The Habitat Preference of The Invasive Common Buckthorn in West Holland Sub-watershed, Ontario

by

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A thesis submitted in conformity with the requirements for the degree of Master of Forest Conservation
Faculty of Forestry
University of Toronto

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Abstract

The project objective is to examine the habitat preference of the invasive common buckthorn \((Rhamnus cathartica)\) in West Holland Sub-watershed located in the Lake Simcoe Watershed in Ontario. Filed data from monitoring plots, dispersed throughout the West Holland, were collected as part of the natural cover monitoring in the watershed during the summer of 2017. In my capstone project, I will 1) examine the possible plot characteristics that are related to common buckthorn presence; 2) explore whether and how common buckthorn abundance is related to the plot characteristics and disturbance; 3) determine the relationship between common buckthorn and other plants in the plot; and 4) give recommendations regard to current common buckthorn issue. This research can improve the knowledge of the invasive common buckthorn in Lake Simcoe Watershed, which is crucial because the non-native common buckthorn is distributed extensively across southern Ontario.
Acknowledgments

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1 Background

Common buckthorn (*Rhamnus cathartica*) is a European plant species introduced to North America in 19 centuries or earlier (Torrey 1824, p. 263). The first European settlers widely planted it as hedgerows and windbreaks. Presently, common buckthorn is widely spread across eastern North America, including southern Ontario. During the VSP inventory in 2017 summer, the common buckthorn had been found in many plots sampled across the Lake Simcoe Watershed. Usually, the common buckthorn is found in the ground vegetation and shrub layers, however, in some plot, it even grew as the sub-canopy.

Common buckthorn is a plant proved to be very invasive (J. S. Kurylo, Knight, Stewart, & Endress, 2007; Moser, Fan, Hansen, Crosby, & Fan, 2016). Due to its aggressive nature and adverse effects to agriculture such as supporting oat rust fungus to spread rust disease (Heneghan, Rauschenberg, Fatemi, & Workman, 2004), common buckthorn has been listed under Ontario’s Weed Control Act (MNRF, 2012). Its strong invasiveness can be partially explained by its ability to adapt to various habitats. Common buckthorn can grow in either wet or dry site conditions (Knight, Kurylo, Endress, Stewart, & Reich, 2007). Sometimes it can even survive in periodic floods (J. Kurylo, Raghu, & Molano-Flores, 2015). Buckthorn has expended its range and establish in new areas due to its ability to tolerate harsh environments.

Common buckthorn has many negative impacts on native ecosystem. These impacts range from changing composition and function of plant communities to impacting fauna. For example, the active pattern of mammals could be altered easily by common buckthorn presence (Vernon, Magle, Lehrer, & Bramble, 2014). For example, it has been found that coyotes (*Canis latrans* Say) are more likely to be found in areas with common buckthorn, while the white-tail deer (*Odocoileus virginianus* Zimm.) appears more frequently in areas without common buckthorn (Vernon et al., 2014). Research shows that common buckthorn could interference the animal-habitat relationship by disturbing the dispersal pattern of native seeds (Guiden & Orrock, 2017). Common buckthorn could also impact bird populations. As a shrub, common buckthorn provides habitat for the birds that build their nest in it. However, other avian communities, mostly aerial and ground nesters, will decrease when the proportion of invasive shrub goes up (Schneider & Miller, 2014). Besides, American scientists found that beetle and ant species are more diverse in a plot without the common buckthorn (Schuh & Larsen, 2015). Moreover, the non-native plant
could change the plant composition in certain plant community. The change of composition is usually observed after the plant community invaded by a non-native plant (Larkin, Steffen, Gentile, & Zirbel, 2014). The non-native plant could become a dominating competitor for the limited resource in the ecosystem, therefore, suppress other native plant species, and result in plant species composition change.

Invasive plants not only have impacts on the terrestrial organism but also influences aquatic communities. Common buckthorn in a riparian forest might influence the stream food web by shading the stream for the longer duration (Freund, Thobaben, Barkowski, & Reiho, 2013). According to Freund et al. (2013), the leaf of common buckthorn will not fall until the middle of November, which is one month later than other native plants. There is less canopy opening when invaded by common buckthorn, and less sunlight reaches the stream comparing to the light condition before common buckthorn invasion. The lack of sunlight in stream result in lower primary production which might influence the stream food web.

The issue of the common buckthorn invasion, along with its negative impacts on local ecosystem suggests that control is urgently needed. Knowing the habitat preference of an invasive species is the first step to establish an effective management plan. Many research about common buckthorn did in the north and middle of the US in past decades (e.g., Heneghan et al., 2006; Heneghan, Rauschenberg, Fatemi, & Workman, 2004; McCay & McCay, 2009; Moser et al., 2016). Since the invaded range of common buckthorn is expanding into northern US and Canada nowadays, more and more Canadian research contribute to this common buckthorn issue. Researcher considers the Canadian Shield as a barrier that could impede the invasion of common buckthorn because of its unique substrate composition (J. S. Kurylo et al., 2007). However, the study area, Lake Simcoe Watershed in southern Ontario, is located southern to the Canadian Shield. Therefore, the study area is susceptible to common buckthorn and might provide a suitable habitat for it. The project will analyze the factors that might influence the common buckthorn presence across the study area, then identify whether and how these factors impact on common buckthorn distribution. Most of the factors are plot characteristics recorded by literature, collected as part of the sampling this summer or derived based on personal observation during the summer inventory.
Several approaches are used to test the hypothesis that the common buckthorn presence is related to factors such as canopy cover, vegetation type, disturbance, plant diversity, and plot surface. In terms of canopy closure, common buckthorn can survive in both open and shady area (Knight et al., 2007; J. S. Kurylo et al., 2007). In native distribution area, they are likely to be found in open space with low canopy closure (J. S. Kurylo et al., 2007). In North America, buckthorn can be found in a dense forest (J. S. Kurylo et al., 2007). The hypothesis is that the more closed canopy has less common buckthorns abundance.

Apart from canopy closure, distribution of common buckthorn might be influenced by a specific vegetation type, either wetland or terrestrial. Common buckthorn prefers moist but not saturated soils and as such typically is found in a non-wetland area (J. S. Kurylo et al., 2007). However, during this summer inventory, many buckthorns are observed in wetland plot, especially in the wetland without stagnant water. Therefore, the hypothesis is the presence of common buckthorn in the wetland is similar with that in the terrestrial environment.

The distribution of common buckthorn might also be impacted by disturbance and environmental characteristics of a site. Research shows that common buckthorn prefers disturbed areas and their abundance might relate to anthropogenic influences and historical land-use (J. S. Kurylo et al., 2007; McDonald, Motzkin, & Foster, 2008). Following disturbance, ecosystem is more susceptible to invasive species (Davis, Grime, & Thompson, 2000). The sub-division development, other human disturbances and land-use change in the West Holland area might contribute to the invasion of common buckthorn. The hypothesis for disturbances is that the common buckthorn is more likely to appear in an area with anthropogenic disturbance.

There is no general agreement about the relationship between species richness and the invasion of exotic plants in the previous study. In the U.S., a positive correlation between species richness and exotic invasion is found in riparian areas and uplands (Brown & Peet, 2003). However, Davis (2000) argues there is no necessary relationship between diversity in a plant community and its susceptibility to invasion of exotic plants. I hypothesize that no relationship is found between the common buckthorn abundance and plant diversity within a plot. As for the relationship between plant species, my hypothesis is there might be specific species in plant communities, either in canopy or ground layer, related to common buckthorn presence.
Common buckthorn is found in many forests in the Lake Simcoe Watershed. Its control and management should be one of the priorities in Lake Simcoe Protection Plan (Lake Simcoe Project Team, 2009). Gaining additional knowledge of its habitat preferences is essential as the more we know about the plant, the more specific we can do in control, and therefore our actions will be targeted and more cost-effective.
2 Materials and Methods

2.1 Study area

This study is conducted at West Holland, a sub-watershed area in Southwest of the Lake Simcoe Watershed. The dominant land-use in the Lake Simcoe Watershed contains agricultural, urban and natural. The watershed includes provincially-significant conservation area and prime agriculture areas such as West Holland (Lake Simcoe Project Team, 2009). Considered as an essential agriculture area, the West Holland Sub-watershed has the specialty crop area, Holland Marsh (Lake Simcoe Project Team, 2009). In West Holland, the percent of natural cover, woodland cover, riparian cover and interior forest cover is below the guideline level of Lake Simcoe Watershed due to historical reason (Lake Simcoe Project Team, 2009). This suggests my study area tend to have less intact forest but more human disturbance comparing to other sub-watersheds around the Lake Simcoe.

2.2 Methods

For this study 35 randomly selected sampling plots (Appendix 1) that are representative of local vegetation type were used to support analysis. The data were collected in summer of 2017, and it is part of Vegetation Sampling Protocol (VSP) program. The shape of a fixed area plot is circular, with the radius of 11.28 meter and the area of 400 square meters (Puric-Mladenovic and Kenny, 2016). For each plot, the vegetation structure, the vegetation composition as well as plot characteristics were recorded. Among the collected data, the following information was used in my research: 1) vegetation type; 2) canopy cover; 3) disturbance appearance; 4) plot surface; 5) plant species and abundance.

The data is collected according to the procedure used by Puric-Mladenovic and Kenny (2016). For each plot, the canopy cover was collected in five 1x1 sub-plots, and the average of five sub-plots represent the canopy cover of the plot. The disturbance appears in each plot such as tree cutting, dumping and disease were also recorded. Each category of disturbance was recorded as the present percentage in each plot respectively. As for plot surface, it was determined using ground cover percentage and classified into five categories: exposed soil, woody debris, trial, water, leaf litter and vegetation ground cover. The type of surface rock and surface stone is
excluded from research because of they only response to topographical features in a specific area but not in my target study area.

The plant diversity of each plot is presented by two indexes: plant species richness and Shannon-Wiener index. The plant species richness is the number of species that appear in one plot, and the Shannon-Wiener index (Shannon, 1948) is calculated as Eq. (1):

$$H^* = - \sum_{i=1}^{R} \frac{N_i}{N} \cdot \ln \frac{N_i}{N}$$

Eq. (1)

Where:
- \(N_i\): the relative cover of species \(i\)
- \(N\): the sum of relative cover in a plot
- \(R\): the number of plant species in a plot

Statistical test was used to analyse the difference between plots with and without common buckthorn in canopy cover, plant diversity and vegetation type (SAS enterprise guide 7.1). To be specific, t-tests were conducted to examine whether the vegetation type would influence common buckthorn presence and abundance, and if the plant diversity index is related to common buckthorn presence; the relationship between canopy cover and common buckthorn presence was determined by logistic regression; factorial ANOVA was used to find out if slope position and microtopography have an impact on common buckthorn presence. The DBH distribution and diversity calculations are done in Office Excel (Excel 365), and the Excel will also illustrate the overall data through graphs.

In addition to statistical tests and ANOVA, the principal component analysis (PCA) was used to explore whether and how common buckthorn presence is related to disturbance, plot surface and other plants in the ecosystem. PCA analysis was done using Canoco (version 4.5). Presence of common buckthorn was plotted in relation to various disturbance and plot surface respectively (in PCA on correlation matrix). Understory plants, canopy trees and their relationship with common buckthorn presence were also analysed using PCA.
3 Results

3.1 Difference between plots with common buckthorn presence and absence

As can be seen from the Appendix 2, 40% (14) plots are invaded by the common buckthorn. Of these 14 invaded plots, about 21% of them have common buckthorn in sub-canopy (Appendix 2), indicating that these common buckthorns are of a substitutional size and older since they have reached sub-canopy.

The average DBH of the plots with common buckthorn (Figure 1), is slightly lower (2.8 cm) than that of the plot without common buckthorn.

![Figure 1. The average DBH (cm) of plots with common buckthorn and plots without common buckthorn.](image)

This difference in average DBH reveals the plot with common buckthorn might have younger age structure. The results also show (Table 1) that 70% plots with common buckthorn are of younger age structure.
Table 1. The age structure of plots. The data was extracted from Appendix 3. When the young represent the DBH of majority trees in this plot is 15 cm to 25 cm; old represent most trees have DBH over 45 cm; others are recorded as a medium.

<table>
<thead>
<tr>
<th>Age Structure</th>
<th>Young</th>
<th>Medium</th>
<th>Old</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot with Common buckthorn</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Plot without Common buckthorn</td>
<td>12</td>
<td>4</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>8</td>
<td>2</td>
<td>31</td>
</tr>
</tbody>
</table>

The Shannon-Wiener index and plant species richness are used to analyze plant diversity. The results of t-test on both indexes show no significant difference between plots with the presence of common buckthorn and its absence. The box plot of two indexes shows a different trend (Figure 2). The plots with common buckthorn have higher average species richness than plots without common buckthorn (Figure 2b). However, regarding Shannon-Wiener index, the average index value of plots with common buckthorn is lower (Figure 2a) than for those without it.

Figure 2. Shannon-Wiener index (a) and Species Richness (b) of study plots grouped by common buckthorn presence/absence.
When comparing common buckthorn across terrestrial and the wetland sites, the percentage of common buckthorn is higher in terrestrial plots than in wetlands (Appendix 4). Almost half (44%; 12 out of 27 plots) of the terrestrial plots have common buckthorn, while 25% of wetland plots have it (Appendix 4). Further t-test showed that there is no statistically significant difference in common buckthorn abundance between terrestrial and wetland areas ($p=0.3550$), neither do the presence of common buckthorn ($p=0.3386$).

Other potential factors such as canopy cover, positions, microtopography, and surfaces which might influence the presence of common buckthorn were also explored. Logistic regression shows that canopy does not have a significant influence on common buckthorn presence ($p=0.3484$). The result of factorial ANOVA indicates that different slope positions and microtopography are not the reason for common buckthorn abundance difference or presence ($p=0.6062$ and $p=0.9204$, respectively).

Site characteristics, captured during sampling as plot surfaces, such as trials, water, leaf litter might relate to common buckthorn presence (Figure 3). In common buckthorn present plot, the average trail cover and water cover is seven times and five times respectively higher than that in common buckthorn absent plot (Appendix 5). The average woody debris does not differ among plots with and without common buckthorn (Figure 3a). Plots with common buckthorn have 20% more leaf litter cover than plot without buckthorn (Appendix 5).

Figure 3. Average values of plot characteristics (plot surface) for plots with and without common buckthorn presence. (a, mean±10%E), (b, mean±SE).
When plot surface characteristics were analyzed using PCA (Figure 4), it was found that trail, exposed soil and water are indicative of common buckthorn presence. The leaf litter might also be a related factor, but this relationship is not as strong as the factors listed above (Figure 4). PCA also shows that vegetation cover at plots and surface stone do not impact buckthorn presence (Figure 4).

Figure 4. Correlation PCA between plots and percentage of plot surface characteristics.
The PCA analysis based on disturbance measures indicates that presence of common buckthorn is related to various disturbance (Figure 5). The results show that most plots disturbed by anthropogenic factors have common buckthorn invaded.

Figure 5. Correlation PCA between plots and different kind of disturbances.
PCA based on tree species and ground plants was used to explore the relationship between the common buckthorn presence and other plants in plots. The results show that plots with more sugar maple (*Acer saccharum* ssp. *saccharum*) and eastern hemlock (*Tsuga canadensis*) as canopy are less likely to be invaded with common buckthorn; while plots with more red pine (*Pinus resinosa*), eastern white pine (*Pinus strobus*) and American elm (*Ulmus americana*) are more likely to face common buckthorn invasion (Figure 6).

![Covariance PCA between plots and relative cover of canopy tree (taller than 10 m) that over 20%](image)

Figure 6. Covariance PCA between plots and relative cover of canopy tree (taller than 10 m) that over 20%.

The PCA of ground layer shows that the following plants grow in plot with common buckthorn (Figure 7): Canada Goldenrod (*Solidago canadensis*), Fowl Blue Grass (*Poa palustris*), Black Raspberry (*Rubus occidentalis*), Wild Carrot (*Daucus carota*), Kentucky Blue Grass (*Poa pratensis ssp. pratensis*), European Stinging Nettle (*Urtica dioica ssp. dioica*), Virgin's Bower (*Clematis virginiana*), Tall Goldenrod (*Solidago altissima var. altissima*) and Common Dandelion (*Taraxacum officinale*). The species above are also common species could be found in open areas.

Figure 7. Correlation PCA between plots and relative cover of ground plants (less than 0.5 m) that over 5%. Species code: SOLICAN, Solidago canadensis, Canada Goldenrod; POA-PAL, Poa palustris, Fowl Blue Grass; RUBUOCC, Rubus occidentalis, Black Raspberry; DAUCCAR, Daucus carota, Wild Carrot; POA-PRP, Poa pratensis ssp. pratensis, Kentucky Blue Grass; URTIDID, Urtica dioica ssp. dioica, European Stinging Nettle; CLEMVIR, Clematis virginiana, Virgin's Bower; SOLIALA, Solidago altissima var. altissima, Tall Goldenrod; TARAOFF, Taraxacum officinale, Common Dandelion; POPUBAB, Populus balsamifera ssp. Balsamifera, Balsam Poplar.
3.2 The findings within common buckthorn present plots

The abundance of common buckthorn was used as variables in analysis within 14 plots invaded by common buckthorn. The abundance of common buckthorn in the wetland is significantly higher than terrestrial site \((p=0.0240)\). However, there are only two wetland plots while 12 other plots are upland, the sample size of two treatment is not equal. Therefore, the result is not convincing and further study is needed.

The vertical structure might influence common buckthorn abundance. As Figure 8 shows, the more layer common buckthorn present, the more abundant it will be. This figure also shows how common buckthorn start developing in a plot. When it establishes in an area as the ground cover, in the beginning, the abundance is relatively low; however, there is high chance that the abundance of common buckthorn increases dramatically after it developed to sub-canopy or canopy layer. In this case, considering the invasiveness of common buckthorn, the invaded forest will be occupied by it irreversibly in the future.

![Figure 8](image)

Figure 8. The relationship between the number of layers the common buckthorn present and their abundance in each plot invaded by common buckthorn. Layers are vertical plant structure and divide into four layers: canopy layer, sub-canopy layer, shrub layer and groundcover layer.

There is an interesting trend between canopy cover and common buckthorn abundance (Figure 9). We can find a small amount of common buckthorn in the plot with various canopy cover from 0% to 91%. However, as the abundance of common buckthorn increase to 5%, the relevant
canopy cover of the plot will become steady and fix at 60-70%. Moreover, when the common buckthorn abundance is more than 10%, the canopy cover of most plots is leveled off at about 65% (Figure 9).

Figure 9. The relationship between canopy cover and common buckthorn abundance in plots with common buckthorn
4 Discussion

Presence of common buckthorn in sub-canopy (Appendix 2) indicates that this species plays a relatively dominant role in some plots. Considering its invasive nature and seed production, it is possible that the abundance of common buckthorn in these plots would continue increasing.

Common buckthorn is more likely to appear in areas with lower average DBH (Table 1 and Figure 1). Based on the available data, it was found that common buckthorn does not appear in older woodlots that are dominated by trees with DBH over 45 cm. This trend indicates that common buckthorn might prefer to establish in a younger forest. The reason for this trend might be the young forest have relatively unsteady resource supply comparing to old forest, and this fluctuation will increase the invasivibility of the ecosystem (Davis et al., 2000). Therefore, the younger forest seems more susceptible to species invasion (Davis et al., 2000).

The species richness index only shows the number of species while the Shannon-Wiener index shows both abundance and species evenness. As Figure 2 presents, the trend of average of two diversity indexes and the trend of range aspect are opposite. The plot with common buckthorn have higher average species richness but lower Shannon-Wiener index, comparing to the plot without common buckthorn. In terms of range, the plot with common buckthorn has a relatively narrow range of species richness but a vaster range for Shannon-Wiener index. The gap between two averages (Figure 2) indicates that even though the number of species in the plot with common buckthorn might be larger (Figure 2b), the plant diversity is relatively low (Figure 2a) comparing to the plot without common buckthorn. Meanwhile, the range of two indexes (Figure 2) also told us that compared to plots with common buckthorn, although the plots without common buckthorn might have species abundance from very low to high, their plant diversity are overall higher than plots have common buckthorn invasion.

This research also showed there is no significant impacts of vegetation system, canopy cover and topography on common buckthorn presence. The results indicate that the common buckthorn can thrive in various conditions which are found to be in line with other research (Knight et al., 2007; J. S. Kurylo et al., 2007).

Presence of trails, water, exposed soil and leaf litter might impact common buckthorn presence. Plots with common buckthorn on average have trail cover that is seven times higher than that of
plots without common buckthorn (Appendix 5). The PCA result also shows that the presence of the common buckthorn in some plots is related to trail surface (Figure 4). In West Holland Sub-watersheds, humans and their pets make significant use of trails. Since the common buckthorn is widely planted in the residential area, people are likely to spread seeds by boots when they walk along trails. This will unintentionally help the common buckthorn develop in the natural area near trails.

Presence of water at a site might relate to the common buckthorn. The average water surface of plots with common buckthorn is higher comparing to plots without common buckthorn (Figure 4). Besides, PCA results suggest that three plots with common buckthorn have a strong relationship with the water factor (Figure 4). Some of the terrestrial plants are adapted to water and able to develop a unique niche in a relatively harsh environment. Common buckthorn is one of these sturdy plants and can grow in saturated land or even flooded area (J. Kurylo et al., 2015). The water resistance of common buckthorn is one of the reasons why the common buckthorn is invading so broadly (J. Kurylo et al., 2015).

The average percentage of exposed soil plots with common buckthorn is slightly lower compared to common buckthorn absent plot (Figure 3). However, in some plots, the presence of common buckthorn has a positive relationship with the percentage of exposed soil (Figure 4). The possible reason for this relationship might be the common buckthorn's interaction with earthworms. Heneghan et al. (2006) observe that a more significant group of invasive Eurasian earthworms is found in soil where common buckthorn grows, as opposed to plots without common buckthorn. The earthworms consume the leaf litter quickly and expose the soil on which the invasive plants could easily establish, hence they might form a co-invasion relationship (Roth et al., 2015). This co-invasive relationship helps the common buckthorn and invasive earthworms have a positive influence on each other. As a result, more exposed soil appears and more chance for common buckthorn to develop. This co-invasive relationship might be the reason why exposed soil is related to the common buckthorn presence in the study.

Leaf litter cover is found 20% more in plots with common buckthorn comparing to plots without common buckthorn (Figure 3b). This trend is also shown in PCA (Figure 4), as plots with common buckthorn tend to have more leaf litter than plots without common buckthorn, though not very significant. These results are consistent with the previous study on common buckthorn
seedling by Roth et al. (2015) and they consider that leaf litter positively affected common buckthorn. Another reason for more leaf litter cover in the plot with common buckthorn might be the common buckthorn tend to appear under the canopy of red pine and eastern white pine (Figure 6), where usually have thicker leaf litter because of the lower rate of decomposition comparing to deciduous forest.

The analysis of plot disturbance determined three main kinds of disturbance: biotic disturbance, environmental disturbance and anthropogenic disturbance. The same pattern appears for both biotic disturbance and environmental disturbance in all the plots. However, the pattern is different for the anthropogenic disturbance between plots with and without common buckthorn (Figure 5). A plot with more anthropogenic disturbance seems more likely to have common buckthorn.

The relationship between common buckthorn and other plants reveals that common buckthorn is less likely to be found in a plot dominated by sugar maple (Figure 6). However, common buckthorn is relatively common in a plot with abundant red pine or eastern white cedar canopy cover.

Plants from ground layer, typical of open and disturbed areas (Figure 7), are commonly found in the plot with common buckthorn. The strong relationship between common buckthorn appearance and open-field ground species that revealed by PCA indicates the common buckthorn might prefer to appear along with those ground species in the open area.

Though the common buckthorn is usually appeared along with open-field species, it can establish in a plot with canopy from 0%-90% (Figure 9). Although it has wide adaption to all kinds of canopy condition, the result implies the common buckthorn prefer canopy cover around 65% (Figure 9).

Besides this, the study has found that generally, the relative cover of common buckthorn will stay at a low level when they only establish in the ground layer; once they struggle to shrub layer and sub-canopy layer, the abundance will increase dramatically. This finding highlights the importance of common buckthorn control in the early stage.
5 Conclusions and Recommendation

This paper has investigated the factors that might influence the common buckthorn presence and abundance in the West Holland Sub-watershed in Ontario. One of significant findings is that common buckthorn is more likely to appear in a woodlot with a higher trail, water and leaf litter cover. Comparing to an old forest with larger DBH distribution, the common buckthorn prefers to establish in a younger forest with relatively low DBH. Moreover, it is less likely to be found in a mature sugar maple woodlot. Instead, common buckthorn usually grows along with red pine (plantations), eastern white pine, American elm and ground species that prefer open areas. Another interesting finding is that common buckthorn has a chance to become more abundant in a closure forest comparing to open forest. The plots with higher common buckthorn abundance all have canopy cover around 65%. Besides, the study also found that the early stage of common buckthorn has low abundance in the ground layer; but when common buckthorn become shrub layer or sub-canopy layer, the abundance will increase dramatically.

Based on my results and discussion, I recommend setting up priority zone for common buckthorn management. The following are suggestions for setting priority zone:

Firstly, list common buckthorn as a major invasive species and keep monitoring. Consider the common buckthorn is already established in many plots in West Holland Sub-watershed, the Ontario conservation community should attach significant importance to it.

Secondly, the vegetation type and canopy cover should not be considered as a factor to identify common buckthorn monitoring priority zone. The study indicate that common buckthorn could establish in various environment and might have no preference for either wetland or terrestrial vegetation type. This result agrees with the review of Knight et al. (2007) which shows the common buckthorn have broad tolerance from moisture to drought. Besides, the dense canopy cover might not necessarily be the reason that impedes the development of common buckthorn. There is no difference whether it lives in a closed forest or open area if it grows to a certain amount. The plots with higher common buckthorn abundance have similar canopy cover at about 65%.

Thirdly, we should put the monitoring priority in an area with more human disturbance. According to this study, common buckthorn is likely to be found in plots with detectable human
disturbance such as recreation and garbage dumping. As for the different surface, apart from a trail, the more exposed soil might also provide potential habitat for the common buckthorn. Thus, an area such as a forest beside the trail is very likely to be invaded by common buckthorn and we should keep monitoring on this type of land-use.

Regarding common buckthorn’s relationship with other plants in the plant community, the common buckthorn seems less common in sugar maple forest. However, the red pine plantation and forest consist of a significant amount of eastern white cedars, is likely facing common buckthorn invasion. This study also shows the presence of common buckthorn is more related to ground species that grow in an area with more human disturbance.

To conclude, for the approach of common buckthorn control, I propose setting priority monitoring zone that based on the habitat preference mentioned above. Some of the factors that should be considered are: 1) human disturbance, especially forest nearby the trail; 2) a place with canopy consists of red pine, eastern white pine and American elm; 3) a place with many open-area ground species; 4) a forest with canopy around 65%. Meanwhile, according to the study, some factors do not influence the presence of common buckthorn and there is no need to consider them when setting a priority zone. These factors are: 1) certain vegetation type; 2) slope position; 3) microtopography. Besides, some factors might impede the common buckthorn establish, such as a canopy dominated with sugar maple. We should exclude a place with these factors when setting a priority monitoring zone.

Besides, to set a threshold for priority monitoring zone might make this approach more feasible. That is, sign different score for each factor depend on its influence on common buckthorn presence and sum up the score for each zone. Classify a zone as priority monitoring zone when its score reaches this certain threshold. The detailed score that signs for each factor need further study.
References or Bibliography


Appendix 1

The location of 35 plots and the common buckthorn abundance.
Appendix 2

![Pie chart showing the invasion of common buckthorn in 35 study plots.]

- No Common Buckthorn: 21
- Common Buckthorn appears as sub-canopy: 14
- Common Buckthorn appears as groundcover or shrub: 3

The invasion of common buckthorn in 35 study plots.
(a). The DBH distribution of trees in all common buckthorn present plots that total number of trees is greater than 5; (b). The DBH distribution of trees in all common buckthorn absent plots that total number of trees is greater than 5. The horizontal axis represents DBH (cm) and the vertical axis represents the number of trees in each DBH class. The DBH class is divided into [5, 15), [15, 25), [25, 35), [35, 45) and [45, +∞ ) five classes.
Appendix 4

The situation of common buckthorn invasion in different vegetation type.

<table>
<thead>
<tr>
<th>Number of plots</th>
<th>CB Present</th>
<th>CB Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Wetland</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>21</td>
</tr>
</tbody>
</table>
## Appendix 5

Average surface percentage of plots. Classified by common buckthorn presence.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Exposed Soil</th>
<th>Woody Debris</th>
<th>Trail</th>
<th>Water</th>
<th>Leaf Litter</th>
<th>Vegetation Ground Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot with Common Buckthorn</td>
<td>0.783</td>
<td>3.286</td>
<td>2.179</td>
<td>7.536</td>
<td>66.246</td>
<td>49.679</td>
</tr>
<tr>
<td>Plot without Common Buckthorn</td>
<td>1.155</td>
<td>3.336</td>
<td>0.314</td>
<td>1.594</td>
<td>46.330</td>
<td>55.775</td>
</tr>
</tbody>
</table>