RESPONSE OF *CYPRIPEDIUM* AND *GOODYERA* TO DISTURBANCE IN THE THUNDER BAY AREA

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ABSTRACT

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Orchids constitute a family of rare plants on the landscape that are facing additional threats from anthropogenic changes to their habitat. Orchids have very specific habitat requirements and can be used as early indicators of changing ecosystems and forest health. The purpose of this study is to update the status of *Cypripedium* spp. and *Goodyera* spp. in the Thunder Bay area in response to change in habitat. The city and surrounding area have been developed further in recent years. Locations that were once ideal habitats for certain orchid species, such as wetland habitats, have been lost. In contrast, orchid populations on the Sibley Peninsula, part of which is protected as Sleeping Giant Provincial Park, have continued to thrive, likely due to the seclusion of some of the locations. As a means to preserve orchids, conservation efforts that focus on increasing local stewardship should be implemented.

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INTRODUCTION

Plants provide a variety of ecosystem services, not the least of which involves aesthetic value that attracts visitors and inspires awe. Species belonging to the family Orchidaceae capture the attention of photographers and conservationists alike due to their beauty and unique habitat requirements. Orchidaceae is the most diverse family of flowering plants, which occupies almost every known terrestrial habitat, save for Antarctica (Christenhusz and Byng 2016). Orchids require mycorrhizal fungi in order to complete their life cycle and many have extremely specific habitats (Dearnaley 2007). In addition, many species of orchids have very specific reproduction methods and are ony pollinated by a few pollinators (Nilsson 1992). Although these unique attributes are what make orchids interesting, they also make them rare and sensitive to change.

The Thunder Bay District is on the border of the boreal and the Great Lakes–St. Lawrence forest regions and is rich in orchid species. In the Canadian boreal forest, there are 15 species of orchids and there are around 20 species of orchids in the Great Lakes-St. Lawrence forest region (Swarts and Dixon 2009). The Thunder Bay District is home to 37 known orchid species, including *Liparis loeselii* (L.) Rich. and *Malaxis paludosa* (L.) Sw., which are regionally rare and provincially rare species respectively.

The purpose of this study is to update the status of *Cypripedium* spp. and *Goodyera* spp. in the Thunder Bay District in response to change in habitat. The first objective is to visit historically documented orchid locations in the Thunder Bay District in an effort to see how these areas have changed and to see if the orchids that once

occupied the area still exist. Herbarium records will provid insight into where these genera were collected in the past, including samples from the now highly developed Intercity area. I predict that some *Cypripedium* spp. and *Goodyera* spp. populations will have been lost from their historic locations. I expect that in the city of Thunder Bay, many of the orchid populations will be extirpated due to commercial and housing developments. I expect that orchid populations will have continued to be successful on the Sibley Peninsula, part of which is protected as the Sleeping Giant Provincial Park.

LITERATURE REVIEW

Orchid species vary greatly in physical appearance and floral morphology. They have inspired many to research their unique morphology and specific habitat requirements. Despite the many differences, the unique feature of fused reproductive organs unites all species belonging to the family Orchidaceae. In all orchids, the male and female reproductive parts, respectively called the stamen and pistil, fuse together in a column called the gynostemium. I will review *Cypripedium acaule* Aiton, *Cypripedium arietinum* W.T. Aiton, *Cypripedium parviflorum* Salisb. var. *pubescens* (Willd.) Knight, *Cypripedium reginae* Walter, *Goodyera repens* (L.) R. Br., *Goodyera tesselata* Lodd., and *Goodyera oblongifolia* Raf. with specific attention paid to their morphology, habitat, pollination, and reproduction.

Cypripedium acaule

Cypripedium acaule, commonly known as Pink Lady's Slipper or moccasin flower, is one of the most easily recognizable orchids of the boreal forest. The species is an herbaceous perennial with two large, basal leaves that are up to 20 cm long, are strongly veined, elliptic in shape, and are thinly pubescent. It has a single flower stalk between the two leaves, which can grow to be as high as 40 cm above the ground. Each stalk produces only one flower. The flower is large, up to six cm long, with the inflated lip of the flower being varying shades of pink (Figure 1). The sepals are reddish brown to green.

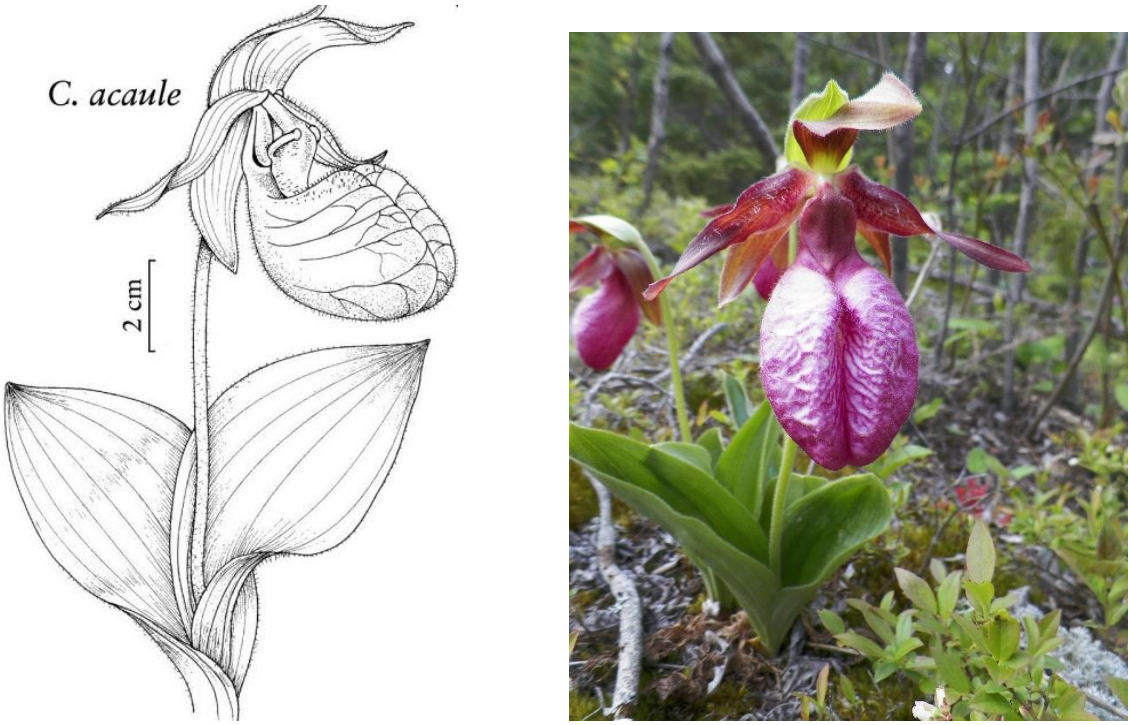

Figure 1. Images of *C. acaule.*

Pink Lady's Slipper occurs from the Northwest Territories east to Newfoundland, south through Minnesota to Alabama and Georgia and are found in many different habitats across this large range. Unfortunately, this species is less common in recent years due to

people taking them from the wild (ICNU 1999). *C. acaule* generally prefers well-aerated soils that are strongly acidic with a pH around four-five and at higher pH the rootstock becomes overwhelmed by fungal attacks (Bunch et al. 2013). In the northern part of its distribution, it is found growing in coniferous forests, such as in jack pine and balsam fir stands and in black spruce bogs. In the southern part of its distribution it is found in deciduous forests, under oak (*Quercus* sp.) or pitch pine (*Pinus rigida*) and alongside ericaceous shrubs.

C. acaule attracts pollinators through deception, similar to most Lady's Slipper species. Bumblebee queens (*Bombus* sp.) primarily pollinate this species in the spring before the worker bees emerge (Argue 2011). The bright color and sweet scent of the flower lure the bees inside, where the bees find no reward of nectar and become trapped with only a single exit. There are hairs that lead to a pair of openings; one beneath each pollen mass. Upon exiting, the bee rubs against the stigma and any pollen it is carrying pollinates the flower. New pollen is deposited on to the bee and is carried to the next plant. Unfortunately, bees quickly learn that these flowers do not have nectar and avoid these flowers, accounting for low pollination rates for this orchid. Although the primary means of reproduction is cross-pollination, the Pink Lady's Slipper is also able to propagate by spreading rhizomes (Primack and Stacy 1998). This species is very slow growing and seeds are able to wait for years until conditions are ideal. The average length of time for the species to bloom is about 12 years.

Cypripedium arietinum

C. arietinum, also referred to as Ram's-head Lady's Slipper, is the smallest of the Lady's Slipper orchids occupying the boreal forest. This long-lived perennial is only 10-33 cm tall and has a flower about the size of a fingertip. There are often multiple stems

arsing from a single rootstock. The lip is inflated out horizontally with a conical extension descending from the bottom. The opening of the flower is mostly white and covered with silky hairs. The lateral petals and sepals are narrow, slightly twisted, and purplish-brown. The upper sepal, which extends over the lip, is much larger and broader. There are three to five leaves along the middle to upper portions of the stem that are finely pubescent and usually folded. The leaves are elliptical with a rounded or blunt tip, textured surfaces, wavy edges, and parallel veins (Figure 2).

Figure 2. Images showing *C. arietinum* morphology.

C. arietinum is often found in cool, acidic soils in dense swamps, bogs, and woodlands. This species has a range from Saskatchewan and Manitoba east to Nova Scotia, south to Minnesota, and east across the Great Lakes region to New England. *Cypripedium arietinum* is globally vulnerable and is rare or endangered throughout much of its range.

Ram's-head Lady's Slipper is capable of out-crossing but is primarily dependent on vegetative reproduction by offshoots (Brower 1977). Autogamy is absent in this species. Female halictid bees of the genus *Lasioglossum* pollinate this orchid

(Stoutamire 1967). The bees are attracted by the scent of vanilla and land in the pouch formed by the labellum. The bees enter the flower and exits with pollen on their dorsal thorax. Within an hour of the pollen grain entering the stigma, the upper sepal closes over the pouch preventing additional entry.

Cypripedium parviflorum var. pubescens

C. parviflorum var. *pubescens* is another beautiful flower in our boreal forests. Due to the rather extravagant flower, this species is adeptly named Large Yellow Lady's Slipper. This was once considered a form of *C. calceolus*, which occurs in Eurasia, and is now known as *C. calceolus* var. *pubescens.* However, advances in genetic testing allowed separate species designation. Stems are 18-75 cm tall and arise from large, spreading rhizomes. Usually a lone flower sits atop the stem. The lip is a deep yellow with reddish markings on the inside (Figure 3).

Figure 3. Image of *C. parviflorum* var. pubescens.

There is much variation among the sepals and petals; they can vary between greenish-yellow and lightly marked or purplish-brown with stripes or spots. The dorsal sepal is often slightly twisted and the lateral sepals are often united. There are usually three to six pointed oval leaves that are evenly spaced apart and alternately clasp the stem. They can be up to 20 cm long and are bright green and ribbed. This species is particularly long lived and one plant has been reported at 80 years old (Light 1998).

C. parviflorum var. *pubescens* is distributed from Newfoundland to western Canada and south to Georgia and Arkansas in the east and New Mexico in the west. This species is endangered or listed as a species of special concern in parts of its range. In the south, the plant prefers rich upland woods, wetlands, and disturbed sites, like ditches and open glades. In northern Ontario, *C. parviflorum* var. *pubescens* is mostly limited to wet coniferous forests and fens. It generally prefers more open areas and lime rich soil conditions.

Cypripedium parviflorum var. *pubescens* is self-compatible and capable of outcrossing. This species is often visited by a variety of small bees which represents its principal method of sexual reproduction. Bees of the andrenid and halictid groups are attracted to the large bright flower and sweet scent, similar to the other species of *Cypripedium*. This species also capable of vegetative reproduction via spreading rhizomes.

Cypripedium reginae

Called Queen’s Lady's Slipper, a translation of the specific epithet *reginae*, this species is the largest of the Lady's Slippers and is practically unmistakable for anything else. Each large stem (20-90 cm) bears one to three large pink and white flowers (Figure 4). Often 25 or so stems will rise from a single spreading rhizome with many cord-like

roots. Both the sepals and petals of this species are white. The dorsal sepal is ovate and arched over the slipper. The lateral petals are narrower and the lateral sepals are joined behind the lip. The lip is inflated and around 5.5 cm long with a circular, in rolled opening. The outside of the lip itself is white flushed with shades of pink and the interior is marked with purplish spots and lines.

Figure 4. Images of *C. reginae* in a moist wetland.

This orchid has a similar range to the other Lady's Slippers, found in Saskatchewan east to Newfoundland, south to Arkansas and North Carolina. This species favours calcareous fens and occurs along the edges of spruce, cedar, tamarack, or balsam swamps. A major limiting factor for this species is a relatively frost-free root environment, rendering it in many cases restricted to open wetlands.

In terms of reproduction, *Cypripedium reginae* is a predominantly outcrossing species. However, it is self-compatible, and some geitonogamy occurs where a flower is fertilized by pollen from another flower on the same plant (Catling 1983). Individual

plants do not emerge every year, and it has been known to have prolonged periods of dormancy lasting several years (Gregg 2004). It may only grow as large as a pencil point in its first year and on average, it takes 14 to 17 years before it blooms. Despite the large flowers, its anther exits are smaller than those of *C. acaule* and therefore it is more difficult for bumblebees to pass through (Stoutamire 1967). Although many insects, such as butterflies and beetles, have been seen visiting this plant, there are only a few species that actually enter the flower. Only a medium sized, unidentified black bee in Michigan and leaf-cutter bees, *Megachile melanophaea* and *M. centuncularis* enter the flower, follow the course to the base of the slipper emerge through the exit hole, and remove pollen from the anther (Guignard 1886).

Goodyera repens

Goodyera repens, or Lesser Rattlesnake-Plantain, is the smallest *Goodyera* orchid. This species is only 5-20 cm tall and has a loose raceme with blossoms along one side or in a loose spiral. The flowers are small; only about 3 mm, downy, and white. There may be up to 25 flowers on one stem. The dorsal sepal and petals converge to create a hood over the lip. The leaves of this species, like most *Goodyera*, are the distinguishing feature. The leaves appear in a basal rosette, pointed, and have a web of white veins (Figure 5).

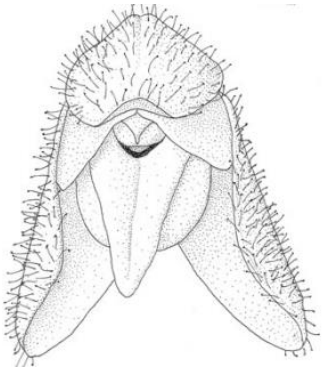

Figure 5. Images showing typical flower structure and leaf colouration of *G. repens*.

This species is most often found in cool, acidic, and nutrient deficient soils. It prefers shade and is common in mossy bogs and coniferous forests. This species is circumboreal and is found in Northern Eurasia, Alaska east to Newfoundland, and south in the Rockies to New Mexico. It is also found in Minnesota across the Great Lakes to Maine, and south in the Appalachians as far as North Carolina. While this species is secure in Ontario, it is listed as endangered, rare, or a species of special concern in other parts of its range.

Pollination and reproduction of *Goodyera* spp. are less studied than those of the bright and large *Cypripedium* spp. This species is thought to be pollinated by moths, butterflies, and bumblebees (Heinrich 1975). *Bombus perplexus* is thought to be an important pollinator of this orchid. The male reproductive organs of the flower come to maturity before the female parts and in young flowers, the column is close to the lip, preventing access to the stigmas. A tube is formed by the labellum and the elongated rostellum. The proboscis of the bee, when not carrying pollinaria, is able to enter this tube and rupture the rostellum. The viscidium, a sticky pad-like gland, is also ruptured and cause the pollinaria to stick to the proboscis as it is withdrawn from the flower. In older flowers, the column and lip are separated; exposing the stigmas for pollination. This type of growth decreases the chance of self-pollination, which would reduce genetic variety.

Goodyera tesselata

Often referred to as Checkered Rattlesnake-Plantain, this species is an incredibly successful hybrid of *G. repens* and *G. oblongifolia* (Kallunki 1976). This species is so successful that it has been reported in Minnesota, while *G. oblongifolia* has not. This orchid is one to 35 cm tall and has a loosely filled raceme. The flowers are spiraled or

one-sided and are pea-sized downy, white blossoms (Figure 6). The lip of this species is formed into a pouch and has an elongated, spout like tip. The upper sepals and petals cup over the lip and the lower sepals are gently flared. This species has three to eight basal leaves forming a rosette. The leaves of this species are about five cm long, narrow, and pointed. The leaves are a light green and have an indistinct white pattern over them.

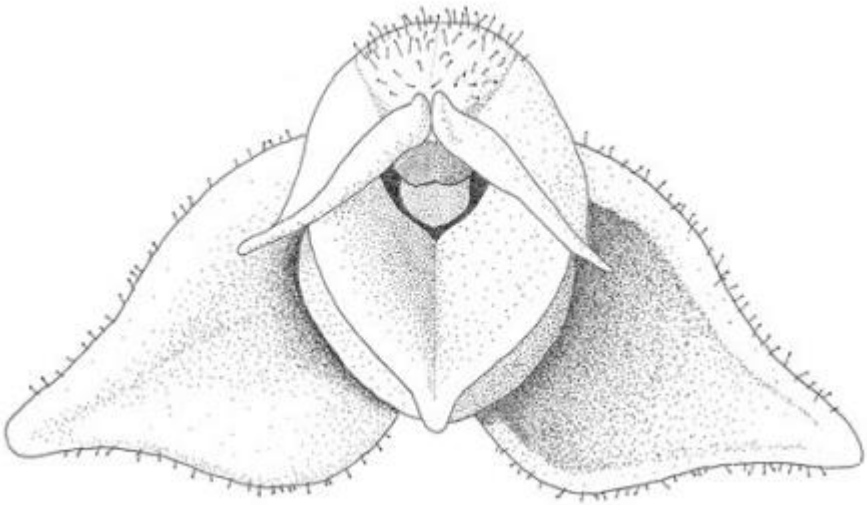

Figure 6. Image showing typical flower morphology of *G. tesselata*.

Goodyera tesselata has a limited distribution; it is found in Manitoba east to Newfoundland, south to Minnesota, Ohio, and Maryland. It is generally thought to be confined to the relic path of Eastern North America's glaciers. Although globally secure, this species is rare or extirpated in several places along the southern edge of its range. *G. tesselata* prefers coniferous or mixed wood forests and is found in dry, sandy soils.

Similar to *G. repens*, little is confirmed about the pollination ecology of *G. tesselata*. Bumblebees are thought to be a primary pollinator, with halictid bees and syrphid flies also found visiting the flowers. As with *G. repens*, the insects are attracted to the sweet scent of the nectar produced at the base of the saccate lip. They access the

nectar source at the base of the lip and pick up pollen on their proboscis. The pollen is transferred to the stigma of the next flower they visit, hopefully completing pollination. As is evident from the origin of *G. tesselata*, hybrid and backcrosses are very common and difficult to identify in the field.

Goodyera oblongifolia

Goodyera oblongifolia, referred to as Giant Rattlesnake-Plantain, has a tall (15-50 cm) stem covered with finely pubescent hairs. The stem emerges from a basal rosette of leaves and a creeping rhizome. The flowers of this species are white and downy and up to 30 are arranged in a loose spiral along one side of a raceme (Figure 7). The upper sepals and the petals are pubescent and they form a hood over the lip. The lower sepals arch backwards. Again, the leaves are the defining feature of this orchid. It has a basal rosette of three-seven oblong leaves that are up to 10 cm long. The leaves taper at the ends and have wavy edges. They are dark green and only have the midrib covered in a white stripe.

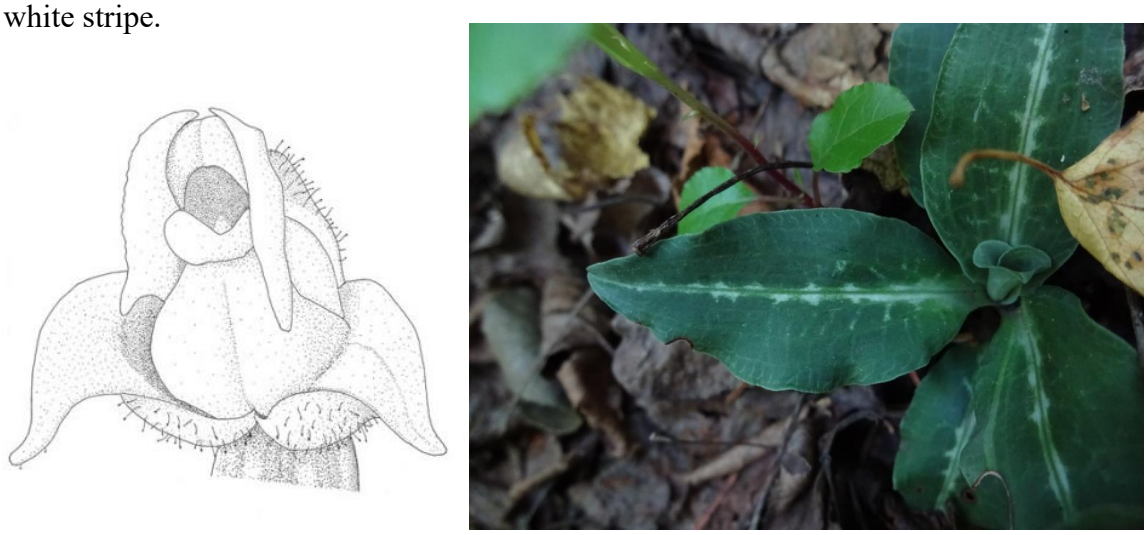

Figure 7. Images showing typical flower morphology and leaf structure of *G. oblongifolia.*

The distribution of this species is particularly disjunct. It is more common in the western part of its range in southeast Alaska to Saskatchewan, South Carolina and New

Mexico. In the eastern portion of its range, it is rarer and local, found in northern Wisconsin, northern Michigan, southeast Ontario, and Maine. Typically, this species is found in dry to moist coniferous or mixed hardwood forests and on the margins of wooded bogs and swamps (Luer 1975).

Bumblebees, such as *Bombus mixtus, Bombus occidentalis, Bombus vagans* and *Bombus vosnesenskii*, are important pollinators of this species of orchid (Ackerman 1975). The pollination mechanism of *G. oblongifolia* is similar to that of *G. repens* and *G. tesselata*; sweet scent attracts the pollinators and they land on the base of the lip. The pollen is transferred to the bees from the rostellum. Upon visiting the next flower, the bee brushes the pollen on the exposed stigmas, allowing cross fertilization. The flowers of *G. repens, G. tesselata,* and *G. oblongifolia* all attract the same type of pollinators, have the same type of pollination mechanism, and are morphologically similar. Such similarities may aid in attracting pollinators and multiple pollination visits as *Goodyera* populations are typically small and flower late in the season (Macior 1971, Mosquin 1971).

METHODS AND MATERIALS

STUDY AREA

Thunder Bay was originally two cities, Port Arthur and Fort William, and until 1970 these cities were separated by a large wetland in what is now the developed Intercity area. The remaining wetland, which is confined to a 730.55 ha area called

William Bog, was once home to *Cypripedium parviflorum* var. *pubescens* and over 500 individuals of *Cypripedium reginae*. In the early 1970s, an expressway was pushed through the area, which was developed into the housing area known as Redwood Park. The water table was lowered by about 3 m and this change proved to be near detrimental to the orchids in that particular area. Mr. C. Garton (pers. comm., November 17, 1970) noted that some of the orchids he had observed in the area had already died and he expressed concern about the other populations. There are still small patches of wetlands in the area but with continued development, these undisturbed locations that are suitable for orchids are becoming short in supply.

In contrast to this highly developed area, the Thunder Bay District is also home to Sleeping Giant Provincial Park, 24,750 ha at the tip of the Sibley Peninsula, which forms Thunder Bay itself. Although the entire peninsula was once logged, the park area has been set aside as a natural area since 1944. Due to its peninsular setting in Lake Superior, Sleeping Giant's environmental conditions are able to support arctic and alpine plants. Its geographical position also makes it favourable to western species. Much of Sleeping Giant Provincial Park is not easily accessible to the public, allowing the orchid species found here to continue to thrive.

HERBARIUM APPROACH

To meet the objectives for this thesis, I went to the Claude E. Garton herbarium located in Lakehead University in order to document historic orchid locations. The orchid species chosen were *C. acaule*, *C. arietinum*, *C. parviflorum* var. *pubescens*, *C.*

reginae, *G. repens*, *G. tesselata*, and *G. oblongifolia.* I chose samples that were located in the Thunder Bay District and were at least 35 years old. Location, habitat descriptions, and collector information were also obtained from the herbarium samples (Appendix I). Some of the locations were difficult to interpret and in these cases habitat clues were important additional information used to determine the field locations. Each sample was given a unique identifier.

FIELD APPROACH

The resulting 24 sites were visited at different times between May and September 2017 to search for orchids during peak blooming conditions. As *Cypripedium* spp. typically bloom earlier, sites with these species were visited first and *Goodyera* spp. sites were visited later in the season. Upon visiting each site, I took habitat notes regarding the dominant species in the area. At each site, the most important factor was the presence or absence of the orchid species. After visiting the variety of sites around Thunder Bay and the Sibley Peninsula, I condensed the information into multiple tables. The tables show the identification, species, location from the herbarium record, and the current habitat where the species was originally found. In addition to the orchid sites gathered from herbarium record, I have amassed my own orchid information, as well as information from various reliable sources to present a more comprehensive list of orchids in the city of Thunder Bay as well as elsewhere.

RESULTS

Of the eight sites visited in the city of Thunder Bay based on the herbarium records, only one site still has orchid species present (Table 1). The habitats in the locations that were found in the Intercity area have all been changed from their initial descriptions. Many of these locations are now paved for parking or walking trails or have been developed into buildings. The areas are highly disturbed and many sites had garbage and other objects, such as plastic bags, bottles, shopping carts, and cigarette butts. Although seven of the eight sites were visited to look for *Cypripedium* spp., none of the sites still had this species of orchid. *Corallorhiza trifida*, commonly called early coralroot, was the only orchid found. This species is a small, green, saprophyte orchid that is able to occur in anthropogenic habitats (Adamowski 2006).

Table 1. Orchid species from herbarium records found in the city of Thunder Bay.

ID	Species expected	Location	Habitat	Presence	Species found
1	*Cypripedium reginae*	Intercity area	Mowed grass, very disturbed shoreline both by humans and geese	no	
2	*Cypripedium reginae*	LaSalle subdivision	Mowed grass, very disturbed	no	
9	*Cypripedium calceolus*	North of Northwood Park	Exposed rock, moss, *Linnaea borealis, Picea mariana*, very disturbed area	no	
10	*Cypripedium calceolus*	Intercity bog	Mixed wood, very disturbed	no	
11	*Cypripedium calceolus*	Riverside Cemetery (now St. Patrick's)	Treed area, field, lots of grass species	yes	*Corallorhiza trifida*
14	*Cypripedium calceolus*	South side of Edwards St	Grass species, shrubs, very disturbed	no	
16	*Cypripedium arietinum*	Intercity	Shoreline with grass species, mowed lawn, bike path, built up rock	no	
29	*Goodyera repens*	George Burke Park	Mixed woods area, disturbed, erosion along river	no	

The orchids on the Sibley Peninsula, on the other hand, often occurred where they were originally listed. Of the 11 sites that I visited, five of them had orchids present (Table 2). A site of note was site 6, in which *Cypripedium acaule* is still found. This population of orchids is growing in very open, rocky areas and has around 100 plants, despite that the location is very popular with motor vehicles and hikers. The plants were often found directly underneath or beside jack pine, showing their preference for highly acidic soil. The Ravine Lake trail sites, which also follows a popular trail, appeared not to have changed too much in terms of habitat. However, the orchids that were once present no longer exist in that area.

Table 2. Orchid species from herbarium records found on Sibley Peninsula.

ID	Species expected	Location	Habitat	Presence	Species found
6	*Cypripedium acaule*	Sibley Peninsula	Open rocky areas, growing under jack pine in moss	yes	*Cypripedium acaule*
17	*Goodyera oblongifolia*	Ravine Lake trail	Moist, mixed woods, talus area	no	
18	*Goodyera oblongifolia*	Ravine Lake trail	Moist, mixed woods, talus area	no	
19	*Goodyera oblongifolia*	S.W. corner of Grassy Lake	Slope, grassy by lake transitioning into conifer dominated forest	no	
22	*Goodyera tesselata*	Ravine Lake trail	Mixed woods, moss	no	
23	*Goodyera tesselata*	Grassy Lake	Floating grass mat, mossy hummocks	yes	*Arethusa bulbosa*
24	*Goodyera tesselata*	East side of Lake Marie Louise	Conifer dominated forest, campground	no	
25	*Goodyera tesselata*	South side of Surprise Lake	Developed for camps and highly used area	no	
26	*Goodyera tesselata*	Kabeyun Trail, 0.5 miles west of Perry's Bay	Balsam dominated, moist and growing in moss	yes	*Goodyera repens*
27	*Goodyera tesselata*	North side of Grassy Lake	Dominated by grass species	yes	*Arethusa bulbosa,*
28	*Goodyera repens*	East side of Middlebrun Bay	Growing in moss along coast, conifer dominated area, shaded	yes	*Goodyera repens*

The final five sites from the herbarium record were elsewhere in the Thunder Bay district, not in the city of Thunder Bay or on the Sibley Peninsula. At these five sites, orchids were found in each case (Table 3). However, at only one of the sites was the expected orchid found. The Ouimet Canyon site is protected as a nature reserve, and although people are still active here there is special consideration to protect the Arctic plants; Ontario Parks has constructed a boardwalk and restricted acess to both certain areas and certain times of day. The Burchell Lake sites are much less protected legally; however, they have the benefit of being less accessible. The species at these sites were found mostly along the edge of lakes or growing in other moist areas. There were four species of orchids found at the Burchell Lake sites, which is more than what was found within the city of Thunder Bay. *Calopogon tuberosus* var. *tuberosus* was found at the Burchell Lake sites and although this species is secure globally, it is rare and uncommon through parts of its range. This species is unique in that the flowers appear to be upside down.

Table 3. Orchid species from herbarium records found in other locations.

ID	Species expected	Location	Habitat	Presence	Species found
4	*Cypripedium acaule*	Burchell Lake	Moist areas, grass species	yes	*Platanthera aquilonis, Pogonia ophioglossoides, Calopogon tuberosus* var. *tuberosus*
5	*Cypripedium acaule*	Burchell Lake	Moist areas, grass species	yes	*Platanthera aquilonis, Pogonia ophioglossoides, Calopogon tuberosus* var. *tuberosus*
7	*Cypripedium acaule*	Ouimet Canyon	Growing in the mossy rocks	yes	*Cypripedium acaule*
20	*Goodyera tesselata*	Burchell Lake	Growing in mossy area	yes	*Goodyera repens*
21	*Goodyera tesselata*	Burchell Lake	Growing in mossy area	yes	*Goodyera repens*

Although the records from the herbarium paint a rather grim picture, there are other locations within the city of Thunder Bay in which orchids exist (Table 4). At William Bog, I have found seven different species of orchids and the Thunder Bay Field Naturalists have recent records of 14 orchid species. The other location of interest in the city of Thunder Bay is Mills Block Forest. At this location, five orchid species have been found, including a small population of *Calypso bulbosa* var. *americana*. These two sites are of important value to the diversity of orchids within the city of Thunder Bay, as they are mostly undisturbed despite the foot traffic.

Table 4. List of orchid species and locations in Thunder Bay.

Location	Species	Habitat
Mills Block Forest	*Cypripedium arietinum*	Open area, slightly rocky field
	Coeloglossum viride var. virescens	Growing along edge of trail in shade of mixed woods
	Calypso bulbosa var. americana	Growing in single patch of about 20 plants, in moss
	Goodyera repens	Found growing along side of trail
	Corallorhiza trifida	Found growing on moss hummocks in a wet, *Thuja occidentalis* dominated forest
Oxford Rd	*Cypripedium arietinum*	Growing along edge of parking lot
Baseball Diamond	*Cypripedium parviflorum var. pubescens*	Growing in conifer dominated forest
William Bog	*Cypripedium arietinum*	Small population growing off of trail under *Abies balsamea*, *Larix laricina*, and *Pinus* species
	Cypripedium acaule	Growing in shaded conifer dominated forest, under *Rhododendron groenlandicum*
	Arethusa bulbosa	Growing atop floating sedge mat
	Pogonia ophioglossoides	Growing atop floating sedge mat
	Cypripedium parviflorum var. pubescens	Gowing both along open trail and with *Abies balsamea* dominated forest with little competition
	Spiranthes romanzoffiana	Among mostly grass species, floating mat
	Platanthera lacera	Among mostly grass species, floating mat

In addition to the other orchids within the city of Thunder Bay, there also exists a wide diversity of orchids and orchid locations on the Sibley Peninsula (Table 5). On the Sibley Peninsula, I compiled 50 different orchid locations. Included within this list are the locally rare and provincially rare *Malaxis paludosa* and *Liparis loeselli* respectively. Many of the sites on the Sibley Peninsula appear to be hotspots for orchids, given that at most sites more than one orchid species is found. In addition, many of the orchid locations are near large bodies of water, some of which are spring fed.

Table 5. List of orchid species found at Sibley Peninsula.

Location	Species	Habitat
Squaw Bay	*Malaxis paludosa*	Floating sedge mat, adjacent to water's edge
	Cypripedium reginae	Conifer dominated forest, growing both atop mossy hummocks and within the water tracks, found in both open and partially shaded areas
	Spiranthes romanzoffiana	Open sedge mat, atop mossy hummocks
	Liparis loeselli	Open sedge mat, atop mossy hummocks
	Platanthera orbiculata	Growing in shaded *Thuja occidentalis* fen
	Platanthera dilatata var. *dilatata*	Open, wet, grassy areas
	Platanthera aquilonis	Open, water track
	Platanthera huronensis	Open, water track
	Platanthera obtusata subsp. *obtusata*	Shaded, wet *Thuja occidentalis* forest
Kay Lake	*Malaxis unifolia*	Floating sedge mat
	Liparis loeselli	Growing on edge of floating sedge mat, adjacent to water
	Pogonia ophioglossoides	Growing close to water's edge on floating sedge mat
	Platanthera aquilonis	Growing in wet, undisturbed roadside ditches
Foster Point	*Cypripedium parviflorum* var. *pubescens*	Wet *Thuja occidentalis* forest
	Platanthera aquilonis	Wet *Thuja occidentalis* forest
	Listera auriculata	Growing in *Alnus* spp. fringe, sandy soils along beach
Finlay Bay	*Listera auriculata*	Growing in *Alnus* spp. fringe, sandy soils along beach
	Goodyera repens	Conifer dominated forest, growing in moss
Fork Bay	*Galearis rotundifolia*	Wet conifer forest, growing in mossy hummocks
	Platanthera obtusata subsp. *obtusata*	Wet conifer forest, growing in mossy hummocks
	Platanthera orbiculata	Moist conifer forest

Table 5. (continued).

Location	Species	Habitat
Camp Bay	*Platanthera aquilonis*	Growing on unused road, in wet area
	Corallorhiza maculata var. *maculata*	Shaded, conifer dominated forest, growing under *Abies balsamea*
	Corallorhiza striata var. *striata*	Alongside road, in open patch
3 km up Thunder Bay Lookout road	*Goodyera oblongifolia*	Upland mixed wood forest
	Corallorhiza striata var. *striata*	Growing under *Abies balsamea*
	Listera cordata var. *cordata*	Upland mixed wood forest
Seep, Thunder Bay Lookout road	*Liparis loeselli*	Growing at base of shrubs in wet moss
	Platanthera aquilonis	Growing in moist, open areas, grass species dominate
	Platanthera dilatata var. *dilatata*	Growing in moist, open areas, grass species dominate
	Spiranthes romanzoffiana	Growing in moist, open areas, grass species dominate
	Spiranthes lacera var. *lacera*	Open, rocky clearing in moss
Grassy Lake	*Platanthera aquilonis*	Growing in moist roadside ditches
	Corallorhiza trifida	Growing in shaded forest, under *Thuja occidentalis*
	Arethusa bulbosa	Growing on floating sedge, atop mossy hummocks
	Arethusa bulbosa forma albiflora	Growing on floating sedge, atop mossy hummocks
South Lake Marie Louise	*Listera cordata* var. *cordata*	Moist, *Thuja occidentalis* grove, growing in moss
	Galearis rotundifolia	Wet *Thuja occidentalis*, adjacent to ground water runoff
North Lake Marie Louise	*Cypripedium parviflorum var. pubescens*	Conifer dominated forest, treed fen
	Galearis rotundifolia	Conifer dominated forest, treed fen
	Corallorhiza maculata var. *maculata*	Conifer dominated forest, treed fen, shaded
Middlebrun trail	*Goodyera repens*	Edge of trail, sandy soils, growing in moss

Table 5. (continued).

Location	Species	Habitat
Middlebrun Bay bog	*Cypripedium acaule*	Open *Picea mariana* forest in moss
	Galearis rotundifolia	Moist area, growing on bottom of mossy hummock in deer paths, partial shade
Rita Lake	*Arethusa bulbosa*	Floating sedge
Ferns Lake	*Cypripedium parviflorum* var. *pubescens*	Treed fen, *Picea mariana*
	Platanthera aquilonis	Open, mossy edge of lake
East of Sawyer Bay	*Goodyera oblongifolia*	On Sawyer Bay trail, shaded and moist, *Thuja occidentalis* dominated
	Platanthera aquilonis	On Sawyer Bay trail, shaded and moist, *Thuja occidentalis* dominated
	Spiranthes lacera var. *lacera*	Open clearing, growing on thin layer of moss/grass over rocks

I also compiled a smaller list of orchids found in locations other than the city of Thunder Bay and the Sibley Peninsula (Table 6). All of these sites exist within the Thunder Bay district and further highlight the orchid diversity. A site of note is the rare *Cypripedium passerinum* found at Pukaskwa National Park. This location is in the southernmost part of the orchid's range and is likely able to survive here due to the cooler climate influenced by Lake Superior. The *Cypripedium acaule* growing at Sandbar Lake Provincial Park was growing trailside, similar to the conditions of the same species at Pukaskwa National Park.

Table 6. List of orchid species in other locations.

Location	Species	Habitat
Nine km up Hwy 527	*Goodyera repens*	Old growth conifer forest, growing in moss under *Abies balsamea*
Cavern Lake	*Cypripedium acaule*	Growing in conifer forest, shaded area
Sandbar Lake	*Cypripedium acaule*	Growing in rocky outcrops
Pukaskwa National Park	*Cypripedium acaule*	Grow in rocky outcrops along trail
	Cypripedium passerinum	Growing in sandy soils with *Juniperus communis* and shaded by trees
	Goodyera repens	Growing in moss on side of sand dunes with *Juniperus communis*, some in open areas
	Goodyera tesselata	Growing in shaded *Abies balsamea* area
	Corallorhiza trifida	Growing in upland mixed forest

DISCUSSION

In summary, while there are some other sites in the Thunder Bay district that have a diversity of orchids, these sites seem to be limited in extent when compared with the numerous sites supporting orchids on Sibley Peninsula. In addition, I found a greater diversity of orchid species on the Sibley Peninsula in comparison to the number of orchid species found in the city of Thunder Bay. These observations support my original hypothesis that the historic orchid locations within the city of Thunder Bay have changed to become unsuitable, while the locations on the Sibley Peninsula have remained more constant.

In undeveloped locations that are now developed, the habitats have been changed in a manner that no longer allows for the orchid populations to thrive. In locations that are still more secluded or less disturbed, orchid populations are still flourishing. In all of the sites in the city of Thunder Bay, habitats have changed drastically. Multiple areas

within the city that were described as bog or sphagnum are now paved over and highly disturbed. At multiple sites I found garbage or evidence of heavy human traffic. None of the sites visited based on herbarium records in the city of Thunder Bay can be considered fen or bog, which is the ideal habitat for *Cypripedium arietinum, Cypripedium reginae,* and *Cypripedium parviflorum* var. *pubescens.* While *Goodyera* spp. can survive in more upland sites, they also typically prefer shady, conifer-dominated areas, which are in short supply within the city.

On the Sibley Peninsula, there is an abundance of lakes that are fed by springs. Many of these areas are not accessible by any road or trail and take hours of walking through dense forest to find. The main difference between the city and the peninsula is seemingly the level of seclusion. However, orchids on the Sibley Peninsula are not without disturbance; they often must withstand trailside disturbance. One such instance is at the Thunder Bay lookout. People heavily use this area as the road provides access directly to the lookout and the trails that start there. There have been studies to suggest that some orchid species cannot only withstand trailside disturbances, but actually benefit from this type of disturbance, likely due to the light trampling which reduces competition, compacts the soil, and exposes the mineral soil (Catling 2011). In addition, the disturbance also increases the light and there are microclimatic differences near the edge of trails. Notwithstanding, on the Ravine Lake trail on Sibley Peninsula, orchids used to be close to the footpath but appear not to have been able to survive the disturbances of passersby.

It is an apparent conundrum that the family with the largest number of flowering plants is also experiencing some of the greatest threats. Rarity in orchids is generally linked to their unique habitats and pollinator requirements. While this specialization is

responsible for the great species diversity, it has also contributed to the high level of threat found in this family. Around one third of orchid species are terrestrial, yet almost half of extinct species are terrestrial herbaceous perennials (IUCN 1999). This would suggest that orchids are therefore a life-class form likely to experience a higher risk of extinction. Orchids are also particularly sensitive to the implications of climate change. Due to warming climate, important behavioural and developmental, such as pollination and seed germination, events that require specific timing are changing (McCarthy 2001). The implications could be detrimental for orchids. Many orchids have evolved to be pollinated by very specific pollinators, sometimes only one species, and if these species are now active at different times, the orchids could miss their opportunity to be pollinated. Climate change also affects species ranges. It has caused species to move to higher latitudes and altitudes to find suitable habitat (Chen et al. 2011). However, if a species is unable to migrate quicker than the habitats are changing it will face extinction. While climate change presents a series of problems that a species must deal with, other human activities have their own effect. Land clearing for agriculture, mining and urban development, weed invasion, grazing, altered environmental conditions, and collection of plants have all had detrimental effects on orchid populations (Swarts and Dixon 2009). Orchid populations are also suffering from other threats, including habitat fragmentation, increased susceptibility to fire threats, pollinator decline, and introduction of feral animals.

In addition to the threats of climate change, orchid pollinators are facing growing concern from neonicotinoids. Neonicotinoids are a class of agricultural insecticides that have a chemical structure similar to that of nicotine and are the most widely used insecticides in the world. They are highly effective as pest control because they strongly

effect arthropods in small quantities, while not having such effects on vertebrates. They are extremely persistent in the environment, water soluble, and systemic, meaning the insecticide can be absorbed by the plant and is often found in both the pollen and nectar of the plants (Goulson 2013). Thus, neonicotinoids are available to pollinators at sublethal concentrations for most of the year (Van der Sluijs et al. 2013). These concentrations have been seen to cause reduced learning, foraging ability and homing ability in both honeybees and bumblebees (Mommaerts et al. 2010; Henry et al. 2012). This set of effects can lead to colony collapse and reduced pollination rates, which could have detrimental effects for the continued success of Orchidaceae.

Although there are 20,000 orchid species, there are no cases where they are linked to distinct, large-scale ecosystem services. This presents a challenge as large ecosystem services are worth trillions of dollars on a global scale and many of our conservation efforts focus on impacts to these services, such as clean air, clear water, and productive soils (Swarts and Dixon 2009). However, orchids have intrinsic value and can act as early indicators of forest health and changing ecosystems.

While this study does suggest that human development has changed orchid locations in the city of Thunder Bay so that they can no longer survive, an important point is that this study is not comprehensive. For the sake of completing the thesis in a timely manner, only two genera of orchids were chosen. In the herbarium, there exists location information for every species of orchid found in the Thunder Bay district and some of these species would be able to tolerate areas that have been disturbed by humans. *Platanthera dilatata* and *Corallorhiza trifida* are two examples of orchids that can survive in these types of habitats; they are commonly found in ditches and along roadsides (Wallace 2003). In addition, there has been a study that suggests that

apophytism is becoming common among orchids. This is a term coined by Adamowski (2006) to describe a species that is able to colonize anthropogenic habitats. He cites two genera of orchids, *Epipactis* and *Dactylorhiza,* which are now more common in anthropogenic habitats. However, he also notes that orchid populations growing in the secondary habitat, being an anthropogenic habitat, consistently have shorter life cycles and broader ecological amplitudes. In order to get a full understanding of how orchid locations have changed in the city of Thunder Bay, it would be necessary to look at every single orchid species in the herbarium record and proceed to visit these locations. Documenting which orchids are still found in the given locations might allow more firm conclusions about how economic development is affecting certain species of orchids.

CONCLUSION AND POTENTIAL REMEDIAL ACTIONS

The populations of *Cypripedium* spp. and *Goodyera* spp. within the city of Thunder Bay have declined due to changes in habitat. On the Sibley Peninsula, the orchid populations have also changed but are still thriving in various locations. Orchids belong to the largest family of flowering plants which is facing some of the largest threats. This is in part due to their unique habitat requirements and pollinator specializations. With changing climate and other anthropogenic factors influencing this species, conservation efforts should be considered.

The conservation of a rare plant includes balancing the protection of the plant with raising awareness to the threats it is facing. This can be a delicate balance for plants that are sensitive to any changes in habitat and negatively affected by frequent human

visits. Methods for conservation can include more extreme means, such as assisted migration and seed storage. Assisted migration is the process by which a population of a species is intentionally moved beyond the boundary of its historic range. Assisted migration must be assessed on a case-by-case basis as it technically could constitute the introduction of an unwanted species and unintended consequences can arise (Barman and Devadas 2013). In the face of such alarming climate changes, seed storage and vaulting are other options. While more passive, they can help to preserve biodiversity and genetic diversity (Walters et al. 2004). There are smaller scale methods for conserving and enhancing awareness of particular species as well.

Other methods of conservation can involve bringing awareness to the public by building boardwalks or trails through sensitive areas. While these types of ventures do open up a sensitive area for potentially further degradation, if done correctly they open the area up as a teaching environment. Boardwalks for viewing sensitive areas allow for easy access into the vicinity while minimizing damage to certain areas. Boardwalks allow the public to be in closer contact with sensitive areas and can help create a feeling of protection and appreciation (Roach et al. 2006). Buffer zones between the trail and areas of greater sensitivity, such as those supporting rare plants or nesting birds, are an essential part of their protection. Interpretive signs along a trail can help to explain to a user why the area is sensitive and how it is being protected. A prime example is in Pukaskwa National Park. As an effort to protect the fragile habitat of sand dunes, wardens have installed a series of boardwalks to keep people from trampling the fragile habitat. This area contains successive sand dunes that provide certain niches as time progresses. The boardwalks keep people from furthering erosion in a delicate area and the threat of enforcement by Park officials keeps people on the boardwalk.

To conclude, more research needs to be done into orchids, as these rare and complex species occur only sporadically on the landscape. In order to see how human development specifically affects orchids, populations would need to be monitored closely with a program to assess the importance of a variety of factors like soil moisture, photosynthetically active radiation, and community composition over a period of time. Understanding the pollination biology and the association with mycorrhizae is another important step to conserving this species. All of this combined would give information that is more precise in regards to what these unique species can and cannot tolerate. Overall, orchid species are declining at an alarming rate and conservation efforts should be implemented as a means to protect these plants.

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APPENDIX I

Appendix 1. List of summarized orchid information with Lakehead Herbarium numbers in parentheses.

ID	Species	Date	Location	Habitat	Collector
1 (11870)	*Cypripedium reginae*	19/07/1950	Intercity area	Wet sphagnum	C.E. Garton
2	*Cypripedium reginae*	11/07/1970	LaSalle subdivsion	Sphagnum bog	Hartley
4 (20200)	*Cypripedium acaule*	28/07/1981	Burchell Lake	In *Pleurozium schreberi*, under *Pinus banksiana*	C.E. Garton
5 (20508)	*Cypripedium acaule*	18/08/1981	Burchell Lake	Rocky and mossy woods	C.E. Garton
6 (12906)	*Cypripedium acaule*	13/06/1970	Sibley Peninsula	In humus in jack pine and birch	C.E. Garton
7 (2785)	*Cypripedium acaule*	10/06/1956	Ouimet Canyon	Crevices in rocks in humus	C.E. Garton
9 (16523)	*Cypripedium calceolus*	26/06/1975	North of Northwood Park	Fen among black spruce	C.E. Garton
10 (13137)	*Cypripedium calceolus*	06/07/1970	Intercity bog	Sphagnum bog and black spruce	C.E. Garton
11	*Cypripedium calceolus*	28/06/1967	Riverside Cemetery (Now St. Patrick's)	Field	E. Beckett
14 (100)	*Cypripedium calceolus*	04/06/1967	South side of Edwards St	Cedar-Spruce forest	R.A.Wilson
16 (586)	*Cypripedium arietinum*	01/06/1935	Intercity	Cleared patches, dry shale	C.E. Garton
17 (21700)	*Goodyera oblongifolia*	05/09/1982	Ravine Lake trail	Top of dolomitic ridge, shaded	C.E. Garton
18 (18005)	*Goodyera oblongifolia*	03/09/1977	Ravine Lake trail	Moist, humusy soil on rocky crest	C.E. Garton
19 (5538)	*Goodyera oblongifolia*	01/09/1958	S.W. corner of Grassy Lake	Balsam woods along logging trail	C.E. Garton
20 (20328)	*Goodyera tesselata*	13/07/1981	Burchell Lake	Mossy woods, under black spruce	C.E. Garton
21 (20510)	*Goodyera tesselata*	18/08/1981	Burchell Lake	Mossy jackpine over schistose ridge	C.E. Garton

ID	Species	Date	Location	Habitat	Collector
22 (18003)	*Goodyera tesselata*	03/09/1977	Ravine Lake trail	Thick woods, dolomitic limestone	C.E. Garton
23 (1538)	*Goodyera tesselata*	19/08/1967	Grassy Lake	Humus soil under mixed forest	P.Barclay
24 (5540)	*Goodyera tesselata*	01/09/1958	East side of Lake Marie Louise	Dense balsam along lakeshore	C.E. Garton
25 (2243)	*Goodyera tesselata*	31/08/1953	South side of Surprise Lake	Rocky moist woods	C.E. Garton
26 (2240)	*Goodyera tesselata*	25/08/1953	Kabeyun Trail, 0.5 miles west of Perry's Bay	Rich mixed woods	C.E. Garton
27 (1340)	*Goodyera tesselata*	02/09/1950	North side of Grassy Lake	Damp, rich woods	C.E. Garton
28 (4283)	*Goodyera repens*	15/08/1956	East side of Middlebrun Bay	Rocky woods on slope	C.E. Garton
29 (7834B)	*Goodyera repens*	15/07/1971	George Burke Park	Moist mixed forest near river	P.Barclay