PATTERNS OF NORTHERN RIVER OTTER (*LONTRA CANADENSIS*) HABITAT SELECTION, DIEL ACTIVITY, GROUP SIZE AND ACTIVITY AT LATRINE SITES IN NEWFOUNDLAND, CANADA

by © Chelsey Lawrence

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Abstract

I investigated the presence and activity of northern river otters (*Lontra canadensis*) at latrines in relation to anthropogenic disturbances. I examined the validity of spraints as an index for latrine use and determined if diel activity or group size was related to anthropogenic disturbance. Latrine data were collected using boat surveys, and motion-activated camera traps were used to observe otter activity and group size. I found that disturbances such as logging, cabins or roads, did not differ between the locations of northern river otter latrine sites. However, the level of activity was higher at latrines that were distant from them. I found that spraint counts are not a good index for latrine use intensity, but there is potential for them to be useful when investigating otter abundance within a large landscape. Diel patterns of otters were not influenced by disturbances, but overall amount of activity was low in areas with disturbances meaning otters tend to avoid latrines in such areas.

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Chapter 1

General Introduction

1.1 Background

The northern river otter (*Lontra canadensis*; hereafter river otter), is a member of the weasel family (Mustelidae; Kruuk 1995). One of 13 extant otter species in the world (Kruuk 1995), they have a range extending throughout North America, inhabiting inland waterways and coastal areas in Canada, the Pacific Northwest, the Atlantic states, and the Gulf of Mexico (Toweill and Tabor 1982).

Living up to 13 years of age in the wild (Melquist and Dronkert 1987), both males and females reach sexual maturity at around 2 years (Hamilton and Eadie 1964). Breeding usually occurs from December to April (Hamilton and Eadie 1964) with gestation usually lasting from 61-63 days (Melquist and Hornocker 1983). Litter size usually ranges from one to three (Hamilton and Eadie 1964; Tabor and Wight 1977).

Mustelids are among the least social of carnivores (Gittleman 1989), however there is notable social variation within Lutrinae. It has been found that the social behaviour of otters include groups of monogamous pairs (Ostfeld et al. 1989), large family groups (Proctor 1963), male groups (Arden-Clarke 1986), family groups with solitary males (Melquist and Hornocker 1983), mixed-sex groups (Duplaix 1980), as well as solitary individuals (Kruuk and Moorhouse 1991).

Home range and movement of otters have been described by a number of studies which utilized radio-telemetry techniques (Melquist and Hornocker 1983; Reid et al. 1994; Helon 2006). Home range can vary from 3 to 200 km along marine-coastline, riparian or lake habitats (Foy 1984; Reid et al. 1994).

Studies have suggested that the diet of the river otter consists mostly of fish (Melquist and Hornocker 1983; Cote et al. 2008), but also includes insects, small mammals, birds, clams, and snails (Cote et al. 2008; Toweill 1974; Melquist and Hornocker 1983; Larsen 1984). Dietary components of river otter are identified mainly by spraint (fecal) analysis. Spraint collection efforts are facilitated by the frequent usage of terrestrial sites.

Terrestrial sites are known as latrines (Durbin 1989; Kruuk 1992; Bowyer et al. 1995; Ben-David et al. 1998). They are sites that otters visit habitually to defecate, urinate or rest. The spraint serve as a means of intraspecific communication (Kruuk 1995). Most other areas used by otters are not used for feeding or denning, and otters seldom defecate in the water, therefore, latrine sites have high levels of otter activity and are used primarily for communication and social interactions (Rostain et al. 2003).

Scent marking serves multiple functions. Male and female social otters seem to scent mark for intra-group communication while solitary, non-social otters use scent marking for mutual avoidance (Ben-David et al. 2005). Some studies implicate scent marking as male-female communication for the advertisement of reproductive status (Kruuk 1992). Other hypotheses suggest that it signals the use and depletion of food patches in an area by otters (Kruuk 1992, 1995).

River otters are commonly found in both freshwater and marine ecosystems throughout North America. Throughout their distribution, river otters are a top predator in aquatic food webs (Toweill 1974) and as a result may play important roles in ecosystems as a keystone species (Bowyer et al. 2003). They are also sensitive to environmental disturbances and can be useful in measuring the health of an ecosystem (Bowyer et al. 2003). For example, Stevens et al. (2011) used river otters to determine the influence of habitat quality their detection rates.

On the island of Newfoundland, river otter habitats include a large portion of the provinces coastal regions. Along these coastal areas there are sections of human disturbances in the form of logging and cabin development. While the river otter population is not in jeopardy due to these anthropogenic disturbances, understanding how these types of disturbances impact river otters can provide greater insight and understanding to the biology of the species as well as provide crucial information the management of the species and the ecosystem.

Ecologists are increasingly concerned with the effects of human disturbances on ecosystem structure and function (Ben-David et al. 2005). Habitat fragmentation caused by human disturbance has long been suggested to be a major limiting factor in the distribution of mustelids (Harris 1984). Degradation and loss of natural habitats through habitat fragmentation and landscape development lead to population declines, extinctions and overall loss of biodiversity within natural ecosystems (Diamond 1989). Anthropogenic impacts are now widely accepted by ecologists as a key factor that can cause changes in an ecosystem's biodiversity, and in doing so alter its overall structure and function (Loreau et al. 2001; Cardinale et al. 2006)

Historically, extirpations of mammals from settled landscapes in North America have occurred through over-hunting, habitat loss and predator control (Kellert et al. 1996;

Lancaster et al. 2008). Moreover, the addition of stress due to an anthropogenic disturbance can force an ecosystem into a new equilibrium, making it difficult for conservation biologists to re-establish the historical range of the species and equilibrium of the ecosystem (Jackson et al. 2001).

River otter populations diminished significantly due to human intervention in the 19th and early 20th centuries, despite having few natural predators. By the 1970s their distribution had been reduced to only 25% of their historical range (Melquist et al. 2003). One of the main contributing factors to this range reduction was habitat loss. In North America, very large wetland areas were drained and destroyed for agricultural and developmental use, which in turn eliminated many high-quality habitats (Melquist et al. 2003). Riparian habitats and areas for dens and cover are vital components in a river otter habitat (Melquist and Hornocker 1983; Swimley et al. 1998); therefore the loss of such areas through development has negative consequences on otter populations.

Landscape use by otters has mostly been studied with radio-telemetry, track surveys or visual observations (Melquist and Hornocker 1983; Reid et al. 1987; Kruuk and Moorhouse 1990; Kruuk 1995). A common approach to determine the presence of otters within a landscape is surveying for latrines. Bowyer et al. (2003) suggested that otters transport nutrients into terrestrial systems when defecating at latrine sites. This nutrient transport helps to shape the composition of near-shore communities (Ben-David et al. 1998) and therefore their presence and use can be an important indicator not only for the health of the population, but for the ecosystem as well.

River otters require large areas and are sensitive to many anthropogenic influences such as water contamination, wetland drainage, human disturbance and overexploitation for fur (Duffy et al. 1993; Bowyer et al. 1995; Ben-David et al. 2001; Bowyer et al. 2003). As in the European otter (*Lutra lutra*; Prenda and Granado -Lorencio 1996), river otters must have ready access to food and water, and shelter from potential predators and harsh weather (Kruuk 1995).

As reported in Chapter 2, I aimed to investigate both river otter latrine presence and intensity of latrine use in relation to natural and anthropogenic landscape features. I used latrines and randomly selected sites combined with Geographic Information Systems (GIS) data to determine which habitat variables otters select to place latrine sites. I also used thermally triggered video cameras to quantify otter activity at latrine sites, and compared my findings to the same habitat variables to determine which variables otters select for when visiting sites. Information relating to latrine presence and intensity of use in relation to natural and anthropogenic landscape features would be beneficial to natural resource managers and foresters wishing to incorporate the habitat requirements of otters in their land-use decisions. Also, a better understanding of which landscape features influence otter behaviours and distribution may help improve or possibly limit biases associated with survey techniques for the species.

Removal of the majority of the forest cover by means of human influence, such as logging, is perceived both by biologists (Franklin 1995) and the general public (Wagner et al. 1998) to pose serious risks to the environment and most especially mammals. Changes are most apparent in the alteration of the surrounding vegetation; however changes in mammal population can be much less obvious, especially in some nocturnal species, whose presence is evident only by scent markings, track signs or trap captures (Gashwilder 1970).

The use of scat surveys is the most common method for assessing the distributions and abundances of animals due to its low cost (Palomares et al. 2002; Perez et al. 2006; Cossios et al.2007; Mondol et al. 2009; Ruell et al. 2009). Most knowledge about different species of otter is obtained from indirect signs, such as footprints and spraints (otter feces) deposited at these latrine sites. Spraint surveys consist of searches at latrines along the banks of bodies of water (Mason and Macdonald 1987; Reuther et al. 2000; Chanin 2003). However, the efficacy use of indirect signs to assess latrine-use intensity by otters is uncertain (Kruuk and Conroy 1987).

In chapter 3, my goals were to use both camera data and spraint counts to assess the reliability of otter scent marking behaviour (spraints) as an index of their abundance and latrine-use intensity. I also wanted to investigate desiccation rates of freshly deposited spraints, and attempted to identify a temporal period in which spraint surveys may be an accurate index for latrine use. The results of this study can help wildlife managers choose the most appropriate cost-effective method for assessing river otter latrine use and abundance. This can provide greater insight and understanding to river otter biology in terms of abundance, habitat use and rage, as well as provide crucial information to conservation and management of the species and the ecosystem.

Logging and other forms of landscape development can lead to changes in the abundance of mammals (Tevis 1956; Gashwiler 1970; Hooven 1973; Hooven and Black 1976). Some studies have found that small mammals remain rare, or even disappear altogether for up to 10 years, from an ecosystem following a logging event (Gashwiler 1967; Hooven 1969; Krefting and Ahlgren 1974). This is a problem because, due to the lack of available prey, predators that normally prey on these small mammals will have difficulty re-establishing in these areas.

In Chapter 4, my goals were to characterize diel activity patterns and group size in a protected, undisturbed landscape area, and compare them with those in a landscape altered by human activity. I also aimed to determine the relationship of diel activity of river otters to tidal patterns. I report on data collected by motion-triggered cameras to characterize diel activity patterns and group size in a protected, undisturbed landscape area, and I compare those data with data for a landscape altered by human activity. This information gives insight into river otter ecology and, by extension, allows biologists to better manage wildlife interactions and enables them to improve the design of surveys for monitoring populations.

Studying species in high-level trophic positions (such as river otters) is important for understanding the effects that human activity and disturbances, such as logging, has on ecosystem structure and function. As top-level predators they can act as an indicator species, allowing ecologists to attain a greater understanding about effects of anthropogenic changes on the study species and on the surrounding ecosystem as a whole (Estes et al. 2011).

1.2 Study area

I conducted my research along the marine coast in the vicinity of Terra Nova National Park, Newfoundland, Canada, in the areas of Clode Sound, Newman Sound, Alexander Bay and just outside of Freshwater Bay. All four study sites reside within Bonavista Bay (Fig. 1) on the island of Newfoundland. These waters are characterized by rocky headlands, intricate shorelines and numerous islands (Cote et al. 2008). The inland landscape of Bonavista Bay consists of a widely varied and rugged topography containing a dense boreal forest with rolling hills, wetlands, numerous ponds and lakes, and many freshwater streams.

This area's climate is typical of a boreal forest, consisting of short summers that are less than 4 months and long, cold winters lasting up to 6 months and with average temperatures below freezing. This area has regions with high levels of human activity such as logging and land development, in the form of cabins along the coast in the same area as the logging. There are also areas in close proximity to these disturbed areas that have little human development.

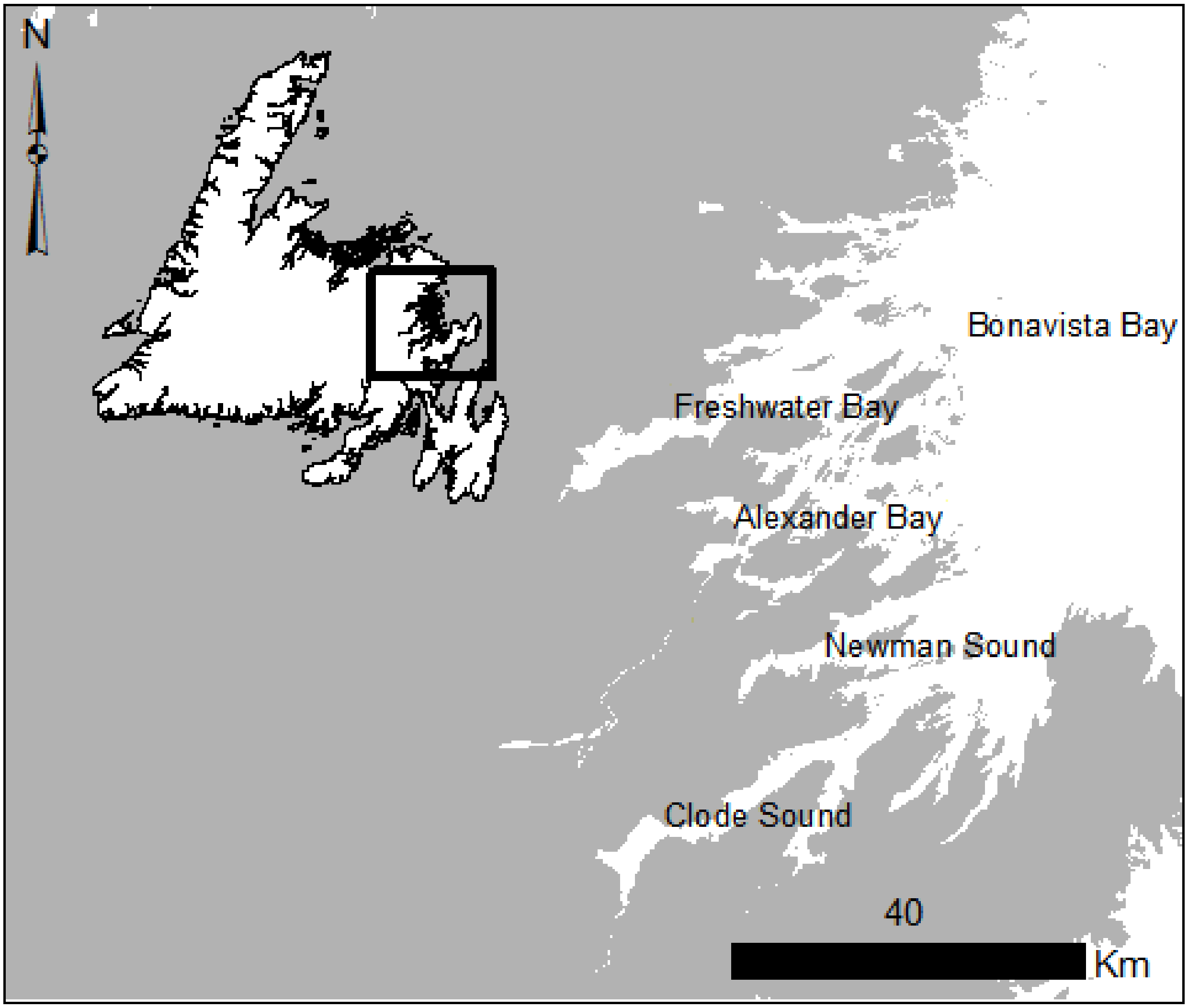


Figure 1.1. Map of northern river otter (*Lontra canadensis*) study sites in Bonavista Bay, Newfoundland, 2012-2013. Coastal areas of Alexander Bay and Clode Sound were used for camera data collection and spraint counts, while coastal areas of Newman Sound and the areas between northwestern Alexander Bay and eastern Freshwater Bay were only used for latrine placement and distribution.

Chapter 2

Latrine-site characteristics and patterns of latrine activity and preference in marine-coastal northern river otters (*Lontra canadensis*) in Newfoundland

2.1 Introduction

Animals select habitats based on multiple environmental features that reflect access to food, water, shelter and other important resources (Crowley et al. 2012) , while minimizing conditions that compromise survival (Brower et al. 1995). Knowledge of the mechanisms of habitat selection by animals is necessary to understand a species' requirements to live and thrive. This is especially important when considering how animals may be impacted in a negative manner and forced to change habitat selection methods based on nearby disturbances.

Like other species of otters, the northern river otter must have ready access to food and water, and to shelter from potential predators and harsh weather (Prenda and Granado-Lorencio 1996). Habitats where river otters hunt and seek shelter differ and are spatially separated from one another. As they are one of the few mammal species on the island of Newfoundland that have this habitat requirement, they are a unique species for study. Furthermore, the use of the linear shoreline by otters probably puts stress on their habitat requirements due to the limited availability of resources within these areas. River otters require large areas and are sensitive to diverse anthropogenic influences such as water contamination, wetland drainage, human disturbance and overexploitation for fur (Duffy et al. 1993; Bowyer et al. 1995; Ben-David et al. 2001; Bowyer et al. 2003). It is therefore predicted that otters would place latrines and visit them more frequently in areas that have enhanced access to key ecological requirements such as freshwater and foraging habitat, and distant from anthropogenic disturbances such as roads, logging and cabin development.

Most studies used methods such as radio-telemetry, track surveys or spraint surveys (Melquist and Hornocker 1983; Reid et al. 1987; Kruuk and Moorhouse 1990; Kruuk 1995) to determine habitat selection, activity patterns or group size. However, these methods are all indirect, and few have been in areas with human disturbance. My study focuses on investigating these aspects of river otter ecology in areas with and without anthropogenic disturbances using motion-triggered game cameras. This method allows for direct visual observations, and is a relatively inexpensive way to ground-truth other methods.

The river otter is an ecologically adaptable species that can inhabit diverse aquatic environments, from small freshwater stream and pond networks to extensive marine coastlines. Throughout their distribution, river otters are a top predator in aquatic food webs (Toweill 1974), feeding mostly on fish and small invertebrates (Cote et al. 2008) and as a result may play important roles in ecosystems (Bowyer et al. 2003; Cote et al. 2008). For example, demographic and behavioural indicators (population density, seasonal breeding, reproductive success, carrying capacity, foraging behaviour and local mortality rates) of the related European otter are affected by prey availability (Ruiz-Olmo et al. 2001).

Landscape use by otters has been studied using radio-telemetry, track surveys or visual observations (Melquist and Hornocker 1983; Reid et al. 1987; Kruuk and Moorhouse 1990; Kruuk 1995). Home range typically ranges in size from 3 to 200 km along coastlines, rivers or lakes (Foy 1984; Reid et al. 1994). An approach to determine the presence of otters is surveys of latrine sites. Latrines are sites that otters of different species visit habitually to defecate, urinate or rest (Kruuk 1995), and they serve as locations for intraspecific communication through deposition of urine, feces or anal-gland secretions

(Depue and Ben-David 2007). Otters also use latrines to rest and raise body temperature after swimming in cold water (Kruuk 1995).

Latrines are found within the riparian zones of lake, pond, river and coastal habitats. Typically several metres from the water's edge, they may be used extensively (Rostain et al. 2004); multiple latrine sites occur within an individual's home range (Bowyer et al. 1995; Kruuk 2006; Olson et al. 2008) and are shared by many individuals within a home range (Depue and Ben-David 2007). Identifiable properties of latrines are disturbed ground cover such as overturned earth and altered vegetation (e.g. presence of grass when moss should be present, which are sustained by frequent use by otters. Therefore, it is reasonable to assume that latrine presence and level of use reflect habitat use and quality (Melquist and Dronkert 1987; Depue and Ben-David 2007).

For example, nearby access to prey, and shelter from weather and predation, need to be present at a site for it to be selected as a latrine by the river otter (Melquist and Dronkert 1987). Other features have also been linked to the presence of latrine sites. Durbin (1993) found that European otters (*Lutra lutra*) preferred to set up latrines in areas with large boulders or gravel substrates versus areas with sandy or muddy bottoms. For the river otter, Crowley et al. (2012) found that in freshwater systems the presence, consistency and intensity of latrine activity were related to the distance to freshwater sources with greater amounts of certain types of vegetation for cover from predation.

Anthropogenic land use also has important effects on the placement of latrine sites. While habitat selection by European otters is greatly influenced by natural landscape features, the effects of human activity on their distribution is more disruptive and has a greater influence on otter habitat selection (Barbosa et al. 2001). Similarly, in river otters, natural factors are more important than anthropogenic ones in influencing habitat selection and use (Gallant et al. 2009). However, river otters avoid latrines close to anthropogenic disturbances (Brower et al. 1995). Nevertheless, if a latrine provides good access to prey and shelter from weather and predation, otters can tolerate some disturbance (Melquist and Hornocker 1983).

While previous studies investigating river otter presence and landscape use have provided great insight into their habitat selection, they have used techniques that did not allow for direct observation of the animals. I conducted a survey to investigate both latrine presence and intensity of use in relation to natural and anthropogenic landscape features using both boat surveys and camera traps to directly observe the species.

In Newfoundland, river otters are widespread across diverse habitats. Much of the island is not altered severely by urbanization, however, both industrial (e.g. commercial logging) and recreational (e.g. cabins) uses are widespread. In many cases, protected and working landscapes are in close proximity to one another and allow for the study of habitat use and responses to land use.

2.2 Methods

2.2.1 Data Collection

2.2.1.1 *Latrine presence*

Study area-I studied river otters in two marine-coastline areas in Newfoundland, Canada: (1) Clode Sound (48°33'3.31"N, 53°42'52.24"W; Fig. 2.1) and Alexander Bay (48°46'59.61"N, 53°53'57.45"W; Fig. 2.1). These sites were chosen for comparative purposes, as they differ in the nature and extent of human influence, and river otters are resident in both areas. A section of coast in Clode Sound is protected by Terra Nova National Park (TNNP), but also has regions of cabin development and landscape development where logging has occurred within the last four years. Similarly, Alexander Bay has coastal areas with substantial cabin development plus nearby logging, as well as other relatively undeveloped areas. Both areas have many small islands, rocky headlands, and intricate shorelines, all used by river otters.

Latrine survey-Coastlines were surveyed by boat for the presence of river otter latrines in Alexander Bay on 16 and 25 July 2012 and in Clode Sound on 5 and 7 August 2013. Surveys were done on days of good visibility with little to no wind, between 0900hr and 1600hr. A 19-foot aluminum boat with outboard engine was used, at a speed of ~10 km/hr. Latrine sites were visually identified along ~95 km of coastline. Areas with apparent disturbance of ground cover, slide trails leading into the water, altered vegetation (e.g. abundant grasses; Fig. 2.2) or evidence of nutrient enrichment (lichens on rocks) were surveyed from the vessel and identified as potential latrine sites. Each potential site was visited on foot to confirm the presence of otter scats and upon inspection, many were not used for the study. Identified latrines included those that were extremely conspicuous and others that consisted only of a narrow trail leading from the shoreline.

We landed at and inspected these sites, and judged them to be latrine sites if spraints (regardless of age) were found. Latrine sites were marked on a GPS and given a unique reference number. Additional latrine-site locations were available from surveys in previous years by TNNP staff and were combined with my survey dataset. If a latrine from the current data set was within 50 m of a latrine found by the TNNP staff, then only data on the most current latrine were used.

From the combined data, 154 latrines were found in Alexander Bay and 345 in Clode Sound (total coastlines surveyed for each area 95 km and 115 km respectively). Out of these latrines I chose 150 randomly in each area. I also chose 150 random points for comparison along each of the coastlines (ArcMap 10.2.2). Latrines and their access trails often extend across tens of metres of shoreline (Mason and McDonald 1986; Swimely et al. 1998). I therefore restricted selection of random points to areas beyond 50m of an established latrine.

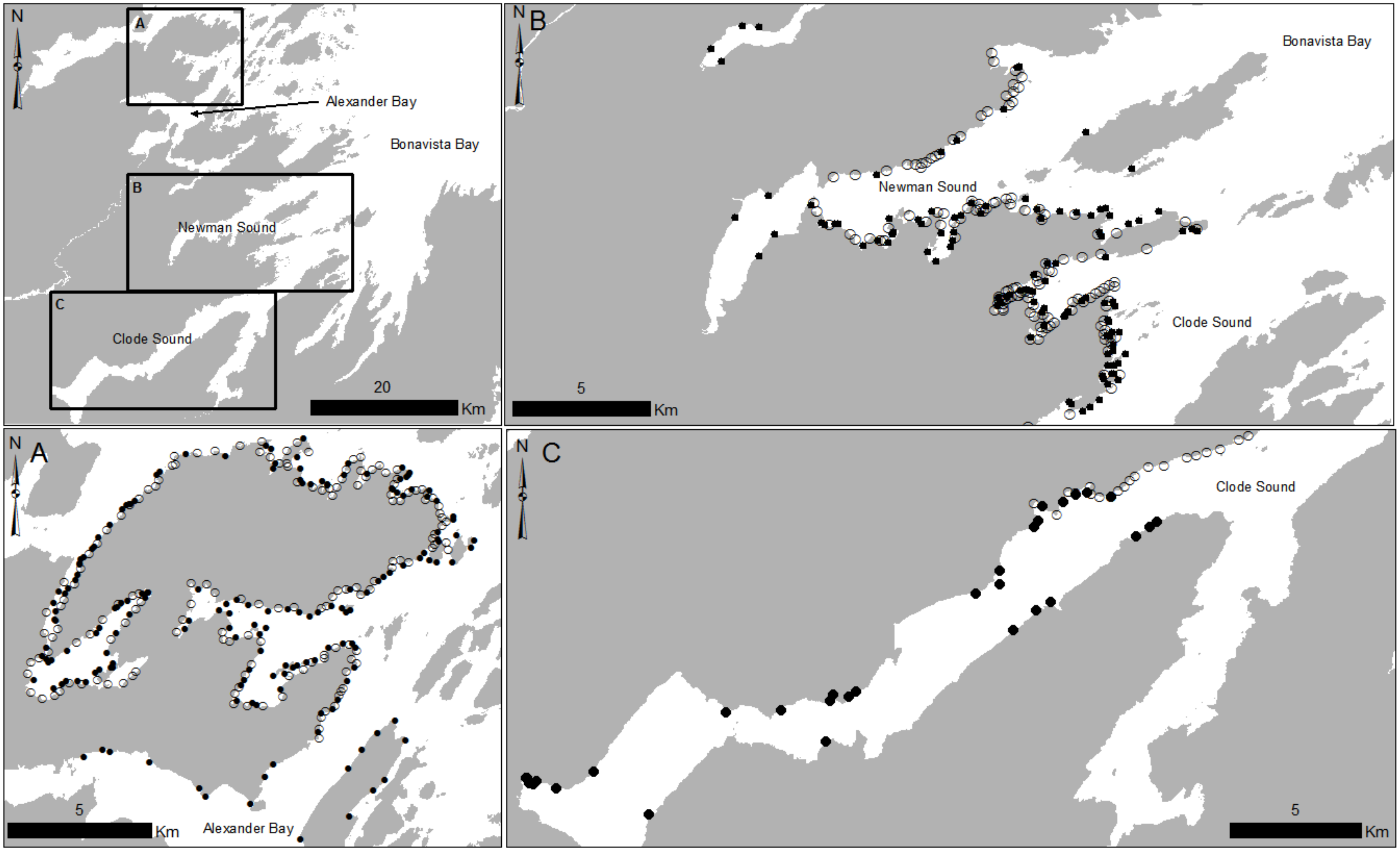


Figure 2.1. Locations of study sites used to investigate latrine presence in relation to habitat variables selected by marine-coastal northern river otters (*Lontra canadensis*) in A) Alexander Bay and Clode Sound (broken into (B) north and (C) south ends), Newfoundland, Canada. Dots represent locations of otter latrines and hollow circles represent randomly selected sites. Random sites did not cover the entirety of the surveyed coastline as additional latrines were added to the data set after the random sites were chosen.

Figure 2.2. Latrines (within circle) were identified as areas with disturbed ground cover such as overturned earth and altered vegetation (e.g. presence of grass when moss normally would be present).

I assessed selection of latrine sites by otters by comparing various habitat attributes to those of random points along the same coastlines. Habitat variables included those that reflected anthropogenic use, foraging potential or proximity to key ecological services (e.g. fresh water; Table 2.1). Otters typically forage in shallow water (less than 3m depth; Nolet et al. 1989) to maintain their fur's insulative qualities. Therefore, I delineated foraging areas based on the shallowest bathymetric interval available (6m).

Table 2.1. Habitat variables used to assess latrine-site selection and use by marine coastal river otters in Alexander Bay and Clode Sound, Newfoundland.

Variable acronym[1]	**Description**
droad	Distance to nearest road (m)
dfreshwater	Distance to nearest body of freshwater (m)
dcabin	Distance to nearest cabin (m)
dlogging	Distance to nearest logged area (m)
dstreammouth	Distance to nearest stream mouth (m)
foragingarea*	Area of water ≤ 6m deep (m^2) within a 50-m radius of the latrine

[1]In units of m or log m, as indicated by variable names.

* denotes variables omitted from full data set.

Habitat variables were measured for each latrine and random site using map data of the Newfoundland and Labrador Department of Natural Resources and Terra Nova National Park (Parks Canada), and were entered into Geographic Information Systems (GIS; ArcMap 10.2.2).

Some latrine and random sites lacked bathymetry data, so foraging areas for those sites could not be determined. Therefore, two data sets were created: the foraging-area data set (FAD): including only sites with all habitat variables including foraging area; and the full data set (FD), which included all sites but omitted the FAD variable *foragingarea*.

2.2.1.2 *Latrine activity and preference*

Study sites - A subset of Clode Sound and Alexander Bay study areas (Fig. 2.3) was available to assess intensity of use at latrine sites. Both areas have components with substantial cabin development and commercial logging operations adjacent to sections of coast that experience little anthropogenic impact.

I selected sites for intensity-use monitoring at random from 18 1-km long sections of coastline in each of Alexander Bay and Clode Sound.

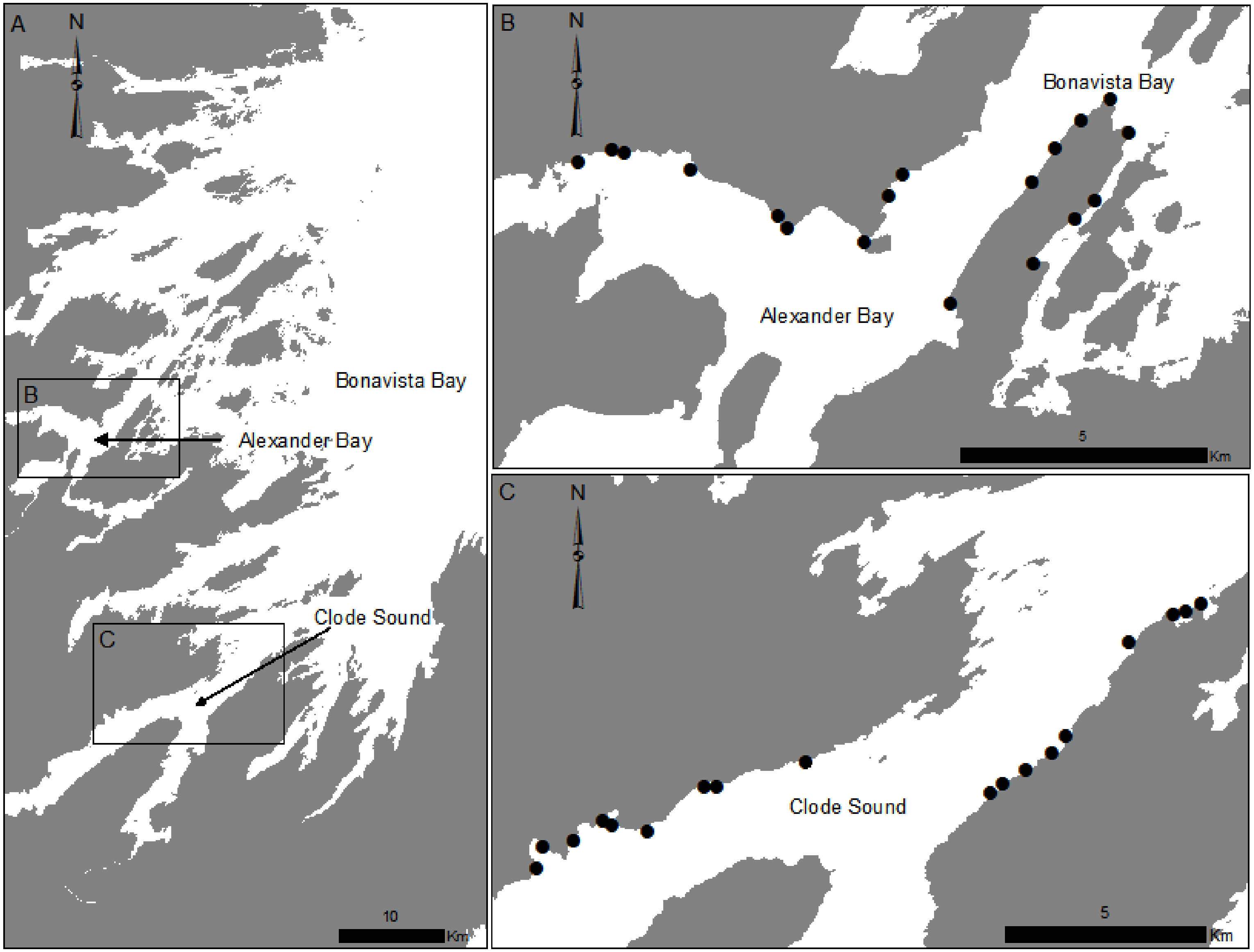


Figure 2.3. Locations of study sites used to investigate latrine activity and preference of northern river otters (*Lontra canadensis*) in Clode Sound and Alexander Bay, Newfoundland, Canada. Dots represent locations of latrines where cameras were placed.

Camera placement and data retrieval - Thirty-six Moultrie M-100 (Model number MFH-DGS-M100) and two Reconyx (Model # P800FE 12143459) cameras were deployed at latrines (Fig. 2.4). The infra-red cameras are triggered by motion; the Moultrie cameras first takes a photograph and then, after a 4-sec delay, record a 30-sec video; Reconyx cameras take photos only but, when triggered, rapidly take multiple photos (one photo per second) until the camera is no longer triggered. Following a video or picture capture, the camera traps could not be triggered again for 1 min. SD memory cards (8 GB capacity) were used in the cameras.

In 2012, I set up the cameras on latrines from 11 June to 5 July, and retrieved them on 23 October. In 2013, I set up cameras from 28 May to 12 June, and retrieved them from 30 May to 27 June 2014. The inaccessibility of the study areas precluded maintaining the cameras during times of the year when ice was present. As a result some cameras were not operating the winter and the small amount of data from any cameras that were working cameras was not used. However, sprainting at latrines occurred throughout the time periods studied, confirming that activity persists outside of the mating season.

One camera was also stolen mid-way through the first season of data collection. As a result, the data used in this study was from the remaining 35 cameras.

Figure 2.4. Typical setup of a Moultrie M-100 camera trap at a latrine site. Camera traps were positioned ~15 cm to ~1 m above the ground, with the field of view encompassing as much of the latrine as possible. Placing the motion cameras further back to encompass more of the latrine would cause the camera to be triggered less. Also, at most latrines, vegetation precluded seeing the entire latrine at these distances.

I checked camera traps every 3-4 weeks to ensure sufficient memory and battery power. On the few occasions when batteries were depleted or the memory cards were at capacity, I considered the camera to have been not operating since the last recording. I visited each site five times in 2012 and four times in 2013, to change SD cards and batteries.

2.2.2 Data Analysis

2.2.2.1 *Latrine presence*

A correlation matrix was created using Pearson's r (Table a1; Appendix) from latrine sites to assess dependencies among variables. The variables *dstreammouth* and *dfreshwater* were positively correlated, because in many cases the nearest freshwater inflow was also the nearest source of freshwater. Since the variable *dfreshwater* includes all sources of fresh water, including stream mouths, it was retained in the analysis. Finally, after conducting a Shapiro–Wilk's test, to check variable distributions for normality of residuals, logarithmic transformations were applied to both *droad* and *dcabin* to normalize the distribution of these variables.

Using t-tests, I tested the difference on each variable between random and latrine sites, and used a Bonferroni correction (adjusted $\alpha = 0.01$) to adjust for multiple comparisons. This α level was chosen because five tests were conducted.

2.2.2.2 *Latrine activity and preference*

Within a site I quantified otter activity as the number of days on which otters were detected on cameras, divided by the total number of days the cameras were active. A visit was defined as the occurrence of an otter or otters that previously moved to a latrine from another area. Otters have no distinguishable markings; I was unable to distinguish multiple visits by the same individual from different individuals. Multiple detections frequently occurred in short succession while animals visited a site. To minimize the autocorrelation of such detections, different detection events were defined as being separated by >24h (Fig a1; Appendix).

It is possible that two different groups of otters can pass a single camera within 24 hours, and that therefore I would underestimate the number of visits made by otters; however, it seems more likely that if this time was reduced, then I would have overestimated data due to repeated trigger events (i.e., multiple short-term visits) by groups.

This method can be used as an index of abundance as shown in the prevalence of latrine sites and how often they are visited. For example, higher prevalence of latrines and high visitation frequency could reflect high otter density. Similarly, high prevalence of latrine and low visitation frequency could indicate lower density.

Variables that best described latrine use by otters were determined using a forward-stepwise regression with otter activity as the dependent variable.

2.3 Results

2.3.1 *Latrine presence*

Latrines were situated where less foraging area was available (Table 2.2; Figure 2.5). Latrine sites also were farther from cabin development than were randomly chosen sites; however, the Bonferroni-adjusted P-value was not significant (Table 2.2).

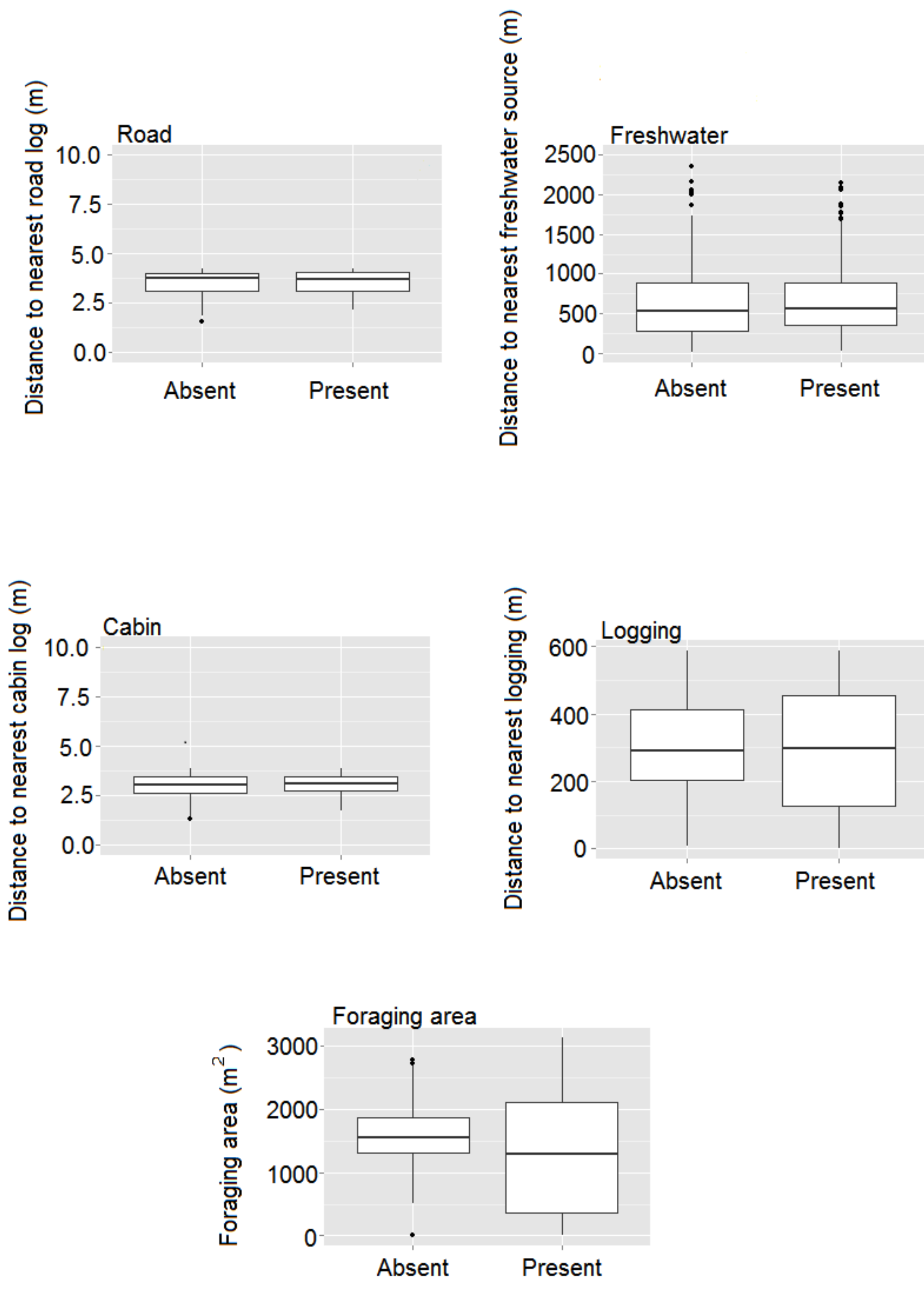


Figure 2.5. Most latrines of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland were in areas with less foraging area available. Sample sizes were 150 for both latrine and randomly chosen sites.

Table 2.2. Most latrines of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland were located where relatively little foraging area was nearby and distance from cabins was greater. Sample sizes were 150 for both latrine and randomly chosen sites. Bonferroni-adjusted $p = 0.01$.

Habitat variable[1]	Latrine site[2]	Random site[2]	t	df	p
logdroad	3.65 ± 0.501	3.61 ± 0.563	0.98	134	0.33
dfreshwater	650 ± 433	620 ± 476	0.33	134	0.74
logdcabin	3.09 ± 0.471	2.98 ± 0.572	1.95	134	0.04
dlogging	306 ± 184	317 ± 156	0.57	47	0.57
foragingarea	1138 ± 902	1456 ± 536	-2.89	60	0.005

[1]In units of m or log m, as indicated by variable names; for full names, see Methods.

[2]Cell entries are Mean ± SD.

2.3.2 *Latrine activity*

Otters were detected by cameras at 31 latrines in 2012 and at all latrines in 2013. Latrine activity by otters varied greatly across latrines (mean, 0.11; range, 0.005 - 0.32; Table 2.3).

Table 2.3. Range of northern river otters (*Lontra canadensis*) habitat and response (distance (m) to and area (m^2) of variable from latrine) variables for the full dataset (FD) and the foraging area dataset (FAD) in marine-coastal Newfoundland.

Habitat variable	FD (n=36)[1]	FAD (n=18)[2]
logdroad (log m)	3.62 (2.48-3.98)	3.619 (3.50- 3.98)
dfreshwater (m)	490 (8.52-3775)	357.10 (8.52-1057)
logdcabin (log m)	3.09 (1.47-3.83)	3.61 (1.47-3.83)
dlogging (m)	3047 (178.70-7959)	3811 (380-7959)
foragingarea (m^2)	---	723.2(0-2510.0)

1 Full dataset (includes all sites and omits foraging area variable)

2 Foraging area dataset (includes only sites which have foraging area variable)

The forward-stepping regression analysis identified distance to nearest cabin as the best model for latrine activity in FAD (R^2=0.14; Table 2.4, Figure 2.6), while for FD a combination of distance to nearest road, distance to nearest freshwater source and distance to nearest cabin was the best model (FD; R^2=0.339; Table 2.4, Figure 2.6).

Table 2.4. Distance to road, freshwater and cabins are related to northern river otter activity (*Lontra canadensis*) in the full dataset (FD; n=35), while in the foraging area dataset (FAD; n=18) only distance to nearest cabin is related to activity for coastal latrines. Models identified by the interactive forward stepping multiple regression are indicated in bold.

Data set	Habitat variable[1]	Intercept	Slope (SE)	R^2	p
FD (Full data set)	**logdroad* +dfreshwater +logdcabin***	**-0.19**	**0.43 (0.16)** **0.04 (0.03)** **0.04 (0.02)**	**0.34**	**0.004**
	logdroad*	-0.23	0.09 (0.03)	0.19	0.007
	dfreshwater	0.08	3.79 e-5 (1.57 e-5)	0.09	0.02
	logdcabin*	-0.03	0.05 (0.02)	0.13	0.03
	dlogging	0.08	1.07e-5 (6.67 e-6)	0.07	0.12
FAD (Foraging area dataset)	logdroad*	0.11	0.11 (0.15)	0.03	0.49
	dfreshwater	0.09	5.01e-5 (0.04)	0.02	0.59
	logdcabin*	**-0.04**	**0.05 (0.03)**	**0.14**	**0.12**
	dlogging	0.1	3.60 e-6 (8.32 e-6)	0.01	0.67
	foragingarea	0.09	2.92 e-5 (2.33 e-5)	0.09	0.23

*denotes log transformed variables.

[1]In units of m or log m, as indicated by variable names; for full names, see Methods.

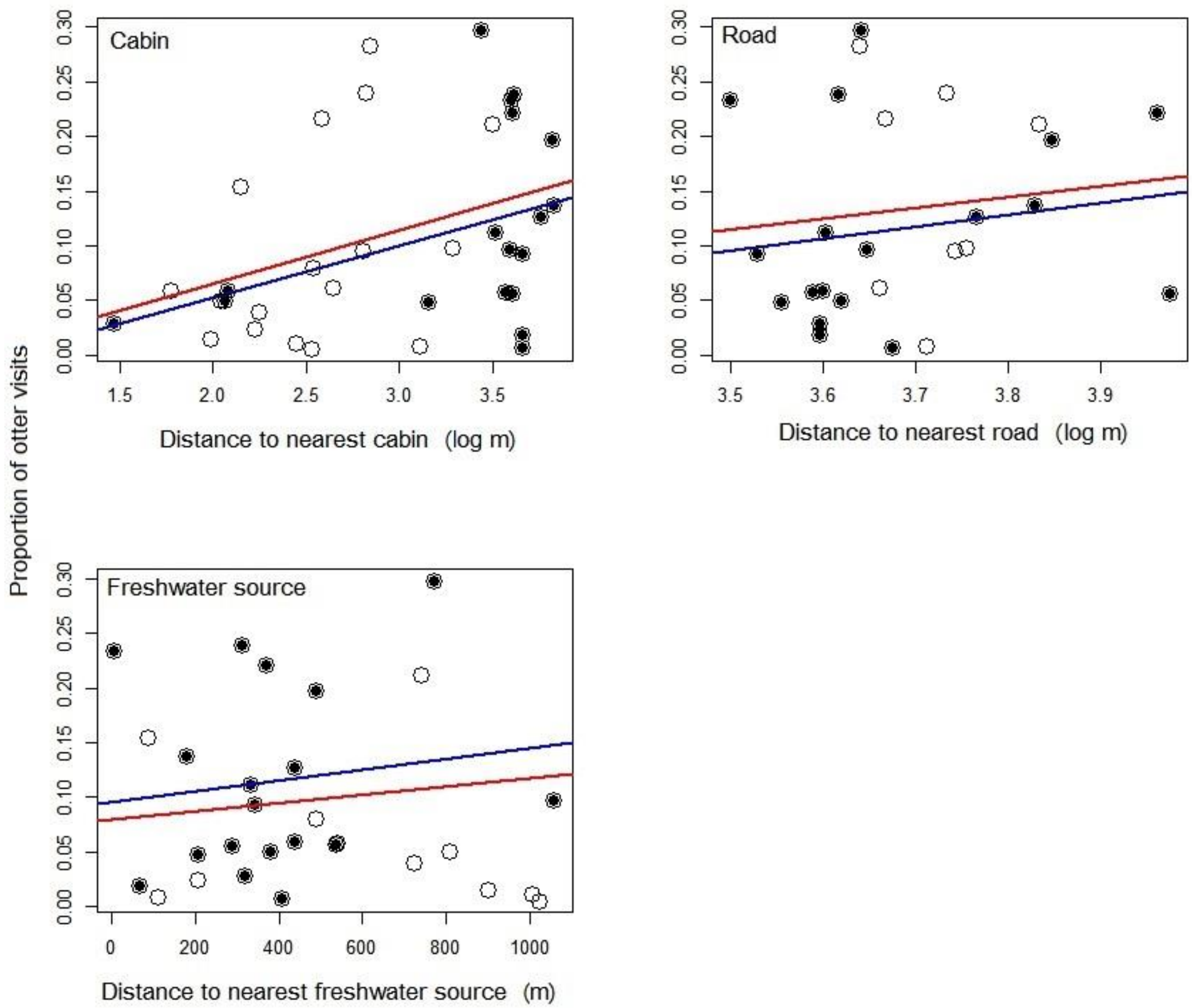


Figure 2.6. Northern river otter (*Lontra canadensis*) activity at latrines increased with distance to the nearest cabin, road and freshwater source and size of foraging area near latrines. Blue lines represent the linear model from the full data set (FD; represented by filled circles). Red lines represent the linear model of the data set including foraging area (FAD; represented by open circles). Foraging area came from only one data set (FAD).

2.4 Discussion

I predicted that otters will place latrines and visit them more frequently in areas with access to key ecological requirements such as freshwater and foraging habitat, and distant from anthropogenic disturbances. However, I found that while high levels of activity occurred at latrines that were further away from cabins and roads, sources of anthropogenic disturbance such as logging, cabins and roads did not differ between latrine and control sites.

The northern river otter is a top-level predator and thus can indicate ecosystem health (Estes et al. 2011). Romanowski et al. (2013) found that otter presence or absence must be interpreted with care as an indicator of good aquatic habitat quality. However, important environmental parameters such as access to food supply or freshwater was not considered (Romanowski et al. 2013). The absence of river otters, as expressed by little use of latrines, may be used as a proxy for low otter abundance in an area.

When northern river otters defecate at latrine sites, they introduce aquatic productivity into terrestrial ecosystems (Ben-David et al. 1998). This transfer of nutrients from freshwater and marine to terrestrial systems partly shapes near-shore community composition (Ben-David et al. 1998), and so northern river otters are ecologically important for riparian zones (Melquist et al. 2003; Crimmins et al. 2009; Crowley et al. 2012). Past research has shown that natural landscape features influenced the presence of European otters more than anthropogenic factors (Barbosa et al. 2001). Similarly, with river otters, natural factors were more important than anthropogenic ones to influence habitat use (Gallant et al. 2009). However, it has also been found that in areas with very high levels of anthropogenic disturbances, river otters tend to avoid nearby latrines (Bowyer et al. 1995). Due to this avoidance, the level of nutrient transport in disturbed areas may be decreased.

Latrine presence

River and European otters have a high basal metabolic rate and need to eat frequently (Estes 1989; Kruuk 1995; Pfeiffer and Culik 1998). The river otters that reside in Bonavista Bay, Newfoundland, feed primarily on marine-coastal fish species (e.g. sculpins, Cottidae), and invertebrates (e.g. molluscs and crustaceans; Cote et al. 2008). Both species of otter often bring their food onto latrines and eat it there (Kruuk 1995), making latrines an important feature in otter habitat. It can therefore be assumed that the foraging area around a latrine would be large. However, this was not the case in my study. I found that otters placed latrines in areas with significantly smaller foraging area than random locations. Sections of the surveyed coastlines were inaccessible due to boat limitations in very shallow waters or narrow inlets, causing an observational bias as some latrines may have been overlooked.

I found that sources of anthropogenic disturbance such as logging, cabins and roads did not differ between the locations of northern river otter latrine sites and control sites in marine-coastal Newfoundland. The only habitat variable with a significant relationship to the presence of latrines was the total amount of foraging area, but the relationship was opposite to my prediction: latrine sites were situated close to foraging areas of relatively small size. There may be an intervening variable that I did not recognize in this study such as slope of the terrain leading from the waterline or water quality. In addition my prediction may have been based on a flawed assumption, such as the requirement of latrines for rest rather than their placement in relation to any particular habitat variable.

Similar to the European otter, northern river otters rarely travel on land, where their locomotion is clumsy and inefficient (Williams et al. 2002). The fur of otters provides little insulation from cold temperatures; furthermore a higher quality insulative layer would interfere with an otter's agility in the water (Estes 1989). Their bodies cool rapidly and they lack the ability to stay in the water indefinitely (Kruuk 1995, Kruuk 2006). To compensate for heat loss and energy expended, otters must return to latrines frequently to increase body temperature (Kruuk 1995). Therefore, numerous latrines are set up along the coast. An otter may visit all or some latrines while traveling along the coast, depending on the rate of cooling while in the water (Kruuk 1995).

Latrine activity

In this study I found that activity levels increased with distance to cabins and roads. I also found that logging had no detectable impact on placement of or activity at latrines. Other studies of the species have documented varied relationships of otter latrine use to human activity. River otters avoid areas with high levels of human influence (Potter et al. 2007). These areas include cabins and the waters surrounding the cabins due to boating activities. Bowyer et al. (1995) found that river otters tended to avoid latrines that are close to anthropogenic disturbances, and Melquist and Hornocker (1983) noted that the species avoided latrines altogether at high levels of disturbance. Helon (2006) suggested that river otters may avoid bridge crossings and roads due to human impacts, while Crimmins et al. (2009) found that although river otter presence is apparent at bridge locations, otters prefer to visit sites that are farther away.

Cabins in my study area are visited frequently by people from early spring to late fall, but seldom during winter. The roads in my study area were old logging roads, which are used frequently by people as recreational vehicle trails to gain access to coastal cabins around the year. After speaking with several cabin owners in the area, it was clear they were not aware of, nor had most ever seen otters on shore or in the waters near their cabins. Furthermore, there was evidence of trapping in the area. While I found no new trap lines during the study period, I did find old trap posts and otter snares in the area indicating that the area has been used recently for otter trapping. Therefore, the lack of otters captured on camera, combined with the lack of visual sightings made by resident cabin owners indicated that otters visit latrines near cabins less frequently, especially when people are nearby.

River otters require fresh water to wash after being submerged in salt water. Extended exposure to sea water interferes with the insulative capacity of the pelts, forming salt crystals along the guard hairs and under-fur (Tarasoff 1974). The hair and guard cells tangle and mat together, impeding air retention in the fur and interfering with lipid secretions by skin glands (Tarasoff 1974). To maintain their fur’s insulative qualities, river otters must wash frequently in freshwater. It could be assumed that otters may position latrines near freshwater sources such as lakes, ponds and stream mouths.

However I found higher levels of activity occurring at latrines located further away from freshwater sources. Cameras frequently captured otters bathing in puddles of freshly fallen rainwater. These puddles, combined with ample prey available in coastal water may render other sources of freshwater such as lakes and rivers unneeded. There may be an intervening variable that I did not recognize in this study such as the water quality of those freshwater sources.

Logging is a large anthropogenic disturbance, affecting large areas within landscapes; therefore otters avoid such areas (Bowyer et al. 1995). As such, I predicted that logging would affect the placement of latrine sites or activity levels at latrines. However, the most recent logging took place in my study area in 2011 (Department of Natural Resources 2014), a year prior to the study. Nonetheless the access roads and associated developments (e.g. cabins) remain. Furthermore, coastal areas in Newfoundland are buffered by no-cut zones 20 m in width (Department of Natural Resources 2014).

In this study, logged habitat has no detectable impact on placement of or activity at latrines of river otters. Nevertheless, past logging activities established roads that now are used in human recreational activities and that provide access to some cabins – factors that negatively influence levels of latrine use. Therefore river otters seem to adapt to anthropogenic activity by using affected latrines less frequently, rather than abandoning the entire coastline altogether. As a result, human activity levels in these areas during and after logging operations should be kept to no more than they are now. If levels are increased, river otters may be forced to abandon the impacted coastline and as a result the key impacts of otters on ecosystem function would be disrupted.

Both assessments explored in this study allow biologists to better manage resources, standardize survey methods, and serve as an index of the relative density of a species and gives a better understanding of the ecology of a species within a landscape. Not all latrines are the same: otters seem to be less discriminating when placing latrines along a coastline and focus more on ecological factors when choosing which sites to visit, visiting latrines near anthropogenic factors less frequently. As a result, when biologists and resource managers survey an area, latrine activity should be focused on as it acts as a better indicator of the overall status of otter abundance.

I believe that additional research is required to investigate how otters select for and visit latrines in the presence of more severe anthropogenic influences than those I analyzed. While my study sites are representative of conditions in Newfoundland, they are less developed by humans than in many areas of river otter range. Furthermore, conducting research during winter months, when freshwater habitats are more limited, may provide useful information pertaining to the use of latrines during this time of year. My study, while including much of the year, did not provide any data during harsh periods. Data collected during these harsh periods may provide important information to managers and ecologists and allow for the implementation of appropriate landscape planning.

Chapter 3

Spraint counts as a method of defining latrine-use intensity by marine-coastal northern river otters (*Lontra canadensis*) in Newfoundland

3.1 Introduction

Scat surveys are the most common method for assessing mammal distribution and abundance because of the low cost (Palomares et al. 2002; Perez et al. 2006; Cossios et al.2007; Mondol et al. 2009; Ruell et al. 2009). This method is useful when studying species that are rare (Lozano et al. 2003), live in hazardous or inaccessible areas (Lunney et al. 1998), or (as for various otter species) difficult to detect due to elusive behaviour (Sharp et al. 2001).

Using scat to study river otters in coastal ecosystems provides insight and understanding of abundance and habitat use, and provides information for conservation and management. Furthermore, spraint counts provide information about otter density though latrine prevalence and activity frequency.

All otter species are semi-aquatic, frequently visiting latrine sites (Durbin 1989; Kruuk 1992; Bowyer et al. 1995; Ben- David et al. 1998). Latrines serve as locations for intraspecific communication through deposition of spraints (feces), jellies (anal-gland secretions) and urine (Bowyer et al.1995; Ben-David et al. 1998; Rostain et al. 2004). Therefore latrines experience high levels of use, making them ideal places to study river otter.

Most knowledge about otters is obtained from indirect signs, such as footprints and spraints (feces) deposited at latrine sites. Spraint surveys consist of visual searches at latrines along the banks of bodies of water (Mason and Macdonald 1987; Reuther et al.

2000; Chanin 2003). However, the relationship of spraint counts to assess the intensity of latrine use is unknown (Kruuk and Conroy 1987).

Spraint counts are currently a key component in identifying status, abundance, and distribution of European otters (*Lutra lutra*; Reuther et al. 2000), however for river otters, no relationship has been found between spraint counts at latrine sites and density, abundance, or habitat use (Kruuk et al. 1986; Conroy and French 1987). Spraints are the most common sign of otter presence, apart from visual observation, and therefore provide the greatest potential for cost-effective and non-invasive methods to monitor and assess populations over time (Hutchings and White 2000).

The number of spraints found at latrines varies according to coastline or river-bank characteristics, and season (Bas et al. 1984; Conroy and French 1987; Macdonald and Mason 1987). Due to these factors, spraint counts are not the best method for identifying status, abundance, or distribution of river otters. For example, Conroy and French (1987) found that spraint counts at latrine sites vary greatly across seasons, while Jenkins and Burrows (1980) documented spraint counts ranging from 10 to 240 in an area with stable otter density. As a result, the validity of spraints as an index of abundance is uncertain (Kruuk and Conroy 1987; Mason and Macdonald 1987).

Desiccation and scattering of spraints may account for the ineffectiveness of spraint counts as an index of latrine use. In one study on river otters, over 50% of spraints deposited at sites disappeared within only two weeks (Jenkins and Burrows 1980). The primary food of river otters is fish (Melquist and Hornocker 1983; Cote et al. 2008), so otter spraint consists mostly of bone fragments and other indigestible items, such as carapaces, hairs, shells, beaks, berry rinds, and seeds (Toweill 1974; Melquist and Hornocker 1983; Larsen 1984; Cote et al. 2008). These components are loosely packed within a moist matrix (Harris 1968), so spraints may disappear by the processes of desiccation and scattering.

Karanth (1995) was the first to use camera traps, in his study of an endangered tiger (*Panthera tigris*) population. Since then, the method has proven to be accurate for detecting and even counting certain species of carnivores (Trolle and Kéry 2003; Silver et al. 2004; Balme et al. 2009). However, camera-trapping is expensive and time-consuming, especially when part of a large-scale monitoring program. It has proved effective in studies on otters (Guter et al. 2008; Olson et al. 2008; Stevens and Serfass 2008; García-Díaz et al. 2011), but no comparative studies have been done using game cameras to determine the effectiveness of spraint counts in determining population size, distribution, or abundance of river otters.

The goal of my study was to use game cameras to compare and assess the reliability of river otter spraints as an index of latrine use, over short and long and periods of time, and to investigate monthly trends in spraint deposition and latrine-use intensity. I also investigated desiccation rates of fresh spraints in the latrine environment of Newfoundland, to identify a temporal period in which spraint surveys may be an accurate index for latrine use.

I predicted that automated game cameras would be superior to other methods (especially spraint counts) for assessing latrine use over various periods of time (Olson et al. 2008; Stevens and Serfass 2008). This prediction is based on that fact spraints can disappear rapidly, as noted above (Toweill 1974; Melquist and Hornocker 1983; Larsen 1984; Cote et al. 2008).

3.2 Materials and Methods

3.2.1 Data Collection

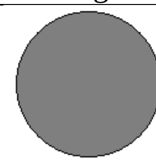
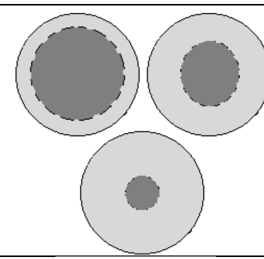
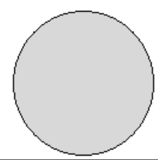
3.2.1.1 *Spraint desiccation*- I only visited latrines every 3-4 weeks, therefore, monitoring spraint desiccation at latrines, where all the environmental factors would be natural was impractical. I therefore collected fresh spraints and created a similar environment that was more accessible to monitor spraint desiccation.

After counting all spraints found at latrines, I collected the fresh ones. They were placed in individual air-tight plastic bags, with the air removed, and identification tags (collection site, plus date and time of collection) and subsequently placed in a -20˚C freezer.

The spraints were removed from the freezer and thawed for four hours prior to the trials. Spraints were separated into two groups and placed in one of two treatments (closed or exposed) that resembled the same shore-line conditions as the latrines from which they were collected. The closed spraints were taken to an area of forest canopy where they were protected from the elements. Within treatments, spraints were placed on one of two substrates (rock or soil). The rock spraints were placed onto flat stones to replicate the rocky substrates normally found within latrine sites, while the spraints placed on overturned soil were done so to replicate the normal ground disturbance created by river otter activity at the latrine sites.

Spraint trials began at 0700h. I visited them every three hours for a total of 96 hours. During each visit the date, time, temperature, color (black, dark grey, grey, light grey, white), and state (old, medium, fresh; Table 3.1) were recorded. I terminated the trails when all spraints were fully desiccated (dry throughout).

Table 3.1. Three stages of spraint desiccation were recognized. In the illustrations, dark grey areas represent moist spraint or parts of spraints; light grey areas are fully desiccated.

Spraint state	Description	Images
Fresh	Moist throughout; no evident desiccation	
Medium	Moist in centre; some surface desiccation	
Old	Spraint completely desiccated	

All spraints were removed from the latrine after they were counted, to reduce the possibility of recounting spraints on the next visit. Fresh spraints were retained for spraint desiccation trials.

3.2.1.2 *Latrine use intensity*- The same study area, latrine survey and camera placement and retrieval were completed as described in the latrine activity and preference methods section in Chapter 2.

I counted spraints at each latrine site, immediately following battery replacement and SD card change from cameras. Spraint was classified as old, medium or fresh, as in the experiment (Table 5). After counting the spraints, fresh spraints were collected and the remaining were destroyed to ensure they were not recounted on the next visit to the site.

3.2.2 Data Analysis

3.2.2.1 *Spraint desiccation*- Using t-tests, I tested differences between desiccation times for the experimental groups. I pooled rock and dirt subgroups in each experimental group to increase the number of points for each data set.

3.2.2.2 *Latrine use intensity*- As otters have no distinguishable marking, I was unable to differentiate between multiple visits by the same individual and visits from different individuals. When analyzing camera data from each latrine, I considered the videos to be of different individuals if more than 24 hours had passed between camera trigger events. I considered these individual videos to represent trigger events and hence single visitations.

It is possible that two different groups of otters could pass a single camera within a 24-hour period, thus the number of otters may be underestimated. However, by reducing the interval past 24 hours, the number of otters may be overestimated due to repeated trigger events (i.e., multiple short-term visits) by groups.

A total of 262 days of 24 hour video recording was obtained during the study: 152 in 2012 and 110 in 2013, using 35 camera taps. All spraints counted at a site were pooled for each site and sample period.

Trends over scales of landscape and long time period - To study latrine-use intensity over a long period of time, the latrine sites were monitored for a total of 9170 camera days over both seasons, and spraints were counted on 35 latrine sites from June to October 2012, and June to September 2013 (5 and 4 times for each year, respectively).

To determine if spraint counts can be considered a useful index for latrine-use intensity at individual latrine sites I used data at each latrine over the entire study period. I first tested to see if the data was normally distributed using a Shapiro-Wilk test and subsequently log transformed the data. I then used a linear regression with a predict function and the number of visits made by otters within this period, with the total number of spraints found at the corresponding latrine. I did this for each latrine.

To determine if long temporal periods, incorporating the entire landscape were required for spraint counts to be considered a useful index for latrine-use intensity, I used camera data from all cameras over the entire study period. I first tested to see if the data was normally distributed using a Shapiro-Wilk test and subsequently log-transformed the data. I then used a mixed-effects model with a predict method and the number of visits made by otters within this period, with the total number of spraints found at the corresponding latrine and the random effect as the latrine site. This predict method gives the result of a LOESS line of best fit

Trends over small time scale – To determine if activity was linked to when spraints were deposited, the temporal period for sampling was restricted to four days. I used a Shapiro–Wilk test to see if the data was normally distributed and then, as it was not, did a log transformation. To determine if shorter temporal periods were required for spraint counts to be considered as a useful index for latrine-use intensity, data were used from each camera four days before spraints were counted. I used mixed-effects model using the predict method and the number of visits made by otters within this period, with the total number of spraints found at the corresponding latrine and the random effect as the latrine sites. Again, this predict method gives the result of a LOESS line of best fit

<u>Monthly trends and sprainting rates</u> – To determine if monthly spraint count was related to the number of visits, I categorized the counted spraints into three groups (fresh, medium + fresh, and total) and used a mixed-effects model and the number of visits made by otters within each month, with each of the spraint categories and latrine site as the random effect.

Deposition rates of otters visiting the latrine were found by determining how many visits made by otters resulted in sprainting behaviour. Spraiting behaviour was observed using the game cameras and recorded. To determine if there was monthly variation in sprainting behaviour a mixed-effects model was done with sites as the random effect. The same was done for monthly variation in total number of spraints counted.

3.3 Results

3.3.1 *Spraint desiccation times*- In the open habitat, spraints began to show signs of high desiccation 51 hr after deposition, and all spraints were fully desiccated at 69 hr. Spraints in closed habitats began to show signs of high desiccation 81 hr after deposition and all spraints were fully desiccated at 93 hr.

Figure 3.1. Open-habitat (A) spraints showed higher desiccation at 51 hr and were completely desiccated at 58.5$\pm$ 5.71 hr (n=17). Closed-habitat (B) spraints showed signs of higher desiccation at 81 hr and were completely desiccated at 84.5 $\pm$ 4.01 hr (n=18).

3.3.2 *Latrine-use intensity*

Trends over scales of landscape and long time period - Otter visitation was detected on at least one of the 35 active cameras on 250 of the 262 days the cameras were active (95.4% of days). All 35 cameras were running for a total of 262 days, for a total of 9170 camera-days. Otters were recorded visiting latrines on 888 of 9170 (9.7%) camera-days. Sprainting occurred on 182 of these 888 latrine visits (20.5% of visits).

The number of spraints at single latrines was not related to the number of otters that visited between sample times (Table a2; Appendix). Only two latrines showed correlations between the number of spraints counted and the number of otters that had visited.

On a larger spatial scale, which includes the entire study landscape by combining all otter visits and spraint counts during the two years of study, otters visited latrines a total of 888 times; 903 spraints were counted (1.02 ± 0.17 per visit). The number of spraints was related to the number of visits over these scales (β=0.17, t (101) = 2.09, p=0.039, marginal R^2=0.01, conditional R^2= 0.29; Fig. 3.2).

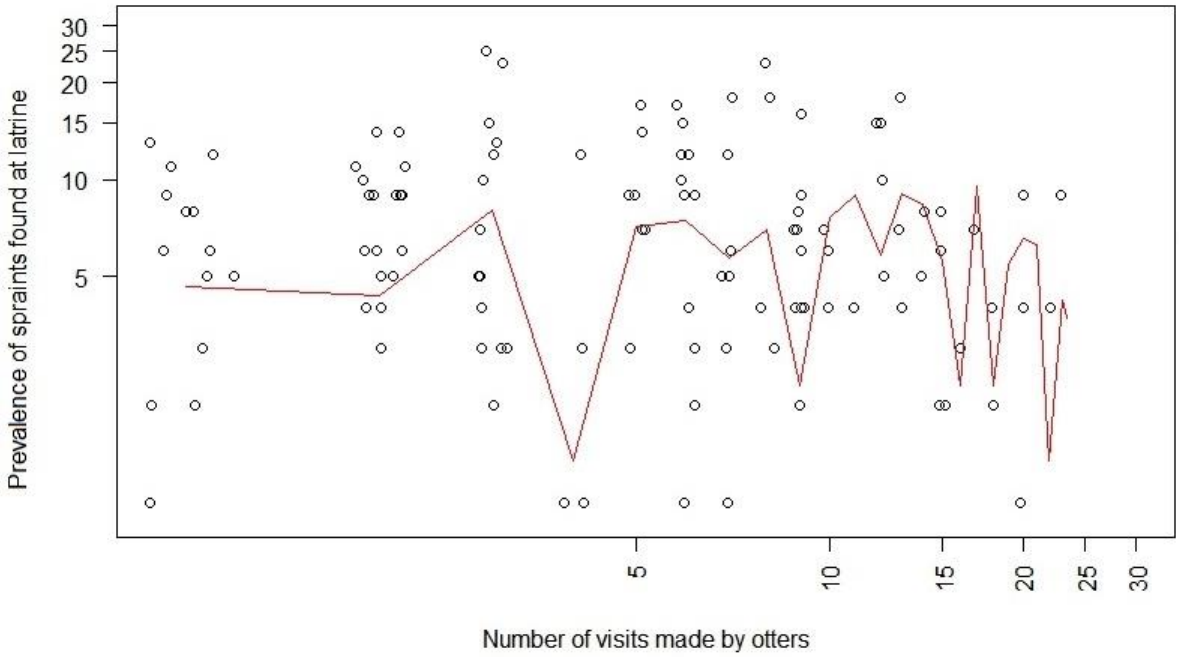


Figure 3.2. At the landscape level, the prevalence of spraints at latrines was related to number of visits made by otters (*Lontra canadensis*) in marine-coastal Newfoundland. Hollow dots represent the number of visits made by river otters and subsequent spraints counted at each latrine. Red line represents mixed-effects model with smoothing.

Trends over short time scale- Otters were recorded visiting latrines on 54 of these 1260 (4.3%) camera-days. The number of spraints found at latrines was not related to the number of otters that visited four days prior to spraint counts (β=0.51, t (29) = 0.73, p=0.47, marginal R^2=0.003, conditional R^2= 0.08; Fig. 3.3).

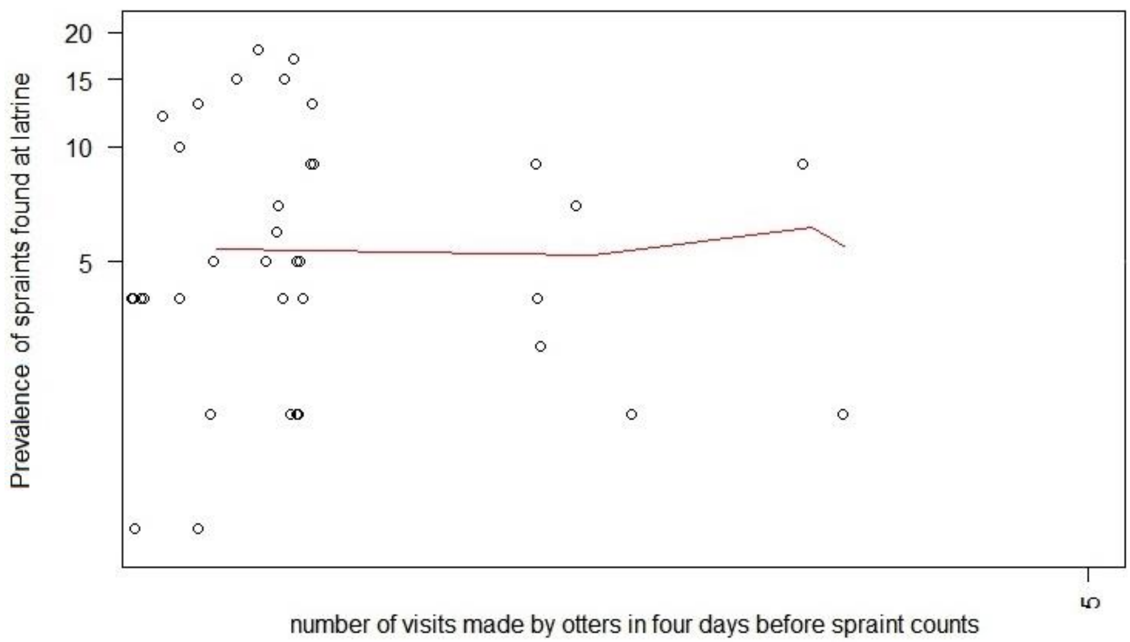


Figure 3.3. The prevalence of fresh spraints at latrines was not related to the number of northern river otter (*Lontra canadensis*) in marine-coastal Newfoundland visits four days before spraint counts. Hollow dots represent the number of visits made by otters and subsequent spraints counted at each latrine. Red line represents mixed-effects model with smoothing.

Monthly trends of latrine-use intensity and spraint counts- The numbers of total spraints (β=1.11, t(3)= 0.86, p=0.45, marginal R^2=0.16, conditional R^2= 0.94); fresh + medium (β=0.33, t(3)= 0.52, p=0.64, marginal R^2=0.06, conditional R^2= 0.94); fresh spraints (β=-0.31, t(3)= -1.36, p=0.27, marginal R^2=0.06, conditional R^2= 0.094) counted at latrines, were not related to the number of monthly visits made by otters.

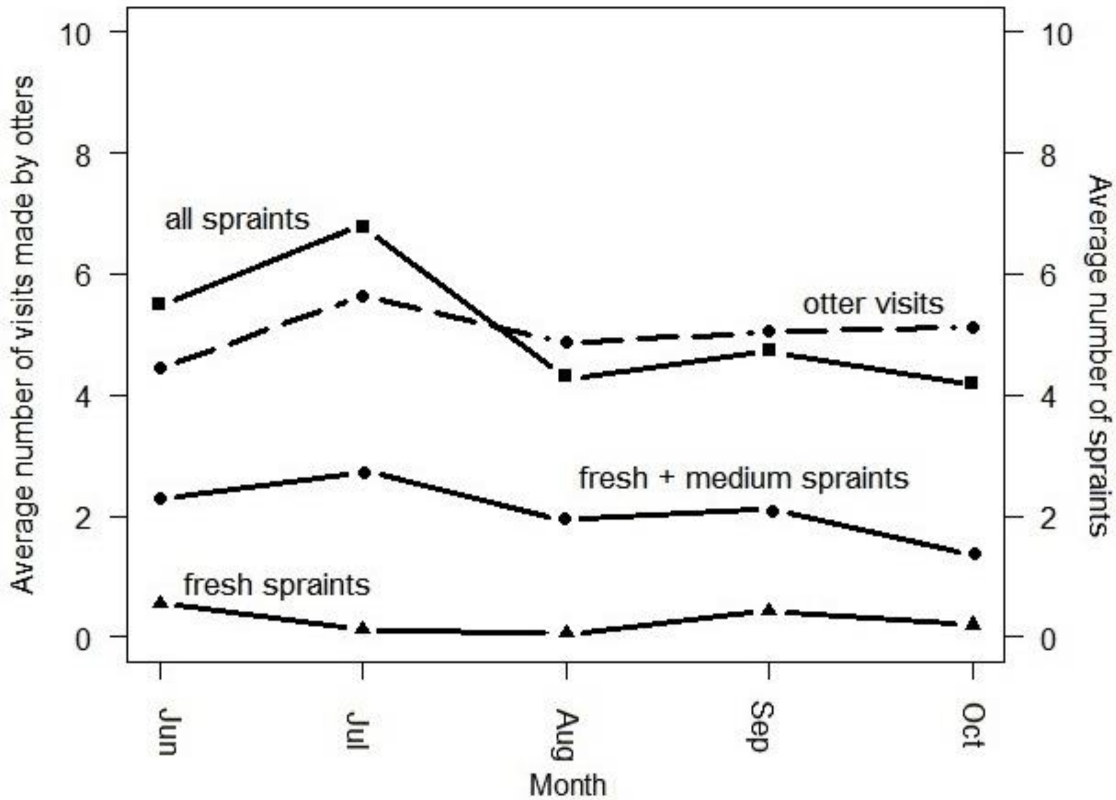


Figure 3.4. The monthly number of visits made by northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland was not related to the number of total spraints, fresh + medium spraints, fresh spraints counted at latrines. On a monthly basis, total sprainting visits of otters varied but total spraint counted did not. Otter visit data corresponds to left y-axis, all sprainting data corresponds to right y-axis.

The only month with significant variation in defecation rates was October (Table 3.). Total spraints counted at latrines did not vary between months (Fig. 3.4).

Table 3.2. Defecation rates at latrines of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland did no vary across months. Bold indicates significant variation. The random effect of latrine sites was not related to the majority of the variation.

Month	β	t	df	p
June	1.25	3.71	138	0.00
July	0.11	0.27	138	0.78
August	-0.06	-0.14	138	0.9
Steptember	-0.24	-0.58	138	0.57
October	-1.01	-2.46	138	0.02
Marginal R^2	0.04			
Conditional R^2	0.03			

Table 3.3. Total spraint counts at latrines of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland did no vary across months. The random effect of latrine sites was related to the majority of the variation.

Month	β	t	df	p
June	5.5	6.04	138	0.00
July	1.08	0.86	138	0.39
August	-1.19	-0.94	138	0.34
Steptember	-0.76	-0.6	138	0.55
October	-1.31	-1.03	138	0.3
Marginal R^2	0.03			
Conditional R^2	0.07			

3.4 Discussion

I found that spraint counts are not a good index for latrine-use intensity for either long or short time periods at single latrines. However, the technique has potential for investigating river otter abundance over a large landscape. The majority of visits to a latrine do not result in sprainting in European otter (Yoxon and Yoxon 2014), and sprainting efforts also vary by month. Highly active latrines may result in the removal of spraints, making them uncountable for activity investigation.

The validity of spraints as an index of abundance or even presence has been criticized for both river and European otter (Kruuk and Conroy 1987; Mason and Macdonald 1987). For example, it is possible that latrines with numerous spraints are visited only a few times. To the same degree, sites which are frequently visited by otters will not always be scent marked. The absence of spraints at a latrine does not necessarily mean that otters are absent from an area (Hutchings and White 2000). Instead, absence or low numbers of spraints may just signify that population density is low, and hence that the need for intraspecific communication via spraints is reduced. Furthermore, while visits by large groups of otters typically mean the presence of more spraint, it also means higher levels of activity. The activity of river otters and other animals that visit latrines to play or scavenge spraints for food may disturb the spraints by removing them or otherwise rendering them uncountable. Spraints may dry out quickly depending on the latrine habitat and the level of exposure. Therefore, they could be removed from latrines by wind, rain or water runoff.

Landscape and long temporal periods - I found no relationship between visitation rates or the number of spraints on single latrines and the number of visits. Therefore, over long periods of time (roughly annual scale), spraints are not a reliable means to assess intensity of use at single latrines.

However, on the same temporal scale but larger spatial scale (the entire study area), the number of spraints at latrines was positively related to visitation rates at latrines. As reported elsewhere (Chapter 2), latrines are used differentially according to their placement and physical features: e.g. latrines with proximity to freshwater are visited disproportionately often. Spraint counts are not an appropriate index for determining river otter activity on a single latrine, but may be useful in determining presence, abundance and activity on a regional scale.

It is unknown how long it takes for spraints to degrade in Newfoundland conditions. Having long periods of time between spraint counts may contribute to the unreliability of using them as an index at single latrines. Fresh spraint deposited under experimental conditions tended to desiccate within four days. This provides researchers with a general time frame in which spraints can persist at a latrine. It can therefore be assumed that if fresh spraints are found at a latrine, than an otter has visited and defecated at the latrine within the last 18-48 hours. Desiccation rates vary based on habitat type and the level of exposure to the elements. There was a 24-hour time difference in desiccation rates between exposed and closed habitat, thus adding error to any spraint indices.

Studies that consist of checking latrines for spraints every day have shown that counts can be used as an index for latrine-use intensity (Guter et al. 2008). Checking latrines every 24 hours is costly however, particularly in remote areas. Four-day periods were therefore considered to be both more realistic and reasonable.

Short temporal periods - It was found that there was no significant relationship between the number of otters visiting a latrine four days prior to spraints counts and the total number of spraints found; only 0.4% of variance was explained. Therefore for short temporal periods, total spraints counts are not a reliable means to assess latrine-use intensity.

Due to the behaviour of otters while visiting latrines, sprait counts can be unreliable when including all spraints found there. After being submerged underwater, otters must dry themselves off to maintain the high insulation quality of their fur. They do this by rolling around on grass and soil at the latrine site (Melquist and Hornocker1983). Once at the latrine otters can walk, bound, run or slide as a form of locomotion and play (Stevens and Serfass 2008). This heavy amount of activity that occurs at latrines may disturb the spraints and make them difficult or even impossible to count.

Other animals visited latrine sites and were observed to occasionally disturb the spraints. As captured on cameras, the most common visitors to the sites were birds and small mammals. American crow (*Corvus brachyrhynchos*) and gulls (*Larus* spp.) picked through the spraints for food, while red fox (*Vulpes vulpes*) and snowshoe hare (*Lepus* *americanus)* frequently passed through the sites. Red fox, in particular, was noted playing and rolling around where sprainting by otters took place.

Due to the rapid desiccation of spraints, I used only fresh spraints to assess latrine use. There was no relationship between the number of visits made by otters to a latrine four days prior to spraints counts and the number of fresh spraints found.

Monthly variation – There was no relationship between the number of monthly fresh, fresh + medium or total spraints counted at latrines and the number of otters that visited the latrines.

Monthly variation in sprainting rates and the level of activity that occurs on latrines may play a role in the discrepancy of using spraint counts. Sprainting rates of European otters vary seasonally in accordance with food availability; rates are lowest in late spring and highest in summer and fall (Kruuk 1992). I therefore expected the number of total spraints in river otter would show a similar pattern, but this was not the case.

I could not estimate the hourly rate of sprainting, but observed the number of visits made by river otters in which sprainting occurred. Monthly sprainting visits at latrines varied only during the month of October.

The lack of variation in visits indicates that the level of river otter activity remained constant at latrines. The amount of spraints deposited by otters on latrines did not vary monthly and once deposited, they were vulnerable to the same level of disturbances caused by otter play and activity regardless of month. This constant activity can remove the spraints or render them uncountable.

Cameras are not infallible and do create certain biases. For example, in many instances it was not possible to move the camera back and capture the entire latrine as it would decrease the sensitivity of the camera and therefore fewer otters could be captured on camera. Otters sometimes may have traveled in front of the camera too quickly to trigger the camera, or moved out of view of the camera before it had time to record. However, spraints were only found at latrines without camera evidence of otters being present a total of seven times during short temporal periods.

I found that spraint counts were not a good index for latrine-use intensity under long or short temporal periods, but the method holds promise for judging otter abundance over a larger landscape. The lack of a relationship may have resulted from activity of otters or resident animals which visit the latrines thus disturbing the spraints or the length of time between spraint count survey efforts allowing them time to desiccate.

The presence or abundance of spraints was not indicative of latrine-site activity levels, but the absence of spraints did not mean that a site was not visited. Only about a fifth of river otter visits resulted in sprainting behaviour.

Determining the distribution and abundance of river otter populations is of great importance for managing and assessing the species' status. Due to the elusiveness of river otters, gathering the required data can be difficult. Documenting spraint presence and counts is the most common method for judging population status, habitat use and latrine-use intensity in different otter species (Mason and Macdonald 1987; Hutchings and White

2000). My study supports concerns that the spraint index is not valid for those purposes (Kruuk and Conroy 1987; Kruuk 1995).

Chapter 4

Diel activity and group size of marine-coastal northern river otters (*Lontra canadensis*) in Newfoundland

4.1 Introduction

The activity of many species of wildlife follows endogenous biological rhythms that are influenced by external factors (Martin et al. 2010). Understanding these factors gives insight into a species' ecology and, by extension, allows biologists to better manage wildlife interactions and optimize survey methods (Martin et al. 2010).

Diel activity patterns refer to animal activities that vary over a daily (24h) cycle (e.g. in physiology or behaviour; Aschoff 1979). Animals can change diel activity in response to abiotic factors (Alderman et al. 1989; Kolowski et al. 2007) and human disturbances (Riley et al. 2012; Corcoran et al. 2013). For example, activity of desert bighorn sheep (*Ovis canadensis nelsoni*) increases with temperature (Alderman et al. 1989), while the reverse is observed in red fox (*Vulpes vulpes*; Ables 1969). Additionally, wild Atlantic salmon (*Salmo salar*) alter their migratory patterns in response to the human-induced disturbance of artificial street lighting (Riley et al. 2012), and feeding supplementation by humans reverses normal diel activity of southern stingray (*Dasyatis americana*; Corcoran et al. 2013).

Few studies have investigated activity patterns of the Mustelidae in detail, but nevertheless, diverse activity patterns have been observed. Sea otters (*Enhydra lutris*; Estes et al. 1986) and fishers (*Pekania pennanti*; Arthur and Krohn 1991) are mostly active during morning and evening hours, and American martens (*Martes americana*) and yellow-throated martens (*M. flavigula*) are active nocturnally (Thompson and Colgan 1994; Drew and Bissonette 1997; Grassman et al. 2005).

Other studies have documented diel activity of inland northern river otter (*Lontra canadensis*; river otter hereafter) in diverse habitats, including eastern deciduous (McDonald 1989) and boreal (Melquist and Hornocker 1983) forests. Melquist and Hornocker (1983) and McDonand (1989) found that the activity of river otters was rhythmic, and was greatest during twilight and at night, with peaks of activity around midnight and dawn. Those studies provide insightful information on the ecology of the species; however, they represent only a portion of the species' geographic and ecological ranges. There is little information available for other habitats (e.g. marine-coastal environments) where foraging habitats and prey ecology differ considerably.

In a related species, the European otter (*Lutra lutra*), marine-coastal populations are most active nocturnally and move into shallow waters during periods of high tide (Kruuk et al. 1988). Many populations of river otter inhabit marine-coastal areas on Pacific and Atlantic coasts of North America, where diel rhythms may differ due to effects of tide or prey activity. This has been found in mammals including American mink (*Neovison vison*; Gerell 1969), red fox (Ables 1969), various fish and invertebrates (Sainmont et al. 2013), and birds (Roth and Lima 2007).

I studied marine-coastal river otters in Bonavista Bay, Newfoundland and Labrador. The otters in this area feed primarily on invertebrates and marine fish that move into shallow water at night (Cote et al. 2008). These otters also limit their dive depths to maintain the insulative quality of their fur (Kruuk 1995).

I also documented the size of river otter groups in undisturbed and disturbed landscapes. A population with varied group sizes is indicative of a healthy population (Blundell et al. 2000; Olsen et al. 2008) as it represents differing stages of life histories (e.g. rearing young, mating, and dispersing).

A study by Green et al. (2015) investigated otter behaviour and group size at latrine sites. However, while their study used motion triggered cameras, similar methods to my study, the study by Green et al. (2015) was done on inland river otters. To date, diel activity and group-size variation have not been investigated during a long-term study in coastal areas where anthropogenic disturbances and predator-prey interactions differ.

My goals were to characterize (a) diel activity patterns and (b) group size in a protected, undisturbed landscape area, and compare them with those in a landscape altered by human activity. Furthermore, I wanted to determine the relationship of diel activity of river otters to tidal patterns. Within this context, I investigated activity in relation to time of day and tide level. I predicted that river otters in regions without human disturbance would be active nocturnally, with activity peaking at low tide (Melquist and Hornocker 1983; Chanin 1985; Garcia de Leaniz 2006). I also predicted these otters would show lower levels of activity (Riley et al. 2012, Corcoran et al. 2013). Finally, I predicted that river otters would visit latrines near human disturbances less frequently (Bowyer et al. 1995); and that group size in disturbed areas would be smaller than in undisturbed areas.

4.2 Material and Methods

4.2.1 Data Collection

Study area, latrine survey and camera placement and retrieval are described in Chapter 2.

4.2.2 Data Analysis

4.2.2.1 *Diel activity* - When analyzing camera data, I noted the month and hour of the day each time a camera was triggered by otters. Each of these triggers was considered its own separate event. I allocated trigger events to hourly intervals (00h-01h; 01h-02h etc.) and summed the data for each hourly interval for each month. The number of trigger events that occurred each hour was a representation of activity. Data from June, July, August and September were used; other months had too few data for analysis (few otters triggered the cameras in May, and most batteries began to lose power at the beginning of October).

I used a generalized additive model (GAM, k value =3) to determine the pattern and level of diel activity for each month, and the upper and lower 95% confidence intervals. Diel activity was measured as the number of times otters triggered the cameras at latrine sites at undisturbed and disturbed areas. I repeated the analysis on the pooled data for the entire study period (i.e., both study seasons).

Using the Kolmogorov–Smirnov test, I determined whether activity level differed between disturbed and undisturbed areas month-by-month, as well as over the entire study. I used Kendall's coefficient of concordance to test if diel activity patterns between the two areas were similar. For all statistical tests, I used $\alpha = 0.05$.

4.2.2.2 *Diel activity and the tidal cycle* - I pooled camera data across all latrines and study areas, and used hourly number detections as the proxy for activity. I obtained hourly tide level data from the Department of Fisheries and Oceans, collected in Bonavista, Newfoundland (Department of Fisheries and Oceans 2015). I then used a generalized additive model (GAM, k value =3) to determine the relationship of otter activity to tidal levels by comparing hourly tide level to the number trigger events during each hour.

4.2.2.3 *Group size* - When analyzing camera data from each latrine, I considered that the videos obtained were of different individuals if more than 24 hours had passed between camera trigger events. As otters have no distinguishable marking, I was unable to differentiate between multiple visits by the same individual and visits from different individuals. I considered these 24-hour pooled videos to be single visitations by single groups of otters.

It is possible that two different groups of otters could pass a single camera within 24hr, thus I might have underestimated the number of otters. However, by reducing the interval too much, I felt that I might overestimate the number of groups visiting sites, due to repeated triggers (i.e., multiple short-term visits) by groups.

I estimated group size during a single visitation as the minimum number of otters visible on camera within that visitation. The range of group sizes was characterized for undisturbed and disturbed areas, as well as both areas pooled.

To determine if group sized varied monthly within and between undisturbed and disturbed areas, I used a mixed-effects model using group sizes, with the month each group visited a latrine and the random effect as the latrine site.

4.3 Results

Otters were detected by cameras at 31 latrines in 2012 and at all 35 latrines in 2013.

4.3.1 *Diel activity* - Otters were mainly active at night. Over the study, otter activity peaked around 0100h or slightly later (~0200h) in undisturbed areas; lowest activity was from late morning to late afternoon (Fig. 4.1).

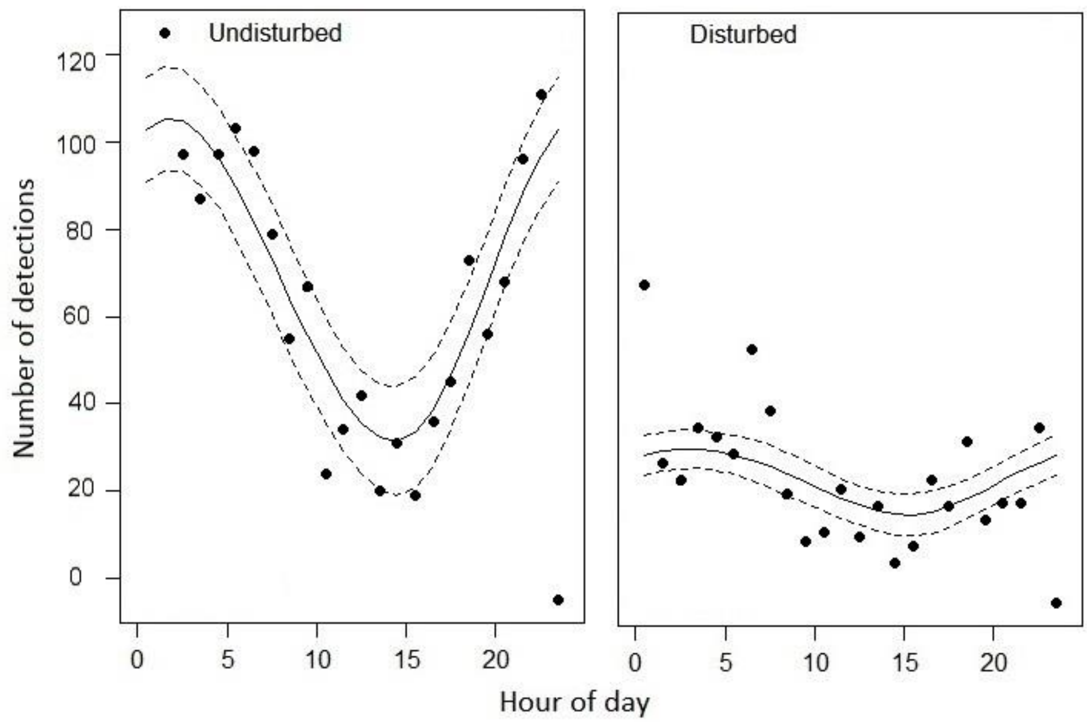


Figure 4.1. Northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland, Canada, are mostly active at night. Activity levels were highest in areas with little human disturbance. Data points represent the sum of detections for each hour across all latrine sites, for the entire study. The solid line represents the mean trend, as fitted by GAM; the dashed lines show the 95% confidence limits. Both GAMs were significant: p=0.0017 (undisturbed, n=18), p= 0.049 (disturbed, n=18).

The pattern of diel activity shifted slightly each month; activity peaks were between 0000h and 0100h in June and July, 0200h and 0300h in August, and 0500h and 0600h in October (Fig. 4.2).

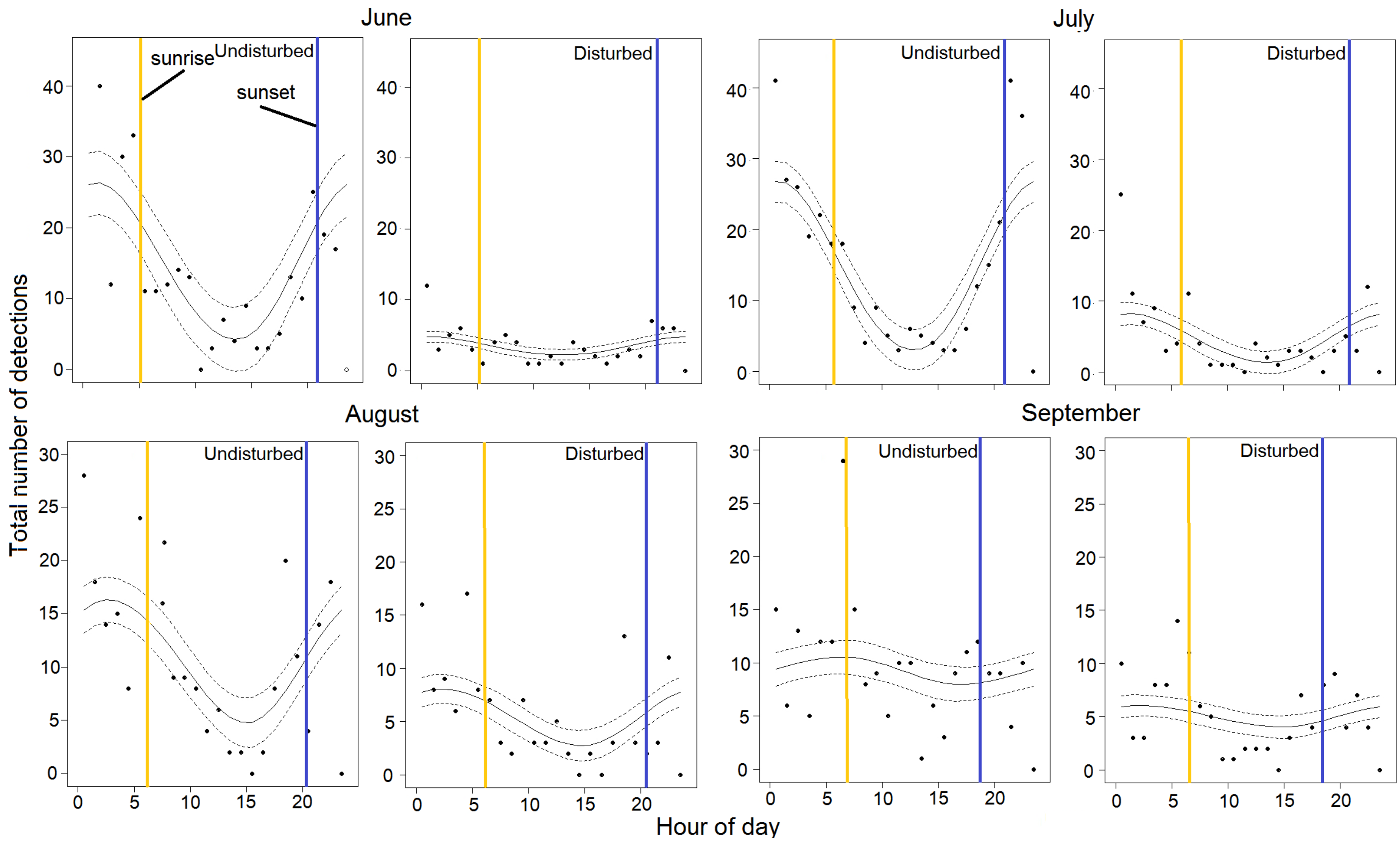


Figure 4.2. Level of activity was lower in in disturbed areas than undisturbed areas. GAMs were significant in June **(**disturbed, p=0.046; undisturbed, p= 0.008), July (disturbed, p=0.016; undisturbed, p=<0.001) and August (disturbed, p=0.03; undisturbed, p= 0.0060). Monthly diel activity patterns of northern river otters (*Lontra canadensis*) were similar between disturbed and undisturbed areas, with otters being more active at night. Solid lines represent the mean number of triggers and broken lines represent upper and lower confidence intervals. Yellow and blue lines represent times of sunrise and sunset, respectively.

Patterns of diel activity, as indicated by Kendall's coefficient of concordance, were similar between undisturbed and disturbed areas for all months and over the whole study period (Table 4.1). Kolmogorov-Smirnov tests indicated that levels of activity differed between areas when considering the entire study period, as well as in June, July and September separately (Table 4.1).

Table 4.1. Patterns of activity of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland, Canada, were similar between undisturbed and disturbed areas for all months and over the whole study period. Levels of activity differed between undisturbed and disturbed areas June, July and September, and over the whole study period.

Time period	W[a] (p)	D[b] (p)
Whole study period	0.56 (<0.001)	0.96 (<0.001)
June	0.78 (0.045)	0.63 (<0.001)
July	0.79 (0.038)	0.46 (0.013)
August	0.79 (0.039)	0.38 (0.068)
September	0.76 (0.049)	0.46 (0.013)

[a]Kendall's coefficient of concordance.

[b]Kolmogorov-Smirnov test.

4.3.2 *Diel activity and tide levels* – River otter activity was related to tidal patterns with more activity around intermediate tides; activity was lowest at both low and high tides (r = 0.69, n =250, p=<0.001,(Fig. 4.3).

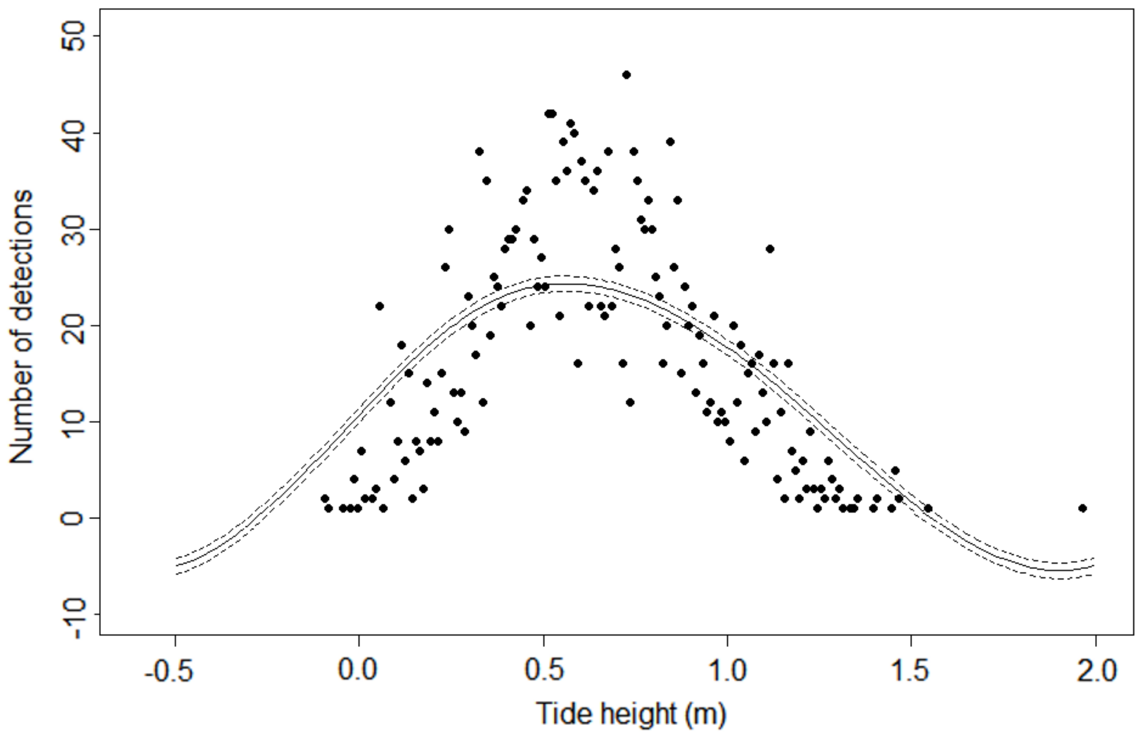


Figure 4.3. Diel activity patterns of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland were related to tidal height, with more activity around intermediate tides; activity was lowest at both low and high tides. GAM was significant (p=<0.001).

4.3.3 *Group size* – River otters were detected mainly as solitary individuals in both study areas (Fig. 4.4), but groups as large as 8 detected in undisturbed areas and 5 in disturbed areas.

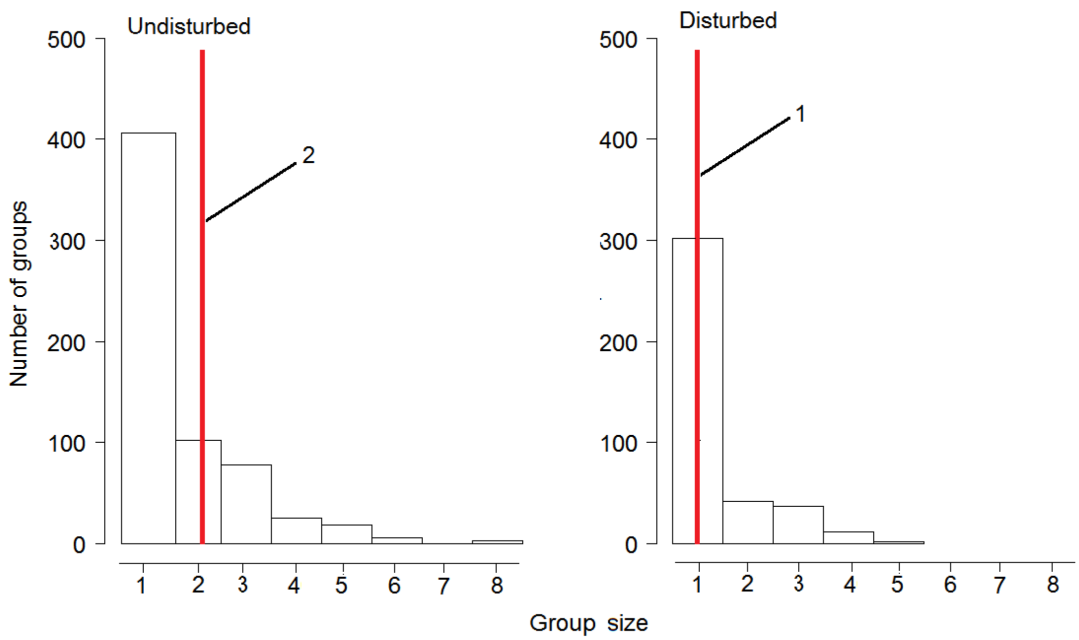


Figure 4.4. The most common group size of northern river otter (*Lontra canadensis*) in marine-coastal Newfoundland was one individual. Group size ranged from 1-8 individuals in undisturbed areas, and 1-5 in disturbed areas. Red lines represent medians.

The highest monthly mean group size within the undisturbed area was 2.6 in January, vs. 2.4 in December within disturbed areas (Fig. 4.5).

In undisturbed areas, otters were not caught on cameras during the months of February and April, while the same can be said for disturbed areas during the months of February through April. However, during months with no river otter activity, few cameras were working and many visits by otters were not recorded. These months, along with months in which otters were observed in one area but not the other were removed from further data analysis.

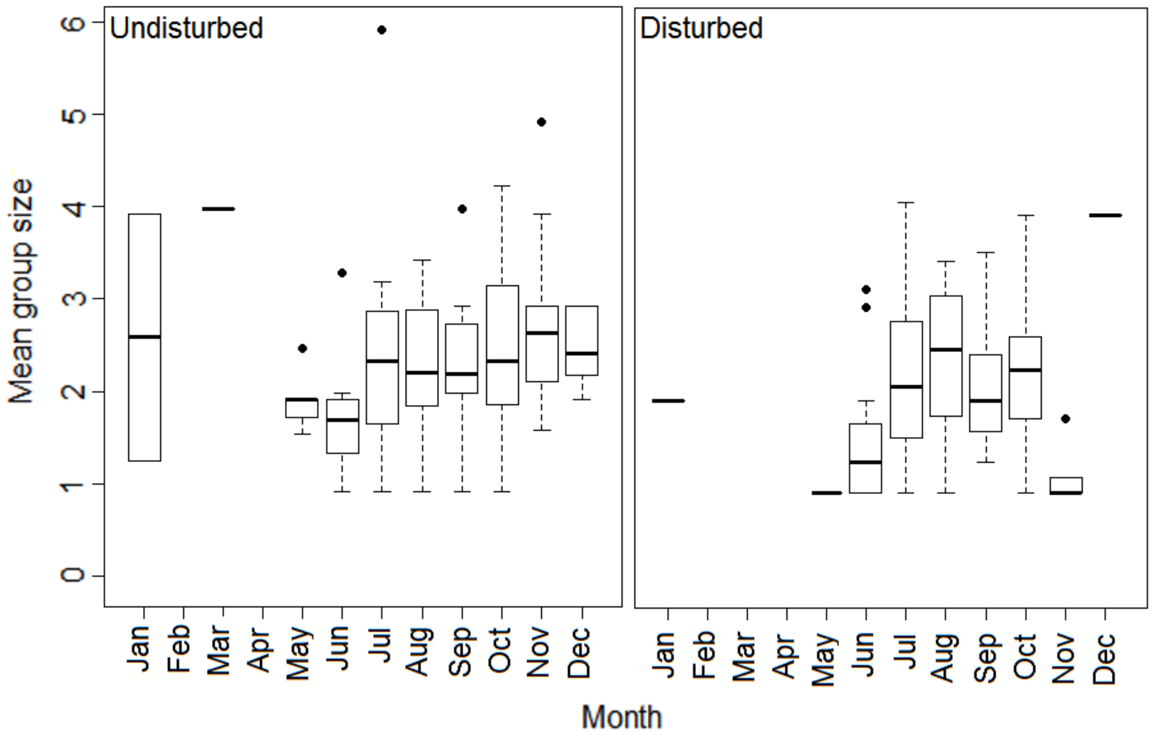


Figure 4.5. Group size of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland varied seasonally: it was generally smaller in areas with human disturbance, and high in the summer.

Group size did not vary seasonally in and between both undisturbed and disturbed areas (Table 4.2). In each case the random effect of the size explained the majority of the variance.

Table 4.2. Group size of northern river otters (*Lontra canadensis*) visiting latrines in marine-coastal Newfoundland did not vary significantly monthly both between and within undisturbed and disturbed areas.

	Disturbed + Undisturbed				Undisturbed				Disturbed			
Month	β	t	df	p	β	t	df	p	β	t	df	p
January	2.35	4.41	987	0	2.69	3.08	610	>0.01	1.99		369	0.00
February	-	-	-	-	-	-	-	-	-	-	-	-
March	-1.61	-1.08	987	0.28	-1.74	-1	610	0.32	-	-	-	-
April	-	-	-	-	-	-	-	-	-	-	-	-
May	-1.05	-1.48	987	0.14	-1.14	-0.16	610	0.87	-1.05	-1.05	369	0.29
June	-0.79	-1.45	987	0.15	-0.92	-1.05	610	0.3	-0.71	-1.19	369	0.24
July	-0.22	-0.4	987	0.69	-0.39	-0.44	610	0.66	-0.11	-0.17	369	0.86
August	-0.11	-0.21	987	0.83	-0.37	-0.42	610	0.67	0.13	3.49	369	0.82
September	-0.09	-0.16	987	0.87	-0.26	-0.29	610	0.77	0.03	0.05	369	0.96
October	-0.13	-0.25	987	0.81	-0.17	-0.19	610	0.85	-0.17	-0.29	369	0.77
November	-0.22	-0.41	987	0.69	-0.15	-0.16	610	0.87	-0.87	-1.36	369	0.17
December	-0.4	-0.66	987	0.51	-0.73	-0.42	610	0.68	1.95	1.53	369	0.13
Marginal R^2	0.03				0.03				0.07			
Conditional R^2	0.07				0.04				0.08			

4.4 Discussion

Northern river otters in marine-coastal Newfoundland were active mainly at night. Diel activity patterns were not influenced by anthropogenic disturbances such as logging or cabin development. However, activity levels were lower in areas with disturbance. Otters visit latrines that have been impacted by anthropogenic disturbances less frequently. While this lowered state of human activity may not be a substantial enough disturbance to disrupt natural diel rhythms, it may be enough to disrupt the level of activity at disturbed latrines. Furthermore, diel activity patterns also were related to tide level, with greater amounts of activity occurring during intermediate tidal levels.

Diel Activity – Diel activity of marine-coastal river otters in Newfoundland was rhythmic and primarily nocturnal, as for this species in inland habitats (Melquist and Hornocker 1983; Green et al. 2015), and for European otters in freshwater systems (Garcia de Leaniz 2006; Chanin 1985). The greatest activity occurred during nighttime and twilight hours and steadily decreased after dawn, with lowest activity during midday. Furthermore, this activity pattern was similar during all months of the study (2012-2014) in both undisturbed and disturbed areas. These patterns may be related to one or a combination of the following: tidal height (Kruuk and Moorhouse 1990), activity level of prey (Westin and Aneer 1987; Kruuk et al. 1988), or avoidance of human disturbance (Riley et al. 2012; Corcoran et al. 2013) or predators (Kruuk 1995).

As in the European otter (Kruuk and Moorhouse 1990), northern river otters in my study were more active during periods of falling and rising tides, and less active during high and low tides. This pattern may be related to the activity patterns of their prey, as well as their frequent bathing for maintenance of the pelage.

Northern river otters in Bonavista Bay feed primarily on marine fish species such as sculpins (Cottidae) and winter flounder (*Pseudopleuronectes americanus*), plus invertebrates such as crustaceans (Cote et al. 2008). These predatory fish species move into shallow water at night (Cote et al 2008). As a result, they could be more susceptible to predation by river otters.

I predicted that river otters would be most active at high tide, when their prey is most active in shallow waters, but this was not the case. When searching for prey, otters limit the depth of their dives between 0 and 3m, as it reduces the thermal efficiency of their fur (Nolet et al. 1989). Otters avoid diving during high tide as the insulative quality of their fur becomes compromised at greater depths.

My findings agree in part with Bowyer et al. (1995), in that river otters avoid latrines in close proximity to anthropogenic disturbances; however, their study did not investigate whether disturbance affects diel activity. In my study, while diel activity was not related to levels of anthropogenic disturbances the amount or level of activity was.

The old logging roads in my study area are used as access roads for coastal cabins, but there is little to no logging activity (the most recent area was logged in 2011; Department of Natural Resources 2014). Furthermore, most activity in these areas occurs around cabins and during daylight hours, when otters are least active. As a result, otters may not be subjected to these anthropogenic influences to such a degree that their diel patterns would be altered.

In disturbed areas, activity was lower than in undisturbed areas for all months except August. This may reflect otters avoiding latrines that are close to human disturbance. When otters choose latrines to visit, they focus on particular habitat characteristics (e.g., proximity to freshwater) while avoiding anthropogenic disturbance such as roads or cabins (Chapter 2). However, in disturbed areas, the importance of ecological factors such as food and freshwater may outweigh the threat of disturbance. Therefore, otters in those areas may not abandon latrines completely, but simply move though the area faster, visiting fewer latrines.

Group size – Group size in my study area was smallest in winter and early spring, and increased through summer and fall. Similar patterns were found for river otters by Olsen et al. (2008), and are similar in European otters (Kruuk 1995). The summer and fall group size increase corresponds with mobility of young-of-the-year juveniles; when juvenile otters begin traveling with their mothers (Mills 2004). The decrease in late winter to early spring is due to the juveniles leaving prior to the arrival of the next litter (Kruuk 1995).

Certain biases from previous studies may have affected conclusions about diel/tidal activity patterns and group sizes. Other investigations into diel activity were done from a distance using binoculars and telescopes, and did not sample behaviour at night. My study and method of using cameras to capture images of otters were not affected by this bias. Admittedly, there are potential limitations to my study. For example, from the cameras, I rarely observed otters eating, and only observed them coming onto land after they completed other unseen activities such as swimming, playing or hunting.

Group sizes reported above may be biased, for two reasons. First, cameras did not operate in winter or early spring, when group size may have differed from the period in which I sampled. Second, my cameras did not encompass the full extent of latrines, so some animals in a group may have went undetected.

Otter group size did not vary monthly both between and within undisturbed and disturbed areas, and was smaller in disturbed areas. This pattern may reflect avoidance of disturbed areas by female otters with young in during summer months (Bowyer et al. 1995). In contrast, solitary males or young in their first year away from their mothers may exhibit more boldness and visit areas with disturbances more frequently (Kruuk 1995).

Disturbances do not seem to have a strong effect on diel activity or group size of coastal river otters in Newfoundland. However, while the study sites are representative of rural Newfoundland, they are altered little by humans compared with most parts in the species' range. Conducting a similar study in more severely disturbed area with ongoing logging operations would give a better understanding of the effect of anthropogenic influences. Furthermore, conducting research during winter months, when freshwater habitats are more limited, may provide useful information pertaining to the use of latrines during this time of year, thereby providing important information to resource managers and allows for the implementation of appropriate landscape planning for conservation.

Chapter 5

General Summary and Future Research

In this study I examined habitat selection, diel activity, and group size of northern river otters in marine-coastal areas with and without anthropogenic disturbance. I also investigated the validity of using spraints as an index for latrine use in the coastal waters of Clode Sound and Freshwater Bay, Newfoundland, Canada.

Throughout their distribution, river otters are a top predator in aquatic food webs (Toweill 1974) and as a result may play important roles in ecosystems as a keystone species (Bowyer et al. 2003). Due to their use of both marine and terrestrial environments, marine-coastal river otters act as a conduit by which marine productivity is brought into terrestrial ecosystems, through repeated defecation and eating at fixed latrine sites (Bowyer et al. 2003). This nutrient transport helps to shape the composition of near shore communities in freshwater habitats (Ben-David et al. 1998), so may have similar effects in marine-coastal habitats (in which the activity might enhance coastal fish nurseries; Cote et al. 2008). Knowledge of river otters in a disturbed landscape allows for improving management efforts (Gallant 2007).

In Chapter 2, I reported on a survey to investigate the presence of river otters at latrines, and the intensity of latrine use in relation to natural and anthropogenic landscape features. I found that sources of anthropogenic disturbance such as logging, cabins and roads, did not differ between the locations of northern river otter latrine sites and control sites, whereas the level of activity was higher at latrines that were distant from cabins and roads. Latrine sites were characterized as areas with disturbed ground cover such as overturned earth and altered vegetation; their presence and use can be altered in relation to proximity to anthropogenic factors. I found that all latrines are not created equally; otters seem to be less discriminating when placing latrines along a coastline and focus more on ecological factors while avoiding anthropogenic ones when choosing which sites to visit more frequently. As a result, when biologists and resource managers survey an area, latrine activity should be focused on as it acts as a better indicator of the overall status of otters.

In Chapter 3, I discussed the validity of spraints as an index for latrine use. I attempted to identify a temporal period in which spraint surveys provide an accurate index for latrine use over small and large spatial scales. I also determined the rate of desiccation of fresh spraints. Spraint counts are unreliable for estimating intensity of use of single latrines, over short or long temporal periods. In addition, the absence of spraints at a latrine does not necessarily signify the absence of otter activity. However, sprint counts may be useful when investigating otter abundance over a large landscape. Spraints desiccate quickly (by ~70 hr), and are prone to removal and dispersal by otters and other animals. Consequently, I recommend that spraint surveys be used as an index of population density with caution.

In chapter 4, I analyze river otter diel activity and group size, and relate these to human disturbance. I found that the overall diel pattern of river otters was nocturnal, occurring mostly around intermediate tide levels, and not influenced by anthropogenic disturbances such as logging and cabin development. However, the overall amount or level of activity was lower in areas with disturbances due to infrequent use of latrines in such areas.

Otters have a high metabolic rate and must eat frequently, so rarely leave the vicinity of the coast. They have higher periods of activity during intermediate tide levels. Group size of river otters did not vary seasonally and was not influenced by human disturbances. Activity levels were depressed in disturbed areas, because few otters visited latrine sites there. These findings suggest that anthropogenic disturbances such as logging, cabin development and roads did not interfere with otters and their natural diel rhythms or group size substantially in my study areas; however, otters seemed to avoid those areas to some degree.

Future work

My study sites, while representative of conditions for parts of the range of river otters in Newfoundland, are altered by humans much less than in most areas of the species' range. There are several areas of potential future research related to river otter habitat selection, latrine use, diel activity and group size within disturbed landscape.

Firstly, in my study area, logging roads are used for access to coastal cabins, but there is no logging at present; the most recent logging was in 2011 (Department of Natural Resources 2014). Otters may show more dramatic or different changes in areas with larger or ongoing disturbances. I believe that conducting additional research is required to investigate how otters are affected in the presence of more severe or ongoing anthropogenic influences in similar context to this study.

Furthermore, it may be of benefit to study river otters in similar context to this study before and immediately after a large scale disturbance for an extended period of time to determine how long it takes for the species to re-establish normal patterns again. This could address confounding issues in my study and determine if differences seen in this study were because of inherent unmeasured differences in habitat or, because of the disturbance itself.

Since dens are a key factor listed as habitat necessities for otter survival (Hanson 2003), work completed in identification of den sites would be particularly helpful. No active dens were found at latrines in my study. However, while it is assumed that with sufficient riparian vegetation that lack of den availabilities is not an issue, it still needs to be investigated. Habitat requirements for denning otters may be more sensitive to anthropogenic disturbances than non-denning individuals and therefore the existing levels of disturbances affect these otters. Expanding the study area within the researched area could help to determine whether or not anthropogenic disturbances are inhibiting den availability.

Incorporating radio tracking into a future study would give the ability to recognize individual animals, obtain accurate locations, and determine home range of each individual (Sanderson 1966). While I was able to determine otter activity, it was impossible to determine otter movement within the landscape. How animals move within a landscape, especially one that has anthropogenic disturbances can be especially informative. Altered activity levels could be a result of the same animals using undisturbed parts of their home range more frequently, or it could be that otters that are restricted to disturbed areas have to spread themselves out thinner, possibly adding energetic costs. Also, movement would help determine if coastal areas are better habitat for river otters than freshwater habitats.

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Appendix:

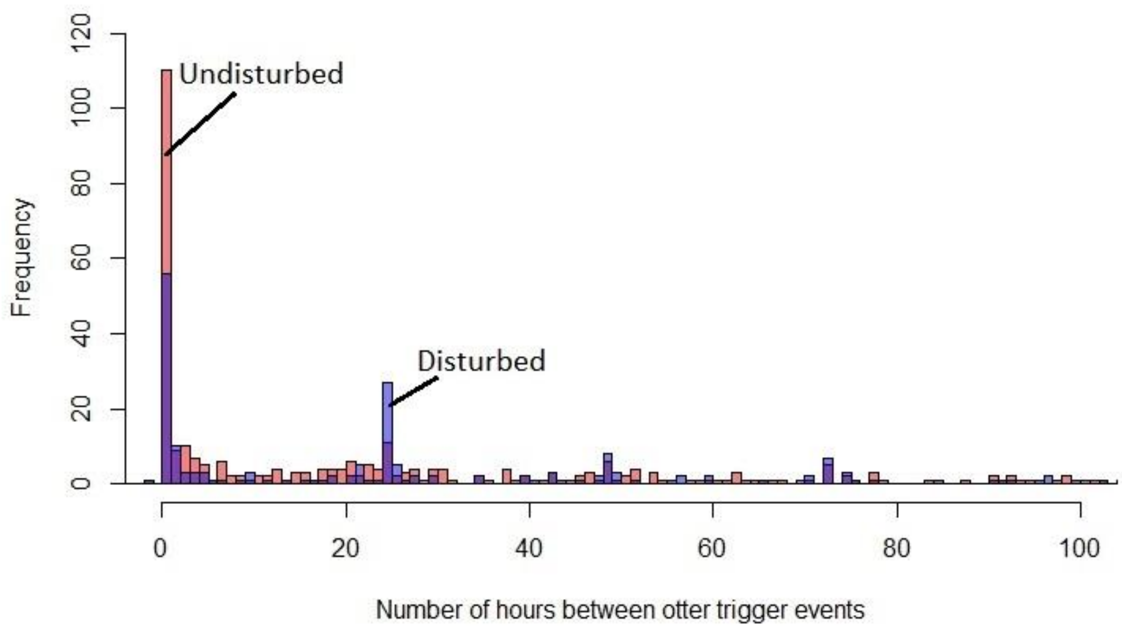

Figure a1. Spikes in activity of northern river otters (*Lontra canadensis*) in marine-coastal Newfoundland suggested patterns of 24hr activity This indicates that it is likely that when otters were re-detected within short time frames that it was the same animal(s).

Table a1. Pearson's correlations on each habitat variable indicated that the variables dstreammouth and dfreshwater were positively correlated; dstreammouth was subsequently removed as it was redundant. Bold indicates high correlation.

Variable	droad	dcabin	dlogging	dstreammouth	dfreshwater	foragingarea
droad	1	-	-	-	-	-
dcabin	0.24	1	-	-	-	-
dlogging	0.15	-0.09	1	-	-	-
dstreammouth	-0.24	0.031	-0.12	1	-	-
dfreshwater	-0.09	0.03	-0.03	**0.85**	1	-
foragingarea	-0.08	-0.21	0.2	-0.24	-0.21	1

Table a2. Total number of spraints at single latrines and number of otter visits were not related to each other (according to linear regression). Bold font indicates significant relationship; dashes represent sites with insufficient data. I recorded no otters or spraints at site CHU6.

Site[1]	Intercept	Slope (SE)	R^2	p
CHU1	-1	0.97 (0.59)	0.3	0.2
CHU2	8.95	-0.38 (0.74)	-0.22	0.64
CHU4	7.96	-0.12 (1.12)	-0..33	0.92
CHU6*	0	0	0	0
CHU7	2.13	0.85 (1.42)	-0.19	0.59
CHU8	1.11	1.94(0.78)	0.57	0.09
CHU9	11.1	-0.11 (0.66)	-0.32	0.88
CHU10	14.06	-0.69 (0.32)	0.48	0.12
CHU11	1.17	0.1 (0.29)	-0.28	0.75
CH3	5.07	0.48 (0.87)	-0.21	0.62
CH4	13.64	-1.39 (1.9)	-0.14	0.53
CH5	3.0	0.5 (2.29)	-0.31	0.84
CH8	2.21	1.15 (1.15)	0.003	0.39
CH15	7.4	0.01 (0.99)	-0.33	1.0
CH17	9.48	-0.32 (0.68)	-0.24	0.67
CH18	**0.14**	**7.07 (0.75)**	**0.96**	**<0.05**
CH19	**28.01**	**-1.28 (0.14)**	**0.95**	**<0.05**
CH20	0.84	0.53 (0.63)	-0.08	0.46
GTC1	-0.71	2.3 (1.56)	0.22	0.24

GTC2	0.01	2.75 (0.43)	0.95	0.10
GTC3	-4.64	3.35 (1.44)	0.52	0.10
GTC4	6.01	-0.77 (1.12)	-0.15	0.54
GTC6	---	---	---	---
GTC7	---	---	---	---
GTC9	3.42	-0.86 (3.67)	-0.31	0.83
GTC10	5.63	0.49 (0.89)	-0.21	0.62
GTC11	5.6	0.19 (0.70)	-0.30	0.80
GTU1	---	---	---	---
GTU3	1.43	-0.14 (0.61)	-0.31	0.83
GTU5	8.43	-0.31 (0.55)	-0.20	0.61
GTU6	10.46	-0.93 (0.42)	0.51	0.11
GTU7	9.05	-0.23 (1.04)	-0.31	0.84
GTU8	0.38	-1.26 e-15 (0.43)	-0.33	1
GTU9	6.82	-0.19 (0.28)	-0.16	0.55
GTU11	25.29	-2.3 (1.32)	0.34	0.18
GTU13	-7.47	0.68 (0.28)	0.55	0.09

[1]Individual identification code for latrines used for study period.