Introduced Species Management Plan: Quadra Hill on Galiano Island (British Columbia, Canada)

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Territorial Acknowledgement

The property described in this report (DL 58) is located within the traditional, unceded, and shared territory of the Penelakut, Hwlitsum, and other Hul'qumi'num-speaking Indigenous peoples of the Salish Sea, as well as the ceded territory of the Tsawwassen First Nation.

Abstract

The prevalence and potential for negative impacts makes the management of introduced species a central component of most stewardship and restoration projects today. Areas that have been disturbed by human use may be especially vulnerable to impacts of introduced species, such as out-competing native species. This report is a contribution to an Introduced Species Management Plan for the District Lot 58 (DL 58), also known as Quadra Hill, on Galiano Island, British Columbia, Canada. To assess the state of introduced species on this property, field surveys were carried out over two days in June 2023 at our study site, which covered the section of the property most affected by recent logging and agriculture activities. Field surveys were undertaken to meet the objectives of collecting data to map these species at the site, providing baseline data for future monitoring, and creating recommendations for a management strategy. We used a belted transect method for monitoring species of concern, collected GPS data, analyzed and mapped the data using ArcGIS Pro, and generated a series of maps intended for use by the Galiano Conservancy Association in their management of this property. Of the seven introduced species that we mapped, we found that *Cytisus scoparius* (Scotch broom), *Rubus laciniatus* (cutleaf blackberry), and *Rubus armeniacus* (Himalayan blackberry) are the most abundant and concerning species at our study site. We provide tips for the management of each species, recommending the use of three methods of introduced species treatment: hand-pulling, cutting, and digging/grubbing. Our findings highlight the importance of an impact-focused approach to introduced species management.

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1.0 Introduction

The prevalence and potential for negative impacts makes the management of introduced species a central component of most stewardship and restoration projects today. Though debate exists surrounding the necessity or futility of controlling for non-native species, most agree that limiting certain pernicious plants contributes to overall ecological health, particularly in sensitive ecosystems (Shackelford et al., 2013). For example, some of these species may spread aggressively and outcompete native ones, jeopardizing their survival as well as that of other species that depend on them, leading to an overall decline in biodiversity (SCCP, n.d.). Furthermore, areas that have been heavily disturbed by human use may be especially vulnerable to impacts (Meyer et al., 2021).

This report is a contribution to an Introduced Species Management Plan for the District Lot 58 (DL 58), also known as Quadra Hill, on Galiano Island, British Columbia, Canada. It has been prepared on behalf of the Galiano Conservancy Association (GCA), "a community based non-profit society and registered charity that aims to protect, steward and restore Galiano Island ecosystems" (GCA, n.d.). The property in question is directly adjacent to the Millard Learning Center to the south, and the Vanilla Leaf and Great Beaver Swamp protected areas to the East and North, respectively (see Figure 1). This centers it squarely within the Mid-Island Protected Areas Network (MIPAN), some 668 ha of protected lands that span the island from the Trincomali Channel to the Georgia Strait (Huggins & Thompson, 2023), a setting which contributes to its ecological importance for both protection and restoration. To assess the state of introduced species on the property, field surveys were carried out over two days in June 2023, contributing baseline data on the presence of introduced species and informing future management prescriptions. In this report we present the results of these surveys, including detailed mapping and discussion, and provide recommendations for the management of the site.

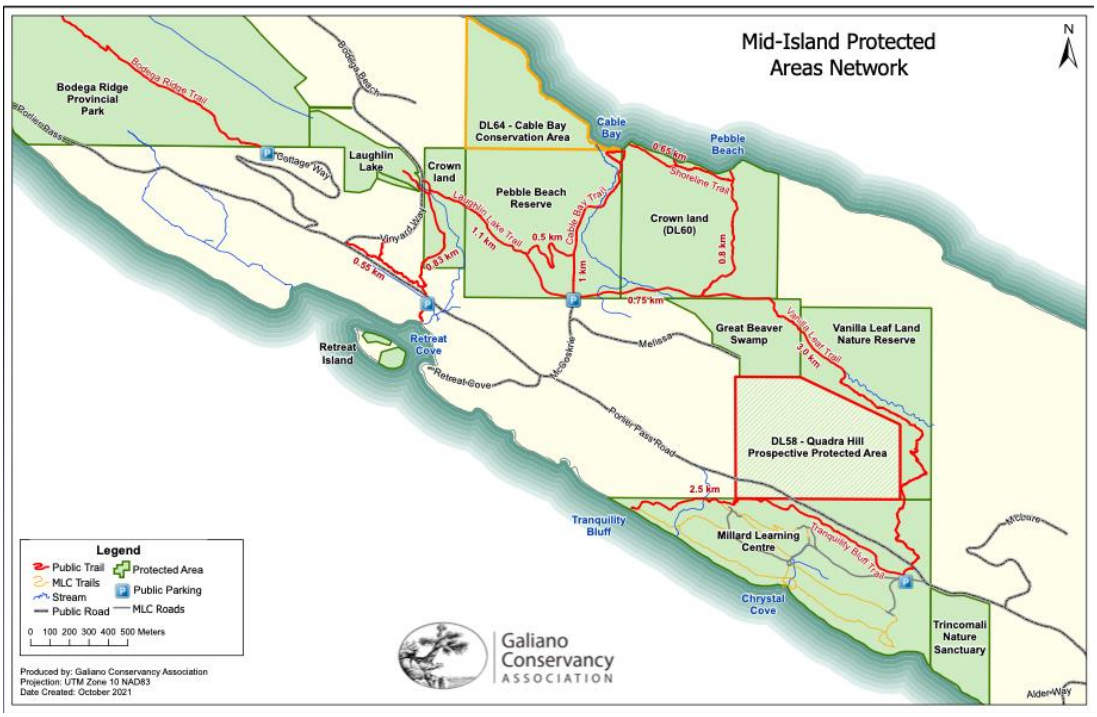

Figure 1. *Quadra Hill in relation to the Mid-Island Protected Areas Network (GCA, 2021)*

2.0 Site Description & Background

The Quadra Hill (DL 58) property is located on Galiano Island in the Salish Sea between Vancouver Island and the lower mainland of British Columbia, Canada (see Figure 2). It consists of 46.81 ha of forest and wetland communities, a comprehensive assessment of which was performed for the Quadra Hill Baseline Report produced by the GCA (Huggins & Thompson, 2023).

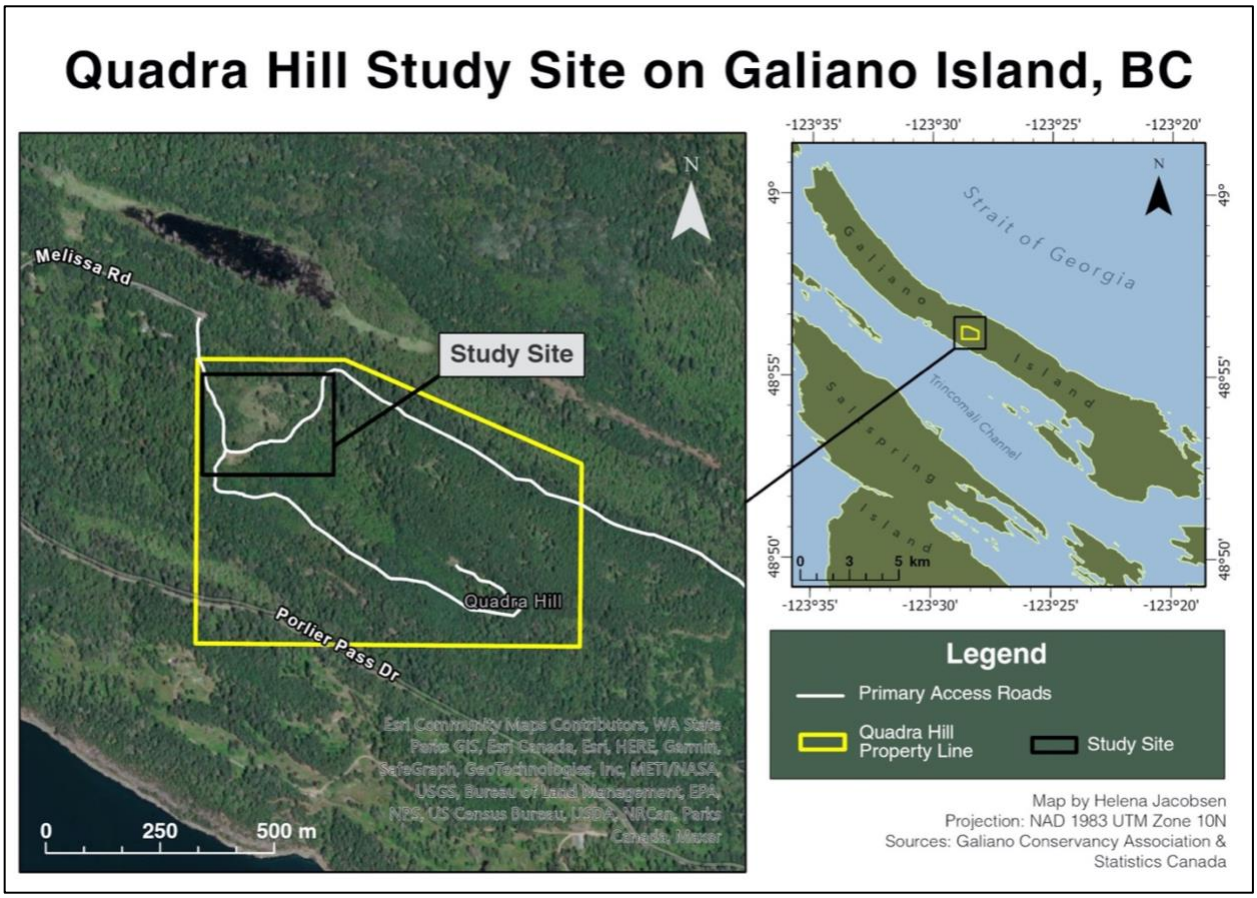

Figure 2*. Map of study site within Quadra Hill (DL58).*

2.1 Ecological context

Located in the Georgia Depression Ecoprovince, Galiano Island falls within the Coastal Douglas-fir, moist maritime Biogeoclimatic subzone (CDFmm). The climate is mediated by the rain shadow of the Olympic and Vancouver Island mountains, as well as by the moderating effect of the ocean (Islands Trust, 2013). Therefore, Galiano generally experiences warm, dry summers and mild, wet winters. The island also boasts some of the rarest ecosystems in Canada, many of which are under threat from development, climate change and habitat degradation (Islands Trust Conservancy, n.d.).

2.2 Study site

The Baseline Report mentioned above identified 17 ecological communities, ranging from pole/sapling and young forest to mature forest. Previous disturbances on the DL 58 were assessed, with most of the forest stands having been clear-cut in the 1940s and/or the 1990s (Huggins & Thompson, 2023). The areas of highest disturbance include a settlement zone and a former gravel pit. In the first, several hectares

of rich, wet forest in the northwest corner of the property were cleared by the 1960s and used for small-scale agriculture and goat grazing (Huggins & Thompson, 2023). Several buildings and fenced areas are scattered throughout this zone (see Figures 2, 3 & 5). The gravel pit was excavated sometime in the early 90s, then expanded for a couple of decades before being partially filled with concrete and leveled with soil (ibid). Furthermore, several logging roads surround this high-density zone, providing access. The present study surveyed this area exclusively for several reasons:

- Due to timing constraints, focusing our efforts was required.
- Being the area with the most human disturbance, the likelihood of finding introduced species was greater here than on other parts of the property.
- The roads surrounding this area improved ease of access.
- Personal communications with members of the Galiano Island Conservancy indicated this as the highest priority area for restoration.

2.3 Ecology of the study site

The Quadra Hill Baseline Report presents the results of ecological survey work done at the DL-58 property. The ecological communities found within the study site zone (see Figure 1) include: disturbed swamp area, disturbed marsh-swamp complex, treed pasture, cultivated fields, young broadleaf forest (red-alder) and pole-sapling mixed forest (see Figure 3).

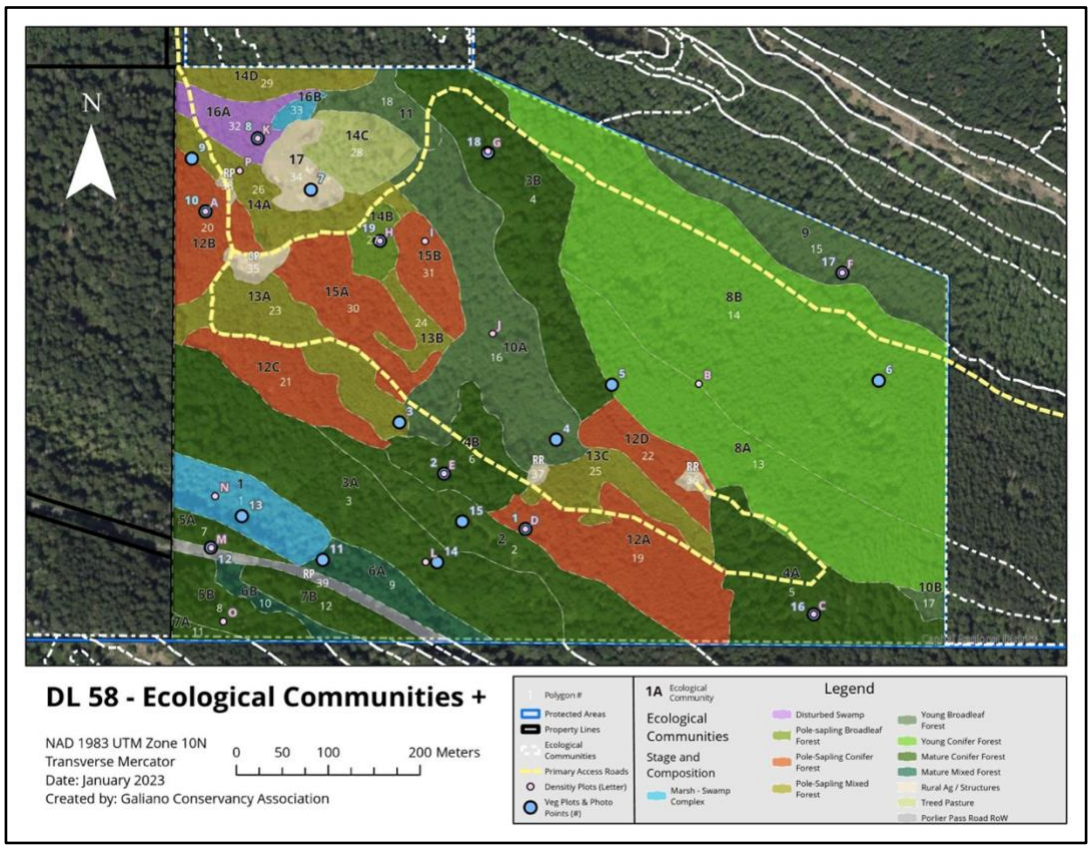

Figure 3. *Ecological Communities of Quadra Hill* (Huggins & Thompson, 2023).

2.4 Species profiles

Many non-native plant species are found across the study site and were considered for inclusion in the present study. The following were selected because of their characteristics and the particulars of the site itself. More information about the selection process can be found in Sections 4 & 6 (Methods & Discussion).

- **Scotch broom** easily and quickly invades sunny, disturbed areas, which makes it a particular concern for this site. It crowds out native species and changes the chemistry of the soil. Once soil properties are affected, native species can be excluded from the area and its removal becomes complicated (Slesak et al., 2022). It is best to remove scotch broom before it is well established on a site.

- **Cutleaf blackberry and Himalayan blackberry** spread quickly in disturbed areas, especially in open pastures or wetland areas. These species are of concern because of their ability to spread rapidly in the various ecosystems of this site and crowd out native species. Once established, they create large thickets that are difficult to remove due to their large root balls and thorns. These can create biological blockades for wildlife and fragment ecological corridors (Sea to Sky Invasive Species Council, 2021; Soll, 2004).

- **Wild teasel** grows to a large size quickly and prefers sunny, disturbed sites. It is inedible to wildlife and provides little benefit to local ecosystems. Its establishment on Quadra Hill could be detrimental to native plants and animals in the area (Invasive Species Council of BC, n.d.).

- **English holly** is highly adapted to both shade and sun, and it can spread very quickly. Once mature, it is difficult to remove. It is important to remove English holly as it emerges, which is why we chose to map the locations of this species to alert the GCA of their presence (Invasive Species Council of BC, n.d.).

- **Common Hawthorn** trees can be very difficult to remove once they are mature. When well established, they can outcompete shade-intolerant native deciduous tree saplings and crowd out other species. They are also capable of hybridizing with the native hawthorn species, altering the gene pool. This species is important to remove early because of these reasons (Fraser Valley Invasive Species Society, n.d.).

- **Tansy Ragwort** establishes itself easily in disturbed areas, especially on grazed pastures, decommissioned croplands and clearcut forests. This plant can be toxic to wildlife, so its presence on the site is concerning. It is also well adapted to soil disturbance, so it is important to remove it before any restoration work is performed (Invasive Species Council of BC, 2019). The individual remaining on the site was mapped in order to alert the GCA of its presence for removal and monitoring purposes.

3.0 Goals and Objectives

3.1 Goal: To conduct preliminary surveying of introduced species cover in a portion of the Quadra Hill property and provide suggestions for management.

The Galiano Conservancy has been asked to develop a management plan for DL-58 and this report contributes important data and analysis to this goal. Future restoration plans and their monitoring and evaluation will depend on comprehensive baseline data against which to assess progress.

3.2 Objectives

- Collect data & map introduced species of concern
- Provide recommendations for species management at the site

3.3 Purpose

The main reasons behind our project were to collect baseline data to inform restoration activities and support funding applications while, importantly, containing any pernicious introduced species before they become a larger problem at the site. As acknowledged at the outset of this report, the removal of non-native species as a means of restoring ecosystems or landscapes is not a universally accepted or completely effective practice. Despite this, we were motivated by research that suggests that an impact-focused assessment of introduced species is good practice. For example, Jeschke et al. (2014) notably explain that "[t]he breadth and potential severity of the impacts of non-native species means that a better understanding of them is of broad relevance, for example, for prioritizing management, conservation and restoration actions, and for appropriate policy responses to invasions" (p. 1189).

4.0 Methods

4.1 Field surveying techniques

We based our data collection methodology on both the Introduced Species Management Plan for the Millard Learning Centre (Galiano Conservancy Association, 2021) and personal communications with GCA staff, notably Conservation Coordinator Michelle Thompson. We conducted a belted transect field survey for a selection of introduced species across the study site at Quadra Hill (DL-58). This method involved one person at the front of the group on the transect line orienting the group with a compass, one person walking directly behind the compass-bearer with the GPS, looking in front and on either side for selected introduced species, and two people spaced 4 meters on either side of the transect line searching for introduced species in the space between them (see Appendix 1). We covered a total area of 8 meters across for each transect, with ~1-2 meters of variability on either side. Transect F overlapped with the gravel pit (see Figure 4), so we slightly deviated from the 8-meter coverage standard in order to include the entirety of the gravel pit, since it was a primary area of concern as expressed by GCA staff. After the gravel pit was covered in Transect F, we walked the rest of it with our standard 8-meter coverage and finished this transect past the primary access road (see Figure 4).

Our transect lines were mostly bounded by the primary access roads surrounding the highly disturbed portion of the property, as seen in Figure 4. The first transect (A) started from the Northwest corner of the property on the primary access road and was directed 90^{o} East from the starting point to the other side of the access road. Only Transect A was completed on our first day of data collection, and the first transect

of the second day of field work (Transect B) started on the same side of the access road as Transect A. Once Transect B was complete, the following transect (C) alternated direction to 90º West from the primary access road starting point, and this alternating direction was conducted for the rest of our transects. Flags were placed at the start and end points of each transect and left at the site for ease of re-locating the transects by GCA staff. This was the method of our seven transects (A-G) conducted across the entire study area, with each transect spaced approximately 25 meters apart, excluding Transect G, which was spaced 20 meters from Transect F with the intention of monitoring any spread of introduced species into the nearby Pole-sapling mixed forest and Pole-sapling conifer forest surrounding the disturbed area past the gravel pit, as requested by GCA staff.

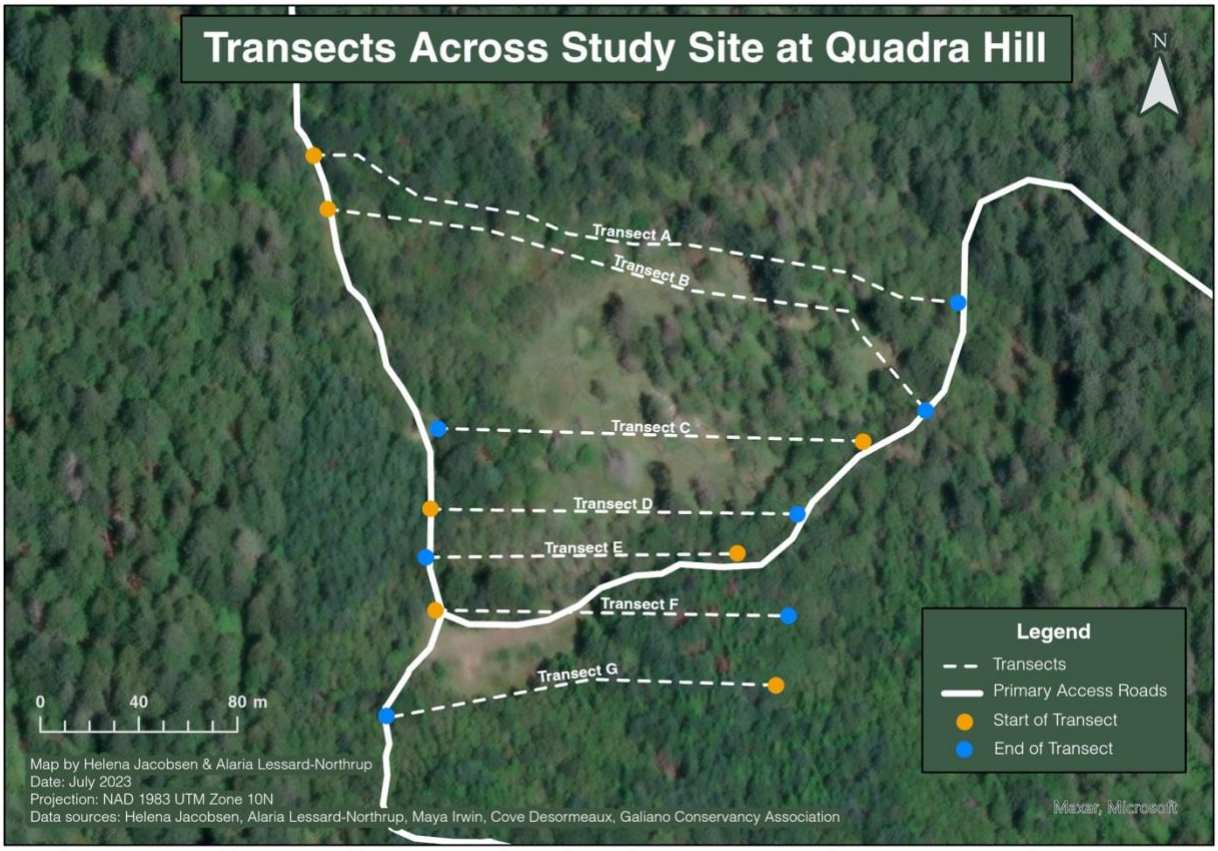

Figure 4. *Map of transects walked across study site on Quadra Hill (DL-58) labelled from A-G, showing start and end point of each transect.*

4.2 Field data collection

4.2.1 Selecting introduced species

The list of introduced species selected for monitoring was adapted accordingly as field work progressed. The initial list of species included *Cytisus scoparius* (scotch broom), *Rubus laciniatus* (cutleaf blackberry), *Rubus armeniacus* (Himalayan blackberry), *Ilex aquifolium* (English holly), *Daphne laureola* (spurge-laurel), *Phalaris arundinacea* (reed canary grass), and *Vinca minor* (common periwinkle). Following site visits, this list was altered to include *Crataegus monogyna* (common hawthorn), *Senecio*

jacobaea (tansy ragwort), and *Dipsacus fullonum* (wild teasel). In the presence of already established introduced agricultural grasses, germination and growth of *P. arundunacea* could be suppressed, as it favors the bare ground conditions and high light availability often found on recently restored wetland sites (Reinhardt Adams & Galatowitsch, 2005). We decided to not monitor *P. arundunacea* in our study because it was hard to distinguish from other competing introduced grasses at the study site, possibly due to its growth stage. However, it should not be omitted from introduced species to monitor in the future. As the site gets restored to a wetland, more favourable conditions could be created for *P. arundunacea* to germinate and should thus be monitored closely as competition is removed. The adapted list of selected species we observed and surveyed during our transects can be seen in Table 1

Table 1. *Adapted list of introduced species selected to monitor at Quadra Hill (DL-58) study site with their associated codes used for data collection.*

Introduced Species	Species Code
Rubus laciniatus (cutleaf blackberry) & *Rubus armeniacus* (Himalayan blackberry)	BB (CL, HL)
Ilex aquifolium (English holly)	EH
Crataegus monogyna (common hawthorn)	EHAW
Senecio jacobaea (tansy ragwort)	TR
Cytisus scoparius (scotch broom)	SB
Dipsacus fullonum (wild teasel)	TE

4.2.2 Recording observations

When we encountered a patch or individual plant of the species we were monitoring, we would record point (individuals) or line (patches) data in the Trimble Geoexplorer 6000 GeoXH, and associated information about the plant observation in the GPS separated by commas, as well as in a notebook. We made a code system for recording different kinds of data, including an observation code with a letter (A-G) and number (1-22); the letter indicating the transect and the number indicating the point along the transect. Each transect should have a point with 0 and X to indicate the start (0) or end (X) point of each transect. We also made codes for selected introduced species, which can be seen in Table 1.

In the GPS and notebook, we would record: (1) GPS coordinates (in GPS only), (2) the observation code (e.g. A1, A2), (3) species code (see Table 1); (4) density percentage (patches only), and (5) any additional notes about the plant, such as the maturity or height of the plant/s (in notebook only). See Appendix 2 for a page of field notes showing example observations.

4.3 Mapping data

The point and line recordings from the transects were transferred from the GPS device and converted to shapefiles in order to analyze the data and create maps. The shapefiles were manipulated to create straightforward attribute tables with metadata corresponding to each observation. Each observation has associated notes about individual plant heights or any notable plant features. These shapefiles will be sent to the GCA so that they can access the metadata, conduct analyses, and create their own maps. Our maps were made to display the data using ArcGIS Pro.

5.0 Results

The results of our field study are represented in Figure 5. This map of our observations includes the site's human features to situate our findings in relation to fences, structures, and primary access roads. The primary access roads (see the bold white lines in Figure 5) acted as the Western and Eastern boundary lines of our field work, with the exception of the transects that crossed the gravel pit zone in the Southwest corner of our study site (see sub-section 4.1).

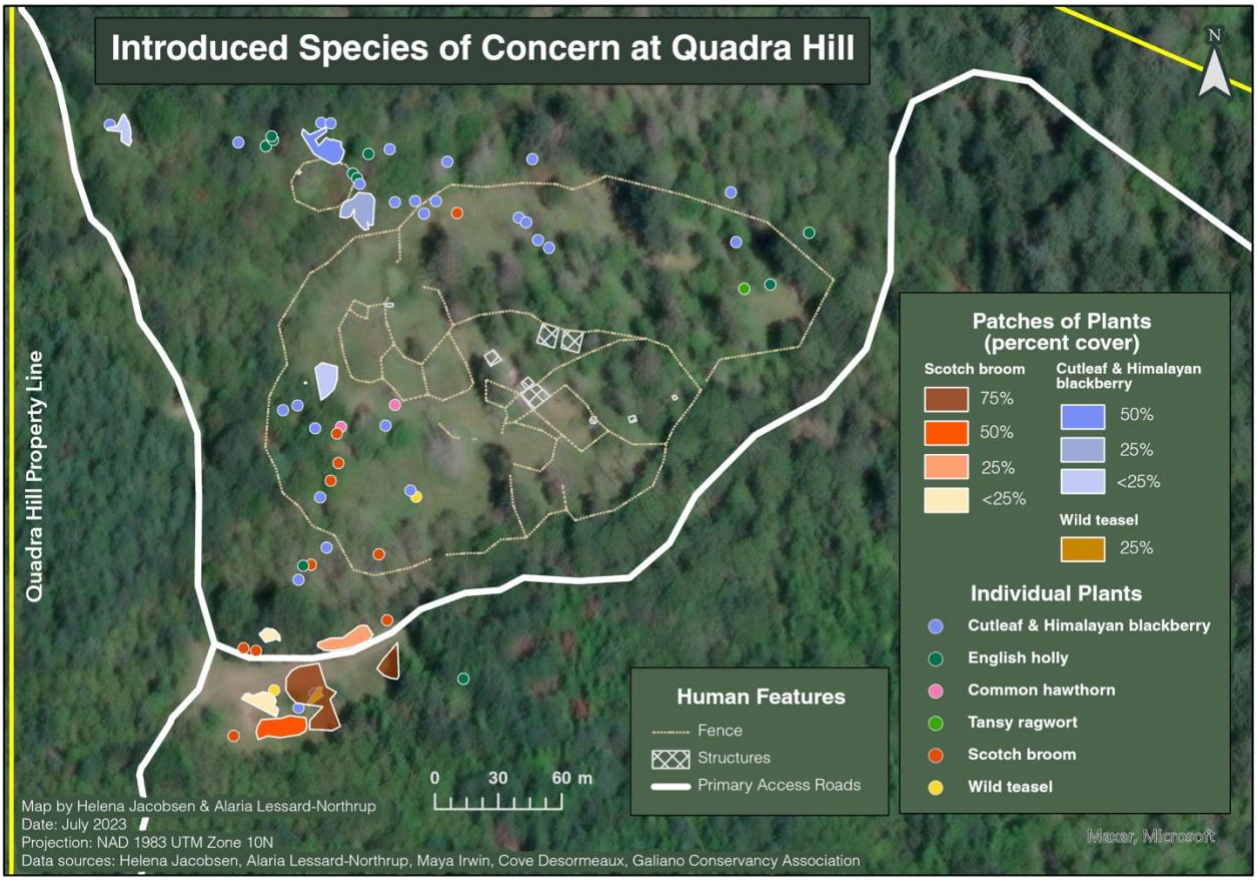

Figure 5. *Map of introduced species of concern recorded along transects at study site on Quadra Hill Property (DL58).*

5.1. Specific findings

Cytisus scoparius (scotch broom) is heavily concentrated in the gravel pit zone, in the Southwest corner of our study site and adjacent to the intersection of two primary access roads. There are individual scotch broom plants across the former agricultural zone and in forested areas bordering the gravel pit. This northbound spread of scotch broom, along with the general composition of introduced species observed in the gravel pit, can also be seen in the map of Area of Concern A (Figure 6).

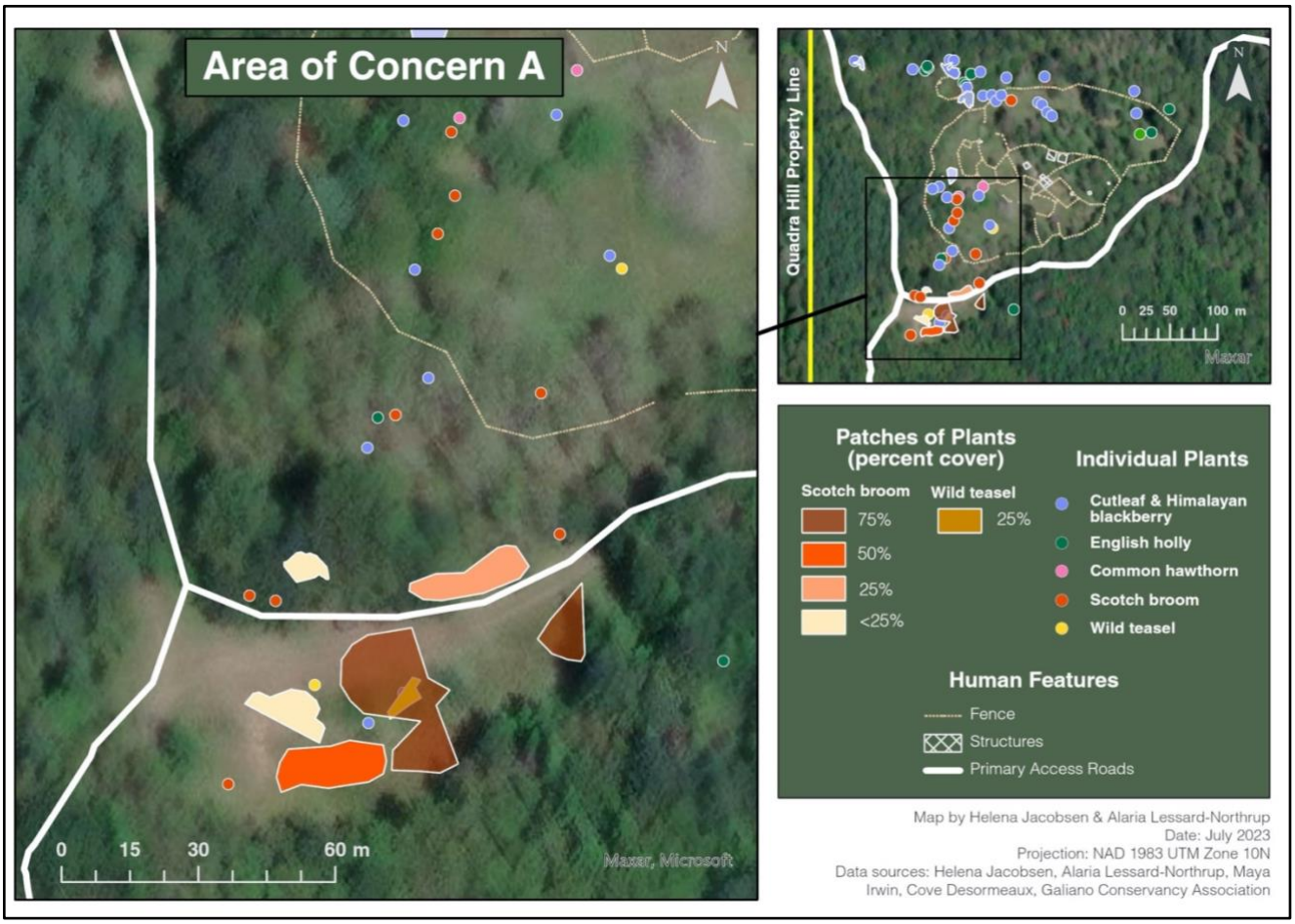

Figure 6. *Map of Area of Concern A, located in the site's gravel pit: map shows several large patches of scotch broom as well as its Northbound spread across the primary access road, a patch and two individuals of wild teasel, and scattered individual cutleaf and Himalayan blackberry plants.*

Two introduced blackberry species, *Rubus laciniatus* (cutleaf blackberry) and *Rubus armeniacus* (Himalayan blackberry), are present on the site. Cutleaf blackberry exists on a large portion of the land we surveyed, accounting for most of the individual plant observations and all but one of the polygons of blackberry represented on the map. The only blackberry species polygon recorded with a 50% cover estimate (see the darkest shade of purple on Figure 7) is of the Himalayan variety located in a forested swamp area at the Northwest corner of the property (see Appendix 3). There are single mature Himalayan blackberry plants in the gravel pit area, visible in the map of Area of Concern A (Figure 6).

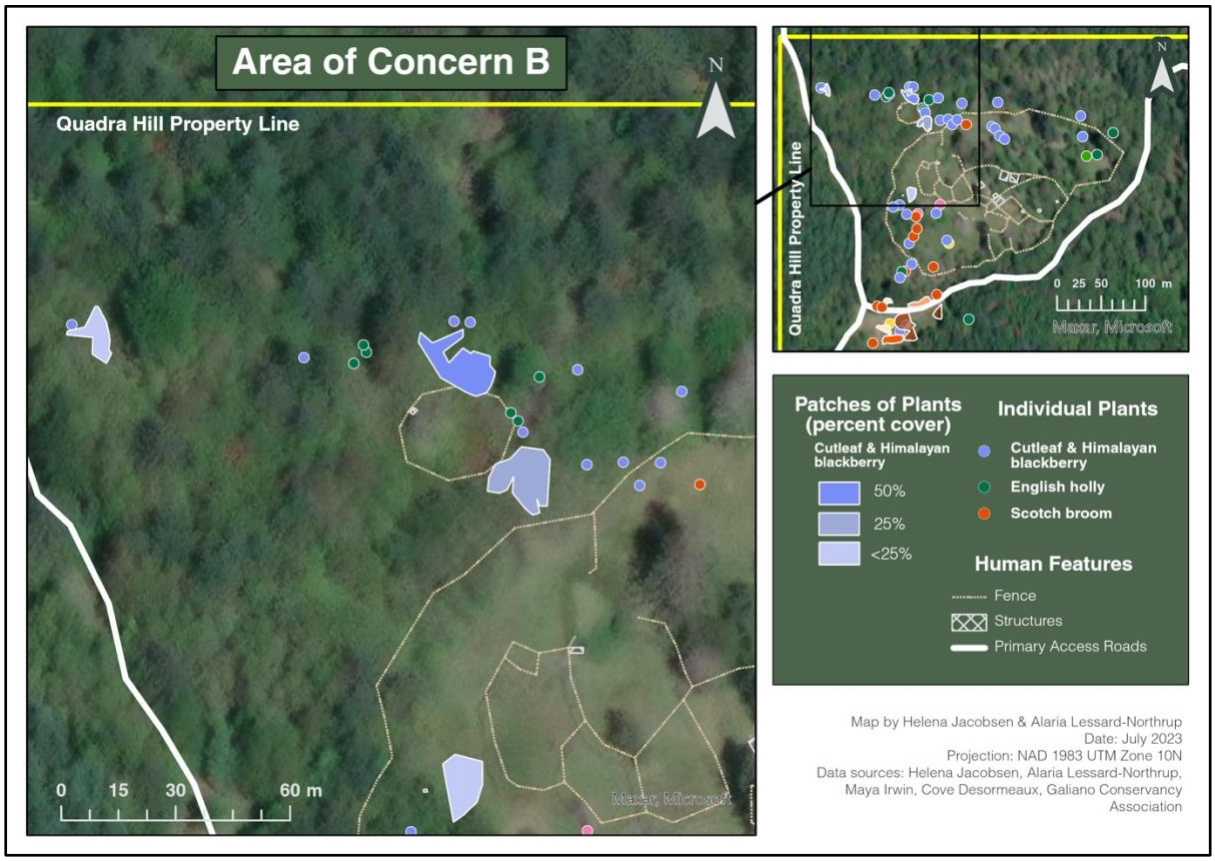

Figure 7. *Map of second Area of Concern (B), on the Northwest section of the study site with larger patches and many individuals of cutleaf and Himalayan blackberry, an individual scotch broom plant, and numerous individual observations of English holly.*

Ten individual *Ilex aquifolium* (English holly) plants were observed on the study site. None of the plants exceeded two meters in height. Two thirds of the observations happened in the disturbed swamp area represented in the Ecological Communities map (see Figure 3). All the English holly recorded is close to the perimeter of our study site, in forested areas.

Crataegus monogyna (common hawthorn) was found in two spots on the site. Both observations were of small (≤1 m tall) individual plants. These two saplings are within approximately 30 meters from one another and are located at the Western edge of the agricultural zone.

The presence of *Senecio jacobaea* (tansy ragwort) was observed in one spot on the study site. While the map of our observations at Quadra Hill (Figure 5) contains the location of only one individual tansy ragwort plant, we observed a second one approximately ten meters away from the recorded location that we removed for identification.

Dipsacus fullonum (wild teasel) is present in three spots on the study site. Of the three observations, two are individual plants and one is a polygon with a 50% cover estimate (see Figure 6 for a clearer view of

the patch). The wild teasel plants observed on the site are growing in disturbed areas with little to no shade.

6.0 Discussion

6.1 Species selection

Informed by the Millard Learning Centre's Introduced Species Report and through early meetings with GCA staff, our initial plan was to map the presence and extent of scotch broom, cutleaf blackberry, Himalayan blackberry, English holly, spurge-laurel, reed canary grass, and common periwinkle. This group of species shifted as we began the mapping process and found species that were not anticipated, while others were not encountered at all. Reed canary grass was not mapped as it did not exhibit strong growth among competing introduced grasses and was difficult to distinguish. Neither Daphne laurel nor common periwinkle were found, a positive indicator for the site as these can be particularly pernicious species (Invasive Species Council of BC, n.d.). Though we had no previous awareness of their presence at the site, common hawthorn, tansy ragwort and wild teasel were found and were indicated as species of concern by the GCA.

The study site has a very widespread and dense population of both *Digitalis purpurea* (common foxglove) and *Cirsium vulgare* (bull thistle). See Appendix 4 for a photo showing the area's largest and most dense patch of bull thistle. After discussion with GCA staff, it was decided to exclude these prominent species from our mapping due to tentative restoration plans for the site. The *Cirsium vulgare* population is mostly contained within the former agricultural and homestead zones, where a planned wetland construction would involve major earthworks that would see this area extensively dug up and inundated, drastically altering its species composition. Common foxglove is found throughout the site, in forested areas, agricultural zones, swamps, and disturbed areas such as roadsides. However, *Digitalis purpurea* is listed as a "non-native" but not an "invasive" species in the Vanilla Leaf Land Nature Reserve management plan (Islands Trust Fund, 2013, p. 38). Therefore, the presence of common foxglove on DL-58 is not a pressing issue and does not warrant targeting in the early stages of the introduced species management plan for this property. This decision aligns with work done by Shackelford et al. (2013) in their contribution to the ongoing native vs. non-native species debate: "Often for pragmatic reasons and/or due to resource constraints, managers have long tolerated the persistence of low-impact non-native species" (p. 56). Thus, since bull thistle and foxglove are considered relatively easy to manage and their survival at the site may be impacted by future restoration activities, they were not chosen for the present study.

6.2 Impact-focused approach

The above-mentioned emphasis on highly noxious introduced species was part of our decision to take an impact-focused approach to introduced species management. Due to time and resource constraints, as well as the highly established nature of some plant communities found at the site (e.g. the large patches of C*irsium vulgare* and *Digitalis purpurea*), the exclusion of certain introduced species was a pragmatic decision. Focusing on the direct or potential impact of a species in making management decisions, rather than solely on its presence, can help focus both monitoring and restoration efforts, and free up time and resources for other work. This is especially important in the context of small organizations such as the GCA who need to maximize their output with limited resources.

Furthermore, just as it is important to consider the implications of the establishment of a given species in a system, it is crucial to consider the impacts of its removal before proceeding with treatment options (Shackelford et al., 2013). This dimension is of particular relevance to the management of *Cytisus scoparius* (Scotch broom), one of the species found in the largest concentrations at DL-58. In a recently published study, Slesak et al. (2022) measure and analyze the effects of scotch broom in early successional coastal Douglas-fir ecosystems of the Pacific Northwest, specifically in Oregon and Washington. They report on and discuss changes in soil measures and vegetation at two sites with contrasting soil quality (for example in texture and its influence on water and nutrient availability), finding that soil quality alters how ecosystems are affected by Scotch broom and its removal. The authors note that this shrub is "an N-fixing invasive species of major ecological concern capable of dominating sites […] and altering ecosystem function" (p. 244). Scotch broom has both the tendency to form extensive thickets and the ability fix moderate quantities of nitrogen in the soil, and in combination these components weaken the potential for affected systems to undergo soil and vegetation recovery post removal (Slesak et al., 2022).

The results of their study show that low-quality sites are more at risk of invasion, re-invasion, and negative effects post removal. The chemical properties of the low-quality study sites changed significantly following the removal of broom when compared with the other two treatments - lower concentrations of extractable P, Mg, K, and Ca were found in those soils post-removal, something which can negatively impact the growth of desirable species (Slesak et al., 2022). Furthermore, of the three different types of broom treatments measured in their study (broom removal, broom retained, and uninvaded by broom), areas where broom was removed saw the highest level of introduced species richness and cover (excluding Scotch broom). In short, their study reveals that removing established populations of scotch broom can intensify its negative effects on a site's soil chemistry and plant communities. Informed by their results and by the existing literature, the authors conclude that it is best for management of scotch broom to be focused on prevention or early intervention whenever possible.

The insights and findings provided by Slesak et al. (2022) are especially relevant for managing introduced species in and around Quadra Hill's gravel pit zone, where Scotch broom is the densest and most extensive. The potential for negative impacts should not discourage targeting it for removal, but rather be considered in the creation of an appropriate management plan. As mentioned in section 2.2, the gravel pit is partially filled with concrete and is one of the areas of lowest soil quality, so extra care may need to be taken in restoration efforts. This could include soil remediation work, prompt and abundant native species planting, and frequent and extensive monitoring of the site. Previous soil sampling work undertaken by GCA staff in this zone could be used to inform such planning. Finally, our field observations and data collection show that the spread of Scotch broom beyond the perimeter of the highly disturbed zone is currently minimal. There are nine individual plants and two small patches north of the gravel pit, in both forested and open areas (see Figure 6). Because of the risks of delaying removal, we suggest prioritizing the removal of this species as there is an opportunity to target young plants and avoid further negative impacts to soil chemistry and plant communities.

6.3 Limitations & error

The largest limitation in our dataset comes from the gap between Transect B and Transect C. Due to suspected compass interference and user error, the first two transects are not East-West parallel. This

issue became exacerbated for Transect B by the fencing on the property which was difficult to cross (see Appendix 5). This resulted in a larger than 25m distance between the end of Transect A and B. As seen in Figure 4, there is a significant area of the site that was not covered by our transects due to these circumstances. Additional surveying should be conducted to fill in this gap. We also encountered some difficulties with the GPS device. Transect B and Transect F do not have recorded end points due to equipment failure. These points were estimated based on a phone-recorded route of our movement during the surveying, though these are approximate.

Other limitations include time constraints and space constraints. With only two days to complete this study, we were not able to cover the entire study area. Future surveys with less time constraints should use smaller intervals between transects in order to get a more detailed dataset of introduced species locations. Additionally, we were only able to cover a small portion of the property due to its size and our lack of time. For a more comprehensive understanding of the spread of introduced species on Quadra Hill, the entire property could be surveyed. Since our study area exhibited the greatest impact across the property, further monitoring would not require such detailed methods as conducted in our study. For example, the remainder of the Quadra Hill property could be surveyed with transects spread further than 25 meters apart whilst still achieving a comprehensive understanding of species presence.

7.0 Recommendations for Introduced Species Management

There exist many potential treatment options to manage introduced species, some better than others, while none are perfect. The limitations of each should be explored and assessed in relation to the resources and time available. In what follows, we provide an introductory guide to three treatment methods we recommend for this site (Table 2) and a table summarizing our recommendations (Table 3). More detailed recommendations for managing the study site's species of concern can be found in Appendix 6.

7.1 Treatment methods

Table 2. *General techniques and supply lists for three introduced species treatment methods.*

	Hand-pulling	**Cutting**	**Digging/grubbing**
Technique	• Firmly grasp plant stem as close to ground level as possible and pull upwards steadily to avoid snapping stem above ground • For tougher or larger plants, use both hands • Hand-pulling is easiest when soil is moist or loose • If needed, use hand tools such as a trowel to loosen surrounding soil	• Use suitable tool to cut plant • Different species require different cut locations (above ground, just below ground, etc.), so research further before proceeding or refer to tailored recommendations (Appendix 6) • Remove all plant matter, paying close attention to seed pods, berries, etc.	• Use suitable tool to dig up underground portion of plant, using body weight to lever root system out of ground if necessary • Soil disturbance creates ideal situations for some introduced species, so research further before proceeding or refer to tailored recommendations (Appendix 6) • Remove all plant matter, paying close attention to seed pods, berries, etc.

Supplies Needed	• Gloves (garden, leather, or rubber, depending on species) • Protective clothing, especially when dealing with thorny plants such as common hawthorn	• Pruners • Brush cutter • Weed eater • Saw (hand or chain) • Loppers • Soil knife • Herbicides - If not harmful to a site's ecology, (for application to cut surfaces/stumps, etc.)	• Claw mattock • Shovel • Forked weeder • Garden hoe • Sturdy footwear

Note on chemical control: Due to the prevalence of wetlands and in the study zone, use of herbicides and chemicals is not recommended. Furthermore, some herbicides, such as glyphosate are non-selective and can kill desirable vegetation, thus impacting native species found on site (Soll, 2004).

7.2 Species-specific recommendations

Table 3. *Summarized methods, techniques, and notes for management of seven introduced species of concern at DL58.*

	Hand-pulling	Cutting	Digging/grubbing	Post-treatment
Scotch broom *(Cytisus scoparius)*	• Only hand-pull when doing so will not result in high level of soil disturbance as this can encourage broom growth • Most effective when soil is wet	• When pulling will result in soil disturbance, cut plants at or just below ground level • Ideal time to cut is when in bloom or soon before (avoid cutting when seeds are produced as this will help spread them)	• If digging is necessary to remove belowground portion of broom, try to create minimal soil disturbance and ensure all plant matter is removed	• Manual removal treatments might need repetition for up to 5 years because of broom's seed banking and resprouting potential • Hand-pull new seedlings
Cutleaf blackberry (*Rubus laciniatus)* **& Himalayan blackberry** (*Rubus armeniacus*)	• Only hand-pull seedlings & young plants • Most effective in soft or wet soil • Not effective for established plants	• First step for established plants is cutting and removing aboveground plant matter	• After cutting, dig up root crowns to prevent resprouting	• Plant native species in removal site to discourage regrowth • Monitor area for regrowth and re-treat as necessary
Wild teasel (*Dipsacus fullonum*)	• Most effective for small number of plants	• When hand-pulling is not possible, cut or mow plants before seed heads develop	N/A	• Monitoring is necessary as seeds can be viable in soil for many years
English holly (*Ilex aquifolium)*	• Hand-pull small plants	• Cut larger trees at base and ensure all plant matter (especially berries) is removed • Herbicides can be applied directly to stump, but foliar herbicides are not effective due to its waxy leaves	N/A	• Monitor cut stumps for regrowth and re-treat as necessary

Common hawthorn *(Crataegus monogyna)*	• Hand-pull small plants	• Cut larger plants at base • Cut surface can be burned or treated with an herbicide • Ideal time to cut is before plant fruits (early summer)	• Seedlings or small plants can be dug out • Dig up roots and ensure cut fragments are removed to avoid resprouting	• Monitor area for regrowth and re-treat as necessary
Tansy ragwort (*Senecio jacobaea*)	• Most effective for small number of plants • Ensure entire root system is removed	N/A	N/A	• Monitoring is necessary as growth may be stimulated if rootstalk removal is incomplete

8.0 Conclusion

This study examined the introduced species in a heavily disturbed portion of the Quadra Hill property, part of District Lot 58. Through transect surveying, we collected locational and observational data on seven different introduced species. Our fieldwork revealed that there is a significant number of introduced species of concern present at the site. The species of most concern are *Cytisus scoparius* (scotch broom) and two introduced blackberry species, *Rubus laciniatus* (cutleaf blackberry) and *Rubus armeniacus* (Himalayan blackberry). Since scotch broom and the two blackberry varieties can be difficult to remove once established, we identified and created maps of two areas of concern to act as baseline data for the status of their presence and spread. By determining the location and spread of these species, the results communicated in this report enabled us to provide the GCA with detailed maps and tailored recommendations for treatment and removal methods. Our findings and analyses highlight the value of impact-based assessment of introduced species and early intervention in introduced species management, in hopes that these maps and recommendations can aid in the restoration efforts of the Quadra Hill site.

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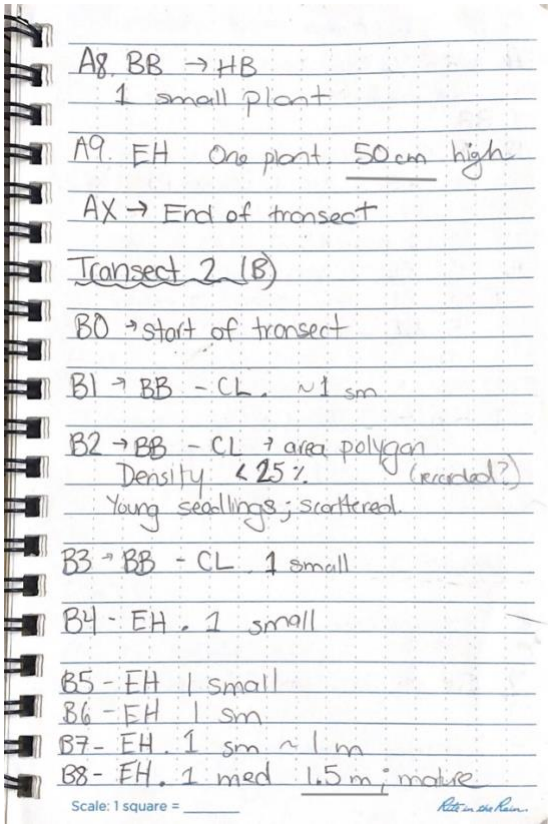
10.0 Appendices

Appendix 1*. Photo showing the transect formation. Maya (left) is guiding the group using a compass and taking notes, Cove (middle) is following Maya while making observations and inputting GPS data, Helena (right) is making observations on the right-hand portion of the belted transect, and Alaria (taking the photo) is making observations on the left-hand portion of the belted transect.*



Appendix 2. *Example of field notes taken to supplement GPS data collection.*

Appendix 3. *Maya standing next to a large patch of Himalayan blackberry for scale.*

Appendix 4. The site's largest and most dense patch of bull thistle, located in the former agricultural fields.

Appendix 5. *Photo showing the presence of fences and other human-made structures that contributed to our difficulty walking straight transects.*

Appendix 6. *Tailored recommendations*

A. Scotch broom

Hand pulling: Plants with stems less than 1.5 cm in diameter may be hand pulled, preferably in the late spring when the plant is directing its energy into flowering (but before seeds have set) (Coombs, 2019). Only hand-pull when doing so will not result in a high level of soil disturbance as this can encourage broom growth. Pulling is most effective when the soil is wet.

Cutting: Larger plants may be cut, preferably below ground level to discourage regrowth, and again in late spring before seed set (Coombs, 2019). Removal of all plant materials is recommended due to their potential to continue to release toxins into the site.

Replanting: Recommendations for controlling Scotch broom often include prompt replanting of competitive shrubbery, including snowberry, salmonberry, thimbleberry, and Oregon grape, as well as red alder trees for shading, in order to introduce competition and to reduce further regrowth (Coombs, 2019). Due to the heavily modified nature of the gravel pit zone where the majority of the Scotch broom is located (see Figure 6, Area of Concern A), the planting of desirable species may be dependent on the general remediation of the site.

B. Himalayan and cutleaf blackberry

Hand pulling: Recommended only for seedlings or young plants. Most effective in soft ground or wet soil. Not appropriate for established plants (Soll, 2004).

Cutting: In large thickets, cutting will be necessary before other methods are attempted in order to remove the aboveground portion. Manual tools such as brush cutters, machetes, loppers or clippers may be used. This method alone is unlikely to be successful, however, as the root crowns aggressively resprout and produce more canes (Soll, 2004, p. 6). Be sure to wear appropriate protective clothing.

Digging/Grubbing: As a follow-up to cutting, digging out the root crowns will likely be necessary to adequately control the thickets of blackberry (See Figure 7 for area of concern B) to prevent resprouting and be sure of removal. Using a claw mattock is especially effective, as the "claw loosens the dirt around the root, and the plant is pulled out in the same way that a claw hammer is used to pull out nails" (Soll, 2004, p. 6).

Planting: Following-up removal with planting or seeding of native plants will also help discourage regrowth. As most of the blackberry was found within the degraded swamp zone dominated by *Carex obnupta* (slough sedge), replanting of this native species in the affected zone could be helpful.

C. Wild Teasel

Hand pulling: Since the total number of plants found was quite small, we recommend hand-pulling and/or cutting to manage this species. However, continued monitoring will be necessary since "teasel plants produce up to 3,000 seeds per year, and the seeds can be viable in the soil for several years" (Gover & Johnson, 2011).

Cutting: If pulling all plants is not possible, controlling for seed dispersal through cutting/mowing should be done before seed heads develop.

D. English Holly

Hand pulling: Suitable for small seedlings with minimal soil disturbance (GCA Introduced Species Management Plan). Some hand-digging with a hoe or other tool may be necessary.

Cutting: For larger trees, cut at ground level, ideally before the formation of berries to prevent further spread (GCA Introduced Species Management Plan). Monitor cut stumps for regrowth. Foliar herbicides are not effective because of waxy leaves but direct application to cut stumps can be effective (Coastal ISC, n.d.).

E. Common Hawthorn

Hand pulling: Seedlings and juveniles can be pulled, though digging may be necessary to completely remove the rootstock. Ideally prior to fruiting. Most of the Hawthorn encountered at the site were small and can likely be targeted with this treatment.

Cutting: Larger plants can be cut at the base and treated with herbicide (GCA Introduced Species Management Plan).

CAUTION: Since English hawthorn is covered in thorns, ensure you are wearing proper protective clothing and gloves.

F. Tansy Ragwort

Hand pulling: Effective for small infestations, the entire root system must be completely removed. Monitoring and re-treatment may be necessary (especially since vegetative reproduction may be stimulated by incomplete removal of the rootstalk) (Scott, 2019). As only a minority of plants were discovered on site, this is the treatment option we would recommend.