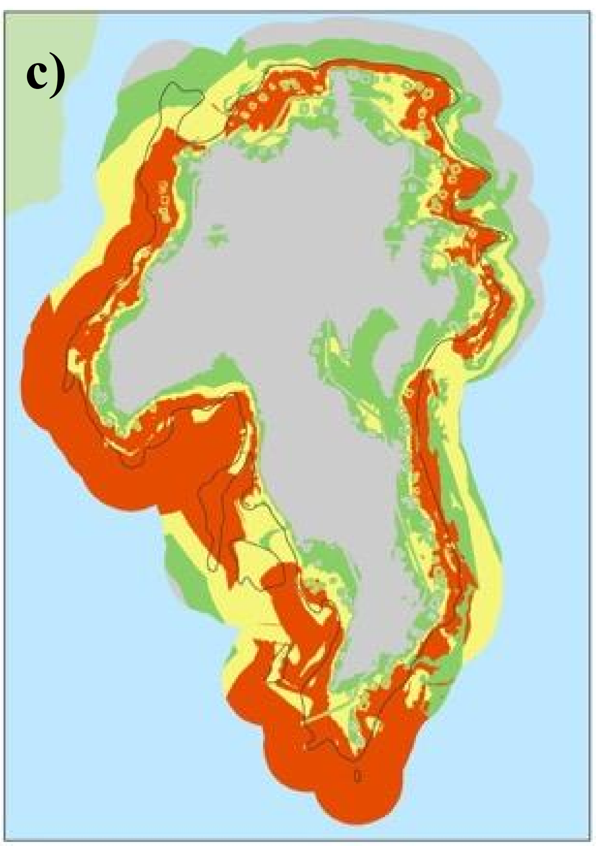


Figure D-9-Habitat suitability for river otters on Protection Island based on the MaxEnt analysis using the subset of more accurate occurrences, and using the proposed new classifications for a) Scenario 1 (full occurrences), b) Scenario 2 (spatially rarefied), and c) Scenario 3 (bias file).