Golden-winged Warbler, female.

Golden-winged Warbler, male.
Photo: Laurie Smaglick-Johnson

Population densities of Golden-winged Warbler, Blue-winged Warbler and their hybrids, in eastern Ontario

Assessment with standardized survey protocols and mapping using Geographic Information Systems (GIS)

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Introduction

Golden-winged Warblers (*Vermivora chrysoptera*) have long fascinated birders and ornithologists alike, due in part to their flashy plumage, distinctive songs, and ability to hybridize with the closely related Blue-winged Warbler (*Vermivora pinus*). The Golden-winged Warbler population near the Queen's University Biological Station (QUBS) north of Kingston, Ontario, has been the subject of extensive, ongoing study since 1997. However, researchers have never systematically surveyed tracts of land to estimate densities of Golden-winged and Blue-winged Warblers or their hybrids in the area. We present survey protocols and results from populations at QUBS; these baseline data are crucial in order to develop a long-term conservation strategy for the declining Golden-winged Warbler. Detailed population data from QUBS also has the potential to act as a case study, providing an in-depth example of how abundances might change through time in other locations. Population surveys are particularly important in light of current threats to Golden-winged Warblers that include the advancing range of Blue-winged Warbler populations and habitat loss.

Distributions, habitat and ecology of Golden-winged and Blue-winged Warblers

Golden-winged Warblers breed from extreme southeast Saskatchewan, southern Manitoba and Minnesota, east through southern Ontario and southwest Quebec, and south to Georgia

Golden-winged and Blue-winged pair. *Photo: Laurie Smaglick-Johnson*

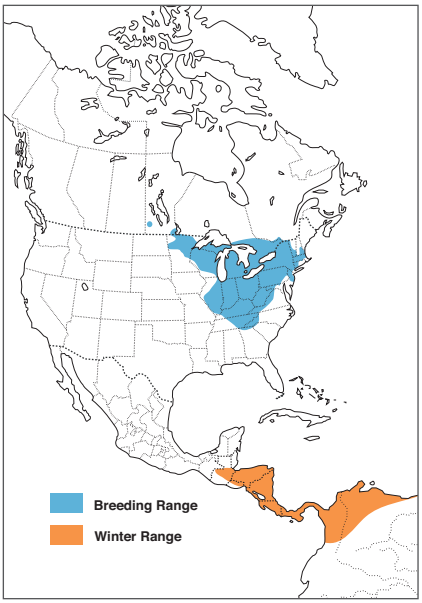


Figure 1. Summer (breeding) range, shown in blue, and winter (non-breeding) range, shown in orange, of the Golden-winged Warbler.
Source: Birds of North America

Figure 2. Summer (breeding) range, shown in blue, and winter (non-breeding) range, shown in orange, of the Blue-winged Warbler.
Source: Birds of North America

(Confer 1992, COSEWIC 2006; Figure 1). They are Neotropical migrants, wintering in a large area from southern Mexico, through Central America, to northwestern South America (Mills *in* Cadman *et al.* 1987a; Figure 1). The Blue-winged Warbler breeds from South Dakota to Oklahoma to South Carolina, and into southern Ontario (Gill *et al.* 2001; Figure 2). They winter from mid-Mexico through the coasts of Central America, and south to Panama (Mills in Cadman *et al.* 1987b; Figure 2). Both species breed in open, early successional areas where most vegetation is less than three metres in height (Mills *in* Cadman *et al.* 1987a, b, Hunter *et al.* 2001). Territories also contain deciduous trees used as singing perches, and are often positioned along a forested edge (Confer 1992). Surrounding trees are essential for foraging on moth larvae and caterpillars (Confer 1992, Demmons 2000).

Golden-winged and Blue-winged Warbler distributions have undergone a series of changes with breeding range expansions and contractions over the past century or more (Hamer *et al.* 2005). These changes correlate closely with patterns of human land use and changes to management practices (Confer *et al.* 2003). Golden-winged Warbler distribution expanded northward from the Appalachian region into Ontario in the early 1900s, Manitoba and Saskatchewan as early as the 1960s, and Quebec in the

1970s (Hamer *et al.* 2005, COSEWIC 2006). Blue-winged Warblers, historically west of the Appalachians and south of the Great Lakes, began to expand northward beginning in the 1860s, and eventually reached Minnesota, Ontario and the southern New England states (Mills *in* Cadman *et al.* 1987b, Vallender *in* Cadman *et al.* 2007b).

Conservation concerns

Golden-winged Warblers are declining across most of their range in Canada and the United States. Populations in Ontario have declined by approximately 12% per year during the past ten years (Gill 1997, Sauer *et al.* 2005), leading them to be classified as Threatened by the Committee on the Status of Endangered Wildlife in Canada and protected under the Species at Risk Act (COSEWIC 2006, 2007). In Canada, populations were growing until 10 years ago, likely because of a northeastward range expansion. Since that time, the species has started to disappear from regions in the southernmost portions of Ontario (presumably due to the arrival of the Blue-winged Warbler and subsequent hybridization; COSEWIC 2006). Moreover, it has been suggested that the species may have reached the uppermost limits of suitable habitat within Ontario (K.V. Rosenberg pers. comm.). Considered in concert, these factors are likely both contributing to why the increasing trend in the province is no longer occurring.

Loss of early successional habitat is thought to be the primary factor behind range-wide Golden-winged Warbler declines (Smith *et al.* 1993, Confer and Larkin 1998); this is caused by the anthropogenic suppression of natural forest fires (Hunter *et al.* 2001), and encouragement of forest regrowth after disturbance or abandonment. Evaluation and conservation of suitable habitat will therefore be critical for slowing declines of the Golden-winged Warbler. Another factor in the decline of Golden-winged Warblers may be nest parasitism by the Brown-headed Cowbird (*Molothrus ater*). Cowbird parasitism may be particularly important in declines in the United States; the impact in Canada is largely unknown (Confer *et al.* 2003, COSEWIC 2006).

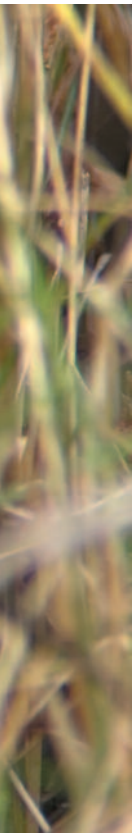
Hybridization is another cause for concern. Blue-winged and Golden-winged Warblers can mate to form two recognized types of hybrids, as well as a wide range of hybrids which are not easily classified as either type, and are, therefore, classified as introgressed. The two main hybrid types are designated by different plumages and known as "Lawrence's" and "Brewster's" (Brewster 1874, Parkes 1951), so named because they were once considered separate species (Lawrence's Warbler and Brewster's Warbler).

These hybrids are both rare in Ontario, with the Brewster's hybrid found most often around the Niagara Escarpment and Oak Ridges Moraine, along the southern edge of the Canadian Shield, and in the Long Point area (Vallender and Leckie *in* Cadman *et al.* 2007). The Lawrence's hybrid, the much rarer form, was

Golden-winged Warbler nest. *Photo: Laurie Smaglick-Johnson*

reported as a possible, probable or confirmed breeder in only five Ontario locations, during the course of surveying for the second Atlas of the Breeding Birds of Ontario (Cadman *et al.* 2007). Breeding was reported as possible in one square in the region of Waterloo, possible in two squares and probable in one square in the region of Hamilton, and confirmed at one location near Elgin, close to QUBS (Vallender and Leckie *in* Cadman *et al.* 2007).

Although a sighting of one of these rare birds can be exciting, they signal a growing problem for the persistence of Golden-winged Warblers. As the Blue-winged Warbler's range expands northward, hybridization between the species has been implicated in Golden-winged Warbler declines. 'Pure' Golden-winged Warbler genes can become extirpated from local populations, a process termed "genetic swamping" (Gill 1997), although these genes can also persist in the population within hybrids (Dabrowski *et al.* 2005). At present, there is no evidence that hybrids are at a disadvantage compared to the parental species in this system (Vallender *et al.* 2007a), so numerically



dominant Blue-winged Warblers may be able to 'swamp out' Golden-winged Warblers after a short period of contact.

However, given that gene flow is bidirectional between these species (Shapiro *et al.* 2004, Dabrowski *et al.* 2005), it should be noted that the mechanism by which Blue-winged Warblers replace Golden-winged Warblers in areas of contact remains largely unknown (Vallender *et al.* 2007b). Over the past century, the Blue-winged Warbler has replaced the Golden-winged Warbler in substantial regions of its historic breeding range, especially at lower elevations west of the Appalachian Mountains and in the area to the south of Lake Ontario and Lake Erie (Dabrowski *et al.* 2005, Hamer *et al.* 2005). Establishment of Blue-winged Warbler populations usually coincides with decreases in local Golden-winged Warbler populations, with complete replacement typically occurring within 50 years of Blue-winged Warbler arrival (Gill 1980, 1987, 1997). The only known site where this has not yet occurred is in New York State, where the two species have co-existed for over 100 years (Confer and Tupper 2000).

Though interactions with Blue-winged Warblers may play a large role in the decline of Golden-winged Warblers, the relative contribution of competition versus hybridization to the declines remains unknown (Gill 1997, Vallender *et al.* 2007b). In addition, the relative importance of Blue-winged Warblers amid other factors, such as habitat loss and parasitism, in Golden-winged Warbler declines remains poorly understood and appears to depend on the geographic location of the population (COSEWIC 2006). Habitat loss is severe in some areas yet nonexistent in other areas where the species is nevertheless declining (J.L. Confer pers. comm.); Blue-winged Warblers are absent from some declining Golden-winged Warbler populations, and the prevalence of nest parasitism varies across the range (Confer *et al.* 2003, COSEWIC 2006).

Golden-winged Warblers and Blue-winged Warblers in Ontario

Golden-winged Warbler males begin to arrive in Ontario in early May, and are followed thereafter by females, who breed between early June and mid-July (COSEWIC 2006). In southern Ontario, Golden-winged Warblers have shown recent declines and range contractions which have been paralleled by a northward expansion of the Blue-winged Warbler into many areas of southern and eastern Ontario (Mills *in* Cadman *et al.* 1987a,b, Vallender *in* Cadman *et al.* 2007 a,b). Hybridization occurs in all areas where these two species come into contact (Gill 1997).

The Golden-winged Warbler's Ontario range spans from the northern shore of Lake Erie near London, to the eastern

edge of Lake Ontario near Kingston north to Ottawa, Sudbury and Spanish, including the Bruce Peninsula. Separate from this area, there is a small group south of Kenora near Lake of the Woods (COSEWIC 2006). An estimated 18.2% of the global population of Golden-winged Warblers (estimated at 105,000-270,000 breeding pairs) reside in Ontario each breeding season, with the majority of these birds concentrated in southern Ontario (Vallender *in* Cadman *et al.* 2007a, K.V. Rosenberg, pers. comm.). Blue-winged Warblers are now distributed throughout much of southern Ontario, as far north as the east shore of Georgian Bay (Vallender *in* Cadman *et al.* 2007b). Initially recorded in Ontario in the early 1900s, Blue-winged Warblers were confirmed to be breeding by the 1950s and the species has been increasing in local abundance since then (McCracken 1994, Vallender *in* Cadman *et al.* 2007b). Blue-winged Warblers were confirmed to be breeding at QUBS in 2005 (R. Vallender unpublished data), but likely first arrived in the late 1980s, albeit in very low numbers (Weir 1989, R.J. Robertson and T. Demmons unpublished data).

Studies at Queen's University Biological Station

The Golden-winged Warbler population of approximately 200 breeding pairs near the Queen's University Biological Station (QUBS) north of Kingston (44°34N, 76°19 W, Leeds & Grenville and Frontenac Counties) has been extensively studied since 1997. These studies have provided excellent long-term breeding, demographic and genetic data, some of the best available for the species. Investigations have ranged from nesting habitat, site fidelity, feeding behaviour, reproductive performance, migratory origins, plumage and genetic relationships between Golden-winged and Blue-winged Warblers (Demmons 2000, Paquin 2006, Reed *et al.* 2007, Vallender *et al.* 2007a,b, Fraser *et al.* 2008, McKinnon and Robertson 2008, Neville *et al.* 2008). This extensive research has required males to be colour-banded for individual identification. These banding efforts provide an excellent opportunity for surveys such as ours, allowing us to use colour band sightings to confirm auditory point count observations and differentiate between males on neighbouring or overlapping territories.

The study sites at QUBS are within the hybrid zone, yet right at the northern, expanding edge of the Blue-winged Warbler distribution. The northernmost hybrids in Ontario have been found approximately one hundred kilometres north of our study sites, west of Ottawa (Vallender and Leckie *in* Cadman *et al.* 2007). This is an area of recent, yet active, hybridization (Vallender *et al.* 2007b).

Given the historical and continuing expansion of Blue-winged Warblers northward, there is a need to document changes in Blue-winged Warblers and their hybrids in terms of their relative and absolute abundance, habitat use, and breeding sites at QUBS, as well as at other sites in Ontario.

No Blue-winged Warblers or hybrids were detected on QUBS land when research began in 1997 (T. Demmons unpublished data) and were not thought to be present in the area (Weir 1989), yet one or two Brewster's hybrids were present in 1991 and an introgressed Blue-winged Warbler hybrid was found on QUBS property from 1991-1993 (Martin and Robertson 1994). With continual study, the arrival of Blue-winged Warblers and increasing numbers of hybrids at this site have been documented. The population at QUBS provides the unique chance to follow a population from its initially pure Golden-winged Warbler demographic through to the predicted complete turnover to pure Blue-winged Warbler, monitoring hybridization throughout.

Our investigation aimed to estimate population densities of Golden-winged Warblers, Blue-winged Warblers and their hybrids (Brewster's, Lawrence's and introgressed) for the first time in a systematic way on QUBS property. This provided baseline data that can be used in long-term monitoring of population densities, hybridization and habitat use of these species. We also colour banded new males to allow continued estimates of return rates for this population. By surveying three different areas containing a variety of successional land types, we can follow population shifts with habitat changes that include both loss and gain of suitable habitat. These baseline data will allow researchers to document future changes in populations around QUBS. This project holds incredible potential to inform conservation and management plans across the Golden-winged Warbler range, especially in Ontario.

Methods

Survey sites

Our three survey sites were chosen based on their previous roles in Golden-winged Warbler studies at QUBS, confirmed breeding pairs and varying degrees of succession.

The Pangman Conservation Reserve near the village of Chaffey's Lock, is one of the central QUBS properties and has been used for a variety of wildlife studies for many years, including multiple Golden-winged Warbler projects mentioned earlier. The Pangman survey area measured 152 ha, or 1.52 km^2. The area contained five large marsh areas, one lake, and a portion of a second lake, with large forested areas and localized open habitat. The terrain was generally flat and often wet, and common plant species included white ash (*Fraxinus americana*) and common prickly-ash (*Zanthoxylum americanum*) (V.J. Emery and L.E. King unpublished data).

The Massassauga Tract is a large property south of the town of Westport. Approximately one-third of Massassauga was surveyed, for a total area of 220 ha, or 2.20 km^2. This section was chosen as it was most accessible by road, included areas where Golden-winged Warblers had been detected in previous years, and contained additional open areas which could potentially provide suitable habitat. The property consists of a mix of mature

forest and grassy areas, with occasional patches of scrub. The terrain is generally dry, very rocky with hills and small cliffs, and several small marshes in the southern section. Common plant species were similar to those in the Pangman area.

The Bracken Tract is a large waterfront property south of the town of Westport, and west of the town of Newboro. We surveyed the entire mainland section of the tract (204 ha, or 2.04 km^2) because previous research found many Golden-winged Warblers here, especially in the western areas. The tract consists largely of abandoned farmland with active seasonal cattle grazing in the eastern portion and large but fragmented forest sections. The terrain is generally even with some exposed portions of flat rock, one pond, and one large central wetland, in addition to several smaller marshes. Common plant species included meadowsweet (*Spiraea* spp.) and common milkweed (*Asclepias syriaca).*

Previous surveys

We include bird counts from 2006 and 2007 in our discussion. In these years, surveys were conducted by visiting sites with apparently suitable habitat and areas that were known to be occupied by Golden-winged Warblers in previous years (Paquin 2006, H.J. Munro pers. comm.). During these years, song playback was used inconsistently and did not adhere to a standardized protocol. The method used here involved consistent playback and complete surveying, and thus should provide better detection and more observations even if the population is decreasing. For these reasons, and because the protocols in previous years did not include a way to test for the absence of birds in an area, comparisons between years are for interest only. Continued use of the formalized protocols of 2008 will allow informative comparisons with future surveys.

Measuring population densities can prove difficult as it is necessary to ensure that every individual is counted only once. Therefore, to improve accuracy we combined (i) colour banding for individual identification, (ii) comprehensive survey methods including both auditory and visual techniques and (iii) Geographic Information Systems (GIS) to help maximize coverage of plots, analyze survey results and map locations of focal males.

Visual confirmation of birds

We recorded band combinations of previously banded birds and attempted to band all males without bands using both aluminum numbered Canadian Wildlife Service (CWS) bands and coloured plastic bands. Maintaining a banded population is essential for determining return rates of birds and improving estimates of population changes. Keeping a record of banded bird locations also ensured no birds were counted twice during the survey, and confirmed species identification as Golden-winged, Blue-winged, or hybrid warblers with close inspection in the hand. Birds banded in 2008 have band combinations starting with BS, or blue and silver bands on the left leg.

Playback design

The survey playback was based on a monitoring protocol developed by the Cornell Lab of Ornithology Conservation Science Department. The playback has four elements: silence, type 1 and type 2 Golden-winged Warbler songs (Confer 1992), and a recording of Black-capped Chickadees (*Poecile atricapillus*) mobbing a singing Eastern Screech–Owl (*Megascops asio*). Type 1 songs function primarily to attract mates and for species recognition (different for the two species), and type 2 songs are used in territory defense (shared by both species) (Spector 1992). Blue-winged Warblers and hybrids also responded to type 2 song of Golden-winged Warbler (as previously observed in Murray and Gill 1976). We used all four of these elements to ensure that as many male birds as possible were detected. Females cannot be reliably surveyed as they will not consistently respond to playback or to mobbing, so only males are included in results.

For efficiency, we shortened the playback at alternating survey points from 18 minutes (long playback) to 10 minutes (short playback) (Table 1). We also tested the detection ability of playback to verify our survey methodology. Although the shorter protocol was not perfect at detecting birds, we minimized error with multiple visits to survey sites, along with visual identification of colour banded birds to confirm auditory detection. Additionally, the shorter playback is the same length or longer than previous survey playbacks that have been shown to be effective (e.g., 3 minutes of playback, 6 minutes of total observation, Kubel and Yahner 2007; 3 minutes of playback, 7 minutes of total observation, Martin *et al.* 2007).

Table 1. Playback design for detecting Golden-winged Warblers, showing the sequence of playback components for long (17 minutes) and short (10 minutes) survey protocols.

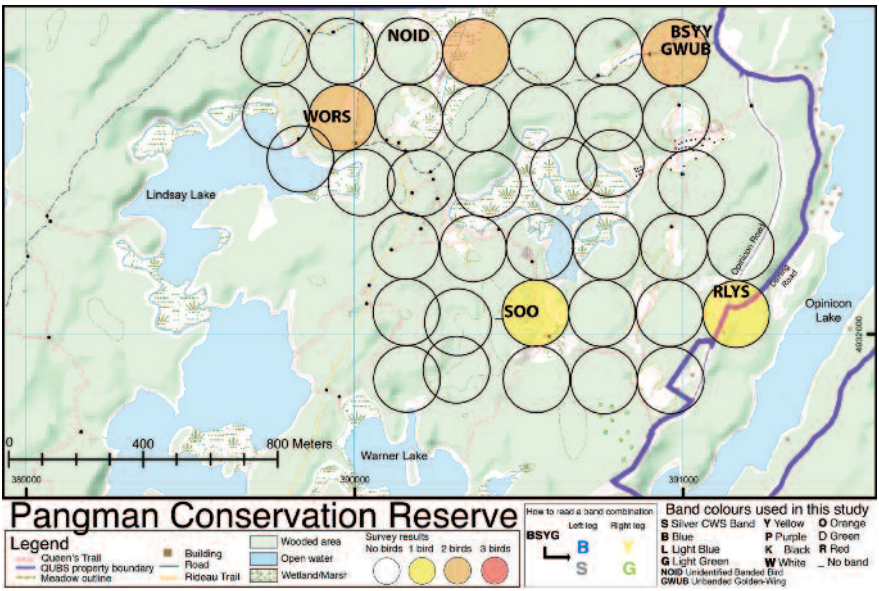
Minute	Playback type (long protocol)	Playback type (short protocol)
1	Silence	Silence
2	Silence	Silence
3	Silence	Silence
4	Type 1	Type 1
5	Type 1	Type 1
6	Type 1	Type 1
7	Type 1	Silence
8	Type 1	Type 2
9	Silence	Type 2
10	Type 2	Silence
11	Silence	
12	Mobbing	
13	Mobbing	
14	Mobbing	
15	Mobbing	
16	Mobbing	
17	Silence	

Survey point count layout

Previous work has shown that Golden-winged Warbler songs can be detected at a maximum distance of 100-150 meters from their territories (Kubel and Yahner 2007) or even as far as 200 metres in some areas (K.V. Rosenberg pers. comm.). However, based on field experimentation of hearing distances in our study area, we concluded that a 100-meter radius circle was most appropriate and placed a circle of this size around each point count to represent the area surveyed. Any birds with territories within each circle should be heard or seen from the survey point. Birds whose territories occupied more than one circle were unlikely to be counted twice because we visually confirmed colour band combinations of banded birds for most of our detections.

A total of 142 point counts was conducted. We focused our efforts on three tracts of QUBS land that have had known Golden-winged Warbler territories in the past two years [Pangman (38 points), Massassauga (53 points) and Bracken (51 points)]. Using GIS software (ArcGIS 9.2, ESRI, Redlands, California, USA), we set out a grid of points separated by 200 meters in all directions to prevent survey overlap. We assigned alternating long and short protocols to each of these survey points.

Figure 3. Distribution of birds shown by band combinations, and results of point counts shown by survey radii, within the Pangman Conservation Reserve, near Chaffey's Lock, ON, Queen's University Biological Station (QUBS). The purple outline represents the property boundary. All band combinations represent Golden-winged Warblers.



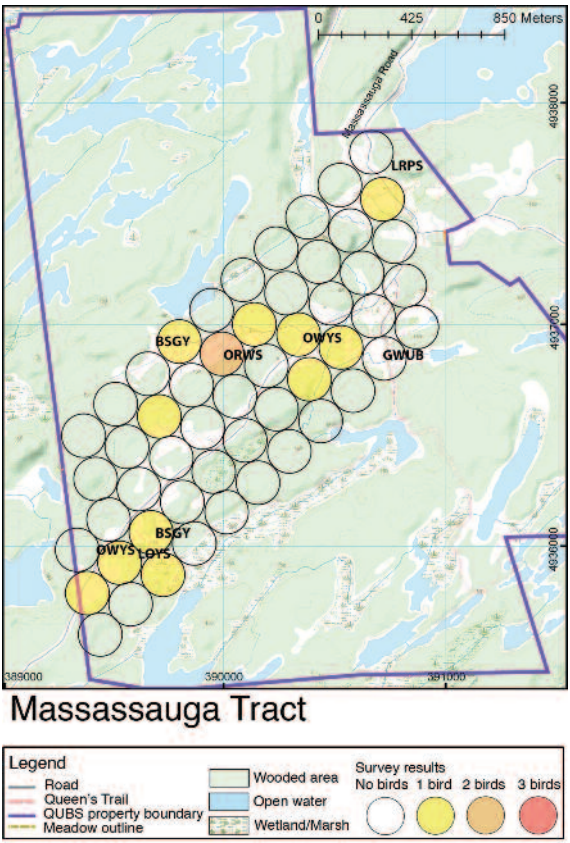


Figure 4. Distribution of birds shown by band combinations, and results of point counts shown by survey radii, within the Massassauga Tract, near Newboro, ON, Queen's University Biological Station (QUBS). Purple outline represents the property boundary. All band combinations represent Golden-winged Warblers. Note that two band combinations (BSGY and OWYS) are repeated on the map, as these males changed territories during the field season. See Figure 3 for complete legend.

Survey protocol

Surveys were conducted between 04:30 and 11:00h, between 10 May and 20 June 2008. Every-other survey point on every-other transect (1/4 of all points) was visited twice within the survey period, and every survey point was visited at least once between 25 May and 20 June 2008.

Using a handheld Global Positioning System (GPS) unit (GPSMAP 60Cx, Garmin International, Olathe, Kansas, USA) we hiked to each of the survey points, recorded the latitude and longitude coordinates of each field site, and followed the designated playback protocol for that point count. When a point was inaccessible (in the middle of a lake or deep swamp) the point on the shoreline which was closest to the original point was used instead. We recorded the minute of detection for all birds seen and heard during the protocol, as well as those birds seen or heard after the protocol had ended and upon subsequent visits.

Mapping survey results

We created the precise maps of Figures 3, 4, and 5 showing survey results and the locations of each male bird using GIS software (ArcGIS 9.2, ESRI, Redlands, California, USA). These maps include the following data; (1) The UTM (Universal Transverse Mercator) coordinates in Zone

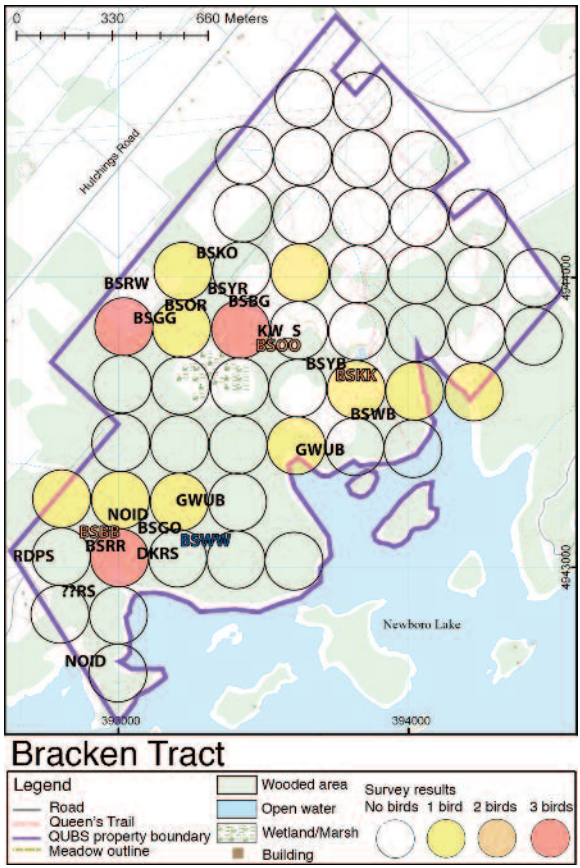


Figure 5. Distribution of birds shown by band combinations, and results of point counts shown by survey radii, within the Bracken Tract, near Newboro, ON, Queen's University Biological Station (QUBS). Purple outline represents the property boundary, which for this tract delimited the survey area. Black band combinations represent Golden-winged Warblers, blue band combinations represent Blue-winged Warblers and red band combinations represent the hybrid Brewster's Warbler. See Figure 3 for complete legend.

18 along the map borders (the same coordinates used to locate sites by GPS); (2) landscape information, including forested, open, wetland and aquatic habitat; (3) circles representing the approximate area in which birds could be detected when observers were at the centre of the circle completing the protocols, coloured according to the number of birds detected; (4) the locations of birds, marked as a band combination, unbanded Golden-winged Warbler (GWUB), or Golden-winged Warblers for which band combinations were unknown (NOID). As there were discrepancies between auditory and visual identifications (eg: some birds were heard twice), all densities were calculated using the visual identifications.

Results

In the 5.76 km^2 surveyed at intervals of 200 metres, we found 30 Golden-winged Warblers, one Blue-winged Warbler, three Brewster's hybrids and zero Lawrence's hybrids, for a total of 34 birds across all areas. The mapped results of surveys conducted in Pangman, Massassauga and Bracken are presented in Figures 3, 4 and 5 respectively.

General observations

Males usually responded well to playback and mobbing, becoming visibly agitated while approaching the speaker. Playback seemed more useful earlier in the breeding season, and mobbing more effective later in the season. This may result from males aggressively defending territories in the beginning of the season, then defending their mate and perhaps offspring from a perceived predator later in the season during nesting.

Golden-winged Warblers often nest in aggregations of as many as ten pairs (Confer and Knapp 1981, Vallender *in* Cadman *et al.* 2007a), and we often found several males within the same small area. This is well illustrated in Figure 4 (the southwest corner of the survey area of Massassauga) and Figure 5 (most birds located in Bracken were in close proximity to each other). This could be a result of the birds clustering at suitable habitat patches (Vallender *in* Cadman *et al.* 2007a), as the open habitat, when present, is often large enough to support several adjacent territories. Pangman Conservation Reserve

Six male Golden-winged Warblers were found in the surveyed area (Figure 3), a density of 0.039 per ha. Of these, we banded one, three had been banded in previous years, one remained unbanded, and one was unidentified as to whether or not it was banded. The densities of Blue-winged Warblers and hybrids were zero.

Massassauga Tract

Six male Golden-winged Warblers were found in the surveyed area (Figure 4), a density of 0.027 males per ha. Of these, we banded one, four had been banded in previous years, and one remained unbanded. The densities of Blue-winged Warblers and hybrids were zero.

Bracken Tract

Eighteen male Golden-winged Warblers were discovered during surveying (Figure 5). Of these, we banded ten, four had been banded in previous years, two we were unable to band, and two were unidentified as to whether or not the bird was banded. This represents a density of 0.088 males per ha. One Blue-winged Warbler and three hybrid (Brewster's) males were found, and we banded all four of these birds.

Discussion

In total, we detected 30 Golden-winged Warblers, one Blue-winged Warbler, three Brewster's hybrids, and zero Lawrence's hybrids during our surveys in three separate areas on QUBS property (Figures 3-5). This represents a total of 34 male birds across an area comprising 5.76 km^2, representing an overall density of 0.052 male Golden-winged Warblers per ha, 0.0017 male Blue-winged Warblers per ha, and 0.0052 male hybrids per ha.

Geographic Resources

We used GIS software and GPS units in order to visualize large-scale patterns and collect precise and informative data in the field. Previously, surveyors navigated to bird territories with the aid of landmarks, descriptions, and approximate visual measurements, which may change with time. For repeatability, all point count locations were GPS marked and surveyors will be able to locate this point exactly in future years. In addition to helping recognize patterns such as the distribution of males over certain areas of cleared or forested land, the precision of GIS technologies is essential to monitoring population changes in such late successional species that may show only subtle shifts in habitat use over many years. We are confident that GIS and GPS technologies will be central to precisely measuring future shifts in Golden-Winged Warbler habitat use.

Pangman Conservation Reserve

Pangman (Figure 3) had an intermediate density of Golden-winged Warblers at 0.039 males per ha, slightly below the overall average across the three areas.

In 2006 and 2007, twelve and ten male Golden-winged Warblers, respectively, were found within this study area, even without the use of a standardized survey protocol. We had expected to find higher numbers in 2008 when surveying with a standard protocol for the first time, but were surprised to find fewer birds. If this trend continues in future years, it may suggest that the advancing succession in this area is reducing the suitability of the habitat for Golden-winged Warblers. Blue-winged Warblers and hybrids have not been reported within this area in the past two years, but it is noteworthy that a rare Lawrence's hybrid was sighted in 2006 just adjacent to this area, that has been undetected by researchers in the past two years.

Massassauga Tract

Massassauga (Figure 4) had the lowest density of Golden-winged Warblers at 0.027 males per ha, approximately one-half of the average density across the three areas. Land cover on this tract appeared either too mature (tall, closely spaced trees) or not mature enough (open, grassy fields devoid of shrubs) with fewer areas in the in-between stages that are suitable for Golden-winged Warblers than the other tracts (V.J. Emery and L.E. King unpublished data). Additionally, gradual and shrubby edges of forests are thought to be important to the nesting success of Golden-winged Warblers (Demmons 2000). We noticed that most forest edges at Massassauga were more abrupt than those found at Bracken, and hypothesize that the edge habitat in Massassauga is suboptimal, an idea we will explore with future vegetation studies.

Interestingly, two males in this area showed territory shifts within this same 2008 season (BSGY and OWYS, Figure 4). This underscores the importance of a banded population, as the shifts were immediately confirmed in the field, and we avoided counting each bird twice.

In 2006 and 2007, one and four male Golden-winged Warblers, respectively, were detected within the surveyed areas of the Massasauga Tract, along with two male Brewster's hybrids in 2006 and one male Blue-winged Warbler in 2007 (Paquin 2006, H.J. Munro pers. comm.). The increase in the number of Golden-winged Warblers found in 2008 likely reflects the much larger area surveyed, including discovery of several new territories, and the use of standardized protocols.

Bracken Tract

Bracken (Figure 5) had the highest density of all surveyed areas at 0.088 Golden-winged Warbler males per ha. It was also the only area in which Blue-winged Warblers and hybrids (Brewster's) were found, with one and three males sighted, respectively. The presence of a Blue-winged Warbler and hybrids may simply result from higher overall densities of birds, including Golden-winged Warblers, in this area. Bracken may represent habitat most suitable for Golden-winged Warblers, as active cattle grazing in the eastern portion has helped to maintain an early successional state over many years (QUBS 2004).

In 2006 and 2007 respectively, ten and seventeen male Golden-winged Warblers were found within the surveyed areas of the Bracken Tract, along with one male Brewster's hybrid in 2006 and one male Blue-winged Warbler in 2007 (Paquin 2006, H.J. Munro pers. comm.). The increased numbers in 2008 likely reflects surveying throughout the entire tract as opposed to only certain sections.

Golden-winged Warbler Densities

Golden-winged Warbler densities have rarely been reported in the literature, but range from 0.55 males per ha in an area comprising only seedling trees, to 0.04 males per ha for an area with saplings and medium-sized aspen (Roth and Lutz 2004). Given that Golden-winged Warbler territories can be as large as two or even five hectares (Confer 1992), the first density (0.55) represents an extremely high concentration of male birds, more than five times the highest density found in this study (0.088 males per ha at Bracken). Other densities have been reported as males per station, with the highest being 0.79, or approximately 0.20 males per ha (calculated from Martin *et al.* 2007). Since all of Bracken is not entirely suitable habitat for Golden-winged Warblers, our intermediate estimates of density seem reasonable.

However, we still do not know whether all suitable habitat on QUBS property is currently occupied by Golden-winged Warblers. Additionally, the detection of all male birds in a given area is generally not possible (Thompson 2002); detection probabilities can vary widely, including with habitat (Kubel and Yahner 2007), which differed greatly across our study areas. Previous work with Golden-winged Warblers has demonstrated that detection can be extremely difficult, even when close to an

active nest (Confer *et al.* 2008). While we attempted to address this issue with repeated sampling, and a survey protocol which included both song playback and mobbing, it is nevertheless important to acknowledge that our counts likely did not include every male bird, and, therefore, our calculated densities represent our best estimates.

Early successional habitats

Golden-winged and Blue-winged Warblers specialize in using early successional land such as old farm fields (Litvaitis 2003, Vallender *in* Cadman *et al.* 2007). Species such as these which rely on open areas have declined more than those found in mature forests (Askins 1993, 2000, Rich *et al.* 2004, Cadman *et al.* 2007), often due to habitat loss, whether anthropogenic or natural (the inevitable process of succession). Anthropogenic habitat loss is likely a problem for species such as the Golden-winged Warbler, as the Atlas of the Breeding Birds of Ontario shows "rural non-farm" areas, such as abandoned farms, have been decreasing since approximately 2001 in areas south of the Canadian Shield, where the Golden-winged Warbler is concentrated (Cadman *et al.* 2007).

Compounding this problem, natural habitat loss also contributes to declines. Since the Golden-winged Warbler relies on an inherently ephemeral early stage of succession, habitat maintenance is a challenge because appropriate habitat rapidly progresses to forest if intervention is not implemented (Hamer *et al.* 2005). To maintain suitable early successional habitat, disturbances such as timber harvesting, grazing, or periodic use of fire, need to be reinstated, requiring active management (Confer 1992, Klaus and Buehler 2001, Roth and Lutz 2004). Another management approach is leaving gradual or soft edges to hayfields, which can increase the suitability of habitat for nesting sites (Demmons 2000).

At our study sites, many of the open fields of Massassauga are mowed annually for hay, leaving 'sharp' edges, while in Bracken, open areas are maintained by late-summer grazing by cattle, leaving much more 'gradual' edges, which appeart o better support Golden-winged Warblers. These types of simple modifications to agricultural practices and management could affect habitat suitability for Golden-winged Warblers.

When management plans such as these are put into place, careful monitoring will be needed to ensure that the managed habitat is fulfilling the needs of these declining shrubland species. Our results will serve as a baseline for this type of monitoring at QUBS and contribute to the Golden-winged Warbler conservation initiatives currently underway across the breeding range of the Golden-winged Warbler.

To meet this challenge of monitoring Golden-winged Warblers, the help of amateur and professional field ornithologists and birders is more important than ever. With limited resources, professional ornithologists cannot survey the amount of land required to follow population

changes across the entire province. The Atlas of the Breeding Birds of Ontario was one of our greatest resources in identifying trends, and the level of detail provided in the most recent Atlas allowed us to compare changes in populations in the areas around our survey sites. The importance of this information cannot be overstated, and we hope that in the future field ornithologists and birders will continue to monitor bird species, especially those which are declining and most in need of our attention.

To help monitor Golden-winged Warblers, Blue-winged Warblers, and three other declining migratory songbirds, submit your sightings to Priority Migrant eBird coordinated through Cornell Lab of Ornithology at www.ebird. org//primig. Finally, if birding in an area where our studies have taken place, please report colour banded warblers to the North American Bird Banding Program at http://www.pwrc. usgs.gov/bbl/ or call **1-800-327-BAND (2263)**, and help play a part in the crucial long-term monitoring of these threatened species.

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Literature Cited

Askins, R.A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34.

Askins, R.A. 2000. Restoring North America's songbirds. New Haven, Connecticut: Yale University Press.

Brewster, W. 1874. A new species of North American warbler. American Sportsman 5:33.

Cadman, M.D., **P.F.J Eagles** and **F.M. Helleiner** (eds.) 1987. Atlas of the Breeding Birds of Ontario. Federation of Ontario Naturalists and Long Point Bird Observatory. Waterloo: University of Waterloo Press.

Cadman, M.D., **D.A. Sutherland**, **G.G. Beck**, **D. Lepage** and **A.R. Couturier** (eds.), 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto.

Confer, J. L. 1992. Golden-winged Warbler (*Vermivora chrysoptera*), The Birds of North America Online (A. Poole, ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online:http://bna.birds.cornell. edu/bna/species/020doi:10.2173/bna.20

Confer, J.L. and **J.L. Larkin**. 1998. Behavioral interactions between Golden-winged and Blue-winged warblers. Auk 115:209-214.

Confer, J.L. and **K. Knapp** 1981. Golden-winged Warblers and Blue-winged Warblers: The relative success of a habitat specialist and a generalist. Auk 98:108-114.

Confer, J.L. and **S.K. Tupper.** 2000. A reassessment of the status of Golden-winged and Blue-winged Warblers in the Hudson Highlands of Southern New York. Wilson Bulletin 112:544-546.

Confer, J.L., J.L. Larkin and **P.E. Allen.** 2003. Effects of vegetation, interspecific competition, and brood parasitism on Golden-winged Warbler nesting success. Auk 120:138-144.

Confer, J.L., R. E. Serrell, **M. Hager**, and **E. Lahr**. 2008. Field tests of the Rosenberg-Blancher method for converting point counts to abundance estimates. Auk 125:932-938.

COSEWIC 2006. COSEWIC assessment and status report on the Golden-winged Warbler *Vermivora chrysoptera* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. (www.sararegistry .gc.ca/status/ status _e.cfm).

COSEWIC 2007. Canadian Species at Risk. Committee on the Status of Endangered Wildlife in Canada, September 2007.

Dabrowski, A., **R. Fraser**, **J.L. Confer** and **I.J. Lovette**. 2005. Geographic variability in mitochondrial introgression among hybridizing populations of Golden-winged (*Vermivora chrysoptera*) and Blue-winged (*V. pinus*) Warblers. Conservation Genetics 6:843–853.

Demmons, T.D. 2000. Nest site selection and nest predation patterns at forest-field edges M.Sc. Thesis. Department of Biology, Queen's University, Kingston ON.

Fraser, K. C., T. K. Kyser, **R. J. Robertson** and **L. M. Ratcliffe**. 2008. Seasonal patterns in hydrogen isotopes of claws from breeding wood-warblers (Parulidae): utility for estimating migratory origins. Avian Conservation and Ecology - Écologie et conservation des oiseaux 3:2.

Gill, F.B., Canterbury R.A. and **J L. Confer**. 2001. Blue-winged Warbler (*Vermivora pinus*), The Birds of North America Online (A. Poole, ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/ bna/ species/584

Gill, F. B. 1980. Historical aspects of secondary contact and hybridization between Blue-winged and Golden-winged Warblers. Auk 97:1-18.

Gill, F.B. 1987. Allozymes and genetic similarity of Blue-winged and Golden-winged Warblers. Auk 104:444-449.

Gill, F.B. 1997. Local cytonuclear extinction of the golden-winged warbler. Evolution 51: 519-525.

Hamer, P.B., K.V. Rosenberg and **D.A. Buehler**. 2005. Is Management for Golden-winged Warblers and Cerulean Warblers Compatible? USDA Forest Service Gen. Tech. Rep. PSW-GTR-191

Hunter W.C., D.A. Buehler, R.A. Canterbury, **J.L. Confer** and **P.B. Hamel**. 2001. Conservation of disturbance-dependent birds of eastern North America. Wildlife Society Bulletin 29: 440–455.

Klaus, N.A. and **D.A. Buehler**. 2001. Golden-winged Warbler breeding habitat characteristics and nest success in clearcuts in the southern appalachian mountains. Wilson Bulletin 113: 297-301.

Kubel, J. and **R. Yahner**. 2007. Detection probability of Golden-winged Warblers during point counts with and without playback recordings. Journal of Field Ornithology. 78:195-205.

Litvaitis, J.A. 2003. Shrublands and early-successional forests: critical habitats dependent on disturbance in the northeastern United States. Forest Ecology and Management 185:1-4.

Martin, P.R. and **R.J. Robertson**. 1994. Effects of forest management practices and forestcutting history on the songbird communities of mature hardwood forest stands, Lake Opinicon, Leeds/Frontenac Cos., Ontario. Eastern Ontario Model Forest Program. 190pp.

Martin, K.J., R.S. Lutz and **M. Worland**. 2007. Golden-winged Warbler habitat use and abundance in northern Wisconsin. Wilson Journal of Ornithology 119:523-532.

McCracken, J.D. 1994 Golden-winged and Blue-winged Warblers: their history and future in Ontario. Pp 279-289 *in* Ornithology in Ontario. Spec. Publ. No. 1. M.K. McNicholl and J.L. Cranmer-Byng, eds. Ontario Field Ornithologists. Hawk Owl Publishing, Whitby, Ontario.

McKinnon, E.A. and **R.J. Robertson**. 2008. The signal function of a melanin-based plumage ornament in Golden-winged Warblers. Wilson Journal of Ornithology 120: 366-370.

Mills, A. 1987a. Golden-winged Warbler, pp. 358-359 *in* Cadman, M.D., Eagles P.F.J, and F.M. Helleiner (eds). Atlas of the Breeding Birds of Ontario. Federation of Ontario Naturalists and Long Point Bird Observatory. University of Waterloo Press, Waterloo, Ontario.

Mills, A. 1987b. Blue-winged Warbler, pp 356-357 *in* Cadman, M.D., Eagles, P.F.J., and F.M. Helleiner (eds.). Atlas of the Breeding Birds of Ontario. Federation of Ontario Naturalists and Long Point Bird Observatory. University of Waterloo Press, Waterloo, Ontario.

Murray, B. J. and **F. B. Gill**. 1976. Behavioral interactions of Blue-winged and Golden-winged Warblers. Wilson Bulletin 88:231–254.

Neville, K.J., **R. Vallender** and **R.J. Robertson**. 2008. Nestling sex ratio of golden-winged warblers (*Vermivora chrysoptera)* in an introgressed population. Journal of Avian Biology 39:599-604.

Parkes, K.C. 1951. The Genetics of the Golden-winged x Blue-Winged Warbler Complex. Wilson Bulletin 63:5-15.

Paquin, N. 2006. Demography and breeding site fidelity in male Golden-winged Warblers (*Vermivora chrysoptera*). Honours Thesis, Department of Biology, Queen's University, Kingston ON.

Queen's University Biological Station (QUBS) Annual Report, 2004. pp.18. Available at http://biology.queensu.ca/~qubs/qubs/Documents.html

Reed, L.P., R. Vallender and **R.J. Robertson**. 2007. Provisioning rates by Golden-winged Warblers. Wilson Journal of Ornithology 119:350-355.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, **M. S. W. Bradstreet**, **G. S. Butcher**, **D. W. Demarest**, **E. H. Dunn**, **W. C. Hunter**, **E. E. Iñigo-Elias**, **J. A. Kennedy, A. M. Martell**, **A. O. Panjabi**, **D. N. Pashley**, **K. V. Rosenberg, C. M. Rustay, J. S. Wendt** and **T. C. Will**. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology, Ithaca, New York.

Roth, A.M. and **S. Lutz.** 2004. Relationship between territorial male Golden-winged Warblers in managed aspen stands in northern Wisconsin, USA. Forest Science 50: 153-161.

Sauer, J.R., **W. A. Link, J.D. Nichols** and **J.A. Royle**. 2005. Using the North American Breeding Bird Survey as a tool for conservation: A critique of BART *et al.* (2004). Journal of Wildlife Management 69:1321-1326.

Shapiro, L.H., **R.A. Canterbury, D.M. Stover,** and **R.J. Flesicher.** 2004. Reciprocal introgression between Golden-winged Warblers (*Vermivora chrysoptera*) and Blue-winged Warblers (*V. pinus*) in eastern North America. Auk 121: 1019-1030.

Smith, C.R., D.M. Pence, and **R.J. O'Connor**. 1993. Status of Neotropical migratory birds in the northeast: A preliminary assessment. pp. 172-188 *in* Status and management of Neotropical migratory birds (D. M. Finch and P. W. Stangel, Eds.). United States Forest Service General Technical Report RM-229, Newton Corner, Massachusetts.

Spector, D.A. 1992. Wood-warbler song systems: A review of paruline singing behaviors. Current Ornithology 9:199-238.

Thompson, W.L. 2002. Towards reliable bird surveys: Accounting for individuals present but not detected. Auk 119:18-25.

Vallender, R. 2007a. Golden-winged Warbler, pp. 462-463 *in* Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage and A.R. Couturier, eds. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources and Ontario Nature, Toronto.

Vallender, R. 2007b. Blue-winged Warbler, pp 460-461 *in* Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage and A.R. Couturier, eds. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources and Ontario Nature, Toronto.

Vallender, R. and **S. Leckie.** 2007. Brewster's Warbler/Lawrence's Warbler, pp 464-465 *in* Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier, eds. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources and Ontario Nature, Toronto.

Vallender R., **V.L. Friesen** and **R.J. Robertson**. 2007a. Paternity and performance of golden-winged warblers (*Vermivora chrysoptera*) and golden-winged X blue-winged warbler (*V. pinus*) hybrids at the leading edge of a hybrid zone. Behavioral Ecology and Sociobiology 61:1797-1807.

Vallender R., **R.J. Robertson**, **V.L. Friesen** and **I. J. Lovette**. 2007b. Complex hybridization dynamics between golden-winged and blue-winged warblers (*Vermivora chrysoptera* and *Vermivora pinus*) revealed by AFLP, microsatellite, intron and mtDNA markers. Molecular Ecology 16:2017-2029.

Weir R.D. 1989. Birds of the Kingston region. Quarry Press, Kingston, Ontario.

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