



Duffin Heights

Terrestrial Monitoring Baseline Conditions Report

March, 2013

Toronto and Region Conservation for The Living City®

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Executive Summary

The Toronto and Region Conservation Authority (TRCA) conducts a long term Regional Watershed Monitoring Program that is designed to assess the health of the region's watersheds and natural heritage features. Under this program fish, geomorphology, water quality and benthic invertebrates are being assessed regularly. In 2008, this program was augmented with the addition of a number of terrestrial long-term fixed plots. The purpose of these plots is to detect spatial and temporal trends in the vegetation, breeding bird, frog and red-backed salamander (*Plethodon cinereus*) communities within the TRCA jurisdiction.

In 2008-09, TRCA biologists established fixed plots across the jurisdiction in forest, wetland, and meadow habitats to monitor vegetation, birds, frogs, and red-backed salamanders (only birds were monitored at meadow stations). More plots will continue to be added where possible. Through the use of standardized data collection protocols, the response of the terrestrial system to various landscape changes such as increased natural cover through reforestation efforts or to increased human use of the natural area due to recent nearby urbanization can be quantitatively documented. The assessment of changes in these natural systems can then be used to better guide management actions on site with the aim of improving overall biodiversity.

In addition to the regional network, plots were established in several special projects including the Duffin Heights development area in order to monitor conditions at specific locations. In the case of Duffin Heights, there was a particular interest in monitoring changes in the forest ecosystem before, during, and after urban development in the vicinity.

The plots at Duffin Heights were set up in 2008 in forest habitat. Data covers all the years from 2008 to 2012 for birds and 2008, 2010, 2011, and 2012 for vegetation. For flora the data collected over this five year period represents the baseline conditions. Fauna species and communities are expected to respond to development impacts sooner and therefore the first two years data (2008 and 2009) establish the baseline against which subsequent data are to be compared.

The monitoring methodology employed by TRCA is very closely based on the one used by Environment Canada in its Ecological Monitoring and Assessment Network (EMAN) and the Credit Valley Conservation Authority (CVC) (EMAN 2004a, EMAN 2004b, CVC 2010). By implementing the same monitoring protocols as other agencies, especially those nearby, a larger data set is available for comparison. This is truly advantageous as the data collected in the TRCA jurisdiction can be validated by being placed into a larger context in the Greater Toronto Area or south-central Ontario which could strengthen data analysis for certain applications. For further details on the monitoring methodology used by TRCA for its forest, wetland, and meadow stations refer to Section 3.0.

Forest Health at Duffin Heights

Vegetation

The age distribution of trees at Duffin Heights indicates a young to mid-aged forest with the largest age cohort being 31-60 years old. Older trees up to or over 100 years of age are rare; the oldest trees often show an open-grown form. The composition of the forests was highly variable: 19 species were noted. White cedar (*Thuja occidentalis*) had the greatest abundance; white pine (*Pinus strobus*), trembling aspen (*Populus tremuloides*, sugar maple (*Acer saccharum* ssp. *saccharum*) and eastern hemlock (*Tsuga canadensis*) were also prominent in various plots.

The forest canopy was generally healthy with minimal crown die-back (<10%) on more than 80% of the total trees. However, some species such as Scots pine (*Pinus sylvestris*) and white ash (*Fraxinus americana*) showed more decline. A few pathogens seemed to be prevalent, notably a mysterious pine canker (probably *Caliciopsis pinea*) affecting white pine, and ash yellows affecting white and red ash (*Fraxinus americana* and *F. pennsylvanica*). Beech scale is ubiquitous. Emerald ash borer has not yet been detected. Overall mortality rates of 1-2% per year were at the borderline of what is considered normal for a healthy forest; however, this could have been related to natural thinning of densely-stocked mid-aged forest stands.

Few species are represented in the regeneration / sapling layer. Ash (white and red) accounts for the vast majority. European buckthorn (*Rhamnus cathartica*) was the most abundant shrub. Woody vines ascended into the crown of over 20% of the trees in three of the ten plots where they may be dense enough to inhibit tree recruitment.

Ground vegetation overall was heavily dominated by dog-strangling vine (*Cynanchum rossicum)*, although its prevalence varied from plot to plot. Sedges were also fairly well-represented but spring ephemerals were virtually absent. Deer browse was highly evident.

Overall biodiversity as indicated by the Floristic Quality Index was at the lower end of the average range compared to the TRCA regional rural forest plots.

The results indicate that while the forest at Duffin Heights is not in serious decline, there are nonetheless concerns about invasive species (dog-strangling vine and buckthorn) present in sufficient quantities to suppress regeneration and biodiversity, along with possible issues related to woody vine cover, deer browse, and certain tree pathogens.

Forest Birds

Baseline data collected in the first two years (the years immediately prior to onset of the major residential development) at the five stations at Duffin Heights presented an overall list of 31 breeding bird species including 14 (45%) forest-habitat dependent species. Variation of habitat guild richness across the five stations was considerable with forest species best represented at the more isolated and intact forest patches on the west edge side of the site.

The bird communities associated with the two central stations, i.e. stations in relatively close proximity to busy roads and low density residential development, were already dominated by generalist bird species. Finally, the extreme eastern station, included to provide a control sample in an area that was not expected to be impacted by the new development registered a surprisingly low richness of forest species, only a slightly higher forest-guild component than the central stations.

Over the course of the three years of monitoring at the stations immediately after the initiation of major development and throughout ongoing residential development (i.e. a period of intense heavy machinery activity), declines in the forest-guild species richness at the two western stations was apparently quite dramatic. Meanwhile, little change was noted at the already somewhat disturbed central stations although enough to bring the already low forest-bird richness to a level below that of the eastern control station. Considering the site as a whole, i.e. combining all five stations, the overall proportion of forest-species within the local bird community dropped from the initial 45% at baseline to 29% in 2012.

Red-backed Salamanders

The first three years of red-backed salamander monitoring at Duffin Heights served simply to indicate the species' absence at the station selected. In 2011 a new location, 250 metres to the south-east of the initial location, but within the same forest block, was selected and monitoring in 2012 confirmed the presence of red-backed salamanders.

Next Steps

The most important step to take is to ensure that annual monitoring continues using the same protocol(s). Five more years of data following completion of the development are needed in order to start seeing meaningful results in relation to long-term trends with urbanization for vegetation. For birds, a longer set of data will help to clarify the initial trend that is evident after these first three years of monitoring beyond the baseline period. The following are a few possible temporal trends to watch for in particular, while continuing the overall monitoring program:

- Changes in the proportion of native to exotic species cover in the forest vegetation plots. These could result from natural succession and competitive pressures and climate change, as well as impacts from urbanization

- Changes in species richness and Floristic Quality Index in the forest and wetland vegetation plots

- Continuation of the decline in forest-bird species richness and representation recorded from the monitoring stations.

- Stabilization of overall bird species richness and representation once the period of heavy building activity ends, possibly with a return of less sensitive forest species.

- Changes in red-backed salamander population.

- Impacts of emerald ash borer, or any other pests or pathogens that may irrupt

- Consider adding more plots and stations where restoration work is undertaken to assess the success of any restoration projects and improve practices.

1. Introduction

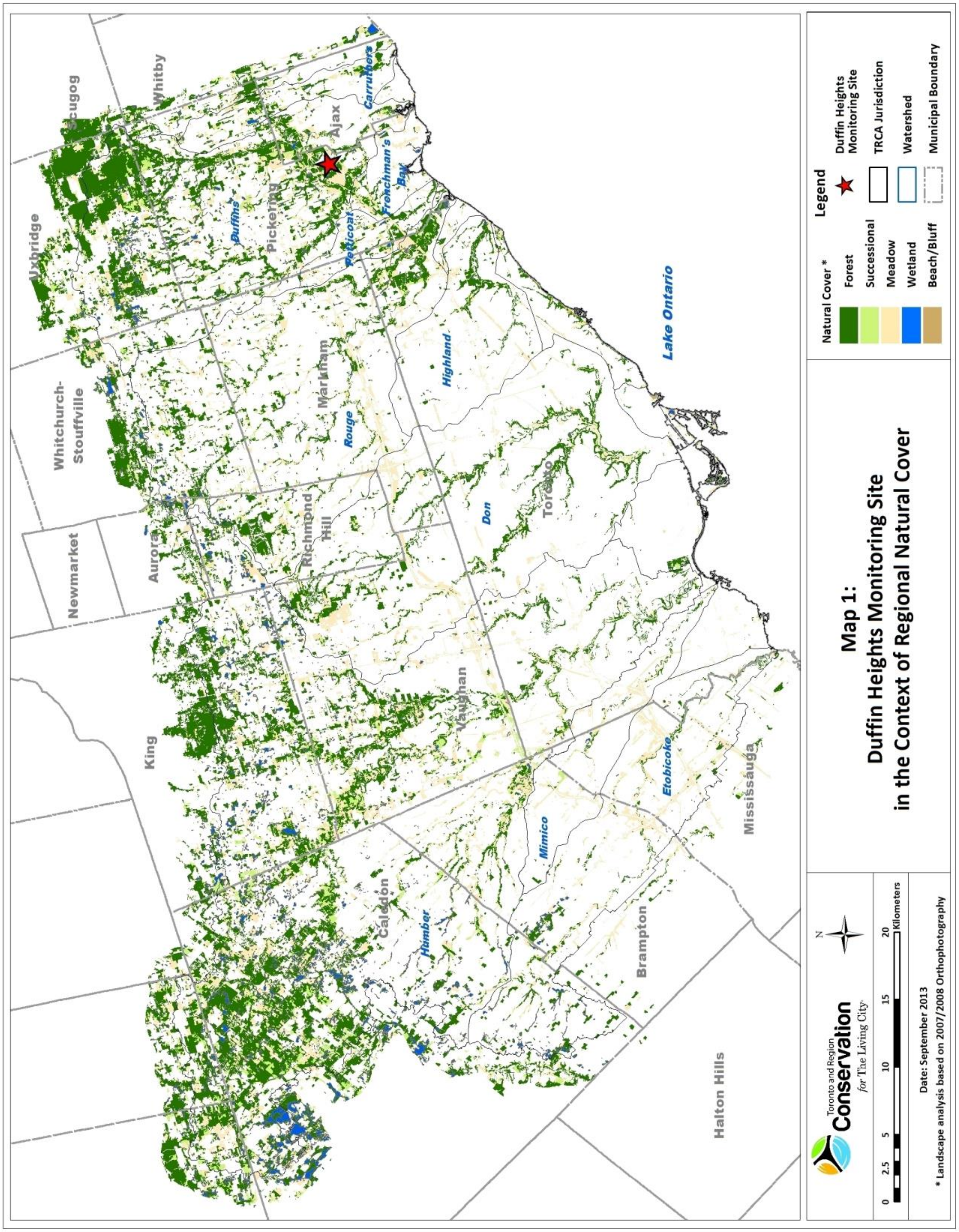
The Toronto and Region Conservation Authority (TRCA) has implemented a long-term Regional Watershed Monitoring Program (RWMP) that is designed to assess the health of the region's watersheds and natural heritage features. In 2008, this program was augmented with the addition of a number of terrestrial long-term fixed plots. The long-term monitoring plots represent an addition to other projects: the systematic natural heritage inventory and assessment information that maps comprehensive vegetation community, flora and fauna species data across the landscape, which began in the late 1990s (TRCA 2007); and the terrestrial volunteer monitoring program (started in 2002) that focuses on occurrences of a limited number of indicator species.

Toronto Region Conservation biologists established fixed plots at Duffin Heights in 2008 through funds obtained in relation to the Duffin Heights development (see Map 1). Plots were placed in forest habitat types using the TRCA's Long Term Monitoring Project (LTMP) protocol. Such habitats were identified across the entire area in 2002 when it was subject to an inventory of vegetation communities, flora, and fauna species according to the TRCA field inventory protocol (TRCA 2007). This biological inventory provided a one-time picture of the flora and fauna communities present.

The general purpose of the regional LTMP plots is to detect changes and trends in the flora and fauna communities over time. The specific objective at Duffin Heights is to gather information on the site under pre- and post-development conditions in order to quantify changes in the flora and fauna communities that can be related to urbanization impacts. This data, gathered using standardized scientific protocols, can be used to support adaptive management and additional mitigation measures during the development phases. For example, if this monitoring reveals declines in tree health and floristic quality, an attempt will be made to identify the causes of such declines and adjustments may be made to the management policies to reverse these trends. Findings from Duffin Heights may be used to inform how other development projects are implemented in terms of possible alternative practises that could be employed to reduce associated negative impacts.

Urban development began at Duffin Heights in late 2009 (after the growing and breeding seasons) with heavy machinery clearing and grading the subdivision sites. By 2012, some of the houses had been built but were not yet occupied by residents. Thus, the first two years of survey were essentially pre-development conditions, while 2010 to12 were years of construction impacts and loss of vegetation in the matrix, but did not yet have the impacts of long-term urban residency (e.g. recreational use, subsidized predators such as cats, or invasive plants escaping from backyards).

The purpose of this report is to characterize the fauna and flora communities at Duffin Heights over the course of the first five years of data collection (2008 to 2012). As the purpose of monitoring is to detect change, several years of data are required in order to have a data set that is large enough to conduct analysis and to start to identity any trends. TRCA has collected five full years of bird data. Given the full data set and the fact that bird communities react quickly to changes in the environment, it is possible to make some preliminary inferences about the impact of development so far. However, the flora data only cover four years (2008 and 2010 to 2012 with 2009 missing). Since flora communities respond more slowly to environmental changes than do fauna, the four years of flora data effectively represent a summary of pre-urbanization conditions rather than a comparison of pre- and post-development.


Map 1:
Duffin Heights Monitoring Site
in the Context of Regional Natural Cover
Natural Cover *
Forest
Successional
Meadow
Wetland
Beach/Bluff
Legend
Duffin Heights Monitoring Site
TRCA Jurisdiction
Watershed
Municipal Boundary
Toronto and Region Conservation for The Living City
N
0 2.5 5 10 15 20 Kilometers
Date: September 2013
* Landscape analysis based on 2007/2008 Orthophotography
Lake Ontario
Uxbridge
Whitby
Ajax
Pickering
Whitchurch-Stouffville
Markham
Newmarket
Aurora
Richmond Hill
King
Vaughan
Toronto
Caledon
Brampton
Mississauga
Halton Hills
Duffins
Carruthers
Frenchman's Bay
Petticoat
Highland
Rouge
Don
Humber
Mimico
Etobicoke

2. Methodology

The monitoring methodology employed at Duffin Heights is the same as that used for the TRCA's jurisdiction-wide Terrestrial Long-term Monitoring Project. By implementing the same monitoring protocols at this site, a larger data set is available for comparison. This is truly advantageous as the data collected at Duffin Heights can be validated by being placed into a larger regional context which is important during the data analysis stages. For the full monitoring methodology used by TRCA for its forest stations please refer to TRCA (2009).

2.1 Selection of Site Quality Indicators

Before plots were set up, several indicators needed to be chosen in order to interpret site quality. While measures of tree health are self-explanatory, how does one measure and interpret biodiversity?

Species richness and the relative dominance of native or exotic species are important indicators of ecosystem health. A closer look at the native flora and fauna present at a site reveals that they vary in their degrees of tolerance to disturbance. Some are indicators of high-quality remnant habitat, thus of successful preservation or restoration efforts. They are of greater conservation concern. Others occur in a wide range of disturbed habitats. Various methods of assessment can be used to interpret any observed changes in composition of plants or animals. Toronto Region Conservation has developed a local ranking system for flora and fauna species; this ranking system was designed to reflect the ability of each species to thrive in the changing landscape of the Toronto region. The ranks range from the extremely sensitive species (L1) to the largely urban tolerant species (L5), with an additional L-rank for exotic (non-native) species (L+). Ranks are reviewed annually and subject to updates (TRCA 2010). Species with ranks of L1 to L3 are considered to be of concern throughout the TRCA jurisdiction, while those ranked L4 are of intermediate sensitivity and are of conservation concern within urban and suburban landscapes such as that being created at Duffin Heights.

An additional ranking system for plants, the coefficient of conservatism (CC) was used for calculating Floristic Quality Index (FQI) of the plots. The CC is assigned to native plants and is a measure of a plant's fidelity to high-quality pristine habitats (with 10 being the most sensitive score and 0 the lowest). This system is used for various regions across North America (Masters 1997). It therefore provides us with a continent-wide standard for assessing site biodiversity and quality. TRCA uses the CC values assigned for southern Ontario plants that were documented by Oldham *et al*. (1995).

Breeding bird diversity is tracked by referring to habitat guild-groupings; these guild groupings are listed in Appendix 3 and were produced primarily through staff biologists' understanding of the various species' nesting requirements.

2.2 Forest Monitoring Methodology

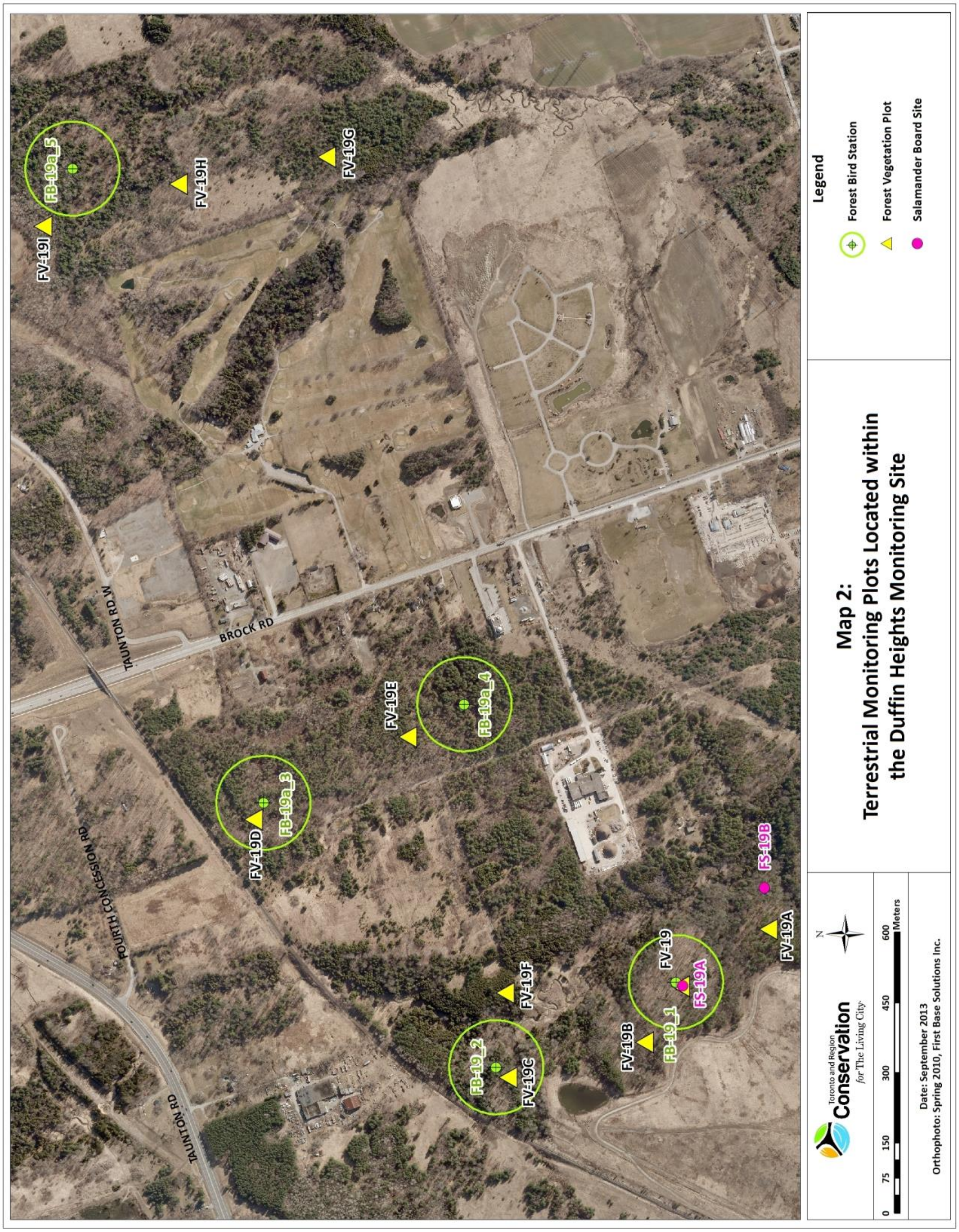
Forest monitoring plots at Duffin Heights were distributed across the study area to identify the health and condition of the vegetation and bird communities associated with forest habitat and to track changes in their condition over time (specific monitoring locations are shown on Map 2). The data will broaden the understanding of the effects of local land use and management decisions.

Specifically, vegetation monitoring within the forest plot is designed to:

- Determine the health of forests at Duffin Heights
- Determine regeneration rates in the understory of saplings
- Determine if the population and abundance of flora species, including those of conservation concern, are changing over time
- Determine the floristic quality of the site.
- Determine the rate of spread of selected invasive species, and
- To determine if non-native invasive species are replacing native species.

The purpose of establishing bird monitoring stations in the forest patches at the Duffin Heights is to facilitate management decisions regarding future development practices. The fact that the TRCA is concurrently running its Terrestrial Long-term Monitoring Project means that any trends identified through the monitoring of local bird species' populations and richness at the site can be compared to the broader regional trends. This comparison enables the TRCA to identify whether trends are due to local influences or not. Either way, future management decisions can then be steered to address these trends.

The monitoring of red-backed salamander populations (terrestrial salamanders) has been recognised as an effective method for assessing forest ecosystem health in North America (Zorn, 2008). Again, given the Terrestrial Long-term Monitoring Project in effect across the jurisdiction (at a total of 23 stations), data gathered from Duffin Heights can be analysed in comparison to data collected regionally.


Map 2:
Terrestrial Monitoring Plots Located within the Duffin Heights Monitoring Site
Legend
Forest Bird Station
Forest Vegetation Plot
Salamander Board Site
Toronto and Region Conservation for The Living City
N
0 75 150 300 450 600 Meters
Date: September 2013
Orthophoto: Spring 2010, First Base Solutions Inc.
BROCK RD
TAUNTON RD W
TAUNTON RD
FOURTH CONCESSION RD
FB-19a_5
FB-19a_4
FB-19a_3
FB-19_2
FB-19_1
FV-19I
FV-19H
FV-19G
FV-19E
FV-19D
FV-19F
FV-19C
FV-19B
FV-19
FV-19A
FS-19A
FS-19B

2.2.1 Vegetation Plots

Forest plots were set up according to standards developed by Environment Canada's Ecological Monitoring and Assessment Network (EMAN 2004a, EMAN 2004b, Roberts-Pichette and Gillespie 1999), with slight modifications. This is the same protocol used by TRCA to monitor a network of forest plots through the RWMP, and is almost identical to that used by the Credit Valley Conservation in its forest plot monitoring (CVC 2010).

Detailed information on plot set-up can be found in TRCA (2009). In summary, each forest plot consists of one 20 x 20 m square plot (i.e. 400 m^2) for monitoring tree health; and five 2 x 2 m subplots (i.e. 4 m^2) for monitoring saplings and shrubs. Four of the subplots are placed 1 m outside the perimeter of the 20 x 20 m tree health plot, and the fifth is located in its centre. Ground vegetation is measured in a 1 x 1 m subsection (1 m^2) of each subplot at its southwest quarter (Figure 1). Two visits are conducted per year: in the spring and in early-to-mid summer. While there is a 5 year period covered (2008-2012), only 1 of the 10 vegetation plots was visited in 2009, so there is in fact 4 years of data.

Ten forest vegetation plots were set up at Duffin Heights, roughly in three groups (Map 2). The four westernmost plots (FV-19, FV-19A, FV-19B, FV-19C) were located west of Ganatsekiagon Creek and beside the Brock West landfill site. Three more plots were located west of Brock Road (and east of Ganatsekiagon Creek): FV-19D, FV-19E, and FV19-F. And the three easternmost were located east of Brock Road behind the Seaton Golf Course and south of Old Taunton Road: FV-19G, FV-19H, and FV-19I. Exact GPS locations can be found in Appendix 1.

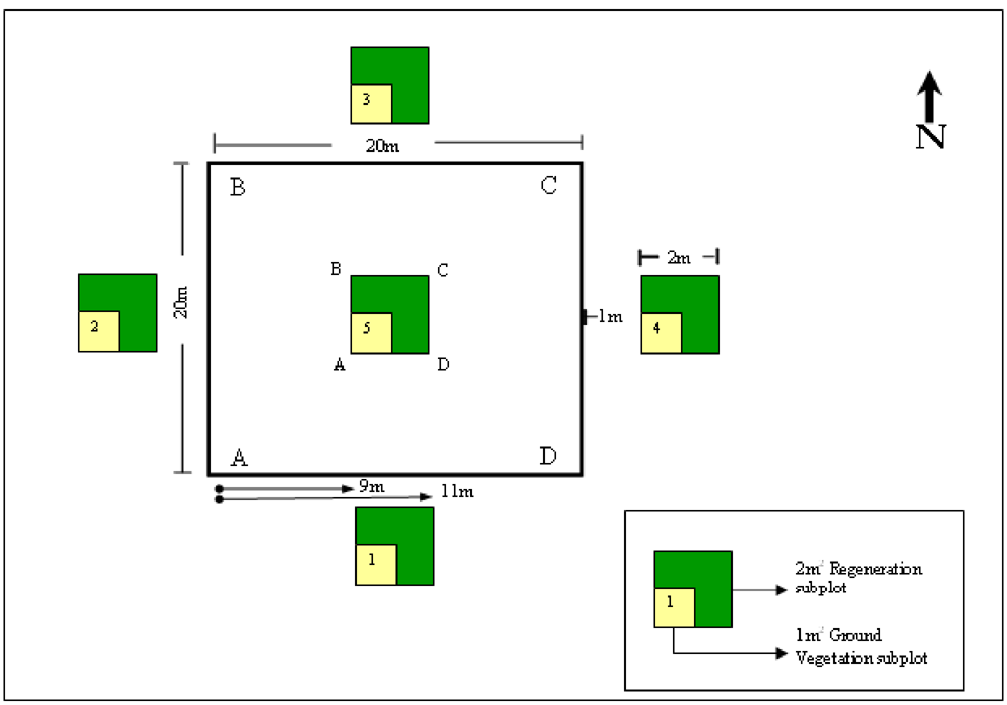


Figure 1. Forest plot design (not to scale)

Variables Monitored and Monitoring Frequency

Tree health is assessed in early-to-mid summer (late June to early August) when trees are in full leaf but prior to any late summer onset of natural leaf decline. Tree health is monitored in the 20 x 20 m plot. All trees >10 cm diameter at breast height (dbh) are assessed. Tree health assessment includes a variety of measures including; age, tree height, tree diameter, condition, crown class, crown vigour and stem defects. A detailed summary of the measures taken and their frequency is shown in Table 1. Note that stand age is assessed only once, at the time of plot set-up, while height and diameter are assessed at five-year intervals rather than annually. Crown class denotes the relative height of the tree in relation to its neighbours. Dominant trees emerge above the main canopy and receive direct sunlight on all sides of the crown. Co-dominant trees are in the main canopy and receive direct sunlight on the upper half of the crown. Intermediate trees are in the lower part of the main canopy and receive direct sunlight on a small portion of the crown. Suppressed trees are below the canopy and are completely shaded.

Tree regeneration and shrub assessment is done during the main early-to-mid summer visit (late June to early August). Assessments are undertaken in each of the 2 x 2 m subplots and include all woody plants (including vines) that are over 16 cm in height but less than 10 cm dbh. Stem counts by 6 height classes (16-35, 36-55, 56-75, 76-95, 96-200 cm and over 2 m) are recorded for each species. In addition, surveyors obtain a percentage cover estimate based on those stems that originate within the subplot. Tree saplings and shrubs are measured at the same time but are separated for analysis purposes because saplings represent the future tree canopy, while shrubs always remain in the understorey. Woody vines (also known as lianas) are counted with the shrubs, although they frequently climb into the canopy.

Ground vegetation assessment is conducted twice per year (Table 1). The first visit in May captures spring ephemerals, while the second assessment in summer at the same time as the sapling and shrub assessment captures herbaceous species that emerge more slowly and remain visible through the growing season. Ground vegetation measurements in the 1 m^2 subsections include percentage cover of vascular plants by species and also mosses and liverworts as groups. Cover assessment includes overhanging leaves as well as stems originating from within the subsection.

Finally, a total list of all vascular plant species is taken every year for each plot. This includes all types and sizes found within the 400 m^2 tree health plot as well as the subplots. The species list yields the following information:

- Total species richness (number of species)
- Number of native versus exotic species
- Occurrence of species of regional (or urban) concern (ranks L1 to L3 (L4))
- Mean coefficient of conservatism – see Masters (1997) for explanation
- Floristic Quality Index (FQI) – calculated from native species richness and mean coefficient of conservatism (TRCA 2011a).

Table 1. Forest vegetation monitoring variables and frequency

Indicator	Variable	Details	Frequency
Tree Health	Age of Stand	Cores taken from 5 trees outside plot using increment borer	Once at plot set-up
	Tree Height and Diameter	Height as measured with range-finder and diameter at breast height	At plot set-up, then every 5 years; new recruits as they appear
	Tree Status and Condition	Living/dead/damaged/leaning etc.	Annually
	Crown Class	Dominant, co-dominant, intermediate, suppressed	Annually
	Crown Vigour	Fullness of canopy, presence of dieback	Annually
	Stem Defects	Wounds, scars, seams, decay, disease, insect damage	Annually
Tree Regeneration	Stem Counts	By species in 6 height classes	Annually
	% Cover by Species	Based on all stems that originate within the subplots	Annually
Shrubs and Woody Vines	Stem Counts	By species in 6 height classes	Annually
	% Cover by Species	Based on all stems that originate within the subplots	Annually
Ground Vegetation	% Cover	Cover estimates including overhang for all species found in 1 m^2 subplot	Twice annually (spring and summer)
All Vascular Plants	Total Species Richness	All species recorded in main tree health plot plus subplots	Annually (pool both visits)
	# Native vs. Exotic	Separation of species identified into native (L1-L5) and exotic (L+)	Annually
	Occurrence of Species of Conservation Concern	Native species are subdivided into species of regional concern (L1-L3), species of urban concern (L4), and species not of concern (L5)	Annually

A photo of the forest plot is taken for documentation purposes annually. It is taken from the southwest corner of the tree health plot (post A) diagonally toward the northeast (post C). GPS co-ordinates for the plot were taken (Appendix 1).

2.2.2 Forest Bird Stations

Forest birds were monitored using the Forest Bird Monitoring Program (FBMP) protocol designed by the Ontario Ministry of Natural Resources (BSC 2008). This protocol was originally developed for use in large forest patches across the Province and plots are generally centred at least 100 m inside from the edge of the forest patch in order to target forest bird species. At the initial set-up, 5 station locations were selected which satisfy the 100 m requirement. However, as development has progressed, in the latter 3 years one of the 5 stations has been encroached upon to the extent that the station centre is now just 50 m from the west forest edge. Although this particular station no longer satisfies the FBMP protocol for long term monitoring of persistent forest habitats, the protocol still works very well as a monitoring technique at the site level, monitoring site-level changes in response to changes in habitat and the surrounding landscape.

The centre of each plot is marked with a piece of rebar hammered into the ground (with the top 2-5 cm remaining above ground) in order to be able to repeat the monitoring from exactly the same location in future visits. This location is referenced using a GPS unit to ensure repeatability at that location (see Appendix 1 for the UTM coordinates of each station).

The forest bird stations are monitored twice per year at times considered optimum for recording forest bird breeding species. The first count is conducted between 24th May and 17th June; the second count should be conducted no sooner than 10 days after the first visit and between the dates 15th June and 10th July. Many species that are recorded before the first week of June may still be passing through the area as migrants, therefore registering a second observation in late June or July supports the indication of a territorial and likely breeding individual. All counts should be completed between 05:00 am and 10:00 am. The second visit should maintain the same timing for each station, and likewise an attempt should be made to maintain the same schedule of visits in subsequent years for as long as the project runs.

Counts are conducted in weather conditions that optimize the detection of songbird species. Ideally there should be very little to no wind, and precipitation should be at most a light rain. Overnight rainfall will also potentially have considerable impact on the ability of the recorder to hear bird song and calls since the noise from dripping trees may be enough to mask quieter species.

The FBMP requires the biologist to plot every individual bird observed and heard within a 100 m circle centred on the point station over a 10 minute period. In addition, any birds identified at distances beyond the 100 m circle are mapped at their approximate position. The count period is divided into two 5 minute segments with the observations divided between them. The following metadata are recorded on the field forms: date and start time of count period, weather conditions (wind speed and direction, cloud cover and precipitation), and observer.

2.2.3 Red-backed Salamander Plot

Plethodontid salamanders are represented in the TRCA region by just one species, the eastern red-backed salamander (*Plethodon cinereus*). Local populations of red-backed salamanders are monitored by establishing grids of 40 artificial cover boards at forest stations across the jurisdiction. The cover boards are left in place for the entire year in order to “weather” before monitoring begins. Monitoring occurs over a 5 week period shortly after spring thaw (late April and early May) when frost is no longer a threat. Data collected over and above each board’s salamander count include the presence or absence of black or red ants at the board, the disturbance of soil beneath the cover board (e.g. small mammal tunnels), any disturbance of the boards themselves (either by animal or human), weather conditions (wind speed and direction, cloud cover and precipitation), indication of precipitation within the previous 24 hours, and air and soil temperatures. The following metadata are recorded on the field forms: date and start time of count period, cover board type (double or single), cover board installation year, and observer (TRCA 2011a).

A single red-backed salamander station (i.e. 40 cover boards) was installed in the fall of 2008 and then first monitored in the following spring (2009). Data from this initial site has suggested that red-backed salamanders are in fact absent from this portion of the forest (forest floor conditions may be unsuitable for the species).Therefore, in the fall of 2011, a new grid of 40 cover boards was installed approximately 270 m to the south-east of the initial site, to be monitored from spring 2012 (Map 2). This new location was selected due to the results of a 20 minute search (conducted by two field-staff) which revealed that red-backed salamanders were in the area.

3. Results

The findings documented in this report cover the first five years of monitoring from 2008 to 2012. There are a full five years of bird data and four years of vegetation data (given the gap in 2009).

3.1 Forest Vegetation

3.1.1 Age and Tree Species Composition

Stand Age and Character

The forest stands at Duffin Heights in which the 10 vegetation plots were placed are in the early mid-aged age range. Based on the sampling of trees in the vicinity of the plots at time of set-up, the dominant age cohort (as of 2012) was 31-60 years with some at 61-100 years (Figure 2). Therefore, this forest would have started growing in the 1960s and 1970s.

The overall distribution of age across the set of forest plot sites loosely resembles a classic bell curve, with smaller numbers of trees in the under-30 years of age and over-100 years of age cohorts. There was only one tree sampled that had an age of over 100 years: a hemlock (*Tsuga canadensis*) in the vicinity of FV-19C. Overall, the oldest stand was the dense grove of cedar (*Thuja occidentalis*) at FV-19F; these were all in the 70-80 year-old range.

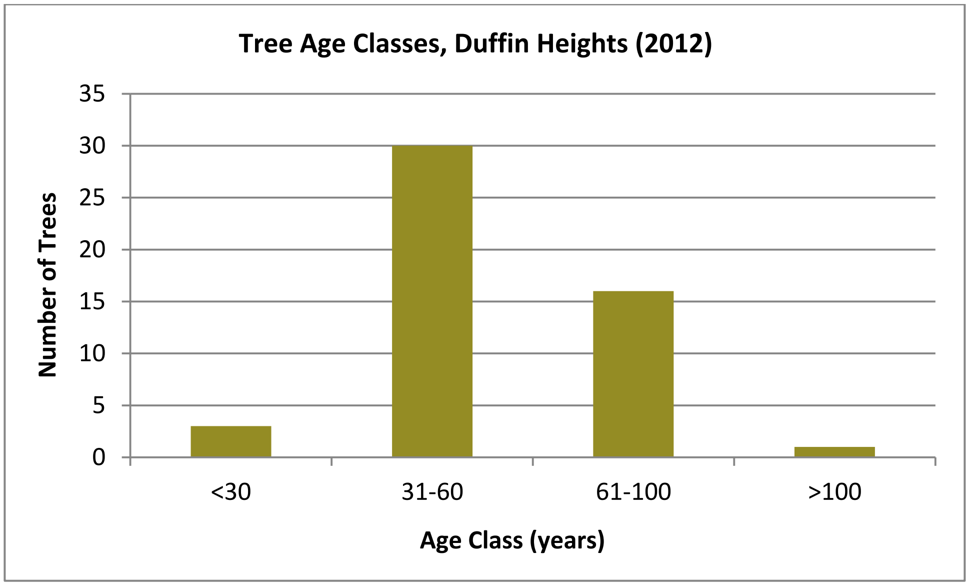


Figure 2. Age classes (year cohort) of trees sampled at Duffin Heights (2012)

Size

The average height of trees at Duffin Heights was 15 m (Table 2). All height classes (i.e. dominant, co-dominant, intermediate and suppressed) were factored into this figure; if the latter 2 groups were excluded a higher average canopy height would result. The tallest trees were 30 m in height, with plot FV-19A having the tallest trees overall (average tree height 19.7 m).

Table 2. Average tree heights at Duffin Heights forest vegetation plots (2008-2012)

Sample	Height(m)	Stn dev. (m)
Duffin Heights average	15.1	± 4.6
Plot FV-19A (plot with tallest trees)	19.7	± 5.6
Plot FV-19G (plot with shortest trees)	12.8	± 3.2

Diameter at breast height ranged from 10 cm (the smallest size incorporated into our sampling protocol) to 91.2 cm (a red oak, *Quercus rubra*, at FV-19B). On average plot FV-19A had the largest tree, with an average diameter of 30.3 cm.

Tree Composition

In 2012, the 10 tree health plots at Duffin Heights contained a total of 376 *live* trees of ≥10 cm dbh. Across the whole set of plots, there were 19 species of trees encountered (Figure 3). White cedar was by a wide margin the most common tree, comprising 117 trees (31.1% of the total stem count, i.e. relative abundance). Other prominent species included white pine (*Pinus strobus*) – 50 trees (13.3% of the total), trembling aspen (*Populus tremuloides*) – 40 trees (10.6% of the total), eastern hemlock – 35 trees (9.3% of the total), and sugar maple (*Acer saccharum* ssp. *saccharum*) – 30 trees (8.0% of the total). These figures represent the finding of the single year 2012 because earlier years still had some incompleteness in data collection (for example omitted trees that were discovered later).

Tree species were not evenly distributed across Duffin Heights; for example, plot FV-19F is in an extremely dense stand of white cedar; the 94 living cedar in that plot accounted for 80% of that species at Duffin Heights as a whole and fully a quarter of all the tree stems at the entire set of plots. Likewise, most of the white pine were at FV-19E and most of the hemlock at FV-19C. Trembling aspen was restricted to two of the plots: FV-19H and FV-19I. No single tree species occurred at every plot, although white pine was found in 8 and sugar maple in 6 of the 10 plots; thus the latter 2 species actually had the highest frequency values.

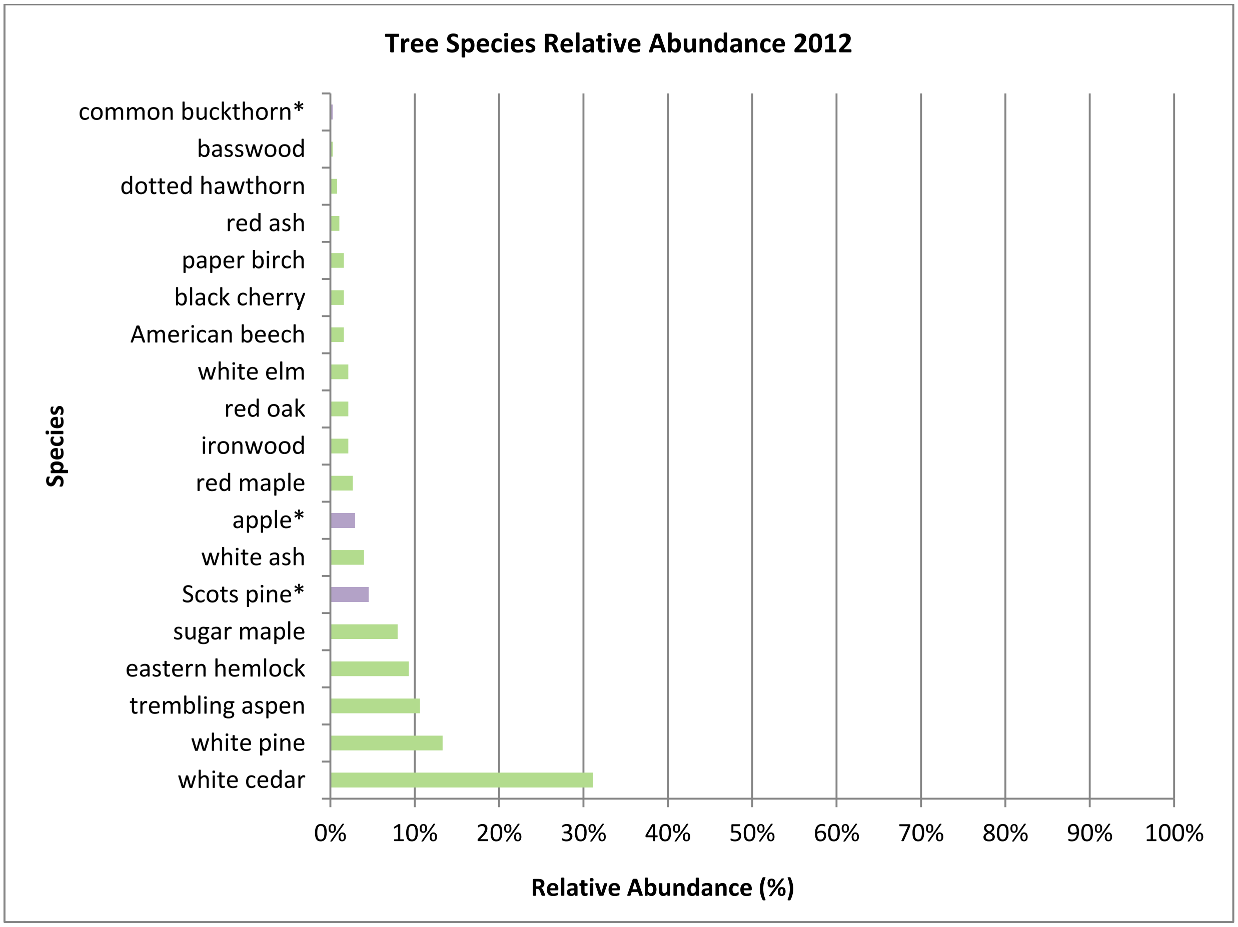


Figure 3. Tree species relative abundance in set of Duffin Heights tree health plots (2012). *Exotic species are indicated by an asterisk (*) and mauve colour.*

Basal area, which is calculated from diameter values and takes into account the size of trees, follows a very similar pattern to abundance at Duffin Heights (Table 3). White pine and white cedar are the two most dominant trees using this measure as well.

Table 3. Basal area of tree species at Duffin Heights vegetation plots (2008) *Exotic species are indicated by an asterisk (*).*

Species	Basal Area (m^2/hectare)	Relative Basal Area
white pine	8.8	23%
white cedar	7.6	20%
trembling aspen	4.7	12%
sugar maple	4.3	11%
red oak	3.4	9%
Scots pine*	2.0	5%
eastern hemlock	1.9	5%
red maple	1.3	3%
white ash	0.9	2%
apple*	0.7	2%
American beech	0.7	2%
black cherry	0.6	2%
white elm	0.5	1%
red ash	0.5	1%
paper birch	0.4	1%
ironwood	0.2	0%
dotted hawthorn	0.1	0%
common buckthorn*	0.03	0%
basswood	0.02	0%
Total Basal Area	**38.6**	100%

Given the large component of cedar at Duffin Heights, conifers outnumbered deciduous trees overall (58.3% coniferous: 41.7% deciduous) (Figure 4). Conifers account for 53% of the total basal area.

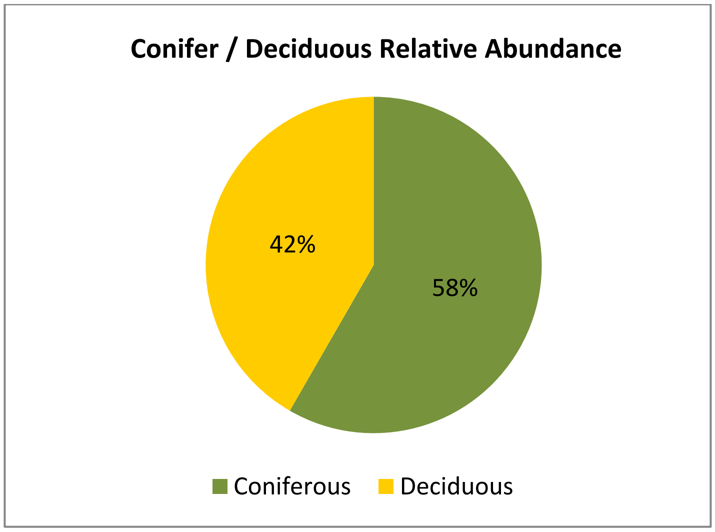


Figure 4. Proportion of coniferous and deciduous trees at Duffin Heights (2008-2012)

Native species made up the overwhelming majority of trees sampled with 92% of the total in the forest plots (Figure 5). There were three exotic tree species: Scots pine (*Pinus sylvestris*) (17 trees), apple (*Malus pumila*) (11 trees), and common buckthorn (*Rhamnus cathartica*) (1 stem over 10 cm diameter of this usually shrub-sized species) (see Figure 3).

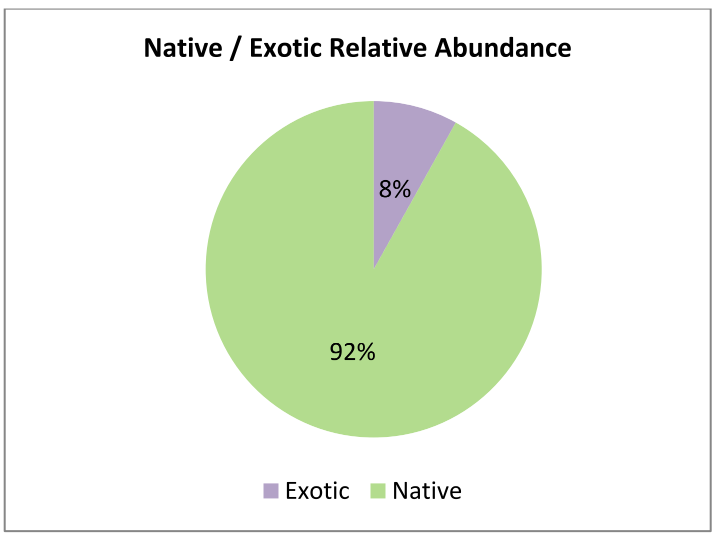


Figure 5. Proportion of native and exotic trees at Duffin Heights (2008-2012)

3.1.2 Tree Health

Crown Vigour

Crown vigour is measured by the percentage of the crown showing recent dieback (bare, defoliated twigs). Healthy trees show less than 10% crown dieback; 10-50% dieback indicates moderate decline, while over 50% indicates severe decline.

The vast majority of trees surveyed at Duffin Heights (over 80% of stems) showed minimal crown decline (i.e. <10% dieback). In 2010, 90% of the total had healthy crowns, while 83% were healthy in 2012 (Figure 6). Trees in the intermediate or suppressed crown classes were more likely to show crown dieback. The proportion of intermediate and suppressed trees ranged from 10-22% showing moderate decline (10-50% dieback) and 4-8% showing severe decline (>50% dieback).

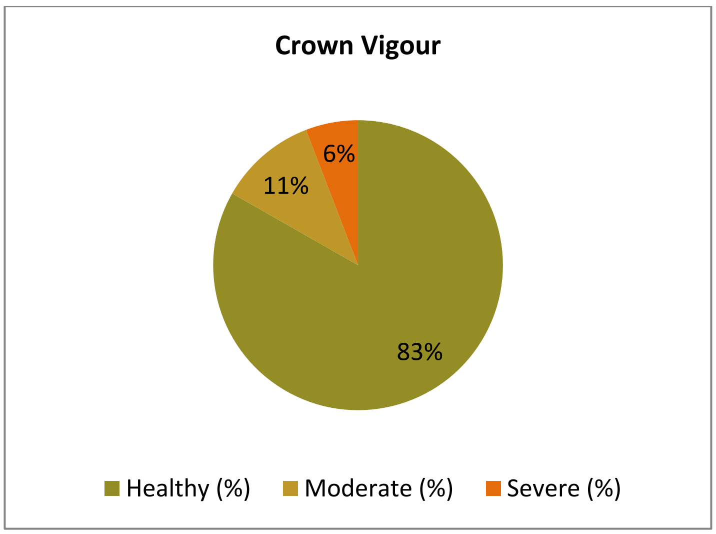


Figure 6. Crown vigour of trees at Duffin Heights (2012)

Conifers showed slightly poorer health than deciduous trees. The proportion of conifers with “healthy” crowns was 88% in 2010 and 78% in 2012. Severe decline affected 8% of conifers in 2012. Among deciduous trees, those with healthy crowns were consistently 90% of the total or a bit above.

A few species seemed to show more crown dieback. In particular, Scots pine went from 68% with healthy crowns in 2008 to all trees being in decline by 2012 (12 of 17 stems or 71% in severe decline). White ash (*Fraxinus americana*) also showed a tendency for increased crown dieback, with the number of trees showing moderate to severe dieback increasing from three to seven (out of 15 trees). White pine had slightly elevated dieback, with 18% of stems showing moderate dieback and 2% severe. Other species (e.g. American beech (*Fagus grandifolia*), apple, white elm (*Ulmus americana*)) that seemed to have above-normal dieback were present in very small numbers (fewer than 10 trees across the Duffin Heights plots).

Stem Defects

Slightly fewer than half of the trees at Duffin Heights had recorded stem defects (Table 4). Stem defect data in 2008 and 2009 were excluded from data analysis due to inconsistencies in field collection (i.e. diagnosis of particular defect types which improved over time), while results from 2010-2011 were similar to 2012. For this reason, only 2012 data are discussed.

Table 4: Stem defects observed at Duffin Heights (2012)

Defect Type	Number of Stems	Proportion of Stems
With at least one defect (any type)	165	44%
Open wound	88	23%
Canker	43	11%
Closed wound	30	8%
Dry seam / crack	14	4%
Insect damage	6	2%
Wet seam / crack	2	0.5%
Decay fungus†	2†	0.5%†
Animal damage	1	0.3%

†Results from 2011 only (not observed in 2012)

The most common stem defects were open wounds. A total of 88 trees (23% of the total) had open wounds. The next most common defect was canker, affecting 43 stems (11%) (see also Pests and Diseases results below). Six trees had insect damage, one had animal damage, and two had open or seeping cracks or seams. Healed defects (including closed wounds and dry seams) affected 44 trees (12% of the total).

Pests and Diseases

Duffin Heights has a number of pathogens affecting various tree species. Of the numerous pathogens that can affect trees in the region, there were seven main agents identified based on what reliable identification could be gained by 2012 and their actual or potential seriousness (Table 5).

Ash yellows affect only ash trees (*Fraxinus* spp.). It is a mycoplasmic disease whose symptoms are similar to Dutch elm disease: blockage of the vascular system followed by deformed branching, crown dieback and death of the tree (Pokorny and Sinclair 1994, Gillman 2005). Ash yellows was tentatively identified on eight trees by 2012: six white (*F. americana*) and two red ash (*F. pennsylvanica*). Identification, especially in mild cases, could not be certain, but some of the trees were in significant decline.

Dutch elm disease (*Ophiostoma* sp. probably *O. novo-ulmii*) was identified on one living tree in 2012. Three or 4 trees out of a total of 24 elm have been infected and died at Duffin Heights over the 5 year period of survey. The disease is spread by several species of bark beetle or by direct contact through root grafts where elms grow in close proximity to each other.

Gypsy moth (*Lymantria dispar*) is periodically a major defoliator of numerous tree species, especially but by no means restricted to oak. Gypsy moth was observed on only six trees in 2012 and one in 2011. It was observed in very low numbers (a few egg cases and caterpillars); there was no visible damage to the trees.

Beech bark disease is composed of a combination of beech scale (*Cryptococcus fagisuga*) and *Nectria* cankers, causing decline and often death of the tree after several years. Beech scale damage was present on all six of the living beech trees in 2012; however there was no clear evidence of *Nectria* canker at Duffin Heights (another type of canker was observed in conjunction with beech scale, see below).

Several *Phytophtora* fungus species cause bleeding cankers with dark stains on numerous deciduous tree species. A dark bleeding canker was identified as *Phytophthora* cf. *cactorum* on a beech tree; it appeared to be invading via beech scale wounds. The tree was still living in 2012 although with mild crown dieback and noticeable chlorosis (yellowing of leaves).

Caliciopsis pinea is a little-known canker that affects white pine, often under conditions of crowding or sub-optimal sites; its symptoms are sunken, discoloured lesions on the trunk (not the branches as with white pine blister rust) (Lombard 2003). The lesions bleed resin (Figure 7). These symptoms were observed on 38 of the 50 white pine at Duffin Heights in 6 of the 7 plots in which white pine occurred. Plot FV-19E near Tillings Rd is in an overgrown white pine plantation and every tree there had symptoms.

Figure 7. Pine canker (likely *Caliciopsis pinea*) on white pine at Duffin Heights (2012)

A seventh unknown pathogen was included because it was observed affecting a high proportion of Scots pine; the symptoms are generalized crown thinning and decline with eventual mortality. More than half of the Scots pine at Duffin Heights showed this sort of decline in 2012.

Table 5. Seven identified pest(s) and/or disease(s) at Duffin Heights forest plots (2012)

Pest/Disease	Species affected by pathogen	# trees affected	total # trees	% trees affected
ash yellows	white and red ash	8	19†	42%
Dutch elm disease	white elm	1	8†	13%
gypsy moth	American beech, hemlock, ironwood and sugar maple at Duffin Heights, potentially many species	6	79†	8%
beech scale	American beech	6	6†	100%
Phytopthora canker	American beech at Duffin Heights, potentially many deciduous species	1	6†	17%
Caliciopsis pinea canker	white pine	38	50†	76%
Scots pine decline, agent unknown	Scots pine, possibly other species	11	17†	65%

†live trees in 2012 of the particular species affected

Mortality

Mortality rates averaged about 2% per year overall (sufficient data were available for 2010-2012). Rates were higher for the more shaded trees in the intermediate and suppressed crown classes (about 3-4%) and only about 1% for co-dominant and dominant trees.

Elevated mortality rates were observed for a few tree species but their sample size was small. For example, 2 out of 8 paper birch (*Betula papyrifera*) recorded at Duffin Heights died over the period 2010-12. Three of 11 elm died in 2010, and an additional tree in 2011. Three hemlock out of a total of 36 trees, and 1 of 7 beech died in 2010-12.

Dead trees (snags) accounted for 82 stems (18% of the total 457) in the entire set of plots averaged over the period of 2008-2012. This total includes newly-fallen trees so the number of standing snags may be slightly lower.

3.1.3 Woody Regeneration

Forest Sapling and Shrub Composition

Total Quantity of Woody Regeneration

Density of woody regeneration (i.e. tree saplings, shrubs and woody vines) varied enormously across the Duffin Heights regeneration subplots. The densest plot was FV-19I near Old Taunton Rd east of Brock Rd, which had an average of 127 tree, shrub, and woody vine stems irrespective of species (averaging 6 stems per m^2). The lowest density was at FV-19C near the Brock West

Landfill site, which averaged 5 woody regeneration stems (0.25 per m^2 or 1 per regeneration subplot).

Native and Exotic Woody Regeneration

Native species dominate the woody regeneration in the Duffin Heights forest plots with at least 80% of both relative abundance and relative cover measures (Table 6). However, the shrub component of the woody regeneration had a much higher exotic component than the trees. While trees were almost entirely native, exotic shrubs were approximately equal to native shrubs in abundance and exceeded them in terms of cover (exotic shrubs comprised 15.7% of total relative cover and native shrubs 8.4% of total relative cover). However, the greater pre-eminence of tree saplings overall tilted the total woody regeneration in favour of native species.

Table 6. Relative abundance (based on stem counts) and cover of native and exotic woody regeneration (both sapling and shrub species) (2008-2012)

Measure	Relative Abundance	Relative Cover
Native	80%	84%
Exotic	20%	16%

Forest Regeneration Composition by Growth Form

When woody regeneration is divided into growth form (i.e. tree, shrub, woody vine), it was found that the number of tree species generally was higher than the number of shrub species, which in turn was much higher than the number of woody vine species (Figure 8).

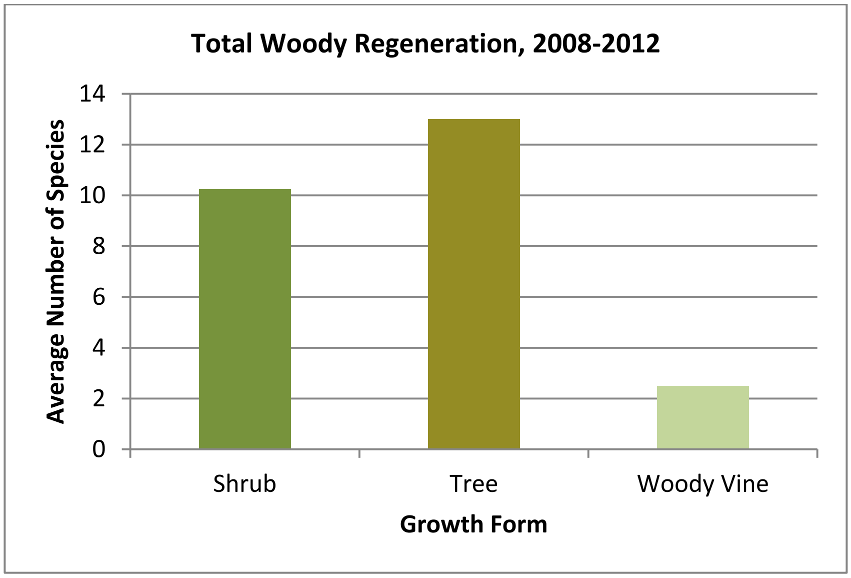


Figure 8. Average species richness of tree saplings, shrubs, and woody vines at Duffin Heights (2010-2012)

In terms of dominant plant type in the understorey layer, tree saplings were higher in relative abundance (more stems), and particularly in terms of relative cover (Figure 9). Tree saplings comprised 73% of the total understorey cover. Woody vines had both relative abundance and cover of 3%. There was a slight tendency for woody vine cover to increase its share over the time period (from 2.1% in 2008 to 3.2% in 2012).

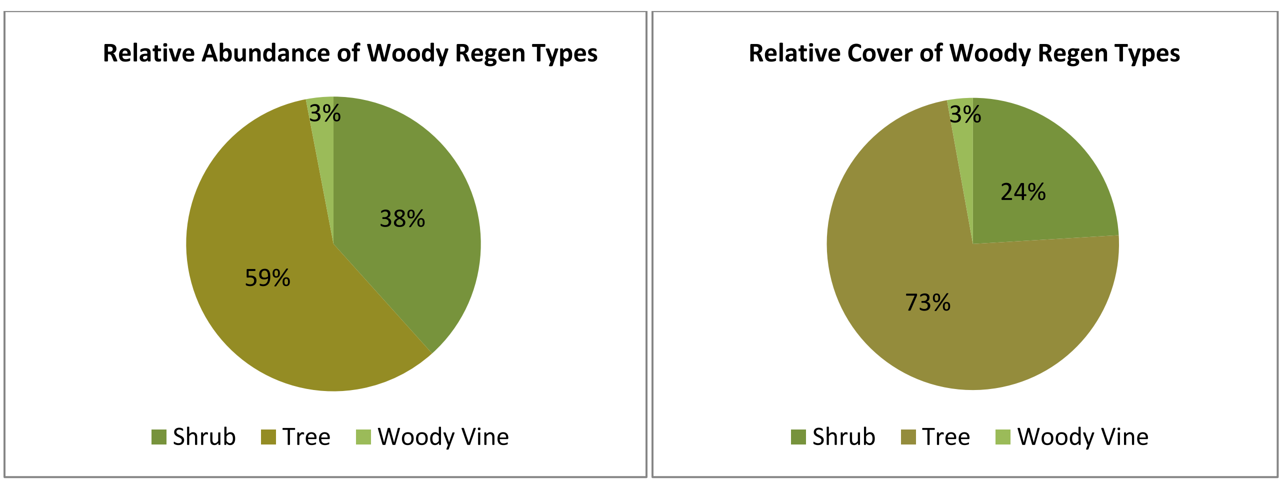


Figure 9. Relative abundance and cover of tree saplings, shrubs, and woody vines at Duffin Heights (2008-2012)

Tree Regeneration

A total of 15 species of tree saplings were recorded in the forest plots over the period 2008-2012 (Figure 10). Ash (both red and white) overwhelmingly dominated the tree sapling populations (relative abundance), especially at plots FV-19D and FV-19I. White ash was particularly abundant at FV-19I, although several other plots had noticeable regeneration of this species. Red ash was extremely abundant at FV-19D, which averaged about 3-4 stems per square metre based on regeneration subplot calculations over the period of survey. Sugar maple was a distant third although it was fairly well-distributed, being found in 7 of the 10 plots (the 4 western ones beside the Brock West Landfill site: FV-19, 19A, 19B, 19C; and the 3 eastern plots east of Brock Rd: FV-19G, 19H, 19I). It was absent from the central three plots just west of Brock Rd: FV-19D, 19E, 19F. The fourth most abundant tree sapling was trembling aspen. However, these occurred only as shaded suckers in the three eastern plots where trembling aspen occurred in the tree canopy in or adjacent to the plot. The remaining species were present in very low populations.

Conifers were almost absent in the understorey: they were represented by a single white cedar sapling at FV-19B.

Only one exotic tree species was found in the sapling layer: Manitoba maple (*Acer negundo*), which was present as a single stem in FV-19I.

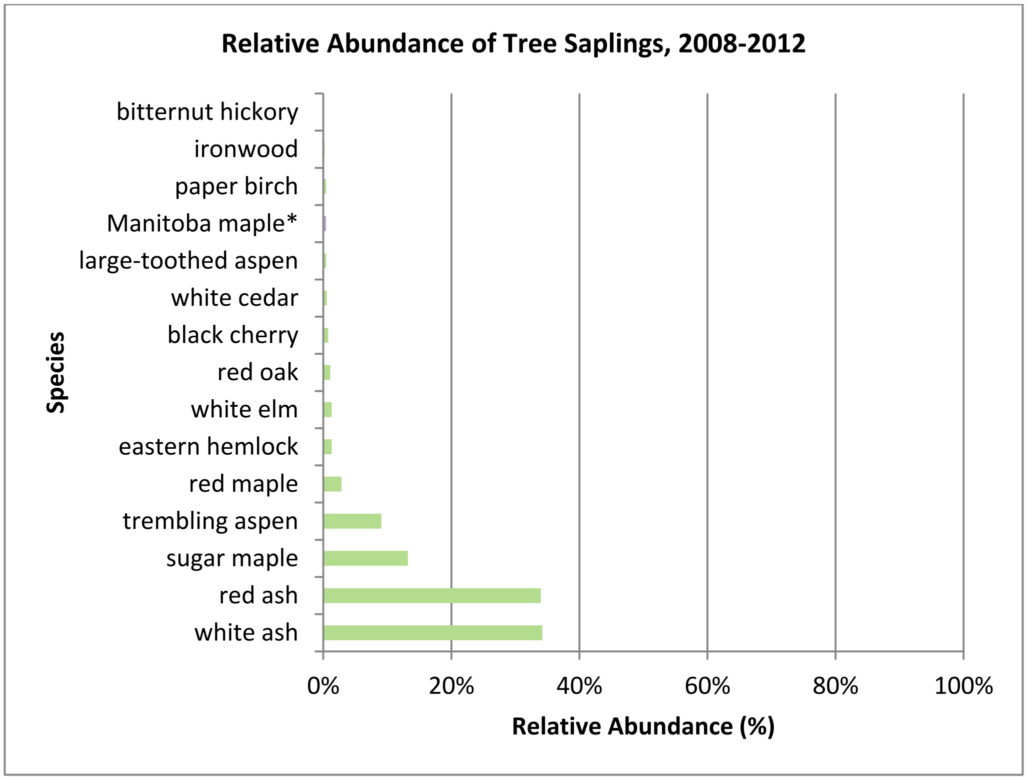


Figure 10. Relative abundance of tree sapling species at Duffin Heights (2008-2012). *Exotic species are indicated by an asterisk (*) and mauve colour.*

Shrubs and Woody Vines

Shrubs and woody vines, considered together, were represented by 17 species (13 shrubs, 4 woody vines) (Figure 11). Common buckthorn had the highest relative abundance, about 32% of the total number of stems. It was widely distributed, being found in 9 of the 10 plots. However, in most plots, there were only one or two stems of this species; most of it occurred in FV-19D, FV-19E and FV-19I. Poison ivy (shrub form: *Toxicodendron rydbergii*) had 19% relative abundance and was found in 5 plots. Red raspberry (*Rubus idaeus* ssp. *strigosus*) and European highbush cranberry (*Viburnum opulus*) were also somewhat abundant (11% and 10% relative abundance respectively), with raspberry restricted to one plot (FV19-I) and the highbush cranberry being found in 5 plots. There were 4 woody vine species found in the regeneration subplots, with riverbank wild grape (*Vitis riparia*) accounting for the vast majority of stems (it had 4% of the total relative abundance of shrubs and woody vines together). A couple of stems of thicket creeper (*Parthenocissus inserta*) were found in two plots and there was one stem each of the native and Asiatic bittersweets (*Celastrus scandens* and *C. orbiculatus*).

Exotic species accounted for 5 of the 13 shrubs and 1 of the 4 vines, with common buckthorn being by far the greatest contributor to exotic stem count and cover. Although the majority of shrub and woody vine species are native, the density of buckthorn meant that aggregate exotic shrub cover was greater than native shrub cover.

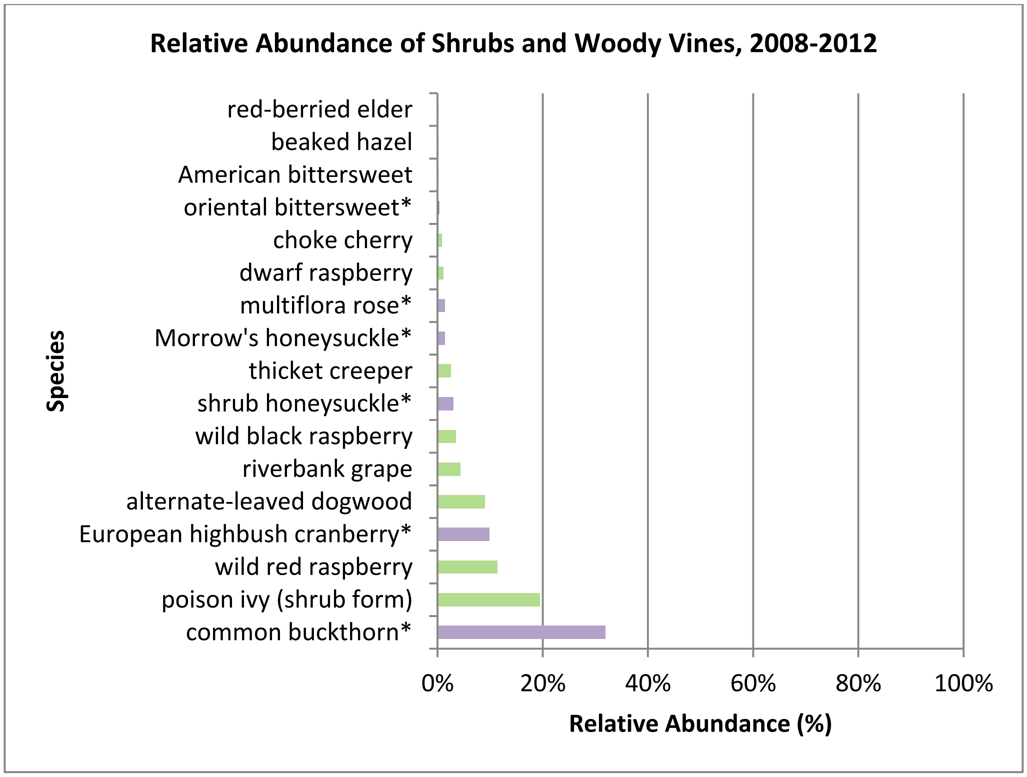


Figure 11. Relative abundance of shrub and woody vine species at Duffin Heights (2008-2012). *Exotic species are indicated by an asterisk (*) and mauve colour.*

While woody vines have a low abundance in the 2 x 2 m regeneration subplots, they are very much present in the tree canopy, where they ascend from bases that are generally outside the 2 x 2 m subplots. TRCA has recently been tracking the presence of woody vines in canopy trees, and Duffin Heights has a high occurrence of these, mostly riverbank grape (*Vitis riparia*) in the canopy. Trees with vines in the canopy are found in 5 of the 10 plots, with FV-19D and FV-19G having the greatest incidence (Table 7). The proportion of trees with vines in the crown is 11% for the whole project site, while FV-19D has 41% and FV-19G has 36%.

Table 7. Duffin Heights plots with woody vines recorded in tree crowns (2012)

Location	# Trees with vines	Total # Trees	% Trees with vines
Whole site	43	381	11%
FV-19D	12	29	41%
FV-19E	8	41	20%
FV-19G	17	47	36%
FV-19H	3	48	6%
FV-19I	2	34	6%

3.1.4 Ground Vegetation

Forest Ground Vegetation Composition

A total of 103 species were observed in the Duffin Heights 1 x 1 m forest ground vegetation subplots in 2008-2012. The average number of species per plot was 16.3 with a possible slight increase over time (Table 8).

Table 8. Number of species in ground vegetation subplots by year

	Number of species per year				
	2008	**2010**	**2011**	**2012**	**Average**
Number of species per plot	13.0	17.2	16.9	18.3	16.3 (±9.7)

Ground vegetation diversity varied greatly. Plot FV-19E (one of the centre plots between Tillings and Brock Rds) averaged only 5.5 ground layer species and FV-19F (west of Tilllings Rd) had an average of 6.0. There was a hint of a declining trend at FV-19E which had 7 ground species in 2008 and 2010, 5 in 2011, and only 3 in 2012. On the other hand, FV-19A (near Brock West landfill) had an average of 32 ground vegetation species and FV-19I (near Old Taunton Rd) had an average of 31. Thirty-seven species were found at FV-19I in 2010, the highest value for any plot in any given year. Aside from FV-19E, the number of ground vegetation species recorded was roughly stable or perhaps slightly increasing.

While there was a fairly large number of species observed in the ground vegetation, the cover was heavily dominated overall by the invasive dog-strangling vine (*Cynanchum rossicum*) with other species occurring less frequently and with lower cover values. Dog-strangling vine alone accounted for over 50% of the cover of all ground vegetation species (Figure 12).

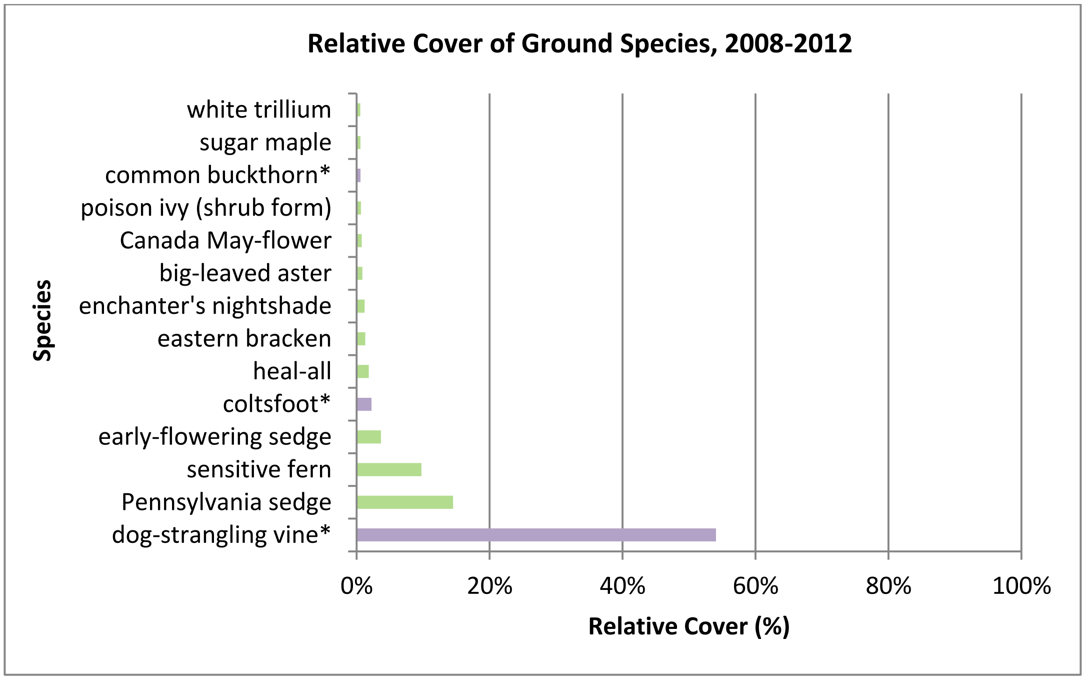


Figure 12. Relative cover of ground vegetation species having more than 1% of total (2008-2012). *Exotic species are indicated by an asterisk (*) and mauve colour.*

Dog-strangling vine was also present in all of the 10 plots (it was the only ground vegetation species present in all plots). However, it varied in dominance with the highest concentrations at FV-19D, FV-19E, and to some extent at FV-19H and FV-19I (Figure 13). The 4 western plots near the Brock West landfill site (FV19 through FV-19C) tended to have low to moderate dog-strangling vine with more ground vegetation diversity. FV-19I near Old Taunton Rd had both high ground vegetation diversity but also a significant presence of dog-strangling vine, while FV-19F and FV-19G had little ground vegetation of any kind.

Figure 13. Dog-strangling vine at plot FV-19d (2012).

Two sedges (Pennsylvania sedge, *Carex pensylvanica* and early-flowering sedge *C. pedunculata*) and sensitive fern (*Onoclea sensibilis*) were the next most prevalent ground species. All other species were present in low quantities.

Dog-strangling vine also heavily skewed the ground cover total in favour of exotics (Figure 14); however, other invasive exotic species were not prevalent, with natives dominating the non-dog-strangling vine share of the total relative cover. For example, garlic mustard (*Alliaria petiolata*) was found in only three plots, and in low quantities. Common buckthorn occurred somewhat frequently in the ground vegetation as seedlings, but with low cover and vigour.

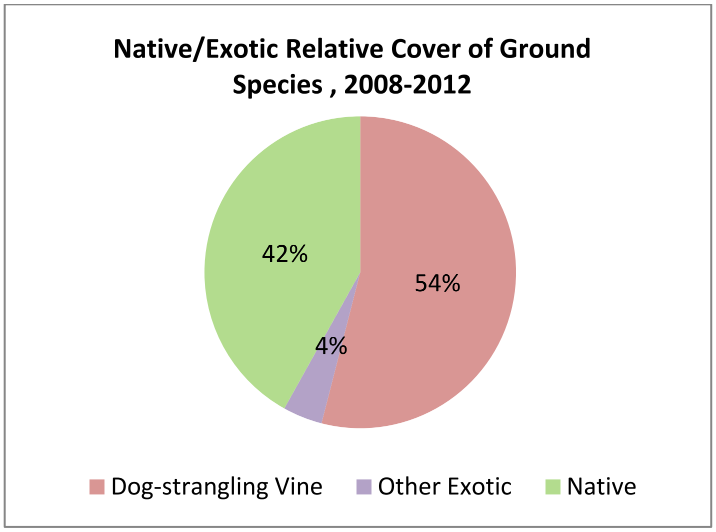


Figure 14. Relative cover of native and exotic (with dog-strangling vine highlighted) ground vegetation at Duffin Heights (2008-2012)

The frequency of occurrence for ground vegetation species other than dog-strangling vine was sporadic. Only common buckthorn and riverbank wild grape were found in over half the plots. Pennsylvania sedge, the species with the second-highest relative cover, was found in three plots. Sensitive fern, which had the third-highest relative cover, was found only at FV-19I where there were dense patches of this species.

Forest Ground Vegetation Composition by Growth Form

When ground vegetation is divided into growth form (e.g. tree, shrub, forbs etc.), it was once again found that dog-strangling vine skewed the pattern as being the only herbaceous vine (54% of the total cover) (Figure 15). Sedges and ferns follow. Forbs (regular broad-leaved herbaceous seed plants) comprise only 8% of the relative cover. Spring ephemerals are almost completely absent from the forests at Duffin Heights; the only occurrence was trout lily (*Erythronium americanum*) at FV-19H and its cover was low. Most of the forbs are generalist species that emerge in the spring and are able to produce new growth throughout the summer, e.g. heal-all (*Prunella vulgaris* ssp. *lanceolata*), enchanter's nightshade (*Circaea canadensis*), and big-leaved aster (*Eurybia macrophylla*). Another minor group of forbs, species that emerge and flower in the spring but remain green through much of the summer, included Canada May-flower (*Maianthemum canadense*), white trillium (*Trillium grandiflorum*), and Jack-in-the-pulpit (*Arisaema triphyllum*).

Woody seedlings such as buckthorn, white ash, sugar maple, riverbank grape, and poison ivy, although relatively frequent and widespread (each found in at least four of ten plots), had very low cover.

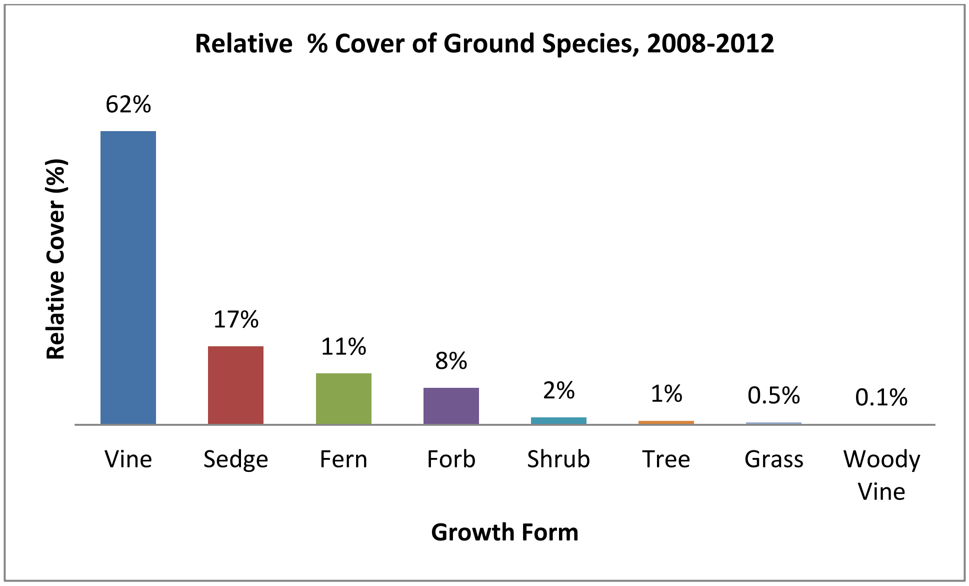


Figure 15. Relative cover of growth forms in forest ground vegetation subplots (2008-2012)

3.1.5 Floristic Quality Indicators

Floristic quality, based on the species list for the whole plot (tree health plot plus subplots), was revealed by several indicators: species richness and proportion of native species; the presence and number of species of regional conservation concern (TRCA L-rank L1 to L3); the mean coefficient of conservatism (CC) of the native species found within the plot, and the plot Floristic Quality Index (FQI) derived from native species richness and mean CC.

Total cumulative species richness for the set of Duffin Heights forest vegetation plots (i.e. all species observed during 2008-12) was 180 (Table 9). There were 143 native species and 37 exotics observed; the proportion of native species was 79.4%. There seemed to be an incipient trend toward increasing species richness over the period of observation.

Table 9. Floristic quality indicators (yearly) at Duffin Heights forest plots

Floristic Index	Year	Measure (±std dev)
Total Species Richness	2008	138
	2010	142
	2011	151
	2012	154
	cumulative 2008-12	180
	average 2008-12	146 (±7.5)
Native Species Richness	2008	112
	2010	113
	2011	119
	2012	126
	cumulative 2008-12	143
	average 2008-12	118 (±6.5)
Plot Average Co-efficient of Conservatism (CC)	2008	3.9 (±0.5)
	2010	3.9 (±0.5)
	2011	3.9 (±0.5)
	2012	4.0 (±0.6)
	average 2008-12	3.9 (±0.5)
Plot Average Floristic Quality Index (FQI)	2008	21.4 (±6.2)
	2010	22.5 (±6.9)
	2011	23.4 (±7.0)
	2012	23.6 (±7.2)
	average 2008-12	22.7 (±6.7)
Number of L1-L3 species	cumulative 2008-12	12

The plots with the highest floristic scores were those on the west side of the study area near the Brock West Landfill (FV-19, FV-19A, and FV-19B) along with FV-19I at the northeast end of the study area near Old Taunton Rd. Plots FV-19A and FV-19I had 76 native species recorded during the period of observation. At the other extreme, FV-19E had only 19 native species (along with10 exotics). The average CC for native plants was more consistent across the set of plots, with averages ranging from 3.1 (FV-19E) to 4.5 (FV19, FV19-B). The west side plots (FV-19 through FV-19C) had average CC over 4. Floristic quality index, which takes into account both native species richness and coefficient of conservatism, followed more the pattern of species richness with greater variation. Plot FV-19A had the highest FQI of 33.3 and FV-19E had the lowest FQI of 11.2.

There were 12 flora species of regional conservation concern (TRCA rank L1 to L3) observed in all the plots over the 2008-12 period: all had a rank of L3. The most sensitive species were Back's sedge (*Carex backii*) and thicket horsetail (*Equisetum pratense*). These have a rank of L3 like the other species of regional concern, but also score high on the coefficient of conservatism measure: 8 out of a possible 10. There were also 4 plants with a CC of 7 and 28 with CC of 6 (Appendix 2).

3.2 Forest Birds

The five forest bird monitoring stations that are installed in forest habitat are indicated as FB-19_1, FB-19_2, FB-19a_3, FB-19a_4 and FB-19a_5 on Map 2 and are subsequently referred to as stations 1 through 5. The two most westerly stations (FB-19_1 and FB-19_2) are situated in the extensive mature forest on the eastern edge of the Brock landfill, on the west side of the Ganatsekiagon Creek, i.e. somewhat removed from the location of future residential development. The third and fourth stations (FB-19a_3 and FB-19a_4) are located on the east side of Tillings Road, adjacent to the main residential development. Finally, the fifth station (FB-19a_5) is located in a separate forest block 1km east of Brock Road and is therefore well-removed from the main development but is still situated within the Duffin Heights forest complex.

In order to identify any trends in the biodiversity at each station over time, it is necessary to calculate an initial baseline against which all other data can be compared. To this end, since the main construction commenced in late 2009, data from the first two years (2008 and 2009) have been combined to produce a mean value for data from those two years. This pre-construction data-set will be the baseline against which subsequent monitoring data can be compared.

For the baseline period (2008 and 2009) a total of 14 of the 31 species recorded at the 5 stations (only considering individuals reported from within the 100 m count circle) are from the group of L5 species (Table 10), i.e. those species that are considered to be secure within the urban landscape of the Toronto region. Approximately one quarter (8) of the species are ranked L4 (species of concern in urban landscapes), with 9 species ranked as L3 (species of regional concern).

Table 10. Total number of bird species recorded within the 100 m count circle at the five forest bird stations for the baseline period (combined 2008 and 2009)

Forest Station (FB19/19a)	Number of L3 Ranked Species	Number of L4 Ranked Species	Number of L5 Ranked Species	Number of L+ Ranked Species	Total number of Species
Station 1	7	2	5	0	14
Station 2	9	6	7	0	22
Station 3	3	7	9	0	19
Station 4	0	3	9	0	12
Station 5	2	2	5	0	9
Totals	9	8	14	0	31

Table 11 shows the breakdown of species recorded from the forest monitoring stations according to their habitat-use guilds. These guilds are based on both habitat preference (forest, forest-edge, meadow and wetland) of the species, and the preferred canopy level at which the species' nest is placed (see Appendix 3 for a complete list of these guilds for the regional breeding avifauna). As might be expected, the species are mainly either forest-specialists (14 species, 45%) or generalist in their habitat requirements (12 species, 39%). A generalist species is one that is not considered to be specifically associated with any one habitat type, and as such can be found nesting in a range of different habitat types. A further 4 species (13%) are considered to be forest-edge specialists, with one that is a meadow specialist.

Table 11. Species list for the five forest bird stations showing habitat guilds and L-ranks, combined for the two year baseline period (2008 and 2009)

Guild	Species	Scientific names	L-rank
Forest lower-level nester	ovenbird	*Seiurus aurocapillus*	L3
	winter wren	*Troglodytes troglodytes*	L3
Forest mid-level nester	red-eyed vireo	*Vireo olivaceus*	L4
	brown creeper	*Certhia Americana*	L3
	wood thrush	*Hylocichla mustelina*	L3
Forest upper level nester	black-throated green warbler	*Setophaga virens*	L3
	eastern wood-pewee	*Contopus virens*	L4
	great-crested flycatcher	*Myiarchus crinitus*	L4
	pileated woodpecker	*Dryocopus pileatus*	L3
	pine warbler	*Setophaga pinus*	L3
	red-breasted nuthatch	*Sitta canadensis*	L4
	scarlet tanager	*Piranga olivacea*	L3
	hairy woodpecker	*Piccoides villosus*	L4
	white-breasted nuthatch	*Sitta carolinensis*	L4
Forest-edge low-level nester	mourning warbler	*Geothlypis philadelphia*	L3
Forest-edge mid-level nester	downy woodpecker	*Picoides pubescens*	L5
	indigo bunting	*Passerine caerulescens*	L4
	rose-breasted grosbeak	*Pheucticus ludovicianus*	L4
Meadow upper-level	eastern kingbird	*Tyrannus tyrannus*	L4
Generalist mid-level nester	American goldfinch	Carduelis tristis	L5
	American robin	*Turdus migratorius*	L5
	black-capped chickadee	*Poocetes atricapillus*	L5
	cedar waxwing	*Bombycilla cedrorum*	L5
	common grackle	*Quiscalus quiscula*	L5
	northern cardinal	*Cardinalis cardinalis*	L5
	red-winged blackbird	*Agelaius phoeniceus*	L5
Generalist upper-level nester	American crow	*Corvus brachyrhynchos*	L5
	Baltimore oriole	*Icterus galbula*	L5
	blue jay	*Cyanocitta cristata*	L5
	red-tailed hawk	*Buteo jamaicensis*	L5
Generalist special case*	brown-headed cowbird	*Molothrus ater*	L5

*brown-headed cowbird is a brood parasite, i.e. does not nest

The five stations each accommodate quite different avifauna and this variation can be seen in comparing the baseline calculations at each station (Table 12). Broadly speaking, stations #1 and #2 are situated at some distance from the main development and are both in relatively mature, undisturbed forest habitats. Station #1 is the most isolated from any edge habitat, with station #2 located very close to the Canadian National railway line that runs along the north edge of the forest. Stations #3 and #4 are located extremely close to the centre of development, and furthermore are located closest to the existing developments along the busy Brock Road. Station #5 acts as something of a control station since it is well removed from the new development and in fact is within a separate forest block (however, it is situated just 400 m from the busy Taunton Road).

Table 12. Bird species richness by habitat guild at each of the five stations at baseline conditions (averaged 2008 and 2009)

Forest Station	Average Number of Forest Species	Average Number of Forest-Edge Species	Average Number of Non-Forest and Generalist Species	Average total number of Species
Station 1	7	0	3.5	10.5
Station 2	8.5	1	4.5	14
Station 3	3.5	2.5	5.5	11.5
Station 4	1.5	0.5	6	8.5
Station 5	2	1	4	7

Table 13 shows the species richness counts for each station in the 2012 season, three years after the commencement of major construction that occurred in close proximity to stations #3 and #4. The most significant changes occurred in forest bird species richness in the two more western stations (stations #1 and #2) as illustrated in Figures 16 and 17, showing the variation in the annual changes across these 2 stations throughout the monitoring period, 2008 – 2012. Graphs for all 5 stations are shown in Appendix 4.

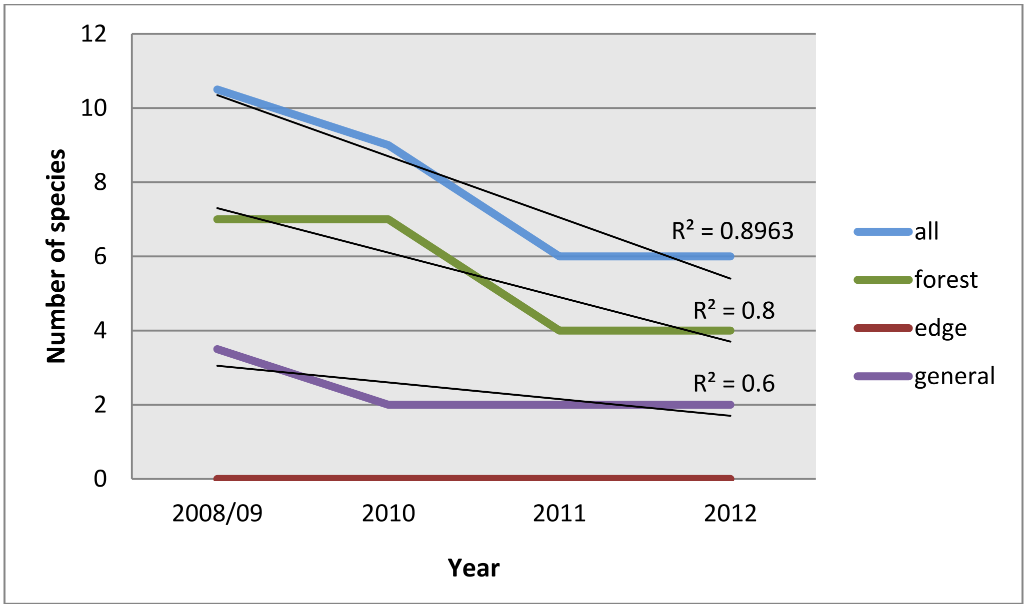


Figure 16. Annual changes in bird species richness for station 1 (2008-2012)

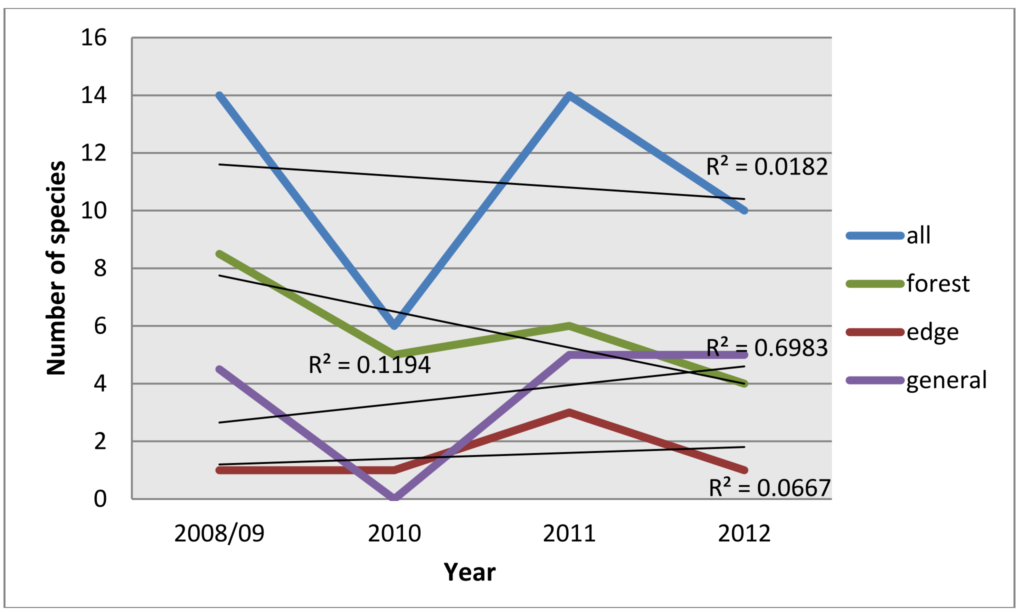


Figure 17. Annual changes in bird species richness for station 2 (2008-2012)

Table 13. Bird species richness by habitat guild at each of the five stations for the most recent survey year, 2012.

Forest Station (FB19/19a)	Number of Forest Species	Number of Forest-edge Species	Number of Non-Forest and Generalist Species	Total number of Species
Station 1	4	0	2	6
Station 2	4	1	5	10
Station 3	2	0	4	6
Station 4	1	1	7	9
Station 5	3	1	4	8

After three years of monitoring beyond the time of construction it is perhaps a little too early to consider possible changes in avifauna populations at the site but already it appears that significant changes have occurred. The change in forest bird species richness is illustrated in Figure 18. Again, the most significant change in forest bird species richness has occurred at stations #1 and #2, and the forest bird species richness across all five stations, measured as a proportion of the total avian community, has decreased from 45% to 29%.

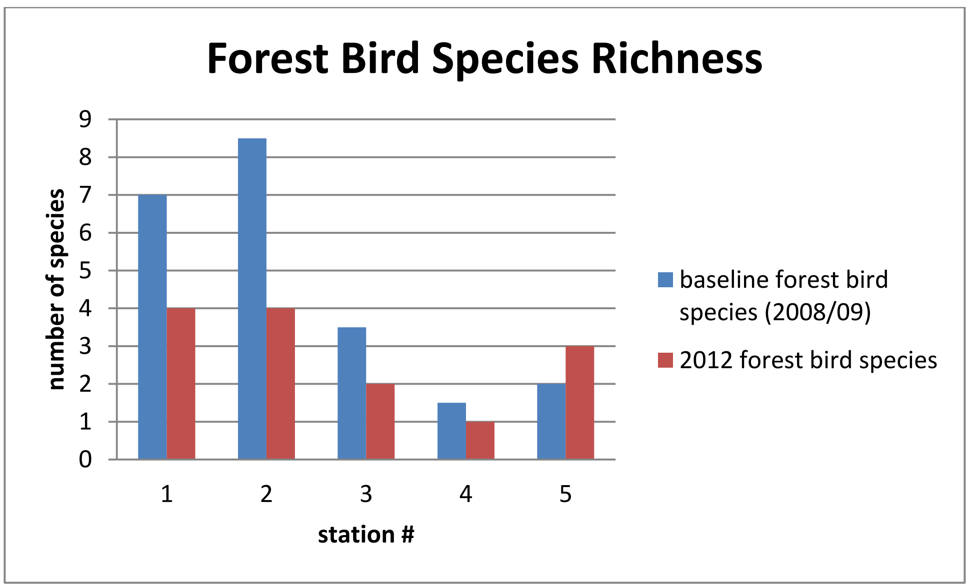


Figure 18. Comparison of forest bird species richness between baseline (2008/09) and 2012

The trends in species richness presented in Appendix 4 and illustrated in Figure 18 are very similar to the results of analysis based on species abundance as presented in Appendix 5. This is perhaps to be expected since in the vast majority of cases, particularly for the forest habitat guild, the species are represented at the stations by just one or two territories (usually indicated in the field by singing males). Figure 19 shows just how closely the trends in forest species richness are replicated in forest species abundance.

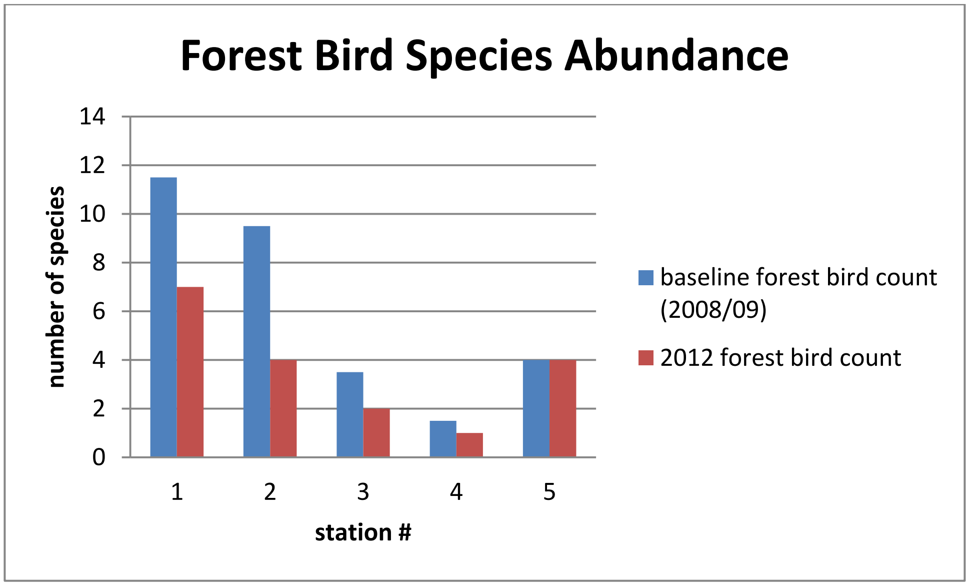


Figure 19. Comparison of forest bird species abundance between baseline (2008/09) and 2012

It should be noted that a potentially significant difference between the five stations is the proximity to busy major roads, either Taunton Road to the north, or Brock Road to the east. Station #1 is approximately 1000 m away from major roads whereas station #4 is only 300 m (Table 14).

Table 14. Proximity of forest bird monitoring stations to major roads at Duffin Heights

Station #	Distance to major road
1	1000 metres
2	660 metres
3	360 metres
4	300 metres
5	400 metres

3.3 Red-backed Salamander

A red-backed salamander monitoring station was installed at Duffin Heights in the fall of 2008, located adjacent to the first forest bird station, FB-19_1a, on the west side of the site. After three monitoring seasons it was apparent that there were no red-backed salamanders in the immediate vicinity of the station and that therefore it would be necessary to relocate. A new station was installed at a location approximately 250 m to the south east of the initial location (FB-19_1b). Presence of red-backed salamander was confirmed at this new site by conducting a brief search, lifting logs within the immediate vicinity of the new station. Given the delayed commencement of this new location (2012) the results are extremely limited but can at least confirm that red-backed salamanders are using the new station boards (see Map 2).

4. Discussion

4.1 Forest Vegetation

At this point, the monitoring data do not yet have the ability to reveal the impacts of past agriculture and newly-initiated urbanization on biodiversity and floristic quality at Duffin Heights. There have been only four seasons of monitoring (given the observation gap in 2009). They do, however, provide a baseline picture of the vegetation just prior to the onset of matrix urbanization impacts.

4.1.1 Age and Species Composition

Forests at Duffin Heights are relatively young with the majority of trees sampled being under 60 years of age, although the age distribution is roughly bell-curved. The age pattern is younger than the sample of regional plots across the whole TRCA jurisdiction (i.e. the Terrestrial Long-term Monitoring Project) (TRCA 2012). A few older trees can be found, especially in the four western plots near the Brock West landfill site: for example, there are some very large red oak and white pine with broad crowns that suggest they were open-grown and established themselves before the rest of the forest. A few older hemlock occur on ravine slopes bordering a couple of plots.

Species composition is quite different from the TRCA set of regional plots. Most notably, two conifer species: white cedar occupying 31% of the relative abundance and white pine (13% of the relative abundance) are the most prevalent tree species. Conifers make up 58% of the total abundance. On the other hand, the regional plots in the Terrestrial Long-term Monitoring Project have sugar maple as the most dominant species (33% of regional cover) and the same is true of the forest plots in the adjacent Credit River watershed (CVC 2010). Sugar maple comprises just 8% of the trees at Duffin Heights.

The 10 plots within the Duffin Heights project also differ from one another. One plot, FV-19F, is an even-aged single-species stand of white cedar, and in fact contains 80% of the cedar in the whole site; the date of establishment based on age sampling seems to be the 1920s-30s. Meanwhile, FV-19E is actually an overgrown white pine plantation dating from the 1960s. Hemlock is found along the ravine edges at plots FV-19C and FV-19H. Sugar maple is present at several of the plots, and is growing vigorously among younger cohorts at FV-19G and FV-19H. Plot FV-19H and FV-19I have trembling aspen in the overstorey, while FV-19D is an open stand with ash, elm, white pine and Scots pine; the Scots pine are in severe decline and some elm have died from Dutch elm disease; this plot has significant canopy gaps. The four western plots near the landfill have a wide range of species that include white pine, red oak, red maple and beech.

Overall, the impression is of a forest cover that is in the early to middle stages of succession; shade-tolerant sugar maple has not become dominant as it tends to do in this part of southern Ontario. Likely a patchwork of species colonized largely open ground, mostly in the mid-twentieth century. These colonized from available seed sources and rootstocks, or in the case of FV-19F (and probably partially in FV-19E), were planted. The presence of cedar, along with occasional apple and hawthorn, suggest that cow pasture was a past land use on at least some of the land.

4.1.2 Tree Health

Crown vigour

Tree decline as measured by crown die-back was generally low at Duffin Heights; over 80% of all trees were in the minimal decline category with under 10% crown die-back. This is below the 25% (i.e. 25% of trees showing die-back) threshold of concern established by EMAN (Sajan 2006). The higher proportion of trees showing die-back in the intermediate and suppressed crown classes is to be expected given the impact of competition and reduced light on such trees.

There was a slight tendency for more crown dieback among conifers than deciduous trees; in 2012, the proportion of conifers showing moderate or severe dieback (at least 10% loss of crown foliage) was 22%. This is still below the 25% threshold of concern, and most of this result is due to the poor condition of one conifer species, Scots pine. The difference in crown vigour between deciduous and coniferous trees was not replicated in the regional Terrestrial Long-term Monitoring Project although CVC reported similar results as Duffin Heights (TRCA 2012, CVC 2010).

Certain species at Duffin Heights were showing elevated levels of crown dieback. While the sample size for white elm, dotted hawthorn, red ash and apple were too small to make a judgment, Scots pine and white ash both exceeded the 25% threshold of declining trees in at least one year of the record. The case of Scots pine is interesting in that it is not only a moderately invasive exotic species, but also seems to be in such a steep decline that live trees may be eliminated from the Duffin Heights plots within a few more years. By 2012, 12 of the 17 trees had at least 50% crown dieback. Most of these were in plot FV-19D, whose canopy is opening up and trees are being replaced by sapling, shrub and vine growth. The reason for this precipitous decline could not be identified; the trees are simply losing their leaves and dying.

White ash went from about 20% of trees with moderate-to-severe decline in 2008-10 to 46% in 2012. (A similar pattern was noted for the much smaller number of red ash). As discussed below under Pests and Diseases, this decline could not be attributed to emerald ash borer but rather more likely to ash yellows.

Stem defects

Stem defects can be divided into those that are simply the result of physical damage (open and closed wounds, and frost cracks or seams) and those that are caused by live agents such as diseases, insects, and the occasional larger animal such as a deer rubbing velvet from its antlers and damaging the bark.

The various uninfected wounds detected as stem defects are generally the result of physical damage (wind, the fall of neighbouring trees). For example, the very dense stand of cedar at FV-19F is prone to such damage because the slender trees are very close together. Leaning trees rub against one another, and wind throw results in damage to adjacent trees. Such wounds may become pathways for infection, or they may result in hollow trees even if the bark seals over the visible external wound. The hollow trees are structurally less stable but do provide important wildlife habitat. In any case, the physical wounds are not necessarily clear indicators of threats to overall forest health (aside from speculation about the effect of climate change on increased or decreased wind events).

The presence of cankers, decay fungi, or insect damage is of more interest. The occurrences of insect or animal damage, and decay fungi (excluding canker) were negligible (0.3-2% of trees) and well below the threshold of concern of 10% (CVC 2010). However, canker exceeded this threshold, affecting 43 trees (11% of the total at Duffin Heights). Almost all of these cases were a single pathogen afflicting white pine tentatively identified as *Caliciopsis* pine canker.

Pests & disease

The *Caliciopsis* cankers on the white pine affected 38 of the 50 trees of this species. At first, it was thought to be white pine blister rust. However, the canker affected the internodes of the trunk, not the young branches, and there was no obvious rapid death of branches, just a subtle crown thinning that resulted in 18% of the trees showing crown dieback. Thus the diagnosis was changed in 2012. The virulence and long-term impact of this disease are not known. It is of concern, however, as a relatively recently-discovered agent and one not before detected in the TRCA jurisdiction. Even if it does not cause outright mortality, one might expect it to reduce the vigour and growth of white pine which could reduce its ability to compete with deciduous (and likely invasive) species. It will also have implications for forestry.

The frequency of ash decline probably due to ash yellows – even in the absence of emerald ash borer observations, is also concerning and requires further investigation. Ash is a major component of many TRCA jurisdiction forests, especially young to mid-aged ones such as those at Duffin Heights. Is there a serious ash yellows disease problem or is it natural thinning due to succession (white ash is somewhat of a pioneer species though less so than poplars)? Ash yellows is a subtle disease, not discovered until the 1980s and difficult to diagnose (Pokorny and Sinclair 1994, Gillman 2005). The fact that ash is showing possible signs of weakness even as emerald ash borer is beginning to show up in the TRCA jurisdiction is ominous. The loss of most ash trees in our area is considered to be imminent based on the impact of emerald ash borer in the U.S. Midwest and south-western Ontario.

Dutch elm disease is present at Duffin Heights, and trees once infected die rapidly. Because this disease kills trees usually within a year or so of first symptoms, the seemingly low incidence of still-living diseased trees is misleading. There are not sufficient numbers of elm in the plots to determine whether this species is in serious decline here, along with being prone to Dutch elm disease, it has prolific reproductive abilities in disturbed and young forests. The low density of elm actually works in its favour, because the rate of dispersal of the disease is reduced. The bark beetles are not rapid travelers, and well-separated trees are less likely to be infected by them or by root grafts.

Every beech at Duffin Heights was affected by beech scale. One tree was observed to have probably *Phytophthora* cankers associated with the beech scale damage, although *Nectria* was not observed. The bark on beech trees was roughened and there appeared to be subtle loss of vigour. The sample size and time period are too small to assess whether beech is declining at Duffin Heights due to the scale. *Phytophthora*-type cankers have been observed on deciduous trees (including sugar maple) in several of the Terrestrial Long-term Monitoring project regional forest plots and this set of fungal diseases could be on the increase (McIlveen 2012).

Gypsy moth has been a major defoliator of many species of trees during periodic outbreaks in the second half of the 20th century. In 2011-12, widely-scattered larvae and egg masses were observed on beech, hemlock, ironwood, and sugar maple. Numbers were low overall, the larvae seen were generally dead, and little or no defoliation was observed. It is possible that the appearance of gypsy month in the past two years may be a build-up to a new outbreak; on the other hand, natural controls (e.g. diseases, parasites) may have ‘kicked in’ to control high populations of gypsy moth; no severe outbreaks have occurred in the Toronto area since the 1990s.

We assume that the rapid Scots pine decline is due to a pathogen, but this needs further investigation. Is it a shoot borer or moth, or a disease? Live shoots were not located within reach of the biologists so samples could not be taken. There appeared to be no rapid twig necrosis, fruiting bodies, cankers, boreholes, or stem defects. Scots pine is itself exotic – and invasive in some situations, especially moist open areas where it is thriving (e.g. in and near the mineral fen habitats at the Brock North lands (TRCA 2011b). The loss of Scots pine from the forest may not be a serious problem in itself, but the opening of the canopy seems to be facilitating the spread of aggressive woody vines and other, worse invasive species such as European buckthorn and dog-strangling vine.

Mortality

The overall tree mortality rate of 1-2% per year at Duffin Heights is right on the threshold of what is considered to be elevated levels (i.e. over 1.6%) for mature forests of the northeastern United States (Tierney *et al*. 2009). In mature and old-growth forests in southern Ontario, Parker and Craig (2003) consider 0.2-0.8% to be typical mortality rates for healthy stands; however, their basal area-based calculation of mortality rate is different from that which is employed in this study. Thus, there appears to be a slightly elevated death rate for trees at Duffin Heights: not enough to indicate severe decline but enough to bear close watching. On the other hand, given the mostly young-to-mid-aged status of the forest at this set of plots, the mortality rate may be naturally slightly higher than for more mature, late successional forests. There could simply be some natural thinning of early successional shade-intolerant species and of overcrowded smaller stems. This may be the case for some of the tree species that seem to have elevated mortality rates (though the sample size is very small for most of them). For example, paper birch is a shade-intolerant, naturally short-lived species; two of these died over the five-year period. The mortality rate for cedar and hemlock – two normally long-lived species, was 2-3%, again slightly higher than what should be expected. In these cases, the species are in crowded stands, especially the cedar at FV-19F.

Death directly attributable to disease (Dutch elm disease) was observable with the elm (three dead in 2010, one more in 2012).

Dead trees contribute organic material and wildlife habitat to forests. Standing dead trees (snags) comprise 82 stems (18% of the total). This is slightly below the norm (25%) for mature forests in eastern North America (Sajan 2006), but the forest at Duffin Heights is not mature.

In conclusion, the baseline health of the trees at Duffin Heights at the onset of development was in the generally “good” category, but at the lower end of that category. Crown vigour was mostly in the acceptable range but there are a couple of disease issues and possibly a slightly elevated mortality rate. The site is not quite as healthy as the set of TRCA regional plots as a whole.

To help understand the future direction of the forest at Duffin Heights, one must look beyond the existing canopy trees, especially the shade-intolerant species, and examine the regeneration and ground layers.

4.1.3 Woody Regeneration

The amount of woody species regeneration varied greatly, largely dependent on the amount of light penetration. Shaded plots such as FV-19C had fewer saplings and shrubs, while more open ones such as FV-19E and FV-19I had more.

Tree Saplings

At first glance, tree regeneration seems to be robust. There are more tree saplings than shrubs, and the majority of saplings are native. However, a closer look at the data reveals that almost all of the tree regeneration is ash (red and white). The other 13 tree species are present in very low numbers. Sugar maple is a distant third. Although they are shade-tolerant species, there were no beech or hemlock saplings observed. Other shade-tolerant species such as ironwood (*Ostrya virginiana*) or intermediate species such as red oak and bitternut hickory (*Carya cordiformis*) were extremely scarce. This pattern mirrors that of the regional Terrestrial Long-term Monitoring Project, except that they show abundant sugar maple regeneration (TRCA 2012).

Beech bark disease is causing serious decline in recruitment of this tree species; stressed trees may fail to produce much viable seed. The beech that showed signs of beech scale but had reasonably full canopies over the 2008-2012 period may still be failing to produce viable seed crops. Instead, saplings are produced from root suckers. In addition, the restriction of regeneration to clonal suckering only means that there is no opportunity for genetic recombination that may result in resistant trees. There do not appear (yet) to be any emergent pathogens affecting hemlock in the Toronto area. Explanations for decreased hemlock recruitment could range from climate change exacerbated by urban heat island and edge effects resulting in decreased atmospheric humidity and high temperatures, and air pollution to subtle changes in soil structure, metabolism and chemistry resulting from nitrate deposition and earthworm activity; and deer browse.

With ash being almost the only tree regenerating and the imminent threat of emerald ash borer, the prospects for tree recruitment at Duffin Heights are poor, even without considering coming urban impacts. As canopy trees die out, they are likely to be partly replaced by shrubs, woody vines, and herbaceous species to form a more thicket-like community.

Shrubs

Shrub growth was less prevalent than tree (at least ash) sapling regeneration, but was still locally abundant. The invasive common buckthorn was the most common shrub species (one stem attained tree size) and caused the total shrub count to be slightly more exotic than native. Low-growing poison ivy and red raspberry were also common, but conditions are favourable for further expansion and domination by buckthorn, especially if ash succumbs to emerald ash borer and there continues to be a lack of other tree species reproducing. Buckthorn fruits heavily and the seed is dispersed by birds. It exhibits rapid growth, high photosynthetic rates, and appears to alter soil chemistry with its nitrogen-rich leaf litter (Knight *et al*. 2007). This results in rapid leaf-litter decomposition, bare soil, and more suitable conditions for its own germination as well as that of other invasive species. We can perhaps see here a synergistic interaction of increased nutrient loading, reduced native biodiversity, and more invasions. If due to pathogens or other reasons there is an increase in tree mortality, buckthorn is well-poised to take advantage of canopy openings.

Woody Vines

Woody vines, especially the native riverbank grape and thicket creeper have also been casually noted during TRCA Ecological Land Classfication surveys as being extremely abundant in areas of declining or disturbed forest, for example, where Dutch elm disease has heavily depleted an elm-rich stand (Figure 18). Invasive woody vines such as kudzu (*Pueraria lobata*), oriental bittersweet (*Celastrus orbiculatus*), and Japanese honeysuckle (*Lonicera japonica*) are devastating to urban forest remnants in the eastern USA, where they are preventing regeneration of tree species (Sauer 1998). There is some evidence that woody vines are increasing in many types of forest, especially warm temperate and tropical forest, perhaps in response to increased carbon dioxide and nitrates (Allen *et al*. 2007, Schnitzer and Bongers 2011). Woody vines remain as only a minor component of the TRCA regional Terrestrial Long-term Monitoring Project, perhaps because of the mostly intact tree canopy at these sites so far (TRCA 2012). Duffin Heights similarly had a low occurrence of woody vines in the regeneration subplots – they made up only a small fraction of the stems. However, the occurrence of vines in the crowns of trees in the tree health plots is probably a better measure of prevalence because the number of individual stems rooted at ground level can be quite low even though there may be a lot of leaf cover aloft. High ascending woody vines also tend to be less than 10 cm diameter at breast height so would also usually get missed in the tree health plot. This measure of woody vine occurrence indeed revealed that at least parts of the Duffin Heights study area has heavy vine cover. Affected trees would suffer from increased competition for light and sometimes weighing-down of branches. The three plots with 20% or more of trees affected may have enough cover to inhibit sapling recruitment and lead to eventual decrease in tree canopy.

Figure 20. Intense woody vine growth (riverbank grape and oriental bittersweet) a few kilometres from Duffin Heights (2012)

4.1.4 Ground Vegetation

The overwhelming fact to note about the herbaceous vegetation at Duffin Heights is the infestation of dog-strangling vine. It dominates the set of plots as a whole and is present in every plot although it was less abundant in the four westernmost plots adjacent to the Brock West landfill site. The data appear to suggest an increase in relative cover as well but are not sufficient yet to ascertain a statistical trend. Dog-strangling vine is probably the single most virulent invasive species in the TRCA jurisdiction, characterized by prolific wind-dispersed seed, high germination rates, rapid growth, and ability to dominate many kinds of vegetation community (TRCA 2008). Younger forests (such as those at Duffin Heights) and shrublands are the worst affected. The mature forests more represented in the set of regional plots are more shaded and have less dog-strangling vine. In addition, the species was probably getting established at Duffin Heights when the trees were younger and there was even more light than at present.

The four western plots, as well as FV-19I (furthest to the northeast) have more ground vegetation diversity, and two species of sedge (early-flowering sedge and Pennsylvania sedge) are particularly common to the west.

The observed lack of spring woodland flowers at Duffin Heights is probably due to a combination of early successional state of the forests (lack of time for colonization) and heavy deer browse. In particular, deer browse was observed on the trilliums. Further evidence of heavy deer impact was observed in the form of an often sharp browse line in the forest. Sedges, prevalent in some of the plots, are tolerant of browsing, since they are graminoids that are adapted to mammalian herbivory. Deer may be also aiding the advance of dog-strangling vine since this plant is poisonous and avoided by them.

Thus, deer and dog-strangling vine may be acting synergistically to impoverish the ground layer at Duffin Heights.

4.1.5 Floristic Quality and Vegetation Health Summary

Floristic Quality and other indicators of botanical biodiversity are lower at Duffin Heights than for the regional set of plots. In particular, the Duffin Heights results can be compared with those of the 11 regional plots located in the rural land-use zone because the sample size is almost the same and also because development has only just begun at Duffin Heights; thus, the floristic character represents pre-development, rural conditions (Table 15).

Table 15. Comparison of floristic quality indicators at Duffin Heights and regional rural plots (2008-2012)

Plots	Total Species Richness	Native Species Richness	Average plot CC	Average plot FQI
Duffin Heights (n=10)	180	143	3.9(±0.02)	22.7(±1.01)
Regional Rural (n=11)	186	153	4.7(±0.4)	26.2(±6.4)

The lower floristic quality at Duffin Heights places it in the low-to-average quality range as described for TRCA forest plots (Masters 1997, TRCA 2012). While the forest is not currently in serious decline, the floristic quality values do sum up some of the various issues that have been disclosed in this study:

- Early-to-mid successional stage of the forest has allowed invasive species to colonize concurrent with the trees while slower-dispersing native forest species have not yet arrived;
- Invasive species are predominantly dog-strangling vine with some European buckthorn, which appear to be present in populations large enough to suppress native regeneration;
- Deer browse is probably having an impact on ground vegetation species such as trillium and may be affecting tree sapling recruitment;
- Several tree pathogens are present: notably *Caliciopsis* pine canker and beech scale that may be affecting the vigour of the affected tree species;
- Canopy gaps and forest edges seem to be allowing woody vine species to enter the forest canopy, with possible future impacts on tree health;
- The existing tree canopy is currently relatively healthy with native species dominating; however there is very poor recruitment of most native tree species in the sapling layer and a possibly slightly elevated rate of tree mortality, at least for some species;
- All of the abovementioned issues are occurring prior to the establishment of an urban matrix, which will lead to even more pressure on native plant communities.

4.2 Forest Birds

The results of this monitoring project are analysed by grouping the birds reported from all stations into guilds. These guilds are based on broad habitat preferences of the bird species but also incorporate an indication of the preferred nest-height for each species. This is done to provide a surrogate indication of sensitivity, it being assumed that ground-nesting species are generally more prone to the negative impacts of human disturbance than those species nesting in the higher levels of the habitat. Appendix 3 also indicates a third and fourth consideration that may be used in future analyses: cavity-nesting species and aerial-feeding species. The latter has been included in order to maintain awareness of possible future declines in aerial feeding insectivores, a group of species that has already been identified as exhibiting persistent population declines across the continent over recent years.

It is important, early in the project, to properly identify the target species that the project intends to monitor. In many habitat specific monitoring projects, species that are known not to utilize the specific habitat type are automatically omitted from any analysis. However, the Duffin Heights project intends to monitor changes in the guilds of birds that are utilizing the whole forest habitat as the surrounding matrix changes from largely rural to urban. With this in mind it is important to maintain a record of all species recorded from each station. In this way changes in the habitat composition of the local landscape and changes in urban pressures will be reflected and tracked in the species composition in the forest communities. The expectation is that as the local landscape urbanizes, the representation of more sensitive forest guild species will decline throughout the forest habitats at the site. Such variation in species use of the different forest locations is already indicated when comparing the baseline data from the different stations.

Even before the commencement of major construction in the area, the two stations located closest to Brock Road and the Pickering Operations Centre – FB-19a_3 and FB-19a_4 – show a much reduced representation by forest guild species compared to the two forest stations located furthest to the west, away from either the development or the urbanization around Brock Road. Rather unexpectedly, the control forest location to the east of Brock Road does not indicate a higher forest bird representation than at the two locations closest to the development. By 2012, the fifth year of monitoring, the forest bird populations at the two central stations have dropped below the control site but the most dramatic change can be seen in the number of forest birds at the two forest stations furthest from the development. Here, the representation by forest bird species has almost halved, decreasing almost to the same level as the representation in the considerably less intact forest habitats located at the central stations. This is especially significant since there has been no direct impact from the construction on these two more isolated stations. The implication of this is that sensitive forest bird species are reacting to impacts felt at the larger landscape level rather than directly on their nesting habitats.

Pre-development (i.e. the baseline period) the variation in species richness across the five stations seems to reflect the proximity of major roads. One impact of such proximity is the level of noise disturbance emanating from roads with high traffic volumes. Both Brock Road (running through the site) and Taunton Road (to the north) are major roads and it is expected that traffic volumes will increase in the near future. Such noise pollution impacts on forest breeding songbirds have been well-documented both in North America (Habib, 2007), and in Europe (Reijnen, 1994). The poor showing of the control station (station 5) in the baseline richness calculations suggests that such traffic noise levels were already impacting local forest-bird populations prior to construction. Furthermore, the seemingly immediate response in forest-bird richness at the two western stations, neither of which is directly affected by forest habitat loss as a result of development activities, suggests that the high level of noise during the construction period may have impacted nesting activity.

It is possible in due course, as the construction phase ends and impacts such as heavy machinery noise diminish, that some of these breeding forest species will re-establish themselves in the remaining intact forest. On the other hand, as the development becomes occupied it may be that this will impose new and more persistent negative influences on the local natural habitat, perhaps felt even as far afield as the most western stations. Monitoring the effects of these influences and impacts, and charting the presence or absence of forest dependent avifauna over the next few years is of considerable importance.

5. Next Steps

The most important step to take is to ensure that annual monitoring continues using the same protocol(s). The following are a few possible trends to be looking for in particular, while continuing the overall monitoring program:

- Changes in the proportion of native to exotic species cover in the forest vegetation plots. These could result from natural succession and competitive pressures; the new urban matrix now under construction, climate change, etc.

- Changes in species richness and Floristic Quality Index in the forest vegetation plots

- Changes in the proportions of forest bird species richness and abundance versus generalist bird species richness and abundance

- Population trends in particular individual native flora species of concern (e.g. thicket horsetail) or invasive species (e.g. common buckthorn or dog-strangling vine)

- Any incursion or colonization by additional invasive species not yet observed in the plots or present in very small numbers (e.g. oriental bittersweet or common reed, *Phragmites australis*)

- Impacts of existing pathogens on site such as *Caliciopsis* or *Phytophthora* canker, or new arrivals such as emerald ash borer

- Changes due to any restoration efforts undertaken at Duffin Heights

- Comparison between trends observed at the Duffin Heights stations/plots and those observed concurrently through the TRCA's regional Long Term Monitoring Project.

An additional consideration is to add forest plots in areas where tree planting or other restoration work is undertaken. Plots in new plantings would initially show only ground vegetation and new saplings, but provide valuable information on the success and development of new forest cover at Duffin Heights.

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Appendix 1: Locations of Duffin Heights Monitoring Plots and Stations (2012)

Monitoring Plot / Transect / Station Type	Plot	General Description of Plot Location	co-ordinates (m) NA		˚N	Land-use
			Easting	Northing		
Forest Vegetation	FV-19	east of Brock West landfill site	652835	4859433		influence from development starting 2010
	FV-19A	east of Brock West landfill site	652956	4859247		influence from development starting 2010
	FV-19B	east of Brock West landfill site	652716	4859510		influence from development starting 2010
	FV-19C	northeast of Brock West landfill site	652641	4859800		influence from development starting 2010
	FV-19D	west of Brock Road on tableland	653189	4860341		adjacent to development starting 2010
	FV-19E	west of Brock Road on tableland	653365	4860013		adjacent to development starting 2010
	FV-19F	west of Brock Road in ravine	652821	4859806		adjacent to development starting 2010
	FV-19G	east of Brock Road near golf course	654597	4860186		adjacent to development starting 2010
	FV-19H	east of Brock Road near golf course	654540	4860500		adjacent to development starting 2010
	FV-19I	east of Brock Road near Old Taunton	654450	4860788		influence from development starting 2010
Forest Birds	FB-19_1	east of Brock West landfill site	652843	4859443		influence from development starting 2010
	FB-19_2	east of Brock West landfill site	652662	4859825		influence from development starting 2010
	FB-19a_3	west of Brock Road on tableland	653224	4860319		adjacent to development starting 2010
	FB-19a_4	west of Brock Road on tableland	653434	4859892		adjacent to development starting 2010
	FB-19a_5	east of Brock Road near Old Taunton	654572	4860725		control site, 1.5km to east of 2010 development
Forest Salamanders	FS-19_1a	east of Brock West landfill site	652836	4859429		influence from development starting 2010
	FS-19_1b	east of Brock West landfill site	653045	4859255		influence from development starting 2010

Appendix 2: Flora Species observed at Duffin Heights (2008-2012)

Plant Species in set of plots (in order of L-rank)		L-rank	Coeff. Con-	Year of Observation (*2009 - only one plot: FV-19)				
Scientific Name	**Common Name**	**(2012)**	**servatism**	**2008**	***2009**	**2010**	**2011**	**2012**
Carex backii	Back's sedge	L3	8					x
Celastrus scandens	American bittersweet	L3	3	x		x	x	x
Desmodium glutinosum	pointed-leaved tick-trefoil	L3	6	x		x	x	x
Equisetum pratense	thicket horsetail	L3	8	x		x	x	x
Gymnocarpium dryopteris	oak fern	L3	7			x	x	x
Hypopitys monotropa	pinesap	L3	6	x			x	x
Lonicera canadensis	fly honeysuckle	L3	6			x	x	x
Mitchella repens	partridgeberry	L3	6	x		x	x	x
Monotropa uniflora	Indian-pipe	L3	6	x		x		
Penstemon digitalis	foxglove beard-tongue	L3	6	x		x	x	x
Trientalis borealis	star-flower	L3	6	x	x	x	x	x
Viburnum acerifolium	maple-leaved viburnum	L3	6	x	x	x	x	x
Acer rubrum	red maple	L4	4	x	x	x	x	x
Acer spicatum	mountain maple	L4	6					x
Acer x freemanii	hybrid swamp maple	L4	5	x				
Actaea pachypoda	white baneberry	L4	6	x	x	x	x	x
Amelanchier arborea	downy serviceberry	L4	5	x		x	x	x
Amelanchier laevis	smooth serviceberry	L4	5				x	x
Apocynum androsaemifolium	spreading dogbane	L4	3	x		x	x	x
Aquilegia canadensis	wild columbine	L4	5			x	x	x
Asarum canadense	wild ginger	L4	6	x		x	x	x
Betula alleghaniensis	yellow birch	L4	6	x				x
Betula papyrifera	paper birch	L4	2	x		x	x	x
Cardamine diphylla	broad-leaved toothwort	L4	7	x		x	x	x
Carex arctata	nodding wood sedge	L4	5	x	x	x	x	x
Carex communis	fibrous-rooted sedge	L4	6			x	x	x
Carex deweyana	Dewey's sedge	L4	6	x	x	x	x	x
Carex gracillima	graceful sedge	L4	4	x	x	x	x	x
Carex peckii	Peck's sedge	L4	6			x	x	x
Carex pedunculata	early-flowering sedge	L4	5	x	x	x	x	x
Carex pensylvanica	Pennsylvania sedge	L4	5	x	x	x	x	x
Carex sparganioides	bur-reed sedge	L4	5					x
Carex tenera	straw sedge (sensu lato)	L4	4	x		x	x	
Carya cordiformis	bitternut hickory	L4	6	x		x	x	x
Caulophyllum giganteum	long-styled blue cohosh	L4	6	x	x	x	x	x
Corylus cornuta	beaked hazel	L4	5	x	x	x	x	x
Crataegus macracantha	long-spined hawthorn	L4	4	x		x	x	x
Cystopteris bulbifera	bulblet fern	L4	5	x		x	x	x

Appendix 2: Flora Species observed at Duffin Heights (2008-2012)

Plant Species in set of plots (in order of L-rank)		L-rank	Coeff. Con-	Year of Observation (*2009 - only one plot: FV-19)				
Scientific Name	**Common Name**	**(2012)**	**servatism**	**2008**	***2009**	**2010**	**2011**	**2012**
Danthonia spicata	poverty oat grass	L4	5	x				
Dichanthelium acuminatum ssp. *acuminatum*	hairy panic grass	L4	2	x		x		
Dryopteris intermedia	evergreen wood fern	L4	5	x		x	x	x
Epifagus virginiana	beech-drops	L4	6				x	x
Epilobium coloratum	purple-leaved willow-herb	L4	3					x
Eurybia macrophylla	big-leaved aster	L4	5	x	x	x	x	x
Fagus grandifolia	American beech	L4	6	x	x	x	x	x
Maianthemum canadense	Canada May-flower	L4	5	x	x	x	x	x
Oryzopsis asperifolia	white-fruited mountain-rice	L4	6	x	x	x	x	x
Osmorhiza claytonii	woolly sweet cicely	L4	5	x		x	x	
Parthenocissus quinquefolia	Virginia creeper	L4	6	x		x	x	
Pinus strobus	white pine	L4	4	x		x	x	x
Polygonatum pubescens	downy Solomon's seal	L4	5	x		x	x	x
Populus grandidentata	large-toothed aspen	L4	5	x		x	x	x
Prunella vulgaris ssp. *lanceolata*	heal-all (native)	L4	5	x		x		x
Prunus pensylvanica	pin cherry	L4	3	x				
Pteridium aquilinum var. *latiusculum*	eastern bracken	L4	2	x	x	x	x	x
Pyrola elliptica	shinleaf	L4	5	x		x	x	x
Quercus rubra	red oak	L4	6	x	x	x	x	x
Ranunculus recurvatus var. *recurvatus*	hooked buttercup	L4	4	x				x
Rubus pubescens	dwarf raspberry	L4	4	x			x	x
Schizachne purpurascens	purple melic grass	L4	6	x	x	x	x	x
Symplocarpus foetidus	skunk cabbage	L4	7	x		x	x	x
Thuja occidentalis	white cedar	L4	4	x		x	x	x
Trillium erectum	red trillium	L4	6				x	x
Trillium grandiflorum	white trillium	L4	5	x	x	x	x	x
Tsuga canadensis	eastern hemlock	L4	7	x	x	x	x	x
Viola pubescens var. *pubescens*	downy yellow violet	L4	5					x
Viola pubescens var. *scabriuscula*	smooth yellow violet	L4	5					x
Acer saccharum	sugar maple	L5	4	x	x	x	x	x
Achillea millefolium ssp. *lanulosa*	woolly yarrow	L5	0					x
Actaea rubra ssp. *rubra*	red baneberry	L5	5	x		x	x	x
Ageratina altissima var. *altissima*	white snakeroot	L5	5	x				
Agrimonia gryposepala	agrimony	L5	2	x		x	x	x
Amphicarpaea bracteata	hog-peanut	L5	4	x		x	x	x
Anemone virginiana	common thimbleweed	L5	0	x		x	x	x
Aralia nudicaulis	wild sarsaparilla	L5	4	x	x	x	x	x
Arisaema triphyllum	Jack-in-the-pulpit	L5	5	x		x	x	x

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Plant Species in set of plots (in order of L-rank)		L-rank	Coeff. Con-	Year of Observation (*2009 - only one plot: FV-19)				
Scientific Name	**Common Name**	**(2012)**	**servatism**	**2008**	***2009**	**2010**	**2011**	**2012**
Asclepias syriaca	common milkweed	L5	0			x	x	
Athyrium filix-femina var. *angustum*	northeastern lady fern	L5	4	x		x	x	x
Bidens frondosa	common beggar's-ticks	L5	3		x			
Carex blanda	common wood sedge	L5	3	x	x	x	x	x
Carex rosea	curly-styled sedge	L5	5	x		x	x	x
Circaea canadensis ssp. *canadensis*	enchanter's nightshade	L5	3	x	x	x	x	x
Clinopodium vulgare	wild basil	L5	4			x	x	x
Cornus alternifolia	alternate-leaved dogwood	L5	6	x	x	x	x	x
Crataegus punctata	dotted hawthorn	L5	4	x		x	x	x
Crataegus sp.	hawthorn sp.	L5	4	x		x	x	x
Dryopteris carthusiana	spinulose wood fern	L5	5	x		x	x	x
Echinocystis lobata	wild cucumber	L5	3			x	x	x
Epilobium ciliatum ssp. *ciliatum*	sticky willow-herb	L5	3					x
Equisetum arvense	field horsetail	L5	0	x		x	x	x
Equisetum hyemale ssp. *affine*	scouring-rush	L5	2	x		x	x	x
Erythronium americanum ssp. *americanum*	yellow trout-lily	L5	5			x	x	x
Fragaria virginiana	wild strawberry	L5	2	x		x	x	x
Fraxinus americana	white ash	L5	4	x	x	x	x	x
Fraxinus pennsylvanica	red ash	L5	3	x	x	x	x	x
Galium aparine	cleavers	L5	4				x	x
Galium palustre	marsh bedstraw	L5	5	x				
Galium triflorum	sweet-scented bedstraw	L5	4	x		x	x	x
Geum canadense	white avens	L5	3	x		x	x	x
Glyceria striata	fowl manna grass	L5	3	x		x	x	
Hackelia virginiana	Virginia stickseed	L5	5	x				x
Impatiens capensis	orange touch-me-not	L5	4			x	x	x
Juglans nigra	black walnut	L5	5			x	x	x
Lysimachia ciliata	fringed loosestrife	L5	4				x	x
Maianthemum racemosum ssp. *racemosum*	false Solomon's seal	L5	4	x	x	x	x	x
Maianthemum stellatum	starry false Solomon's seal	L5	6				x	x
Matteuccia struthiopteris var. *pensylvanica*	ostrich fern	L5	5			x	x	x
Mentha arvensis ssp. *borealis*	wild mint	L5	3				x	
Nabalus altissimus	tall wood lettuce	L5	5	x	x	x	x	x
Onoclea sensibilis	sensitive fern	L5	4	x		x	x	x
Ostrya virginiana	ironwood	L5	4	x	x	x	x	x
Oxalis stricta	common yellow wood-sorrel	L5	0	x		x	x	x
Parthenocissus inserta	thicket creeper	L5	3	x	x	x	x	x
Phryma leptostachya	lopseed	L5	6	x		x	x	x

Appendix 2: Flora Species observed at Duffin Heights (2008-2012)

Plant Species in set of plots (in order of L-rank)		L-rank	Coeff. Con-	Year of Observation (*2009 - only one plot: FV-19)				
Scientific Name	**Common Name**	**(2012)**	**servatism**	**2008**	***2009**	**2010**	**2011**	**2012**
Podophyllum peltatum	May-apple	L5	5	x		x	x	x
Populus tremuloides	trembling aspen	L5	2	x		x	x	x
Prunus serotina	black cherry	L5	3	x		x	x	x
Prunus virginiana var. *virginiana*	choke cherry	L5	2	x	x	x	x	x
Ranunculus abortivus	kidney-leaved buttercup	L5	2	x		x	x	x
Rhus typhina	staghorn sumach	L5	1	x				
Ribes americanum	wild black currant	L5	4	x		x	x	
Ribes cynosbati	prickly gooseberry	L5	4	x	x	x	x	x
Rubus allegheniensis	common blackberry	L5	2				x	
Rubus idaeus ssp. *strigosus*	wild red raspberry	L5	0	x	x	x	x	x
Rubus occidentalis	wild black raspberry	L5	2	x		x	x	x
Rubus odoratus	purple-flowering raspberry	L5	3	x		x	x	x
Sambucus racemosa ssp. *pubens*	red-berried elder	L5	5	x		x	x	x
Smilax herbacea	carrion-flower	L5	5	x		x	x	x
Solidago altissima	tall goldenrod	L5	1	x		x	x	x
Solidago caesia	blue-stemmed goldenrod	L5	5	x		x	x	x
Solidago flexicaulis	zig-zag goldenrod	L5	6	x	x	x	x	x
Solidago gigantea	late goldenrod	L5	4	x		x	x	x
Symphyotrichum cordifolium	heart-leaved aster	L5	5	x		x	x	x
Symphyotrichum lanceolatum var. *lanceolatum*	panicled aster	L5	3			x		x
Symphyotrichum lateriflorum var. *lateriflorum*	calico aster	L5	3	x		x	x	x
Tilia americana	basswood	L5	4	x		x	x	x
Toxicodendron radicans var. *rydbergii*	poison ivy (shrub form)	L5	0	x	x	x	x	x
Ulmus americana	white elm	L5	3	x		x	x	x
Viburnum lentago	nannyberry	L5	4					x
Viola labradorica	dog violet	L5	4	x		x	x	x
Viola pubescens	stemmed yellow violet (var. not determined)	L5	5	x		x	x	
Viola sororia	common blue violet	L5	4	x				x
Vitis riparia	riverbank grape	L5	0	x	x	x	x	x
Alliaria petiolata	garlic mustard	L+		x	x	x	x	x
Arctium minus	common burdock	L+					x	x
Berberis thunbergii	Japanese barberry	L+		x		x	x	x
Berberis vulgaris	common barberry	L+				x	x	x
Celastrus orbiculatus	oriental bittersweet	L+		x		x	x	x
Cirsium arvense	creeping thistle	L+						x
Crataegus monogyna	English hawthorn	L+				x	x	x
Cynanchum rossicum	dog-strangling vine	L+		x	x	x	x	x
Epipactis helleborine	helleborine	L+		x	x	x	x	x

Appendix 2: Flora Species observed at Duffin Heights (2008-2012)

Plant Species in set of plots (in order of L-rank)		L-rank	Coeff. Con-	Year of Observation (*2009 - only one plot: FV-19)				
Scientific Name	**Common Name**	**(2012)**	**servatism**	**2008**	***2009**	**2010**	**2011**	**2012**
Geum urbanum	urban avens	L+				x	x	
Hypericum perforatum	common St. John's-wort	L+		x		x	x	
Leucanthemum vulgare	ox-eye daisy	L+					x	
Ligustrum vulgare	privet	L+		x				
Lithospermum officinale	Eurasian gromwell	L+		x		x	x	
Lonicera morrowii	Morrow's honeysuckle	L+		x		x	x	x
Lonicera x *bella*	shrub honeysuckle	L+		x		x	x	x
Malus pumila	apple	L+		x		x	x	x
Medicago lupulina	black medick	L+				x		
Melilotus albus	white sweet clover	L+		x		x	x	
Pilosella caespitosa	yellow hawkweed	L+		x		x	x	x
Pinus sylvestris	Scots pine	L+		x		x	x	x
Poa compressa	flat-stemmed blue grass	L+		x		x	x	x
Poa pratensis ssp. *pratensis*	Kentucky blue grass	L+		x		x	x	
Quercus robur	English oak	L+						x
Ranunculus acris	tall buttercup	L+		x		x	x	x
Rhamnus cathartica	common buckthorn	L+		x	x	x	x	x
Rosa multiflora	multiflora rose	L+		x		x	x	x
Solanum dulcamara	bittersweet nightshade	L+		x		x	x	x
Sonchus sp.	sow-thistle sp.	L+					x	
Sorbus aucuparia	European mountain-ash	L+		x		x	x	x
Taraxacum officinale	dandelion	L+		x	x	x	x	x
Tussilago farfara	coltsfoot	L+		x		x	x	x
Veronica officinalis	common speedwell	L+		x	x	x	x	x
Viburnum lantana	wayfaring tree	L+					x	x
Viburnum opulus	European highbush cranberry	L+		x	x	x	x	x
Acer negundo	Manitoba maple	L+?		x		x	x	x
Epilobium sp.	willow-herb sp.	L+?						x
Geranium robertianum	herb Robert	L+?						x

Appendix 3: Regional breeding bird list, showing local ranks (L-ranks) and assigned nest-habitat guilds.

				HABITAT GUILD					PREFERRED NEST HEIGHT/LOCATION					
Common Name	**Code**	**L-Rank**	**Duffin Heights**	**forest**	**edge**	**wetland**	**meadow**	**general**	**cavity**	**low**	**mid**	**upper**	**aerial**	**guild***
Acadian flycatcher	ACFL	**L3**												C
barred owl	BADO	**L2**												C
black and white warbler	BAWW	**L2**												A
Blackburnian warbler	BLBW	**L3**												C
black-throated blue warbler	BTBW	**L3**												B
black-throated green warbler	BTNW	**L3**	**x**											C
blue-grey gnatcatcher	BGGN	**L4**												C
blue-headed vireo	BHVI	**L3**												C
broad-winged hawk	BWHA	**L2**												C
brown creeper	BRCR	**L3**	**x**											B
canada warbler	CAWA	**L2**												A
cerulean warbler	CERW	**L2**												C
Cooper's hawk	COHA	**L4**												C
eastern screech-owl	EASO	**L4**												C
eastern wood-pewee	EAWP	**L4**	**x**											C
golden-crowned kinglet	GCKI	**L3**												C
great-crested flycatcher	GCFL	**L4**	**x**											C
hairy woodpecker	HAWO	**L4**	**x**											C
hermit thrush	HETH	**L3**												A
hooded warbler	HOWA	**L2**												B
long-eared owl	LEOW	**L3**												C
magnolia warbler	MAWA	**L3**												B
merlin	MERL	**L2**												C
northern saw-whet owl	NSWO	**L3**												C
nothern goshawk	NOGO	**L2**												C
olive-sided flycatcher	OSFL	**L2**												C
ovenbird	OVEN	**L3**	**x**											A
pileated woodpecker	PIWO	**L3**	**x**											C
pine siskin	PISI	**L3**												C
pine warbler	PIWA	**L3**	**x**											C
red-breasted nuthatch	RBNU	**L4**	**x**											C
red-eyed vireo	REVI	**L4**	**x**											B
red-shouldered hawk	RSHA	**L2**												C
ruby-crowned kinglet	RCKI	**L3**												C
ruffed grouse	RUGR	**L2**												A

Appendix 3: Regional breeding bird list, showing local ranks (L-ranks) and assigned nest-habitat guilds.

				HABITAT GUILD					PREFERRED NEST HEIGHT/LOCATION					
Common Name	**Code**	**L-Rank**	**Duffin Heights**	**forest**	**edge**	**wetland**	**meadow**	**general**	**cavity**	**low**	**mid**	**upper**	**aerial**	**guild**
scarlet tanager	SCTA	**L3**	**x**											C
sharp-shinned hawk	SSHA	**L3**												C
veery	VEER	**L3**	**x**											A
whip-poor-will	WPWI	**L1**												A
white-breasted nuthatch	WBNU	**L4**	**x**											C
white-winged crossbill	WWCR	**L3**												C
winter wren	WIWR	**L3**	**x**											A
wood duck	WODU	**L3**												C
wood thrush	WOTH	**L3**	**x**											B
worm-eating warbler	WEWA	**L1**												A
yellow-bellied sapsucker	YBSA	**L3**												C
yellow-throated vireo	YTVI	**L3**												C
American redstart	AMRE	**L3**												E
American woodcock	AMWO	**L3**												D
black-billed cuckoo	BBCU	**L3**												E
blue-winged warbler	BWWA	**L2**												D
brown thrasher	BRTH	**L3**												E
chestnut-sided warbler	CSWA	**L3**												E
downy woodpecker	DOWO	**L5**	**x**											E
eastern bluebird	EABL	**L4**												E
eastern towhee	EATO	**L3**												E
golden-winged warbler	GWWA	**L2**												D
indigo bunting	INBU	**L4**	**x**											E
least flycatcher	LEFL	**L4**												F
mourning warbler	MOWA	**L3**	**x**											D
Nashville warbler	NAWA	**L3**												D
purple finch	PUFI	**L4**												F
red-bellied woodpecker	RBWO	**L4**												F
red-headed woodpecker	RHWO	**L3**												F
ring-necked pheasant	RINP	**L+**												D
rose-breasted grosbeak	RBGR	**L4**	**x**											E
ruby-throated hummingbird	RTHU	**L4**	**x**											E
white-throated sparrow	WTSP	**L3**												D
wild turkey	WITU	**L3**	**x**											D
yellow-billed cuckoo	YBCU	**L3**												E

Appendix 3: Regional breeding bird list, showing local ranks (L-ranks) and assigned nest-habitat guilds.

				HABITAT GUILD					PREFERRED NEST HEIGHT/LOCATION					
Common Name	**Code**	**L-Rank**	**Duffin Heights**	**forest**	**edge**	**wetland**	**meadow**	**general**	**cavity**	**low**	**mid**	**upper**	**aerial**	**guild**
yellow-breasted chat	YBCH	**L2**												E
yellow-rumped warbler	YRWA	**L3**												F
alder flycatcher	ALFL	**L4**												K
American bittern	AMBI	**L2**												J
American black duck	ABDU	**L3**												J
American coot	AMCO	**L2**												J
black tern	BLTE	**LX**												J
black-crowned night heron	BCNH	**L3**												L
blue-winged teal	BWTE	**L2**												J
Canada goose	CANG	**L5**												J
canvasback	CANV	**L2**												J
Caspian tern	CATE	**L3**												J
common moorhen	COMO	**L3**												J
common tern	COTE	**L3**												J
common yellowthroat	COYE	**L4**	**x**											J
double-crested cormorant	DCCO	**L3**												L
gadwall	GADW	**L4**												J
great black-backed gull	GBBG	**L3**												J
great blue heron	GBHE	**L3**												L
great egret	GREG	**L3**												L
green heron	GRHE	**L4**												L
green-winged teal	AGWT	**L2**												J
herring gull	HERG	**L3**												J
hooded merganser	HOME	**L3**												L
least bittern	LEBI	**L2**												J
mallard	MALL	**L5**												J
marsh wren	MAWR	**L3**												K
mute swan	MUSW	**L+**												J
osprey	OSPR	**L3**												L
pied-billed grebe	PBGR	**L3**												J
redhead	REDH	**L2**												J
ring-billed gull	RBGU	**L4**												J
sora	SORA	**L3**												J
swamp sparrow	SWSP	**L4**												J
trumpeter swan	TRUS	**L+**												J

Appendix 3: Regional breeding bird list, showing local ranks (L-ranks) and assigned nest-habitat guilds.

				HABITAT GUILD					PREFERRED NEST HEIGHT/LOCATION					
Common Name	**Code**	**L-Rank**	**Duffin Heights**	**forest**	**edge**	**wetland**	**meadow**	**general**	**cavity**	**low**	**mid**	**upper**	**aerial**	**guild**
Virginia Rail	VIRA	**L3**												J
Wilson's snipe	WISN	**L3**												J
bobolink	BOBO	**L3**												G
clay-coloured sparrow	CCSP	**L3**												G
eastern kingbird	EAKI	**L4**	**x**											I
eastern meadowlark	EAME	**L4**												G
field sparrow	FISP	**L4**												G
grasshopper sparrow	GRSP	**L2**												G
Henslow's sparrow	HESP	**LX**												G
horned lark	HOLA	**L4**												G
loggerhead shrike	LOSH	**LX**												H
northern harrier	NOHA	**L3**												G
savannah sparrow	SAVS	**L4**												G
sedge wren	SEWR	**L3**												G
short-eared owl	SEOW	**L3**												G
spotted sandpiper	SPSA	**L4**	**x**											G
upland sandpiper	UPSA	**L2**												G
vesper sparrow	VESP	**L3**												G
western meadowlark	WEME	**L3**												G
willow flycatcher	WIFL	**L4**												H
American Crow	AMCR	**L5**	**x**											O
American goldfinch	AMGO	**L5**	**x**											N
American kestrel	AMKE	**L4**												O
American robin	AMRO	**L5**	**x**											N
Baltimore oriole	BAOR	**L5**	**x**											O
barn swallow	BARS	**L4**												N
black-capped chickadee	BCCH	**L5**	**x**											N
blue jay	BLJA	**L5**	**x**											O
Carolina wren	CARW	**L4**												N
cedar waxwing	CEDW	**L5**	**x**											N
chimney swift	CHSW	**L4**												O
chipping sparrow	CHSP	**L5**	**x**											N
cliff swallow	CLSW	**L4**												O
common grackle	COGR	**L5**	**x**											N
common nighthawk	CONI	**L3**												M

Appendix 3: Regional breeding bird list, showing local ranks (L-ranks) and assigned nest-habitat guilds.

				HABITAT GUILD					PREFERRED NEST HEIGHT/LOCATION					
Common Name	**Code**	**L-Rank**	**Duffin Heights**	**forest**	**edge**	**wetland**	**meadow**	**general**	**cavity**	**low**	**mid**	**upper**	**aerial**	**guild**
eastern phoebe	EAPH	**L5**												N
European starling	EUST	**L+**												N
great-horned owl	GHOW	**L4**												O
grey catbird	GRCA	**L4**												N
house finch	HOFI	**L+**												N
house sparrow	HOSP	**L+**												N
house wren	HOWR	**L5**												N
killdeer	KILL	**L5**												M
mourning dove	MODO	**L5**	**x**											N
northern cardinal	NOCA	**L5**	**x**											N
northern flicker	NOFL	**L4**	**x**											O
northern mockingbird	NOMO	**L5**												N
orchard oriole	OROR	**L5**												O
peregrine falcon	PEFA	**L4**												O
red-tailed hawk	RTHA	**L5**	**x**											O
red-winged blackbird	RWBL	**L5**	**x**											N
rock dove	ROPI	**L+**												N
song sparrow	SOSP	**L5**	**x**											M
tree swallow	TRES	**L4**												N
warbling vireo	WAVI	**L5**												O
yellow warbler	YWAR	**L5**												N
northern waterthrush	NOWA	**L3**												Q
prothonotary warbler	PROW	**L2**												P
bank swallow	BANS	**L4**												sc
belted kingfisher	BEKI	**L4**												sc
brown-headed cowbird	BHCO	**L5**	**x**											sc
northern rough-winged swallow	NRWS	**L4**												sc
purple martin	PUMA	**L4**												sc
turkey vulture	TUVU	**L4**												sc

note that the given habitat is that in which the species places the nest.

forest-edge can also be used to indicate thicket habitat

ground = on or very near to ground-level. <0.5m = low level

undrstry = lower shrub layer (in forest), or generally in shrubs (open country). 0.5 to 3m = mid level

canopy = middle or upper canopy in forest habitat - small to large trees. > 3m = upper level

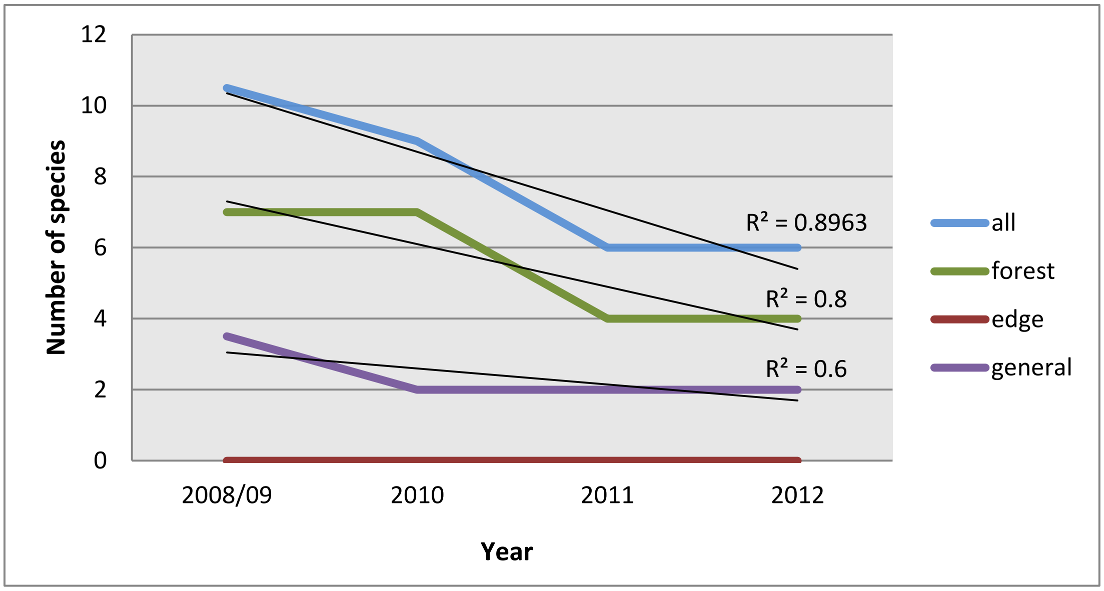
Appendix 3: Regional breeding bird list, showing local ranks (L-ranks) and assigned nest-habitat guilds.

***Guild descriptions:**	
A) forest low-level nester	J) wetland low-level nester
B) forest mid-level nester	K) wetland mid-level nester
C) forest upper-level nester	L) wetland upper-level nester
D) forest-edge low-level nester	M) generalist low-level nester
E) forest-edge mid-level nester	N) generalist mid-level nester
F) forest-edge upper-level nester	O) generalist upper-level nester
G) meadow low-level nester	P) swamp mid-level nester
H) meadow mid-level nester	Q) swamp low-level nester
I) meadow upper-level nester	sc = special case

Appendix 4: Annual changes in bird species richness by habitat guild at Duffin Heights

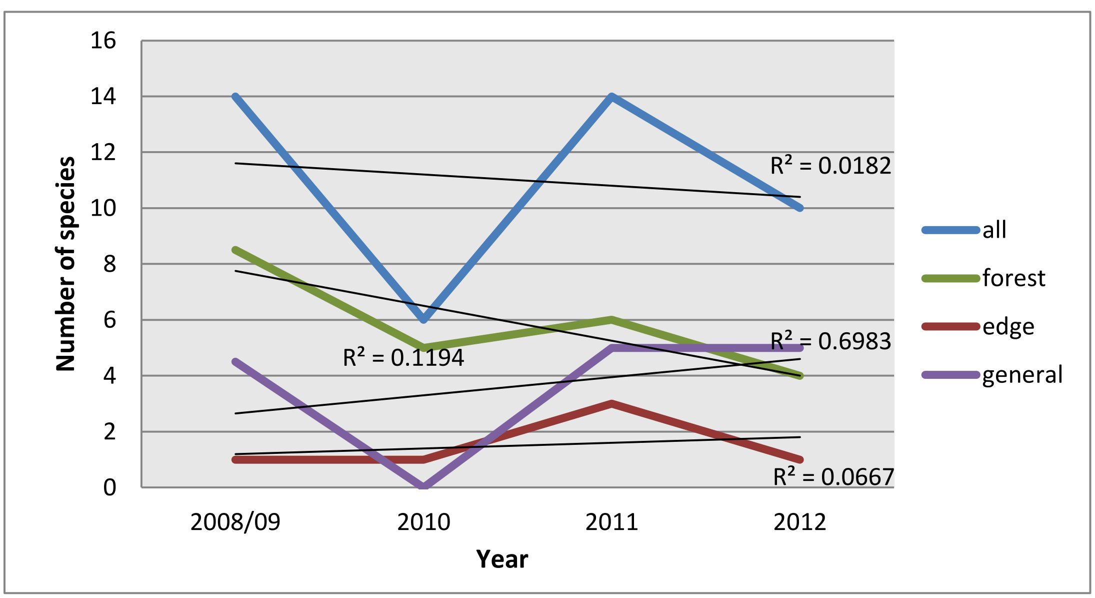
Station 1

	2008/09	2010	2011	2012
all	10.5	9	6	6
forest	7	7	4	4
edge	0	0	0	0
general	3.5	2	2	2



Station 2

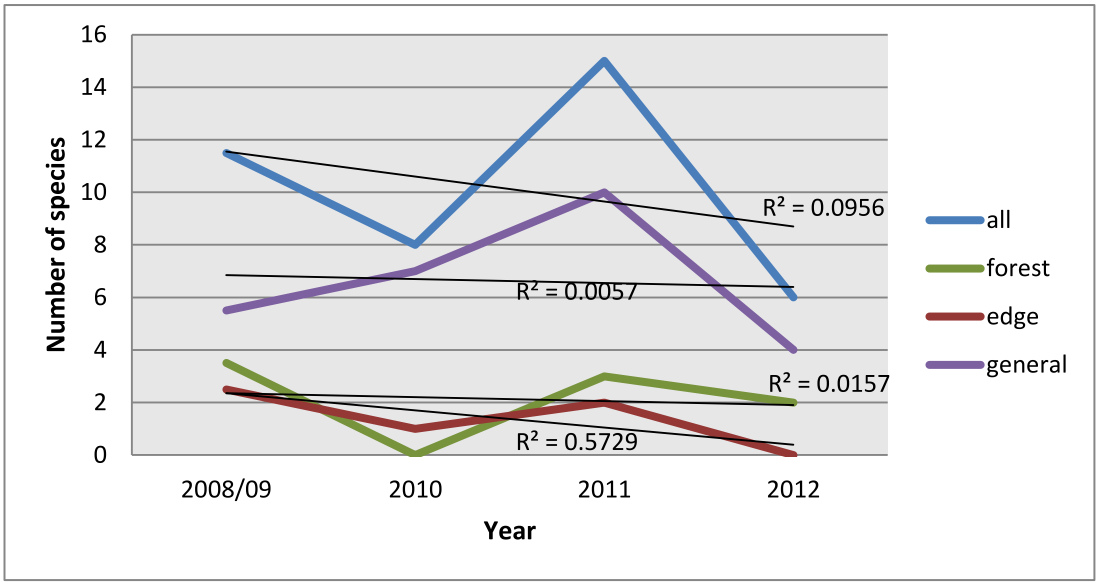
	2008/09	2010	2011	2012
all	14	6	14	10
forest	8.5	5	6	4
edge	1	1	3	1
general	4.5	0	5	5



Appendix 4: Annual changes in bird species richness by habitat guild at Duffin Heights

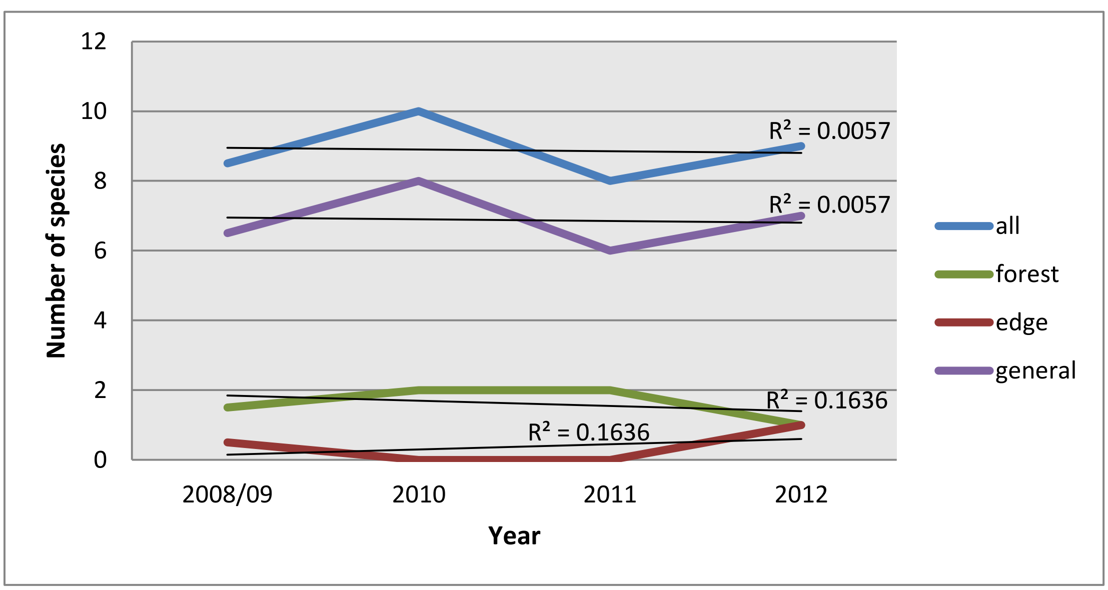
Station 3

	2008/09	2010	2011	2012
all	11.5	8	15	6
forest	3.5	0	3	2
edge	2.5	1	2	0
general	5.5	7	10	4



Station 4

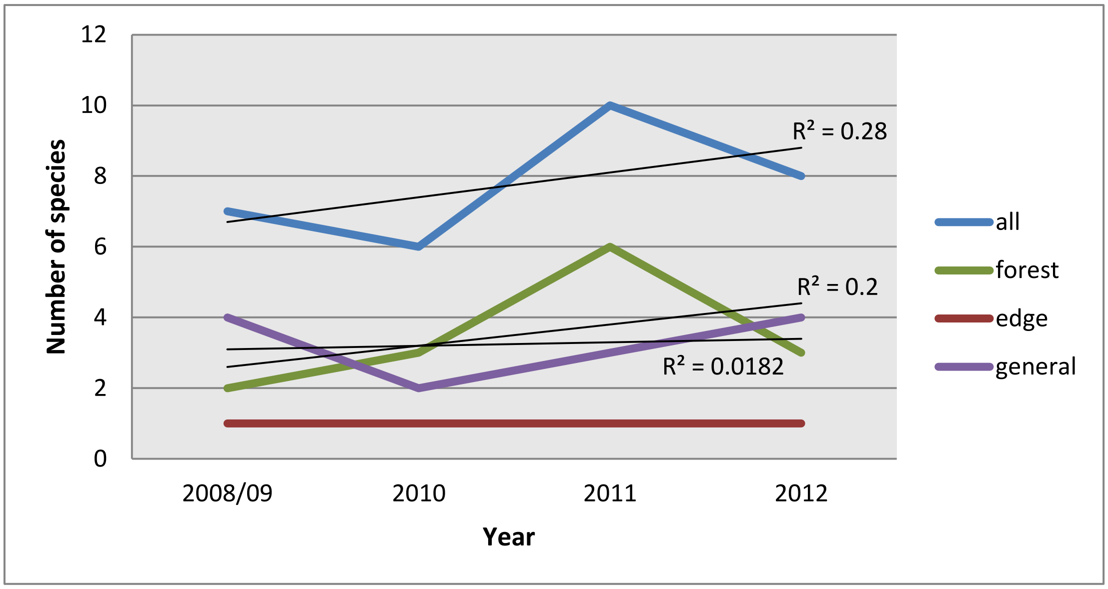
	2008/09	2010	2011	2012
all	8.5	10	8	9
forest	1.5	2	2	1
edge	0.5	0	0	1
general	6.5	8	6	7



Appendix 4: Annual changes in bird species richness by habitat guild at Duffin Heights

Station 5

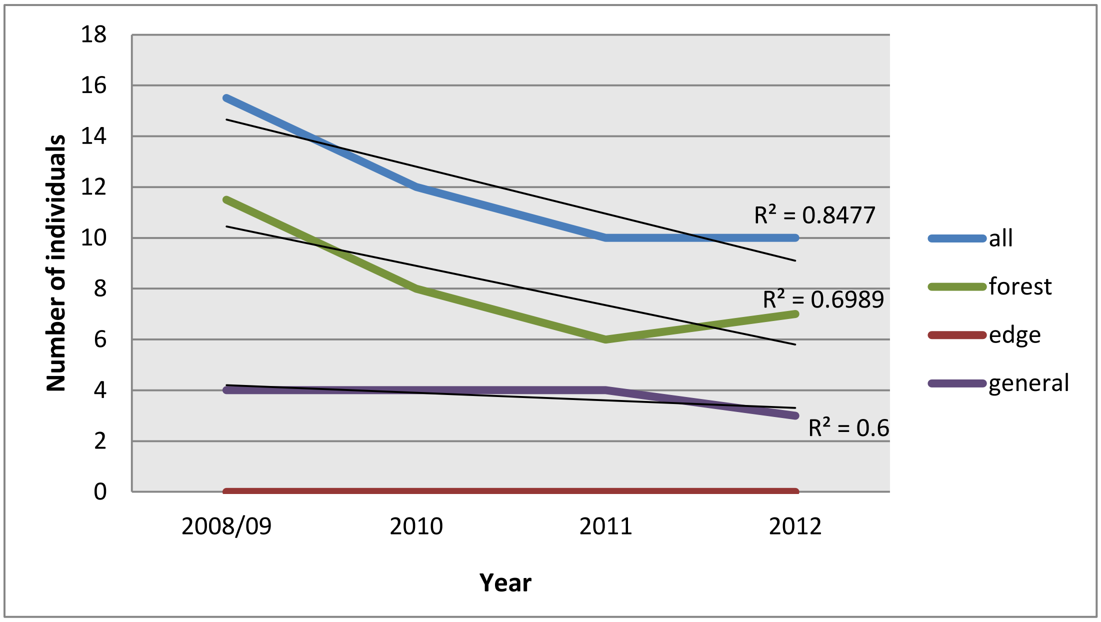
	2008/09	2010	2011	2012
all	7	6	10	8
forest	2	3	6	3
edge	1	1	1	1
general	4	2	3	4



Appendix 5: Annual changes in bird species abundance by habitat guild at Duffin Heights

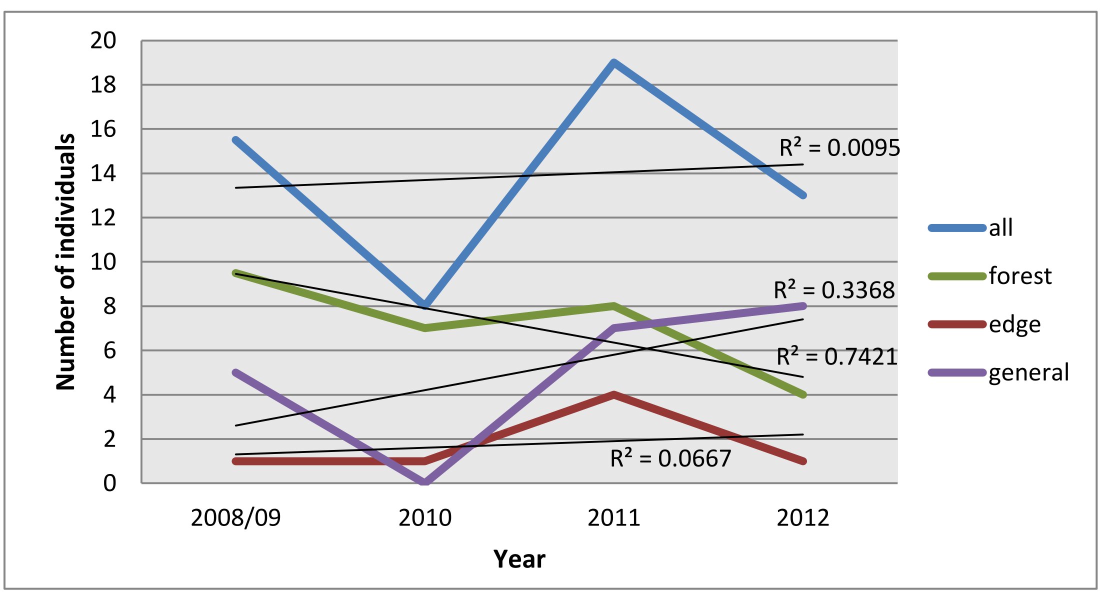
Station 1

	2008/09	2010	2011	2012
all	15.5	12	10	10
forest	11.5	8	6	7
edge	0	0	0	0
general	4	4	4	3



Station 2

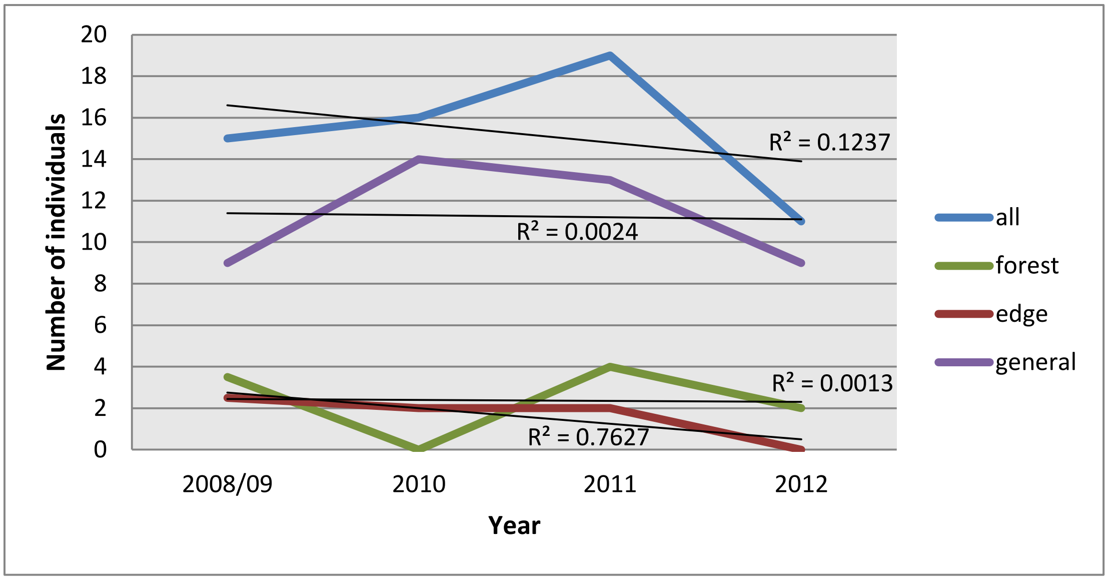
	2008/09	2010	2011	2012
all	15.5	8	19	13
forest	9.5	7	8	4
edge	1	1	4	1
general	5	0	7	8



Appendix 5: Annual changes in bird species abundance by habitat guild at Duffin Heights

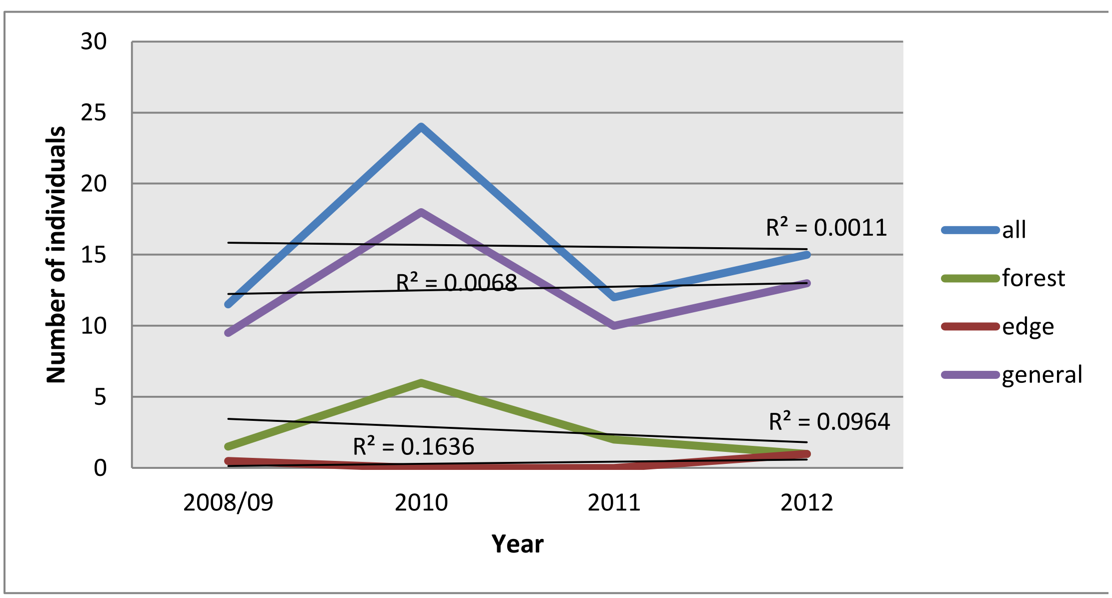
Station 3

	2008/09	2010	2011	2012
all	15	16	19	11
forest	3.5	0	4	2
edge	2.5	2	2	0
general	9	14	13	9



Station 4

	2008/09	2010	2011	2012
all	11.5	24	12	15
forest	1.5	6	2	1
edge	0.5	0	0	1
general	9.5	18	10	13



Appendix 5: Annual changes in bird species abundance by habitat guild at Duffin Heights

Station 5

	2008/09	2010	2011	2012
all	12	14	15	11
forest	4	6	8	4
edge	2	1	1	1
general	6	7	6	6