LISTE DES TABLEAUX

CHAPITRE 1

INTRODUCTION GÉNÉRALE

La Paruline à gorge grise (*Oporornis agilis*) est un migrateur néotropical et une espèce forestière peu commune partout à l'intérieur de son aire de répartition (Huff, 1929; Lapin, 2010). Elle est insectivore et parcourt la végétation au sol pour se nourrir (Pitocchelli *et al.*, 2012). Elle niche de façon éparse et en faible densité le long d'une mince bande au sud de la forêt boréale : au Canada, de la Colombie-Britannique au Québec, et aux États-Unis, dans les états du Michigan, du Wisconsin et du Minnesota (Pitocchelli *et al.*, 2012). Discrète, l'espèce a été décrite pour la première fois en 1812 et on aura attendu 70 ans pour la découverte du premier nid (Huff, 1929).

La perte d'habitats propices dans les aires de nidifications et dans les aires d'hivernage (déforestation) est la principale cause du déclin mondial des oiseaux migrateurs néotropicaux (Böhning-Gaese *et al.*, 1993). Dans certains états américains, l'espèce a été ajoutée au début des années 2000 à la liste des espèces à statut préoccupant. Selon le Plan américain de conservation des oiseaux, les populations de Parulines à gorge grise subissent un déclin modéré dans les états du Minnesota, du Wisconsin et du Michigan (Matteson *et al.*, 2009). Au Canada, la Paruline à gorge grise a été ajoutée à la liste des espèces à statut préoccupant de la Colombie-Britannique en 2007 (Cooper *et al.*, 1997; Cooper et Beauchesne, 2004; Matteson *et al.*, 2009). Elle n'a pas de statut particulier au Québec, mais elle se trouve à l'extrême est de sa distribution et les habitats qu'elle y occupe sont exploités par l'industrie forestière ou, comme au Lac-Saint-Jean, convoités pour la culture du bleuet. Dans ce dernier cas, il y a une conversion permanente de l'habitat.

Au Québec, les habitats généralement occupés par la Paruline à gorge grise sont des pinèdes grises (*Pinus banksiana* Lambert) matures et peu denses, et dans une moindre mesure, surtout dans l'ouest de la province, elle occupe les tourbières arborescentes d'épinettes (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) et de mélèzes (*Larix laricina.* (Du Roi) K. Koch) (Ibarzabal *et al.*, 1995; Pitocchelli *et al.*, 2012). Peu importe la strate arborescente, le sol où elle niche est recouvert de mousses sous un étage dense d'Éricacées, principalement de kalmia à feuilles étroites (*Kalmia angustifolia* Linnaeus) et de thé du Labrador (*Rhododendron* *groenlandicum* (Oeder) Kron & Judd) (Cooper *et al.*, 1997; Cooper et Beauchesne, 2004; Matteson *et al.*, 2009; Lapin, 2010).

Au Lac-Saint-Jean, la Paruline à gorge grise fréquente et niche dans les peuplements de pins gris dont le sol est recouvert de kalmia à feuilles étroites et de bleuets (*Vaccinium sp.*) (Ibarzabal *et al.*, 1995; Lavoie, 2009). Ces peuplements sont localisés sur des terrains plats formés par des dépôts de sable postglaciaire d'origine deltaïque et de dunes éoliennes (Chagnon, 1970; Lavoie, 2009; CAFN, 2010). Ces milieux réservés à l'industrie forestière, sous contrat d'aménagement forestier, sont prisés pour la culture du bleuet sauvage, un petit fruit renommé mondialement pour ses propriétés anti-oxydantes. Pour accommoder les deux industries, un concept d'agroforesterie, nommé aménagement forêt/bleuet, a vu le jour à Normandin dans les années 2000 (CAFN, 2010). Ce concept consiste en l'établissement de bandes permanentes de production de bleuets (45 ou 60 m de largeur) assujetties aux traitements agricoles habituels pour cette culture alternées de bandes de forêts (42 ou 60 m de largeur) sous un régime de sylviculture intensive dans le but d'obtenir un rendement forestier (qualité et volume) équivalent à celui d'une forêt naturelle de même superficie. Chaque bande de forêt est divisée en trois sous-bandes de 14 m ou 20 m de largeur. Il est souhaité que ces sous-bandes soient récoltées en alternance à tous les 17 ans et subissent des travaux sylvicoles (ex. reboisement, dégagement de plantation) servant à maintenir le rendement forestier pour une rotation complète de la bande forestière en 51 ans. En augmentant le niveau de fragmentation de la forêt naturelle dans le paysage, ce type d'aménagement pourrait altérer les sites potentiels de reproduction de la Paruline à gorge grise. La fragmentation du paysage forestier et la conversion permanente de portions de forêt en terres agricoles sont reconnues pour avoir des impacts directs sur la faune aviaire (Bayne et Hobson, 1997; Schmiegelow et Monkkonen, 2002).

Dans un souci d'aménagement écosystémique durable et responsable, la Forêt modèle du Lac-Saint-Jean et ses partenaires ont pris conscience des problématiques environnementales liées à l'exploitation du bleuet et de la forêt, qui pourraient entraîner le déclin de la population de la Paruline à gorge grise. Ils ont tenu à développer des solutions d'aménagement comme le concept forêt/bleuet, qui assure la pérennité de cette espèce. C'est dans une telle optique que cette étude a vu le jour et a été soutenue par la Forêt modèle du Lac-Saint-Jean. Cette étude avait pour buts de déterminer les superficies nécessaires à la reproduction et de déterminer quelles étaient les caractéristiques de la végétation au sol utilisées par la Paruline à gorge grise. Nous avons aussi évalué en termes de caractéristiques du paysage, l'influence de l'aménagement forêt/bleuet sur l'utilisation de l'habitat par cette paruline.

CHAPITRE 2

UTILIZATION OF HABITAT CHARACTERISTICS BY CONNECTICUT WARBLERS WITHIN HOME RANGE IN JACK PINE STANDS OF THE LAC-SAINT-JEAN REGION, QUEBEC

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Ce chapitre est le fruit du travail de la candidate. Jacques Ibarzabal et Jean-Pierre Savard ont participé à l'élaboration des idées, à la révision et au financement du projet.

1. INTRODUCTION

1.1 Connecticut Warbler distribution

The Connecticut Warbler (*Oporornis agilis*) is a neotropical migrant that reproduces almost exclusively throughout a small band at the southern end of the boreal forest (Hobson and Bayne, 2000) across Canada, from British Columbia to Quebec and in Wisconsin, Minnesota and Michigan states (Pitocchelli *et al.*, 2012). Even with a large breeding range, populations are sparse and at low densities (Cooper et al., 1997). Population trends are hard to evaluate because of low sample sizes (Danz *et al.*, 2007) and its secretive behaviour (Pitocchelli *et al.*, 2012). During the first Quebec Breeding Bird Atlas (data collected between 1984-1989) the Connecticut Warbler was detected in only 21 of about 5000 parcels and its breeding status confirmed in only three(14% of confirmation when detected; Ibarzabal *et al.*, 1995). Comparatively, a more common warbler, the Yellow-rumped Warbler (*Dendroica coronata*) was detected in 1539 parcels and confirmed in 507 (33 % of confirmation when detected; Letourneau and Lafontaine, 1995).

1.2 Connecticut Warbler habitat

This small and secretive warbler forages on the ground, walking between shrubs and feeds mainly on insects captured on the forest floor or just above it (Pitocchelli *et al.*, 2012). Males are usually seen when they sing at the top of trees. Nests are found on or near the ground in thick undergrowth of shrubs, moss and thickets (Pitocchelli *et al.*, 2012).

Habitat preferences vary across the breeding range. Breeding grounds occur in various places: from poorly drained areas, such as spruce-tamarack forests (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh; *Larix laricina (Du Roi) K. Koch*) to wet second-growth forests, even in small grass margins along spruce forests or deciduous forests and jack pine barrens (*Pinus banksiana* Lambert) (Pitocchelli *et al.*, 2012). At the western limit of their breeding range, they nest in trembling aspen stands (*Populus tremuloides* Michaux) with a well-developed shrub layer mainly composed of Labrador tea (*Rhododendron groenlandicum* (Oeder) Kron & Judd), bog laurel (*Kalmia polifolia* Wangenheim), bog rosemary (*Andromeda polifolia* var. *latifolia* Aiton) and sheep laurel (*Kalmia angustifolia* Linnaeus) (Johns, 1993; Cooper *et al.*, 1997). In the United-States, Connecticut Warblers are seen in open forest with dense and relatively high (> 1 m) shrubs or herbaceous and herb layers (Binford, 1991; USDA, 2002). In Ontario, a study on general wildlife conservation management strongly associated Connecticut Warblers with deep organic soils and wet, nutrient poor vegetation types with black spruce/tamarack as the dominant tree component (Welsh and Venier, 1996). In Quebec, the extreme east of its breeding range, sparse populations are found in spruce and tamarack peat bogs, clear spruce stands and more regularly in jack pine stands, with a well-developed shrub layer composed mainly of sheep laurel and blueberries, especially *Vaccinium myrtilloides* Michaux. and *V. angustifolium* Aiton (Ibarzabal *et al.*, 1995). In the Abitibi region, Connecticut Warblers are found in stands growing on eskers and for the Saguenay–Lac-Saint-Jean region, it is the jack pine stands usually growing on almost flat terrain (or sand dunes) originating from postglaciation deltaic sand deposits (Chagnon, 1970).

1.3 Forest/blueberry management

Blueberry culture is one of the main industries in Saguenay-Lac-Saint-Jean, increasing from 19 398 ha in 2004 to 27 100 ha in 2010, it represents 85% of Quebec's total area for blueberry culture (MAPAQ, 2011). To accommodate the needs of the forest industry and blueberry culture, an alternative to conventional blueberry culture was developed in Normandin (Gouvernement du Québec, 2002). Since the late 90's, a new concept of agroforestry, called "forest/blueberry management", is being tested by the Corporation d'aménagement forestier de Normandin (CAFN), in Lac-Saint-Jean region. The goal is to produce blueberries while supporting the initial forest productivity by intensive sylviculture within the remaining forest matrix (Gouvernement du Québec, 2002).

Forest/blueberry management consists of alternating bands of blueberry fields with bands of forest. Blueberry bands (45 to 60 m) are under normal agricultural management (grindings, mowing and fertilizers, pesticide and herbicide spraying) (Gouvernement du Québec, 2002; CAFN, 2010). Forest bands are divided into three equal sub-bands, about 14-20 m wide. Eventually, a new sub-band is cut entirely each 17–year approximately, leading to an uneven aged band. An intense sylviculture is held in forest bands to compensate for the lost of forested area due to the introduction of blueberry field bands. Connecticut Warblers occur and breed in this area (Lavoie 2009; Saulnier 2011).

1.4 Home range and spatial requirements

Landscape fragmentation has become a major issue in conservation biology (Ewers and Didham, 2006). Permanent conversion of forest into agricultural land has large impacts on wildlife (Bayne and Hobson, 1997; Schmiegelow and Monkkonen, 2002). Landscape fragmentation includes patch size, edge and isolation effects (Andrén, 1992; Fahrig, 2003), all leading to a change in suitable habitats for wildlife. Loss of suitable habitats on the breeding and wintering grounds is one of the main causes of decline in neotropical migrant populations (Böhning-Gaese *et al.*, 1993). Habitat loss caused by conversion of forested land to agriculture has serious consequences on nesting birds (Bayne and Hobson, 1997), especially ground nesting species (Kurki *et al.*, 2000; Schmiegelow and Monkkonen, 2002). Logging activities and permanent conversion of aspen stands into agricultural lands recently led the British-Columbia government to add the Connecticut Warbler on the British-Columbia Red list as a threatened species (Cooper and Beauchesne, 2004), at a level 2 of conservation framework priority (B.C. Conservation Data Centre, 2013). The Connecticut Warbler population from the Chippewa National Forest (Ontario) has been declining since 1991, a rate of -13% between 1991 and 2007 (Danz *et al.*, 2008). The United-States considers the Connecticut Warbler as a species of concern because of its specifics habitat requirements and because of the threats on its nesting habitat (Matteson *et al.*, 2009). Habitat loss can induce changes in behaviour that negatively affect foraging (Mahan and Yahner, 1999; Fahrig, 2003), breeding (Kurki *et al.*, 2000; Fahrig, 2003), dispersal success (With and King, 1999; Bélisle *et al.*, 2001; Fahrig, 2003) and predation (Bayne and Hobson, 1997; Fahrig, 2003). On wintering grounds, Warkentin and Hernandez (1996) documented that neotropical migrant songbirds with high levels of site fidelity between years have shown less adaptability to habitat degradation and losses. Site fidelity on breeding grounds by Connecticut Warbler has been suggested by Cooper and Beauchesne (2004) and has been observed in Quebec by Saulnier (2011). Therefore, it is important to understand how the Connecticut Warbler uses its breeding habitat to avoid or limit the effects of habitat loss upon its population.

Territory size is defined as any defended area and home range is the area traversed by the individual during its normal activities (foraging, mating and caring for young) (Burt, 1943; Anich *et al.*, 2009). Home range size among individuals of the same species varies depending on habitat quality, resource, distribution, mating status, and experience (Adams, 2001; Barg *et al.*, 2005). It has never been measured accurately for Connecticut Warbler; it has only been estimated with no precise data. Niemi and Hanoski (1984) have evaluated territory size of singing male between 0.24 and 0.48 ha, having encountered Connecticut Warblers during their study on the impact of power lines on passerines. This data was based on the occurrence of singing individuals along their survey route.

1.5 Objectives

It is important to understand the impact of the forest/blueberry concept on this little known warbler. Given the fact that this management conserves a certain amount of residual forest, by opposition to traditional blueberry culture, it may have the potential to maintain the Connecticut Warbler population already present in the area. To evaluate the impact of landscape fragmentation and adjacent intensive forest management, we needed to determine what could be a suitable breeding habitat. According to the literature, few studies have been done on Connecticut Warbler, most of them describing the general habitat (USDA, 2002; Cooper and

Beauchesne, 2004; Pitocchelli *et al.*, 2012). Within all these studies, even though habitats occupied by Connecticut Warblers throughout its distribution range are largely different, the large presence of a good undergrowth vegetation stratum could be a common link between these habitats.

Our objectives were to evaluate the size of the home range of Connecticut Warblers in Lac-St-Jean area, Quebec, to determine their preferences among ground vegetation characteristics, to determine selection of landscape features within home range and to estimate the influence of forest/blueberry management.

We predicted that: 1) Connecticut Warblers would select within home range areas with well-developed shrubs (high density, great cover and tall shrubs); 2) Connecticut Warblers would avoid recently open areas such as blueberry fields, roads and harvested forest.

2. METHODS

2.1 Study area

The study area was divided in two main areas : the CAFN area located about 10 km west of Normandin (48°50'99''N, 72°37'21''W) and the DAFTA (Développement, Aménagement Forestier et Touristique Albanel) area located about 10 km east of Albanel (48°57'48''N, 72°22'31''W).

DAFTA and CAFN areas had a similar forest matrix, mostly composed of jack pine stands and black spruce, but trembling aspen and white birch (*Betula papyrifera* Marshall) were also presents. Pine stand understory was dominated by shrubs of sheep laurel, Labrador tea and blueberries. Jack pine stands ranged between 30 and 50 years of age based on digital forest polygons of the third decennia from *Ministère des resources naturelles et de la faune du Québec*.Many peatlands of various sizes are located on both sites.

Both sites were located in a post-glaciations river delta, where the ground was mostly flat and made out from glaciofluvial sandy deposits (Chagnon, 1970; Savard, 2001). About 77% of all CAFN stands originated from 1941's forest fire (CAFN, 2010). The DAFTA and CAFN sites have regulated logging activities. Forest/blueberry management activities, done on CAFN site only, have been mostly created in 2005-2006 (Lavoie, 2009; Simard, 2010). Managed areas ranged in size from 4 to 31 ha.

2.2 Capture and radiotracking

Surveys to find Connecticut Warblers were done daily (CAFN in 2008-2009 and DAFTA in 2009) from late May to mid-June, using walking, driving and stationary listening to detect singing males. When needed, we stimulated territorial males with defensive call playbacks previously recorded in 2007 in the same area.

Connecticut Warblers were captured at their arrival from wintering grounds. The capture array was composed of two mist nets (12 meters; 30 mm mesh) placed at 90° near a singing male. A small amplified speaker broadcasting playbacks was placed at the junction of the two mist nets, hidden in the ground vegetation and played until the defending male was captured. Special care was taken to catch females as they rarely responded to playbacks. When a female was heard or seen walking on the ground, we used an ambush like technique to get them close to the mist nets and flush them into the net.

When captured, birds were banded with a metal Canadian Wildlife Service (CWS) band and a unique combination of three Darvic colors bands used to identify the year of capture and the individual. We fitted a BD2-A radio transmitter (Holohil Ltd.) with a harness over the synsacrum using a method similar to the one developed by Rappole and Tipton (1991). We used a small elastic rope on which a breaking point was done with a drop of glue. That way, the radio transmitter would stay on the bird long enough for the study but would eventually fall. Each radio transmitter weighted about 0.62 g, less than 4.1% of the bird body mass (mean of 15,2 g after Dunning (1993)) and batteries lasted about 22 days.

After being captured and radiomarked, each Connecticut Warbler was given an adaptation period of at least 24 hours before the beginning of radiotracking. Birds were tracked using two STR-1000 telemetry receivers (Lotek Engineering inc.) during the mating and breeding periods, between the beginning of June until mid-July or until the transmitters fell down or batteries ran out. Tracking was done in teams of two for a good accuracy of locations, which was tested prior to the study by estimating the bird location and disturbing it to see where it actually was. Accuracy was good within 3 m and both bearers could easily see each other due to the low forest density, therefore, birds could be located more accurately if needed.

Locations were recorded with a Global Positioning System (GPS) every five minutes and when the bird moved away within that time. If, for any reason, we induced a drastic change in the bird's behaviour (it fled if we have got to near from it for example), we left and gave it time to ease down (at least 20 minutes) before continuing. In addition, we stopped tracking females as soon as the nest was found to avoid any disturbances that might lead to desertion. Data were collected intensively, but we avoided tracking the same individual two days in a row. Even knowing that the assumption of independence between observations may be violated and may lead to pseudoreplication, we kept all ground locations for our habitat selection analysis to avoid the loss of relevant biological information (White and Garrott, 1990).

2.3 Home range size and vegetation mapping

We used minimum convex polygons (MCP) 95% to evaluate home range size of all individuals followed by telemetry. Based on an area-location curve, we needed at least 30 observations to reach asymptotic values of home range area (Powell, 2000). Home range size between sexes and non-breeders versus breeders was compared using Student-*t* test, considering $P < 0.05$ as significant.

Vegetation mapping was done only for confirmed breeders and was conducted when breeding was over. A breeding attempt was confirmed if an individual was seen with another sex partner more than once, if a nest was found or if the bird was seen carrying food/nest materials. We mapped ground vegetation using a grid of 10 m x 10 m squares covering the entire home range. At every intersection of the grid, we quantified ground vegetation characteristics within a 1 m^2 plot. We focused on known shrubs species usually associated with Connecticut Warbler (Pitocchelli *et al.*, 2012), like Sheep laurel, Labrador tea and blueberries. For each shrub, we estimated the percentage of cover (in classes: none, <1%, 1-25%, 26-50%, 51-75%, 76-100%). Also, the density of each shrub was evaluated by counting the number of single stems touching a rope (the guideline's grid) passing through the plot's center and were defined as low (1-6 stems), medium (7-11 stems), or high (12 or more). Finally, the average height of each shrubs species was noted into classes: 0-30 cm, 31-60 cm and > 61 cm. Lichen and moss were noted only for their percentage of coverage.. Other less encountered species, such as Cassandra/leatherleaf (*Chamaedaphne calyculata* (Linnaeus) Moench), Bog rosemary, Bog laurel or Swamp laurel, Sweetfern (*Comptonia peregrine* (Linnaeus) Coulter), and grass were noted but were not analysed for this paper. All grids were georeferenced in ArcGIS 9.3 (ESRI, 2008). Using the *natural neighbor* in Spatial Analyst tool, we interpolated the values of cover, density and height of ground vegetation between vegetation plots of the grid. This method was previously evaluated directly in one of the Connecticut Warbler's home range under study to make sure that this interpolation technique was close enough to reality to be taken into account.

Landscape features were evaluated in ArcGIS, based on shapefiles shared by the CAFN. For each location, distance to the edge of each adjacent habitat and proportion (%) of each habitat (within a 30 m radius) were calculated using *Identity* and *Near* in Analysis tool (ArcGIS 9.3). This buffer of 0.28 ha seemed sufficient to evaluate habitat characteristics within home range since Niemi and Hanoski (1984) evaluate home range size of singing males Connecticut Warblers between 0.24 and 0.48 ha.

Available resource units within home range of breeding individuals were randomly generated using Hawth's tool (Beyer, 2007). An equal number of used and available locations were used for each individual. Then, values of each ground vegetation characteristics were interpolated and metrics of landscape were calculated for all observed and random locations.

2.4 Resources selection by Connecticut Warbler

To assess resources selection by Connecticut Warblers, it was modelled at the third scale order: within home range (Johnson, 1980), i.e. Connecticut Warbler home range. To avoid assumption that some areas might never be used within home range, we chose the "use versus available" approach instead of the "presence/absence" approach (White and Garrott, 1990). Again to avoid the loss of relevant biological information for understanding utilization of vegetation within the home range, we kept all locations on the ground in our analysis (White and Garrott, 1990).

We estimated the probability of selecting a resource while accounting for differences in availability (Johnson, 1980; Boyce *et al.* 2002; Okamura *et al.*, 2008). Availability for each animal was defined by drawing as many random locations as observed from the 95% minimum convex polygon (MCP) home range size, availability was unique to each animal (samples were unbalanced, varying between individuals). We modeled habitat selection with Generalized Linear Mixed Models (GLMMs). GLMMs are flexible and allow the modeling for spatial autocorrelated data (Pearce and Boyce, 2006; Dormann *et al.*, 2007). It is recognized as one of the best tools for analyzing non-normal data with random effect (Dormann *et al.*, 2007; Bolker *et al.*, 2009). Statistical analyses were performed in statistical environment R version 2.10.1.

Model building was done with the package lme4 (Bates and Sarkar, 2006) using GLMER for binomial response with the individual as random effect (used = 1 and available = 0), because each individual actually monitored represented a random sample of all Connecticut Warblers potentially present in the study area. GLMMs were fitted using Laplace approximation. Two general models were built in order to understand selection based on ground vegetation characteristics and selection of landscape features within home range. First, we built 11 candidate models for selection based on ground vegetation. The general model contained 9 variables: three shrubs species and their respective density, height and cover. The reduced models checked for the selection between each species and within a species. For selection based on landscape features, the general model with 16 variables (described in Table 1) was compared to three reduced models, one involving roads features, a second model containing wetlands variables (this term included water and peatland variables), and a third one containing only vegetation related habitats (i.e. roads and wetland variables were not included).Model selection was based on the Bayesian Information Criterion (BIC) which is parsimonious and tends to favour more conservatives models (Courbin *et al.*, 2009). Delta BIC (ΔBIC) were calculated as the difference between the BIC of each model and the BIC of the most parsimonious and was used to evaluate the support (strong if $\Delta BIC < 2$, moderate if $2 < \Delta BIC < 4$) (Burnham and Anderson 2002). BIC weights (BIC_w) were used to assess the relative support for each model and were illustrated with evidence ratio. BIC_w compares the likelihood of a given model in relative to the other models. If $BICw_i$ were less than 0.90, we used all supported models to explain selection.

Table 1. Habitat variables at landscape-scale for habitat selection by Connecticut Warblers in forest/blueberry management in Lac-St-Jean, Quebec.

Habitat	**Description**	**Distance**		**Proportion (%)**	
		Available	**Used**	**Available**	**Used**
Forest	Residual forest matrix	0 - 95 m	0 - 83 m	0 - 99.5	0 - 99.5
Cut stripe	Harvested stripe in a forest band	0 - 975 m	0 - 917 m	0 - 28.7	0 - 28.2
Forest stripe	Forest stripe in a forest band	0 - 268 m	0 - 230 m	0 - 88.5	0 - 89.9
Blueberry field	Blueberry field in forest/blueberry site	0 - 197 m	0 - 155 m	0 - 57.4	0 - 48.4
Roads variables					
Access road	Small alley for the machinery to access a band	0 - 884 m	7 - 825 m	0 - 8.3	0 - 5.4
Secondary road	Small road accessible by car, mainly use by ATV	0 - 261 m	0 - 268 m	0 - 11.6	0 - 12.3
Main road	Principal access to the site, two cars wide	0 - 471 m	0 - 448 m	0 - 21.7	0 - 15.8
Wetland variables					
Peatland	Any wetland/peatland	0 - 898 m	0 - 876 m	0 - 99.5	0 - 99.5
Water	Lakes, streams and rivers	157 - 1058 m	147 - 1038 m	0	0

3. RESULTS

3.1 Bird monitoring

All birds were located in jack pine stands; although one couple home range was adjacent to a relatively small woody peatland. In total, 5 females and 17 males were followed by telemetry (9 in 2008 and 13 in 2009). We were unable to get enough locations for 2 non-reproductive males. They were left out of home range size analysis. Number of days of observations varied depending on the date of capture, the date of nest discovery or the loss of signal, and averaged of 6 days of observation per individual. An average of 61.2 ± 22.3 locations was obtained by telemetry for each bird. The longest consecutive observation period lasted for about 2 hours and the shortest lasted 5 minutes (one location).

Out of 22 individuals, 5 females and 5 males were considered successful reproductive individuals and they were all located in the CAFN area. Those 10 breeders had their home range's ground vegetation mapped. Birds have been observed to cluster in loose aggregates of a few individuals.

Seven nests were found during this two-year study. All nests were located within a low dense forested area, but three were within a clearing with almost no tree canopy in its immediate surroundings. Five nests were located near the edge of the forest (from 0.3 to 25 m to the edge). As for the other two, one was about a 1 m from a road and about 30 cm from an All-Terrain-Vehicles (ATV) trail for the other. Only two nests out of seven were found within a forested band under forest/blueberry management, the others were in the residual forest matrix.

3.2 Home range size

For home range size analysis, we kept only individuals that had 30 observations or more, a total of 20 individuals. Home range size averaged 2.61 ± 1.91 ha (n=20); Mean home range size of males (3.05 ± 1.99 ha) was larger than those of females (1.29 ± 0.71 ha). There was a difference between male and female home range size (t-test = -1.8013, df = 20, P = 0.08676). There was no difference between breeders (males and females included, n=10) and non reproductive individuals (unsuccessful breeders: 3.78 ± 2.00 ha; successful breeders: 1.44 ± 0.78 ha; t-test = 0.5831, df = 20, P = 0.5663).

3.3 Habitat selection: ground vegetation

We compared 11 models including only ground vegetation variables to investigate the influence of ground vegetation on habitat selection within home range by 10 Connecticut Warblers. Two out of eleven models received strong support (ΔBIC < 2) and a third one received moderate support (2< ΔBIC < 4) (Table 2). Model 11 (with blueberries' density and cover variables) was the second best model. The best supported model (model 5) had an evidence ratio of 2.65 (BIC_w of 0.61 against 0.23 for the second best model) and included cover variables for lichens and moss. Model 5 was therefore 2.65 times more likely than model 11 to explain selection. Connecticut Warblers were more likely to select areas with a good cover but with a low density of blueberries and areas with less lichens and moss.

Table 2. Best candidate models based on BIC for resource selection of ground vegetation's coverage, height and density (for blueberry, *Kalmia angustifolia* as kalmia, *Labrador tea* as ledum (from the old name *Ledum groenlandicum*), lichens and mosses) within the home range for 10 Connecticut Warblers (*Oporornis agilis*) during 2008 and 2009 in Lac-Saint-Jean, Quebec.

Model	**Model ID**	**logLik**	**BIC**	**ΔBIC**	**BICw**	**Deviance**
Cover: lichens and moss	5	-600.9	1229	0	0.61	1202
Blueberry density and cover	11	-601.8	1231	2	0.23	1204
Blueberry density and cover; lichens and moss	12	-595.7	1232	3	0.14	1191
Blueberry density, height and cover	3	-601.8	1238	9	0.01	1204
Cover: kalmia, blueberry and lichens	7	-602.2	1238	9	0.01	1204
Kalmia density, height and cover	2	-603.3	1240	11	0.00	1207
Cover: blueberry , kalmia, ledum, lichens and moss	6	-596.3	1240	11	0.00	1193
Density : blueberry , kalmia, ledum	8	-603.7	1241	12	0.00	1207
Height: blueberry , kalmia and ledum	9	-603.4	1241	12	0.00	1207
Ledum density, height and cover	4	-605.1	1244	15	0.00	1210
All variables	1	-590.0	1268	39	0.00	1180
All variables except lichens and moss	10	-597.6	1270	41	0.00	1195

Table 3. Best models based on BIC for ground vegetation selection within home range by 10 Connecticut Warblers (*Oporornis agilis*) during 2008 and 2009 in Lac-Saint-Jean, Quebec.

Model ID	Fixed effects	Estimate	SE	z value	P[a]
5	Lichens	-0.313	0.131	-2.396	0.0166 *
	Moss	-0.086	0.043	-2.012	0.0442 *
11	Blueberry cover [b]	0.403	0.144	2.791	0.0053 **
	Blueberry density [b]	-0.573	0.245	-2.334	0.0196 *
12	Blueberry cover [b]	0.467	0.147	3.177	0.0015 **
	Blueberry density [b]	-0.676	0.252	-2.686	0.0072 **
	Lichens	-0.331	0.132	-2.515	0.0119 *
	Moss	-0.105	0.044	-2.407	0.0161 *

a Signification codes: 0.001 '**' 0.01 '*'

b Correlated variables (r = - 0.86)

3.4 Habitat selection: landscape characteristics

Four models were built to investigate the influence of landscape characteristics on Connecticut Warbler (Table 4). Only Model 4 had a strong support (ΔBIC < 2) and seemed to be the only model best fitted to explain selection at landscape level. Connecticut Warbler selected areas close to or within forest stripes and stayed away from a cut stripes. Even if they kept their distances with cut stripes, they preferred a higher proportion of cut stripes ($P > 0.0001$) than a high proportion of blueberry field within a 30 m radius around each location.

Table 4. Best candidate models based on BIC for resource selection within the home range based on landscape characteristics for 10 Connecticut Warblers (*Oporornis agilis*) during 2008 and 2009 in Lac-Saint-Jean, Quebec.

Model	**Model ID**	**logLik**	**BIC**	**ΔBIC**	**BIC*w***	**Deviance**	**Variance**	**Std. Dev.**
Without roads and wetlands	4	-585.2	1238	0	1	1170	0.0008	0.0278
Without wetlands	2	-581.8	1252	14	0	1164	0	0
Without roads	3	-578.0	1264	26	0	1156	0	0
All variables	1	-575.5	1280	42	0	1151	0	0

Table 5. Best model based on BIC for resource selection within the home range based on landscape characteristics for 10 Connecticut Warblers (*Oporornis* agilis) during 2008 and 2009 in Lac-Saint-Jean, Quebec.

Fixed effects		**Estimate**	**S.E.**	**z-value**	**P** [a]
Distance to -	blueberry field [b]	0.0028	0.0044	0.650	0.5159
	forest stripe [b]	-0.0124	0.0039	-3.211	0.0013 **
	cut stripe	0.0008	0.0003	2.382	0.0172 *
	Forest	-0.0034	0.0073	-0.465	0.6419
Proportion of -	blueberry field	-0.0151	0.0089	-1.701	0.0890 *
	forest stripe	-0.0005	0.0060	-0.088	0.9300
	cut stripe	0.0466	0.0138	3.376	0.0007 ***
	Forest	0.0069	0.0047	1.477	0.1396

a Signification code: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

b Correlated variables (r =-0.824)

4. DISCUSSION AND RECOMMANDATIONS

4.1 Home range size

We observed a mean home range size ranging from 1.29 ha for females and 3.05 for males based on our telemetry data. During summer, males are highly territorial and defend their territory against other conspecifics males (Cooper and Beauchesne, 2004; Pitocchelli *et al.* 2012). Singing males territory size has been previously estimated at 0.25 to 0.5 ha based only on observed singing males during a study on the effects of a transmission line on bird populations in northern Minnesota (Niemi and Hanowski, 1984). This is approximately 6 times smaller than male home range size estimated using our telemetry data. Collecting only singing bird locations tends to underestimate the total area occupied by an individual because it considers only the defended area (Anich *et al.*, 2009). Therefore, identifying potential conservation zones only by detecting singing males in the area may not be adequate. Our findings suggest we must consider a buffer zone around any singing male location to evaluate more adequately the total area used for normal activities (defined as home range; Anich *et al.*, 2009) by individual Connecticut Warbler if teledetection is not available. This area should be large enough to include potential nesting areas, most of the preferred ground vegetation and landscape characteristics available in the surroundings of the detected singing male.

Connecticut Warblers clustered their territories into small groups composed of a few singing males. Literature has shown the importance for most songbird species to settle territories into loose aggregates of conspecifics within continuous forest (Bourque and Desrochers, 2006). Loose aggregation has been clearly related to the breeding success of many passerines (Bourque and Desrochers, 2006). We also observed that some males Connecticut Warblers were site-faithful (Saulnier, 2011). Based on these observations, there might be a relation between habitat selection and the existing population within the study area. Previously unsuccessful breeders and dispersing young males might tend to favour habitat near an already successful breeder and site-faithful male as cue for habitat quality beyond structural habitat cues (Ahlering and Faaborg, 2006). Thus, young birds without experience could reduced searching and settlement costs by using older males as a source of information about habitat quality within the area and this could also increase their mating success (Ahlering and Faaborg, 2006; Fletcher, 2009). Conspecific attraction occurs in colonial-nesting species and is also common among bird species that forms loose aggregations, such as many territorial European passerines (Ahlering and Faaborg, 2006). In their paper, Ahlering and Faaborg (2006) suggested that manipulating an existing population using artificial stimulus (such as playbacks) to attract and establish site-faithful individual could be a more effective approach than increasing the amount of available habitat.

4.2 Site characteristics

We did not successfully relate selection of a particular habitat with Labrador tea or even with sheep laurel, a close species to swamp laurel. We related habitat selection at the home range scale mostly to blueberries when less dense but in greater cover. Some models even shown selection related to lichens, in a low coverage. The Connecticut Warbler has been previously associated with habitats consisting of a ground layer of *Sphagnum* spp., Labrador tea, and swamp laurel (*Kalmia polifolia*) (Danz *et al.*, 2007; Lapin, 2010; Niemi and Hanowski, 1992). Other studies (Cooper and Beauchesne, 2004; Lapin, 2010) on Connecticut Warbler habitat characteristics did not specified if the presence or absence of blueberries was important. Could that mean that the total amount of ericaceous plants might be more important for the selection than the presence of different ericaceous species? Or was it because our study was located in an area covered mostly by pine stands on well-drained soil, providing less peatbog species such as swamp laurel and Labrador tea? We investigated ground vegetation species selection separately, without looking into a more general view of ground vegetation. We noted on both study area that many peatland (with Labrador tea and swamp laurel) were adjacent to jack pine stands, but we did not observed Connecticut Warbler within this particular type habitat. Future studies should investigate selection at a higher level of habitat type to determine whether it is the landscape characteristics that influence the selection of a particular site for breeding.

Connecticut Warbler territories were almost all within the residual forest matrix surrounding forest/blueberry areas and individuals did use forest bands (this includes both cut stripes and forest stripes). In fact, warblers greatly preferred areas within forest band with a higher proportion of cut stripes and where the proportion of blueberry field was lower; suggesting that Connecticut Warblers might prefer the edge of a cut stripe to the one of a blueberry field. This could be partially explained by the absence of trees for protection against predators. Intensive management in a cut stripe includes planting new trees which are planted within a few years after the cut. Also, harvesting mature trees maintains a certain amount of bushes and young trees, and in comparison with a blueberry field, there is a lot more opportunities for a bird to hide from predators. Another explanation would be that many blueberry bands were relatively new (some had been mowed in the previous year) and were in colonization phase. These new blueberries might not have offered sufficient protection and hiding opportunities, and thus could explain the avoidance of blueberry field. During our study, we observed some individuals walking in an old blueberry band, but never in a recently mowed one.

Small-scale habitat fragmentation can affect foraging and territorial activities. Our analysis of landscape fragmentation variables within the home range suggests that Connecticut Warblers modified their foraging patterns to avoid the proximity of blueberry fields while maintaining a certain amount/proximity of forest stripes as foraging areas. We observed territorial males crossing fragmented areas to defend their territory against an intruding male (personal observation). Harris and Reed (2001) found that Black-throated Blue Warbler (*Dendroica caerulescens*) territorial movements into open areas (clearcuts) in response to territorial intrusion were not negatively affected by small-scale habitat fragmentation due to forestry. Gap crossing studies on other neotropical migrants revealed that they moved into clearcuts for an average of about 40 m and crossed 10–30 m (Harris and Reed 2001) and 30-50 m (Desrochers and Hannon 1997; Rail *et al.* 1997) wide roads. Connecticut Warblers living in forest stands surrounded by forest/blueberry management areas may avoid blueberry fields partially because they create wide gaps (about 60 m) between the forested areas.

Connecticut Warblers seemed to select edges for nesting. Nests were found relatively close to the forest edge within a forest band under forest/blueberry management as well as in the residual forest matrix. Forest/blueberry areas should be a forest dominated matrix while conserving a high proportion of edges within its area and its immediate surroundings to accommodate Connecticut Warbler preferences.

Total vegetation cover (like the tree canopy) within different habitats influences forest bird movements. Trees offer perches and protection against predators. While being considered as open habitats, cuts provide both perches and cover by maintaining the residual shrub layer. Large blueberry fields, at least 60 m wide, provide no protection except at forest edges. Also, bands of forest within forest/blueberry managed areas are divided into three stripes. The first harvested stripe was in the center of a forest band, which limits the size of the open area in the first 17-years rotation. Maybe this is the reason why we observed a higher selection of habitats near cuts instead of blueberry fields and it is interesting to observe that they use it (5-6 year after cutting) (J. Ibarzabal and M.-C. Saulnier, pers. comm.). The second harvested stripe will be next to a blueberry field, and this will lead to a significant increase of the size of the open area (increasing from 60 m to 74-80 m). Also, forest band are under a high regime of sylviculture such as commercial thinning, plantation clearing and pruning (CAFN, 2010). In Quebec and Minnessota, Connecticut Warblers are known to preferred mature low-dense coniferous forests (Ibarzabal *et al.*, 1995; Lapin, 2010). All of those managements may reduce considerably Connecticut Warbler habitat of interest within its home range without occupying greater surfaces. More and smaller forest patches could be problematic. Cooper and Beauchesne (2004) mentioned that habitat patch size may be critical as Connecticut Warbler never occurred in smaller than 4 ha aspen groves in Saskatchewan (Johns, 1993). Connecticut Warblers depend on habitats with less complex patches (few total edges and less patches; Lapin, 2010). Increasing isolation of suitable habitat negatively affect Connecticut Warbler occurrence (Johns, 1993; Cooper and Beauchesne, 2004). As the landscape becomes increasingly fragmented, Connecticut Warblers reduce their use of isolated suitable patches (Cooper and Beauchesne, 2004). To increase reproductive success of forest nesting birds, it is suggested to maintain a high percentage of forest cover, interior forest and adequate patch size (Robinson *et al.*, 1995; Fahrig, 2003). Our results suggest that Connecticut Warbler could also settle in fragmented landscapes and favour edges. Our study area showed small-scale high fragmented habitats within a larger matrix of less fragmented ones. Thus, even if forest/blueberry concept seems to maintain Connecticut Warbler population some years after the beginning of this management method, we are unable to predict the issue after many years (after other changes in forested band) and even less able if this management was issued at a larger scale (J.Ibarzabal pers. comm.).

5. MANAGEMENT IMPLICATIONS VERSUS CONNECTICUT WARBLER SUSTAINABILITY

Connecticut Warblers are usually found in mature low-dense pine stands. It is unlikely that the 17 years rotation proposed in the present blueberry/forest management scheme would sustain a reasonable proportion of mature low-dense stands in the landscape. If the goal of forest exploitation must be maintained we recommend keeping larger forest patches, waiting longer before cutting another forest stripe and regenerating forest with low-density plantations. This would help maintain sufficient forest cover and older trees in areas where Connecticut Warblers occur. For area-sensitive species such as the Connecticut Warbler, Mourning Warbler, and Black-throated Blue Warbler, protecting large areas can help meet their needs in terms of habitat (Matteson *et al.*, 2009). The species has been associated with mature, lowland coniferous forests (Lapin, 2010), with black spruce-tamarack bogs in the south (Danz *et al.* 2007) and with aspen stands in western Canada (Cooper and Beauchesne, 2004). Our results suggest that it might be something else, like the overall shrub layer characteristics instead of a specific tree species that could lead to the choice of a specific site for reproduction. Researches done in British-Columbia also came to a similar conclusion, as this warbler forages almost exclusively on, or very near, the ground, herbaceous and shrub layers are probably the most important habitat features (Cooper and Beauchesne, 2004).

However, in addition to the rotation of logging, forest and blueberry culture activities may cause significant anthropogenic disturbances during the breeding season and the landscape fragmentation created by this management could also negatively affect Connecticut Warblers. In areas with human disturbance combined with an increase in the total amount of edges, the breeding density of bird species foraging on the ground is reduced (Di Giulio *et al.*, 2009). Also we suggest, like Cooper and Beauchesne (2004) : maintaining ground vegetation, especially blueberries, within the forested area; minimizing disturbance during the nesting season by limiting logging activities; and avoiding disturbance around known breeding territories from June to at least late July.

Males Connecticut Warblers have also shown that they are site-faithful birds (Saulnier, 2011). Was it because these territories were a good habitat quality or was it because there was a successful breeding male in this area? The approach suggested by Ahlering and Faaborg (2006) could be a good way to maintain a Connecticut Warbler population in the area, by stimulating the existing population using playbacks to stimulate new males to settle into forest bands and the remaining forest around the forest/blueberry managed portion of land,.

All these information and our results lead us to think about these assumptions:

1) If one of the goals of forest/blueberry management was to keep the landscape matrix a forested status, it could better support the Connecticut Warbler population, at least in the short-term, than a conventional blueberry management strategy. In long-term, intensive sylviculture of the remaining forest that could lead to the extinction of existing populations of Connecticut Warblers in the area. A 17-years rotation within forest bands is probably not compatible with Connecticut Warbler habitat requirements. As said earlier, this species is found in mature low-dense pine stands. A 17-years rotation and intensive sylviculture will lead to younger and denser pine stands. Denser stands will also let less light pass through for the undergrowth, which would increase the average height of ericaceous species, it would result in lower canopy covers by the shrub layer and our results have shown that Connecticut Warbler did not select this type of structure within its home range. It is probably better to limit this management to small scale areas instead of applying it to the whole landscape and increasing the length of rotation would help maintaining more mature low-dense pine stands in the landscape.

2) Even if nests were found near openings and forest edges within the remaining forest matrix, maintaining over 50% of forest within the landscape would probably increase chances of long-term stability in the Connecticut Warbler population in the area (Ibarzabal, 2012).

3) Human disturbance will increase with intensive sylviculture and could jeopardize the reproductive success. During our study, some females have deserted their nest and eggs when disturbed by human's activities. Harvesting and other sylviculture operations should not be done during the breeding period, which is likely to be done after July 20th.

4) Maintaining larger forest patches could help for the conservation of the Connecticut Warbler population in the forest/blueberry management. Each patch should be large enough, about 15 to 20 ha, to support a few males territories (4 ha each) for the establishment of successful breeding couples in a patch. Some harvesting activities could be done outside the breeding period to maintain mature low dense pine stands in these conservation patches. This would not only benefit the Connecticut Warbler, but it will also help to maintain indigenous natural pollinators of blueberry, such as bumblebees (Ibarzabal, 2012).

6. CONCLUSION

We answered some questions. We now know that Connecticut Warblers occupy larger areas than what was expected and with no significant differences between successful and unsuccessful breeding territories. We know that they reproduce in the area; nests were found within and in the immediate surroundings of the forest/blueberry matrix. We found that Connecticut Warblers within their territories selected areas with older blueberries, which offered a greater cover but lower density. Also, this warbler avoided areas with lichens and moss, suggesting a preference for a well covered ground level but allowing easy circulation (low density of stems) for an above ground walking bird. Connecticut Warbler used forest bands within forest/blueberry management units but also used the residual forest matrix. Cut stripes were preferred to blueberry fields probably because they provide more ground cover for protection and they create smaller gaps than blueberry fields (14-20m wide instead of 45-60m). Preference for edges at the landscape scale was supported also by nests localisation mostly found within 25 meters from the forest edge.

Nevertheless, the Connecticut Warbler is still a relatively unknown species. Our study was probably the first ever done at the eastern limit of its breeding range. It shed some light on its reproduction behavior and its habitat requirements but did not answer all questions. In fact, it opened the door to a lot more. Even if this study achieved its main goal, which was to learn a little more about this species reproduction (Saulnier, 2011) and habitat selection, only a long term study could evaluate long term impact of forest/blueberry management on the sustainability of the Connecticut Warbler's population as the habitat will evolved during many years with this kind of management.

CHAPITRE 3

CONCLUSION GÉNÉRALE

Nos objectifs ont été atteints. Les Parulines à gorge grise qui nichent dans les pinèdes grises du Lac-Saint-Jean occupent et défendent des territoires en moyenne 6 fois plus grand que la taille mentionnée dans la littérature. La découverte de nids a confirmé que cette population s'y reproduit. Nous avons observé aucune différence dans la taille des territoires entre les individus qui ont eu un succès reproducteur et ceux qui ne se sont pas reproduits. Les relevés cartographiques de la végétation au sol dans les territoires des individus nicheurs ont démontré une préférence pour la présence de bleuets, dont les plants plus matures offraient un bon recouvrement au sol tout en étant en faible densité. L'évitement des zones avec un bon recouvrement du sol par le lichen laisse croire que cette paruline préfère les milieux plus humides où elle est mieux camouflée. Nous avons observé dans de petites scènes à l'échelle du paysage que la Paruline à gorge grise évite les bleuetières au profit des sous-bandes de forêt récoltée. De plus, elle utilise clairement la bande forêt et la matrice de forêt résiduelle autour de la forêt/bleuet. Sa préférence pour les bordures forestières est suggérée par la découverte de nids à moins de 25 mètres de celles-ci.

Toutefois, les résultats obtenus soulèvent un bon nombre de questions sur l'avenir des populations qui sont en interaction avec l'industrie du bleuet. Bien que le concept forêt/bleuet vise le développement durable des ressources bois et bleuet, son impact sur l'habitat faunique pourrait limiter à long terme la croissance et le maintien des populations de Paruline à gorge grise dans le secteur. Il semble que l'utilisation des caractéristiques de l'habitat à l'intérieur des limites du territoire occupé par la Paruline à gorge grise tend vers des caractéristiques beaucoup plus liées à l'habitat forêt et aux lisières qu'à l'habitat bleuetière. Nous suggérons d'intégrer ces notions au concept forêt/bleuet. Nous recommandons des temps de rotation plus longs entre les coupes des sous-bandes de forêt et de faible densité reboisé pour, à la fois, conserver les caractéristiques recherchées dans la composition de la végétation au sol et offrir un couvert forestier suffisant en permanence. L'aménagement pourrait aussi prévoir des massifs forestiers matures suffisamment larges autour des zones de forêt/bleuet pour conserver un habitat forestier non fragmenté sur le territoire et permettre le maintien d'espèces sensibles comme la Paruline à gorge grise. La Paruline à gorge grise s'est avérée être une espèce sensible aux dérangements humains. Pour protéger la population de cet oiseau dans le secteur, nous recommandons d'éviter les interventions sylvicoles pendant la période de reproduction.

Pour de futurs projets de recherche sur les préférences en termes d'habitats utilisés par la Paruline à gorge grise et le développement d'outils de gestion de territoire, nous suggérons l'emploi de données LANDSAT et d'effectuer des analyses de sélection fonctionnelle des ressources basées sur la comparaison des ressources utilisées versus ressources disponibles. Cela permettrait de créer des cartes de probabilité d'occurrence dépendamment des ressources, des caractéristiques et des habitats disponibles sur le territoire. Ce type d'analyse est de plus en plus utilisé pour créer des outils de gestion efficaces pour les espèces fauniques visées par des mesures de protection et de conservation comme le caribou (Gunn *et al.*, 2004; Courbin *et al.*, 2009). Finalement, une gestion des ressources sur un territoire occupé par la Paruline à gorge grise devrait être faite avec précaution afin de réduire les impacts négatifs pouvant affecter cette espèce encore méconnue.

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