The ecological effects of the cleared boundaries of Bruce Peninsula National Park

by

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A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Master of Science

in

Geography

Waterloo, Ontario, Canada, 2009

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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ABSTRACT

Bruce Peninsula National Park (BPNP) clears a 2 m swath of trees on the boundary in order to make it clear when one is entering the park from any neighbouring land; this in particular aims to protect the park and its inhabitants from illegal actions such as hunting and logging. This study looks at the ecological effects of this practice by measuring various microclimate variables and the abundance of eastern redback salamanders (*Plethodon cinereus*) on the boundary and comparing these measurements to parallel transects at 5, 10, 15, 20, and 40 m. Because it is a small linear development, it is then compared to other types of linear developments, such as roads, trails, and pipelines.

The microclimate variables of air temperature, slug abundance, canopy cover, soil pH, total cover area, litter depth, and relative humidity were all significantly affected ($p<0.05$) up to 10 m into the adjacent forest, indicating that the cleared boundaries do change the surrounding microclimate. Soil pH, downed woody cover area, litter depth, and canopy cover were significantly affected ($p<0.05$) up to 5 m away from the boundary. Sixty hectares, or 0.4%, of the land area of BPNP is thus affected by the microclimate changes caused by the cleared boundary. These effects are similar to those found for other narrow, vegetated linear developments such as trails.

Over double the number of salamanders were found on the boundary as compared to in the forest; this is due to higher cover area availability on the cleared boundary from the felled trees. Therefore, the boundary does not act as a barrier to eastern redback salamander movement, nor does it fragment the local population. Salamander abundance was best explained by the amount of cover area, snail abundance, and the dominant type of vegetation present along transects. It was also found in an additional study that salamander abundance tended to increase with increasing days since the last precipitation event, contrary to most woodland salamander monitoring protocols and methods.

The boundaries were seen also to be used by hunters and recreationalists through incidental observations of human disturbance. This increased access to remote areas of the park through use of the cleared boundaries is an issue that requires further study, as the boundary itself may be leading to an increase in illegal activity.

Recommendations to BPNP include leaving downed woody cover on the boundary, minimizing the boundary width, reducing lines of sight, decreasing accessibility, increasing landowner and park staff education, communicating with adjacent landowners, and securing funding to complete and maintain the boundary clearing.

Acknowledgements

First and foremost, I want to thank Dr. Stephen Murphy, my advisor, for being the most helpful, most available, funniest advisor I have ever heard of. I had no idea what to expect going into my Masters, and you helped me along the way at every step. Many times I walked in to your office stressed or thinking I was doing something wrong, and left feeling like a million bucks. And thanks for the cookies!

Next, my spectacular field assistants, Allie Service, Dr. Daniel Harvey, and Lindsay Theriault: you guys not only made my field seasons possible, but you also made them exciting, full of learning, and complete. I hope you had as much fun as I did.

The scientists and staff at Bruce Peninsula National Park made us feel incredibly welcome. Thanks to Scott Parker for introducing me to all the important people and topics, John Haselmeyer for organizing my methods and equipment, and Katherine Welch for showing me how to actually get to all of the boundaries. I literally would have been lost if it wasn't for your generous time.

And to my mom, Barbara St.James – the most faithful and reliable proof-reader in the world. Thanks for reading this for the eighth time! And to the other proofreaders: Dr. Stephane Menu and Dr. Daniel Harvey – thanks for doctoring it up!

This thesis was funded by NSERC, Parks Canada, and the President's Graduate Scholarship of the University of Waterloo.

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1.0 INTRODUCTION

> When we draw a line on a map and declare that within that line is a park, we make a gross intrusion on the landscape. We try to demarcate two separated entities in nature's seamless web of affairs. Myers – National Parks, Conservation, and Development (1984)

When one contemplates a land use map, with property boundaries marked in lines and polygons, it is not evident that the existing biophysical processes, landscape features, wildlife, and plants do not generally recognize those same jurisdictional boundaries. Where biological and anthropogenic boundaries coincide, such as at some shorelines, there is little need to demarcate the property boundary on the land in order that other humans can visually recognize the change in ownership. But where boundaries are placed through an interior forest, open grassland, or otherwise consistent habitat type, the need to differentiate between the two jurisdictions can manifest itself through fencing, signing, or other delineation methods. If the interests of the adjoining landowners are similar, such as between a wildlife reserve and a national park, there may be no need to mark the boundary; however, when the interests diverge, such as between a forest designated for lumber and a national park, it then is necessary to ensure that the boundary is apparent. Yet, the way the boundary is delineated can affect the habitat that the park is protecting. This case study looks at the practice of marking protected area boundaries by cutting a swath of trees around the edge of the park, and whether or not this causes significant ecological effects.

A cleared boundary creates habitat edges as it fragments the landscape, and it is a linear corridor development similar to a road or trail, depending on its width. The literature review here thus looks at research done on the ecological effects of creating edges and linear developments. When edges are created, naturally or artificially, edge effects can occur. 'Edge effects' is a term used here to describe all of the ecological changes that occur between two different, juxtaposed habitats. The habitats may be different naturally or in response to management. Linear developments have a high edge: area ratio simply because of their geometry, and so an understanding of edge effects is fundamental to understanding how linear developments affect their environment. Because roads are considered to have the strongest impacts of all linear developments, the ecological effects of roads are described first, and then the ecological effects of trails, pipelines, seismic lines, hydro corridors, and railways are considered. The systematic effects of multiple linear developments in an area are then described. Issues relating to increased access, caused by linear developments, are considered in detail.

The case study of cleared boundaries was carried out in Bruce Peninsula National Park (BPNP), where the interaction of public and private land caused by changing ownership as the new park grows makes for a complex social landscape. A park ecologist at BPNP, Scott Parker, expressed his concern with BPNP's current practice of clearing a two metre swath of trees along the boundary of the park to demarcate it on the land. Although logging still occurs in some land adjacent to BPNP, he was more concerned that the ecological integrity mandate of Parks Canada made the directive to cut trees, in order to protect land and its inhabitants, debatable. This mandate to protect ecological integrity was designated as Parks Canada's first priority in 1988 (Parks Canada 2000a). Unfortunately, park managers generally have little influence on activities that occur outside of the park boundaries (Slocombe 2009). Demarcating the boundaries is thus considered one way to increase protection. However, another approach should be considered if these cuts have a negative impact on BPNP's flora, fauna, or environment.

In order to understand the ecological effects of the boundaries, the following research questions were studied:

1.1 RESEARCH QUESTIONS

1. What is the effect of the cleared boundaries on the microclimate of the surrounding forest?

   To study the effects of these cuts, the impact of the cleared boundaries on the microclimate of the adjacent forest was measured; edge effects found could be considered negative ecological impacts. My hypothesis was that the boundary would be significantly different from the other adjacent transects for the environmental variables of air temperature, soil pH, soil moisture, relative humidity, litter depth, downed woody cover area, canopy cover, snail abundance, and slug abundance. If edge effects were to be found, the boundary clearing practice should be reconsidered in light of those findings.

   To test my hypotheses, 26 sites were placed randomly along cleared parts of the BPNP boundary. Each site consisted of 50 m transects of 2 m width placed on and parallel to the boundary at 0, 5, 10, 15, 20, and 40 m. Microclimate variables were measured on each transect.

2. What is the effect of the cleared boundaries on the spatial distribution of *Plethodon cinereus?*

   Another goal of this research was to see if the boundary caused changes in the abundance of *P. cinereus* – a ubiquitous, small, and sensitive woodland salamander; if these salamanders actively avoided the boundary, then there could be fewer salamanders crossing, leading to restricted gene flow and possibly genetically isolated populations. My hypothesis was that the abundance of salamanders on the boundary would be significantly less than that on corresponding transects further into the adjacent forest, with highest abundances on the furthest transects from the boundary. If this is shown to be true, further study into the possibility of genetic isolation would then be warranted. This would also show that the boundaries are causing negative ecological effects, and the boundary clearing practice should be considered with this in mind. Salamanders in this case are used as an indicator species because of the important role they play in the region's ecosystem and foodweb; thus, a problem with salamander populations would indicate a larger issue.

To test this hypothesis, the methods of the study described above for microclimate variables included measuring salamander abundance under natural cover objects. The abundance of salamanders as well as the salamanders' weights and lengths were measured at each transect.

3. When is the best time to sample for woodland salamanders?

   An additional study looking at the abundance of woodland salamanders found with respect to the length of time since the last precipitation event was also carried out. This study is shorter and meant to supplement the methods used for the main case study, and it is thus described in detail in Appendix A. My hypothesis here, as a result of my field observations in the transect study described above, was that salamander abundance increased with time since a precipitation event, which was counter to methods used in other research on woodland salamanders.

   To test this, after a precipitation event, a random subset of 10 out of 40 boards on an Ecological Monitoring and Assessment Network (EMAN) monitoring plot in BPNP was searched each day for four days. If there was no precipitation in the next four days, the same subsets were sampled again, eight to eleven days after the original precipitation event. Data from EMAN monitoring plots in other protected areas were collected as well. The length of time was then correlated with the abundances of terrestrial salamanders, and the results supplemented the methods used in the main case study.

The results of these studies are then presented. A discussion of these results follows, specifically on the ecological effects of BPNP's boundaries, the response of *P. cinereus* to the boundaries, the use of woodland salamanders as indicators of forest integrity, and the real cost of BPNP's boundaries. Future research opportunities, recommendations to BPNP, a summary of contributions that this research makes to the existing literature, and conclusions are then provided.

Geography is the study of spatial differences between objects in our world – where things and people are and why they are there. Biogeography considers the spatial distributions of the objects in our world studied in the biological discipline, and in this case, the spatial distribution of salamanders and microclimate changes in relation to the boundary line of BPNP. Therefore, this thesis is considered part of biogeography research.

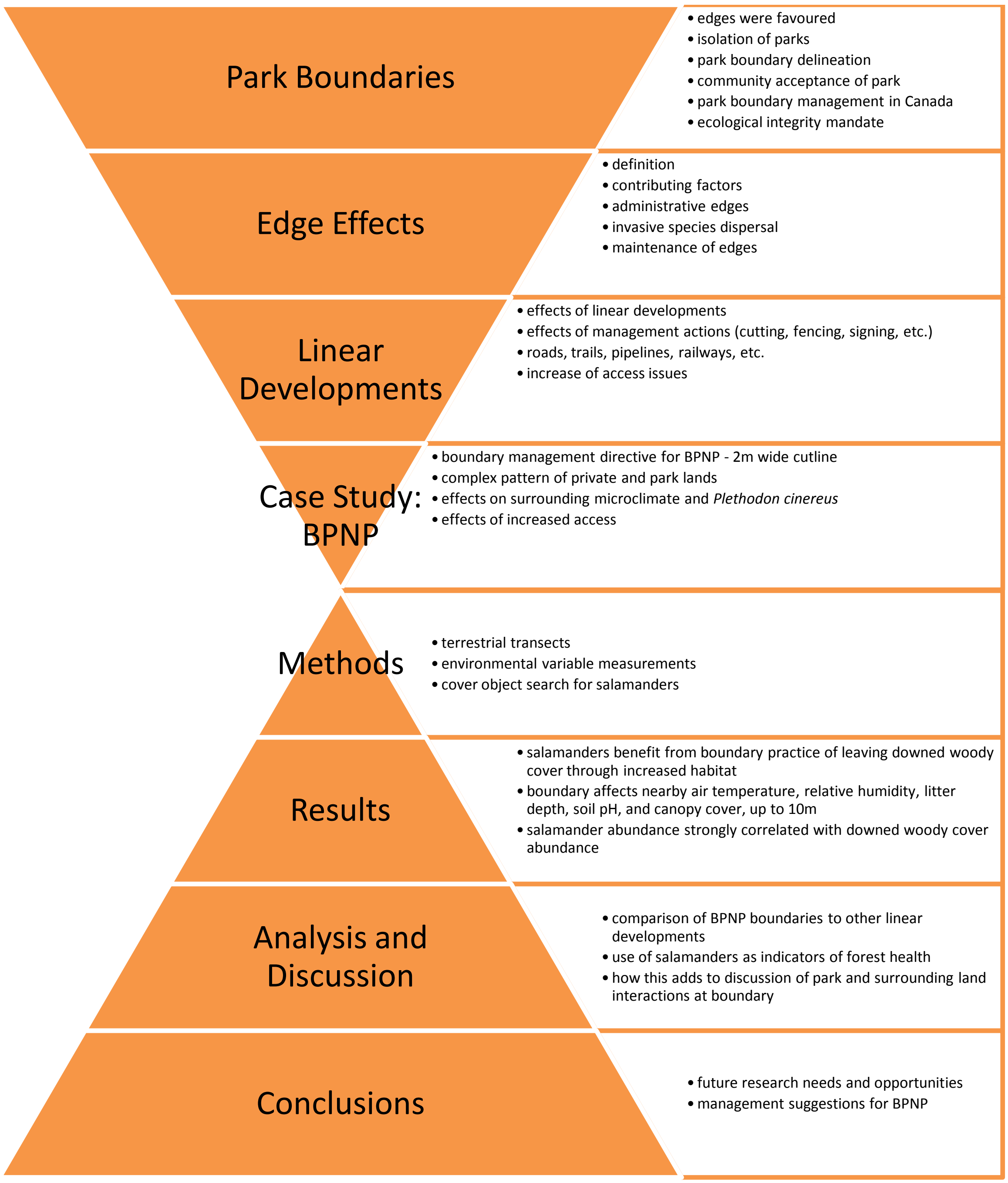

Figure 1. Flow diagram of development of thesis, from introduction of boundary issue to conclusions.

2.0 BACKGROUND

When it was determined that edges may provide easy access to multiple habitats for many animals, such as large game animals that have various survival needs, creating edges in the landscape became a somewhat common practice in wildlife management (Leopold 1933). Large game animals, such as deer, fed in meadows and found shelter under forest canopy, and so fragmenting the landscape could improve their survival rate. Deer, in this regard, were, and still are, considered an edge species (Forman et al. 2003). Predators learned to prefer these edge areas because of the higher concentration of prey. This improved predator survival, and conservationists and hunters alike were content. However, not all species favoured edge environments, and declines in other species began as fragmentation of the landscape increased. Species that depended on core habitat, such as the Northern Spotted Owl (*Strix occidentalis caurina*), could not survive in fragmented habitat and previous edge creation techniques were questioned (Diaz 2004).

With the increase in urban sprawl and the 'wilderness-island' quality of our parks, the question arose as to whether large parks were better than many small parks. The 'Single Large or Several Small reserves' debate began from the idea that nature reserves, surrounded by a sea of human development, may function essentially as islands and can be studied using island biogeography theory (Diamond 1975). Species richness, which is correlated with area, would therefore be higher in larger reserves. But this would depend on whether many small reserves had an overlap in species compared to one large reserve (Simberloff and Abele 1976). It would also depend on the purpose of the reserve as sedentary biota such as plants could be satisfied with a small habitat, whereas animals with a large home range would require larger areas of protected habitat (Grumbine 1994). It turns out that the connectivity of these parks, no matter what the size, plays a large role and many small, well-connected parks can play an important ecological role, as can large parks with ample core habitat to support threatened wildlife and plants (Noss 1995).

Connectivity is described as the degree of movement of biota or abiotic processes between sites, and the level of connectivity depends greatly on the scale, species, or process concerned (Crooks and Sanjayan 2006). When there is more movement between protected areas, connectivity is said to be higher; however, the opposite case is the particular problem – when there is little movement in and out of an area, the population of a species could become genetically unsustainable (Frankham et al. 2002). In particular, much loss of habitat within a region can result in the remaining habitat being disconnected or fragmented – it is here that connectivity between these disconnected portions becomes important to conservation (Wiens 2006). It is now understood that parks rely on their greater ecosystem for many processes, from animal immigration and emigration, to disturbance pressures, to public support (Janzen 1983; Hanski and Gaggiotti 2004; Crooks and Sanjayan 2006). With these findings came the Multiple-Use-Module, Greater Park Ecosystem concept, ecosystem-based management, biosphere reserves, buffer zones, corridors, and other ways to increase the effective influence of the park's ecological management, maintain connectivity, and manage the park based on its ecological and biophysical boundaries rather than solely the jurisdictional boundaries (Slocombe 1998; Slocombe and Dearden 2009). "Air, soil, wildlife, and plant propagules are not bounded by parks. The boundaries of protected areas are constructs of human perception, not impermeable ecological barriers" (Theberge and Theberge 2009).

With human activity encroaching on the boundaries of parks came the need to clearly delineate the boundaries. For example, in parks surrounded by lands managed for forestry, there may not be a clear distinction between the forest to be cut and the park's forest. Thus the practice of cutting a boundary swath around the edge of some Canadian national parks began. Although this practice varies in application, it is used in a variety of situations. As previously mentioned, BPNP clears a 2 m swath around their boundary (Parks Canada 2000b). A park warden at Yoho National Park described their boundary management practice of clearing a 3-4 m swath in forested areas and using different types and amounts of signage where necessary (R. Hawryluk, pers. comm., May 10, 2008). Waterton Lakes National Park in Alberta, Canada, and Glacier National Park in Montana, USA, form an International Peace Park, yet the U.S. border control requires that a 7 m swath is cleared across the countries' borders for national security purposes, as described by a park ecologist at BPNP (S. Parker, pers. comm., February 5, 2008). On the other hand, Gwaii Haanas National Park does not clear its terrestrial boundaries, and simply demarcates them with signs (P. Bartier, pers. comm., April 25, 2008). Pacific Rim National Park also does not clear the boundaries, but does require loggers on adjacent land to survey the boundary themselves and recommends that a buffer strip is left at the edge of the park (B. Redhead, pers. comm., April 23, 2008). The important point here is that each national park in Canada has a different approach which responds to the unique needs and issues of the region in which it is located.

The need to take management action at the boundary to clearly delineate it from its surroundings can depend strongly on the community's acceptance of the park. National parks that are created in areas where hunting was common practice could experience strong opposition to regulations that now protect wildlife from hunting. This increases the need to delineate where the park begins. For each park, an individual solution to marking the boundaries is found, and boundaries are managed only if there is a need to do so (Dr. J. Waithaka, pers. comm., August 14, 2008). There is no national standard guideline to follow as of 2009. Federal and provincial surveyors general provide guidance on when it is necessary to take management action on the boundaries of a park. Social, ecological, political, historical, and physical factors are all used to determine how and when the boundaries are marked. And of course, cost and accessibility can be prohibitive to managing the boundaries of any park.

The integration of a national park with the surrounding community is important, and BPNP is not an exception. Interactions with local foresters, hunters, and recreationalists have caused some tension in BPNP in the past. Relations with the two local Anishnabe First Nations groups are also important to the decision-making process in BPNP. A park warden at BPNP explained how some local residents are not even aware that the original provincial park around Cyprus Lake has been extended and changed into a national park (K. Welch, pers. comm., May 14, 2008). In an attempt to phase in new national park regulations, the national snowmobile trail running through BPNP is still in use, even though snow machines are generally banned from national parks. The BPNP boundary is currently fragmented with private landholdings and is difficult to protect from outside foresters and hunters as the growing park extends its boundaries when property comes up for sale. Even when the park is completed, demarcating the boundaries could be important in order to protect the interior area from prohibited activities such as all-terrain vehicle (ATV) use, hunting, or logging that do occur outside the boundaries.

In Canada, the boundary management directive for each park is created by Parks Canada in consultation with the individual park to ensure that the directive is appropriate and successful. Consistency of this approach within each park is important for law enforcement, maintenance of ecological protection of the interior area, public safety, and park planning. BPNP's boundary management directive falls under the 1999 Canadian Environmental Assessment Act Regulatory Amendments Section 3, Part I, subsection 13.4, as a Class Assessment which states that,

> The removal of vegetation qualifies as a project under the Act when it is done for the purpose of delineating a boundary or establishing a viewscape… The proposed operation of an existing physical work that (c) is the same as an operation for which an environmental assessment has been previously conducted under either the Canadian Environmental Assessment Act or the Environmental Assessment Review Process Guidelines Order, where (I) as a result of the assessment, the environmental effects have been determined to be

insignificant taking into account the implementation of mitigation measures, if any. (19/10/94 Canada Gazette Part II, Vol. 128, No.21)

Important excerpts from the Boundary Management Directive created for BPNP include mitigation measures to reduce the impact of the cutting: no large machinery can be used – only hand chainsaws and brush cutters – and the cutting is done in the winter months to reduce erosion and destruction of nearby vegetation. Snow machines are preferred for access. Vegetation is cut close to the ground and not piled in order to reduce fuel sources. All vegetation less than 12 cm in diameter at chest height should be cut and dispersed into the forest as this size can be easily lifted; larger trees should be cut into smaller sections and then dispersed away from the boundary to reduce piled fuel sources. The boundary is cut to a 2 m width into the parkland. This width is intended to be minimally intrusive while still visible and obvious. Signs are then erected, not on trees, but at breast height (approximately 1.5 m) on 2.5 cm metal posts every 50 m. The purpose of these measures is to make individuals crossing the boundary at any point aware that they have entered BPNP. A review of each clearing project is done prior to cutting in order to assess for the presence of rare, threatened, or endangered species. The review process could lead to a change in how the work is carried out if deemed important to the survival of any of these species (Parks Canada 2000b). See Figure 8 in Appendix B for an image of a section of the cleared boundary of BPNP.

The first legally mandated priority of Parks Canada is to protect the ecological integrity of the lands they own (Parks Canada 2000a). Although other priorities such as providing recreation, learning opportunities, and a positive outdoor experience can conflict with this mandate, park management policies and plans work towards improving ecological integrity. The Canadian National Parks Act defines ecological integrity as "…a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes" (Parks

Canada 2000a). Protecting and enhancing ecological integrity should be built into every action in national parks. The purpose of BPNP's boundary management directive is to protect the ecological integrity of the lands within the boundary; however, the full ecological effects of the cleared boundary itself have not been studied thoroughly.

In BPNP, the 2 m cleared boundaries are, coincidentally, a good width for ATVs, and there have been incidents of illegal access of these vehicles, which are prohibited in the park. The boundary of BPNP is cleared and signed in order to show an apparent change in vegetation as an indication to those using adjacent lands, such as loggers or hunters, that they have reached the park boundary and should not continue their activity past this boundary. However, a 1999 court case between the Nawash Tribal Council and the Northern Bruce Timber Company (NBTC) questions whether this level of demarcation of the boundary is necessary. NBTC had been logging forest around BPNP and continued to log 40.5 hectares into the park (Bacher 2003). According to the park wardens of BPNP, the boundary was neither cleared nor signed at the time of the infraction (K. Welch, pers. comm., May 28, 2009). Regardless, NBTC was found guilty of damaging park resources and was required to sell 567 hectares of its lands to the Nature Conservancy of Canada, of which 162 hectares were donated to BPNP, as well as to pay for the restoration of the forest which was cut in the park (Bacher 2003). The onus was found to be on NBTC to know where its property ended and the park began, not the park's responsibility. This calls into question the absolute need to clear the boundary if it is not the park's legal responsibility to demarcate the boundary for loggers. The boundary may provide environmental protection to BPNP in that it prevents some infractions – but it comes at a financial and environmental cost of cutting and maintaining the boundaries. In fact, the boundaries themselves may provide the opportunity for more infractions through increased access for hunters. Because of this example, a need to revise the management practice of clearing the boundary has appeared; if there is not a legal need to demarcate their boundary by clearing, should national parks continue this practice?

3.0 LITERATURE REVIEW

3.1 ECOLOGICAL EFFECTS OF EDGES

A cleared boundary creates an edge between the natural forest and the newly cleared area. This edge is anticipated to have some effect, whether good or bad, on the forest; the sum of these effects is termed 'edge effects' (Hilty et al. 2006). These edge effects will depend partially on the width of the cleared swath. A wider boundary will see more windthrow effects, increased sunlight penetration, and less boundary-crossing movements by species that avoid edges (Forman 1995).

An edge occurs on a landscape between two areas of contrasting land and can be caused by natural disturbances and landforms or variations in human behaviour. Edges occur in a variety of forms, and they can have characteristics ranging from wide to thin, abrupt to gradual, or curvy to straight. An abrupt edge will most likely experience edge effects such as increased wind strength, increased sunlight penetration, and subsequent changes in vegetation. These effects can discourage some species from crossing the boundary; however, this will depend on the ecological malleability of the species. Different shapes of edges on the landscape, for example straight versus curvilinear, also influence whether a species perceives the edge as a threat to or an opportunity for crossing. The distance that biota and abiotic factors, such as sunlight, wind, and moisture, can penetrate varies between each type of edge. The difference between the two sides of an edge extends beyond to create a gradient of change, or an area of mixing, which in turn is the width of the edge. The magnitude of difference between the opposing sides is considered the 'contrast' between the two areas, and where the gradient of change is gradual, there is a possibility of allowing biota from one side to cross into the other area, simulating a pore in a membrane. Where the gradient of change is abrupt, it is more akin to a wall for some species because of the drastic change for some important physical factor. (Forman 1995)

At an administrative edge, such as at the edge of a national park, the 'generated edge' is the line where the gradient of the change begins as described by the 'boundary' model of Schoenwald-Cox and Bayless (1986). The actual habitat edge as a result of differing management practices may or may not occur at the same place as the administrative edge. This indicates that the administrative edge does not necessarily represent the actual edge, which is seen on the landscape in terms of changes in the biota, microclimate, or soil structure. At edges caused by a disturbance, early-successional as well as invasive species can more easily colonize the area directly adjacent to original core habitat (Pauchard and Alaback 2006). The influence of increased disturbance may cause the actual edge to move.

Anthropogenic edges placed on the landscape, such as roads, trails, or cleared national park boundaries produce edge effects, but eventually become more naturalized. An example of this occurs at the edge of a clear-cut forest: increased wind energy, sunlight, and the disturbance create favourable conditions for certain tree saplings, which grow and fill in the gaps which had originally been shaded out in the forest. This slowly allows the forest to grow back into the clearing over time if permitted. In contrast, more natural boundaries, such as the contrast between two forest types, or at the edge of a wetland surrounded by forest, generally occur because of natural conditions such as water drainage capacity, glacial topography, or soil pH. Because they depend on ecological conditions, their presence will only change if the set of ecological conditions changes, such as an adjustment in precipitation due to a changing climate. (Forman 1995)

One way for edges to be maintained is through differing management practices, not necessarily through direct maintenance of the edge. A farmer ploughing a field, which borders onto a forest, is not directly maintaining the forest boundary; but by continuing to use the field for crops and leaving the forest intact, the edge is maintained (Janzen 1983). Another example of this is at the edge of park boundaries, where conservation and other resource activities, such as forestry, mining, agriculture, urban development, or recreation, meet. These management differences can create contrasts in species composition, soil exposure, disturbance regimes, and other factors.

Forman (1995) found that natural areas have more curvilinear edges and are softer with convex and concave sections where adjacent ecosystems interdigitate – indicating that there is considerable movement between the patches; on the other hand, developed areas tend to have abrupt, straight edges, which tend to have high contrast and less movement across. In a study done in the Great Smoky Mountains National Park, vertebrate and plant species crossed soft edges (i.e. wider, curvier, and less obvious) in greater numbers than abrupt, linear edges (Ambrose 1987). Because herbivores, such as ungulates, tend to concentrate in the edges, and predators follow, maintaining soft edges to encourage prey as well as predator conservation is important.

When a species' range extends outside of an administrative edge, at least some individuals of the species will have to interact with that edge. Some will be more concerned with certain characteristics of the differing sides of the boundary, such as canopy cover, soil type, or light availability. In general, the probability that the boundary will be crossed is determined by the permeability of the boundary, the perception of the edge by the organisms, and how enticing the adjacent patch is to the organisms; this then is compounded by how often the individuals encounter the boundary as a result of the size of their range (Wiens 1992; Wiens 2009).

Where invasive species are of concern, it is important to consider the locations of the administrative boundary, the generated edge, and the contrast at the edge of the boundary. Interestingly enough, in some situations a strong contrast can be better than a gentle contrast for certain park objectives: for example, "a patch of pristine forest may remain ecologically intact longer if surrounded by croplands and closely grazed pastures than if surrounded by extensive and productive areas of secondary succession, rich in plants and animals that can invade pristine forest" (Janzen 1983). In fact, a richly productive area of secondary succession is suggested by Janzen to be equivalent to greatly reducing the predator population in a protected area: in secondary successional forests, the strong food supplements available to herbivores can cause a surge in their population, leading to overgrazing of the nearby protected area. Janzen found also, that in a forested reserve with adjacent non-invasive croplands, the wall of forest cover effectively repelled most exotics, perhaps because of the sudden contrast in solar input beneath the canopy or change in soil composition. Janzen suggests further research into the area of movement of biotic vectors across a boundary zone. Park mandates may include discouraging invasive plants from entering the park, and this may be accomplished naturally at certain boundary types such as croplands, as Janzen suggests above. From this information, it may also be determined at which boundary types invasive species pose the greatest threat. On the other hand, the park mandate may include, for example, encouraging predators to be part of the greater ecosystem and promoting biotic flow across the park's boundaries.

The negative impacts of edges can be seen in a variety of situations. Humans specifically tend to create linear developments on the land, leading to fragmentation. Linear developments such as roads and trails can play an adverse ecological role, and they will be explored further in the following section.

3.2 Ecological effects of linear developments

From roads to trails to pipelines, humans frequently create disturbance in the landscape in a linear fashion. These linear developments are created at various scales and for a variety of purposes, but they all share common disturbance characteristics: fragmentation of the landscape, edge effects, and subsequent effects on habitat and wildlife populations.

In contrast, the patch and corridor matrix as described by Forman (1995) depends on patch connections through remnant corridors such as are seen by hedgerows in agricultural fields. These corridors contain vegetation similar to the patches, and work as conduits for wildlife to travel between patches and maintain genetically viable populations. On the other hand, disturbance corridors, which comprise all linear developments, are linear developments cut out of an otherwise continuous interior habitat. By definition, the long and narrow, rectangular shape guarantees that the edge to core ratio will be high, meaning that it could improve habitat for edge species and disrupt it for core species, possibly fragmenting their populations depending on the severity of the barrier effect (Forman 1995; Jalkotzy et al. 1997; Dyer et al. 2002). Linear developments are often transportation corridors, such as highways and trails, and many are used in resource development, such as seismic lines, pipelines, survey lines, and forestry roads. We develop in lines because it is usually the most cost and space efficient way to transport people or things.

Linear developments have a variety of effects on wildlife; however, these effects depend on the species of wildlife and the corridor characteristics. Important characteristics of disturbance corridors include internal structure (width, edge characteristics, plant and animal communities, and structures such as pipelines, ditches, or pavement) and external structure (matrix, corridor shape, patchiness, curvilinearity, connectivity, and habitat suitability in edges) (Forman 1995; Jalkotzy et al. 1997). Edges in general tend to have high species diversity and abundance, but the diversity of species that are drawn to edges may be quite different from those in interior habitat (Forman 1995).

Jalkotzy et al. (1997) identified several effects of linear developments, consistent with the findings in other landscape fragmentation literature (De Santo and Smith 1993; Forman 1995; Jackson 2000):

- Individual disruption: a change in behaviour caused by the corridor, costing energy and possibly lost opportunities, usually due to human presence on the corridor;
- Social disruption: a change in social structure or behaviour because of a corridor, or changes in species or groupings;

- Habitat avoidance: the avoidance of habitats close to corridors because of disruption, leading to fragmentation of the population;
- Habitat disruption or enhancement: the removal of habitat by fencing or a similar disturbance, or the enhancement of habitat if new habitat features are created because of the corridor (roads, for example, are frequently used as travel routes for ungulates and large carnivores for energetic savings because they are cleared and ploughed in winter);
- Direct and indirect mortality: caused by collisions with vehicles, or providing increased human access, leading to additional mortality through hunting, trapping, poaching, and management actions, or increased predator access; and
- Population effects: usually a population reduction because of altered behaviours.

As with all linear developments, but especially those with variable widths, "the extent of disruption or enhancement depends principally on the width of the disturbance corridor" (Jalkotzy et al. 1997). With increased width of the linear development comes decreased connectivity of the adjacent habitats, generally making narrower developments such as hiking trails the least disruptive and wider developments such as roads more so (Rich et al. 1994; Jalkotzy et al. 1997).

Faunal species with large home ranges and migratory patterns tend to be affected by linear developments more strongly than their more sedentary counterparts simply because they will encounter linear developments more frequently. These species are particularly affected if the linear development affects their habitat availability or crossing rate (Ward et al. 1980; Jalkotzy et al. 1997).

Because roads are an especially well-studied, prevalent, and ecologically harmful linear development, the effects of roads are described in detail first. The studied effects of trails, pipelines, seismic lines, hydro corridors, and railways are then described. In order to later compare the effects of BPNP's boundaries with other linear developments, there is an emphasis on how each linear development affects the microclimate as well as salamanders.

3.2.1 Roads

Roads are the most common linear development in the North American landscape (Forman et al. 2003). In Canada, there are 900,000 km of roads (Transport Canada 2006), covering over 2 million hectares of land (Brown 2001). This is only about 0.2 % of the land in Canada, but with Canada's low population and huge landmass, there are more miles of road per capita than in any other country in the world (Federal Highway Administration 1996). Only 1/3 of the roads in Canada are paved (Transportation Association of Canada 2000). Comparatively, in the USA, there are 6.4 million km of roads, covering about 1% of the land area of the USA (Forman et al. 2003). The road network results in loss of habitat for species, directly through modification of habitat and indirectly through modification of behaviour through avoidance of habitat near roads.

Jalkotzy et al. (1997) stated that of all linear developments, roads have the greatest impact on wildlife. Roads cause individual disruption, habitat avoidance, habitat disruption as well as enhancements, and direct and indirect mortality. The individual disruption of large mammals such as elk (*Cervus canadensis*) and grizzly bears (*Ursus arctos horribilis*) tends to be greater than for smaller mammals, particularly when human presence is increased from passing traffic to humans getting out of cars to take photos, as is common in national parks (Horejsi 1981; Singer and Beattie 1986).

Because of repeated disturbances in road rights-of-way, habitat avoidance is a major issue; wildlife may avoid roads altogether or only at certain times of day. Habitat avoidance varies between species, ranging from 500 m for grizzly bears (Aune and Stivers 1985) to 200-1600 m for elk in the northwestern USA (Irwin and Peek 1983). When roads such as abandoned forestry roads are closed, wildlife tend to show less of a response to the disturbance (Jalkotzy et al. 1997; Marsh

2007), encouraging the closure and removal of old forestry roads. In terms of preventing negative habitat disruptions, the placement of roads could be considered the most important factor; when roads are built in natural or previously undisturbed areas, the ecological effects are the greatest (Spellerberg 2002; Andrews and Jochimsen 2007).

Habitat enhancements can also be found in road rights-of-way such as the provision of travel routes for wildlife with large ranges, as well as accessible vegetation for herbivores and in turn accessible prey for predators (Jalkotzy et al. 1997; Gaines et al. 2003). Way (1977) found that roadside verges sustained 20% of the native bird species, 40% of the mammalian species, 100% of reptilian species, 83% of the amphibian species, and 42% of the butterfly species occurring in Great Britain. Although this does not address the abundance of those species, the presence of them in the roadside verges indicates that habitat for wildlife can be available along roadsides.

Direct mortality from car collisions causes the greatest disruptions in association with roads, and ungulates are attracted to the road salt and green-up of roadside vegetation (Ward et al. 1980; Fraser and Thomas 1982). Carcasses of road mortalities can then attract scavengers to roads, which can in turn cause further mortality by collisions of the scavengers with vehicles.

Indirect disruption through the introduction of exotic plants and pollutants such as dust and emissions further increases the negative effects of roads. On the landscape scale, fragmentation can occur as a result of high road density. This occurs when a core habitat is split up into smaller sections by a growing road system: one road can split a continuous habitat area into two, and a network of roads has a multiplying effect. Paved roads can pose a barrier to some species that are susceptible to desiccation (such as amphibians) and can cause more direct mortality than unpaved roads due to the higher travelling speed of traffic. In a comparison between the fragmentation caused by roads as opposed to a clear-cut, the edge habitat associated with roads was 1.54 to 1.98 times higher (Spellerberg 2002).

3.2.1.1 Roads: microclimate effects

While about 0.2% of land in Canada, and 1% of land in the USA, is used in roads and road rights-of-way, the actual area of land affected by roads is much greater. Based on calculations done by Forman and Deblinger (2000), 19% of land in the USA is affected ecologically by roads (Spellerberg 2002). Effects which tend to be localized but acute are air pollution, dust, salt, and water contamination in the areas adjacent to roadways.

Forman (2000) referred to the extent of environmental effects of roads as the "road-effect zone," and stated that it has extended between 100-800 m from the road edge, although each factor (thermal, hydrological, noise, light, invasive species, human access, and pollutants) affected the surrounding area to its own characteristic extent. For the factors that have been found to extend up to 800 m from the road, the implication is that 73% of the land area in the USA is impacted (Riitters and Wickham 2003). Areas not affected include high mountain ranges, the Everglades, and other remote regions that have few roads.

However, most physical microclimate effects seem to be concentrated in the area on or immediately adjacent to the road. Little change in evapo-transpiration, air temperature, relative humidity, species richness, percent of salt-resistant plants, soil pH, or soil nitrogen was observed beyond the forested edge adjacent to the road (Ellenberg et al. 1981); however, Forman et al. (2003) recommend empirical studies of forest edge width – a measure of the extent of edge characteristics surrounding core habitat – next to roads of various types, width, and directions. Forest edge widths next to clearings such as agricultural fields have been measured as 10-200 m into the adjacent forest (Chen et al. 1992; Forman 1995), and so the adjacent matrix is important in the consideration of edge width as well.

These edge effects can change the preferred habitat availability for some species. Edge-species were found to extend up to 100 m into the forest adjacent to roads in Maine, USA (Ferris 1979); in contrast, decreased abundances of elk, caribou, and some bird species were found 125-1200 m into the forest (Ferris 1979; Van der Zande et al. 1980; Witmar and de Calseta 1985; Murphy and Curatolo 1987). Haskell (2000) also found that roads decreased the abundance and richness of soil macroinvertebrates and the depth of the leaf litter up to 100 m into adjacent forest, and these effects were exacerbated by the width of the road and the openness of the adjacent forest canopy. Macroinvertebrates are prey for many vertebrate species such as birds and salamanders, and therefore the effects of a change in macroinvertebrate species richness can extend further up the ecological food web.

3.2.1.2 Roads: effects on salamanders

"The ecological impacts roads have on herpetofauna across temporal and spatial scales are profound, beginning during the early states of construction and progressing through to completion and daily use" (Andrews and Jochimsen 2007). Because development in general has been linked as a major factor to the worldwide decline of amphibians, the assessment of amphibian response to different types of development is important (Vestjens 1973; Blaustein and Wake 1990; Reh and Seitz 1990; Fahrig et al. 1995). Seasonal migration patterns involving movement towards breeding ponds and subsequent dispersal into adjacent forest often require amphibians to cross roads and to then experience high mortality. Exposure to calcium chloride, herbicides, de-icing agents, and vehicle effluents can lead to desiccation and toxic exposure for salamanders in roadside habitats, particularly due to their permeable skin. Water collection ditches alongside roads do, however, provide seasonal habitat for amphibians (Spellerberg 2002). Studies on the impact of roads on amphibian habitat are limited; however, there have been many studies on the barrier effect that roads have on amphibian species.

DeMaynadier and Hunter (2000) studied the effects of forestry roads on the movements of salamanders and other amphibians. Anurans were commonly found in roadside habitats, and the roads were not found to have a barrier effect to movement; some life stages and species even selected roadside verges. Salamanders, conversely, were less abundant in roadside verges than in forest control plots. In terms of direct mortality, because a salamander's defence is usually to remain still when threatened, they tend not to move away from approaching vehicles, unlike anurans which may move more readily. For redback salamanders and red-spotted newts, a major road posed a barrier to movement. Because very few were found to have crossed the road, DeMaynadier and Hunter (2000) concluded that the salamanders were either reluctant to cross the road or had very limited success in doing so. Salamanders may be reluctant to cross roads due to exposure to predators, dry substrate, increased exposure to sunlight, or traffic. They also suggested that wider roads lead to salamanders being exposed from cover longer, giving their edge-adapted predators such as snakes, racoons, hawks, and skunks an advantage. Langton (1989) found that predation increased for road-crossing amphibians during their short migratory season because of a congregation of their predators.

Aquatic salamanders are also affected. The construction of linear developments such as roads can have effects on aquatic salamanders extending beyond their edges through the soil erosion and scouring caused by stream road-crossings. Orser and Shure (1972) found that as urbanization and road development increased, the population of dusky salamanders (*Desmognathus fuscus*) in stream beds crossing those roads significantly decreased ($F=6.954$, $p<0.05$).

In order to find the distance into adjacent forest that salamanders are affected, Marsh and Beckman (2004) took redback salamander counts at intervals of 5, 20, 40, 60, and 80 m from unpaved forest roads. They found that redback salamander abundance, soil moisture, and cover object area significantly decreased ($p<0.05$) at 5 m from the edge of roads, and found that these edge effects extended up to 20 m into the adjacent forest, while soil temperature increased near roads. They also found that salamander counts steeply declined with a decline in soil moisture. Semlitsch et al. (2007) had similar findings of woodland salamanders avoiding roads, showing a road-effect zone for salamanders to be 35 m on either side of the narrow, low-traffic forest roads sampled.

Marsh (2007) further found that roads had consistent edge effects that were varied by the road width, the width of the roadside verge, and the habitat gradients (soil moisture, temperature, and leaf litter depth) at the forest edge. Gated or closed roads, by contrast, had no detectable edge effects – indicating that perhaps it is the disturbance of traffic or people on the roads that establish the effects, or that closed roads can naturalize and have softer gradients at the edges. Semlitsch et al. (2007), however, determined that decommissioned forest roads maintained the road-effect zone of 35 m on woodland salamanders measured in their trafficked roads – indicating that the abandonment of forest roads was not enough to stem their negative effects. Although some of these results are conflicting, the life history, behaviours, and tolerances of different salamander species can determine their sensitivity to linear developments.

Marsh et al. (2008) later established that only a large, divided interstate highway posed a more complete barrier to salamander movements because of significant genetic differences between the groups on either side. Other, smaller roads did not produce this population isolation effect.

3.2.2 Trails, Pipelines, Seismic Lines, Hydro Corridors, and Railways

The effects of dirt and vegetated tracks such as trails, pipelines, and seismic lines, are similar to roads; however, because corridors are narrower, more curvilinear, and have fewer people associated with them, the impacts are generally smaller (Jalkotzy et al. 1997; Gaines et al. 2003). But not in all cases: in terms of causing animals to react in fear, it seems that pedestrians have a greater effect on wildlife than humans using vehicles. Deer, for example, were more disturbed by hikers than by humans on snowmobiles (Freddy et al. 1986). The responses vary by species and by how habituated to humans and exposed to hunters the species are (King 1985). Grizzly bears avoided habitat within 274 m of trails on average (Kasworm and Manley 1990), but small carnivores such as fisher, river otter, and bobcat did not avoid areas with pipelines, seismic lines, or trails (Powell 1977; Reid et al. 1984; Lovallo and Anderson 1996). Ungulates seem to use trails and other narrow linear developments as movement corridors only if suitable habitat can be found in the vicinity (Rost 1975), but this varies seasonally and regionally. Visibility across the linear development, and the physical ability to cross the development (for example, above-ground pipelines can create difficulty) were major factors in crossing rates over narrow corridors (Morgantini 1981; Morgantini 1984).

In the vegetated linear developments, foraging enhancements can occur for herbivores and omnivores such as bears, as the corridor can open up an area to be colonized by earlier successional plants favoured by these species, as well as through the availability of cleared travel routes for wide-ranging wildlife – probably more so than roads because of a reduced human presence (Manville 1983; Bergerud et al. 1984; Brusnyk and Westworth 1985; Eccles and Duncan 1986; Koehler and Aubry 1994). In an oil and gas development area in Alberta, seismic lines did not play a significant role in determining grizzly bear habitat use at the landscape level (Linke et al. 2005). However, it was found that seismic line cutting in an area decreased mean forest patch size and increased variation of mean nearest neighbour distances. Both of these characteristics have been known to decrease grizzly bear habitat use.

Direct mortality is not generally associated with narrow linear developments, although indirect mortality can be attributed to increased accessibility for hunters, poachers, trappers, and predators such as with roads (Jalkotzy et al. 1997; Gaines et al. 2003). Increased hunting, poaching, trapping, and general wildlife harassment from snowmobiles and ATVs have been noted particularly on seismic lines and pipelines (Yukon Fish and Wildlife Management Board, n.d.). In a comparison of corridors with width of 8 m (unpaved roads), 16 m (paved roads), and 23 m (powerline corridors), forest-interior neo-tropical bird species were significantly reduced only along 16 m and 23 m wide corridors (Rich et al. 1994). As well, brown-headed cowbirds, a common forest-edge and nest parasitic species, were more abundant than 20 of the 21 bird species studied along all of the corridors.

Mortality can also be caused by the structures on linear developments. Raptors tend to nest, roost, and hunt in tall structures such as powerline supports, and thus can be affected by hydro corridors. Collisions with the powerlines and structures, as well as electrocutions, are the main factor in increased direct mortality as a result of hydro corridors. Also, human disturbance when hydro corridors are used for access or maintenance of the power structures can cause nest abandonment (White and Thurow 1985). Some nesting raptors flee their nests when pedestrians are seen 476 m away on average (Jalkotzy et al. 1997).

Studies on the ecological effects of railways beyond those based on direct mortality are few; however, due to the reduced human presence, and predictable traffic patterns, railways are likely less disruptive than roads and all trails, aside from direct and indirect mortalities. This stands in contrast to the vastness of disturbance when a train derails or a large fire ignites as a result of railway-side vegetation (Forman 1995). Railways can also be used for access by hunters and predators in a similar fashion to trails: Kolb (1984) and Trewhella and Harris (1990) observed that the movement of foxes (*Vulpes vulpes*) into the Edinburgh area was strongly influenced by the presence and direction of railway lines.

Because of their similarity in size and types of effects, these narrow, vegetated corridors will be grouped together to look at their microclimate effects and effects on salamanders.

3.2.2.1 Trails, pipelines, seismic lines, hydro corridors, and railways: microclimate effects

Recreational trails, although narrow, have impacts on the adjacent forest though the trampling of trackside vegetation, up to 3 m from either side of the trail (Dale and Weaver 1974; Cole 1987). Leaf litter and soil organic matter also tend to be lower next to recreational trails (Burden and Randerson 1972; Liddle and Thyer 1986; Adkison and Jackson 1996). Grasses and graminoids tend to be more resistant to trampling (Hall and Kuss 1989; Whinam and Chilcott 1999), and weed species can be brought in by recreationalists and thrive along these linear developments.

In a comparison between grassy powerlines, paved highways, and perennial creeks, microclimate edge effects were determined as much by the nature of the linear development as by its width (Pohlman et al. 2007). The human-made linear developments showed stronger variations in microclimate near the edges: temperature and vapour pressure deficit were particularly elevated for measurements close to the ground at 30 cm rather than 165 cm, which poses problems for understory plants and seedlings. The effects found continued for 20-25 m on either side of powerline and highway edges. By contrast, creek edges were not affected. The microclimate effect most strongly affected by the presence of a creek was light intensity, which was most strongly correlated with distance outward from the edge. The main differences between creeks and the other two linear developments were attributed to the openness of the canopy and subcanopy adjacent to creek edges, most likely due to periodic flooding. This results in a softer gradient of change at the edge, in comparison to abrupt edges at the human-made corridors.

3.2.2.2 Trails, pipelines, seismic lines, hydro corridors, and railways: effects on salamanders

In the only published study examining the effects of trails specifically on salamanders, numbers of slimy salamanders (*Plethodon glutinosus*) were compared in transects beside trails to paired transects 25 m into the forest in north-east Georgia (Davis 2007). More salamanders were detected near trails, most likely due to there being a higher abundance of logs beside trails due to trail-clearing activities. When salamanders per log were compared, there was no significant difference between on and off trail transects, indicating that the higher abundance of salamanders near the trail was related to higher cover availability. An average of only 0.01 salamanders was found per stone and so stones were excluded from analysis.

Hydro corridors are essentially equal to trails, pipelines, and seismic lines for ground-dwelling animals such as salamanders; on the other hand, railway lines may physically pose problems for salamanders attempting to cross. In a study comparing salamander abundance on a transmission line corridor to a similar transect 40 m in the adjacent forest, it was found that redback salamanders, Jefferson's salamanders (*Ambystoma jeffersonianum*), and spotted salamanders (*Ambystoma maculatum*) preferred the forest, but were also found under coverboards placed in the corridor (Yahner et al 2001).

However, non-linear, narrow canopy openings created by selective logging have been studied more thoroughly. Gaps formed by selective logging did not strongly affect redback salamander abundance in the year following the harvest (Messere and Ducey 1998). Greenberg (2001) had the same findings in canopy gaps formed by wind disturbances and salvage logging. Shelterwood harvesting similarly had few effects on salamanders, with complete recovery following 3-4 years of forest regeneration (Messere and Ducey, 1998). Crown thinning also had no effect on redback salamander abundance in oak forests in southern New England (Brooks 1999). Small-scale forestry actions thus seem to have fewer effects than large-scale actions such as clear cutting, which caused salamanders to decrease in abundance (Pough et al. 1987; Petranka et al. 1993; Mitchell et al. 1996; deMaynadier and Hunter 1998; DeGraff and Yamasaki 2002; Duguay and Wood 2002) or disappear (Wyman 1988; Dupuis et al. 1995; Waldick et al. 1999).

3.2.3 Systematic Effects

Single linear developments may in some cases have serious negative ecological effects, and in other cases, only minor or even positive effects. A bigger issue becomes the cumulative effect when linear developments occur in a landscape not as single entities but rather as networks such as interstate highway systems, hiking trails, railway lines extending from a station, or powerline corridors extending from a power generation station. The ecological effects of linear developments, especially roads, is a growing body of research, but the cumulative effects of all linear developments in an area, with respect to landscape level fragmentation, need further consideration (Noss 1995). But because species respond differently to various types of linear developments, creating a model that accounts for various species of different sizes, behaviours, and life histories can be a challenge.

Few studies have been able to accomplish this. One study that assessed the impact of multiple linear developments on wolf habitat choice found that road density strongly predicted habitat suitability (Thiel 1985; Jensen et al. 1986). Wolf populations declined as road density increased, and once the density reached 0.58 km per square kilometre, wolves abandoned the area. Although wolves actually use linear developments as travel corridors and hunting sites, those linear developments that were used by humans who hunt, trap, and harass the wolves became a major deterrent (Noss 1995).

Multiple roads in an area contribute to changes in landscape-level species distribution. In a study considering the effects of roadless areas and concentrations of roads in an area, overall species richness increased with decreasing road density for fish, plants, and herpetofauna (Chen and Roberts 2008). Haskell (2000) looked at the effects of roads on macroinvertebrates and argued that if roads have local effects and cumulative effects, they have a smaller effect if concentrated in one area of a forest than spread evenly throughout the entire forest.

3.2.4 Increased Access

All linear developments, but especially roads, increase accessibility for humans, predators, and invasive species into areas otherwise difficult to reach. Wildlife populations suffer from increased hunting and trapping due to this increased accessibility. Nest parasitism by brown-headed cowbirds (*Molothrus ater*) is particularly increased near edges caused by linear developments: Rich et al. (1994) found that cowbirds were significantly ($p<0.05$) more abundant along forested edges on paved roads than at corresponding interior points, and all avian nest predators were significantly more abundant ($p<0.05$) at edges of powerline corridors than at corresponding interior points.

Linear developments can also provide the space for the spread of invasive faunal species, such as the cane toad (*Bufo marinus*) in Australia, which uses roads and trails to disperse (Seabrook and Dettmann 1996). A study done in Banff National Park showed that invasive plants originating from linear developments spread up to 150 m into the forest (Hansen 2000). The collection of rare plants and animals for pet and medicinal purposes also increases with greater human access (Noss 1995).

Wildfires, which tend to increase where human presence is high, can also have severe impacts. Although naturally occurring fire can be beneficial to ecosystems, anthropogenic fire can occur out of the historic fire season and fire regime, and in the USA, most wildfires begin near roads: 78% of all human-caused fires began within 81 m of a road (Shaw et al. 1941).

The effects of increased access on wildlife are described in detail in Sections 3.2.1 and 3.2.2, particularly through the effect of indirect mortality and habitat disturbance. Depending on a species' needs and sensitivity, a linear development could seriously disrupt its dispersal, or provide a conduit for travel, allowing an animal to more easily access a wider range (Witmar 1985; Forman 1995). This, however, includes humans. The access provided to hunters, poachers, predators, and invasive species is an important ecological effect caused by any linear development, regardless of size or remoteness (US Fish and Wildlife Service 1993; Rich et al. 1994). For some species, it is not the linear development itself, but the human presence on it that causes the negative effects (Lyon et al. 1985; White and Thurow 1985; Jalkotzy et al. 1997). Wildlife that is hunted is particularly affected by human presence. For example, caribou found near linear developments were under significantly greater risk of predation from wolves as caribou mortalities from wolves were found an average of 316 m closer to linear developments than the caribou's average locations as established through radio-tracking (James and Stuart-Smith 2000). Greenberg and Dew (2000) studied the effects of increased road density on the accessibility of bushmeat to hunters in Yasuni National Park in Ecuador and found that the creation of an oil development road in previously undisturbed habitat increased accessibility of prey by 180%. A nearby trail system further increased prey accessibility by 62%. This was further compounded by oil workers providing transportation to the local hunters, allowing them to access to more distant areas more easily. The increased accessibility of previously remote areas can be one of the most damaging problems associated with linear developments, leading to increased direct and indirect mortality as well as habitat disturbance.

3.3 RESEARCH GAPS

A large amount of research has been devoted to the effects of linear developments on wildlife – in particular, the effects of roads on large, economically-important, and/or endangered animals. Where the research becomes sparse is in considering smaller linear developments such as trails or equivalently-sized developments such as hydro corridors on species that are smaller and less understood. How deep into the surrounding ecosystem these smaller linear developments have an effect requires further study as these are prolific in our landscape. Further comparison between the different types of linear developments would be useful to help extrapolate the known effects based on existing knowledge. In addition, studies on the effects of linear developments on the smaller species are needed – particularly because these species could be more sensitive to these disturbances due to their size, and they are less likely to be in the public eye. A study on the effects of small linear developments would be worthwhile to compare these with the known effects of the larger, perhaps more intrusive, linear developments such as roads. With this knowledge, further assessment of the cumulative effects of increased linear developments in an area would be possible, particularly in areas such as national parks where the intent and the mandate is to provide good habitat for native species.

Salamanders are known to be sensitive to landscape changes and desiccation and would provide an appropriate study species for understanding the effects of linear developments. A study of the effects of linear developments on salamanders in particular would add to the limited knowledge on this topic, and expand the range of species studied in relation to linear developments. Furthermore, more information on the behavioural response of salamanders to linear developments would be indicative of the effects of linear developments on a range of species that are either similar to redback salamanders in habitat requirements or rely on the ubiquitous population of redback salamanders for prey, population control, or other ecosystem interactions.

4.0 METHODS

Many areas of the ecology of linear developments have been studied thoroughly, particularly in relation to ungulates and other large mammals, roads, and direct mortality. Small linear developments, such as trails and pipelines, receive less attention with regards to their ecological effects, most likely because roads cause significant mortality. Although smaller linear developments cause less direct mortality than roads, indirect mortality caused by increased access and ecological effects spread through an entire network of small linear developments could be an issue.

Comprehensive literature reviews compiling studies done on the effects of linear developments on wildlife have found little research on the effects on herpetofauna specifically (Jalkotzy et al. 1997; Gaines et al. 2003). Because of their small size, importance to the ecological community, and in the case of amphibians, their skin's permeability to the surrounding environment, they represent an important indicator of the impact of linear developments. The surprising lack of research could be indicative of lack of funding, public interest, and difficulty of studying certain herpetofaunal species. According to Gaines et al. (2003), the effects of roads and trails need to be studied more thoroughly with respect to riparian and late-successional forest species, in particular with regards to recreational use and population demographics. Also, the extent to which roads and trails cause barrier, filter, or dispersal effects for amphibians requires further consideration, as most research has concentrated on ungulates and carnivores. For species with lower mobility and smaller home ranges, barrier, filter, and dispersal effects could be more pronounced.

4.1 CASE STUDY: BPNP

Bruce Peninsula National Park is situated on the interface between dolostone cliffs and the freshwater Great Lakes, as well as between the complex interactions of a variety of private landowners and levels of government-owned land. Note Figure 2 for a map of BPNP and the surrounding area. The boundaries of the park reflect this, and a need to demarcate the property lines clearly and unambiguously exists, and thus the practice of cutting a two metre swath of forest along the edge of the park and marking with signs every 50 m was established. In a national park, for which a primary mandate of ecological integrity has been given, this practice is somewhat controversial, although by no means unique to this park. Other national parks in Canada, such as Riding Mountain and Waterton Lakes National Parks, also cut the trees on some or all of their boundaries, but to various degrees (S. Parker, pers. comm., February 5, 2008).

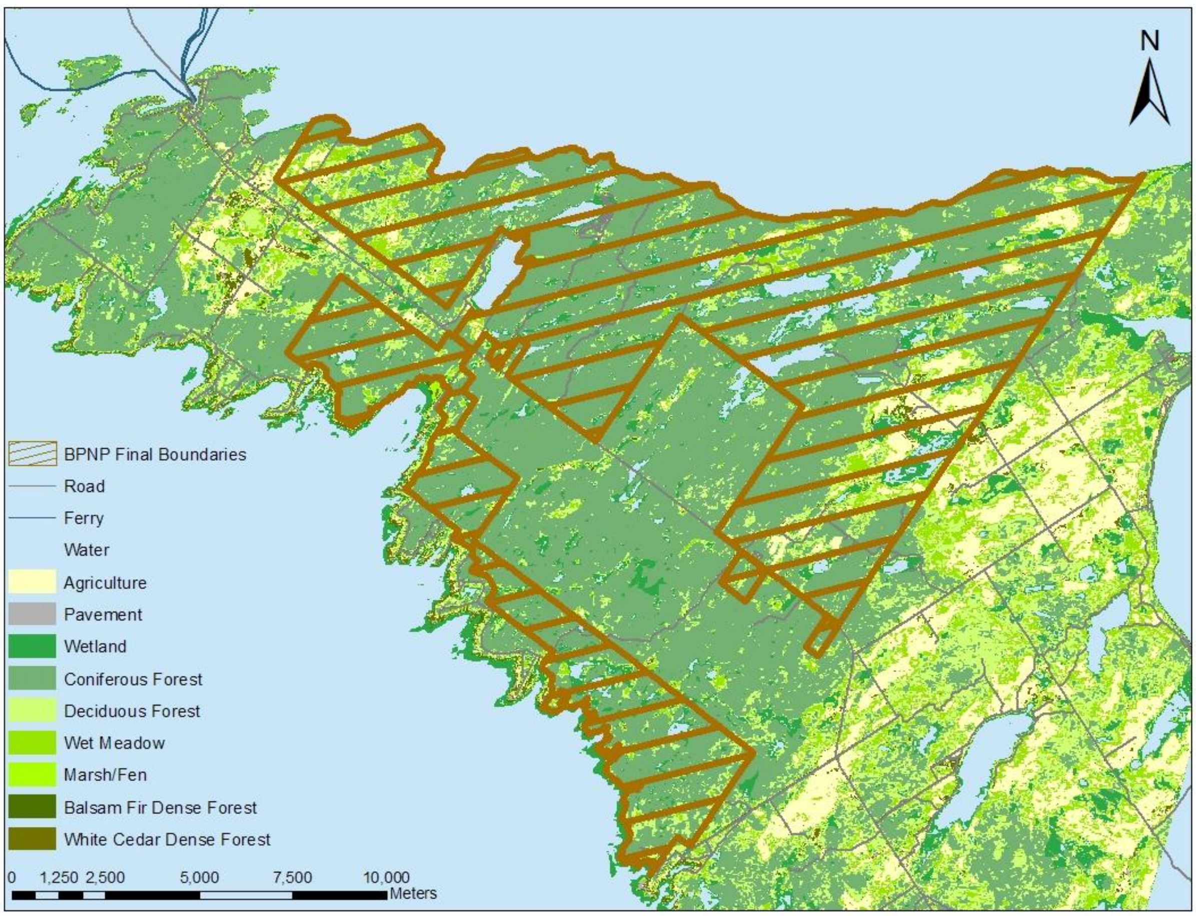

Figure 2. Map of BPNP and the surrounding land use.

The Bruce Peninsula has a history of logging, and most of the valuable timber had been removed by the 1920s. Logging continues today in some regions of the Bruce Peninsula, and it has occurred up to the edge of the national park in some areas. The forests of the Bruce Peninsula are in various stages of regeneration after historic logging and fire regimes, and are considered mostly secondary growth.

The cleared boundaries of Bruce Peninsula National Park represent a linear development on a small scale. Each boundary is cleared to only, on average, two metres wide but cut through generally undisturbed forested habitat. Finding an appropriate study species to determine the ecological effects of such a practice required some consideration. The subject would have to be small and sensitive enough to be affected by a two metre cut, ubiquitous enough to be possibly found on most of BPNP's boundaries, and one whose study would be useful to BPNP. At the time of the study, just under half of the forested boundaries have been cleared. See Figure 3 for a detailed map of the state of the boundaries of BPNP as of 2009.

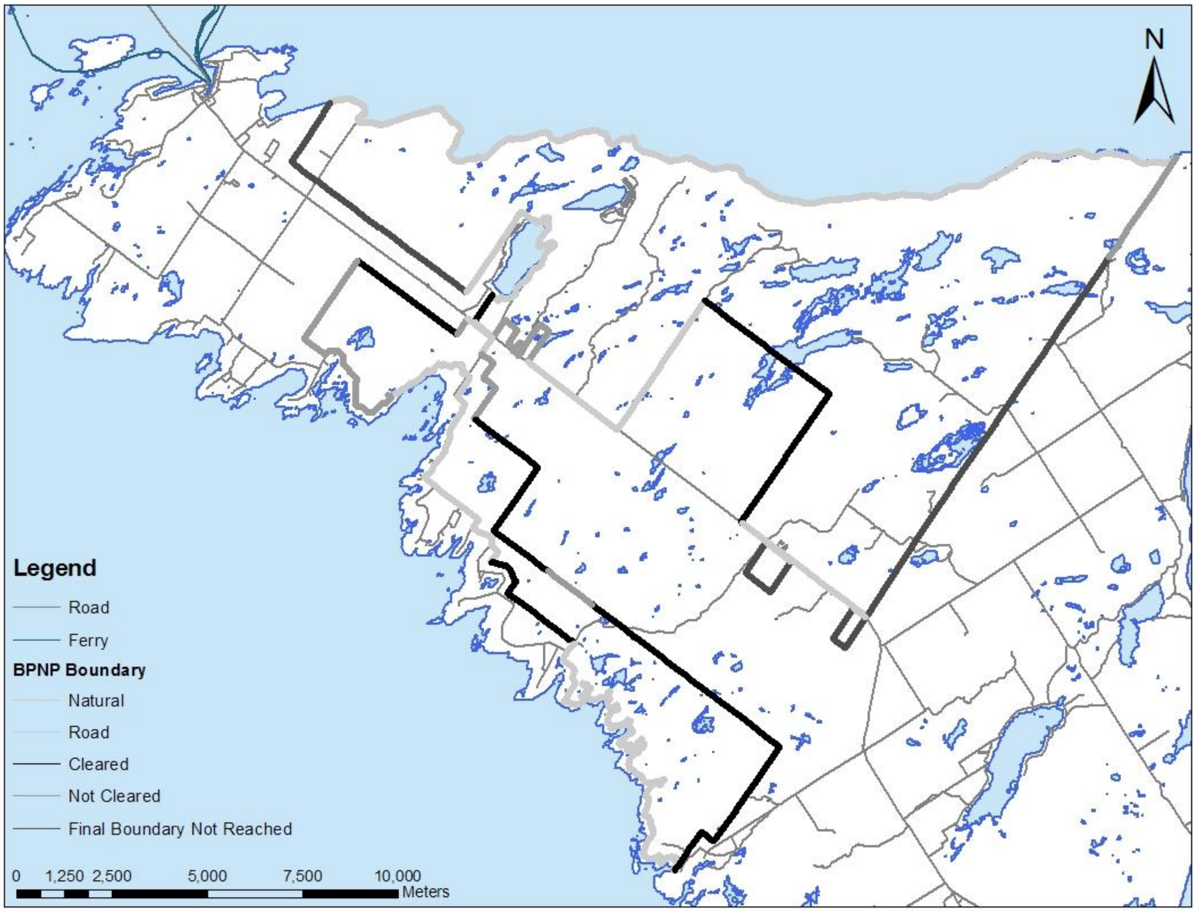

Figure 3. Boundary types present for BPNP. Note that just under half of forested boundaries have been cleared.

4.2 INDICATOR SPECIES: EASTERN REDBACK SALAMANDERS (*P. CINEREUS*)

In order to assess the ecological impact of these boundaries, the eastern redback salamander was chosen as an indicator species. Eastern redback salamanders are found in most forest types of northeastern North America but are most commonly found in deciduous, northern conifer, and mixed-deciduous forest types. They are normally found under logs, rocks, and leaf litter on the forest floor – although this surface population is considered to be only a subset of the larger population, as, at any given time, many are underground (Test and Bingham 1948; Taub, 1961). They have limited burrowing abilities, and prefer to remain in soft leaf litter and in existing burrows or other holes in the soil (Heatwole 1960). According to Grover (1998), redback salamanders are found in their highest abundances in late-successional deciduous forests that have deep soil and high availability of downed woody debris. When this debris is cleared, populations of terrestrial salamanders are likely to be seriously impacted because of the reduced availability of cover objects under which the salamanders can stay moist while remaining at the surface (Grover 1998). Their home range was estimated in Michigan as an average of 13 m^2 for males and juveniles and 24 m^2 for females by Kleeberger and Werner (1982). See Figure 9 for an image of an eastern redback salamander.

The sustainability of forest management practices can be assessed through salamander monitoring because they are found in greater abundances in undisturbed forests (Meier et al. 1996; Hicks and Pearson 2003). Salamanders are considered to be good bioindicators of forest integrity because of their responses to desiccation of the soil (EMAN 2004). When a region of a forest is clear-cut, increased levels of sunlight can penetrate down to the soil. Soil moisture is then evaporated, and plants that prefer high light conditions and disturbed areas, such as colonizers and some invasive species, can grow.

Salamander abundance has been correlated with:

- abundance and area of downed woody debris (Petranka et al. 1994; Brooks 1999; Grover and Wilbur 2002);
- depth/type of leaf litter (Pough et al. 1987; deMaynadier and Hunter 1998; DeGraff and Yamasaki 2002);
- soil pH (Wyman and Hawksley-Lescault 1987; Wyman, 1988; Sugalski and Claussen 1997);
- canopy openings (deMaynadier and Hunter 1998);
- soil moisture (Heatwole, 1962; Grover and Wilbur 2002); and
- understory vegetation cover (Pough et al. 1987; Brooks, 1999; DeGraff and Yamasaki 2002).

Forest management practices can have strong effects on all of these habitat variables (DeGraff and Rudis, 1990; Dupuis et al. 1995). Because *P. cinereus* is a lungless salamander, its skin must stay moist in order for gas exchange and respiration to occur (Spotila 1972; Feder 1983) and thus management regimes that affect the temperature, relative humidity, or soil moisture can particularly influence the distribution of redback salamanders (Herbeck and Larson 1998).

Plethodontid salamanders are used by Parks Canada and the EMAN to monitor forest integrity. They are considered good indicators because they have long life spans of up to 10 or more years, high rates of survivorship between years, and low birth rates, leading to steady population sizes when conditions are stable (Droege et al. 1997; Welsh and Droege 2001; EMAN 2004). They also generally have strong site fidelity, territoriality, and small home ranges, making long-term monitoring feasible. Furthermore, they play an important role in the forest ecosystem, through efficient metabolization of soil invertebrates, and they are involved in the biological food web as prey for many predators such as snakes and birds (Welsh and Droege 2001). Under favourable conditions, they have been found to surpass the biomass of any other vertebrate group in forests (Burton and Likens 1975).

In particular, in terms of long-term and extensive monitoring, plethodontid salamanders are an appealing indicator species because they can be easily found using coverboards, positively identified, and require minimal training to carry out the protocol. The stability of the population means that smaller sample sizes are needed to detect population trends (EMAN 2004). There are four other species of salamander recorded for this region; however, over 99% of all salamanders found in BPNP are eastern redback salamanders (BPNP 2008); therefore, they will be the main study species.

4.2 FIELD METHODS

This study was conducted in the spring and fall of 2008. Twenty-six sites were placed randomly along forested parts of the boundary, at least 150 m apart in order to ensure independent samples (Figure 4). The sites were chosen using a random generator by ArcGIS 9.0. When the sites were found, if there was a large open or wet area such as an alvar, bog, or pond, a further 50 m was added in order to avoid confounding data with nearby natural edges.

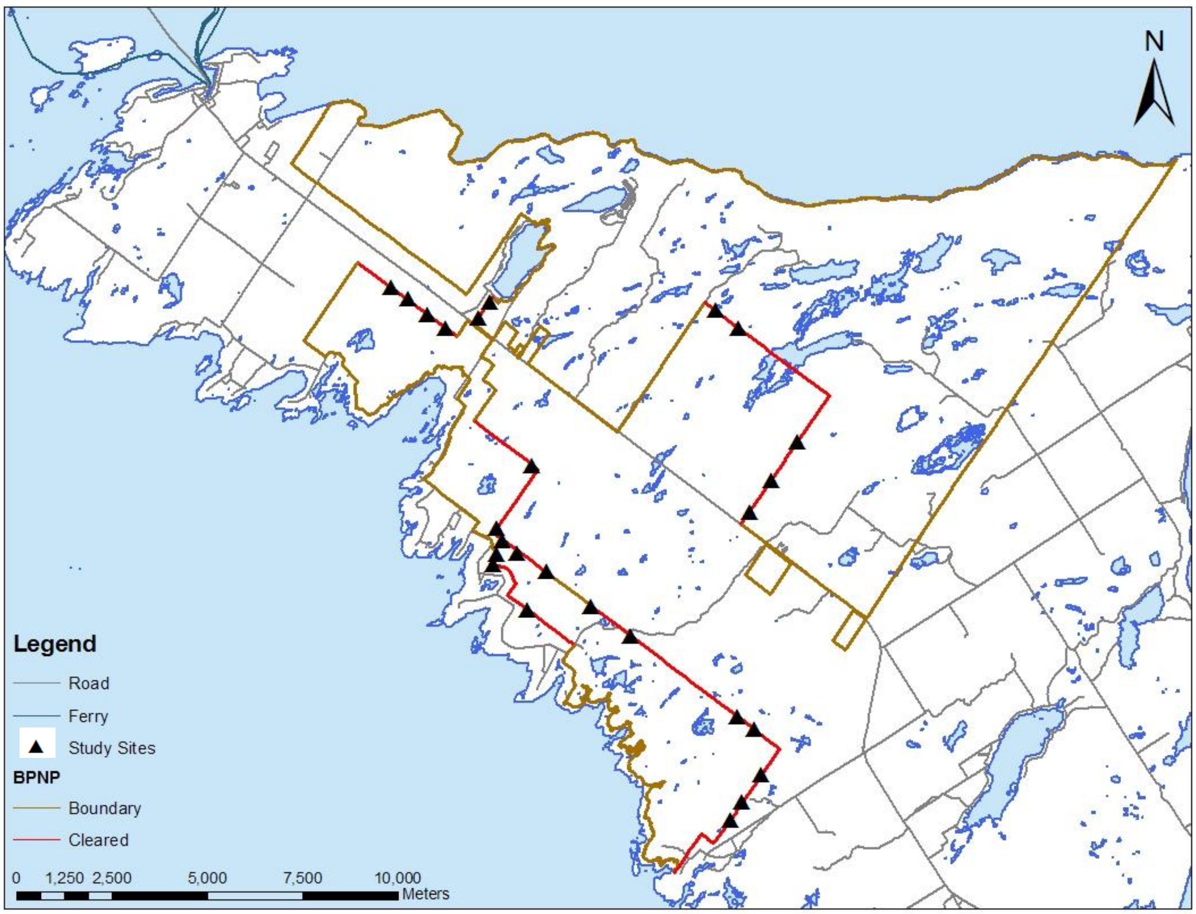

Figure 4. Study site map. There are 26 sites placed on the cleared boundaries.

Each site consisted of 50 m transects of 2 m width placed on and parallel to the boundary at 0, 5, 10, 15, 20, and 40 m. These distances were chosen for three reasons. First, in the study by Marsh and Beckman (2004), microclimate changes and fewer salamanders were found near the logging roads, and these effects extended up to 20 m from the road. In response, I used the multiple transects between 0 and 20 m to detect possible edge effects at a finer scale. Second, clearing a 2 m swath of trees would likely have less of an impact than a much wider and drier road. Because in the study by Marsh and Beckman, effects were rarely seen beyond 20 m, transects up to 40 m would be sufficient. DeGraaf and Yamasaki (2002), in their study of the effects of edge contrast on redback salamanders in hardwood forests, also extended their transects up to 40 m into the adjacent forest. Third, a study done by deMaynadier and Hunter (1998) found that many amphibian species that preferred core habitat were restricted by approximately 30 m at the edges of logging. Most physical edge effects found by Pohlman et al. (2007) extended up to 25 m into the adjacent forest next to powerlines and highways. A distance of 40 m was deemed sufficiently far from the studied boundaries to represent the normal abundance of salamanders present in the habitat but close enough to retain the same habitat and microclimate characteristics of the other transects. A transect at this distance would thus provide a 'control' microclimate and abundance of salamanders to contrast against the 'experimental' effects found in transects closer to the boundary.

The transects at each plot were surveyed in a random order. In order to reduce observer bias, I alone conducted all measurements and searches. Searches were carried out on rainless days in the spring and fall of 2008. Each transect had two measurements each of air temperature, soil moisture, soil pH, canopy cover, litter depth, and relative humidity, from which an average was taken. Each transect was also searched by lifting all downed woody cover objects along the 50 m length of the transect, within 1 m on each side of the centre of the transect, making each transect 2 m wide. For each cover object, the length and width were recorded, and numbers of snails, slugs, and salamanders were counted. Each salamander caught was weighed and the snout-vent and tail lengths were measured. Habitat variables such as soil moisture, soil pH, and litter depth were also recorded at the site where the salamander was found immediately after releasing the animal. The relative decomposition of the woody object under which salamanders were found was recorded on a subjective scale of 1 to 5, with 1 being recently fallen and 5 being decomposed with parts becoming soil-like in texture, as described by Maser et al. (1979).

4.3 DATA ANALYSIS METHODS

All data was analyzed using the software R. The first analysis compared microclimate variables and salamander abundance on the boundary with that on each individual transect through the use of Mann-Whitney U tests, paired by site, to see if the boundary was significantly different to similar transects in the adjacent forest. Because the salamander abundance on the boundary was found to be significantly different than all other transects using non-parametric methods, transforming the data to normal was not necessary in order to carry out this first analysis.

Spearman correlations were then used between environmental variables and salamander counts on each transect to determine which variables are correlated with salamander abundance. This determined important characteristics of salamander habitat, and helped to show if the cleared boundary improved or degraded habitat. Spearman correlations work well with non-parametric data which has an unknown structure. Multivariate statistical methods such as canonical correspondence analysis (CCA), non-metric multidimensional scaling (NMMS), and principal components analysis (PCA) were considered to explain to what salamander abundances were responding; however, these methods rely on more than one dependent variable (CCA) or are unable to juxtapose the dependent and independent variables (NMMS and PCA) in order to explain salamander abundance, and so were not used.

The salamander counts were found to have a Poisson distribution (see Table 1). This is due to the event of finding a salamander being a rare occurrence – most of the time there were no salamanders found on a transect. The probability of finding one more salamander on a transect dropped exponentially. Expected and observed frequencies were not significantly different

(Wilcoxon rank sum test with continuity correction: W = 51, p = 0.554), demonstrating the fit of the data in the Poisson distribution.

Table 1. Poisson distribution of salamander abundance.

Number of Salamanders	Poisson Probability	Poisson Expected Frequency	Observed Frequency
0	0.267	41.6	69
1	0.353	55	37
2	0.233	36.3	22
3	0.102	16	11
4	0.034	5.3	8
5	0.009	1.4	3
6	0.002	0.31	2
7	0.0004	0.06	1
8	0.00006	0.009	2
9	0.000009	0.001	0
10	0.000001	0.0002	1

The assumptions of the Poisson model are violated, however, in that the probability of finding a salamander does change over transects, due to the higher cover area on the boundary leading to a higher probability of finding a salamander. Because of the violation of that third assumption, the data are overdispersed, and this can be seen again with the difference between the mean (1.32) and the variance (3.25). Overdispersion occurs when there is more variability in the data than is expected by the Poisson distribution model, and using a Poisson regression may not give reliable results. If data are overdispersed and this is ignored, the precision of the model can be overestimated (Richards 2008). The log theta of the negative binomial regression analysis was significant (p= 0.008), indicating that in fact the data were overdispersed and the negative binomial model is more appropriate than the Poisson model. A Vuong test (-1.27, p= 0.101) on the zero-inflated negative binomial model was not significant, also indicating that the negative binomial model is more appropriate.

A negative binomial regression was thus carried out with respect to salamander abundance. The negative binomial regression, which is a version of linear regression for data with negative binomial distributions, gives a regression line that illustrates which independent variables (environmental variables in this case) explain the dependent variable (salamander abundance). Negative binomial regression, however, cannot have an R-squared value that is given to explain the goodness-of-fit of the model as in basic linear regression.

The data were then transformed using log or square root transformations, depending on the distribution of each variable, to obtain a normal distribution. Next, multiple linear regression was used to determine which environmental variables explained salamander abundance using the transformed data. This provides a goodness-of-fit statistic (R^2), and allowed the use of residual and Q-Q plots to provide more insight into how well the data fit these models.

Backward stepwise regressions were carried out for both the negative binomial and multiple linear regressions. Backward stepwise regressions begin with all of the variables and remove one at a time until the best model for the data is found, and have the benefit of removing the least significant variables to the model first; this allows the variables which explain the most to remain in the model.

5.0 RESULTS

Throughout the spring and fall surveys, a total of 312 measurements of microclimate variables were done, and 304 salamanders and 5929 cover objects were found.

Air temperature, relative humidity, and slug abundance were significantly affected ($p<0.05$) up to 10 m away from the boundary (Table 2). Soil pH, litter depth, downed woody cover area, canopy cover, and salamander abundance were significantly affected ($p<0.05$) up to 5 m away from the boundary. Soil moisture, downed woody cover decomposition level, salamanders/cover object, salamanders/cover area, and salamander weights and lengths were not significantly affected by the boundary. The salamander and slug abundances as well as the cover area found on the boundary (0 m transect) were found using paired Mann-Whitney U tests to be twice as high as any other transects (5, 10, 15, 20, or 40 m)($p<0.05$).

Table 2. Distance into the forest different environmental variables was affected by the cleared boundary, as determined by paired Mann-Whitney U tests between environmental variables at all transects.

Variable	Is boundary different from 40 m control? P-value:	Increased (+) or decreased (-) on the boundary?	Affects how many m into forest? (m)
Air temperature	0.0001	+	Up to 10
Relative humidity	0.0036	-	Up to 10
Soil pH	0.0010	+	Up to 5
Soil moisture	0.0708	n/a	n/a
Litter depth	0.0002	-	Up to 5
Downed woody cover area	0.0010	+	Up to 5
Wood decomposition level	0.0530	n/a	n/a
Canopy cover	0.00003	-	Up to 5
Snail abundance	0.0501	n/a	n/a
Slug abundance	0.0085	+	Up to 10
Salamander abundance	0.0188	+	Up to 5
Salamanders/cover object	0.0582	n/a	n/a
Salamanders/cover area	0.0643	n/a	n/a
Salamander weight	0.0677	n/a	n/a
Salamander snout-vent length	0.0791	n/a	n/a
Salamander total length	0.0910	n/a	n/a

Cover area, cover object abundance, slug abundance, total site cover area, relative humidity, and site average air temperature had the strongest significant correlations with salamander abundance (Table 3). No other variables were significantly correlated. Because cover area is so important to salamander abundance, and the significant effects of the boundary on salamander abundance are lost with salamanders per cover object or per cover area, it is clear that salamander abundance is strongly related to cover area.

Table 3. Spearman correlations between environmental variables and salamander abundance.

Variable	rho	p-value
Transect Cover area	0.55	1.63×10^{-13}
Number of Cover Objects	0.49	6.68×10^{-11}
Slugs	0.33	2.42×10^{-05}
Site Cover Area	0.26	1.00×10^{-02}
Relative Humidity	0.26	9.48×10^{-04}
Site Air Temperature	-0.21	4.00×10^{-02}

Therefore, using the negative binomial regression model, which regresses salamander abundance against chosen variables and attempts to predict salamander abundance using those variables, salamander abundance was best predicted by the cover area and dominant vegetation of the transect (chi-squared = 68.81, df = 3, p= 7.67e-15). Salamanders were more abundant on transects with more cover area, more snails, and coniferous vegetation. This could be biased by more samples done in coniferous forests, as most of the forest on the Bruce Peninsula is coniferous.

Backward stepwise regressions were both carried out with the same results leading to the model with the lowest Akaike's information criterion (AIC) value of 435.92. The tolerance for entry or exit was designated as a significance level of 0.05.

Table 4. Negative binomial regression table of salamander abundance.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-3.33	0.533	-6.25	4.00×10^{-10}
Cover Area	3.505	0.384	9.12	2.00×10^{-16}
Dominant Vegetation (coniferous)	-0.509	0.245	-2.07	0.038

The expected log count increase for a one-unit increase in cover area was 3.505. This translates to an increase of about 0.704 salamanders for a one standard deviation increase in cover area when the other variables are held constant. Deciduous dominated vegetation plots had an expected log count -0.509 less than coniferous plots, which amounts to about 0.422 fewer salamanders than in coniferous forests while holding the other variables constant.

Backward stepwise multiple linear regressions were also carried out. The tolerance for exit was a significance level of 0.05. As can be seen in Table 5, it was found that dominant vegetation, cover area, and slugs abundance were the only significant factors in explaining salamander numbers.

Table 5. Multiple linear regression table of salamander abundance.

	Estimate	Standard Error	t-value	Pr(>|t|)
(Intercept)	0.718	0.381	1.887	0.061
Dominant Vegetation (coniferous)	-0.945	0.299	-3.162	0.001
Cover Area	0.104	0.015	6.886	1.42×10^{-10}
Slug Abundance	0.183	0.074	2.483	0.014

The residual standard error was 1.42 on 152 degrees of freedom. The multiple R-squared value was 0.387, and the adjusted R-squared was 0.375. The F-statistic was 32.02 on 3 and 152 degrees of freedom, and the p-value of the test was 4.23×10^{-16}. The variance of the results was high and thus the R-squared value was low because one of the measured variables does not dominate; however, the variance was not so high that nothing is significant, as can be seen in the results. The isolated variables of dominant vegetation, cover area, and slug abundance were indeed significant, as was the significance level of the test ($p=4.23x10^{-16}$). The nature of field data compared to lab data is that without complete control over each variable, it can be difficult to interpret and isolate the phenomenon in question.

The residuals of this regression were seen to show a pattern, as given in Figure 5.

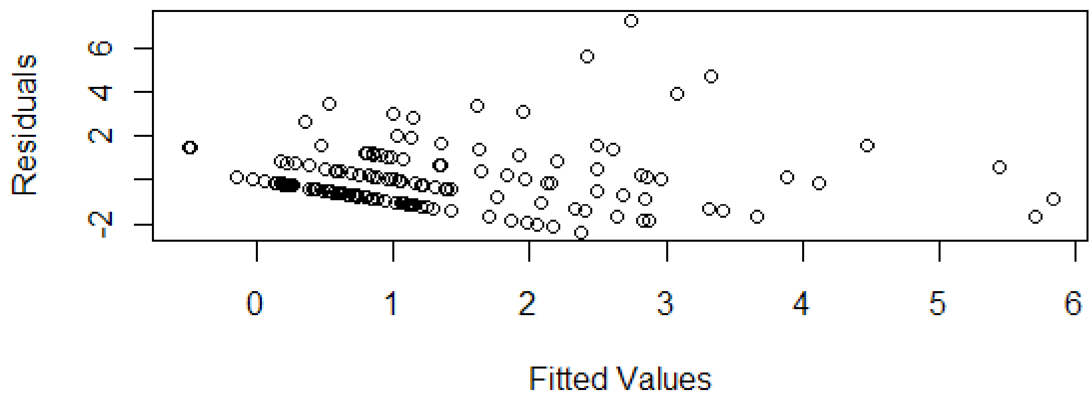

Figure 5. Residuals of multiple linear regression.

The pattern of the residuals was most likely due to the integer counts of salamanders found, ranging from 0 to 8 on different transects. This lends itself to being categorical in nature, leading to a residual pattern such as was seen. A Q-Q plot was used to determine the fit of the data to the regression line determined. This plot is shown in Figure 6.

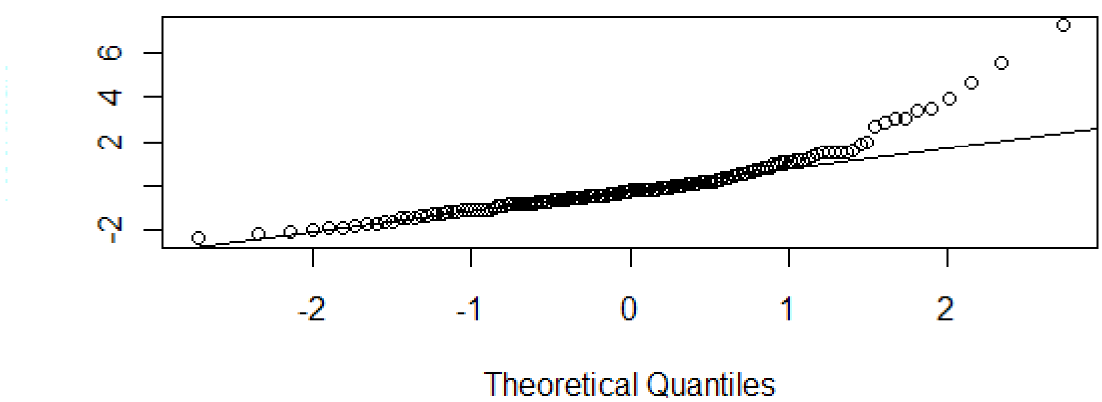

Figure 6. Q-Q plot of multiple linear regression.

From the normal Q-Q plot, it can be seen that most of the data followed the regression line. The highest salamander values however, skewed the data set. When the three transects with the highest salamander numbers found were removed, all three variables had lower p-values, the multiple R-squared value was 0.425, and the adjusted R-squared value was 0.414. This was expected to some extent given the integer counts of salamanders with environmental variability between plots. The low R-squared value was thus expected due to the high level of variance, but as can be seen, the regression line sufficiently explained the data.

5.1 SUMMARY

What can be taken away from these findings is that some of the microclimate variables measured were affected by the cleared boundary, up to 10 m into the adjacent forest. Overall, the boundary is significantly different than the control transects of 40 m measured in the forest for most variables measured. Cover area is the dominant variable in the dataset explaining salamander abundance, with slug abundance and forest type playing a smaller role.

5.2 INCIDENTAL OBSERVATIONS OF ACCESS

Although not directly part of the case study, there were many incidental observations of increased access by humans, in particular hunters, along the cleared boundaries. Along the boundary, the following was found in different areas:

- bear baiting station (see Figure 10 – Appendix B)
- temporary hunting camp (see Figure 11 – Appendix B)
- shooting target with bullet holes (see Figure 12 – Appendix B)
- bullet shells
- beer cans (four on separate occasions)
- ATV tracks (see Figure 13 – Appendix B)
- flagging tape

- fire pit (see Figure 14 – Appendix B)
- unauthorized removal of logs from boundary to further clear the path for recreational uses (see Figure 15 – Appendix B)
- invasive plants (seeds possibly carried in on boots or ATV tires)

While not all of these are indicative of hunting activities, they do indicate human presence, which can be a problem for many types of wildlife as seen in Section 3.2. Because the boundary is cut into the park property, any hunting activity on the boundary is considered within the park and illegal. In particular the bear baiting station, located just above a park boundary sign, is an obvious infringement. The park wardens were given all information regarding human activity on the boundary.

6.0 Discussion and conclusions

6.1 Comparison of BPNP boundaries to other linear developments

A comparison of the findings of studies done on different linear developments is given:

Table 6. Comparison of the effects of linear developments.

Effect	Roads	Trails/Pipelines/Hydro corridors	Boundaries of BPNP
Air temperature	Increased at ground level near edge in wet and dry season (Pohlman et al. 2007); Affected up to 3 m (Delgado et al. 2007)	Increased at ground level near edge in dry season (Pohlman et al. 2007)	Increased up to 10 m (p=1.01E-04)
Soil pH	-	-	Increased up to 5 m (p=1.00E-03)
Canopy cover	Decreased up to 6 m for paved, 3 m for unpaved roads (Delgado et al. 2007)	-	Decreased up to 5 m (p=3.08E-05)
Cover area (dead wood)	Increased with distance from road (Marsh and Beckman 2004)	Increased at trail (t_{124}=2.44, p=0.016) (Davis 2007)	Increased up to 5 m (p=1.04E-03)
Effect on salamander body condition	No effect (Marsh and Beckman 2004)		No effect (p=6.77E-01)
Soil moisture	No effect (Pohlman et al. 2007); Increased with distance from road (Marsh and Beckman 2004)	Significantly (though only weakly) higher near powerline edges (F = 4.955, df = 1, P = 0.029) (Pohlman et al. 2007)	No effect (p=7.08E-02)
Litter depth	Decreased up to 10 m (Arevalo et al. 2008)	Decreased only at edge (Arevalo et al. 2008)	Decreased up to 5 m (p=1.85E-04)
Relative humidity	Increased at ground level near edge in wet and dry season (Pohlman et al. 2007)	Increased at ground level near edge in dry season (Pohlman et al. 2007)	Decreased up to 10 m (p=3.61E-03)
# of Salamanders	Decreased near road, up to 20 m (Marsh and Beckman 2004)	Increased at trail (F1,244=4.46, p=0.036) (Davis 2007)	Increased up to 5 m (p=1.88E-02)
# of Salamanders/cover object	Decreased near road, up to 20 m (Marsh and Beckman 2004)	-	No effect (p=0.582)
# of Salamanders/cover area	Decreased near road, up to 20 m (Marsh and Beckman 2004)	No change at trail edge (t_{124}=1.28, p=0.205) (Davis 2007)	No effect (p=0.643)

The edge effects found at the cleared boundaries of BPNP were similar to but smaller in magnitude than those found for roads, with the exceptions of cover area and relative humidity (see Table 6). A difference in cover area on the cleared boundary is to be expected since the downed woody cover is left on the boundaries. Compared to other narrow, vegetated corridors, cleared boundaries have similar effects for all variables except for soil moisture, which was only found to have a statistically weak difference at powerline edges and no difference at the cleared boundaries. This difference may also depend on the season in which the study was done – the open canopy allows more precipitation to reach the soil as well as allows for faster evaporation from the soil.

From these comparisons, it can be concluded that the effects of the boundaries are similar in type to other linear developments, but have a magnitude similar to trails and other narrow, vegetated corridors. This is reasonable because the cleared boundaries approximate trail width; however, the boundaries are less curvilinear and more vegetated than typical trails.

This study therefore adds to the current literature on linear developments by expanding the knowledge on small, vegetated linear developments. By providing an example of the minimal effect that linear developments can have, it provides a comparative base from which other linear developments can be assessed. It also shows that minimizing width, maintaining structural complexity in the disturbance edge (such as by leaving downed woody cover), and minimizing disturbance in the creation of a linear development really do minimize the negative ecological effects.

Because the cleared boundaries do have an effect on microclimate and possibly on the indirect mortality of wildlife through increased access for hunters, they are adding to the systematic effect we are having on the landscape through additional linear developments. There are approximately 30 km of cleared boundaries in BPNP, and this amounts to about half of the total terrestrial boundary. If there are microclimatic ecological effects up to 10 m into the forest on either side of the boundaries, then this amounts to about 60 hectares of land, or 0.4% of the total land area of BPNP currently being affected. Road, powerline, and trail development is increasing on the Bruce Peninsula, in part because of an interest in the natural landscapes of the area promoting cottage and home developments. The cleared boundary provides a way to access remote areas of the park, and it causes an increase in the systematic effect that linear developments are having on this landscape. In effect, this decreases the coveted 'naturalness' of this landscape.

6.2 Response of *P. cinereus* to BPNP boundaries

Salamander abundance was significantly and positively correlated with the following environmental variables: high cover area, high cover object abundance, high total cover area in the plot, high slug abundance, low air temperatures, and high relative humidity. Salamander numbers were best explained by the amount of cover area, number of slugs, and percent coniferous vegetation present along a transect. These findings are similar to other studies done on redback salamanders, although many habitat variables have been found to explain salamander abundance in the literature (i.e. abundance of downed woody debris, the depth and type of leaf litter, soil pH, canopy openings, substrate moisture, and the abundance of understory vegetation. See Section 4.2 for more details).

The main factors which contribute to the disruption caused by linear developments on wildlife can be considered for the effects of the cleared boundaries on the eastern redback salamander population:

- Individual disruption – There was no measured change in the behaviour of eastern redback salamanders caused by the boundary. Human presence does not normally affect salamanders as they are usually hidden under cover during the day, and they are not a species currently threatened by hunting or poaching.

- Social disruption – There was no measured change in species composition of salamanders or social groupings, structure, or behaviour. There was no significant difference in the age or size of salamanders on the boundary, as compared to the other transects.
- Habitat avoidance – For BPNP, the boundary does not present a barrier or filter to the eastern redback salamander population as the boundary was not avoided. Therefore, fragmentation of the salamander population did not occur. There are, in fact, over double the number of salamanders present on the boundary as there are on any other transect in the surrounding forest. Therefore, the spatial distribution of redback salamanders is changed by the boundary, but not through habitat avoidance, but rather through habitat enhancement.
- Habitat disruption or enhancement – Because of the strong correlations between salamander abundance and cover area, it is clear that the boundary management practice of leaving the downed woody cover on the boundary – even though this departs from the boundary management protocol – provided habitat enhancement for the eastern redback salamanders. Similarly to Davis (2007), it was found that there were significantly more salamanders on the boundaries; however, when salamanders per cover object or cover area were considered, this significant difference is lost, which follows the correlation found between salamanders and cover area. The higher abundance of salamanders on the BPNP boundary is likely an artefact resulting from the higher presence of cover area due to the boundary cutting practice itself. Because of the practice of leaving the downed trees as cover, the surface habitat is actually enhanced for salamanders, or at least the salamanders are drawn to these objects and can remain on the surface for longer because of the abundance of moist covered habitat. If this practice of leaving the downed woody cover on the boundary is discontinued, or if increasing numbers of adjacent landowners clear their

common boundary for access, then the habitat for eastern redback salamanders could be disrupted.

- Direct or indirect mortality – There was no measured increase in direct or indirect mortality of eastern redback salamanders caused by the boundary. It is possible that an increase in predators using the boundaries as movement corridors, such as snakes and raccoons, could lead to an increase in mortality for salamanders; however, this was not studied.
- Population effects – Because of the habitat enhancement provided for salamanders, there was an increase in abundance of salamanders on the boundary. This does not necessarily indicate an increase in the local population of salamanders, however.

Assessing the response of salamanders to linear developments is important in understanding the effects of cumulative developments and fragmentation in a landscape, particularly now with the worldwide decline in amphibians. Marsh and Beckman (2004) found that redback salamander abundance, soil moisture, and cover object area significantly decreased near roads, and found that these edge effects extended up to 20 m; however, they did not study multiple transects between the edge of the road and 20 m. Semlitsch et al. (2007) also found that woodland salamanders avoided forest roads, showing a road-effect zone for salamanders to be over 15 m, and up to 35 m. With regards to trails, Davis (2007) found significantly higher numbers of slimy salamanders (*P. glutinosus*) beside trails, compared to paired transects 25 m into the forest; however, when the data were presented as salamanders per cover object, the significance disappeared. Therefore, in the literature and now in this case study, small and vegetated linear developments have not been shown to disrupt salamander distribution enough to cause fragmentation in their local populations. This study supports the study done by Davis (2007) with a more in-depth look at a small linear development and nearby transects. Also, the edge effects caused by the cleared boundaries on the microclimate extend up to 10 m.

In fact, because habitat enhancement was the only change found for eastern redback salamanders in this study, the disruption caused by linear developments now has an example of a minimum level. This study also demonstrates the fact that not all linear developments are necessarily disruptive. Small-scale linear developments, with minimal disturbance caused in their creation, can produce habitat enhancement with small measurable negative effects – as long as precautions are taken in their creation and maintenance. Although it is has been shown in the literature that salamanders are affected by linear developments, it has now been shown conclusively that small linear developments with adequate cover availability do not cause disruption for eastern redback salamanders.

6.2.1 Use of Woodland Salamanders as Indicators of Forest Integrity

Woodland plethodontids are used as indicators of forest integrity in Parks Canada and through EMAN in Canada. The reasoning given in the Joint EMAN / Parks Canada National Monitoring Protocol for Plethodontid Salamanders (EMAN 2004) is based on the protocol developed for the United States Geological Survey (USGS) by Droege et al. (1997) and described in Section 4.2.

However, there is some controversy with regards to the use of terrestrial salamanders to measure forest integrity. Many researchers agree with the EMAN reasoning. Kolozsvary and Swihart (1999) found that redback salamander abundance was positively correlated with forest patch size, suggesting that “extinction events could limit their occurrence in small patches.” Mitchell et al. (1997) found more redback salamanders in old-growth versus secondary-growth forests, and similarly Gustafson et al. (2001) found more redback salamanders in older, less-altered forests, indicating the association of redback salamanders with forest integrity and age. Welsh and Droege (2001) recommend the use of Plethodontid salamanders for ecosystem integrity monitoring due to their small territory, site fidelity, sensitivity to natural and human disturbances, cost-effectiveness of sampling, and ubiquity in the landscape, and they also show that salamander counts have low coefficients of variation when compared with passerine birds, small mammals, and other amphibians, providing statistical advantages. Salamanders also have tight links with microclimatic conditions, the food web, and forest succession. Sections 3.2.1 and 3.2.2 outlined studies which involved redback salamanders and demonstrated their sensitivity to roads and trails.

In contrast, and particularly with regards to small forest disturbances, redback salamanders have shown limited sensitivity in other studies. Pough et al. (1987) found no effect of firewood harvesting on redback salamanders; similarly, Messere and Ducey (1998) did not find an effect of selective logging. As stated in Gibbs (1998), redback salamanders have shown insensitivity to landscape-scale fragmentation, and the boundaries of BPNP are perhaps demonstrative of that insensitivity. On the other hand, small-scale disturbance does not necessarily cause poor forest integrity – meaning that the salamanders could be sensitive to changes in forest integrity and the cleared boundaries simply did not affect the integrity of the surrounding forest.

For small-scale disturbances, it is worth considering that redback salamanders may not be the best choice as an indicator species. It is not possible to conclude from the goals and results of this study as to whether redback salamanders are insensitive to the disturbance caused by the cleared boundaries, or if their habitat was enhanced and thus responded positively to the boundaries. To determine this, future research into this issue could compare boundaries before and after the removal of all cover objects.

6.3 The Real Cost of BPNP's Boundaries

The main benefit to the practice of clearing BPNP's boundaries is a possible reduction in illegal activities occurring in the park as people can more easily recognize when they have entered park property. There are, however, ecological and financial costs of doing so.

The ecological costs, including those of changes in microclimate factors and salamander abundance, have been discussed thoroughly in this case study. The possibility of increased access, however, can also have detrimental effects, and although it requires further study, it may negate the benefit received from clearing the boundaries: the boundaries provide ways for hunters to access further, more remote regions than they previously could, causing a possible *increase* in illegal activities in the park. The boundaries provide movement corridors for humans who hunt, log, or poach flora or fauna in the national park. Evidence of human presence, from ATV tracks, beverage containers, bullet shells, bear baits, hunt camps, shooting targets, campsites, fire pits, cleared debris, and invasive plants were all noted along the boundaries in the course of this study, as described in Section 5.2.

The financial costs of clearing the boundary are also a major issue. Environmental reviews must be done for each clearing project to ensure that critical habitat of any species-at-risk is not affected. It is expensive to have lines surveyed through dense, remote regions of the park, and then subsequently cleared: depending on the terrain, the time of year, the previous survey activity in the area and the remoteness of the project, the cost of the survey can become expensive – at a minimum of $1000 per kilometre (K.Welch, pers. comm., September 15, 2009). With approximately 75 km of forested boundary, this would cost at a minimum, $75,000, although most likely much more with the survey variables previously mentioned. Because of tight budgets and changes in funding allocations, BPNP has yet been unable to secure funds to clear the entirety of the boundary that has reached the final limit. Only 43% of the forested boundary length has been cleared at this time. Most of the cleared boundary was cut in 2003, and in most cases, the adjacent forest has grown in significantly, making it difficult to see the park boundary signs or the cleared boundary. Without maintenance, this practice is ineffective.

6.4 FUTURE RESEARCH OPPORTUNITIES

Because of the increased accessibility issue, further research into the ecological effects of increased access due to the cleared boundary is strongly recommended. Indicators that can demonstrate the increased accessibility of areas caused by the boundaries could include studies on predators and their prey, invasive species, human presence, and indicators of hunting activity. As an indication of the level of fragmentation caused by the boundaries, studies of interior sensitive species such as the northern flying squirrel (*Glaucomys sabrinus*) or ovenbirds (*Seiurus aurocapillus*) and their nesting behaviours would be valuable. In order to further assess the ecological impacts of this boundary, future research into this issue could integrate smaller organisms that may be more sensitive to small-scale environmental changes, such as macroinvertebrates. Because eastern redback salamanders are the most common species of salamander on the Bruce Peninsula, a region with a history of intense logging resulting in mostly second-growth forests, this species has survived through an extensive historic disturbance regime from which it has recovered. There is, however, no other species of salamander in BPNP that would be ubiquitous enough to compare sites with, or to detect in sufficient numbers to achieve statistical significance. Other species of salamander that were not studied may be negatively affected by this practice of boundary management.

6.5 Recommendations

The results of this study show that, although the boundaries cause minimal ecological effects, BPNP should reconsider this practice because,

a. The boundary does not stop illegal activity, as was demonstrated by the indications of hunting on the boundary. It may in fact be increasing illegal activity. There is also no legal need to clear the boundary if NBTC was found to be legally responsible to know where they were logging, as this is thus not the responsibility of BPNP.
b. There are microclimate changes, and thus edge effects, on the surrounding forest, extending up to 10 m.
c. As of now, the completed boundaries have not all been cleared, and some have not been maintained in six years. If initial clearing and maintenance are not possible, or likely, in the future, then any benefit arising from the boundaries is not achieved.
d. There is a high financial cost in creating and maintaining these boundaries, and this money could be allocated to more beneficial environmental practices.

e. The cleared boundary is not effective in helping BPNP meet its goals – the protection of wildlife would be perhaps improved with fewer linear developments, and the boundary is costly to maintain.

It is therefore recommended that BPNP reconsider its use of this practice for the reasons above. However, if this practice is continued, the existing negative ecological effects on the boundaries could be reduced by changes to the way the boundaries are managed through:

1. Continuing to leave cut woody debris on cleared boundaries.

   This provides habitat to salamanders and inhibits hunters and ATVs from passing through. The boundary management directive should then be amended to reflect this practice. This does increase fuel build-up of dead wood; however, it can also slow re-growth on the boundary.

2. Minimizing corridor width.

   This prevents ATV use and reduces microclimatic effects to a minimum.

3. Reducing lines of sight on the boundary.

   This decreases the use of the boundaries as movement corridors and reduces predation. It can be done easily by not cutting small sections of the boundary, so it is not a continuous trail.

4. Reducing accessibility.

   This could be done by not clearing the boundaries immediately next to roads and trails and removing signs at these access points to make them less visible.

5. Increasing education internally and externally about the issues regarding human presence on the boundary.

   This would have the goal of informing local people of the purpose of the national park and the rules surroundings its use as well as informing BPNP staff to reduce their presence on the boundary whenever possible.

6. Communicating with adjacent landowners.

   This could reduce the practice of clearing the common boundaries to allow for ATV use, and it would improve surrounding landowner relationships with BPNP.

7. Securing funding for this management practice in the future.

   The current practice is ineffective if boundaries are not maintained. If funding cannot be secured, a new method should be found.

This information provides Parks Canada and specifically BPNP with the quantitative effects of this boundary practice on the microclimate of the boundary and nearby salamander populations. Because of the many negative effects of forest fragmentation (such as the increased dispersal of invasive species, sunlight and windthrow in a mid-forest area, corridors for predators, human disturbances, and others), this practice should eventually be considered in light of all its effects on natural processes and biota. If the findings of this practice are considered to show negative effects on the protected area or its flora or fauna, a new way to demarcate national park boundaries should be considered, reducing the negative effects of future management practices.

6.6 Summary of Contributions

1. The cleared boundaries of BPNP had ecological effects.

a. Air temperature and slug abundance were significantly higher up to 10 m away from the boundary. Relative humidity was significantly lower up to 10 m away.

b. Soil pH, downed woody cover area, and salamander abundance were significantly higher up to 5 m away from the boundary. Litter depth and canopy cover were significantly lower up to 5 m away.

c. Soil moisture, downed woody cover decomposition level, salamanders/cover object, salamanders/cover area, and salamander weights and lengths were not significantly affected by the boundary.

d. These effects are similar to those found for other narrow, vegetated linear developments.

2. Eastern redback salamander distribution was affected by the cleared boundaries of BPNP.

a. There was double the number of eastern redback salamanders found on the boundary as in similar transects in the surrounding forest.

b. Salamander abundance was positively correlated with high cover area, high cover object abundance, high total cover area in the plot, high slug abundance, low air temperatures, and high relative humidity.

c. Salamander numbers were best explained by the amount of cover area, number of snails, and the dominant type of vegetation present along a transect.

d. Salamanders, being small and sensitive and not negatively affected by the boundaries, indicate that other species which are less sensitive to forest changes are also not negatively affected.

3. Accessibility to previously remote areas of the park had been increased through the use of the boundaries as movement corridors. Although not directly measured, many indications of increased human access were found.

4. There was a trend for salamander abundance under cover objects to increase with days since the last precipitation event. The causes of this were not identified, and further research into this effect is warranted.

6.7 Conclusions

Linear developments have been found to have negative ecological effects on wildlife, plants, and ecological processes. Because of the systematic expansion of linear developments into deeper reaches of natural habitat, we are having a cumulative effect on large expanses of our environment. The major effects of linear developments on wildlife include individual disruption, social disruption, habitat avoidance, habitat disruption or enhancement, direct and indirect mortality, and population effects. Effects on flora include increased abundance of invasive and lower successional species and displacement of native and higher successional species, the removal of canopy vegetation on the linear development, and the removal of native wildflowers and vegetation due to maintenance activities and increased accessibility for poachers. Ecological processes, such as litter production, decomposition, and shading from the canopy, are affected by linear developments as well.

In general, the wider the linear development, the greater its ecological effects. Direct mortality tends to increase at roads and highways, but to a lesser extent at railways and other developments that have more predictable vehicle movements. Indirect mortality and disturbance is increased at all developments that allow increased human and predator access. As expected, the linear developments that cause less disturbance during their creation and/or have less or predictable human presence during their use generally cause the least amount of disturbance to wildlife and the environment. Wildlife that is hunted tends to be impacted most by anthropogenic linear developments. Taxa that are physically small are also affected by those linear developments that cause desiccation or changes in the microclimate.

Assessing the full range of effects on all wildlife in a landscape affected by multiple linear developments requires substantial funding, time, and effort. As can be seen with the high environmental variation in the case study, results from field observational studies can also prove difficult to interpret. Furthermore, the translation of this research into park or other governmental policy changes, and then action on the ground, requires much further engagement. Linear developments will continue to be created, and at an increasing pace. In order to reach an understanding of the full cumulative impacts of linear developments, funding and research into this area needs to be increased in order to match that pace, followed by the creation of management policies that incorporate the results of this and similar research to address the damage that the systematic expansion of linear developments has caused.

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APPENDICES

APPENDIX A: PRECIPITATION EVENTS AND PREDICTING SALAMANDER ABUNDANCE

In reviewing studies on salamanders to devise my research methods, a consistent sampling approach was not found for the timing of sampling for salamanders with respect to precipitation events (see Table 7 for details). Each study found had a slightly different method. Dr. James Bogart of the University of Guelph agreed that it is known that salamanders move and forage when it is humid and dark out to avoid desiccation (pers. comm., Aug. 7, 2008). During precipitation events that are strong enough to dampen the forest floor, woodland salamanders make use of the opportunity and may move into the forest litter and out from cover objects. In the hot, dry summer months, they tend to move underground and wait for precipitation events in order to return to the surface, making it difficult to find them on the surface under cover objects during dry periods. The EMAN protocol, used for sampling terrestrial salamanders across Canada, states that precipitation events bring salamanders out from below the surface and cover objects, out into the leaf litter to feed (Jaeger 1980). This would imply that waiting a short time after precipitation, but not long enough that the substrate dries completely, would provide for optimal searching. Therefore, one should sample when the soil is moist (Fellers and Drost 1994). For these reasons, I chose to wait at least 24 hr after any precipitation event before sampling for my study.

In the literature, Houze and Chandler (2002) found that salamander abundance and weekly rainfall were significantly correlated for both coverboards ($r^2 = 0.26$, $p = 0.009$) and natural cover ($r^2 = 0.38$, $p = 0.006$). Heatwole (1960) found that *P. cinereus* moved under cover objects during short dry spells but moved under the soil during longer dry periods. Grover (1998) conducted a study to experimentally test how soil moisture influenced salamander (*P. glutinosus* and *P. cinereus*) behaviour. During what was termed "suboptimal conditions," searches were conducted on the dry forest floor, at least 2 days after a precipitation event. A second search under "optimal conditions" was then conducted; these conditions were chosen as wet, humid nights following a rain. Treatments included watering sections of the forest and seeing if salamander abundance increased from the initial searches. Interestingly enough, the watering treatments did not have a significant effect on adult *P. cinereus* abundance ($F_{1,8}$ = 0.39, p = 0.551); however, juvenile *P. cinereus* and both adult and juvenile *P. glutinosus* were significantly more abundant on plots that were watered (F, s = 20.16, p < 0.001; F, s = 12.02, p = 0.01).

Table 7. Studies on woodland salamanders and sampling methods with respect to rainfall events.

Study	Species	Sampling conditions
DeMaynadier and Hunter (1998)	*P .cinereus*	Soon after rainfall or every 7 days
EMAN protocol – (EMAN 2004)	Plethodontid salamanders	Record if there was precipitation in the last 24 hr
Grover (1998)	*P. cinereus* and *P. glutinosus*	On wet and humid nights, following rainfall
Harpole and Haas (1999)	*P. cinereus*, *P. cylindraceus*, and *Desmognathus fuscus*	During or after rainfall
Houze and Chandler (2002)	Terrestrial salamanders	Weekly rainfall recorded, but no specific sampling done with regards to precipitation events
Marsh and Beckman (2004)	*P. cinereus*, *P. glutinosus*, and *P. cylindraceus*	When there was no rain for 3 previous days
Moore (2005)	*P. cinereus*	On a single rainless day
Semlitsch et al. (2007)	Woodland salamanders	Sampling was conducted regardless of weather

During my transect sampling on the BPNP boundary, more salamanders were found with increased time since the last precipitation event. It is possible that because cover objects were searched, and salamanders retreated under cover objects as the surrounding substrate dried, this is reasonable, since this may occur a few days after a precipitation event as the substrate dries. However, even during a long dry spell in August, increasingly higher salamander abundances were found under cover objects. Only once the substrate became very dry under cover objects did I notice a drop in salamander abundance; however, this happened rarely and only after a very prolonged dry period. Because of these observations as well as the inconsistency with respect to precipitation events as to when terrestrial salamanders are sampled, a study to test when the highest abundance of salamanders are found was carried out. Data were also collected from other sites in Ontario which consisted of the abundance of salamanders caught at various lengths of time since precipitation.

Methods

The study used the Emmett Lake EMAN monitoring plot in BPNP which consists of 40 coverboards. After a precipitation event, a random subset of 10 of the boards was searched each day for four days. Each board was not searched more than once per week, as per a study which showed that oversampling of coverboards can cause enough disturbance to reduce the abundance of salamanders under coverboards (Marsh and Goicochea 2003). If there was no precipitation in the next four days, the same subsets were sampled again, eight to eleven days after the original precipitation event. In doing this, the results can be compared as to when the highest abundances of terrestrial salamanders can be found with respect to a precipitation event.

The latter part of the study consisted of collecting data from various EMAN monitoring sites in the region. This dataset included other monitoring sites in BPNP, Georgian Bay Islands National Park, and the *rare* research reserve in Cambridge, Ontario. The number of days between the last precipitation event and sampling date is not recorded under the EMAN protocols, and so it was calculated using the National Climate Data and Information Archive through Environment Canada using the climate station data located nearest to the study site and the most recent precipitation event larger than 1 mm. All of the climate stations chosen were within 10 km of the study site; however, it is possible that inaccuracies occurred because of this distance.

Determining which and how environmental variables affect the probability of observation is paramount in order to control for possible biases, especially for studies comparing salamander abundance between sites. I investigated through this small pilot study only the variable of the length of time since a precipitation event on the observed abundance of terrestrial salamanders. My hypothesis was that optimal conditions for finding terrestrial salamanders are not within the first

24 hr of a precipitation event, but instead at some point later in time. If an effect were found, further study into the causes would then be warranted in the future.

The data from both parts of the study were analyzed by site to keep environmental variables consistent. Spearman correlations between days since precipitation and salamander abundance were used to determine the relationship between these two variables. The Spearman method was used because the data is non-parametric, and a reasonable transformation was not found for this dataset. Spearman correlations were also determined between groups of lengths of days since precipitation; data below four, three, and two days were grouped and compared to longer spans of time since precipitation. This was used to discover if categories of lengths of time show stronger relationships, and thus demonstrate the optimal length of time after a precipitation event in which to sample for terrestrial salamanders.

RESULTS

When data were considered by site, three of the eleven total sites had significant results ($p<0.05$), with reasonably high correlations of 0.48, 0.45, and 0.41 for the single environmental variable of days since precipitation. When data were grouped into salamander abundances within one day of a precipitation event, and compared with abundances after, there was a significantly higher number of salamanders in the later days ($p=0.03$). This significance increased until 3 days after a precipitation event ($p=8.0x10^{-04}$), and generally remained significant. At no point in the data set did salamander abundances significantly drop as days since precipitation increased.

The study done on salamander abundance at Emmett Lake with respect to the number of days since the last precipitation event demonstrated that the longer the time since precipitation, the higher the salamander abundance ($n=16$, $cor=0.72$, $p<0.01$). See Figure 7 for a scatterplot showing this trend.

These two datasets are enough to show that optimal conditions for finding terrestrial salamanders under cover objects is likely not within 24 hr of a precipitation event, and further study is warranted.

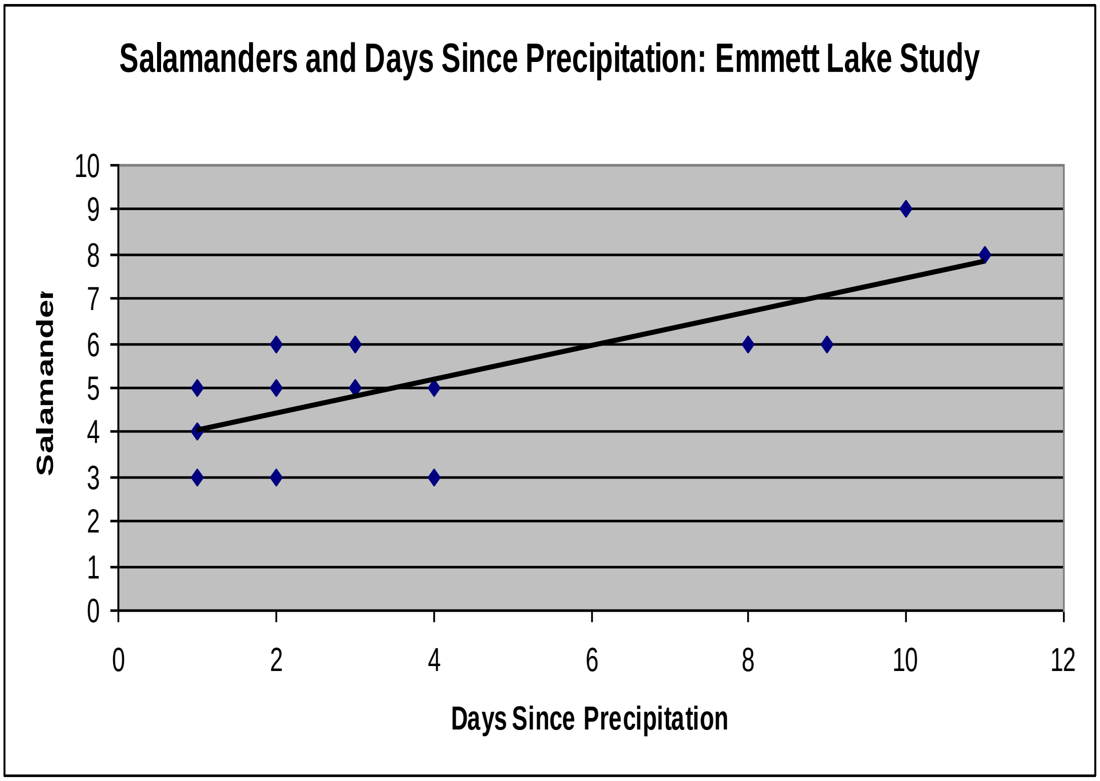

Figure 7. Emmett Lake study dataset showing clear trend of increasing number of salamanders as days since precipitation increases.

DISCUSSION AND CONCLUSIONS

This study involving salamander abundance and length of time since a precipitation event was considered separately from the main study using transects and microclimate variables. The results of the precipitation study indicate that, in the environments from which the dataset originates, salamanders do move under cover objects as days since a precipitation event increase, and do not move underground in significantly large numbers as the number of days progresses.

However, because of the small sample size and limited study area, further research is needed to understand the extent of this trend. This study should thus be extended for longer in the field season and duplicated at different sites in order to make the results applicable across Canada. The implications of this could be to improve the consistency of terrestrial salamander sampling methods as well as to improve the encounter rate under cover objects if many studies are done within 24 hr of a precipitation event. The results may also influence the salamander monitoring protocols developed by EMAN.

Appendix B: Figures

Figure 8. A view down the boundary in BPNP. Photo by Katherine St.James.

Figure 9. Adult eastern redback salamander (leadback morph). Photo by Katherine St.James.

Figure 10. Bear bait station located on BPNP property. Note park boundary sign. Photo by Katherine St.James.

Figure 11. Temporary hunting camp with antlers on display. Photo by Katherine St.James.

Figure 12. Target shooting on BPNP boundary. Photo by Katherine St.James.

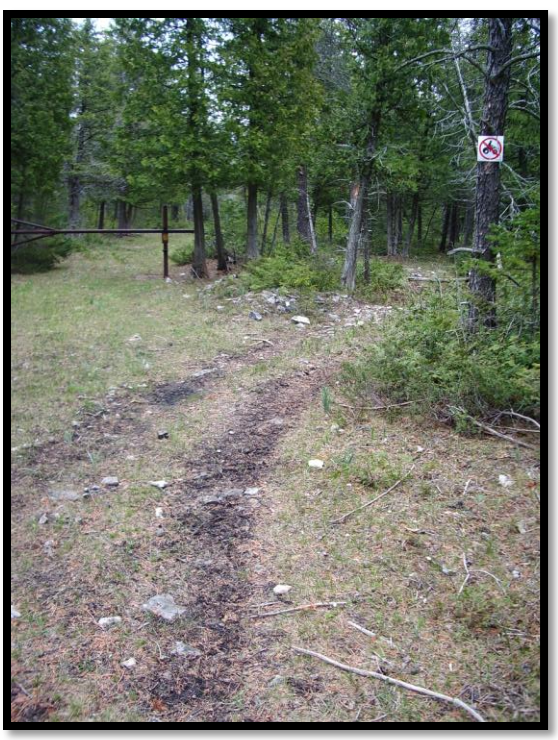

Figure 13. ATV tracks on BPNP boundary. Note the 'No ATV's' sign posted. Photo by Katherine St.James.

Figure 14. Fire pit located on BPNP boundary. Photo by Katherine St.James.

Figure 15. Unauthorized removal of logs on BPNP boundary to clear the path for recreational uses. Photo by Katherine St.James.

APPENDIX C: RAW DATA

Table 8. Raw data: variables measured by each transect.

Site	E	N	Date	Wind	Sky	Precip	Width (m)	Veg Code	Transect	Air temp (deg C)	RH (%)	Moisture (%)	Soil pH	Litter (cm)	Canopy Photo (%)	No. objects	Salamanders	Slugs	Snails
1	452767	5006500	10/9/08	0	0	2	2.4	100	0	15.45	59	6.75	62.5	1	55.5	51	6	11	0
1	452767	5006500	10/9/08	0	0	2	2.4	100	5	15.7	58	6.8	50	1.5	82	12	1	0	0
1	452767	5006500	10/9/08	0	0	2	2.4	100	10	15.25	55.5	6.75	52.5	1	72	15	0	3	0
1	452767	5006500	10/9/08	0	0	2	2.4	100	15	15.5	52.5	6.75	65	1.5	78	18	1	0	1
1	452767	5006500	10/9/08	0	0	2	2.4	100	20	16.05	54	6.8	62.5	1.75	81	16	0	5	0
1	452767	5006500	10/9/08	0	0	2	2.4	100	40	15.55	52.5	6.8	52.5	1.5	84.5	32	4	3	3
2	455525	5000218	16/9/08	0	3	1	1.5	100	0	13.3	64.5	6.55	32.5	1.5	54.5	27	0	1	0
2	455525	5000218	16/9/08	0	3	1	1.5	100	5	13.4	64.5	6.6	37.5	2	53	14	0	0	0
2	455525	5000218	16/9/08	0	3	1	1.5	100	10	13.1	68.5	6.6	42.5	2.25	42	21	2	2	2
2	455525	5000218	16/9/08	0	3	1	1.5	100	15	12.5	69	6.65	22.5	3.5	66.5	12	0	0	0
2	455525	5000218	16/9/08	0	3	1	1.5	100	20	13	70	6.8	20	2.75	64	26	1	0	0
2	455525	5000218	16/9/08	0	3	1	1.5	100	40	13	67	6.45	25	3.5	63.5	14	0	0	0
4	453214	5006210	11/9/08	1	2	3	3	75	0	19	52.5	6.7	45	1.25	64	39	3	3	0
4	453214	5006210	11/9/08	1	2	3	3	75	5	18.4	53	6.8	50	1.75	82.5	29	3	0	0
4	453214	5006210	11/9/08	1	2	3	3	75	10	18.35	54	6.9	45	1.75	84	27	2	6	0
4	453214	5006210	11/9/08	1	2	3	3	75	15	18.5	54	6.85	57.5	1	53	19	0	1	0
4	453214	5006210	11/9/08	1	2	3	3	75	20	18.15	52.5	6.9	52.5	2	72	31	7	9	0
4	453214	5006210	11/9/08	1	2	3	3	75	40	18.25	51	6.9	27.5	2	80.5	14	0	1	1
5	461792	5005509	21/9/08	3	1	6	4.5	30	0	15.65	41	6.25	52.5	2.75	36.5	21	0	0	1
5	461792	5005509	21/9/08	3	1	6	4.5	30	5	15.9	39.5	6.55	50	3	57	8	1	0	0
5	461792	5005509	21/9/08	3	1	6	4.5	30	10	14.95	44	6.65	40	4	81.5	20	3	1	2
5	461792	5005509	21/9/08	3	1	6	4.5	30	15	14.8	45	6.55	47.5	4	81	27	0	0	4
5	461792	5005509	21/9/08	3	1	6	4.5	30	20	14	44.5	6.7	57.5	3.5	88	22	0	0	1
5	461792	5005509	21/9/08	3	1	6	4.5	30	40	13.85	45.5	6.7	45	4	76	25	1	0	6
6	452595	5006664	23/9/08	2	1	8	2	25	0	18.5	59	6.4	80	2.75	33	68	5	0	0
6	452595	5006664	23/9/08	2	1	8	2	25	5	18.3	57.5	6.8	62.5	3.5	65	37	5	0	1

6	452595	5006664	23/9/08	2	1	8	2	25	10	18.55	58	6.6	62.5	2.75	71	28	1	0	1
6	452595	5006664	23/9/08	2	1	8	2	25	15	18.3	59	6.8	75	3	53.5	23	1	0	0
6	452595	5006664	23/9/08	2	1	8	2	25	20	18.6	58	6.35	75	3.75	27	65	0	1	4
6	452595	5006664	23/9/08	2	1	8	2	25	40	18.45	58	6.75	70	3.5	72.5	27	0	0	1
7	455400	5006212	19/9/08	3	3	4	2	40	0	17.35	62.5	6.75	60	0.5	79	41	0	3	19
7	455400	5006212	19/9/08	3	3	4	2	40	5	16.85	61.5	6.8	70	2.25	90	50	1	4	5
7	455400	5006212	19/9/08	3	3	4	2	40	10	16.75	62	6.9	55	2.5	87.5	54	1	1	1
7	455400	5006212	19/9/08	3	3	4	2	40	15	16.75	61.5	6.95	62.5	2.75	83.5	20	1	2	0
7	455400	5006212	19/9/08	3	3	4	2	40	20	16.7	62	6.95	30	2.25	89	36	3	3	0
7	455400	5006212	19/9/08	3	3	4	2	40	40	17	61.5	6.95	55	2	87	16	1	0	0
8	455699	499869	16/9/08	1	2	1	2	100	0	19.95	36	6.75	50	2.25	30.5	23	2	0	0
8	455699	499869	16/9/08	1	2	1	2	100	5	18.95	37.5	6.35	55	2	46	17	0	0	1
8	455699	499869	16/9/08	1	2	1	2	100	10	18.65	40	6.55	40	2	52.5	13	0	1	0
8	455699	499869	16/9/08	1	2	1	2	100	15	18	44	6.75	30	2	51	11	0	0	2
8	455699	499869	16/9/08	1	2	1	2	100	20	17.65	42.5	6.7	40	2.25	60	11	0	0	1
8	455699	499869	16/9/08	1	2	1	2	100	40	17.55	44.5	6.4	45	1.75	49	13	0	0	0
9	458993	4997386	28/9/08	3	4	13	3.4	66	0	14.25	59	6.85	42.5	4.25	39	71	5	9	0
9	458993	4997386	28/9/08	3	4	13	3.4	66	5	13.65	60.5	7	20	4.25	82.5	14	2	1	0
9	458993	4997386	28/9/08	3	4	13	3.4	66	10	13.35	62	6.9	37.5	3.75	81.5	33	3	4	0
9	458993	4997386	28/9/08	3	4	13	3.4	66	15	13.05	63	7	30	5.25	81.5	24	2	1	0
9	458993	4997386	28/9/08	3	4	13	3.4	66	20	13.25	63.5	6.95	27.5	3.75	86	29	0	0	1
9	458993	4997386	28/9/08	3	4	13	3.4	66	40	13.5	64.5	6.9	42.5	5	72.5	30	1	2	0
10	456086	4999575	24/9/08	4	2	9	2	75	0	20.55	60	6.8	45	4.5	78.5	30	2	0	1
10	456086	4999575	24/9/08	4	2	9	2	75	5	20.4	59	6.55	55	5	63.5	31	2	0	0
10	456086	4999575	24/9/08	4	2	9	2	75	10	20.7	59	6.75	52.5	4	73	24	2	0	3
10	456086	4999575	24/9/08	4	2	9	2	75	15	20.55	58.5	6.8	37.5	4.5	80.5	12	0	0	0
10	456086	4999575	24/9/08	4	2	9	2	75	20	20.5	59	6.75	37.5	4.75	89	18	2	0	0
10	456086	4999575	24/9/08	4	2	9	2	75	40	20.65	59.5	6.8	35	4.5	79.5	26	1	1	0
11	455430	4999250	24/9/08	4	1	9	2.5	75	0	22.75	49.5	6.75	17.5	3.25	24	29	1	0	0
11	455430	4999250	24/9/08	4	1	9	2.5	75	5	22.5	52	6.9	32.5	4.5	50	25	0	0	0
11	455430	4999250	24/9/08	4	1	9	2.5	75	10	22.1	53.5	6.8	27.5	5	59.5	9	0	0	0

11	455430	4999250	24/9/08	4	1	9	2.5	75	15	22.15	54	6.8	17.5	4.75	70	10	4	0	0
11	455430	4999250	24/9/08	4	1	9	2.5	75	20	22	54.5	6.85	35	4.25	9	13	0	0	0
11	455430	4999250	24/9/08	4	1	9	2.5	75	40	22.1	55.5	6.85	25	5	78.5	12	0	0	0
12	462156	5000589	17/9/08	2	1	2	3.5	100	0	23.25	38.5	6.6	65	1.5	16.5	39	2	1	0
12	462156	5000589	17/9/08	2	1	2	3.5	100	5	21.95	38.5	6.5	45	2.25	57	12	1	0	0
12	462156	5000589	17/9/08	2	1	2	3.5	100	10	22.05	41	6.85	77.5	2	46.5	14	2	0	0
12	462156	5000589	17/9/08	2	1	2	3.5	100	15	21.85	39.5	6.8	40	2.5	84.5	20	0	0	0
12	462156	5000589	17/9/08	2	1	2	3.5	100	20	21.55	39	6.9	47.5	2	49	15	0	0	0
12	462156	5000589	17/9/08	2	1	2	3.5	100	40	21.5	41	6.7	37.5	2.5	32	18	1	0	0
13	462729	5001470	17/9/08	2	1	2	3	100	0	19.75	56	6.55	35	2.5	58	50	10	0	0
13	462729	5001470	17/9/08	2	1	2	3	100	5	19.8	58	6.85	20	2.25	54.5	33	1	0	1
13	462729	5001470	17/9/08	2	1	2	3	100	10	19.8	58.5	6.45	40	2.75	83.5	27	0	0	0
13	462729	5001470	17/9/08	2	1	2	3	100	15	19.45	57.5	6.5	45	2.25	33	30	2	0	0
13	462729	5001470	17/9/08	2	1	2	3	100	20	19.25	56.5	6.6	22.5	2.5	77	25	0	0	0
13	462729	5001470	17/9/08	2	1	2	3	100	40	19.25	57.5	6.65	32.5	3.25	58.5	27	4	0	0
14	456468	5001833	18/9/08	3	1	3	2.5	66	0	13.25	45.5	6.8	32.5	2.25	50.5	67	2	0	1
14	456468	5001833	18/9/08	3	1	3	2.5	66	5	13.85	43.5	6.95	32.5	3.75	75	24	1	0	0
14	456468	5001833	18/9/08	3	1	3	2.5	66	10	13.6	44	6.7	35	3.25	77	24	3	0	0
14	456468	5001833	18/9/08	3	1	3	2.5	66	15	13.5	45.5	6.8	32.5	3.5	73	21	3	1	0
14	456468	5001833	18/9/08	3	1	3	2.5	66	20	13.2	47	6.85	30	3.5	84	19	0	0	0
14	456468	5001833	18/9/08	3	1	3	2.5	66	40	13.65	48.5	6.75	57.5	3	38.5	20	1	0	0
15	462424	4993789	25/9/08	1	3	10	2	25	0	19.95	64.5	6.8	40	3	43	38	2	3	0
15	462424	4993789	25/9/08	1	3	10	2	25	5	20.05	63	6.9	37.5	3.5	36.5	41	0	1	1
15	462424	4993789	25/9/08	1	3	10	2	25	10	19.6	63.5	6.85	45	3.5	73	38	1	1	1
15	462424	4993789	25/9/08	1	3	10	2	25	15	19.95	63	6.9	35	3.5	65.5	37	0	1	2
15	462424	4993789	25/9/08	1	3	10	2	25	20	19.75	64	6.85	37.5	3.25	87	36	2	1	0
15	462424	4993789	25/9/08	1	3	10	2	25	40	19.8	63.5	6.75	50	3.75	48	50	1	2	2
16	461933	4993036	25/9/08	1	4	10	2.8	35	0	22.6	53	6.7	52.5	3.5	10.5	30	1	2	0
16	461933	4993036	25/9/08	1	4	10	2.8	35	5	22.9	55	7	12.5	3.75	47.5	17	0	0	0
16	461933	4993036	25/9/08	1	4	10	2.8	35	10	22.05	55.5	6.85	37.5	4.5	39.5	44	0	1	2
16	461933	4993036	25/9/08	1	4	10	2.8	35	15	22.25	54.5	6.95	22.5	4	18.5	23	0	3	0

16	461933	4993036	25/9/08	1	4	10	2.8	35	20	22.55	55	6.9	25	3.75	80	22	0	2	0
16	461933	4993036	25/9/08	1	4	10	2.8	35	40	22.35	57.5	6.85	37.5	3.5	38.5	33	0	2	0
17	461651	4992631	25/9/08	1	2	10	2	100	0	24.15	49	6.7	10	2.5	34.5	68	1	3	1
17	461651	4992631	25/9/08	1	2	10	2	100	5	24.2	50	6.7	47.5	3	71.5	25	0	0	1
17	461651	4992631	25/9/08	1	2	10	2	100	10	23.75	50.5	6.65	40	3.5	47	7	0	0	0
17	461651	4992631	25/9/08	1	2	10	2	100	15	23.25	52	6.85	47.5	4	61	8	0	0	0
17	461651	4992631	25/9/08	1	2	10	2	100	20	23.35	52	6.7	40	4.5	79	15	0	0	0
17	461651	4992631	25/9/08	1	2	10	2	100	40	23.1	53	6.7	57.5	4.25	69.5	31	0	0	0
19	458033	4998051	29/9/08	1	4	14	2	100	0	12.15	62.5	6.9	12.5	5.75	75.5	52	6	4	0
19	458033	4998051	29/9/08	1	4	14	2	100	5	12.05	64	7	5	5.5	81	20	2	0	0
19	458033	4998051	29/9/08	1	4	14	2	100	10	12	63	6.9	7.5	5.25	80	23	1	1	2
19	458033	4998051	29/9/08	1	4	14	2	100	15	11.65	64.5	6.95	17.5	5	83	45	8	1	0
19	458033	4998051	29/9/08	1	4	14	2	100	20	11.55	64	7	5	5.5	72	33	8	2	0
19	458033	4998051	29/9/08	1	4	14	2	100	40	11.45	65.5	6.95	7.5	5	81	29	3	2	0
20	461864	4995294	22/9/08	2	2	7	2.75	50	0	20	48	6.8	27.5	3.5	68	36	0	1	0
20	461864	4995294	22/9/08	2	2	7	2.75	50	5	19.25	52	6.8	47.5	4	74.5	19	0	0	0
20	461864	4995294	22/9/08	2	2	7	2.75	50	10	18.85	51	6.9	27.5	3.75	69.5	12	0	0	0
20	461864	4995294	22/9/08	2	2	7	2.75	50	15	18.85	53.5	6.8	15	4	82	11	0	0	0
20	461864	4995294	22/9/08	2	2	7	2.75	50	20	18.7	54.5	6.8	20	3.5	85	16	1	0	0
20	461864	4995294	22/9/08	2	2	7	2.75	50	40	18.1	55	6.9	32.5	3.5	83	23	3	1	1
21	461864	4995294	22/9/08	2	2	7	3	50	0	19.85	47	6.65	37.5	3.75	54	73	4	0	1
21	461864	4995294	22/9/08	2	2	7	3	50	5	19.3	51.5	6.95	30	4.25	85.5	12	0	0	0
21	461864	4995294	22/9/08	2	2	7	3	50	10	19.4	50.5	6.8	47.5	4.25	85.5	17	0	0	1
21	461864	4995294	22/9/08	2	2	7	3	50	15	18.85	51	6.85	40	4	83.5	15	1	0	0
21	461864	4995294	22/9/08	2	2	7	3	50	20	19.55	50.5	6.65	30	4	89	24	0	0	0
21	461864	4995294	22/9/08	2	2	7	3	50	40	19.1	51	6.85	22.5	4.5	83.5	11	1	0	0
22	455070	5005747	30/9/08	2	4	15	1.7	100	0	14.95	66	6.5	15	4.25	67.5	60	4	4	0
22	455070	5005747	30/9/08	2	4	15	1.7	100	5	15.35	67	6.85	30	4.25	81.5	26	2	2	0
22	455070	5005747	30/9/08	2	4	15	1.7	100	10	14.8	71	6.85	22.5	5.75	76	22	1	1	0
22	455070	5005747	30/9/08	2	4	15	1.7	100	15	15.5	65	6.9	20	6	73	43	4	7	0
22	455070	5005747	30/9/08	2	4	15	1.7	100	20	14.4	70	6.95	25	5	64	36	2	2	0

22	455070	5005747	30/9/08	2	4	15	1.7	100	40	14.4	73	7	22.5	4	71.5	29	1	0	0
23	461607	5005664	2/10/08	4	2	2	6	66	0	10.05	60.5	6.4	47.5	3	50.5	10	1	0	0
23	461607	5005664	2/10/08	4	2	2	6	66	5	10.7	57	6.8	20	5	81.5	17	1	0	0
23	461607	5005664	2/10/08	4	2	2	6	66	10	11.1	55	6.85	15	5.75	81.5	20	1	2	0
23	461607	5005664	2/10/08	4	2	2	6	66	15	10.6	51.5	6.6	40	5.25	83.5	21	1	0	0
23	461607	5005664	2/10/08	4	2	2	6	66	20	10.6	56	6.85	15	5.75	82	18	0	0	0
23	461607	5005664	2/10/08	4	2	2	6	66	40	10.2	54.5	6.85	22.5	7	73	29	3	1	0
24	461326	5005832	2/10/08	4	3	2	6	66	0	11.15	52.5	6.4	45	4.25	31	32	4	0	0
24	461326	5005832	2/10/08	4	3	2	6	66	5	11.05	54	6.45	47.5	3.5	48	24	0	0	1
24	461326	5005832	2/10/08	4	3	2	6	66	10	11.25	56	6.8	27.5	3.75	74.5	16	0	1	0
24	461326	5005832	2/10/08	4	3	2	6	66	15	10.85	57.5	6.75	30	4	75.5	14	0	0	0
24	461326	5005832	2/10/08	4	3	2	6	66	20	10.95	58.5	6.75	25	4.5	76	14	0	0	0
24	461326	5005832	2/10/08	4	3	2	6	66	40	10.5	59.5	6.8	25	4.75	82.5	26	2	0	1
25	453891	5005687	3/10/08	4	2	3	2	66	0	11.55	45	6.85	35	3.75	68.5	22	0	0	0
25	453891	5005687	3/10/08	4	2	3	2	66	5	11.8	44.5	6.9	35	3.5	84.5	12	0	0	0
25	453891	5005687	3/10/08	4	2	3	2	66	10	11.45	46	6.9	17.5	4	74.5	23	0	1	0
25	453891	5005687	3/10/08	4	2	3	2	66	15	11.55	46.5	6.95	27.5	3.75	71.5	16	0	1	0
25	453891	5005687	3/10/08	4	2	3	2	66	20	11.05	47	6.9	15	4	45	16	1	0	0
25	453891	5005687	3/10/08	4	2	3	2	66	40	11.45	47	6.85	12.5	5	80.5	20	1	0	0
26	453490	5005993	3/10/08	4	3	3	2	50	0	12.95	46.5	6.75	35	2.25	56	48	2	5	2
26	453490	5005993	3/10/08	4	3	3	2	50	5	11.85	47.5	6.65	45	1.5	76	19	1	1	0
26	453490	5005993	3/10/08	4	3	3	2	50	10	12.15	46	6.75	55	3.75	51.5	13	0	0	0
26	453490	5005993	3/10/08	4	3	3	2	50	15	11.6	48	6.8	57.5	3.25	46.5	12	4	2	0
26	453490	5005993	3/10/08	4	3	3	2	50	20	11.5	49.5	6.75	60	2.75	78	15	0	1	0
26	453490	5005993	3/10/08	4	3	3	2	50	40	11.45	48.5	6.85	42.5	3	62	28	3	3	0
27	455509	4999620	6/10/08	1	2	6	3	75	0	10.3	50.5	6.5	67.5	3.5	30	6	0	0	0
27	455509	4999620	6/10/08	1	2	6	3	75	5	10.45	52	6.85	37.5	4.75	75	20	0	0	0
27	455509	4999620	6/10/08	1	2	6	3	75	10	9.85	54	6.85	37.5	4.5	57.5	15	0	1	0
27	455509	4999620	6/10/08	1	2	6	3	75	15	10.65	54	6.8	22.5	5.75	57.5	15	2	0	0
27	455509	4999620	6/10/08	1	2	6	3	75	20	10.1	53	6.8	27.5	5	80	14	0	0	0
27	455509	4999620	6/10/08	1	2	6	3	75	40	9.95	51.5	6.9	32.5	5	72.5	30	2	1	3

28	455534	4999537	6/10/08	1	1	6	3	100	0	14.65	33.5	6.8	40	3.5	16.5	16	1	0	0
28	455534	4999537	6/10/08	1	1	6	3	100	5	13.85	35.5	6.8	52.5	4.25	22	21	0	0	0
28	455534	4999537	6/10/08	1	1	6	3	100	10	13.65	35	6.8	45	5.5	41	11	0	0	0
28	455534	4999537	6/10/08	1	1	6	3	100	15	13.55	39	6.9	12.5	5.25	62	8	0	0	0
28	455534	4999537	6/10/08	1	1	6	3	100	20	12.9	39	6.8	30	5.25	18	18	0	0	0
28	455534	4999537	6/10/08	1	1	6	3	100	40	12.6	38.5	6.9	45	3.75	59	7	0	0	0

Table 9. Raw data: variables measured for each salamander.

ID	Site	Date	Time	Transect	Width (cm)	Length (cm)	Species	Weight (g)	SVLength (cm)	TotalLength (cm)	Age	pH	Moisture (%)	Litter Depth (cm)	Wood Type
1	1	23/5/08	13:30:00	0	23	95	1	0.3	2.6	5.1	1	6.7	60	1	n/a
2	1	23/5/08	13:30:00	5	14	38	1				1	6.6	60	3	n/a
3	1	23/5/08	13:30:00	15	15	63	1	1.2	4.2	8	2	6.4	60	2	n/a
4	4	25/5/08	10:10:00	0	7	124	1	0.6	3.1	6.8	2	6.8	55	2	n/a
5	4	25/5/08	10:10:00	0	7	124	1	1.1	4	7.3	2	6.8	55	2	n/a
6	4	25/5/08	10:10:00	5	13	80	1	1.3	4.5	7.2	2	6.7	45	2.5	n/a
7	4	25/5/08	10:10:00	5	11	25	1	0.5	2.5	5.2	1	6.8	45	3	n/a
8	4	25/5/08	10:10:00	5	8	60	1	1	3.8	7.5	2	7	35	2.5	n/a
9	4	25/5/08	10:10:00	5	12	150	1	0.9	3.2	7.2	2	6.6	35	3	n/a
10	4	25/5/08	10:10:00	10	9	53	1	1.2	4.2	8.6	2	6.7	55	2	n/a
11	4	25/5/08	10:10:00	15	7	29	1	0.9	3.8	5.9	2	6.8	30	3.5	n/a
12	4	25/5/08	10:10:00	15	11	80	1	1.6	4.1	9	2	6.6	50	3.5	n/a
13	4	25/5/08	10:10:00	20	10	135	1	0.9	3.5	6.8	2	6.8	30	3	n/a
14	4	25/5/08	10:10:00	20	9	32	1	1.3	4	7.8	2	6.7	70	1.5	n/a
15	4	25/5/08	10:10:00	40	15	104	1	0.4	3.1	5.7	2	6.8	70	0	n/a
16	4	25/5/08	10:10:00	40	13	110	1	0.8	4	8.3	2	6.9	55	2	n/a
17	5	27/5/08	09:15:00	0	10	85	1	0.5	2.6	4.3	1	6.3	30	2	n/a
18	5	27/5/08	09:15:00	20	7	72	1	1.1	4.3	8.6	2	7	60	3.5	n/a
19	5	27/5/08	09:15:00	20	13	145	1	1.3	4.2	6.5	2	6.8	60	2	n/a
20	5	27/5/08	09:15:00	20	11	134	1	0.7	4.2	5.6	2	6.8	55	2	n/a
21	5	27/5/08	09:15:00	0	11	89	2	0.7	3.5	5.5	2	6.4	60	1.5	n/a
22	5	27/5/08	09:15:00	15	8	71	2				1	7	75	2.5	n/a
23	5	27/5/08	09:15:00	0	12	116	3	0.4	2.4	4.6	1	6.8	60	1.5	n/a
24	6	28/5/08	12:30:00	5	21	85	1	1.1	3.5	6.7	2	6.8	70	3	n/a
25	6	28/5/08	12:30:00	10	13	96	1	1.4	4	7	2	6.7	60	2	n/a
26	7	29/5/08	11:45:00	5	21	90	1	0.2	1.7	3	1	6.4	90	0	n/a
27	7	29/5/08	11:45:00	15	16	103	1	0.9	3.3	6.8	2	6	80	0.5	n/a
28	7	29/5/08	11:45:00	20	4	127	1	1.3	4.8	9.4	2	6.8	35	3	n/a

29	7	29/5/08	11:45:00	20	11	70	1	1	4	7	2	6.4	40	1	n/a
30	7	29/5/08	11:45:00	20	5	43	1	1	4.5	8.1	2	6.6	50	0.5	n/a
31	7	29/5/08	11:45:00	20	5	57	1				1	6.8	40	2	n/a
32	7	29/5/08	11:45:00	40	8	75	1	0.7	4	6.1	2	6.2	80	3	n/a
33	7	29/5/08	11:45:00	40	7	92	1	0.9	4.4	7.9	2	7	15	1.5	n/a
34	8	30/5/08	09:45:00	10	182	9	1	2.4	6.5	7.4	2	6.8	15	2	n/a
35	8	30/5/08	09:45:00	20	65	9	1	0.3	2.2	4.3	1	6.8	25	2	n/a
36	8	30/5/08	09:45:00	10	67	6	2	1	3.4	7	2	6.8	20	2	n/a
37	8	30/5/08	09:45:00	10	134	5	2	1.1	3.6	6.7	2	6.8	20	2	n/a
38	8	30/5/08	09:45:00	20	51	10	2	0.4	2.7	3.9	1	6.8	40	2	n/a
39	9	2/6/08	10:30:00	0	105	7	1	1.3	4	7.4	2	7	20	2	n/a
40	9	2/6/08	10:30:00	40	95	9	1	0.7	3.1	6.5	2	6.8	65	2	n/a
41	9	2/6/08	10:30:00	10	93	12	2	0.7	4.1	7.2	2	6.9	30	2.5	n/a
42	9	2/6/08	10:30:00	15	54	17	2	0.7	4.1	7.2	2	6.9	30	2.5	n/a
43	9	2/6/08	10:30:00	40	108	11	2	1.1	3.3	5.6	2	7	60	2	n/a
44	10	3/6/08	10:20:00	10	11	112	1	0.8	3.2	6.9	2	6.8	20	2.5	n/a
45	10	3/6/08	10:20:00	10	7	158	1	0.9	4.2	8.2	2	6.6	25	2	n/a
46	10	3/6/08	10:20:00	15	13	512	1	1	3.8	6.8	2	6.5	20	2.5	n/a
47	10	3/6/08	10:20:00	15	4	34	1	0.8	3.3	6.8	2	6.7	5	20	n/a
48	10	3/6/08	10:20:00	15	9	140	1	1.1	3.9	6	2	6.8	25	2	n/a
49	10	3/6/08	10:20:00	15	20	240	1	0.9	3.8	6.4	2	6.8	20	3	n/a
50	10	3/6/08	10:20:00	5	5	124	2	0.8	3.6	5.9	2	6.8	40	2.5	n/a
51	11	3/6/08	13:58:00	0	18.0	116.0	1	0.9	3.8	7.2	2	6.6	30	1.5	n/a
52	11	3/6/08	13:58:00	10	8.0	114.0	1	1.1	4.2	7.2	2	6.8	35	2	n/a
53	11	3/6/08	13:58:00	40	20.0	114.0	1	0.9	3.8	7	2	6.8	25	1.5	n/a
54	11	3/6/08	13:58:00	15	6.5	128.0	1	0.3	25	4.5	2	6.8	20	2	n/a
55	11	3/6/08	13:58:00	0	16	81	2	0.45	2.9	4.8	1	6.8	70	1.5	n/a
56	12	4/6/08	11:00:00	40	131	8	1	0.55	3.3	5.4	2	6.6	40	1.5	n/a
57	12	4/6/08	11:00:00	0	118	9	1	0.5	3.2	6.1	2	7.2	60	2	n/a
58	12	4/6/08	11:00:00	10	95	7	1	0.75	3.8	7.3	2	6.6	30	2	n/a
59	12	4/6/08	11:00:00	10	100	8	1	0.6	3.2	7.6	2	7	15	2.5	n/a

60	12	4/6/08	11:00:00	10	148	10	2	0.9	3.9	6.4	2	6.9	40	2	n/a
61	12	4/6/08	11:00:00	20	101	7	2	0.7	3.6	6.4	2	7	65	2.5	n/a
62	12	4/6/08	11:00:00	15	170	19	2	0.7	3.5	6.3	2	6.7	25	1.5	n/a
63	13	5/6/08	10:50:00	0	89	6	1	0.5	3.2	5.3	2	6.8	15	1.5	n/a
64	13	5/6/08	10:50:00	40	110	5	2	0.7	3.2	7.1	2	6.8	20	2	n/a
65	13	5/6/08	10:50:00	0	121	7	2	0.6	3	6	2	6.8	25	2	n/a
66	14	8/6/08	16:00:00	20	142	9	1	6	3.6	7.6	2	7	30	1.5	n/a
67	14	8/6/08	16:00:00	15	80	8	1				1	6.8	35	1.5	n/a
68	14	8/6/08	16:00:00	5	96	6	1	1.3	3.9	7.4	2	6.6	50	1	n/a
69	14	8/6/08	16:00:00	15	85	5	2	0.25	2.2	4.3	1	7	59	2	n/a
70	14	8/6/08	16:00:00	15	128	5	2	0.1	1.5	2.9	1	6.9	25	2	n/a
71	14	8/6/08	16:00:00	10	180	10	2	1.2	4.1	8.3	2	6.8	56	2	n/a
72	15	12/6/08	09:30:00	0	102	16	1	0.9	3.2	5.8	2	6.4	60	2	n/a
73	15	12/6/08	09:30:00	5	142	12	1	1.6	4.1	8.1	2	6.4	80	1.75	n/a
74	15	12/6/08	09:30:00	10	60	15	2	0.7	3.1	6	2	6.6	55	1.5	n/a
75	15	12/6/08	09:30:00	40	205	11	2	0.55	2.2	4.5	1	6.8	45	1.5	n/a
76	16	12/6/08	12:00:00	20	100	8	1	0.6	3.1	6.2	2	6.8	20	2	n/a
77	16	12/6/08	12:00:00	20	64	8	1	0.7	3.5	7.1	2	6.8	30	2.5	n/a
78	18	16/6/08	10:00:00	5	120	5	1	0.8	3.9	7.6	2	6.8	45	2	n/a
79	18	16/6/08	10:00:00	20	78	7	1	0.8	3.8	8	2	6.8	40	2.5	n/a
80	18	16/6/08	10:00:00	0	142	7	1	1.1	4	7.7	2	6.8	35	3	n/a
81	19	16/6/08	12:00:00	15	126	10	1	0.7	3.9	8	2	6.7	20	1.5	n/a
82	19	16/6/08	12:00:00	10	106	5	1	0.2	2.3	3.9	1	6.8	30	2	n/a
83	19	16/6/08	12:00:00	20	81	12	1	0.9	3.6	7.3	2	6.4	20	2	n/a
84	19	16/6/08	12:00:00	20	140	4	1	0.6	3.6	6.8	2	6.8	40	2	n/a
85	19	16/6/08	12:00:00	0	81	5	1	0.3	2.7	4.2	1	6.9	30	1.5	n/a
86	19	16/6/08	12:00:00	0	190	7	1	1	3.5	7.6	2	6.6	40	2	n/a
87	19	16/6/08	12:00:00	15	124	6	2	1	4	8.2	2	6.7	20	2	n/a
88	19	16/6/08	12:00:00	0	55	10	2				1	6.7	15	2	n/a
89	20	20/6/08	13:00:00	0	6	205	2	0.95	4.2	7.9	2	7.1	25	2	n/a
90	20	20/6/08	13:00:00	0	6	37	2	0.5	3.1	5.5	2	7.1	30	2	n/a

91	20	20/6/08	13:00:00	0	5	25	2	0.65	3.2	6.3	2	7.2	30	2	n/a
92	1	10/9/08	10:22:00	0	28	14	2	0.85	4	6.1	2	6.1	70	1	2
93	1	10/9/08	10:22:00	0	88	9	2	0.7	3.7	6.6	2	6.8	45	2	3
94	1	10/9/08	10:22:00	5	175	4	1	1.1	3.7	7.7	2	6.7	35	1.5	4
95	1	10/9/08	10:22:00	0	87	7	1	0.8	4.2	7.4	2	6.4	60	1.5	3
96	1	10/9/08	10:22:00	0	91	12	1	0.4	3.1	5.8	2	6.8	50	2	3
97	1	10/9/08	10:22:00	0	108	13	1	0.9	3.3	7.5	2	6.3	45	2	2
98	1	10/9/08	10:22:00	0	108	13	1	0.6	3.5	6.8	2	6.3	45	2	2
99	1	10/9/08	10:22:00	40	83	5	1	1.4	4.1	8.3	2	6.7	45	2	3
100	1	10/9/08	10:22:00	40	63	11	1	1	3.5	7.6	2	6.6	65	2	4
101	1	10/9/08	10:22:00	40	152	22	1	1.1	3.6	7.3	2	6.8	35	2	3
102	1	10/9/08	10:22:00	40	59	12	1	1.1	4.1	8.4	2	6.8	35	2.5	4
103	1	10/9/08	10:22:00	15	64	9	1	1.55	4.3	9.3	2	6.8	40	1	4
104	2	16/9/08	09:45:00	20	150	9	2	0.9	3.9	8	2	6.6	25	2.5	4
105	2	16/9/08	09:45:00	10	34	12	1	0.2	2.2	3.3	1	6.7	20	3	4
106	2	16/9/08	09:45:00	10	27	4	1	0.4	3	5.7	2	6.6	40	3	2
107	4	11/9/08	10:30:00	10	75	7	2	0.8	3.5	6.4	2	7	15	1.5	2
108	4	11/9/08	10:30:00	10	54	4	2	0.8	3.3	6.2	2	6.8	25	2	2
109	4	11/9/08	10:30:00	20	36	5	2	0.6	3.3	6.6	2	6.8	60	4	2
110	4	11/9/08	10:30:00	20	33	4	2	1.1	4.1	8.1	2	6.8	60	3	3
111	4	11/9/08	10:30:00	20	123	7	1	1.7	4	9	2	6.9	35	1	2
112	4	11/9/08	10:30:00	20	35	3	1	1.7	4.6	8.3	2	6.9	20	1	2
113	4	11/9/08	10:30:00	20	153	6	1	1.8	4.2	8.6	2	6.6	50	3	3
114	4	11/9/08	10:30:00	20	50	5	1	0.3	2.5	4.7	1	6.6	70	4	2
115	4	11/9/08	10:30:00	20	78	6	1	0.5	2.8	5.3	1	6.7	75	4	3
116	4	11/9/08	10:30:00	0	134	16	1	1.7	4.5	9.3	2	6.8	25	3	2
117	4	11/9/08	10:30:00	0	31	8	1	1.4	4.4	8.8	2	6.8	35	3	3
118	4	11/9/08	10:30:00	0	112	3	1	0.3	2.4	4.7	1	6.9	45	1	3
119	4	11/9/08	10:30:00	5	66	8	1	1.5	4	8.5	2	7	30	3	3
120	4	11/9/08	10:30:00	5	71	6	1	1.4	4	7.7	2	6.9	20	3	4
121	4	11/9/08	10:30:00	5	71	6	1	1	3.7	7.8	2	6.9	20	3	4

122	5	21/9/08	15:00:00	10	165	4	3	0.4	2.6	4.9	1	6.6	55	3	4
123	5	21/9/08	15:00:00	10	176	11	2	0.6	3.6	6.4	2	6.8	65	2.5	3
124	5	21/9/08	15:00:00	10	165	4	1	1.3	3.2	7.9	2	6.6	55	3	4
125	5	21/9/08	15:00:00	5	86	12	1	1.3	3.3	7.5	2	6.9	55	3.5	3
126	5	21/9/08	15:00:00	40	74	3	1	0.9	3.6	7.2	2	6.6	90	3	2
127	6	23/9/08	10:00:00	0	32	10	2				1	6.4	75	2.5	3
128	6	23/9/08	10:00:00	0	75	14	1	0.4	2.3	5	1	6.6	65	3.5	4
129	6	23/9/08	10:00:00	0	69	13	1	0.5	3.2	6.4	2	6.9	60	3	3
130	6	23/9/08	10:00:00	0	31	2	1	0.15	1.5	2.2	1	6.8	55	3	2
131	6	23/9/08	10:00:00	0	62	8	1	0.1	1.7	2.8	1	6.8	80	3.5	3
132	6	23/9/08	10:00:00	5	110	12	1	0.7	3.2	6.8	2	6.7	80	3	3
133	6	23/9/08	10:00:00	5	231	13	1	0.9	3.9	6.8	2	6.8	55	3.5	4
134	6	23/9/08	10:00:00	5	231	13	1	0.8	3.6	7.5	2	6.8	55	3.5	4
135	6	23/9/08	10:00:00	5	56	5	1	0.9	3.7	5	2	6.9	60	3	3
136	6	23/9/08	10:00:00	5	46	7	1	0.05	1.6	3	1	6.9	70	2.5	3
137	6	23/9/08	10:00:00	15	98	14	1	0.6	3.7	7.2	2	6.7	50	4	5
138	6	23/9/08	10:00:00	10	91	7	1	1	3.9	7.5	2	6.8	50	3.5	3
139	7	19/9/08	10:15:00	20	188	13	1	1.1	4.1	8.5	2	6.9	25	1	4
140	7	19/9/08	10:15:00	20	128	21	1	1.3	4.2	8.5	2	7	20	2.5	5
141	7	19/9/08	10:15:00	20	52	6	1	1.1	3.5	8.1	2	6.8	25	2.5	2
142	7	19/9/08	10:15:00	10	44	10	1	1.5	3.9	8	2	6.7	55	2	5
143	7	19/9/08	10:15:00	5	55	10	1	1.4	4	8.5	2	6.7	60	2	4
144	7	19/9/08	10:15:00	40	182	6	1	1.3	3.5	7.7	2	7	25	1	3
145	7	19/9/08	10:15:00	15	109	17	1	1.4	4.1	9.1	2	6.3	80	2	4
146	8	16/9/08	12:30:00	0	26	3	2	0.05	1.6	2.5	1	6.5	50	2	2
147	8	16/9/08	12:30:00	0	28	5	2	0.25	2.6	4.6	1	6.9	15	2.5	2
148	9	28/9/08	12:30:00	15	200	11	2	0.8	3.6	6.9	2	6.6	30	4	3
149	9	28/9/08	12:30:00	10	194	13	2	1	4	8.1	2	6.7	50	3.5	4
150	9	28/9/08	12:30:00	10	74	8	2	0.5	3.1	6.3	2	7	20	3.5	3
151	9	28/9/08	12:30:00	40	78	8	2	0.8	3.7	7	2	6.9	30	4	3
152	9	28/9/08	12:30:00	0	80	10	1	0.4	3.1	5.2	2	7	25	4	3

153	9	28/9/08	12:30:00	10	79	8	1	0.9	3.8	6.5	2	7	20	4	4
154	9	28/9/08	12:30:00	0	53	9	1	0.9	3.9	8	2	6.8	25	4	3
155	9	28/9/08	12:30:00	0	53	9	1	0.5	3	5.4	2	6.8	25	4	3
156	9	28/9/08	12:30:00	0	88	9	1	1	3.7	8.3	2	6.8	25	4.5	1
157	9	28/9/08	12:30:00	0	156	7	1	1.1	3.9	4.5	2	7	30	4	3
158	9	28/9/08	12:30:00	15	57	7	1	0.8	3.5	7.2	2	6.6	50	4.5	4
159	9	28/9/08	12:30:00	5	133	6	1	0.3	2.5	4.8	1	7	25	3.5	2
160	9	28/9/08	12:30:00	5	133	6	1	1.1	3.9	7.6	2	7	25	3.5	2
161	10	24/9/08	11:00:00	20	240	12	2				1	6.6	25	4.5	1
162	10	24/9/08	11:00:00	5	260	14	2	1.4	4.4	8.8	2	6.8	25	5	3
163	10	24/9/08	11:00:00	40	40	13	1	0.7	3.8	5	2	6.7	25	4.5	4
164	10	24/9/08	11:00:00	10	34	7	1	0.7	3.7	7.4	2	6.6	30	4	3
165	10	24/9/08	11:00:00	10	55	11	1	0.05	1.9	3	1	6.7	90	4	2
166	10	24/9/08	11:00:00	0	61	8	1	0.4	2.7	5.4	1	6.3	55	5	4
167	10	24/9/08	11:00:00	0	71	19	1	0.4	2.7	5.3	1	6.6	25	4	1
168	10	24/9/08	11:00:00	20	76	5	1	0.6	3.9	7.8	2	6.9	20	4	2
169	10	24/9/08	11:00:00	5	163	9	1	1	3.7	7.7	2	6.6	55	5	3
170	11	24/9/08	14:30:00	15	190	10	2	0.6	3.2	6.1	2	6.8	20	3.5	4
171	11	24/9/08	14:30:00	15	190	10	2	1	3.7	7.4	2	6.8	20	3.5	4
172	11	24/9/08	14:30:00	15	106	7	1	1.1	3.7	7.4	2	6.9	10	4	2
173	11	24/9/08	14:30:00	15	150	7	1	0.5	3.5	6.8	2	7	50	4	3
174	11	24/9/08	14:30:00	0	91	11	1	0.1	1.8	2.2	1	6.9	20	4	3
175	12	17/9/08	14:30:00	0	132	15	2	0.5	2.8	5	1	6.6	60	2.5	3
176	12	17/9/08	14:30:00	5	65	9	1	0.7	3.8	7.4	2	6.2	75	3	5
177	12	17/9/08	14:30:00	0	132	15	1	0.7	3.7	7.1	2	6.6	60	2.5	3
178	12	17/9/08	14:30:00	40	130	14	1	0.5	2.2	4.8	1	6.7	30	3	4
179	12	17/9/08	14:30:00	10	71	9	1	0.9	3.7	7.7	2	6.4	45	2	4
180	12	17/9/08	14:30:00	10	84	14	1	0.6	3	6.1	2	6.6	25	2.5	4
181	13	17/9/08	11:30:00	5	195	6	2	1.2	4.1	8.2	2	6.6	45	3	4
182	13	17/9/08	11:30:00	0	115	11	2	0.6	2.7	5.3	1	6.6	45	2.5	5
183	13	17/9/08	11:30:00	0	165	8	2	1.1	3.5	7.5	2	6.3	25	2.5	3

184	13	17/9/08	11:30:00	0	165	8	2	1	3.6	6.8	2	6.3	25	2.5	3
185	13	17/9/08	11:30:00	0	53	8	2	0.75	3.2	6.5	2	6.5	40	3	4
186	13	17/9/08	11:30:00	0	24	3	2	0.15	2.1	3.7	1	6.6	35	2.5	2
187	13	17/9/08	11:30:00	15	40	4	2	1.2	3.9	8.2	2	6.6	20	3	1
188	13	17/9/08	11:30:00	40	130	10	2				1	6.7	15	2.5	3
189	13	17/9/08	11:30:00	40	124	8	2	1.1	3.5	7.7	2	6.6	25	2.5	2
190	13	17/9/08	11:30:00	40	112	5	2	1	3.5	7.2	2	6.8	20	3.5	3
191	13	17/9/08	11:30:00	0	124	6	1	0.6	3.5	6.6	2	6.4	25	2.5	4
192	13	17/9/08	11:30:00	0	29	7	1	0.6	3.1	6.8	2	6.8	25	3	1
193	13	17/9/08	11:30:00	0	146	9	1	1	3.7	7.7	2	6.1	35	3	3
194	13	17/9/08	11:30:00	0	82	7	1	0.7	3.5	7	2	6.5	30	2	3
195	13	17/9/08	11:30:00	0	103	5	1	0.8	3.9	6.8	2	6.4	25	2.5	3
196	13	17/9/08	11:30:00	15	114	4	1	0.7	3.3	6.8	2	6.3	40	2.5	1
197	13	17/9/08	11:30:00	40	130	10	1	0.7	3.7	7.3	2	6.7	15	2.5	3
198	14	18/9/08	11:50:00	0	74	7	2	1.2	3.9	8	2	6.6	30	3.5	5
199	14	18/9/08	11:50:00	15	133	6	2	0.6	3	6.3	2	6.9	35	3	3
200	14	18/9/08	11:50:00	10	32	6	2	0.6	3.3	6.7	2	7	30	3.5	2
201	14	18/9/08	11:50:00	10	176	12	2	0.9	3.6	6	2	6.8	25	3	4
202	14	18/9/08	11:50:00	40	45	10	1	0.5	3.2	6.5	2	6.3	45	3	5
203	14	18/9/08	11:50:00	0	178	10	1	0.9	3.4	6.9	2	6.8	55	2.5	4
204	14	18/9/08	11:50:00	5	162	16	1	0.6	3.2	5.8	2	6.8	25	3	4
205	14	18/9/08	11:50:00	15	135	10	1	1	3.6	7.6	2	6.8	50	4	4
206	14	18/9/08	11:50:00	15	24	4	1	0.05	1.5	2.5	1	6.9	25	2	2
207	14	18/9/08	11:50:00	10	188	12	1	1.4	4	8.2	2	6.8	30	3	5
208	15	25/9/08	09:45:00	20	49	10	2	0.05	1.8	2.1	1	7	15	3.5	2
209	15	25/9/08	09:45:00	10	36	9	1	0.1	1.8	2.7	1	6.9	15	4	3
210	15	25/9/08	09:45:00	40	146	9	1	0.6	3.2	6.4	2	6.9	50	4	4
211	15	25/9/08	09:45:00	20	38	9	1	1.1	4.2	8.4	2	7	25	4	2
212	15	25/9/08	09:45:00	0	62	7	1				1	6.8	30	4	2
213	15	25/9/08	09:45:00	0	106	9	1	1.3	4.1	9	2	6.9	20	3.5	4
214	16	25/9/08	12:00:00	0	48	15	2	0.8	4	8	2	7	20	3.5	3

215	17	25/9/08	14:20:00	0	100	4	2	0.3	2.4	4.2	1	6.8	55	3	2
216	18	28/9/08	13:00:00	0	69	10	2	0.9	4.2	7.4	2	6.9	10	6	2
217	18	28/9/08	13:00:00	0	113	11	2	0.7	3.2	6.7	2	7	10	5.5	3
218	18	28/9/08	13:00:00	15	115	9	2	0.8	3.8	7.7	2	6.9	25	5.5	3
219	18	28/9/08	13:00:00	0	78	7	1	0.3	2.6	4.5	1	7.1	5	6	2
220	18	28/9/08	13:00:00	0	56	9	1	0.7	3.6	6.9	2	6.9	15	5.5	3
221	18	28/9/08	13:00:00	15	159	11	1	1.1	4	8.5	2	7	30	6	2
222	18	28/9/08	13:00:00	15	135	4	1	0.9	3.6	7.6	2	6.8	15	5.5	3
223	19	29/9/08	09:30:00	0	109	12	2	1.1	3.7	8.1	2	6.9	15	4.5	2
224	19	29/9/08	09:30:00	0	112	7	2	0.7	3.7	7.5	2	6.8	20	6	2
225	19	29/9/08	09:30:00	0	121	10	2	0.4	2.7	5.3	1	7	15	5.5	3
226	19	29/9/08	09:30:00	0	200	6	1	0.7	3.7	7.5	2	6.9	5	6	2
227	19	29/9/08	09:30:00	0	167	11	1	0.9	4.2	8.3	2	7	15	5.5	2
228	19	29/9/08	09:30:00	0	46	12	1	0.4	2.8	5.5	1	6.9	5	5.5	2
229	19	29/9/08	09:30:00	5	54	5	1	0.2	3.1	5.3	2	7	10	5	2
230	19	29/9/08	09:30:00	5	32	4	1	1.1	3.8	7.7	2	6.9	5	6	2
231	19	29/9/08	09:30:00	10	126	6	2	0.6	3.5	6.5	2	6.9	10	6	2
232	19	29/9/08	09:30:00	15	200	7	2	0.05	1.6	2.7	1	7	10	6	2
233	19	29/9/08	09:30:00	15	137	9	2	0.1	1.9	3.7	1	6.9	15	5	2
234	19	29/9/08	09:30:00	15	90	4	2	0.9	3.9	7.7	2	7.1	5	5	2
235	19	29/9/08	09:30:00	15	93	3	1	0.4	2.9	5.7	1	6.8	10	4	3
236	19	29/9/08	09:30:00	15	71	10	1	1.2	3.9	7.6	2	6.8	25	5.5	3
237	19	29/9/08	09:30:00	15	181	11	1	1	3.7	8.2	2	7	15	5.5	4
238	19	29/9/08	09:30:00	15	100	11	1	0.4	2.7	5.5	1	7	10	5	4
239	19	29/9/08	09:30:00	15	72	11	1	0.7	3.7	7.4	2	6.9	5	4.5	2
240	19	29/9/08	09:30:00	20	93	10	2	0.9	3.5	7.5	2	6.9	15	6	1
241	19	29/9/08	09:30:00	20	37	8	2	0.2	2.3	4.4	1	7	5	5.5	2
242	19	29/9/08	09:30:00	20	77	5	2	0.2	1.6	2.7	1	7	10	5	2
243	19	29/9/08	09:30:00	20	86	4	1	1.2	4.1	8.5	2	7	5	5.5	3
244	19	29/9/08	09:30:00	20	93	10	1	1	4.8	9.5	2	6.9	15	6	1
245	19	29/9/08	09:30:00	20	194	4	1	0.5	3.1	6.1	2	6.8	20	4	2

246	19	29/9/08	09:30:00	20	172	5	1	1	3.9	8.2	2	7	15	5	3
247	19	29/9/08	09:30:00	20	50	5	1	1.1	4	8.1	2	6.8	15	5.5	2
248	19	29/9/08	09:30:00	40	214	8	1	1	4.2	8.5	2	7	10	5.5	2
249	19	29/9/08	09:30:00	40	214	8	1	1	3.7	7.9	2	7	10	5.5	2
250	19	29/9/08	09:30:00	40	68	17	1	0.7	3.6	6.9	2	7.1	5	5	2
251	20	22/9/08	15:00:00	20	67	7	3	0.5	2.5	5	1	7	15	2.5	4
252	20	22/9/08	15:00:00	40	50	3	1	0.05	1.6	2.7	1	6.9	20	3.5	1
253	20	22/9/08	15:00:00	40	140	9	1	0.3	3.1	6.4	2	6.8	35	3.5	3
254	20	22/9/08	15:00:00	40	89	7	1	0.3	2.1	3.1	1	6.8	15	3	2
255	21	22/9/08	11:45:00	0	104	10	2	1	4.1	8.3	2	6.8	20	4	4
256	21	22/9/08	11:45:00	40	58	4	2	0.05	1.3	2.3	1	6.8	20	3.5	3
257	21	22/9/08	11:45:00	15	54	4	2	0.4	2.4	4.7	1	6.3	50	45	2
258	21	22/9/08	11:45:00	0	54	17	1	0.9	4.1	8.9	2	7	25	4	2
259	21	22/9/08	11:45:00	0	65	13	1	0.9	3.6	7.3	2	6.8	25	3.5	2
260	21	22/9/08	11:45:00	0	76	20	1	0.9	3.8	7.5	2	6.3	30	4.5	2
261	22	30/9/08	10:45:00	0	126	12	2	1.2	4.2	8.6	2	6.8	20	4.5	4
262	22	30/9/08	10:45:00	0	105	16	2	1.2	4.2	8.2	2	7.2	10	2.5	5
263	22	30/9/08	10:45:00	15	92	16	1	0.4	2.5	4.6	1	6.9	20	4.5	4
264	22	30/9/08	10:45:00	15	45	11	1	0.5	2.7	4.8	1	7	15	6.5	5
265	22	30/9/08	10:45:00	15	95	10	1	0.1	1.7	2.4	1	7	10	5.5	4
266	22	30/9/08	10:45:00	15	28	7	1	0.1	1.7	2.6	1	6.9	15	6.5	3
267	22	30/9/08	10:45:00	0	92	22	1	0.9	4.1	8	2	6.9	15	5	4
268	22	30/9/08	10:45:00	0	38	10	1	0.3	2.7	5.3	1	6.9	30	3.5	3
269	22	30/9/08	10:45:00	40	103	10	1	0.3	2.8	4.7	1	6.9	30	4	2
270	22	30/9/08	10:45:00	5	131	9	1	0.6	3.5	6.6	2	6.9	25	4	3
271	22	30/9/08	10:45:00	5	105	10	1	0.8	3.5	6.9	2	6.9	20	4.5	3
272	22	30/9/08	10:45:00	10	122	12	1	0.8	3.5	6.6	2	7	16	4.5	3
273	22	30/9/08	10:45:00	20	149	13	1	0.4	3.3	6.6	2	6.9	25	4.5	4
274	22	30/9/08	10:45:00	20	69	10	1	0.5	2.9	5.9	1	6.9	20	5	4
275	23	2/10/08	09:45:00	40	199	7	2	0.9	3.7	7.5	2	6.6	40	6	3
276	23	2/10/08	09:45:00	10	103	7	2	0.3	2.9	5.6	1	6.7	15	5	4

277	23	2/10/08	09:45:00	5	39	4	2	0.3	2.4	5	1	6.8	25	6.5	2
278	23	2/10/08	09:45:00	40	154	13	1	0.9	3.7	7.5	2	6.8	15	6	4
279	23	2/10/08	09:45:00	40	93	4	1	1.1	4.1	8.1	2	6.7	50	6	4
280	23	2/10/08	09:45:00	15	112	13	1	1	3.5	8	2	6.4	25	6	3
281	23	2/10/08	09:45:00	0	126	13	1	1	3.6	7.3	2	6.8	25	4.5	5
282	24	2/10/08	13:00:00	0	235	13	2	0.5	3.2	6.5	2	6.8	25	5	4
283	24	2/10/08	13:00:00	0	212	12	1	0.7	3.6	7.7	2	6.8	25	4.5	4
284	24	2/10/08	13:00:00	0	48	5	1	0.1	1.6	2.5	1	6.8	20	4	3
285	24	2/10/08	13:00:00	40	113	5	1	0.9	3.6	7.9	2	7	15	5	3
286	24	2/10/08	13:00:00	40	140	9	1	0.5	2.9	5.6	1	6.8	30	5.1	3
287	24	2/10/08	13:00:00	0	66	28	3	1.3	3.1	5.8	2	6.6	50	5	4
288	25	3/10/08	11:30:00	40	111	7	2	0.4	2.7	5.5	1	6.8	25	4.5	5
289	25	3/10/08	11:30:00	20	37	9	1	0.3	2.5	4.2	1	6.8	10	4.5	2
290	26	3/10/08	14:00:00	0	136	10	1	0.5	3	5.9	2	6.7	50	2	3
291	26	3/10/08	14:00:00	0	88	12	1	0.5	2.7	5.4	1	7	20	3	3
292	26	3/10/08	14:00:00	5	87	4	1	0.5	3	6	2	6.3	90	2.5	2
293	26	3/10/08	14:00:00	15	130	9	2	1	4.2	8	2	6.6	40	2	2
294	26	3/10/08	14:00:00	15	40	24	1	1.2	3.8	7.9	2	6.8	25	3.5	3
295	26	3/10/08	14:00:00	15	130	9	1	0.8	3.8	7.7	2	6.6	40	2	2
296	26	3/10/08	14:00:00	15	130	9	1	1.5	4.2	8.8	2	6.6	40	2	2
297	26	3/10/08	14:00:00	40	177	28	2	1.6	4.5	9.1	2	6.8	45	2	3
298	26	3/10/08	14:00:00	40	171	15	1	1	4.2	8.5	2	6.6	50	2	4
299	26	3/10/08	14:00:00	40	171	15	1	1.2	4.2	8.7	2	6.6	50	2	4
300	27	6/10/08	10:20:00	40	188	6	2	1.3	4.4	8.7	2	6.6	25	5	3
301	27	6/10/08	10:20:00	40	66	6	2	1	3.8	8	2	6.8	65	4.5	2
302	27	6/10/08	10:20:00	15	107	6	2	0.8	4.2	7.4	2	6.8	25	4.5	2
303	27	6/10/08	10:20:00	15	95	5	2	0.5	4.1	7.5	2	6.8	25	5	3
304	28	6/10/08	13:00:00	0	86	32	1				1	7	25	4	4