Quantifying the Causes of Human-Black Bear Conflicts in Nova Scotia

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Introduction

Motivation for this study

Black bears are curious and will stop at nothing for a good meal. Unfortunately, Nova Scotian residents are seeing an increase in the presence of black bears around their properties and homes (Parsons pers. com., 2020). In 2020, Nova Scotia Department of Lands and Forestry (NSDLF) received a record number of human-black bear conflict (HBBC) reports from residents across the province. The number of conflict reports received in 2020 more than doubles the amount from 2017, totalling over 1000 HBBCs (Figure 1), and experts predict these numbers will continue to rise over the years (Donovan, 2020).

Figure 1 Reported human-black bear conflicts in Nova Scotia from 1999-2020, created using data from the Biodiversity Investigation Reporting System database (NSDLF, 2020).

The rise in reported conflicts is alarming for a number of reasons. These conflicts can lead to a destruction of human property, and in the worst cases, attacks on humans (Lackey et. al, 2018). But outcomes are generally worse for bears. When black bears show continual aggressive behaviour, they may be euthanized by NSDLF staff (Pulsifer et. al, n.d.). Changing social norms have led to the scrutiny of euthanasia, inciting an additional and urgent need to reduce the frequency of these conflicts. Alongside the increasing number of HBBCs, another concern is that the severity of the conflicts may increase as well. When bears are exposed to an easily accessible food source, it is likely they will keep returning to this area (Lackey et al. 2018). Over time, the bears may become more confident and aggressive, with the potential of posing more danger to humans (Lackey et. al, 2018). Mitigating the number of human-bear conflicts and curbing their intensity is therefore a matter of public safety and animal well-being. This will also serve to increase the social acceptability of local management practices by reducing the pushback caused by the euthanasia of large, charismatic animals. To understand which measures can be used to solve this issue, there must first be an examination of its causes.

Background information

The ecology and behaviour of the American black bear (*Ursus americanus*) are widely studied given it is the most abundant bear species globally (Servheen et al., 1999). In Nova Scotia, black bears are considered to have a healthy population (Pulsifer et. al, n.d.); however, no formal prediction of their population size has been recently made. It is generally accepted that black bear populations are limited by their cultural carrying capacity (Garshelis, 1994), referring to “the maximum number of animals that can coexist compatibly with local human interests” (Ellingwood, 1999). When this number is exceeded, human-black bear conflicts arise.

Across North America, the frequency of HBBCs is increasing (Hristienko and McDonald 2007, Baruch-Mordo et al 2014, Beckmann and Berger 2003, Beckmann et al. 2008). General causes for this increase include reduced natural food availability through weather events and changes in land use, as well as increased anthropogenic food sources through growing urban/exurban development (Garshelis 2002, Johnson et al 2015). To date, research quantifying the influence of population demographic factors on patterns of reported HBBCs is limited. Quantifying the level of influence of these causes remains a challenge. Existing studies to examine patterns of HBBCs fail to include both ecological and anthropogenic causal variables, and often leave out critical variables applicable to certain locations. Due to these shortcomings, prior insights are inadequate when applied to Nova Scotia and its unique ecological and social landscape.

Introduction to the study

The goal of this study is to gain greater understanding and context on the issue of human-black bear conflict in Nova Scotia, Canada. Over the years, data on reported HBBCs has been recorded and compiled in a database (Biodiversity Investigation Reporting System; NSDLF a, 2020) that has not been rigorously analyzed or studied. While there is abundant research on the causes of human-bear conflicts, no quantitative study has been done to assess the spatial extent and causal relationships of HBBCs within Nova Scotia. As such, this study uncovers spatial and temporal patterns in the HBBC reporting data and potential causal relationships for those patterns in relation to key variables. This study also contributes to wider scientific efforts to model HBBCs, providing a possible methodological framework for future studies. The research question for this study is: **What geographic and anthropogenic variables are most influential in shaping the spatio-temporal patterns of reported human-black bear conflicts within Nova Scotia?**

The spatial extent of this study covers the entire province of Nova Scotia, Canada, representing approximately 55 284 km^2 (O'Grady and Moody, 2019). Three specific areas are used for a case study analysis: (1) Amherst, (2) New Glasgow, and (3) Waverley. These areas represent locations with high clustering and steep increase in black bear conflicts within recent years. The spatial extent of these areas comprise 435 km^2 (Amherst region), 1290 km^2 (New Glasgow region), and 210 km^2 (Waverley region). The temporal extent of the study is from March 2016 to October 2020.

Summary of approach

To determine the causal variables leading to increased human-bear conflicts, three areas with high clustering in 2016-2020 are examined using a case study analysis. This is done by comparing various data layers and datasets in ArcGIS pro and Microsoft Excel with the dataset featuring Nova Scotia's reported HBBCs, to examine emerging patterns. The geographic and anthropogenic data being used is selected based on common causes of human-bear conflicts, and variables specific to Nova Scotia. Once spatial layers for the presumed causes (variables) are gathered, each variable undergoes a fishnet analysis and a one-way ANOVA test. This is done to assess if the presence of a variable differs significantly in areas with low, medium and high human-black bear conflicts. This helps to determine which factors are the most likely to cause increased HBBC in specific case study areas.

Literature Review

A literature review was carried out to examine the current state of knowledge on the causes for human-black bear conflicts. Gaps in knowledge pertaining to common research methods used to determine these causal relationships were identified, as well the applicability of all findings to a Nova Scotian context. All research was searched and accessed within the Novanet catalogue and Google Scholar. The list of search terms used to yield published papers, articles, and government reports on the topic can be found in the appendix.

Black bear population ecology

The behaviors and habitats of black bears are well studied yet there are few estimates of their total population across provinces and in Canada as a whole. Black bears are found in every province and territory except Prince Edward Island (CWF, n.d.). Their natural diet consists of mostly plant materials, berries, nuts, insects, fish, small mammals and birds (CWF, n.d.). When these natural food stocks are low, bears tend to source food from anthropogenic sources like food crops, beehives, livestock, or residential food waste (Lackey et al. 2018). It is critical for bears to eat a full, steady diet during the warmer months as they mate from June to July and typically enter hibernation as early as October and end as late as May, within Canada (Pattie, 2006). Black bears tend to reside in mixed coniferous-deciduous forests with low human presence (Kolenosky, 1992). Their population density estimates range from around 1 to 10 bears per 10 km^2, with the upper range being very rare and the average lying around 2 bears per 10 km^2 (Kolenosky, 1992). Few total population estimates are known, however the Fur Institute of Canada estimates there to be over 500 000 black bears residing in Canada (2019). Given their prevalence across Canada, management practices could improve to formulate better estimates of the species' total population.

Black bears in Nova Scotia

Despite there being no formal population estimate, black bear populations in Nova Scotia are perceived to be healthy and widespread. Pulsifer et al. (n.d.) note that in Nova Scotia, black bears are considered to have a healthy population, requiring little need for a population estimate to be performed for conservation purposes. However, Witherley (2009) indicates that NSDLF staff members are interested in acquiring black bear population estimates, as they can help to better inform black bear management strategies and curb HBBCs. In 2015, an informal estimate found the population of black bears in Nova Scotia to be around 10 000 (Lackey et. al, 2018), however, this number is likely to have changed drastically and was not found using a formal counting method. It has also been noted that "most, if not all good bear habitats are already occupied" in Nova Scotia (Pulsifer et. al, n.d). This, to some degree, conflicts with the notion that bears are limited by the cultural carrying capacity (Garshelis, 1994). This is defined by Ellingwood (1999) as "the maximum number of animals that can coexist compatibly with local human interests". Taking into account the density range, the informal population estimate, Nova Scotia's viable habitat area, as well as rising HBBCs, it can be presumed that black bears in Nova Scotia are limited both by their available habitat and their cultural carrying capacity.

An overview of human-wildlife conflicts

Human wildlife conflicts can exist as a major threat to the survival of species across the globe and are considered as a human-driven problem with major consequences for local communities and ongoing conservation management success. While this remains true for various species, conflicts pose minimal threats to the populations of black bears in Nova Scotia (Pulsifer et al. n.d.). Human wildlife conflicts are informed by complex underlying social, economic and political conditions. These conflicts should be regarded as human-human conflicts as they often represent conflicts between stakeholders with varying needs (HWCTF, n.d.). This is underscored by Glen Parsons, a wildlife habitat manager for NSDLF, who confirms that these conflicts represent a human driven problem (pers comm. 2020). Human-wildlife conflicts pose risks to local communities as animals can destroy crops, kill livestock, damage property or threaten the safety of pets or humans (WWF, n.d.). Human wildlife conflicts, including HBBC, are driven by shrinking habitats and growing population densities (WWF, n.d.), and solutions to address these conflicts must recognize the root of the issue – human behaviour. This is a critical component of understanding and addressing the issue. of HBBCs in Nova Scotia, given the province has the second highest provincial population density in Canada (Kirpop, 2019). Another concern is that bears can easily become conditioned by the appeal of consistently available food sources. This leads bears to return to the same area many times, a behaviour they can pass onto their cubs as well (Masterson, 2016)

Reporting methods of human-black bear conflicts

The reporting of human-black bear conflicts is impacted by personal biases, and reporting standards differ across Canada. Quantifying these conflicts proves difficult as it is a socio-ecological parameter: quantification of the issue is shaped by human attitudes and beliefs (Lackey et al. 2018). Differences in beliefs can lead to some scenarios being considered a conflict while others aren't, known as the labelling bias. Similar to this, the reporting of these conflicts is impacted by the reporting bias, where people report conflicts based on their level of severity which is in turn impacted by their attitudes and beliefs (Lackey et al. 2018).

To complicate the matter more, no standard reporting practice exists across countries or even provinces, though a standard reporting practice could improve management actions (Lackey et al. 2018). In Canada, reporting parameters vary widely. In British Columbia, where over 18 500 HBBCs are reported yearly, conflicts are divided into three categories based on their severity of harm to humans and property. This involves classifying conflicts as those with serious threats, moderate threats, or representing normal behaviour/low threat risks (COS, n.d.). This differs from the Nova Scotian standard of reporting based on type of conflict. In Nova Scotia, HBBCs are reported in five distinct categories relating to a fear of harm to: humans, property, livestock, pets and crops. These conflicts are then reported in a large database containing the location and date of each reporting (Lands and Forestry NS, 2020). However, the issues of labeling and reporting bias still exist within this system of reporting. Major challenges in the reporting of HBBCs impact the data and outcomes of any related research, and the lack of uniform reporting practices across Canada exacerbates these impacts.

Causes of human-black bear conflicts

Food, through either diminishing access to natural sources or increased access to anthropogenic sources, remains a common cause for HBBCs. The Ontario Ministry of Natural Resources (OMNR) predicts that climate change poses uncertain impacts towards the food supplies of black bears, with reduced precipitation and increased drought (2009). More frequent and extreme weather events leading to late spring frosts and droughts, will lead to continued reductions in natural food availability (OMNR, 2009). Urban and exurban development also reduces the natural food supplies for animals through the clearing of forage lands, and in-turn increases sources of easily accessible anthropogenic food (Johnson et. al, 2015). This draws bears to these areas and can change their habitat selection behaviour, daily activities and foraging habits. The foods offered by unattended garbage cans or crops present reliable and calorie rich sources of food for bears, but also increase their risk of mortality through potential for euthanasia, among other factors (Johnson et. al, 2015, Beckmann and Berger, 2003).

For black bears, foraging food is an act of balance between energy budgets and individual safety (Lewis et al. 2015). One study in Aspen, Colorado found that with garbage as the main source of anthropogenic food that the studied bears used, these bears were influenced not just by the presence of garbage; they also chose areas based on their proximity to riparian habitat and the presence of fruit trees (Lewis et al. 2015). Merkle et al. (2011) found that the likelihood of bear conflicts arising is increased for those living near forest patches, rivers, streams and in intermediate housing densities. The combination of these factors, proximity to their habitat and proximity to easily accessible food sources, makes these areas *energetically beneficial* for foraging by black bears (Lewis et al. 2015). This describes an area that poses high returns using less inputs, or for bears, more food for less work.

Natural food availability has varied impacts on patterns of human-bear conflicts. During periods with lower natural food availability, areas in Aspen, Colorado with higher human density were more frequently visited by bears (Lewis et al. 2015). This study highlights that black bears tend to resort to anthropogenic food sources in times where natural food sources are low. However, these results conflict with patterns found in the Lake Tahoe region where bears foraged anthropogenic food sources despite abundant natural food availability (Beckmann and Berger 2003). These differences indicate the potential presence of different energetic trade-offs based on the geography and characteristics of the land. All of the above findings point towards fluxes in a black bear's access to natural food availability and anthropogenic food sources as a driver for HBBC, however, the geographically contextual nature of these results presents uncertainty for their level of influence on HBBC patterns in Nova Scotia. In addition to this, few studies have properly examined the impacts of differing human demographic variables in their connection to reported HBBC.

The aforementioned studies on the attractance of garbage bins focus on waste bins with unseparated waste. However, within Nova Scotia, most areas follow a system where garbage is separated from food waste/scraps. Nova Scotia has been an early adopter of segregated food waste systems (since 1998), and presently, each county has different collection days and weekly or biweekly schedules (Patil, 2019). These temporal variations in waste collection practices complicate any efforts to quantify the relationship between black bears and garbage/food waste, and thus there is no available research on this phenomenon in Nova Scotia to date. However, there is strong empirical evidence as the NSDLF receives countless complaints of bears getting into their waste bins. Several quotes from residents, as well as supporting images, suggest that compost bins are a major attractant for black bears across the province (Figure 2).

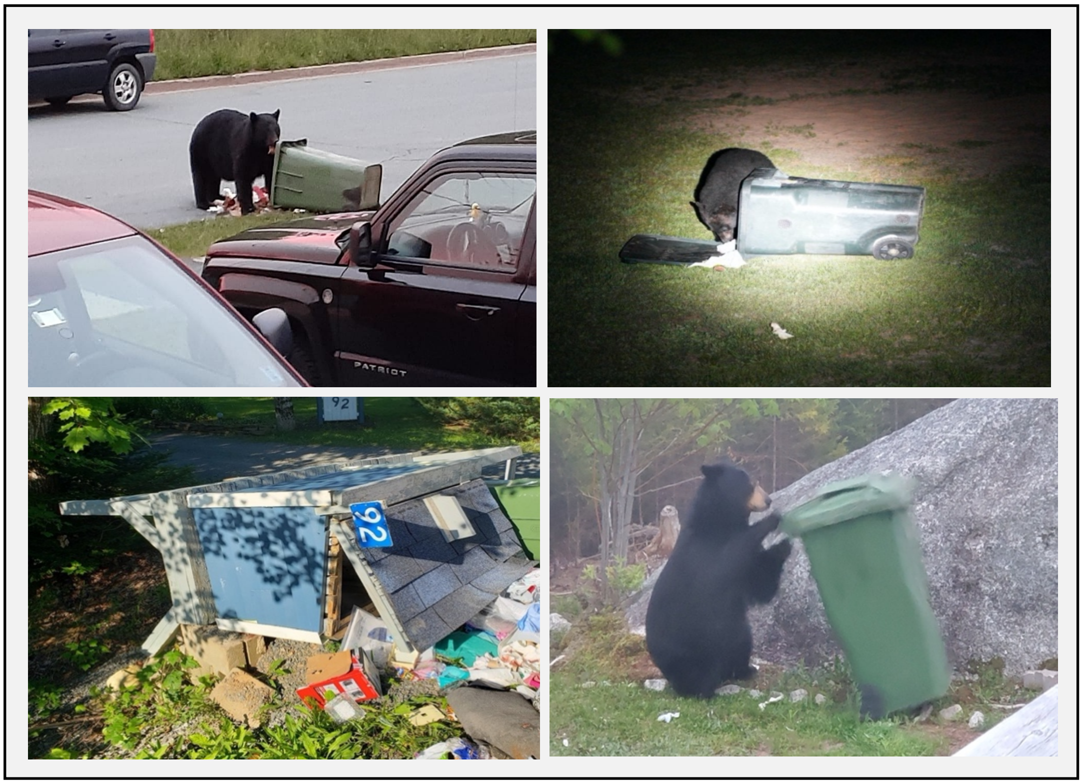

Figure 2 Images of black bears eating from compost/garbage bins within various areas in Nova Scotia in 2020, drawn from an informal bear conflict report (NSDLF, 2021).

Methods for studying human-black bear conflicts

Limited research has been done to effectively model and predict areas at risk of increased HBBC. Existing models predicting the distribution of conflicts use larger spatial scales, contributing to the difficulty in applying these models across landscapes and in differing areas (Merkle et al. 2011). Another pitfall is that these models often do not incorporate both landscape and anthropogenic variables, failing to account for the significant relationships between human patterns and human-black bear interactions. Merkle et al. (2011) developed a logistic regression model to account for these gaps, by performing a small-scaled model and examining the influence of housing density and proximity to rivers and forest patches. While this model provides a solid methodological framework, the model fails to account for other prominent factors, such as the availability of natural and agricultural food sources.

Gaps in the literature

Considerable gaps in knowledge around human-black bear conflicts lie not within understanding what causes these conflicts, but rather, understanding the differing influence of each of the known causes. Naturally, the influence of each causal variable can vary significantly across different landscapes due to the complex myriad of social and ecological conditions from place to place. This is exemplified by differing results found from similar studies (Lewis et al. 2015; Beckmann and Berger 2003), where patterns in the foraging behavior of black bears were ultimately landscape specific. Current models to assess the level of influence of the different causes for HBBC are either too large in scope, lack the combination of both landscape and anthropogenic causes, or fail to encompass all major influences on HBBCs. Thus, these existing models lack applicability to Nova Scotia and a more contextual spatial analysis must be carried out to assess the true influence of causal variables for HBBCs across the province. While outside of the scope of this study, research should also be conducted to estimate the impact of reporting and labelling bias on the distribution HBBCs, the use of human-wildlife conflict reporting data to estimate black bear population size (when such estimates are unavailable), and the general testing of existing models for HBBCs across landscapes with differing ecological and social conditions. Addressing these gaps in knowledge, along with providing a Nova Scotian-focused analysis of HBBC patterns, will help make forward strides in the management practices that help to reduce these conflicts.

Methods

Project overview

This study provides an in-depth analysis of three locations in Nova Scotia, to determine the level of influence of various known causes on reported HBBCs. Using ArcGIS Pro, a spatial analysis is performed to examine data featuring anticipated causal variables in relation to data on reported HBBCs occurring from 2016-2020. Reported HBBC data is retrieved from the Biodiversity Investigation Reporting System database provided by the NSDLF. Variables showing the highest level of influence on patterns of HBBC instances are quantified and tested for significance using One-way ANOVA testing. Post-hoc analyses determine which category pairs are statistically significant within each spatial layer, for each study area, and correlation matrices are produced to determine if any variable pairs are highly correlated to one another.

Study area description

Raw data used for this study covers the total 55 284 km^2 area of Nova Scotia, Canada (O'Grady and Moody, 2019). The data being used is reported from various dwellings across Nova Scotia, with all 458 568 dwellings in the province as possible contributors to the database (Statistics Canada, 2017). This data has been collected by wildlife officers from the Department of Lands and Forestry, Nova Scotia, from March 1999 to October 2020, and is known as the Biodiversity Investigation Reporting System database. When a member of the public calls the NSDLF with a complaint about a bear, the event is reported based on the type of incident (reported fear of harm to humans, pets, property, crops, livestock, or general sightings). A coordinate of the location is attached to each report, alongside additional information on the date and county location. Qualitative data associated with these reports is not available for public use and therefore is not included in the present study. The three case study locations are chosen based on three criteria: (1) an annual human-black bear conflict growth rate above 10% from 2016-2020, (2) an average conflict count equal or above 90 conflicts per year (from 2016-2020), and (3) an average yearly conflict count 3x above the total yearly average (2016-2020). These parameters determine areas with high numbers of HBBCs, as well as growing rates of these conflicts. Oxford, McLellans Brook and Waverley are the three reporting offices that fit these descriptions (Figure 2), however, through a visual assessment the conflicts are found to be concentrated in Amherst, New Glasgow and Waverley.

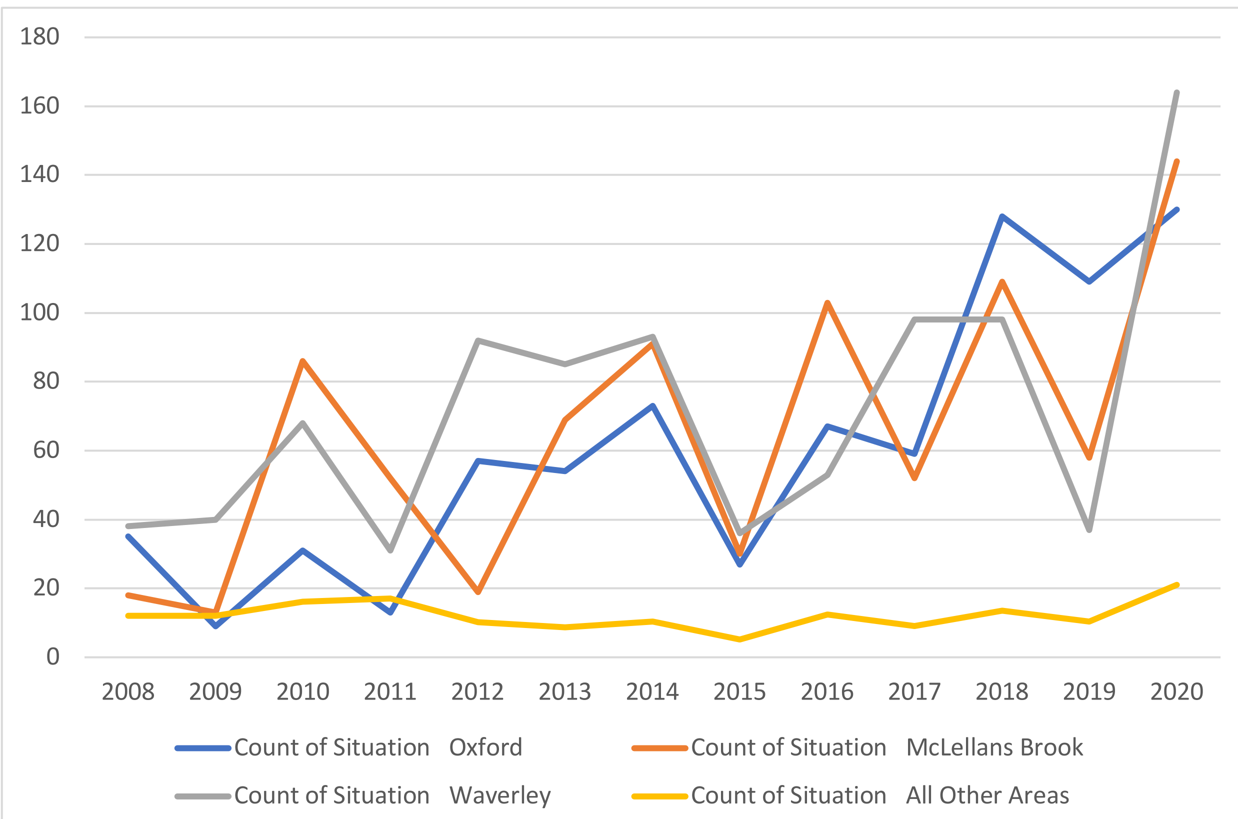

Figure 2 Count of reported human-black bear conflicts by reporting offices in Oxford, McLellans Brook, and Waverley, and an average total count of all other reporting offices, from 2008-2020, using data from the Biodiversity Investigation Reporting System (NSDLF, 2020).

The Amherst region (Figure 3a) has an area of 435 km^2 and is characterized by low-density housing surrounded by large areas of farmland and forests. The New Glasgow region, seen in Figure 3b, is 1290 km^2 in size, and is characterized by mixed density housing, with surrounding farmland, forests and few lakes. Lastly, the Waverley region (Figure 3c) is on the outskirts of urban Halifax, has an area of 210 km^2 and contains low-density suburban housing that borders several lakes and forested areas.

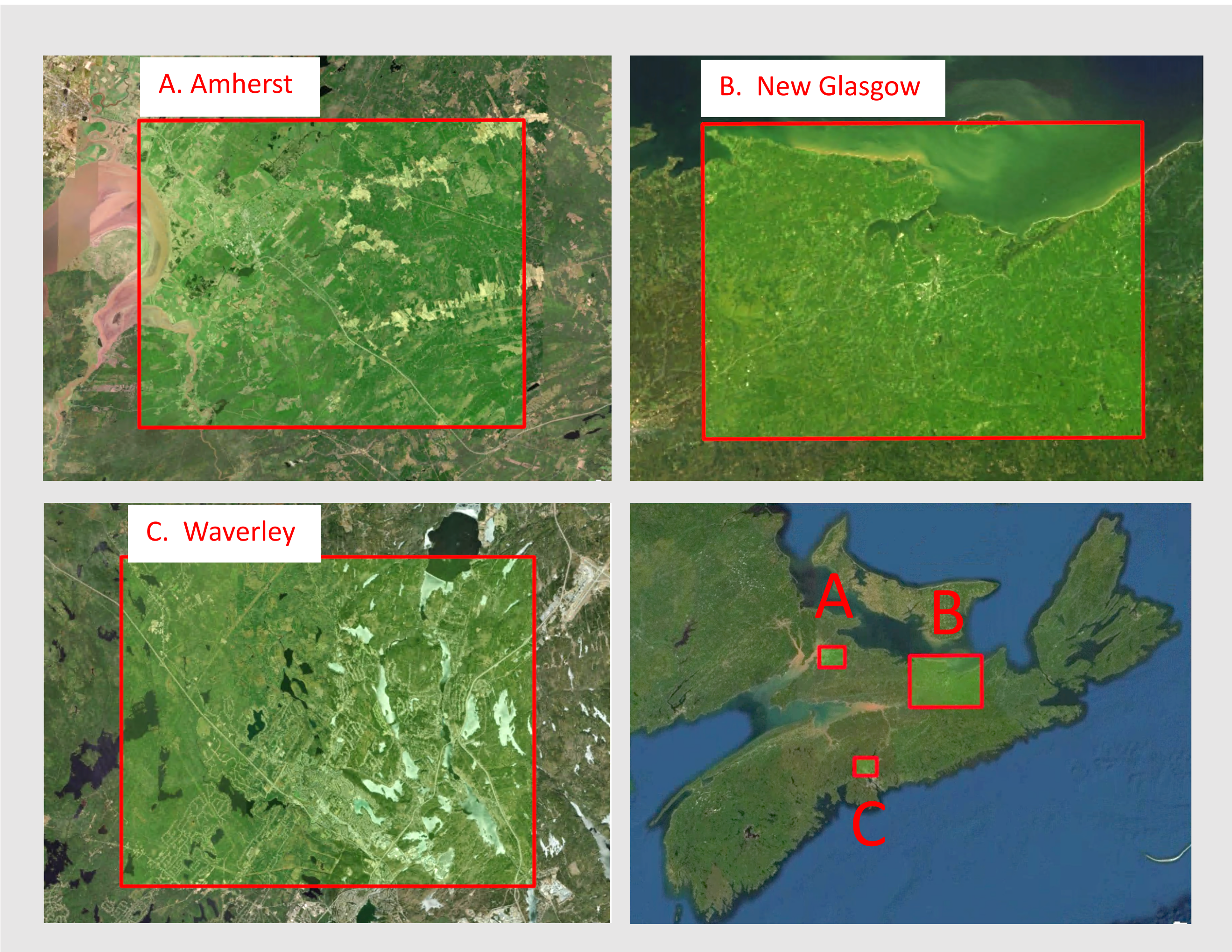

Figure 3 Study areas – A: Amherst, B: New Glasgow and C: Waverley, Nova Scotia – created within ArcGIS Pro.

Methods process

Reported conflict data is input into ArcGIS Pro. The data is then converted to a *WGS 1984, UTM Zone 20* projection, using the UTMN and UTME coordinates, to aid with the use of grids and area calculations. All conflict points falling outside of the Nova Scotia provincial boundary are removed to eliminate human errors in data entry. Additionally, all non-conflict points, such as 'bear sightings' are removed, to keep the focus on instances of negative bear interactions.

The variables being used for analysis are supported as common factors influencing the rate of HBBCs within available research on black bear ecology (Table 1). In addition, this study chooses variables with commonly free and publicly available data to allow for easier replication of the spatial analysis by various wildlife management organizations (Merkle et al. 2018). The variables predicted to have a potential influence on HBBC's are the presence of berry fields, cropland, urban change/development, urban areas nearing forests and population density. The datasets being used include the Annual Crop Inventory from Agriculture and Agri-food Canada (Government of Canada, 2019), and the population density estimates drawn from the 2016 Census (Statistics Canada, 2017). These databases have an over 85% accuracy rate for land reclassification.

Table 1 List of variables drawn from literature, how each variable was operationalized for this study, and what databased were used for each variable.

Variables drawn from literature	How variables were interpreted in this study	Databases used
Berry Areas (crops, orchards and vineyards) (Lewis et al. 2015)	All berry areas (30m x 30m cells) including orchards, berry crops and vineyards, with 1km and 2km buffers	Annual Crop Inventory 2019 (Government of Canada, 2019)

Crops (non-berry) (Ditmer et al. 2015)	All food and non-food crops found in Nova Scotia (30m x 30m cells), with 1km and 2km buffers	
Forest-Urban Fringe (Merkle et al. 2011)	All urban areas (30m x 30m cells) within 100m of a forest edge, with 50m and 100m buffers	
Urban Change/Development (Garshelis 2002, Johnson et al. 2015, Beckmann and Berger, 2003)	All urban areas (30m x 30m cells) created from 2016-2019, with 1km and 2km buffers	Annual Crop Inventory 2016 & 2019 (Government of Canada, 2016, 2019),
Population Density (Lewis et al. 2015)	Categorized into low- high density by population per km2 by dissemination area	2016 Census Profiles (Statistics Canada 2017)

The Annual Crop Inventory consists of reclassified LandSat imagery, with all land types classified in one layer. To isolate the causal variables, the Agricultural Crop Inventory 2019 layer is altered to represent just one variable at a time, in order to isolate berry, crop, urban and forested areas into their own separate layers. To determine areas or urban change, areas of change from 2016-2019 are isolated using the LandSat imagery from 2016 and 2019. Similarly, the forest-urban fringe areas are isolated using the forest layer and urban 2019 layer created from the LandSat imagery, to identify only urban areas within 100m of a forest. The berries, crops, and urban change layers are each given a 1km and 2km buffer, using the Euclidean distance tool. This is done with the understanding that black bears will travel large distances when there are attractants such as easily exposed crops, unattended garbage cans, or bountiful berry fields. The 1km and 2km distances are based upon both existing research on human-black bear conflicts and common bear foraging patterns (Merkle et al. 2011). The forest-urban fringe layer was given smaller 50m and 100m buffers, adjusted based upon the scale necessary to assess these patterns. Figure 4 provides a summary of the processes for creating each layer used within this portion of the analysis.

To prepare the variables for statistical analyses, each study area is divided by a 10 x 15 grid, using the 'fishnet' tool. The fishnet grid is then joined with each buffer layer, to provide the percentage of buffer area falling within each grid cell. The conflict data points, clipped to each study area, are joined to these tables to provide the number of conflict points per grid cell. A summary of this process can be found in Figure 5. This process is done for each buffer layer of the berry, crop, urban change and forest-urban fringe variables within each study area, totalling to 24 different datasets. Each dataset is then prepped for ANOVA testing within Microsoft Excel. This involved classifying the numbers of conflict points into low, medium and high bins, which were attached to each grid cell. An example of the output provided by the fishnet analysis can be found in the appendix.

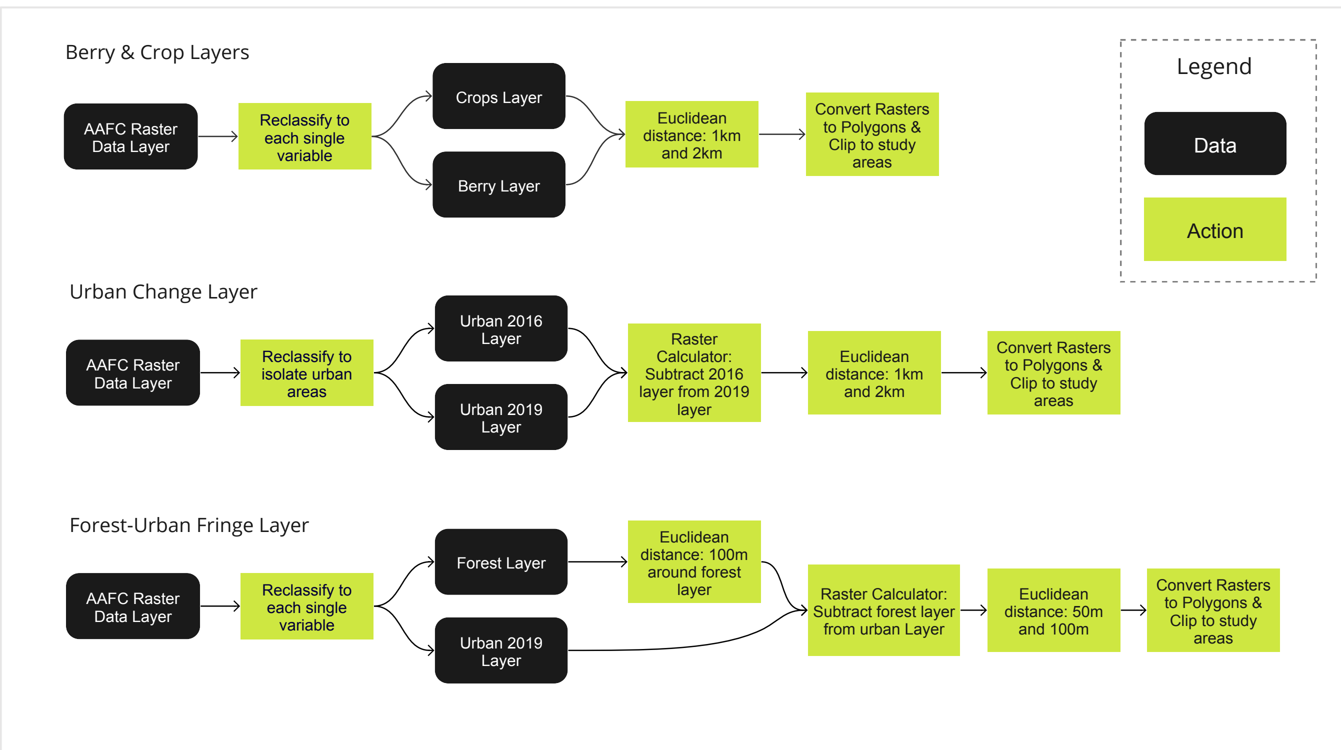

Figure 4 Process for extracting variable layers within ArcGIS Pro.

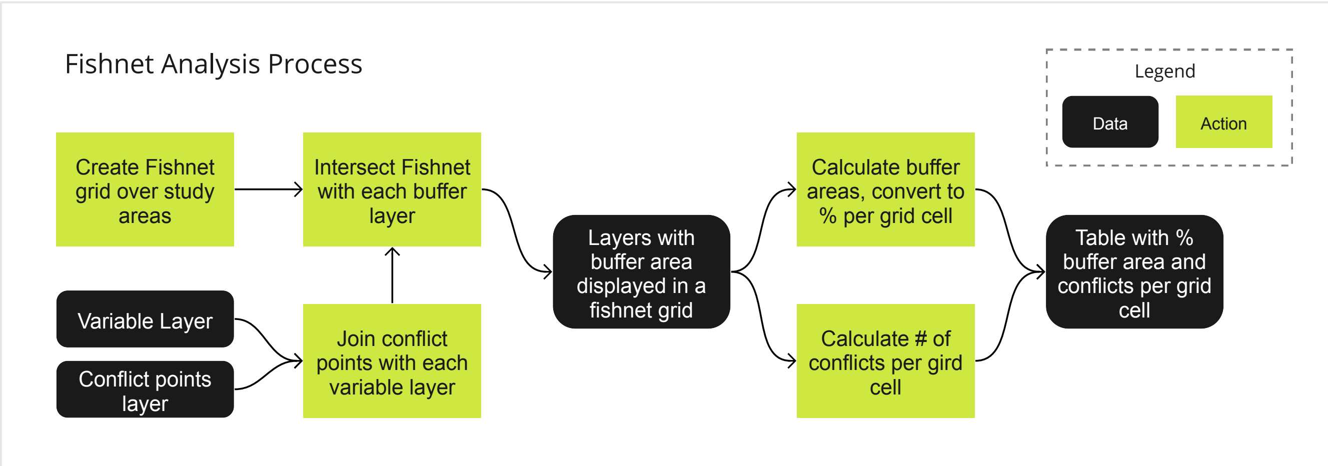

Figure 5 Process used in this study to perform a fishnet analysis within ArcGIS Pro.

For the ANOVA testing, conflicts are classified into four categories based on the average numbers found within each grid cell: no conflicts (0), low conflicts (1-3), medium conflicts (4-6) and high conflicts (7+). Despite the ranging sizes of the grid cells across study areas – 4.23km^2 (Amherst), 23.0km^2 (New Glasgow) and 3.05km^2 (Waverley) – the classification system is used for all study areas, as there are fairly consistent proportions of grid cells per conflict class, within each study area (Table 2). Each grid cell was assigned with its associated conflict class (none, low, medium or high), with the percentage of buffer area attached to each cell, and then put through the one-way ANOVA testing in excel. Variables with a p-value below 0.05 are considered statistically significant. After ANOVA testing, significant variables are put through Tukey Post Hoc analyses. Once the statistically significant variables are identified, correlation matrices are performed within each study area to determine if any variables are closely correlated. This indicates whether any variables help to explain the same phenomenon, rather than each expressing a unique relationship to the independent variable.

Table 2 Distribution of fishnet grid cells falling into pre-determined conflict classes within Amherst, New Glasgow and Waverley, Nova Scotia, 2020.

	Amherst	New Glasgow	Waverley
No conflicts	114	88	105
Low conflicts	23	44	33
Medium conflicts	7	11	7
High conflicts	6	7	5

Population density is analyzed in relation to patterns of HBBCs, using data from the 2016 Census. Population density by dissemination area is displayed using the quantile function on ArcGIS Pro, and numbers were slightly adjusted or rounded to give the following categories of people per km^2: Low (0-30), Low-medium (31-150), Medium (151-500), Medium-high (501-4000) and High (4001+). The number of conflicts falling within each population class are calculated in each study area, however no statistical tests are performed on this variable.

Results

Summary of Results

The variables posed differing influences on the patterns of HBBCs in each study area (Table 4). Across all study areas, the presence of urban fringe poses significant influence on the presence of human-black bear conflict. In both the Amherst and New Glasgow study areas, crops and urban change are found to be significant, however, the crops layers did not follow a positive relationship with conflicts. The Amherst area is the only study area where the berry variable is statistically significant, both linearly and pairwise. Most conflicts occur within low population density areas in Amherst and New Glasgow, and in low-medium population density areas in Waverley.

Table 4 Summary of the ANOVA testing results, showing variables that were found to be significant and insignificant in relation to their influence on the number of conflicts, within each study areas. Circles represent variable/conflict pairs with a linear relationship.

	Berry		Crops		Urban Change		Forest Fringe	
	1km	2km	1km	2km	1km	2km	50m	100m
Amherst	(✓)	✓	(✓)	(✓)	(✓)	(✓)	(✓)	(✓)
New Glasgow	X	X	✓	✓	(✓)	(✓)	(✓)	(✓)
Waverley	X	X	X	X	X	X	(✓)	(✓)

With the exception of the 1km berry buffer, the 1km crops buffer, and the 100m forest-urban fringe buffer layers, all ANOVA tests within the Amherst area fail the assumption of equal variance, dictated by a difference in variance between the lowest and highest variable categories exceeding a 1:4 ratio. Despite the failure to meet this assumption, valuable insights are provided from the ANOVA testing results, alongside visual assessments of the maps used to test each variable (Figure 6).

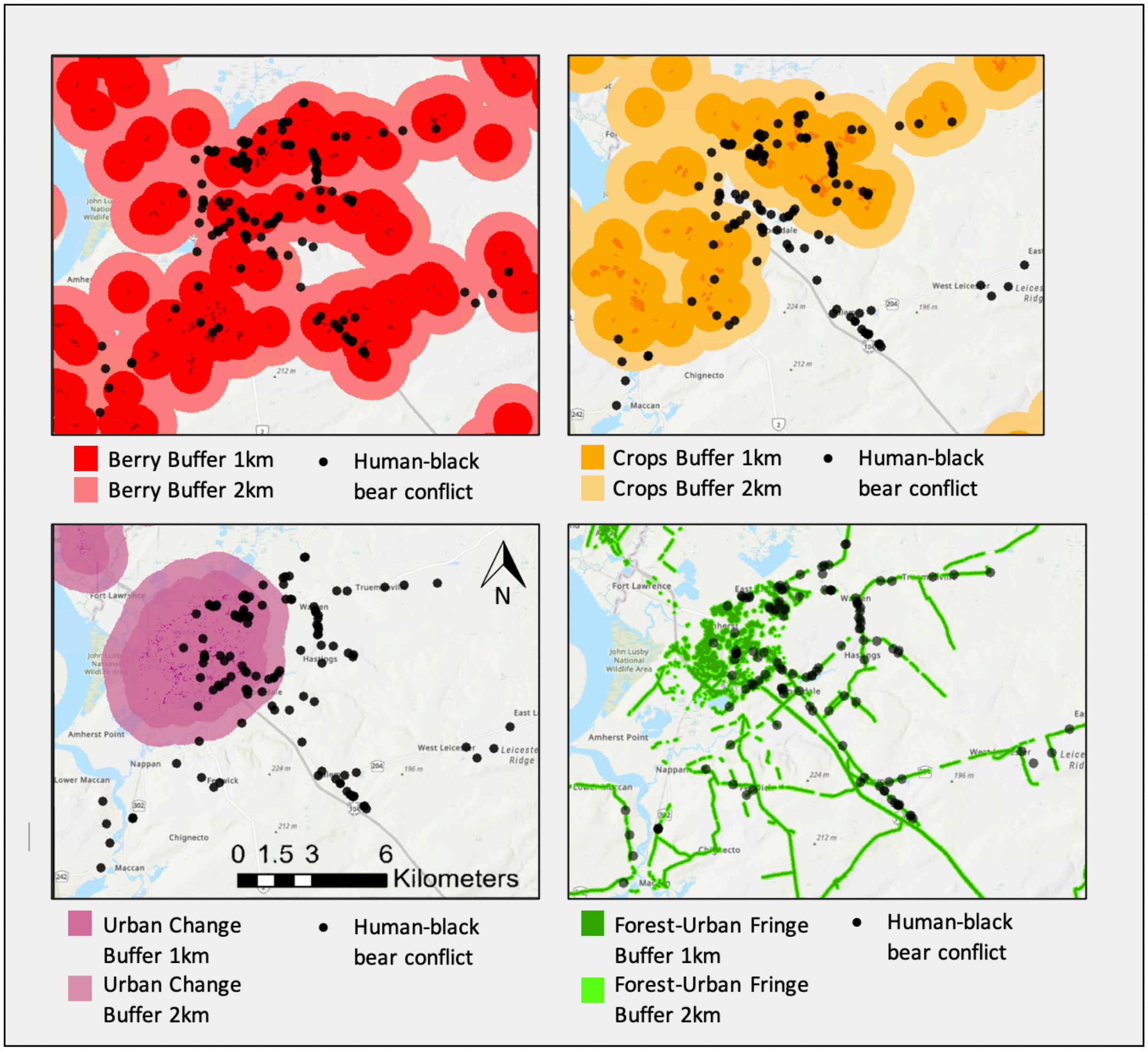

Figure 6 Maps of each variables 1km and 2km buffer layers, with human-black bear conflicts over top, within the Amherst study area. Created within ArcGIS Pro, 2020.

Within the Amherst study area, there is an observed difference in means between the presence of berry fields and numbers of human-black bear conflicts, in both the 1km buffer layer (F-value: 5.09, p-value: 0.002) and the 2km buffer layer (F-value: 6.59, p-value: 0.0003). Both the 1km and 2km berry buffers follow the upwards trend of increasing conflicts where there are increased percentages of buffer area in the fishnet cells, with the lowest average percentage of berry area in areas with no conflicts (33.4%, 63.3%) and the highest average percentage of berry area found in areas of high conflicts (77.4%, 98.0%) (Table 5). For the 1km berry buffer, the

Tukey post-hoc analysis reveals that the only significant difference in mean percentage area and conflict classes is between areas of no conflicts and areas of high conflicts. For the 2km berry buffer, the only significant difference in mean percentage area and conflict classes is between areas with no conflicts and areas with low conflicts, with all other differences between classes found to be insignificant.

Table 5 ANOVA testing results for the Amherst study area, with the reported p-value, F value, and the mean percentages of variable within conflict classes for each 1km and 2km buffer layer, all calculated in Microsoft Excel, 2020.

	P-value	F-value	None	Low	Medium	High
Berry 1km Layer	0.002	5.09	33.4%	52.0%	55.9%	77.4%
Berry 2km Layer	0.0003	6.59	63.3%	90.9%	97.4%	98.0%
Crops 1km Layer	3.36E-05	8.42	14.1%	31.3%	46.1%	61.6%
Crops 2km Layer	0.002	5.35	33.7%	54.6%	65.5%	87.7%
Urban Change 1km Layer	7.45E-25	58.4	3.25%	13.8%	50.7%	99.8%
Urban Change 2km Layer	1.92E-11	21.4	8.94%	28.5%	32.8%	100%
Forest-Urban Fringe 50m	6.61E-10	17.8	4.13%	6.82%	15.3%	26.0%
Forest-Urban Fringe 100m	1.07E-10	19.5	7.71%	13.7%	26.0%	43.6%

Similar to the berry areas, an increase in percentage of crop area aligns with increasing conflicts, with the lowest average percentages in areas with no conflicts (14.1%, 33.7%) and the highest average percentage falling in areas with high conflicts (61.6%, 87.7%) (Table 5). Significant difference is found between the percentages of crop area within conflict classes for both the 1km buffer layer (F-value: 8.42, p-value: 3.365E-05) and the 2km buffer layer (F-value: 5.35, p-value: 0.0016). The post-hoc analyses finds there to be significant differences between areas of no conflicts and medium levels of conflicts and areas of no conflicts and high conflicts within the 1km buffer layer, and only significant differences between areas of no conflict and high conflict within the 2km buffer.

Significant differences are also found between the mean percentages of urban change area in conflict classes for both the 1km and 2km buffer layers, with the lowest p-value of all variables within the Amherst study area at 7.4546E-25 (F-value: 58.4) for the 1km buffer layer, and 1.9161E-1 (F-value: 21.4) for the 2km buffer layer. The same trend of increasing area percentage and increasing conflicts is found within the urban change layers (Table 5). As well, the urban change 1km layer contains the highest number of categories with significant differences out of all the variables, with only the difference in mean percentages between areas of no conflicts and low conflicts being insignificant. In the urban change 2km layer, all category pairs are found to be significant, with the exception of the categories of no conflicts – medium conflicts, and low conflicts – medium conflicts.

The mean differences in percentages of urban-forest fringe area within conflict classes are also significant, at both the 50m layer (F-value: 17.8, p-value: 6.61E-10), and the 100m layer (F-value: 19.5, p-value: 1.07E-10). While following the common trend of increasing area percentage/increasing conflicts, significant difference is only found between the no conflicts – medium conflicts, the no conflicts – high conflicts, and low conflicts – high conflicts category pairs, within both the 1km and 2km buffer layers.

A correlation matrix finds there to be a highest correlation between the urban change and forest-urban fringe variables (0.671) (Table 6). The next most correlated variables are the crops and urban change variables (0.395), with the rest falling below 0.3 (Table 6).

Table 6 Correlation matrix for the variables within the Amherst study area, created in Microsoft Excel, 2020.

	Berry	*Crops*	*Urban Change*	*Forest-urban Fringe*
Berry	1			
Crops	0.289	1		
Urban Change	0.244	0.395	1	
Forest-urban Fringe	0.226	0.283	0.671	1

New Glasgow Study Area

Within the New Glasgow study area, all variable pairs fail the assumption of equal variance, with the exception of the berry 1km and 2km buffer layers, and the crops 2km buffer layer. Each variable's spread and all conflict points in New Glasgow can be seen in Figure 7. In this study area, the differences in mean percentages of berry area within conflict classes for both the 1km buffer layer and 2km buffer layer are found to be insignificant (F-value: 0.43, p-values: 0.729, and F-value: 1.24, p-value: 0.298, respectively). As such, all category pairs are insignificant for both of these layers. Yet a significant difference is found between the mean percentages of crop area within conflict classes in both the 1km buffer layer (F-value: 15.6, p-value: 7.81E-09) and 2km buffer layer (F-value: 11.7, p-value: 6.30E-07). Within both the crop 1km and 2km crop buffer layers, the highest average for percentages of crop buffer fall within areas of medium levels of conflicts (40.6%, 65.8%) followed by areas with low conflicts (14.4%, 32.4%), high conflicts (13.7%, 29.2%) and no conflicts (5.2%, 14.0%) (Table 7). Significant category pairs within the 1km crop buffer layer include no conflicts – low conflicts, no conflicts – medium conflicts, low conflicts – medium conflicts, and medium conflicts – high conflicts. The same pairs, aside from medium conflicts – high conflicts, are also found to be significant in the 2km crop buffer.

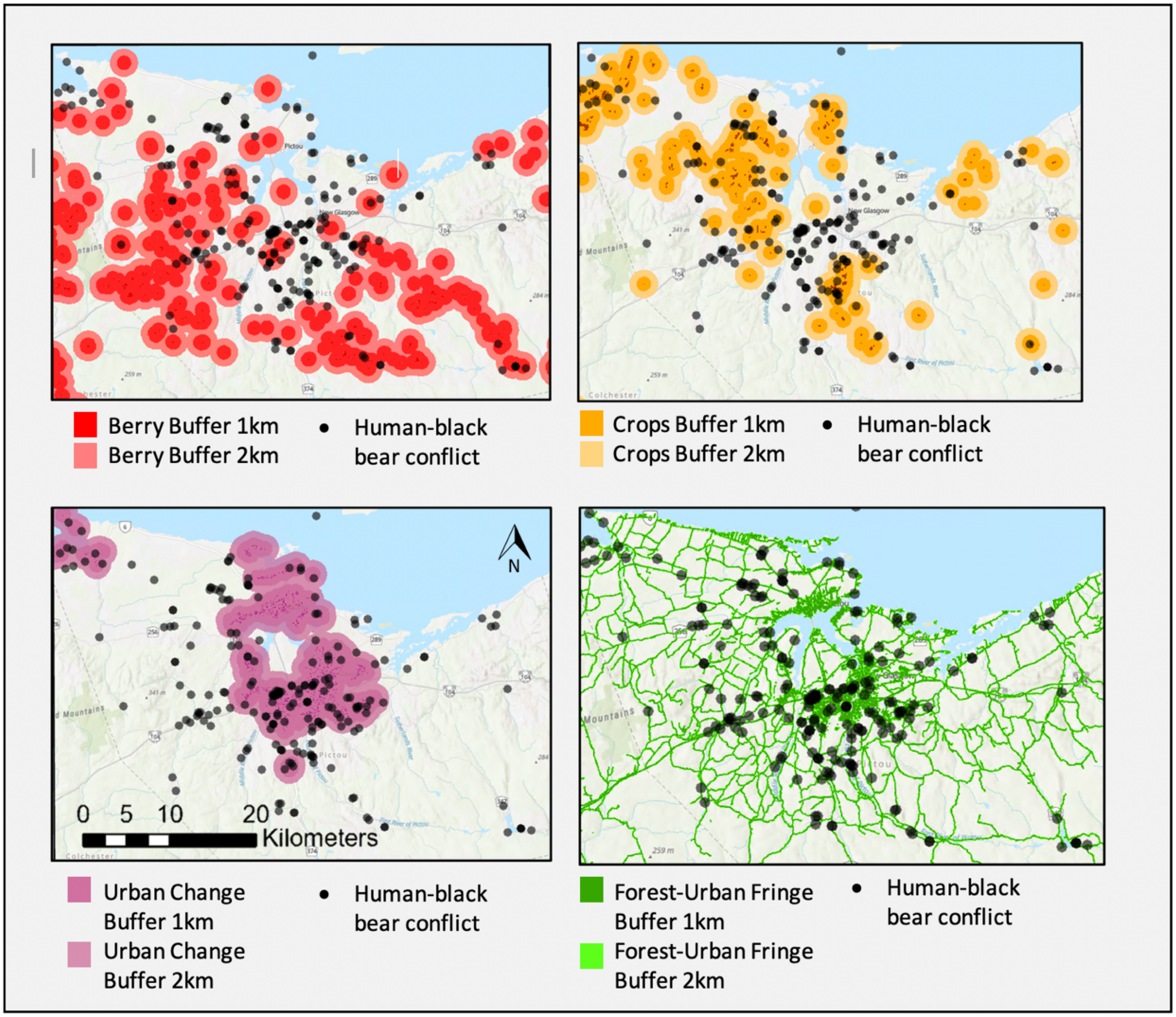

Figure 7 Maps of each variables 1km and 2km buffer layers, with human-black bear conflicts over top, within the New Glasgow study area. Created within ArcGIS Pro, 2020.

Table 7 ANOVA testing results for the New Glasgow study area, with the reported p-value, F value, and the mean percentages of variable within conflict classes for each 1km and 2km buffer layer, all calculated in Microsoft Excel, 2020.

	P-value	F-value	None	Low	Medium	High
Berry 1km Layer	0.729	0.43	15.0%	18.9%	17.6%	13.6%
Berry 2km Layer	0.297	1.24	33.6%	45.6%	43.5%	41.3%
Crops 1km Layer	7.81E-09	15.6	5.20%	14.4%	40.6%	13.7%
Crops 2km Layer	6.30E-07	11.7	14.0%	32.4%	65.8%	29.2%
Urban Change 1km Layer	1.21E-11	21.6	1.86%	13.2%	26.2%	55.4%
Urban Change 2km Layer	3.58E-12	22.8	3.19%	25.3%	46.2%	66.0%
Forest-Urban Fringe 50m	1.06E-06	11.3	6.27%	8.62%	13.7%	20.5%
Forest-Urban Fringe 100m	4.20E-06	10.1	12.2%	15.3%	23.9%	33.3%

Significant difference is also found between the percentages of urban change area in conflict classes, within the 1km buffer (F-value: 21.6, p-value: 1.21E-11) and the 2km buffer (F-value: 22.8, p-value: 3.58E-12). The number of conflicts matches the upward trend of increasing percentages of urban change buffer area, with the lowest average percentage of urban change area falling in areas with no conflicts and the highest average percentage of urban change area in areas with high conflicts. Significant differences are found between every category pair in the 1km buffer layer, except low conflicts – medium conflicts, and every category pair in the 2km buffer, with the exception of low conflicts – medium conflicts and medium conflicts – high conflicts.

The differences in mean percentages of urban-forest fringe area across conflict classes is found to be significant in the 50m buffer layer (F-value: 11.3, p-value: 1.06E-06) and the 100m buffer (F-value: 10.1, p-value: 4.2004E-06). The highest average percentage of urban-forest fringe area falls within areas of high conflicts (20.5%, 33.3%), and the lowest average percentage in the no conflict areas (6.3%, 12.2%), which follows the same pattern as the urban change variable in New Glasgow (Table 7). As for the category pairs, only no conflicts – medium conflicts, no conflicts – high conflicts, and low conflicts – medium conflicts pairs are found to have significant differences between their means in both the 50m and 100m buffer layers. The correlation matrix testing finds a very correlation between all significant variables within the New Glasgow study area (Urban change – Crops: 0.262, Urban change – Forest-urban fringe: 0.163, Forest-urban fringe – Crops: 0.211).

Waverley Study Area

All layers fail the assumption of equal variance test in the Waverley study area, in part due to many classes having a variance of zero (all values in the class are the same). Visual assessments reveal a high level of concentrated urban change, well-spread forest-urban fringe, but little berry or crop area (Figure 8). Aside from the berry 1km buffer layer (F-value: 2.09, p-value: 0.0318), all berry, crop, and urban change layers are found to be not statistically significant under ANOVA testing, with all p-values above 0.05 (Table 7). The post-hoc analyses reveal no significant differences between any category pairs within any berry, crop or urban change layer, despite the berry 1km buffer layer being statistically significant overall. The forest-urban fringe layers are found to be significant with both the 50m buffer (F-value: 11.4, p-value: 8.74E-07) and the 100m buffer (F-value: 10.4, p-value: 2.94E-06). Both layers follow a trend of increasing conflicts with increasing buffer area, with the lowest average percentage of buffer area falling in areas with no conflicts (23.5%, 36.3%) and the highest amount found in areas with high conflicts (59.3%, 74.3%) (Table 7). The average percentage buffer areas for the low and medium conflict areas are similar, with 44.4% and 44.5% in the 50m buffer layer, as well as 61.5% and 63.4% in the 100m buffer layer (Table 7). In both layers, significant difference is found between the category pairs of no conflicts – low conflicts, and no conflicts – high conflicts. No correlation matrix is produced for the Waverley area given there only being one significant variable (excluding the berry 1km buffer layer with no pairwise significance).

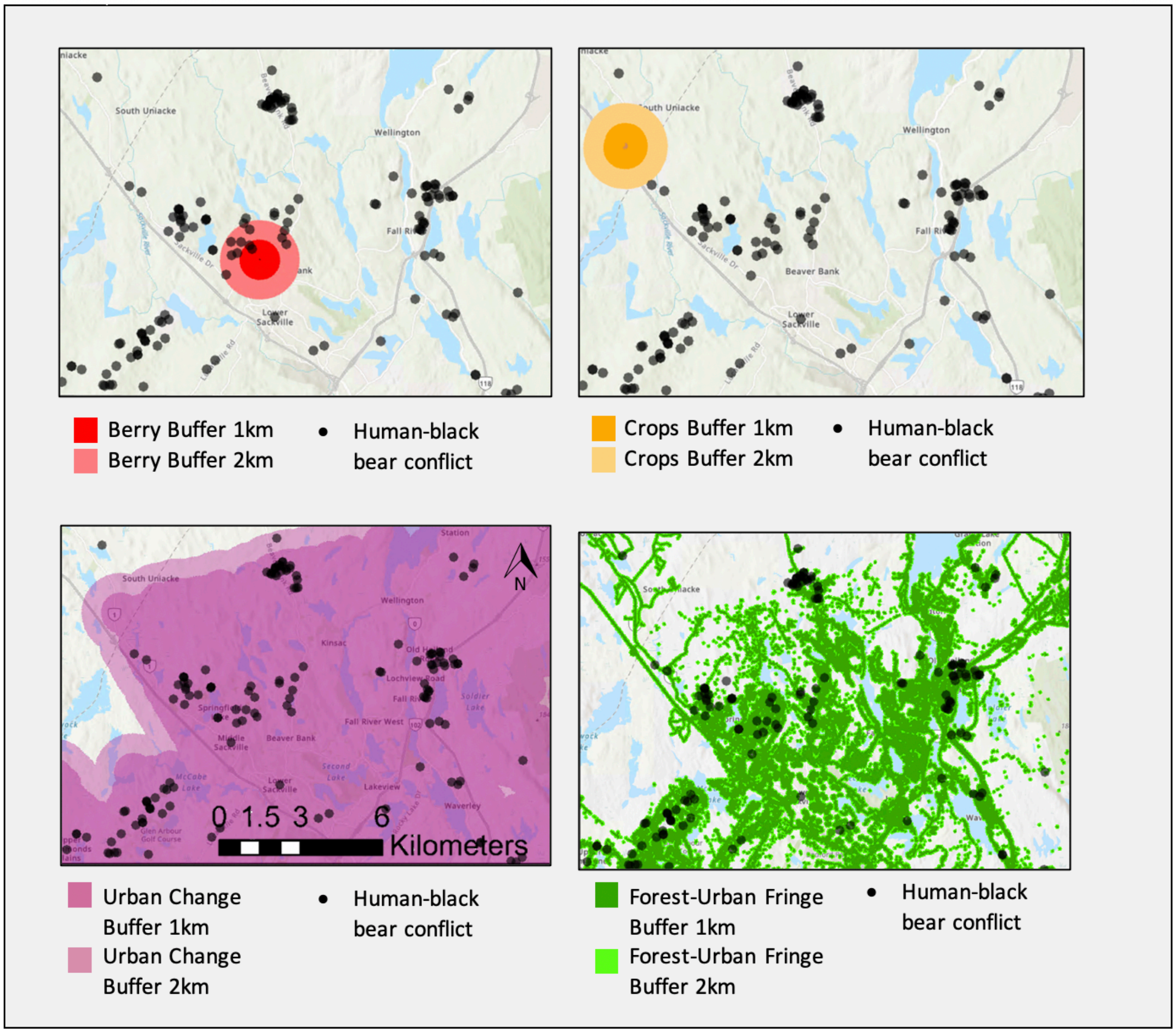

Figure 8 Maps of each variables 1km and 2km buffer layers, with human-black bear conflicts over top, within the Waverley study area. Created within ArcGIS Pro, 2020.

Table 5 ANOVA testing results for the New Glasgow study area, with the reported p-value, F value, and the mean percentages of variable within conflict classes for each 1km and 2km buffer layer, all calculated in Microsoft Excel, 2020.

	P-value	F-value	None	Low	Medium	High
Berry 1km Layer	0.104	2.09	0.39%	0.67%	4.42%	3.14%
Berry 2km Layer	0.0318	3.02	1.38%	3.15%	13.7%	16.1%
Crops 1km Layer	0.799	0.34	1.24%	0.05%	0%	0%
Crops 2km Layer	0.718	0.45	4.00%	1.40%	0%	0%
Urban Change 1km Layer	0.128	1.93	79.2%	90.6%	100%	100%
Urban Change 2km Layer	0.210	1.53	87.6%	96.7%	100%	100%
Forest-Urban Fringe 50m	8.74E-07	11.4	23.5%	44.4%	44.5%	59.3%
Forest-Urban Fringe 100m	2.941E-06	10.4	36.3%	61.5%	63.7%	74.3%

Population Density

An investigation into the relationship between population density and the distribution of human-black bear conflicts reveals a high concentration of conflicts occurring in areas of low to low-medium population density (Figure 9).This helps to confirm the results of the urban change variable, given the areas with higher recent urban changes had higher populations where conflicts were occurring. In total, 50.7% of conflicts occur in low population density areas and 36.0% in low-medium population density areas, with the remaining majority falling in medium population density areas (16.6%). However, these trends differ between study areas, as the majority of Amherst and New Glasgow's conflicts occur in low population density areas (55.6%, 59.4%, respectively), yet Waverley's conflicts are most prevalent in low-medium population density areas (53.7%) (Figure 9). No conflicts occur within the medium-high to high population density areas, however there are few areas of medium-high population density and no areas of high population density within the study areas.

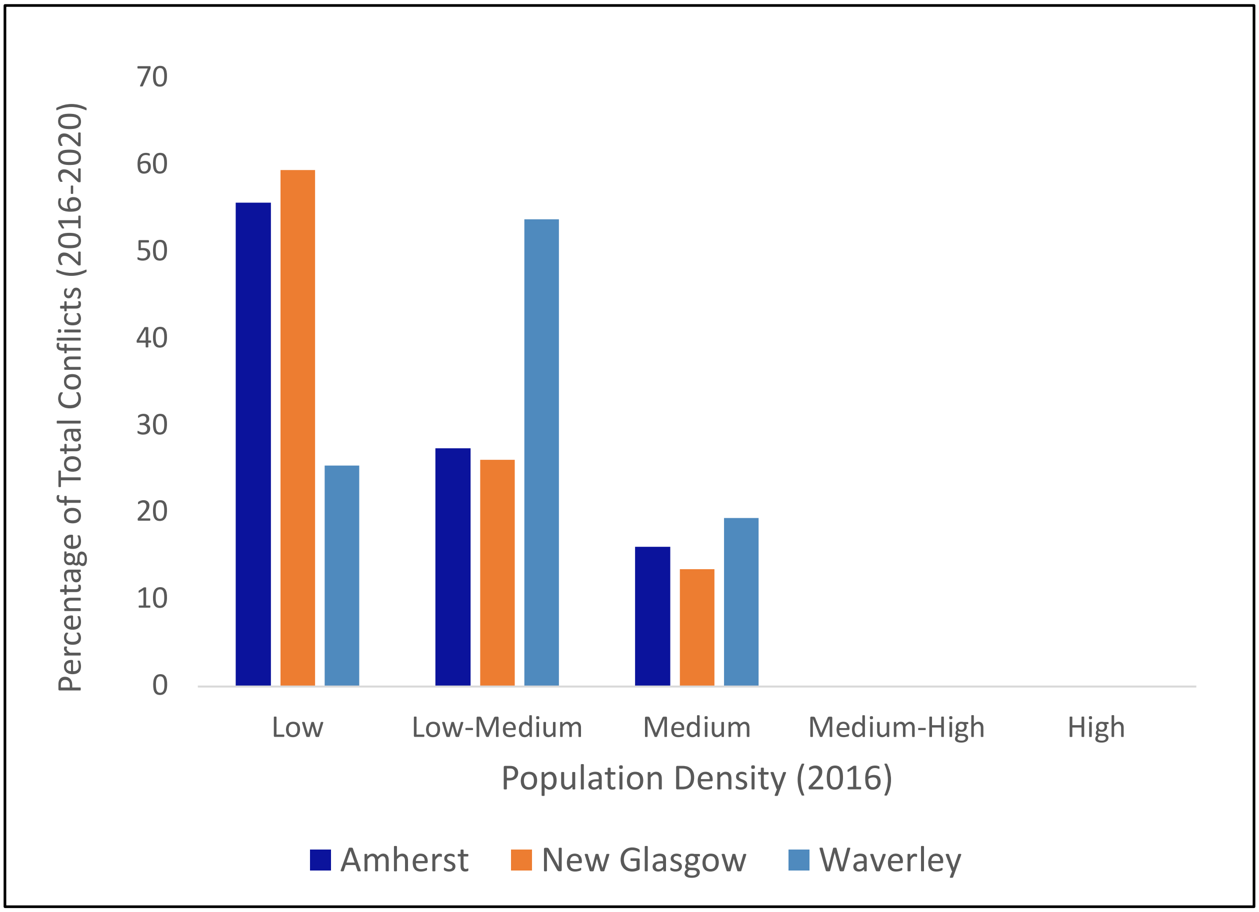

Figure 9 Human population density in relationship to the percentage of total human-black bear conflicts within Amherst, New Glasgow, and Waverley, Nova Scotia. Data drawn from the 2016 census profiles (Statistics Canada, 2017)

Discussion

The results of the analyses across our three study areas leads to the conclusion that an area's unique composition of natural attractants, urban development and habitat fragmentation can help determine their patterns of human-black bear conflicts yet may not be enough to fully predict these patterns. When considering these results, it's important to understand the influence each variable could pose in either drawing bears into urbanized areas or pushing them out of forested areas. And of course, there must be people nearby to report any instances of bears entering urban landscapes. The presence of berries and crops can be seen as attractants for bears given these areas provide an abundant and nutritious food source, thus drawing them into more human-developed areas. The presence of urban change and forest-urban fringe however can be viewed as factors that serve to remove or fragment a bear's natural habitat, effectively easing their access to more human-developed areas. Another immediate result of these two factors is the subsequent loss of natural food that results from a loss of forested area, as bears often forage food in their mixed-forest habitats. As such, trends in conflicts should not be examined just through the sheer presence of these variables, but rather, the overall composition of the landscape and interrelation between them as well.

The HBBC patterns within the Amherst study area are found to be informed by the presence of food attractants like berries and crops, as well as the anthropogenic impacts of urban change and sprawl. With all variables – berry, crops, urban change, forest-urban fringe - deemed significant, Amherst represents an area with a mix of competing factors that influence the location and frequency of conflicts. These results support the notion of 'energetically beneficial' areas, where bears can gain access to large sources of food and do not have to travel far to find them (Lewis et al. 2015). The distribution of attractants near areas of urban change and fragmentation creates an abundance of these 'high value' or 'energetically beneficial' areas across Amherst. However, the correlation testing reveals that the urban change and forest-urban fringe variables were fairly correlated (Table 6), indicating that these phenomena may be related. Through a visual assessment, most urban change occurs within the urban core of Amherst, therefore correlation between these variables can indicate a higher number of forested areas near the urban core, when compared to New Glasgow where there was little correlation between the two variables. With all other variable pairs containing low correlation, we can presume that these variables hold unique patterns of influence on HBBCs.

In the New Glasgow study area, the three significant variables were crops, urban change and forest-urban fringe, and all of which were found to have low correlation between them (representing unique relationships to the independent variable). Surprisingly, the percentages of crop area do not follow a positive upward trend across conflict classes, with the highest percentage of crop area falling in areas with medium conflicts, and the percentage of crop area within high conflict areas similar to that in low conflict areas. This does not entirely support the predicted trend of increased areas of attractant leading to more conflicts but could explain a different phenomenon. One explanation for this can be related to which types of crops are present in the area, with bears favoring certain foods over others. In New Glasgow study area, the majority of crops are barley, oats, corn, soybeans and peas – crops not known to be very desirable to bears, with the exception of corn (Bear Smart Durango, 2017). This differs from Amherst where there is a higher abundance of potatoes – a vegetable that attracts bears – and a positive relationship between crops and conflicts. This unanticipated result indicates that instead of most conflicts falling within 1-2 km of crops, they are happening on the outskirts or just outside these areas. This also calls into question the validity of using the buffer sizes of 1km and 2km, or presents the potential for there to be another variable present.

As there has been little research of the same nature, there are few studied examples to draw on to determine the appropriate size for buffers surrounding variables of interest. As such, these buffer area distances were based on Merkle et. al. (2011) study as well as expert knowledge on bear ecology yet could be better supported through studies examining a larger range of several distances in relation to the patterns of HBBCs. This would help to understand how far bears will travel for food based on the attractant type, as well as a firmer understanding of their decision-making in seeking foods, related to the concepts of payoffs and energy balances. Having buffer areas that accurately reflect the distances bears travel when seeking food would help create a more precise measurement of the relationship between attractants and human-bear interactions. Future research can focus on performing a sensitivity analysis, making use of several buffers of different distances, to help uncover any patterns in the distances of attractants and frequency of conflicts.

While both the urban change and forest-urban fringe are significant, through a visual assessment the spatial distributions of these areas vary widely within New Glasgow. With most urban change area clustered and concentrated to the urban core, many points fall within these buffered areas. In contrast, forest-urban fringe area is equally distributed across the study area. While almost all conflict points fall within an area of forest-urban fringe, there are still several areas of forest-urban fringe that do not contain conflict points. Additionally, conflict points seem to fall within many of the areas of overlapping urban change and forest-urban fringe (Figure 7). Supported by the statistical analyses, it has been determined that these two variables play the most influential role of all variables studied, in the outcome of HBBC patterns across New Glasgow. This result is supported by Johnson et. al (2015), who conclude that urban and exurban development reduces natural food supply and creates more anthropogenic food sources for bears.

The New Glasgow study area contains the factors that help to push bears out of forests, like urban change and sprawling, with proven significance. However, this area also contains a high presence of berry and crop areas, yet a much weaker relationship between these variables and increased conflicts when compared to Amherst. This could indicate that despite containing these desirable attractants, New Glasgow may have competing attractants that are the drivers for conflicts in this area. Simply put, the bears aren't going for the berries or the crops – they're seeking other types of food, with potentially easier access and higher payoffs. Again, this may also be explained by the composition of crop types found within the area, given the low number of crops deemed desirable to bears. Another influence on these results in the scale of the grid-cells used within the fishnet analysis. The New Glasgow study area represented a much larger area, and due to the use of a consistent grid size, each grid cell was much larger than those within Amherst and Waverley. This has the potential to underrepresent swaths of buffer area given they may compromise a smaller percentage of area within the cell. This issue could be remedied through the use of consistently sized grid cells and adjusting the grid size accordingly. Given the level of uncertainty still associated with the causes for these trends, a qualitative analysis of the bear incident reports would help to inform understanding around these results. While this qualitative information was unavailable for use within this study, gaining access to this increased level of detail could provide meaningful context for these results.

Waverley represents a more developed area that contains few attractants like crops or berries but is dominated by urban change. As such, both the berry and crop layers are not found to be significant in influencing the reported conflict patterns. In addition to this, urban change was not found to be significant. This is likely a result of this specific methods approach not lending itself well to the large, unified swath of urban change area found in Waverley. Given the study area was split up using a grid, most cells contained 100% urban change buffer area, however conflicts only fell within a certain number of these cells. This is largely a product of the differences in study area sizes, where a larger study area would capture more variation in urban change levels. This creates uncertainty as to whether the high volumes of buffer area related to there being higher conflicts. Despite the lack of statistical significance, through a visual assessment one can see that all conflict points do fall within these areas of urban change (Figure 8). To reduce the impact of this issue, a smaller buffer area could be used to more closely examine the relationship between these areas of urban change and the resulting numbers of conflicts. Expanding the scale of the area studied to gain a larger view of the landscapes nearby could also help to remedy this issue. Unlike the other study areas, the only significant variable within the Waverley area was the forest-urban fringe.

A similar impact to the urban change variable was experienced within the forest-urban fringe layer, where even with smaller 50m and 100m buffers there were many grid cells containing high percentages of buffer area and no conflicts. This is expected as the Waverley area is a much more urbanized area than Amherst or New Glasgow. This is supported by our findings that most conflicts here occur in low-medium population density areas as opposed to occurring within low population density areas, a characteristic of the Amherst and New Glasgow areas (Figure 9). Despite the more consistent and well-distributed areas of high forest-urban fringe, the variable is still proven to have a significant influence, with almost all conflicts falling within these urban areas close to forests.

While New Glasgow has a high presence of berries and crops with little influence on conflicts, Waverley has almost no ‘attractant’ variables (berries, crops) present. As such, it can be presumed that there are other attractants that are leading to the high numbers of conflicts in this area. While the conflicts could be entirely driven by urban change and fragmentation, the presence of a different food source is more likely to be the case. Given the high levels of population density, the increased presence of anthropogenic food sources like compost or garbage may be an attractant influencing the number of conflicts occurring within Waverley. The lack of data surrounding the access to and frequency of urban-residential food sources like compost remains as a significant inhibitor towards understanding human-black bear conflicts within Nova Scotia. Several studies cite increased urban change leading to human food waste as the largest contributor to rising human-black bear interactions (Garshelis, 2002; Johnson et. al, 2015; Lackey et al. 2018; Baruch-Mordo et al. 2008). While there is abundant observational evidence for this phenomenon in Nova Scotia, providing a numerical quantification for this issue remains as a gap in research.

In a preliminary assessment of compost bin use, conflict points were mapped based on the day of the week they were reported, with the anticipation of clustered zones based upon the local collection days for compost within each area. These results found there to be no evidence of conflicts clustered by days of the week, within any study area (Figure 10). Despite these findings, the lack of clustering may be influenced by inconsistent or delayed reporting of conflicts leading to inaccurate dates associated with the individual points. Studies should work towards quantifying the impacts of urban residential food sources towards to the distribution and frequencies of HBBCs, as well as pilot programs to determine the effectiveness of reducing these food sources as a method of curbing HBBCs. Once the impact of urban residential food attractants is effectively quantified, these values can then be appropriately compared with other attractant variables like berries or crops, to produce a more comprehensive understanding of HBBCs in Nova Scotia.

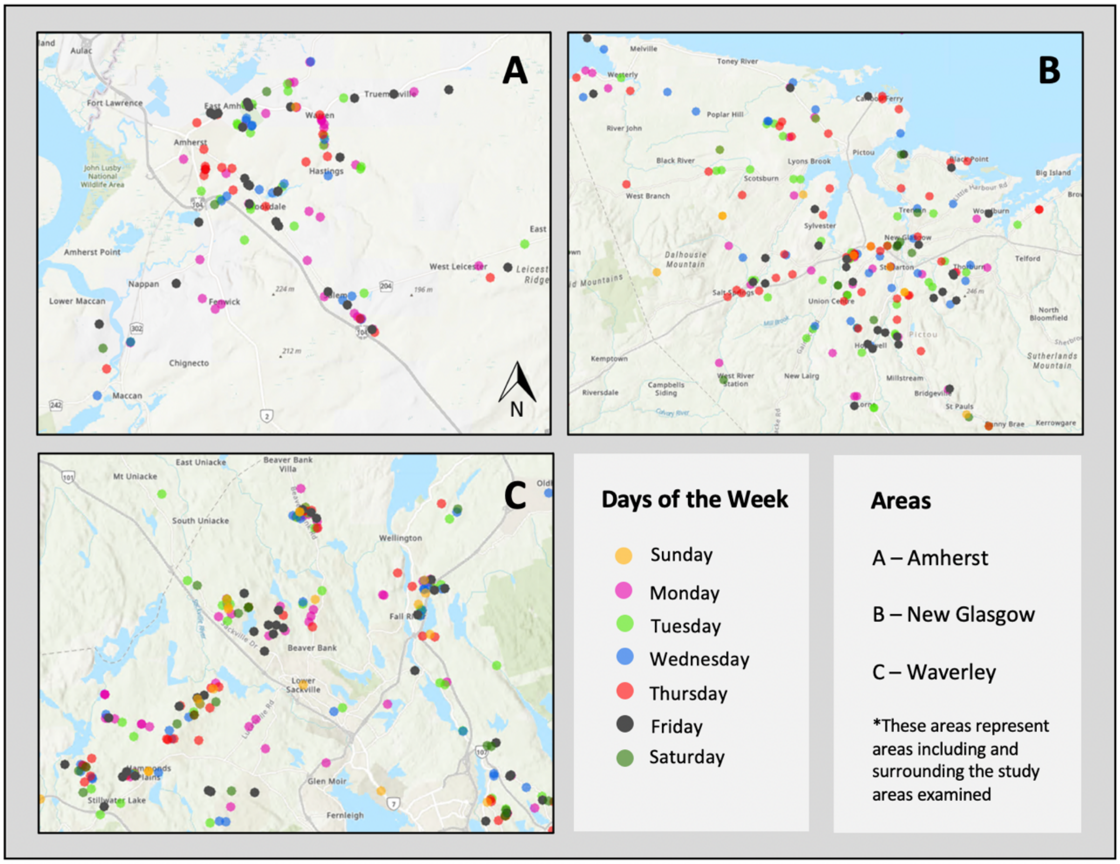

Figure 10 Conflicts by days of the week, in the regions of Amherst, New Glasgow and Waverley, Nova Scotia, created in ArcGIS Pro using the Biodiversity Investigation Reporting System database (NSDLF, 2020).

When comparing the results across study areas, each study shows unique patterns in regard to the influence of varying presences of berry, crops, urban change and forest-urban fringe, and anticipated patterns of low population density in areas with higher numbers of conflicts. This highlights the need for wildlife officers to consider more contextualized management strategies based upon the unique features in the areas being targeted. To assist in this approach, having an understanding of the geography of any area being targeted for solutions can help to provide context towards why there are increased conflicts there. Improvements can also be made to the incident reporting database used by the NSDLF, by increasing the level of detail recorded when logging bear conflicts. This could include fields that indicate whether the bears were eating from compost/garbage bins, a code/number that can help identify instances of multiple nuisances at the same address, and what types of foods/waste may have been available for bears. These may help to determine the causes for conflicts and more easily identify areas where there are persistent conflicts, as well as helping to contribute to our understanding of bear ecology. Additionally, continuously mapping conflicts as they arise can help to pinpoint areas experiencing increasing conflicts, to help mitigate the issue before it potentially becomes worse.

Although all case study areas show differing patterns, one common thread is the significance of the forest-urban fringe layers. This can signify that black bears aren't travelling far into urban cores. More specifically, given that the isolated areas for this layer represent urban areas within 100m of a forest and then include the 50m and 100m buffers, bears are rarely travelling more than 150-200m into urban areas. This is supported by Merkle et al. (2011), who found similar results of significant relationships between higher conflicts near housing that borders forests. Determining the distances in which bears travel into urban cores will be important to follow over time, as more habitat area begins to be used up for urban developments. Johnson et al. (2015) find that bears have shifting foraging behaviour based on changes to their habitat's conditions, therefore there will be a continual response to move towards urban areas to seek food, over time. Predictably, the further bears travel into more urbanized spaces, there are increased chances of encountering humans and posing further conflicts, inciting the need for studies to quantify this issue as it evolves through time. In addition to this, further studies could compare the patterns of conflicts in urban areas that expand into forests, versus urban areas expanding into agriculturally dominant landscapes. When creating management strategies, there should be a focus on educating residents within these areas of forest-urban fringe on black bear safety, as well as their responsibility to reduce access to any nearby attractants. In addition to strategies focused on public education, conflicts can be reduced by targeting policies or management solutions that help to limit urban encroachment or habitat fragmentation to possibly mitigate the issue on the front-end.

Similar to the suggestions of Witherley (2018), a formal bear population study within Nova Scotia should be a priority. Understanding both the current numbers of black bears as well as their distribution across Nova Scotia would help provide clarity towards the extent of HBBCs, and also help to shed light on whether the previously mentioned reporting and labelling biases are present. This will also help in understanding more around the cultural carrying capacity of black bear within Nova Scotia, an aspect that this study does not contribute greatly to. In addition to this, an approach that uses GPS tracking on a subset of black bears would help to identify their spatial patterns and feeding behaviour, as well as identify the rate of 'double counting' that occurs when examining conflict data, in cases where it is one bear posing multiple conflicts.

Conclusion

These results help to answer the question of which geographic and anthropogenic variables pose significant influence the patterns of human-black bear conflicts within Amherst, New Glasgow and Waverley, Nova Scotia, the areas experiencing the largest increases in HBBCs in recent years. Increased forest-urban fringe was found to have a significant influence on the frequency of HBBCs, within each study area. These results show that currently, black bears travel less than 150-200 meters into urban areas from their forest habitats. Additionally, we can now understand that the drivers for HBBCs are unique to the landscapes across communities, and that while features like berries, crops, urban change and forest-urban fringe can contribute to the patterns of HBBCs, they are likely not the only drivers. This study also showcases a novel method for examining trends in HBBCs, through the use of both buffered key features and fishnet analyses. While these methods were successful in their goals of determining causal variables in select study areas, they fell short in quantifying the influence of a variable occupying large swaths of an area, presenting the opportunity for further studies to examine larger study areas.

Most notably, this study was unable to include data on urban residential food sources – known to contribute greatly to human-wildlife interactions – thus, future research should focus on better understanding this relationship. Additionally, research should focus on effectively quantifying the distances bears will travel for food, specifically as they enter deeper into human-dominated landscapes. With these results, it is recommended that wildlife officers employ more contextualized management solutions with a focus on communities near forests, conduct a formal bear population study, and focus efforts on reducing the impact of urban encroachment and habitat fragmentation. These results and associated recommendations can help to reduce the levels of human-black bear interactions, with potential of reducing the number of bears euthanized and in-turn reduce the level of pushback from the public towards NSDLF.

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Appendix

List of search terms used for the literature review:

Black bear
Ursus americanas
Conflicts
Interactions
Spatial
GIS
Modelling
Logistic regression
Causes
Factors
Wildlife
Management
Canada
Nova Scotia
Lands and Forestry

List of variables included within each variable layer

BERRY

Cranberry
Blueberry
Other Berry
Orchards
Vineyards

CROPS

Fallow
Barley
Oats
Rye
Sorghum
Winter Wheat
Spring Wheat
Corn
Canola / Rapeseed
Mustard
Soybeans
Peas
Beans
Fava beans
Potatoes
Other Vegetables

URBAN CHANGE

Urban/Developed

FOREST-URBAN FRINGE

Urban/Developed
Forest Mixed
Forest Coniferous
Forest Deciduous

ANOVA Results Summary Tables

Amherst Berry 1km Buffer Layer

SUMMARY					
Groups	Count	Sum	Average	Variance	
NONE	114	3802.65619	33.3566333	1249.1707	
LOW	23	1195.21087	51.9656899	1202.23928	
MEDIUM	7	391.638103	55.9483004	812.901124	
HIGH	6	464.224946	77.3708244	604.662799	
ANOVA					
Source of Variation	SS	df	MS	F	P-value
Between Groups	18341.6771	3	6113.89238	5.08601925	0.0022325
Within Groups	175506.274	146	1202.09777		
Total	193847.951	149			

Amherst Berry 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	114	7212.84583	63.2705774	1561.89218		
LOW	23	2090.31235	90.8831455	400.494084		
MEDIUM	7	681.457135	97.3510193	23.8976583		
HIGH	6	588.284896	98.0474827	22.8739423		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25114.0231	3	8371.34104	6.58654727	0.00033155	2.66657421
Within Groups	185562.441	146	1270.97563			
Total	210676.464	149				

Amherst Crop 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	114	1605.31075	14.0816732	661.86896		
LOW	23	720.766921	31.3376922	1389.26754		
MEDIUM	7	322.694212	46.0991731	1853.97716		
HIGH	6	369.85101	61.641835	2270.04233		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22119.6368	3	7373.21228	8.42131053	3.3649E-05	2.66657421
Within Groups	127829.153	146	875.542144			
Total	149948.79	149				

Amherst Crops 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	114	3837.91352	33.6659081	1697.8425		
LOW	23	1256.68729	54.6385778	2036.56631		
MEDIUM	7	458.578554	65.511222	2231.56759		
HIGH	6	526.3624	87.7270666	364.430326		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	27683.2004	3	9227.73345	5.3489388	0.00159518	2.66657421
Within Groups	251872.219	146	1725.15218			
Total	279555.419	149				

Amherst Urban Change 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	114	370.480686	3.24983058	248.467464		
LOW	23	318.429896	13.8447781	733.328296		
MEDIUM	7	354.740616	50.6772309	1712.13775		
HIGH	6	598.627695	99.7712825	0.31387005		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	65335.1826	3	21778.3942	58.3587801	7.4546E-25	2.66657421
Within Groups	54484.4418	146	373.181108			
Total	119819.624	149				

Amherst Urban Change 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	938.465706	8.93776863	582.880533		
LOW	23	655.340833	28.4930797	1770.42579		
MEDIUM	7	229.457349	32.7796213	2200.75895		
HIGH	6	600	100	0		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	52935.1286	3	17645.0429	21.4356294	1.9161E-11	2.67068687
Within Groups	112773.497	137	823.164208			
Total	165708.625	140				

Amherst Forest-Urban Fringe 50m Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	114	466.79536	4.09469614	53.036541		
LOW	23	155.944739	6.78020605	41.2672886		
MEDIUM	7	106.906705	15.2723864	191.788062		
HIGH	6	155.951452	25.9919086	261.910991		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3426.35721	3	1142.11907	17.8126448	6.6063E-10	2.66657421
Within Groups	9361.29281	146	64.1184439			
Total	12787.65	149				

Amherst Forest-Urban Fringe 100m Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	114	880.922843	7.72739336	129.247919		
LOW	23	314.75114	13.6848322	146.207512		
MEDIUM	7	181.664506	25.9520723	472.347719		
HIGH	6	261.446377	43.5743961	514.062719		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9317.38666	3	3105.79555	19.52323	1.0672E-10	2.66657421
Within Groups	23225.98	146	159.082055			
Total	32543.3667	149				

New Glasgow Berry 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	1316.52254	14.9604835	432.606822		
LOW	44	835.206283	18.981961	412.63613		
MEDIUM	11	194.023956	17.6385415	471.005034		
HIGH	7	95.4524736	13.6360677	134.67252		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	543.675421	3	181.22514	0.43447682	0.72864048	2.66657421
Within Groups	60898.2326	146	417.111182			
Total	61441.908	149				

New Glasgow Berry 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	2952.87994	33.5554538	1311.33771		
LOW	44	2006.60662	45.604696	1211.06312		
MEDIUM	11	478.335751	43.4850683	1310.04778		
HIGH	7	288.789035	41.2555764	775.175944		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4683.34889	3	1561.1163	1.23929358	0.29768936	2.66657421
Within Groups	183913.628	146	1259.68239			
Total	188596.977	149				

New Glasgow Crops 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	457.78389	5.20208966	124.519707		
LOW	44	634.37283	14.4175643	419.168413		
MEDIUM	11	446.108556	40.5553233	906.927856		
HIGH	7	95.7606719	13.680096	523.593747		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13129.3638	3	4376.45461	15.5585309	7.8124E-09	2.66657421
Within Groups	41068.2973	146	281.289708			
Total	54197.6611	149				

New Glasgow Crops 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	1233.85906	14.0211257	616.82361		
LOW	44	1426.61102	32.4229776	1275.82107		
MEDIUM	11	723.611686	65.7828805	1536.59954		
HIGH	7	204.593566	29.2276523	992.459202		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31278.8499	3	10426.2833	11.7235223	6.3016E-07	2.66657421
Within Groups	129844.711	146	889.347334			
Total	161123.561	149				

New Glasgow Urban Change 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	163.668578	1.8598702	125.098706		
LOW	44	580.468925	13.1924756	461.784466		
MEDIUM	11	288.370643	26.215513	995.668622		
HIGH	7	387.882601	55.4118001	2059.44616		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23565.2161	3	7855.07203	21.6166053	1.2147E-11	2.66657421
Within Groups	53053.6826	146	363.381388			
Total	76618.8987	149				

New Glasgow Urban Change 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	280.41673	3.18655375	224.29759		
LOW	44	1113.52489	25.3073839	1213.18904		
MEDIUM	11	508.580872	46.2346248	1354.13186		
HIGH	7	462.053401	66.0076287	2079.28925		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	45812.2656	3	15270.7552	22.8206165	3.5787E-12	2.66657421
Within Groups	97698.073	146	669.164884			
Total	143510.339	149				

New Glasgow Forest-Urban Fringe 50m Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	551.844544	6.27096072	17.1938207		
LOW	44	379.441189	8.62366338	92.2783196		
MEDIUM	11	150.430349	13.6754862	100.472903		
HIGH	7	143.420126	20.4885894	159.895024		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1722.06127	3	574.020423	11.2826843	1.0603E-06	2.66657421
Within Groups	7427.92932	146	50.8762282			
Total	9149.99059	149				

New Glasgow Forest-Urban Fringe 100m Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	88	1073.05382	12.1937934	63.2337619		
LOW	44	672.253437	15.2784872	217.869935		
MEDIUM	11	263.28263	23.9347845	214.383926		
HIGH	7	233.166453	33.3094932	303.857581		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3920.73827	3	1306.91276	10.1296388	4.2004E-06	2.66657421
Within Groups	18836.7292	146	129.018693			
Total	22757.4675	149				

Waverley Berry 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	41.276656	0.39311101	16.2263079		
LOW	33	22.094595	0.66953318	14.7930645		
MEDIUM	7	30.937909	4.41970129	136.736316		
HIGH	5	15.709445	3.141889	49.3573324		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	136.419065	3	45.4730216	2.08856863	0.10426864	2.66657421
Within Groups	3178.76131	146	21.7723378			
Total	3315.18038	149				

Waverley Berry 2km Buffer Layer

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	144.92612	1.38024876	100.007373		
LOW	33	103.994429	3.15134633	242.632022		
MEDIUM	7	95.606263	13.6580376	1280.49634		
HIGH	5	80.534349	16.1068698	1297.15627		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1926.1935	3	642.064498	3.02035123	0.03176985	2.66657421
Within Groups	31036.5946	146	212.579415			
Total	32962.7881	149				

Waverley Crop 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	130.414436	1.242042248	64.17036976		
LOW	33	1.486035	0.045031364	0.066918182		
MEDIUM	7	0	0	0		
HIGH	5	0	0	0		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	46.06226239	3	15.35408746	0.335791467	0.79947559	2.66657421
Within Groups	6675.859837	146	45.72506738			
Total	6721.922099	149				

Waverley Crops 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	420.863869	4.00822732	289.005487		
LOW	33	46.343811	1.40435791	65.0832975		
MEDIUM	7	0	0	0		
HIGH	5	0	0	0		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	296.781249	3	98.9270828	0.44939942	0.71810046	2.66657421
Within Groups	32139.2362	146	220.131755			
Total	32436.0175	149				

Waverley Urban Change 1km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	8318.98034	79.2283842	1488.86946		
LOW	33	2989.8468	90.6014182	567.455538		
MEDIUM	7	700	100	0		
HIGH	5	499.973353	99.9946706	0.00014201		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6844.46959	3	2281.48986	1.92540804	0.12802887	2.66657421
Within Groups	173001.002	146	1184.93837			
Total	179845.471	149				

Waverley Urban Change 2km Buffer Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	9203.07363	87.6483203	886.876832		
LOW	33	3190.84899	96.6923936	303.409237		
MEDIUM	7	700	100	0		
HIGH	5	500	100	0		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3199.890364	3	1066.63012	1.52757946	0.20983673	2.66657421
Within Groups	101944.2862	146	698.248535			
Total	105144.1765	149				

Waverley Forest-Urban Fringe 50m Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	2467.2492	23.4976114	521.113167		
LOW	33	1464.97592	44.3932097	447.572231		
MEDIUM	7	311.194195	44.4563135	153.13364		
HIGH	5	296.627041	59.3254082	741.522778		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	17028.0405	3	5676.01349	11.4456344	8.7446E-07	2.66657421
Within Groups	72402.9737	146	495.910779			
Total	89431.0142	149				

Waverley Forest-Urban Fringe 100m Layer

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
NONE	105	3810.26914	36.2882775	872.943755		
LOW	33	2030.5495	61.5318029	517.676233		
MEDIUM	7	445.853284	63.6933262	113.888328		
HIGH	5	371.414705	74.2829411	604.781436		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23665.01399	3	7888.338	10.4269179	2.9391E-06	2.66657421
Within Groups	110454.2457	146	756.53593			
Total	134119.2597	149				

Tukey Testing Results

Amherst Berry 1km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	3.3207	0.091983	insignificant
A vs C	2.3665	0.3417862	insignificant
A vs D	4.2862	0.0151403	* p<0.05
B vs C	0.3763	0.8999947	insignificant
B vs D	2.2605	0.3837377	insignificant
C vs D	1.5706	0.6628698	insignificant

Amherst Berry 2km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	4.7919	0.004958	** p<0.01
A vs C	3.4718	0.0716667	insignificant
A vs D	3.2936	0.0961495	insignificant
B vs C	0.5944	0.8999947	insignificant
B vs D	0.62	0.8999947	insignificant
C vs D	0.0497	0.8999947	insignificant

Amherst Crop 1km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	3.6081	0.0564696	insignificant
A vs C	3.9298	0.0310631	* p<0.05
A vs D	5.427	0.0010494	** p<0.01
B vs C	1.6344	0.6376529	insignificant
B vs D	3.1595	0.1191006	insignificant
C vs D	1.3352	0.7559145	insignificant

Amherst Crops 2km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	3.124	0.1254387	insignificant
A vs C	2.7846	0.2046033	insignificant
A vs D	4.3946	0.0120295	* p<0.05
B vs C	0.8576	0.8999947	insignificant
B vs D	2.4576	0.3081504	insignificant
C vs D	1.3596	0.7462763	insignificant

Amherst Urban Change 1km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	3.3932	0.0818363	insignificant
A vs C	8.9165	0.0010053	** p<0.01
A vs D	16.8701	0.0010053	** p<0.01
B vs C	6.2465	0.0010053	** p<0.01
B vs D	13.7222	0.0010053	** p<0.01
C vs D	6.4601	0.0010053	** p<0.01

v

Amherst Urban Change 2km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	4.3232	0.0140031	* p<0.05
A vs C	3.0913	0.1318553	insignificant
A vs D	10.9435	0.0010053	** p<0.01
B vs C	0.4993	0.8999947	insignificant
B vs D	7.8433	0.0010053	** p<0.01
C vs D	6.0753	0.0010053	** p<0.01

Amherst Forest-Urban Fringe 50m Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	2.0749	0.4611052	insignificant
A vs C	5.0697	0.0025672	** p<0.01
A vs D	9.2331	0.0010053	** p<0.01
B vs C	3.4745	0.0713352	insignificant
B vs D	7.4017	0.0010053	** p<0.01
C vs D	3.4029	0.0805228	insignificant

Amherst Forest-Urban Fringe 100m Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	2.9223	0.1692656	insignificant
A vs C	5.2477	0.0016557	** p<0.01
A vs D	9.5961	0.0010053	** p<0.01
B vs C	3.1864	0.1141882	insignificant
B vs D	7.3108	0.0010053	** p<0.01
C vs D	3.5516	0.0624102	insignificant

New Glasgow Berry 1km Buffer Layer

Tukey HSD Results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	1.5082	0.6875447	insignificant
A vs C	0.5799	0.8999947	insignificant
A vs D	0.2335	0.8999947	insignificant
B vs C	0.276	0.8999947	insignificant
B vs D	0.9097	0.8999947	insignificant
C vs D	0.5732	0.8999947	insignificant

New Glasgow Berry 2km Buffer Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	2.6003	0.2596167	insignificant
A vs C	1.2372	0.7946681	insignificant
A vs D	0.7813	0.8999947	insignificant
B vs C	0.2505	0.8999947	insignificant
B vs D	0.4259	0.8999947	insignificant
C vs D	0.1837	0.8999947	insignificant

New Glasgow Crops 1km Buffer Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	4.2086	0.017793	* p<0.05
A vs C	9.3215	0.0010053	** p<0.01
A vs D	1.8204	0.5641371	insignificant
B vs C	6.538	0.0010053	** p<0.01
B vs D	0.1528	0.8999947	insignificant
C vs D	4.687	0.0063066	** p<0.01

New Glasgow Crops 2km Buffer Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	4.7263	0.0057674	** p<0.01
A vs C	7.6755	0.0010053	** p<0.01
A vs D	1.8363	0.5578512	insignificant
B vs C	4.6929	0.0062217	** p<0.01
B vs D	0.3724	0.8999947	insignificant
C vs D	3.5854	0.0587902	insignificant

New Glasgow Urban Change 1km Buffer Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	4.5535	0.0085105	** p<0.01
A vs C	5.6501	0.0010053	** p<0.01
A vs D	10.1167	0.0010053	** p<0.01
B vs C	2.8661	0.1829565	insignificant
B vs D	7.6972	0.0010053	** p<0.01
C vs D	4.4799	0.010001	* p<0.05

New Glasgow Urban Change 2km Buffer Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	6.5498	0.0010053	** p<0.01
A vs C	7.3591	0.0010053	** p<0.01
A vs D	8.7455	0.0010053	** p<0.01
B vs C	3.3939	0.0817396	insignificant
B vs D	5.4681	0.0010053	** p<0.01
C vs D	2.2358	0.3938309	insignificant

New Glasgow Forest-Urban Fringe 50m Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.5264	0.2841872	insignificant
A vs C	4.5907	0.0078355	** p<0.01
A vs D	7.1782	0.0010053	** p<0.01
B vs C	2.9713	0.1577251	insignificant
B vs D	5.7811	0.0010053	** p<0.01
C vs D	2.7939	0.2020316	insignificant

New Glasgow Forest-Urban Fringe 100m Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.0801	0.4589344	insignificant
A vs C	4.571	0.008186	** p<0.01
A vs D	6.6946	0.0010053	** p<0.01
B vs C	3.1971	0.1122723	insignificant
B vs D	5.5169	0.0010053	** p<0.01
C vs D	2.4141	0.3237993	insignificant

Waverley Berry 1km Buffer Layer

Tukey HSD Results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.5082	0.6875447	insignificant
A vs C	0.5799	0.8999947	insignificant
A vs D	0.2335	0.8999947	insignificant
B vs C	0.276	0.8999947	insignificant
B vs D	0.9097	0.8999947	insignificant
C vs D	0.5732	0.8999947	insignificant

Waverley Berry 2km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	0.8608	0.8999947	insignificant
A vs C	3.0508	0.140202	insignificant
A vs D	3.1206	0.1260901	insignificant
B vs C	2.449	0.3112146	insignificant
B vs D	2.6185	0.253762	insignificant
C vs D	0.4057	0.8999947	insignificant

Waverley Crop 1km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.2544	0.7878529	insignificant
A vs C	0.6654	0.8999947	insignificant
A vs D	0.5675	0.8999947	insignificant
B vs C	0.0226	0.8999947	insignificant
B vs D	0.0196	0.8999947	insignificant
C vs D	0	0.8999947	insignificant

Waverley Crops 2km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	1.2437	0.7921077	insignificant
A vs C	0.9787	0.8968393	insignificant
A vs D	0.8347	0.8999947	insignificant
B vs C	0.3217	0.8999947	insignificant
B vs D	0.2789	0.8999947	insignificant
C vs D	0	0.8999947	insignificant

Waverley Urban Change 1km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.3413	0.3515383	insignificant
A vs C	2.1861	0.4143724	insignificant
A vs D	1.8638	0.5469527	insignificant
B vs C	0.9279	0.8999947	insignificant
B vs D	0.8041	0.8999947	insignificant
C vs D	0.0004	0.8999947	insignificant

Waverley Urban Change 2km Buffer Layer

Tukey HSD results			
treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inferfence
A vs B	2.4254	0.3197013	insignificant
A vs C	1.6934	0.6143133	insignificant
A vs D	1.4442	0.7128491	insignificant
B vs C	0.4254	0.8999947	insignificant
B vs D	0.3689	0.8999947	insignificant
C vs D	0	0.8999947	insignificant

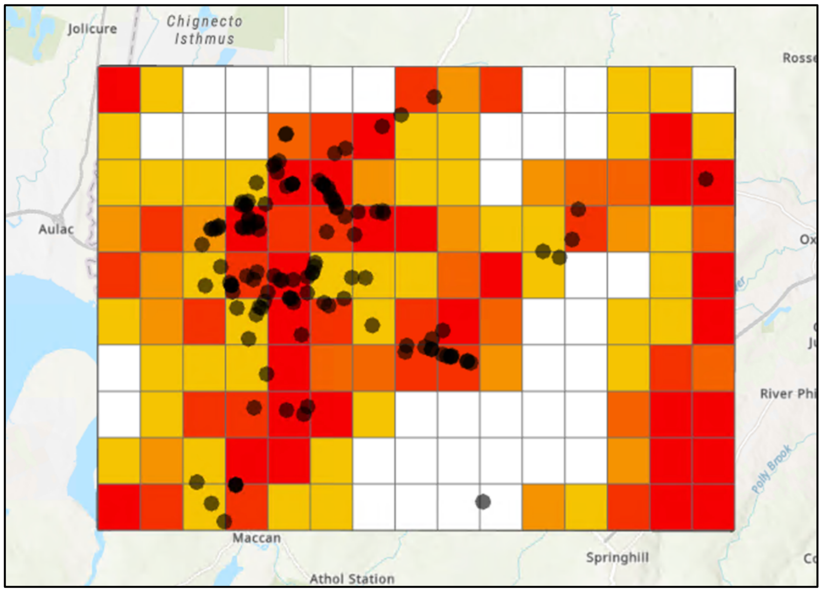
Waverley Forest-Urban Fringe 50m Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	6.6494	0.0010053	** p<0.01
A vs C	3.4097	0.0796196	insignificant
A vs D	4.9707	0.0032577	** p<0.01
B vs C	0.0096	0.8999947	insignificant
B vs D	1.976	0.5026172	insignificant
C vs D	1.6127	0.6462476	insignificant

Waverley Forest-Urban Fringe 100m Layer

Tukey HSD results			
treatments	Tukey HSD	Tukey HSD	Tukey HSD
pair	Q statistic	p-value	inferfence
A vs B	6.5037	0.0010053	** p<0.01
A vs C	3.6097	0.0563097	insignificant
A vs D	4.2678	0.0157355	* p<0.05
B vs C	0.2671	0.8999947	insignificant
B vs D	1.3662	0.7436909	insignificant
C vs D	0.9299	0.8999947	insignificant

Fishnet Grid Example: Berry 2km Buffer, Amherst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